Mathematics

Subject: Mathematics

Mathematics   ESPA

Emerging Scholars: Problem Solving Exploration (204095)

Dusty Grundmeier

2018 Fall (2 Credits)	**Schedule:**	TR 0900 AM - 1015 AM
Instructor Permissions: Instructor	**Enrollment Cap:**	n/a

In his seminal work from 1945, How to Solve It, George Polya introduced principles of mathematical problem solving that are widely applicable to problems in science and engineering. This year-long class focuses on building a powerful and portable problem-solving and modeling tool kit while bridging the divide between mathematics and science courses. The second semester will be organized around projects in areas of student interest. Both Math ESPA and Math ESPB must be taken in the same academic year to receive credit.

Additional Course Attributes:

Attribute	Value(s)
Full Year Course	Indivisible Course
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Undergraduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics   ESPB

Emerging Scholars: Problem Solving Exploration (204096)

Dusty Grundmeier

2019 Spring (2 Credits)	**Schedule:**	TR 0900 AM - 1015 AM
Instructor Permissions: Instructor	**Enrollment Cap:**	n/a

In his seminal work from 1945, How to Solve It, George Polya introduced principles of mathematical problem solving that are widely applicable to problems in science and engineering. This year-long class focuses on building a powerful and portable problem-solving and modeling tool kit while bridging the divide between mathematics and science courses. The second semester will be organized around projects in areas of student interest. Both Math ESPA and Math ESPB must be taken in the same academic year to receive credit.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Undergraduate Students
Full Year Course	Indivisible Course
All: Cross Reg Availability	Available for Harvard Cross Registration
Course Search Attributes	Display Only in Course Search
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics   MA

Introduction to Functions and Calculus I (111161)

Brendan Kelly

2018 Fall (4 Credits)

Schedule: TBD

Instructor Permissions: None   **Enrollment Cap:** n/a

The study of functions and their rates of change. Fundamental ideas of calculus are introduced early and used to provide a framework for the study of mathematical modeling involving algebraic, exponential, and logarithmic functions. Thorough understanding of differential calculus promoted by year long reinforcement. Applications to biology and economics emphasized according to the interests of our students.

Course Notes: This is a lecture course taught in small sections. In addition, participation in two one-hour workshops is required each week. This course, when taken together with Mathematics Mb, can be followed by Mathematics 1b. Mathamatics Ma and Mb together cover all the material in Mathematics 1a (and more).

Class Notes:

Required first meeting in Fall: Tuesday, September 4, 8:15 am, Science Center C

Fall Section Times: MWF 9:00, MWF 10:30, MWF 12, MWF 1:30, MWF 3 with sufficient enrollment.

Brendan Kelly, Rosalie Belanger-Rioux, Matthew Demers, David Freund, Jill Guerra, Caroline Junkins, Katherine Penner, Hakim Walker, and members of the Department.

Additional Course Attributes:

Attribute	Value(s)
FAS: Final Assessment Category	Three-hour Exam
FAS: Core Curriculum	Quantitative Reasoning
FAS: Course Level	Primarily for Undergraduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: General Education	Empirical and Mathematical Reasoning
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics   MB

Introduction to Functions and Calculus II (113464)

Brendan Kelly

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: None   **Enrollment Cap:** n/a

Continued investigation of functions and differential calculus through modeling; an introduction to integration with applications; an introduction to differential equations. Solid preparation for Mathematics 1b.

Course Notes: This is a lecture course taught in small sections. In addition, participation in two one-hour workshops is required each week. This course, when taken together with Mathematics Ma, can be followed by Mathematics 1b. Mathematics Ma and Mathematics Mb together cover all the material in Mathematics 1a (and more).

Class Notes: Required first meeting in Spring: Monday January 28, 8:15 am, Science Center A

Spring Section Times: MWF 9:00, MWF 10:30, MWF 12, MWF 1:30, and MWF 3:00 with sufficient enrollment.

Brendan Kelly, Rosalie Belanger-Rioux, Emily Braley, Robin Gottlieb, Caroline Junkins, Katherine Penner, Hakim Walker, and members of the Department.

Requirements:	Prerequisite: Mathematics MA

Additional Course Attributes:

Attribute	Value(s)
FAS: General Education	Empirical and Mathematical Reasoning
FAS: Core Curriculum	Quantitative Reasoning
FAS: Course Level	Primarily for Undergraduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics   1A

Introduction to Calculus (123680)

Jill Guerra

2019 Spring (4 Credits)

Schedule: MWF 1030 AM - 1145 AM

Instructor Permissions: None   **Enrollment Cap:**   n/a

The development of calculus by Newton and Leibniz ranks among the greatest achievements of the past millennium. This course will help you see why by introducing: how differential calculus treats rates of change; how integral calculus treats accumulation; and how the fundamental theorem of calculus links the two. These ideas will be applied to problems from many other disciplines.

Course Notes:	In the fall, Math 1a is taught in sections of 20-30 students. In the spring, Math 1a is taught in a larger lecture format. Participation in a weekly 90-minute workshop is required.Mathematics Ma and Mb together cover all of the material in Mathematics 1a (and more).
Class Notes:	Spring section time: M.W.F. at 10:30 and weekly lab section to be arranged.
	Jill Guerra
Recommended Prep:	A solid background in precalculus.

Additional Course Attributes:

Attribute	Value(s)
FAS: Core Curriculum	Quantitative Reasoning
FAS: Course Level	Primarily for Undergraduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: General Education	Empirical and Mathematical Reasoning

Mathematics   1A

Introduction to Calculus (123680)

Emily Braley

2018 Fall (4 Credits)   **Schedule:**   TBD

Instructor Permissions: None   **Enrollment Cap:**   n/a

The development of calculus by Newton and Leibniz ranks among the greatest achievements of the past millennium. This course will help you see why by introducing: how differential calculus treats rates of change; how integral calculus treats accumulation; and how the fundamental theorem of calculus links the two. These ideas will be applied to problems from many other disciplines.

Course Notes:	In the fall, Math 1a is taught in sections of 20-30 students. In the spring, Math 1a is taught in a larger lecture format. Participation in a weekly 90-minute workshop is required.Mathematics Ma and Mb together cover all of the material in Mathematics 1a (and more).
Class Notes:	Required first meeting in Fall: Tuesday, September 4, 7:45 am, Science Center C
	Fall Section Times: MWF 9:00, MWF 10:30, MWF 12:00, MWF 1:30, and MWF 3:00 with sufficient enrollment.
	Emily Braley, David Freund, Jill Guerra, Caroline Junkins, and members of the Department.
Recommended Prep:	A solid background in precalculus.

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Undergraduate Students
FAS: General Education	Empirical and Mathematical Reasoning
FAS: Core Curriculum	Quantitative Reasoning
FAS: Final Assessment Category	Three-hour Exam

Mathematics   1B

Calculus, Series, and Differential Equations (111010)

Dusty Grundmeier

2019 Spring (4 Credits)   **Schedule:**   TBD

Instructor Permissions: None   **Enrollment Cap:**   n/a

Speaking the language of modern mathematics requires fluency with the topics of this course: infinite series, integration, and differential equations. Model practical situations using integrals and differential equations. Learn how to represent interesting functions using series and find qualitative, numerical, and analytic ways of studying differential equations. Develop both conceptual understanding and the ability to apply it.

Course Notes:	This is a lecture taught in small sections.
Class Notes:	Required first meeting in Spring: Monday, January 28, 8:15 am, Science Center D
	Spring Section Times: MWF 9:00, MWF 10:30, MWF 12:00, MWF 1:30, and MWF 3:00 with sufficient enrollment.
	Dusty Grundmeier, David Freund, Caroline Junkins, Hakim Walker, and members of the Department.

Recommended Prep: Mathematics 1a or Ma and Mb; or 5 on the AB advanced placement test; or an equivalent background in mathematics.

Additional Course Attributes:

Attribute	Value(s)
FAS: General Education	Empirical and Mathematical Reasoning
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Core Curriculum	Quantitative Reasoning
FAS: Course Level	Primarily for Undergraduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics   1B

Calculus, Series, and Differential Equations (111010)

John Cain

2018 Fall (4 Credits)

Schedule: TBD

Instructor Permissions: None   **Enrollment Cap:**   n/a

Speaking the language of modern mathematics requires fluency with the topics of this course: infinite series, integration, and differential equations. Model practical situations using integrals and differential equations. Learn how to represent interesting functions using series and find qualitative, numerical, and analytic ways of studying differential equations. Develop both conceptual understanding and the ability to apply it.

Course Notes:	This is a lecture taught in small sections.
Class Notes:	Required first meeting in Fall: Tuesday, September 4, 8:15 am, Science Center B
	Fall Section Times: MWF 9:00, MWF 10:30, MWF 12:00, MWF 1:30, and MWF 3:00 with sufficient enrollment
	John Cain, Marius Lemm, Stepan Paul, Hakim Walker, Drew Zemke, and members of the Department
Recommended Prep:	Mathematics 1a or Ma and Mb; or 5 on the AB advanced placement test; or an equivalent background in mathematics.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Final Assessment Category	Three-hour Exam
FAS: General Education	Empirical and Mathematical Reasoning
FAS: Course Level	Primarily for Undergraduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Core Curriculum	Quantitative Reasoning

Mathematics   18

Multivariable Calculus for Social Sciences (125396)

Yu-Wen Hsu

2018 Fall (4 Credits)

Schedule: MWF 0130 PM - 0245 PM

Instructor Permissions: None   **Enrollment Cap:**   n/a

Focus on concepts and techniques of multivariable calculus most useful to those studying the social sciences, particularly economics: functions of several variables; partial derivatives; directional derivatives and the gradient; constrained and unconstrained optimization, including the method of Lagrange multipliers. Covers linear and polynomial approximation and integrals for single variable and multivariable functions; modeling with derivatives. Covers topics from Math 21a most useful to social sciences.

