Mathematics

Chair
Dan Abramovich

The Mathematics Department at Brown balances a lively interest in students and teaching with a distinguished research reputation. Our several strong research groups, Analysis, Algebraic Geometry, Geometry and Topology, and Number Theory, all have active weekly seminars that draw speakers ranging from the local to the international. We support 40 to 50 graduate students in a Ph.D. program whose graduates populate top mathematics departments and prominent positions in industry. Our joint graduate courses and seminars with the adjacent Division of Applied Mathematics add to the breadth of offerings available to our graduate students. The undergraduate program in mathematics at Brown is designed to prepare students for careers in the mathematical sciences and other careers requiring strong analytical skills, while engaging more ambitious students in creative projects that can culminate in a senior thesis.

For additional information, please visit the department's website: http://www.math.brown.edu/

Mathematics Concentration Requirements

Mathematics is a grouping of sciences, including geometry, algebra, and calculus, that study quantity, structure, space, and change. Mathematics concentrators at Brown can explore these concepts through the department’s broad course offerings and flexible concentration requirements. The concentration leads to either the Bachelor of Arts or Bachelor of Science degree (the latter is strongly recommended for students interested in pursuing graduate study in mathematics or related fields). Concentrators begin their learning with multivariable calculus, linear algebra, and abstract algebra. Beyond these prerequisites, students take a variety of advanced topics on the 1000 and 2000 level based on their interests. Students also have the option of completing a thesis project.

Concentrators in mathematics should complete the prerequisites by the end of their sophomore year. It is strongly recommended that students take MATH 1010 before taking MATH 1130.

Standard program for the A.B. degree

Prerequisites:
Multivariable calculus and linear algebra (choose one of the following sequences):

<table>
<thead>
<tr>
<th>Course</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 0180 &amp; MATH 0520</td>
<td>Intermediate Calculus and Linear Algebra</td>
</tr>
<tr>
<td>MATH 0180 &amp; MATH 0540</td>
<td>Intermediate Calculus and Honors Linear Algebra</td>
</tr>
<tr>
<td>MATH 0200 &amp; MATH 0520</td>
<td>Intermediate Calculus (Physics/Engineering) and Linear Algebra</td>
</tr>
<tr>
<td>MATH 0350 &amp; MATH 0540</td>
<td>Honors Calculus and Honors Linear Algebra</td>
</tr>
</tbody>
</table>

Or the equivalent

Program:

<table>
<thead>
<tr>
<th>Course</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 1130 &amp; MATH 1140</td>
<td>Functions of Several Variables and Functions of Several Variables</td>
</tr>
<tr>
<td>MATH 1530</td>
<td>Abstract Algebra</td>
</tr>
<tr>
<td>MATH 1540</td>
<td>Topics in Abstract Algebra</td>
</tr>
<tr>
<td>MATH 1560</td>
<td>Number Theory</td>
</tr>
</tbody>
</table>

Four other 1000- or 2000-level Mathematics courses. The year-long sequence 0750/0760 may be substituted for one of these course credits.

Four additional courses in mathematics, science, economics, or applied mathematics approved by the concentration advisor.

Total Credits 14

Honors

Honors degrees may be recommended for students who have exhibited high achievement in mathematics. Candidates must complete at least eight mathematics courses at the 1000 or 2000 level with sufficiently good grades and must write an honors thesis under the guidance of a faculty member. The honors thesis is usually written while the candidate is enrolled in MATH 1970. The candidate should consult with the concentration advisor for the precise grade requirements.

Those interested in graduate study in mathematics are encouraged to take:

<table>
<thead>
<tr>
<th>Course</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 1130</td>
<td>Functions of Several Variables</td>
</tr>
<tr>
<td>MATH 1140</td>
<td>Functions of Several Variables</td>
</tr>
<tr>
<td>MATH 1260</td>
<td>Complex Analysis</td>
</tr>
<tr>
<td>MATH 1410</td>
<td>Topology</td>
</tr>
<tr>
<td>MATH 1540</td>
<td>Topics in Abstract Algebra</td>
</tr>
</tbody>
</table>

Mathematics-Computer Science Concentration Requirements

Students may opt to pursue an interdisciplinary Bachelor of Science degree in Math-Computer Science, a concentration administered cooperatively between the mathematics and computer science departments. Course requirements include math- and systems-oriented computer science courses, as well as computational courses in applied math. Students must identify a series of electives that cohere around a common theme. As with other concentrations offered by the Computer Science department, students have the option to pursue the professional track (http://www.cs.brown.edu/ugrad/concentrations/professional.track.html) of the ScB program in Mathematics-Computer Science.

Requirements for the Standard Track of the Sc.B. degree.

Prerequisites

Three semesters of Calculus to the level of MATH 0180, MATH 0200, or MATH 0350.

<table>
<thead>
<tr>
<th>Course</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 0520</td>
<td>Linear Algebra</td>
</tr>
<tr>
<td>MATH 0540</td>
<td>Honors Linear Algebra</td>
</tr>
<tr>
<td>CSCI 0530</td>
<td>Coding the Matrix: An Introduction to Linear Algebra for Computer Science</td>
</tr>
</tbody>
</table>

Core Courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 0180 &amp; MATH 0520</td>
<td>Intermediate Calculus and Linear Algebra</td>
</tr>
<tr>
<td>MATH 0180 &amp; MATH 0540</td>
<td>Intermediate Calculus and Honors Linear Algebra</td>
</tr>
<tr>
<td>MATH 0200 &amp; MATH 0520</td>
<td>Intermediate Calculus (Physics/Engineering) and Linear Algebra</td>
</tr>
<tr>
<td>MATH 0350 &amp; MATH 0540</td>
<td>Honors Calculus and Honors Linear Algebra</td>
</tr>
</tbody>
</table>

Or the equivalent

Program:

<table>
<thead>
<tr>
<th>Course</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 1130 &amp; MATH 1140</td>
<td>Functions of Several Variables and Functions of Several Variables</td>
</tr>
<tr>
<td>MATH 1530</td>
<td>Abstract Algebra</td>
</tr>
<tr>
<td>MATH 1540</td>
<td>Topics in Abstract Algebra</td>
</tr>
<tr>
<td>MATH 1560</td>
<td>Number Theory</td>
</tr>
</tbody>
</table>

Four other 1000- or 2000-level Mathematics courses. The year-long sequence 0750/0760 may be substituted for one of these course credits.

Four additional courses in mathematics, science, economics, or applied mathematics approved by the concentration advisor.

Total Credits 14
Students must complete two two-to-four-month full-time professional experiences, doing work that is related to their concentration programs. Such work is normally done within an industrial organization, but may also be at a university under the supervision of a faculty member.

| Total Credits | 19 |
| Select one of the following series: | |
| **Series A** | |
| CSCI 0150 & CSCI 0160 | Introduction to Object-Oriented Programming and Computer Science and Introduction to Algorithms and Data Structures |
| **Series B** | |
| CSCI 0170 & CSCI 0180 | Computer Science: An Integrated Introduction and Computer Science: An Integrated Introduction |
| **Series C** | |
| CSCI 0190 | Accelerated Introduction to Computer Science (and an additional CS course not otherwise used to satisfy a concentration requirement; this course may be CSCI 0180, an intermediate-level CS course, or a 1000-level CS course) |
| CSCI 0320 or CSCI 0330 | Introduction to