Course Notes:	Mathematics 21b can be taken before or after Mathematics 18. Examples draw primarily from economics and the social sciences, though Mathematics 18 may be useful to students in certain natural sciences. Students whose main interests lie in the physical sciences, mathematics, or engineering should consider Math or Applied Math 21a.
Recommended Prep:	Mathematics 1b or equivalent, or a 5 on the BC Advanced Placement Examination in Mathematics.
Requirements:	Anti-Requisite: Not to be taken in addition to Mathematics 21a or Applied Mathematics 21a

Additional Course Attributes:

Attribute	Value(s)
FAS: Final Assessment Category	Three-hour Exam
FAS: Course Level	Primarily for Undergraduate Students
FAS: General Education	Empirical and Mathematical Reasoning
FAS: Core Curriculum	Quantitative Reasoning
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics   19A

Modeling and Differential Equations for the Life Sciences (110596)

John Cain

2018 Fall (4 Credits)

Schedule: MWF 1030 AM - 1145 AM

Instructor Permissions: None

Enrollment Cap: n/a

Considers the construction and analysis of mathematical models that arise in the life sciences, ecology and environmental life science. Introduces mathematics that include multivariable calculus, differential equations in one or more variables, vectors, matrices, and linear and non-linear dynamical systems. Taught via examples from current literature (both good and bad).

Course Notes:	This course is recommended over Math 21a for those planning to concentrate in the life sciences and ESPP. Can be taken with or without Mathematics 21a,b. Students with interests in the social sciences and economics might consider Mathematics 18. This course can be taken before or after Mathematics 18.
Recommended Prep:	A course in one variable calculus preferably at the level of Mathematics 1b.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: General Education	Empirical and Mathematical Reasoning
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Undergraduate Students
FAS: Core Curriculum	Quantitative Reasoning

Mathematics   19B

Linear Algebra, Probability, and Statistics for the Life Sciences (122219)

Rosalie Belanger-Rioux

2019 Spring (4 Credits)

Schedule: MWF 1030 AM - 1145 AM

Instructor Permissions: None

Enrollment Cap: n/a

Probability, statistics and linear algebra with applications to life sciences, chemistry, and environmental life sciences. Linear algebra includes matrices, eigenvalues, eigenvectors, determinants, and applications to probability, statistics, dynamical systems. Basic probability and statistics are introduced, as are standard models, techniques, and their uses including the central limit theorem, Markov chains, curve fitting, regression, and pattern analysis.

Course Notes:	This course is recommended over Math 21b for those planning to concentrate in the life sciences and ESPP. Can be taken with Mathematics 21a. Students who have seen some multivariable calculus can take Math 19b before Math 19a.
Recommended Prep:	A course in one variable calculus preferably at the level of Mathematics 1b.
Requirements:	Not to be taken in addition to Mathematics 21b or Applied Mathematics 21b.

Additional Course Attributes:

Attribute	Value(s)
FAS: General Education	Empirical and Mathematical Reasoning
FAS: Core Curriculum	Quantitative Reasoning
FAS: Course Level	Primarily for Undergraduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics   21A

Multivariable Calculus (119196)

Stepan Paul

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: None

Enrollment Cap: n/a

To see how calculus applies in practical situations described by more than one variable, we study: Vectors, lines, planes, parameterization of curves and surfaces, partial derivatives, directional derivatives and the gradient, optimization and critical point analysis, including constrained optimization and the Method of Lagrange Multipliers, integration over curves, surfaces and solid regions using Cartesian, polar, cylindrical, and spherical coordinates, divergence and curl of vector fields, and the Green's, Stokes's, and Divergence Theorems.

Course Notes:	This is a lecture taught in small sections. May not be taken for credit by students who have passed Applied Mathematics 21a. Activities using computers to calculate and visualize applications of these ideas will not require programming experience.
Class Notes:	Required first meeting in Spring: Monday January 28, 8:15 am, Science Center C
	Spring Section Times: MWF 9:00, MWF 10:30, MWF 12, MWF 1:30, and

MWF 3:00 with sufficient enrollment.

Stepan Paul, David Freund, Yu-Wen Hsu, Drew Zemke, and members of the Department.

Recommended Prep: Mathematics 1b or an equivalent background in mathematics.

Requirements: Anti-requisite: Not to be taken in addition to AM21a.

Additional Course Attributes:

Attribute	Value(s)
FAS: General Education	Empirical and Mathematical Reasoning
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Undergraduate Students
FAS: Core Curriculum	Quantitative Reasoning

Mathematics   21A

Multivariable Calculus (119196)

Janet Chen

2018 Fall (4 Credits)   **Schedule:**   TBD

Instructor Permissions: None   **Enrollment Cap:**   n/a

To see how calculus applies in practical situations described by more than one variable, we study: Vectors, lines, planes, parameterization of curves and surfaces, partial derivatives, directional derivatives and the gradient, optimization and critical point analysis, including constrained optimization and the Method of Lagrange Multipliers, integration over curves, surfaces and solid regions using Cartesian, polar, cylindrical, and spherical coordinates, divergence and curl of vector fields, and the Green's, Stokes's, and Divergence Theorems.

Course Notes: This is a lecture taught in small sections. May not be taken for credit by students who have passed Applied Mathematics 21a. Activities using computers to calculate and visualize applications of these ideas will not require programming experience.

Class Notes: Required first meeting in Fall: Wednesday, September 5, 8:15 am, Science Center B

Fall Section Times: MWF 9:00, MWF 10:30, MWF 12, MWF 1:30, and MWF 3:00 with sufficient enrollment.

Janet Chen, Jameel Al-Aidroos, Brendan Kelly, Yu-Wen Hsu, Stepan Paul, Drew Zemke, and members of the Department.

Recommended Prep: Mathematics 1b or an equivalent background in mathematics.

Requirements: Anti-requisite: Not to be taken in addition to AM21a.

Additional Course Attributes:

Attribute	Value(s)
FAS: Final Assessment Category	Three-hour Exam
FAS: General Education	Empirical and Mathematical Reasoning
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Undergraduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Core Curriculum	Quantitative Reasoning

Mathematics   21B

Linear Algebra and Differential Equations (110989)

Janet Chen

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: None

Enrollment Cap: n/a

Matrices provide the algebraic structure for solving myriad problems across the sciences. We study matrices and related topics such as linear transformations and linear spaces, determinants, eigenvalues, and eigenvectors. Applications include dynamical systems, ordinary and partial differential equations, and an introduction to Fourier series.

Course Notes:	This is a lecture taught in small sections. May not be taken by students who have passed Applied Mathematics 21b.
Class Notes:	Required first meeting in Spring: Monday, January 28, 8:15 am, Science Center B
	Spring Section Times: MWF 9:00, MWF 10:30, MWF 12:00, MWF 1:30, and MWF 3:00 with sufficient enrollment.
	Janet Chen, Jameel Al-Aidroos, Ana Balibanu, Matthew Demers, Jill Guerra, Yu-Wen Hsu, Sebastien Picard, Sebastien Vasey, Drew Zemke, and members of the Department.
Recommended Prep:	Mathematics 1b or an equivalent background in mathematics. Mathematics 21a is commonly taken before Mathematics 21b, but is not a prerequisite, although familiarity with partial derivatives is useful.
Requirements:	Anti-requisite: Not to be taken in addition to Math 19b or AM 21b.

Additional Course Attributes:

Attribute	Value(s)
FAS: General Education	Empirical and Mathematical Reasoning
FAS: Core Curriculum	Quantitative Reasoning
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Undergraduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics   21B

Linear Algebra and Differential Equations (110989)

Matthew Demers

Rosalie Belanger-Rioux

2018 Fall (4 Credits)

Schedule: TBD

Instructor Permissions: None

Enrollment Cap: n/a

Matrices provide the algebraic structure for solving myriad problems across the sciences. We study matrices and related topics such as linear transformations and linear spaces, determinants, eigenvalues, and eigenvectors. Applications include dynamical systems, ordinary and partial differential equations, and an introduction to Fourier series.

Course Notes:	This is a lecture taught in small sections. May not be taken by students who have passed Applied Mathematics 21b.
Class Notes:	Required first meeting in Fall: Tuesday, September 4, 8:15 am, Science Center D
	Fall Section Times: MWF 9:00, MWF 10:30, MWF 12:00, MWF 1:30 with sufficient enrollment, and MWF 3:00 with sufficient enrollment.
	Rosalie Belanger-Rioux, Matthew Demers, Benjamin Knudsen, and members of the Department.
Recommended Prep:	Mathematics 1b or an equivalent background in mathematics. Mathematics 21a is commonly taken before Mathematics 21b, but is not a prerequisite, although familiarity with partial derivatives is useful.
Requirements:	Anti-requisite: Not to be taken in addition to Math 19b or AM 21b.

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Undergraduate Students
FAS: General Education	Empirical and Mathematical Reasoning
FAS: Core Curriculum	Quantitative Reasoning
FAS: Final Assessment Category	Three-hour Exam

Mathematics   22A

Vector Calculus and Linear Algebra I (207485)

Oliver Knill

2018 Fall (4 Credits)

Schedule: TR 0900 AM - 1015 AM

Instructor Permissions: None

Enrollment Cap: n/a

This course covers multivariable calculus and linear algebra for students interested in mathematical sciences. It covers the same topics as Mathematics 21, but does so with more rigor. Students are taught techniques of proof and mathematical reasoning. The workload and content is comparable with the Mathematics 21

sequence. But unlike the latter, the linear algebra and calculus are more interlinked.

Course Notes:	Students in Mathematics 22 are required to participate in a weekly class length workshop dedicated to proof aspects (the schedule of workshop times will be finalized after the first class meeting).

Additional Course Attributes:

Attribute	Value(s)
FAS: General Education	Empirical and Mathematical Reasoning
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Undergraduate Students
FAS: Final Assessment Category	Three-hour Exam
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics   22B

Vector Calculus and Linear Algebra II (207486)

Oliver Knill

2019 Spring (4 Credits)

Schedule: TR 0900 AM - 1015 AM

Instructor Permissions: Instructor

Enrollment Cap: 50

A continuation of Mathematics 22a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Undergraduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: General Education	Empirical and Mathematical Reasoning

Mathematics   23A

Linear Algebra and Real Analysis I (111695)

Paul Bamberg

2018 Fall (4 Credits)

Schedule: R 0300 PM - 0545 PM

Instructor Permissions: Instructor

Enrollment Cap: 45

Linear algebra: vectors, linear transformations and matrices, scalar and vector products, basis and dimension, eigenvectors and eigenvalues, including an introduction to the R scripting language. Single-variable real analysis: sequences and series, limits and continuity, derivatives, inverse functions, power series and Taylor series. Multivariable real analysis and calculus: topology of Euclidean space, limits, continuity, and differentiation in n dimensions, inverse and implicit functions, manifolds, Lagrange multipliers, path integrals, div, grad, and curl. Emphasis on topics that are applicable to fields such as physics, economics, and computer science, but students are also expected to learn how to prove key results.

Course Notes:	Students are expected to watch videos of the lectures from Fall 2015 before attending class. Weekly two-hour classes will consist of a one-hour seminar in which students present key definitions and proofs and a one-hour activity-based session in which students work in small groups to solve problems. Students are expected to continue in either Mathematics 23b (recommended for students who are thinking of concentrating in

mathematics, the physical sciences, or engineering) or Mathematics 23c (recommended for students who are not sure of their concentration, or who are thinking about a concentration in the social sciences, economics, computer science, life sciences or data science).   Either alternative will provide a solid foundation for a concentration in mathematics or any field that uses mathematics.

Class Notes: Required first meeting: Tuesday, September 4, 8:15 am Science Center A.

Recommended Prep: Mathematics 1b or a grade of 4 or 5 on the Calculus BC Advanced Placement Examination, plus an interest both in proving mathematical results and in using them. No background in linear algebra, real analysis, or multivariable calculus is assumed.

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Core Curriculum	Quantitative Reasoning
FAS: Final Assessment Category	Three-hour Exam
FAS: General Education	Empirical and Mathematical Reasoning
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Undergraduate Students

Mathematics   23A Section: 002

Linear Algebra and Real Analysis I (111695)

Paul Bamberg

2018 Fall (4 Credits)   **Schedule:**   F 1200 PM - 0245 PM

Instructor Permissions: Instructor   **Enrollment Cap:**   96

Linear algebra: vectors, linear transformations and matrices, scalar and vector products, basis and dimension, eigenvectors and eigenvalues, including an introduction to the R scripting language. Single-variable real analysis: sequences and series, limits and continuity, derivatives, inverse functions, power series and Taylor series. Multivariable real analysis and calculus: topology of Euclidean space, limits, continuity, and differentiation in n dimensions, inverse and implicit functions, manifolds, Lagrange multipliers, path integrals, div, grad, and curl. Emphasis on topics that are applicable to fields such as physics, economics, and computer science, but students are also expected to learn how to prove key results.

Course Notes: Students are expected to watch videos of the lectures from Fall 2015 before attending class. Weekly two-hour classes will consist of a one-hour seminar in which students present key definitions and proofs and a one-hour activity-based session in which students work in small groups to solve problems. Students are expected to continue in either Mathematics 23b (recommended for students who are thinking of concentrating in mathematics, the physical sciences, or engineering) or Mathematics 23c (recommended for students who are not sure of their concentration, or who are thinking about a concentration in the social sciences, economics, computer science, life sciences or data science).   Either alternative will provide a solid foundation for a concentration in mathematics or any field that uses mathematics.

Class Notes: Required first meeting: Tuesday, September 4, 8:15 am, Science Center A.

Recommended Prep: Mathematics 1b or a grade of 4 or 5 on the Calculus BC Advanced Placement Examination, plus an interest both in proving mathematical

results and in using them. No background in linear algebra, real analysis, or multivariable calculus is assumed.

Additional Course Attributes:

Attribute	Value(s)
FAS: Final Assessment Category	Three-hour Exam
FAS: General Education	Empirical and Mathematical Reasoning
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Undergraduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Core Curriculum	Quantitative Reasoning

Mathematics   23B

Linear Algebra and Real Analysis II (145010)

Paul Bamberg

2019 Spring (4 Credits)

Schedule: F 1200 PM - 0245 PM

Instructor Permissions: None   **Enrollment Cap:**   n/a

A rigorous, integrated treatment of linear algebra and multivariable calculus. Topics: Riemann and Lebesgue integration, determinants, change of variables, volume of manifolds, differential forms, and exterior derivative. Stokes's theorem is presented both in the language of vector analysis (div, grad, and curl) and in the language of differential forms.

Course Notes:	Mathematics 23b is a sequel to Mathematics 23a, recommended for students who are thinking of concentrating in mathematics, the physical sciences, or engineering. Students are expected to watch videos of the lectures from spring 2016 before attending class. Weekly two-hour classes will consist of a one-hour seminar in which students present key definitions and proofs and a one-hour activity-based session in which students work in small groups to solve problems.
Class Notes:	Required first meeting: Monday, January 28, 8:15 am, Science Center A.
Recommended Prep:	Mathematics 23a.
Requirements:	Prerequisite: MATH 23A OR (MATH 21A AND MATH 21B) AND (Not to be taken in addition to MATH 23C)

Additional Course Attributes:

Attribute	Value(s)
FAS: Core Curriculum	Quantitative Reasoning
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: General Education	Empirical and Mathematical Reasoning
FAS: Course Level	Primarily for Undergraduate Students

Mathematics   23C

Mathematics for Computation, Statistics, and Data Science (205386)

Paul Bamberg

2019 Spring (4 Credits) **Schedule:** R 0300 PM - 0545 PM

Instructor Permissions: None **Enrollment Cap:** n/a

Proof strategies and logic. Sets, countability, sigma fields, and axiomatic foundations of probability. Summation of series and evaluation of multiple integrals, with emphasis on calculation of expectation and variance. Abstract vector spaces and inner product spaces, with applications to analysis of large datasets. Key functions and theorems of mathematical statistics. A brief introduction to classical vector calculus as used in electromagnetic theory. Students will learn to use some of the statistical and graphical display tools in the R scription language.

Course Notes:	This course is a sequel to Mathematics 23a, recommended for students who are not sure of their concentration or who are thinking about a concentration in the social sciences, economics, computer science, life sciences or data science. Graduate students wishing to take this course for credit should speak with Dr. Bamberg to arrange enrollment in Mathematics 370 instead.
Class Notes:	Required first meeting: Monday, January 28, 8:15 am, Science Center A.
Recommended Prep:	Mathematics 23a or Mathematics 21a and 21b. The latter option is for seniors who are preparing for graduate programs in statistics, computer science, or data science.
Requirements:	Prerequisite: MATH 23A OR (MATH 21A AND MATH 21B) AND (Not to be taken in addition to MATH 23B)

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Undergraduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics   25A

Theoretical Linear Algebra and Real Analysis I (110808)

Bena Tshishiku

2018 Fall (4 Credits) **Schedule:** MW 0900 AM - 1015 AM

Instructor Permissions: None **Enrollment Cap:** n/a

A rigorous treatment of linear algebra. Topics include: Construction of number systems; fields, vector spaces and linear transformations; eigenvalues and eigenvectors, determinants and inner products. Metric spaces, compactness and connectedness.

Course Notes:	Expect to spend a lot of time doing mathematics.
Class Notes:	Should not be taken for credit after the freshman year without permission from the Mathematics Director of Undergraduate Studies.
Recommended Prep:	5 on the Calculus BC Advanced Placement Examination and some familiarity with writing proofs, or the equivalent as determined by the instructor.

Additional Course Attributes:

Attribute	Value(s)
FAS: Final Assessment Category	Three-hour Exam
FAS: Course Level	Primarily for Undergraduate Students

All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: General Education	Empirical and Mathematical Reasoning
FAS: Core Curriculum	Quantitative Reasoning
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 25B

Theoretical Linear Algebra and Real Analysis II (110855)

Bena Tshishiku

2019 Spring (4 Credits)

Schedule: MW 0900 AM - 1015 AM

Instructor Permissions: None

Enrollment Cap: n/a

A rigorous treatment of basic analysis. Topics include: convergence, continuity, differentiation, the Riemann integral, uniform convergence, the Stone-Weierstrass theorem, Fourier series, differentiation in several variables. Additional topics, including the classical results of vector calculus in two and three dimensions, as time allows.

Course Notes: Expect to spend a lot time doing mathematics.

Class Notes: Should not be taken for credit after the freshman year without permission from the Mathematics Director of Undergraduate Studies.

Requirements: Prerequisite: Mathematics 25A OR Mathematics 55A

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: General Education	Empirical and Mathematical Reasoning
FAS: Course Level	Primarily for Undergraduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Core Curriculum	Quantitative Reasoning

Mathematics 55A

Studies in Algebra and Group Theory (113627)

Joseph D. Harris

2018 Fall (4 Credits)

Schedule: MWF 1030 AM - 1145 AM

Instructor Permissions: Instructor

Enrollment Cap: n/a

A rigorous introduction to abstract algebra, including group theory and linear algebra. This course covers the equivalent of Mathematics 25a and Mathematics 122, and prepares students for Mathematics 123 and other advanced courses in number theory and algebra. (A course in analysis such as Mathematics 25b or 55b is recommended for Spring semester.)

Course Notes: Mathematics 55a is an intensive course for students who are comfortable with abstract mathematics. (Students without this background will gain it and learn the material from Math 55a,b in other courses by continuing into the Mathematics Concentration as sophomores.) Students can switch between Mathematics 55a and either Mathematics 25a, 23a, 22a, 21a during the first three weeks without penalty.

Recommended Prep: Familiarity with proofs and abstract reasoning; and commitment to a fast moving course.

Additional Course Attributes:

Attribute	Value(s)
FAS: Core Curriculum	Quantitative Reasoning
FAS: General Education	Empirical and Mathematical Reasoning
FAS: Course Level	Primarily for Undergraduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics   55B

Studies in Real and Complex analysis (112871)

Joseph D. Harris

2019 Spring (4 Credits)

		Schedule:	MWF 1030 AM - 1145 AM
Instructor Permissions:	Instructor	**Enrollment Cap:**	n/a

A rigorous introduction to real and complex analysis. This course covers the equivalent of Mathematics 25b and Mathematics 113, and prepares students for Mathematics 114 and other advanced courses in analysis.

Course Notes: Mathematics 55b is an intensive course for students having significant experience with abstract mathematics.

Requirements: Prerequisite: Mathematics 55A

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Undergraduate Students
FAS: General Education	Empirical and Mathematical Reasoning
FAS: Core Curriculum	Quantitative Reasoning

Mathematics   60R

Reading Course for Senior Honors Candidates (123883)

Cliff Taubes

2019 Spring (4 Credits)

		Schedule:	TBD
Instructor Permissions:	None	**Enrollment Cap:**	n/a

Advanced reading in topics not covered in courses.

Course Notes: Limited to candidates for honors in Mathematics who obtain the permission of both the faculty member under whom they want to work and the Director of Undergraduate Studies. May not count for concentration in Mathematics without special permission from the Director of Undergraduate Studies. Graded Sat/Unsat only.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

FAS: Course Level	Primarily for Undergraduate Students

Mathematics 60R

Reading Course for Senior Honors Candidates (123883)

Cliff Taubes

2018 Fall (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

 Advanced reading in topics not covered in courses.

Course Notes: Limited to candidates for honors in Mathematics who obtain the permission of both the faculty member under whom they want to work and the Director of Undergraduate Studies. May not count for concentration in Mathematics without special permission from the Director of Undergraduate Studies. Graded Sat/Unsat only.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Undergraduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 91R

Supervised Reading and Research (111297)

Cliff Taubes

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: None

Enrollment Cap: n/a

 Programs of directed study supervised by a person approved by the Department.

Course Notes: May not ordinarily count for concentration in Mathematics.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Undergraduate Students

Mathematics 91R

Supervised Reading and Research (111297)

Cliff Taubes

2018 Fall (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

 Programs of directed study supervised by a person approved by the Department.

Course Notes: May not ordinarily count for concentration in Mathematics.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Undergraduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics   99R

Tutorial (117647)

Cliff Taubes

2019 Spring (4 Credits)

Schedule:	TBD

Instructor Permissions: None   **Enrollment Cap:**   n/a

Supervised small group tutorial. Topics to be arranged.

Course Notes: May be repeated for course credit with permission from the Director of Undergraduate Studies. Only one tutorial may count for concentration credit.

Class Notes: Members of the Department

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Undergraduate Students

Mathematics   99R

Tutorial (117647)

Cliff Taubes

2018 Fall (4 Credits)

Schedule:	TBD

Instructor Permissions: Instructor   **Enrollment Cap:**   n/a

Supervised small group tutorial. Topics to be arranged.

Course Notes: May be repeated for course credit with permission from the Director of Undergraduate Studies. Only one tutorial may count for concentration credit.

Class Notes: Members of the Mathematics Department

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Undergraduate Students

Mathematics 101

Sets, Groups and Topology (122943)

Sebastien Vasey

2018 Fall (4 Credits)

Schedule: MF 0900 AM - 1015 AM

Instructor Permissions: None

Enrollment Cap: n/a

An introduction to rigorous mathematics, axioms, and proofs, via topics including set theory, symmetry groups, and low-dimensional topology.

Course Notes: Familiarity with algebra, geometry and/or calculus is desirable. Students who have already taken Mathematics 22a,b, 23a,b, 25a,b or 55a,b should not take this course for credit. This course given fall term and repeated spring term.

Recommended Prep: An interest in mathematical reasoning. Acquaintance with algebra, geometry and/or calculus is desirable. Students who have already taken Math 25a,b or 55a,b should not take this course for credit.

Requirements: Anti-Req: Not to be taken in addition to Mathematics 23a,b or 25a,b or 55a,b.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Core Curriculum	Quantitative Reasoning
FAS: General Education	Empirical and Mathematical Reasoning
FAS: Course Level	For Undergraduate and Graduate Students

Mathematics 102

Much Ado About Everything: The Mathematics of Leonhard Euler (207544)

William Dunham

2019 Spring (4 Credits)

Schedule: TR 0130 PM - 0245 PM

Instructor Permissions: None

Enrollment Cap: 30

The focus of this course is Leonhard Euler (1707-1783), one of history's greatest mathematicians. After surveying 16th and 17th century results that underlay his work, we consider Euler's contributions to number theory, calculus, algebra, combinatorics, and other fields. The course has historical and biographical elements, but its primary objective is to introduce students to rigorous mathematics through the work of an undisputed master.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	For Undergraduate and Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 110

Vector Space Methods for Differential Equations (126610)

Christian Brennecke

2019 Spring (4 Credits)

Schedule: TR 0900 AM - 1015 AM

Instructor Permissions: None

Enrollment Cap: n/a

Develops the theory of inner product spaces, both finite-dimensional and infinite-dimensional, and applies it to a variety of ordinary and partial differential equations. Topics: existence and uniqueness theorems, Sturm-Liouville systems, orthogonal polynomials, Fourier series, Fourier and Laplace transforms, eigenvalue problems, and solutions of Laplace's equation and the wave equation in the various coordinate systems.

Recommended Prep: Mathematics 22a,b, 23a,b or 25a,b or Mathematics 19a,b or 21a,b plus any Mathematics course at the 100 level; or an equivalent background in Mathematics.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	For Undergraduate and Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 112

Introductory Real Analysis (109817)

Denis Auroux

2019 Spring (4 Credits)

Schedule: TR 1200 PM - 0115 PM

Instructor Permissions: None

Enrollment Cap: n/a

An introduction to mathematical analysis and the theory behind calculus. An emphasis on learning to understand and construct proofs. Covers limits and continuity in metric spaces, uniform convergence and spaces of functions, the Riemann integral.

Recommended Prep: Mathematics 19a,b or 21a,b and either an ability to write proofs or concurrent enrollment in Mathematics 101 or 102; or an equivalent background in mathematics.

Requirements: Anti-Req: Not to be taken in addition to Mathematics 23a,b or 25a,b or 55a,b.

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	For Undergraduate and Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 113

Complex Analysis (113608)

Yum Tong Siu

2019 Spring (4 Credits)

Schedule: TR 0300 PM - 0415 PM

Instructor Permissions: None

Enrollment Cap: n/a

Analytic functions of one complex variable: power series expansions, contour integrals, Cauchy's theorem, Laurent series and the residue theorem. Some applications to real analysis, including the evaluation of indefinite integrals. An introduction to some special functions.

Recommended Prep: Anti-Requisite: Not to be taken in addition to Mathematics 55a without prior permission of the Director of Undergraduate Studies.

Requirements: Anti-Req: Not to be taken in addition to Mathematics 55b.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	For Undergraduate and Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 114

Analysis of Function Spaces, Measure and Integration (123227)

Peter Kronheimer

2018 Fall (4 Credits)   **Schedule:**   WF 1030 AM - 1145 AM

Instructor Permissions: None   **Enrollment Cap:**   n/a

Lebesgue measure and integration; general topology; introduction to L^p spaces, Banach and Hilbert spaces, and duality.

Recommended Prep: Mathematics 22a,b, 23a,b or 25a,b or 55a,b or 112; or an equivalent background in mathematics.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Final Assessment Category	Three-hour Exam
FAS: Course Level	For Undergraduate and Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 115

Methods of Analysis (111065)

Man-Wai Cheung

2018 Fall (4 Credits)   **Schedule:**   MF 1030 AM - 1145 AM

Instructor Permissions: None   **Enrollment Cap:**   n/a

Complex functions; Fourier analysis; Hilbert spaces and operators; Laplace's equations; Bessel and Legendre functions; symmetries; Sturm-Liouville theory.

Course Notes: Mathematics 115 is especially for students interested in physics.

Recommended Prep: Mathematics 22a,b, 23a,b or 25a,b or 55a,b or 112; or an equivalent background in mathematics.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	For Undergraduate and Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 116

Real Analysis, Convexity, and Optimization (118302)

Marius Lemm

2018 Fall (4 Credits)

Schedule: TR 0300 PM - 0415 PM

Instructor Permissions: None   **Enrollment Cap:**   n/a

Develops the theory of convex sets, normed infinite-dimensional vector spaces, and convex functionals and applies it as a unifying principle to a variety of optimization problems such as resource allocation, production planning, and optimal control. Topics include Hilbert space, dual spaces, the Hahn-Banach theorem, the Riesz representation theorem, calculus of variations, and Fenchel duality. Students will be expected to understand and come up with proofs of theorems in real and functional analysis.

Recommended Prep: Mathematics 22a,b, 23a,b or 25a,b or 55a,b; or Mathematics 21a,b plus at least one other more advanced course in mathematics; or an equivalent background in mathematics.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	For Undergraduate and Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 117

Probability and Random Processes with Economic Applications (127947)

Paul Bamberg

2019 Spring (4 Credits)

Schedule: TR 1200 PM - 0115 PM

Instructor Permissions: None   **Enrollment Cap:**   n/a

A self-contained treatment of the theory of probability and random processes with specific application to the theory of option pricing. Topics: axioms for probability, calculation of expectation by means of Lebesgue integration, conditional probability and conditional expectation, martingales, random walks and Wiener processes, and the Black-Scholes formula for option pricing. Students will work in small groups to investigate applications of the theory and to prove key results.

Course Notes: A problem-solving section is required.

Recommended Prep: A thorough knowledge of single-variable calculus and infinite series, plus at least one more advanced course such as MATH 23a that provides experience with proofs and elementary real analysis. Acquaintance with elementary probability is desirable.

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	For Undergraduate and Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration

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Mathematics 118R

Dynamical Systems (118429)

John Cain

2019 Spring (4 Credits)

Schedule: MW 0300 PM - 0415 PM

Instructor Permissions: None

Enrollment Cap: n/a

Introduction to dynamical systems theory with a view toward applications. Topics include existence and uniqueness theorems for flows, qualitative study of equilibria and attractors, iterated maps, and bifurcation theory.

Recommended Prep: Mathematics 19a,b or 21a,b or Math 22a,b,or Math 23a,b or Math 25a,b or Math 55a,b; or an equivalent background in mathematics.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	For Undergraduate and Graduate Students

Mathematics 121

Linear Algebra and Applications (120228)

Alexander Kupers

2018 Fall (4 Credits)

Schedule: TR 1030 AM - 1145 AM

Instructor Permissions: None

Enrollment Cap: n/a

Real and complex vector spaces, linear transformations, determinants, inner products, dual spaces, and eigenvalue problems. Applications to some or all of the following: Ggeometry, systems of linear differential equations, optimization, and Markov processes. This course emphasizes learning to understand and write rigorous mathematics.

Recommended Prep: Mathematics 19b or 21b or an equivalent background in mathematics.

Requirements: Anti-req: Not to be taken in addition to Mathematics 22b, 23a or 25a or 55a.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	For Undergraduate and Graduate Students

Mathematics 122

Algebra I: Theory of Groups and Vector Spaces (122603)

Ana Balibanu

2018 Fall (4 Credits)

Schedule: MW 1200 PM - 0115 PM

Instructor Permissions: None

Enrollment Cap: n/a

Groups and group actions, vector spaces and their linear transformations, bilinear forms and linear representations of finite groups.

Recommended Prep: Anti-Requisite: Not to be taken in addition to Mathematics 55a without prior permission of the Director of Undergraduate Studies.

Requirements: Anti-Req: Not to be taken in addition to Mathematics 55a.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	For Undergraduate and Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Final Assessment Category	Three-hour Exam
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 123

Algebra II: Theory of Rings and Fields (116503)

Peter Kronheimer

2019 Spring (4 Credits)

Schedule: WF 1030 AM - 1145 AM

Instructor Permissions: None

Enrollment Cap: n/a

Rings and modules. Polynomial rings. Field extensions and the basic theorems of Galois theory. Structure theorems for modules.

Requirements: Prerequisite: Mathematics 122 or Mathematics 55a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	For Undergraduate and Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 124

Number Theory (111533)

Cliff Taubes

2018 Fall (4 Credits)

Schedule: MW 0900 AM - 1015 AM

Instructor Permissions: None

Enrollment Cap: n/a

Factorization and the primes; congruences; quadratic residues and reciprocity; continued fractions and

approximations; Pell's equation; selected Diophantine equations; theory of integral quadratic forms. Also, selected applications to coding, introduction to elliptic curves and introduction to zeta functions if time permits.

Recommended Prep:	Mathematics 101 or 122 or 25a or 23a; or 55a which can be taken concurrently; or an equivalent experience and comfort level with abstract mathematics.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	For Undergraduate and Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 129

Number Fields (115734)

Mark Kisin

2019 Spring (4 Credits)

Schedule: MW 0130 PM - 0245 PM

Instructor Permissions: None   **Enrollment Cap:** n/a

Algebraic number theory: number fields, unique factorization of ideals, finiteness of class group, structure of unit group, Frobenius elements, local fields, ramification, weak approximation, adeles, and ideles.

Recommended Prep:	Knowledge of the material in Mathematics 123.
Requirements:	Prerequisite: Mathematics 123

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	For Undergraduate and Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 130

Classical Geometry (123211)

Benjamin Knudsen

2019 Spring (4 Credits)

Schedule: TR 1030 AM - 1145 AM

Instructor Permissions: None   **Enrollment Cap:** n/a

Presents several classical geometries, these being the affine, projective, Euclidean, spherical and hyperbolic geometries. They are viewed from many different perspectives, some historical and some very topical. Emphasis on reading and writing proofs.

Recommended Prep:	Mathematics 19a,b or 21a,b or 22a,b or 23a or 25a or 55a which may be taken concurrently; or an equivalent background in mathematics.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration

FAS: Course Level	For Undergraduate and Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 131

Topological Spaces and Fundamental Group (111458)

Brooke Ullery

2018 Fall (4 Credits)

Schedule: TR 0130 PM - 0245 PM

Instructor Permissions: None

Enrollment Cap: n/a

First, an introduction to abstract topological spaces, their properties (compactness, connectedness, metrizability) and their corresponding continuous functions and mappings. Then, an introduction to algebraic topology including homotopy theory, fundamental groups and covering spaces.

Recommended Prep: Some acquaintance with metric space topology as taught in Mathematics 22a,b, 23a,b, 25a,b, 55a,b, 101, 102, or 112; and with groups as taught in Mathematics 101, 122 or 55a.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	For Undergraduate and Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 132

Differential Topology (123212)

Alexander Kupers

2019 Spring (4 Credits)

Schedule: WF 1200 PM - 0115 PM

Instructor Permissions: None

Enrollment Cap: n/a

Differential manifolds, smooth maps and transversality. Winding numbers, vector fields, index and degree. Differential forms, Stokes' theorem, introduction to cohomology.

Recommended Prep: Mathematics 22a,b, 23a,b or 25a,b or 55a,b or 112; or an equivalent background in mathematics.

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	For Undergraduate and Graduate Students

Mathematics 136

Differential Geometry (111133)

Sebastien Picard

2018 Fall (4 Credits)

Schedule: TR 0130 PM - 0245 PM

Instructor Permissions: None

Enrollment Cap: n/a

The course is an introduction to Riemannian geometry with the focus (for the most part) being the Riemannian geometry of curves and surfaces in space where the fundamental notions can be visualized.

Recommended Prep: Mathematics 19a,b or 21a,b or 22a,b or 23a or 25a or 55a (may be taken concurrently); or an equivalent background in mathematics.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	For Undergraduate and Graduate Students

Mathematics 137

Algebraic Geometry (116452)

Brooke Ullery

2019 Spring (4 Credits)

Schedule: TR 1030 AM - 1145 AM

Instructor Permissions: None   **Enrollment Cap:**   n/a

Affine and projective spaces, plane curves, Bezout's theorem, singularities and genus of a plane curve, Riemann-Roch theorem.

Recommended Prep: Knowledge of the material in Mathematics 123.

Requirements: Prerequisite: Mathematics 123

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	For Undergraduate and Graduate Students

Mathematics 141A

Mathematical Logic I (207500)

Sebastien Vasey

2018 Fall (4 Credits)

Schedule: MF 1200 PM - 0115 PM

Instructor Permissions: None   **Enrollment Cap:**   n/a

Introduction to mathematical logic focusing on the fundamentals of first-order logic (language, axioms, completeness theorem, etc.) and the basic results of model theory (compactness), Lowenheim-Skolem, omitting typesetc.

Recommended Prep: A previous Mathematics course at the level of Mathematics 19a,b, 21a,b, or a higher number. For students from Mathematics 19a,b or 21ab, previous enrollment in Mathematics 101 or 102 or 112, or permission of instructor.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	For Undergraduate and Graduate Students

FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 141B

Mathematical Logic II (207501)

William Boney

2019 Spring (4 Credits)

		Schedule:	TR 0900 AM - 1015 AM
Instructor Permissions:	None	**Enrollment Cap:**	n/a

Introduction to the incompleteness phenomenon, covering the incompleteness theorems and the basic results of recursion theory.

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Undergraduate Students

Mathematics 152

Discrete Mathematics (116191)

Paul Bamberg

2018 Fall (4 Credits)

		Schedule:	TR 1200 PM - 0115 PM
Instructor Permissions:	Instructor	**Enrollment Cap:**	16

An introduction to finite groups, finite fields, finite geometry, finite topology, combinatorics, graph theory, and (for section 2 only) elementary algebraic topology. A recurring theme of the course is the symmetry group of the regular icosahedron. Elementary category theory will be introduced as a unifying principle. Taught in a seminar format: students will gain experience in presenting proofs at the blackboard.

Course Notes:	Covers material used in Computer Science 121 and Computer Science 124. Enrollment limited to16.
Recommended Prep:	For section 1: Mathematics 19b or 21b. Previous experience with proofs is not required. For section 2: Mathematics 23a or 25a or an equivalent background in mathematics that includes experience with proofs.
Requirements:	Not to be taken in addition to Computer Science 20, Mathematics 55a/b or Mathematics 122.

Additional Course Attributes:

Attribute	Value(s)
FAS: Final Assessment Category	Three-hour Exam
FAS: Course Level	For Undergraduate and Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 152 Section: 002

Discrete Mathematics (116191)

Paul Bamberg

2018 Fall (4 Credits)

Schedule: TR 1030 AM - 1145 AM

Instructor Permissions: Instructor   **Enrollment Cap:** 16

An introduction to finite groups, finite fields, finite geometry, finite topology, combinatorics, graph theory, and (for section 2 only) elementary algebraic topology. A recurring theme of the course is the symmetry group of the regular icosahedron. Elementary category theory will be introduced as a unifying principle. Taught in a seminar format: students will gain experience in presenting proofs at the blackboard.

Course Notes:	Covers material used in Computer Science 121 and Computer Science 124. Enrollment limited to16.
Recommended Prep:	For section 1: Mathematics 19b or 21b. Previous experience with proofs is not required. For section 2: Mathematics 23a or 25a or an equivalent background in mathematics that includes experience with proofs.
Requirements:	Not to be taken in addition to Computer Science 20, Mathematics 55a/b or Mathematics 122.

Additional Course Attributes:

Attribute	Value(s)
FAS: Final Assessment Category	Three-hour Exam
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	For Undergraduate and Graduate Students

Mathematics 154

Probability Theory (113811)

Aukosh Jagannath

2019 Spring (4 Credits)

Schedule: MW 0900 AM - 1015 AM

Instructor Permissions: None   **Enrollment Cap:** n/a

An introduction to probability theory. Discrete and continuous random variables; distribution and density functions for one and two random variables; conditional probability. Generating functions, weak and strong laws of large numbers, and the central limit theorem. Geometrical probability, random walks, and Markov processes.

Recommended Prep:	A previous mathematics course at the level of Mathematics 19ab, 21ab, or a higher number. For students from 19ab or 21ab, previous or concurrent enrollment in Math 101 or 102 or 112 may be helpful. Freshmen who did well in Math 22a, 23a, 25a or 55a fall term are also welcome to take the course.

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: General Education	Empirical and Mathematical Reasoning
FAS: Core Curriculum	Quantitative Reasoning
All: Cross Reg Availability	Available for Harvard Cross Registration

FAS: Course Level	For Undergraduate and Graduate Students

Mathematics 155R

Combinatorics (116196)

Lauren Williams

2019 Spring (4 Credits)

Instructor Permissions: None

Schedule: MW 0130 PM - 0245 PM

Enrollment Cap: n/a

An introduction to algebraic combinatorics that comes from the representation theory of the symmetric group. We will start with a quick overview of the representation theory of finite groups and then cover topics such as Young tableaux, Specht modules, the hook-length formula, symmetric functions, the Littlewood-Richardson rule, the RSK correspondence, etc.

Recommended Prep: Prerequisites: linear algebra and abstract algebra. Familiarity with the representation theory of finite groups would be helpful.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	For Undergraduate and Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 157

Mathematics in the World (159763)

Joseph D. Harris

2019 Spring (4 Credits)

Instructor Permissions: None

Schedule: TR 0130 PM - 0245 PM

Enrollment Cap: n/a

An interactive introduction to problem solving with an emphasis on subjects with comprehensive applications. Each class will be focused around a group of questions with a common topic: logic, information, number theory, probability, and algorithms.

Recommended Prep: Mathematics 19b or 21b or 22a,b or 23a; or an equivalent background in mathematics. More importantly, students should have a broad mathematical curiosity and be eager to brainstorm during in-class problem solving sessions.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	For Undergraduate and Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 168

Making Math Material (207518)

Glen Whitney

2018 Fall (4 Credits)
Schedule: MF 0130 PM - 0245 PM

Instructor Permissions: None   **Enrollment Cap:** n/a

How can we make mathematical ideas material, both by translating them into physical embodiments and by making them more accessible and relevant to a broader audience? Conversely, how can mathematics inform the designs we make for physical structures, both from practical and aesthetic points of view? This course will pursue these questions by doing: exploring mathematical topics that connect well with physical structures, modeling those ideas in software, and building real-world structures based on the models. Specific topics will include symmetry, classical geometry, and rigidity; modeling techniques will include dynamic geometry software, matrix manipulation packages, and 3-D modeling applications; and building techniques will range from simple "garage" constructions to computer controlled cutting devices and 3-D printing.

Recommended Prep: Although there are not specific mathematics prerequisites beyond a comfort with upper level high-school mathematics, participants should be comfortable and willing to explore new mathematical ideas in some technical detail.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Undergraduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 212A

Real Analysis (116137)

Horng-Tzer Yau

2018 Fall (4 Credits)
Schedule: MW 1200 PM - 0115 PM

Instructor Permissions: None   **Enrollment Cap:** n/a

Measure theory, functional analysis, Sobolev spaces and introduction to harmonic analysis.

Recommended Prep: Knowledge of the material in Mathematics 114.

Requirements: Prerequisite: Mathematics 114

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 212BR

Advanced Real Analysis (120929)

Christian Brennecke

2019 Spring (4 Credits)
Schedule: MW 0900 AM - 1015 AM

Instructor Permissions: None   **Enrollment Cap:** n/a

Continuation of topics in real analysis, harmonic analysis and functional analysis. Possible topics include: L^p

spaces; Banach spaces and duality; weak and weak* convergence; Banach-Alaoglu Theorem; elements of the theory of distributions, methods from the calculus of variations with applications to PDE, Oscillatory integrals, Brownian motion and its application to the solution of Dirichlet's problem.

Recommended Prep: Knowledge of the material in Mathematics 212a.

Requirements: Prerequisite: Undergrads Require Mathematics 212A

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 213A

Advanced Complex Analysis (110880)

Yum Tong Siu

2018 Fall (4 Credits)

Schedule: TR 0300 PM - 0415 PM

Instructor Permissions: None   **Enrollment Cap:**   n/a

Fundamentals of complex analysis, and further topics such as elliptic functions, canonical products, conformal mappings, the zeta function and prime number theorem, and Nevanlinna theory.

Prerequisites: Basic complex analysis, topology of covering spaces, differential forms.

Recommended Prep: Basic complex analysis, topology of covering spaces, differential forms.

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students

Mathematics 213BR Section: LEC

Riemann Surfaces (111824)

Curtis McMullen

2019 Spring (4 Credits)

Schedule: TR 1030 AM - 1145 AM

Instructor Permissions: None   **Enrollment Cap:**   n/a

Fundamentals of algebraic curves as complex manifolds of dimension one. Topics may include branched coverings, sheaves and cohomology, potential theory, uniformization and moduli.

Recommended Prep: Knowledge of the material in Mathematics 213a.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 221

Algebra (123232)

Ana Balibanu

2018 Fall (4 Credits)

Schedule: MW 0300 PM - 0415 PM

Instructor Permissions: None   **Enrollment Cap:**   n/a

A first course in Algebra: Noetherian rings and modules, Hilbert basis theorem, Cayley-Hamilton theorem, integral dependence, Galois theory, Noether normalization, the Nullstellensatz, localization, primary decomposition. Representation theory of finite groups. Introduction to Lie groups and Lie algebras: definitions, the exponential maps, semi-simple Lie algebras, examples.

Recommended Prep: Mathematics 123.

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students

Mathematics 222

Lie Groups and Lie Algebras (123238)

Wilfried Schmid

2018 Fall (4 Credits)

Schedule: TR 1200 PM - 0115 PM

Instructor Permissions: None   **Enrollment Cap:**   n/a

Lie theory, including the classification of semi-simple Lie algebras and/or compact Lie groups and their representations.

Recommended Prep: Knowledge of the material in Mathematics 114, 123 and 132.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 223A Section: LECT

Algebraic Number Theory (123239)

Alison Miller

2018 Fall (4 Credits)

Schedule: MF 0300 PM - 0415 PM

Instructor Permissions: None   **Enrollment Cap:**   n/a

A graduate introduction to algebraic number theory. Topics: the structure of ideal class groups, groups of units, a study of zeta functions and L-functions, local fields, Galois cohomology, local class field theory, and local duality.

Recommended Prep: Knowledge of the material in Mathematics 129.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Graduate Students

Mathematics 223B Section: LECT

Algebraic Number Theory (123240)

Alison Miller

2019 Spring (4 Credits)

Schedule: MF 0300 PM - 0415 PM

Instructor Permissions: None   **Enrollment Cap:**   n/a

Continuation of Mathematics 223a. Topics: adeles, global class field theory, duality, cyclotomic fields. Other topics may include: Tate's thesis or Euler systems.

Recommended Prep: Knowledge of the material in Mathematics 223a.

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students

Mathematics 229X Section: LEC

Introduction to Analytic Number Theory (123242)

Noam D. Elkies

2019 Spring (4 Credits)

Schedule: MW 1030 AM - 1145 AM

Instructor Permissions: None   **Enrollment Cap:**   n/a

Fundamental methods, results, and problems of analytic number theory. Riemann zeta function and the Prime Number Theorem; Dirichlet's theorem on primes in arithmetic progressions; lower bounds on discriminants from functional equations; sieve methods, analytic estimates on exponential sums, and their applications.

Recommended Prep: Knowledge of the material in Mathematics 113 and 123.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

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Mathematics 230A

Differential Geometry (113369)

Karsten Gimre

2018 Fall (4 Credits)

Schedule: TR 0900 AM - 1015 AM

Instructor Permissions: None

Enrollment Cap: n/a

Smooth manifolds (vector fields, differential forms, and their algebraic structures; Frobenius theorem), Riemannian geometry (metrics, connections, curvatures, geodesics), Lie groups, principal bundles and associated vector bundles with their connections, curvature and characteristic classes. Other topics if time permits.

Recommended Prep: Knowlledge of the material in Mathematics 132 and 136.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 230BR

Advanced Differential Geometry (115039)

Shing-Tung Yau

2019 Spring (4 Credits)

Schedule: TR 1200 PM - 0115 PM

Instructor Permissions: None

Enrollment Cap: n/a

A continuation of Mathematics 230a. Topics in differential geometry: Analysis on manifolds. Laplacians. Hodge theory. Spin structures. Clifford algebras. Dirac operators. Index theorems. Applications.

Recommended Prep: Knowledge of the material in Mathematics 230a.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Graduate Students

Mathematics 231A

Algebraic Topology (123243)

Michael Hopkins

2018 Fall (4 Credits)

Schedule: MW 0130 PM - 0245 PM

Instructor Permissions: None

Enrollment Cap: n/a

Covering spaces and fibrations. Simplicial and CW complexes, Homology and cohomology, universal coefficients and Künneth formulas. Hurewicz theorem. Manifolds and Poincaré duality.

Recommended Prep: Knowledge of the material in Mathematics 131 and 132.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 231BR

Advanced Algebraic Topology (123433)

Alexander Kupers

2019 Spring (4 Credits)

Schedule: WF 0300 PM - 0415 PM

Instructor Permissions: None   **Enrollment Cap:**   n/a

Continuation of Mathematics 231a. Topics may include stable homotopy theory, topological or algebraic K-theory, characteristic classes and vector bundles, cobordism, and categorical homotopy theory.

Recommended Prep: Knowledge of the material in Mathematics 231a.

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students

Mathematics 232A

Introduction to Algebraic Geometry I (123441)

Dennis Gaitsgory

2018 Fall (4 Credits)

Schedule: TR 1200 PM - 0115 PM

Instructor Permissions: None   **Enrollment Cap:**   n/a

Introduction to complex algebraic curves, surfaces, and varieties.

Recommended Prep: Knowledge of the material in Mathematics 123 and 132 and 137.

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students

Mathematics 232BR

Algebraic Geometry II (123444)

Man-Wai Cheung

2019 Spring (4 Credits)

Schedule: MF 1200 PM - 0115 PM

Instructor Permissions: None   **Enrollment Cap:**   n/a

The course will cover the classification of complex algebraic surfaces.

Recommended Prep: Knowledge of the material in Mathematics 232a.

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science

FAS: Course Level	Primarily for Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 233A Section: LEC

Theory of Schemes I (123445)

Arnav Tripathy

2018 Fall (4 Credits)

Schedule: WF 1030 AM - 1145 AM

Instructor Permissions: None   **Enrollment Cap:**   n/a

An introduction to the theory and language of schemes. Textbooks: Algebraic Geometry by Robin Hartshorne and Geometry of Schemes by David Eisenbud and Joe Harris. Weekly homework will constitute an important part of the course.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 233BR

Theory of Schemes II (123479)

Arnav Tripathy

2019 Spring (4 Credits)

Schedule: TR 0130 PM - 0245 PM

Instructor Permissions: None   **Enrollment Cap:**   n/a

A continuation of Mathematics 233a. Will cover the theory of schemes, sheaves, and sheaf cohomology.

Recommended Prep: Knowledge of the material in Mathematics 233a.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 243

Evolutionary Dynamics (119511)

Martin Nowak

2019 Spring (4 Credits)

Schedule: TR 0300 PM - 0415 PM

Instructor Permissions: None   **Enrollment Cap:**   n/a

Advanced topics of evolutionary dynamics. Seminars and research projects.

Recommended Prep: Experience with mathematical biology at the level of Mathematics 153.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Graduate Students

Mathematics 251X

Topics on Geometric Analysis (207503)

Shing-Tung Yau

2018 Fall (4 Credits)

Instructor Permissions: None

Schedule: TR 1030 AM - 1145 AM

Enrollment Cap: n/a

A discussion of how nonlinear analysis is applied to solve problems in geometry and physics. We will cover some basic materials on nonlinear partial differential equations. A discussion of problems related to questions in general relativity such as definitions of quasilocal mass and its dynamical meaning. A discussion of existence of special metrics and connections over bundles. The major focus will be on Kahler manifolds.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 253Y

Symplectic Manifolds and Lagrangian Submanifolds (207504)

Denis Auroux

2018 Fall (4 Credits)

Instructor Permissions: None

Schedule: TR 1030 AM - 1145 AM

Enrollment Cap: n/a

The course will start with a review of standard symplectic topology: symplectic manifolds, symplectomorphisms, Lagrangian submanfilds, neighborhood theorems, almost-complex structures and compatibility, Hamiltonian group actions. The focus will then shift towards J-holomorphic curves: moduli space. Gromov compactness, etc., with a view towards Lagrangian Floer theory. The final part of the course will give a taste of moe advanced toppics: invariants of monotone Langrangians; Fukaya categories; mirror symmetry.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 258

L-Functions and Arithmetic Statistics (207488)

Barry Mazur

2019 Spring (4 Credits)

Schedule: TR 1200 PM - 0115 PM

| **Instructor Permissions:** | Instructor | **Enrollment Cap:** | 50 |

Modular Symbols, Special values of L-functions, Selmer groups, and (statistical) distributions related to them. We will study this in connection with expected behavior of the ranks of Mordell-Weil groups of varieties.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 263

Algebraic Vector Bundles and Motivic Homotopy Theory (207508)

Michael Hopkins

2019 Spring (4 Credits)

		Schedule:	MW 0130 PM - 0245 PM
Instructor Permissions:	None	**Enrollment Cap:**	n/a

The work of Lindel, Quillen and Suslin on a question of Serre shows that the set of isomorphism classes of algebraic vector bundles over a smooth affine variety over a field is "homotopy invariant". This means that questions about algebraic vector bundles can be approachd with motivic homotopy theory. A discussion of Serre's question, the theorems of Lindel, Quillen, and Suslin, the basics of motivic homotopy theory, the "affine representability" theorems of Morel, Asok-Hoyois-Went, and some applications of motivic homotoppy theory to the construction and classification of algebraic vector bundles.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 266Y

Topics in Analysis: Matrix Inequalities and Quantum Entropy (207542)

Marius Lemm

2019 Spring (4 Credits)

		Schedule:	TR 0300 PM - 0415 PM
Instructor Permissions:	None	**Enrollment Cap:**	n/a

Matrix inequalities are used in a variety of mathematical contexts They can be more subtle but more powerful than their scalar analogs. In this course, we will use methods from spectral theory, convex analysis, and complex analysis to develop a toolbox of matrix inequalities (mostly trace inequalities). We will develop the inequalities alongside the basic notions of quantum information theory. We will also discuss applications to random matrix theory.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 267X

Dynamical and Spectral Properties of Large Many-Body Quantum Systems (207510)

Christian Brennecke

2018 Fall (4 Credits)

Instructor Permissions: None

Schedule: MW 0900 AM - 1015 AM

Enrollment Cap: n/a

An analysis of spectral and dynamical properties of large bosonic many-body quantum systems. We will start by recalling first some basic concepts of quantum mechanics (self-adjoint operators, basic criteria for self-adjointness, spectral theorem and spectral types, Stone's theorem and existence of quantum dynamics). The main part of the course will be devoted to the concept of Bose-Einstein condensation. Starting with the microscopic many-body description, we will derive non-linear effective theories that describe energetic and dynamical properties of Bose-Einstein condensates interacting through mean-field and singular interaction potentials.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 269Y

Parabolic Equations on Complex Manifolds (207511)

Sebastien Picard

2019 Spring (4 Credits)

Instructor Permissions: Instructor

Schedule: TR 0130 PM - 0245 PM

Enrollment Cap: 30

An introduction to the theory of linear parabolic equations, including parabolic Schauder estimates and the Krylov-Safonov Harnack ineqality. An application of these techniques to study complex geometry via parabolic methods. Possible topics: Kahler-Ricci flow, fully nonlinear flows in Hermitian geometry, anomaly flow.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 278

Geometry and Algebra of Computational Complexity (207543)

David Hyeon

2018 Fall (4 Credits)

Instructor Permissions: None

Schedule: MW 0300 PM - 0415 PM

Enrollment Cap: n/a

The mathematical aspects of computational complexity theory will be broadly covered. We shall start with the basics of complexity theory (such as various notions of complexity and NP completeness), discuss other computation models and intractability results, and explore the algebro-geometric and representation theoretic approach to P vs NP.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 286

Random Matrices and Applications (207512)

Horng-Tzer Yau

2019 Spring (4 Credits)

Schedule: MW 1200 PM - 0115 PM

Instructor Permissions: Instructor

Enrollment Cap: 50

We will cover two topics in random matrix theory. 1. Concentration inequalities. 2. Stochastic flow method. We will start with a review of basic results in random matrices like local laws and Dyson's Brownian motions. We will discuss coupling methods in random matrices and various concentration inequalities.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 291

Analytic Methods in Differential Geometry (207604)

Karsten Gimre

2019 Spring (4 Credits)

Schedule: MW 1030 AM - 1145 AM

Instructor Permissions: None

Enrollment Cap: n/a

The injection of analysis into differential geometry distinguishes certain geometric objects, such as Ricci flows, Yang-Mills connections, and minimal submanifolds. Since these objects are defined as solutions of geometric partial differential equations, they are not given explicitly except in highly symmetric contexts. Instead, their construction is, broadly, as limits of approximating sequences. The primary concerns are then to do with precompactness theorems, the possible ensuing degenerations, and regularity of the limits. We will cover these problems in a number of contexts. Possible applications include the Kahler-Einstein problem, the positive energy theorem from general relativity, Cheeger-Coding theory, and Ricci flow with applications to 3-manifold topology.

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 292

Cluster Algebras and Cluster Varieties (207549)

Man-Wai Cheung

2018 Fall (4 Credits)   **Schedule:**   TR 0900 AM - 1015 AM

Instructor Permissions: None   **Enrollment Cap:**   n/a

An introduction to the cluster theory. Both the algebraic and geometric points of view will be discussed in this course. On the algebra side, the course will include the original set up and its relations with representation theory, combinations and category theory. On the geometric side, the course will explore the connections between cluster varieties with mirror symmetry and mathematical physics.

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students

Mathematics 295 Section: 1

Topics in Discrete Probability: Random Structures and Algorithms (207567)

David Gamarnik

2018 Fall (4 Credits)   **Schedule:**   MW 0130 PM - 0245 PM

Instructor Permissions: None   **Enrollment Cap:**   n/a

An introduction to probabilistic reasoning for random structures, including random graphs, graphical models and Markov Random Fields (MRF). Topics include: large deviations theory and concentration inequalities Theory of random graphs,the moment method. Combinatorial optimization on random graphs and the differential equations method. Planted clique and applications to sparse PCA in statistics. Gibbs measures on finite and infinite MRF. Algorithms for counting and computing partition functions, Dubroshin's uniqueness and the correlation decay method. Glauber dynamics and rapid/torpic mixing. Introduction to statistical physics. Reconstruction of MRF from observations. Sample and computational complexity.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Graduate Students

Mathematics 300

Teaching Undergraduate Mathematics (124821)

Jameel Al-Aidroos

Robin Gottlieb

2018 Fall (4 Credits)   **Schedule:**   T 0130 PM - 0245 PM

Instructor Permissions: Instructor   **Enrollment Cap:**   n/a

Become an effective instructor. This course focuses on observation, practice, feedback, and reflection providing insight into teaching and learning. Involves iterated videotaped micro-teaching sessions, accompanied by individual consultations. Required of all mathematics graduate students.

Class Notes: Robin Gottlieb and Brendan Kelly

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Not Available for Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None

Mathematics 304

Topics in Algebraic Topology (121078)

Michael Hopkins

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Mathematics 304

Topics in Algebraic Topology (121078)

Michael Hopkins

2018 Fall (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 305

Topics in Symplectic Geometry (207522)

Denis Auroux

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students

Mathematics 305

Topics in Symplectic Geometry (207522)

Denis Auroux

2018 Fall (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 316

Topics in Algebraic Geometry (203255)

Arnav Tripathy

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 316

Topics in Algebraic Geometry (203255)

Arnav Tripathy

2018 Fall (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 318

Topics in Number Theory (121353)

Barry Mazur

2019 Spring (4 Credits)

Instructor Permissions:	Instructor

Schedule:	TBD
Enrollment Cap:	n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Mathematics 318

Topics in Number Theory (121353)

Barry Mazur

2018 Fall (4 Credits)

Instructor Permissions:	Instructor

Schedule:	TBD
Enrollment Cap:	n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 320

Topics in Geometric Representation Theory (205137)

Ana Balibanu

2019 Spring (4 Credits)

Instructor Permissions:	Instructor

Schedule:	TBD
Enrollment Cap:	n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 320

Topics in Geometric Representation Theory (205137)

Ana Balibanu

2018 Fall (4 Credits)		**Schedule:**	TBD
Instructor Permissions:	Instructor	**Enrollment Cap:**	n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Mathematics 321

Topics in Mathematical Physics (118656)

Arthur Jaffe

2019 Spring (4 Credits)		**Schedule:**	TBD
Instructor Permissions:	Instructor	**Enrollment Cap:**	n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 321

Topics in Mathematical Physics (118656)

Arthur Jaffe

2018 Fall (4 Credits)		**Schedule:**	TBD
Instructor Permissions:	Instructor	**Enrollment Cap:**	n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

| FAS Divisional Distribution | Science & Engineering & Applied Science |

Mathematics 327

Topics in Several Complex Variables (113647)

Yum Tong Siu

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Class Notes:

Yum Tong Siu 7550

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 327

Topics in Several Complex Variables (113647)

Yum Tong Siu

2018 Fall (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Class Notes:

Yum Tong Siu 7550

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 332

Topics in Geometry and Topology (205138)

Alexander Kupers

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 332

Topics in Geometry and Topology (205138)

Alexander Kupers

2018 Fall (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor   **Enrollment Cap:** n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Graduate Students

Mathematics 333

Topics in Complex Analysis, Dynamics and Geometry (126825)

Curtis McMullen

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor   **Enrollment Cap:** n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 333

Topics in Complex Analysis, Dynamics and Geometry (126825)

Curtis McMullen

2018 Fall (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor   **Enrollment Cap:**   n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Mathematics 335

Topics in Differential Geometry and Analysis (116319)

Cliff Taubes

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor   **Enrollment Cap:**   n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 335

Topics in Differential Geometry and Analysis (116319)

Cliff Taubes

2018 Fall (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor   **Enrollment Cap:**   n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 340

Topics in Model Theory (205139)

Sebastien Vasey

2019 Spring (4 Credits)

Instructor Permissions: Instructor

Schedule: TBD

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 340

Topics in Model Theory (205139)

Sebastien Vasey

2018 Fall (4 Credits)

Instructor Permissions: Instructor

Schedule: TBD

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 345

Topics in Geometry and Topology (113664)

Peter Kronheimer

2019 Spring (4 Credits)

Instructor Permissions: Instructor

Schedule: TBD

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 345

Topics in Geometry and Topology (113664)

Peter Kronheimer

2018 Fall (4 Credits)

Schedule:	TBD		
Instructor Permissions:	Instructor	**Enrollment Cap:**	n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 346Y

Topics in Analysis: Quantum Dynamics (121102)

Horng-Tzer Yau

2019 Spring (4 Credits)

Schedule:	TBD		
Instructor Permissions:	Instructor	**Enrollment Cap:**	n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 346Y

Topics in Analysis: Quantum Dynamics (121102)

Horng-Tzer Yau

2018 Fall (4 Credits)

Schedule:	TBD		
Instructor Permissions:	Instructor	**Enrollment Cap:**	n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 352

Topics in Algebraic Number Theory (125869)

Mark Kisin

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 352

Topics in Algebraic Number Theory (125869)

Mark Kisin

2018 Fall (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Mathematics 356

Topics in Harmonic Analysis (118827)

Wilfried Schmid

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 356

Topics in Harmonic Analysis (118827)

Wilfried Schmid

2018 Fall (4 Credits)

Schedule:	TBD

Instructor Permissions: Instructor   **Enrollment Cap:** n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 357

Topics in Model Theory (159644)

William Boney

2019 Spring (4 Credits)

Schedule:	TBD

Instructor Permissions: Instructor   **Enrollment Cap:** n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 357

Topics in Model Theory (159644)

William Boney

2018 Fall (4 Credits)

Schedule:	TBD

Instructor Permissions: Instructor   **Enrollment Cap:** n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Mathematics 359

Topics in Probability and Analysis (205140)

Aukosh Jagannath

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor   **Enrollment Cap:**   n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 359

Topics in Probability and Analysis (205140)

Aukosh Jagannath

2018 Fall (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor   **Enrollment Cap:**   n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 360

Topics in Algebraic Combinatorics (207538)

Lauren Williams

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor   **Enrollment Cap:**   n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Graduate Students

Mathematics 360

Topics in Algebraic Combinatorics (207538)

Lauren Williams

2018 Fall (4 Credits)

Schedule:	TBD

Instructor Permissions: Instructor   **Enrollment Cap:** n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Graduate Students

Mathematics 362

Topics in Number Theory (156036)

Alison Miller

2019 Spring (4 Credits)

Schedule:	TBD

Instructor Permissions: Instructor   **Enrollment Cap:** n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	Science & Engineering & Applied Science

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Mathematics 362

Topics in Number Theory (156036)

Alison Miller

2018 Fall (4 Credits)

Schedule:	TBD

Instructor Permissions: Instructor   **Enrollment Cap:** n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	Science & Engineering & Applied Science

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Mathematics 364

Topics in Algebraic Geometry (203316)

Brooke Ullery

2019 Spring (4 Credits)

		Schedule:	TBD
Instructor Permissions:	Instructor	**Enrollment Cap:**	n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Graduate Course

Mathematics 364

Topics in Algebraic Geometry (203316)

Brooke Ullery

2018 Fall (4 Credits)

		Schedule:	TBD
Instructor Permissions:	Instructor	**Enrollment Cap:**	n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

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Mathematics 365

Topics in Differential Geometry (114080)

Shing-Tung Yau

2019 Spring (4 Credits)

		Schedule:	TBD
Instructor Permissions:	Instructor	**Enrollment Cap:**	n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science

All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Mathematics 365

Topics in Differential Geometry (114080)

Shing-Tung Yau

2018 Fall (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 370 Section: 01

Topics in Linear Algebra and Multivariable Calculus; and Their Applications (205357)

Paul Bamberg

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Course Notes: This course is for graduate students only.

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None
FAS: Course Level	Graduate Course

Mathematics 373

Topics in Algebraic Topology (125871)

Jacob Lurie

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 373

Topics in Algebraic Topology (125871)

Jacob Lurie

2018 Fall (4 Credits)

		Schedule:	TBD
Instructor Permissions:	Instructor	**Enrollment Cap:**	n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 375

Topics in Mathematical Physics: Quantum Mechanics (207539)

Christian Brennecke

2019 Spring (4 Credits)

		Schedule:	TBD
Instructor Permissions:	Instructor	**Enrollment Cap:**	n/a

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 375

Topics in Mathematical Physics: Quantum Mechanics (207539)

Christian Brennecke

2018 Fall (4 Credits)

		Schedule:	TBD
Instructor Permissions:	Instructor	**Enrollment Cap:**	n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students

FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 377

Topics in Complex Geometry (207540)

Sebastien Picard

2019 Spring (4 Credits)

Instructor Permissions: Instructor

Schedule: TBD

Enrollment Cap: n/a

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	Science & Engineering & Applied Science
FAS: Course Level	Primarily for Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 377

Topics in Complex Geometry (207540)

Sebastien Picard

2018 Fall (4 Credits)

Instructor Permissions: Instructor

Schedule: TBD

Enrollment Cap: n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 381

Introduction to Geometric Representation Theory (121082)

Dennis Gaitsgory

2019 Spring (4 Credits)

Instructor Permissions: Instructor

Schedule: TBD

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None
FAS: Course Level	Graduate Course

Mathematics 381

Introduction to Geometric Representation Theory (121082)

Dennis Gaitsgory

2018 Fall (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None

Mathematics 382

Topics in Algebraic Geometry (111210)

Joseph D. Harris

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Mathematics 382

Topics in Algebraic Geometry (111210)

Joseph D. Harris

2018 Fall (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None

Mathematics 385

Topics in Set Theory (110218)

W. Hugh Woodin

2019 Spring (4 Credits)

Schedule:	TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None

Mathematics 385

Topics in Set Theory (110218)

W. Hugh Woodin

2018 Fall (4 Credits)

Schedule:	TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Mathematics 388

Topics in Mathematics and Biology (118701)

Martin Nowak

2019 Spring (4 Credits)

Schedule:	TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course
FAS Divisional Distribution	None

Mathematics 388

Topics in Mathematics and Biology (118701)

Martin Nowak

2018 Fall (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Mathematics 389

Topics in Number Theory (119721)

Noam D. Elkies

2019 Spring (4 Credits)

Schedule: TBD

Instructor Permissions: Instructor

Enrollment Cap: n/a

Class Notes:

Noam D. Elkies 2604

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS: Course Level	Graduate Course

Mathematics 389

Topics in Number Theory (119721)

Noam D. Elkies

2018 Fall (4 Credits)

Schedule: TBD

| **Instructor Permissions:** | Instructor | **Enrollment Cap:** | n/a |

Class Notes:

Noam D. Elkies 2604

| **Requirements:** | Prerequisite: Graduate Students Only |

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	None

Mathematics 390

Topics in analysis and Quantum Physics (207547)

Marius Lemm

2019 Spring (4 Credits)		**Schedule:**	TBD
Instructor Permissions:	Instructor	**Enrollment Cap:**	n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
All: Cross Reg Availability	Available for Harvard Cross Registration
FAS Divisional Distribution	Science & Engineering & Applied Science

Mathematics 390

Topics in analysis and Quantum Physics (207547)

Marius Lemm

2018 Fall (4 Credits)		**Schedule:**	TBD
Instructor Permissions:	Instructor	**Enrollment Cap:**	n/a

Additional Course Attributes:

Attribute	Value(s)
FAS: Course Level	Primarily for Graduate Students
FAS Divisional Distribution	Science & Engineering & Applied Science
All: Cross Reg Availability	Available for Harvard Cross Registration

Mathematics 395

Topics in Cluster Algebra (205141)

Man-Wai Cheung

| 2019 Spring (4 Credits) | **Schedule:** | TBD |

Instructor Permissions: Instructor   **Enrollment Cap:**   n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration

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Mathematics 395

Topics in Cluster Algebra (205141)

Man-Wai Cheung

2018 Fall (4 Credits)   **Schedule:**   TBD

Instructor Permissions: Instructor   **Enrollment Cap:**   n/a

Requirements: Prerequisite: Graduate Students Only

Additional Course Attributes:

Attribute	Value(s)
FAS Divisional Distribution	None
FAS: Course Level	Graduate Course
All: Cross Reg Availability	Available for Harvard Cross Registration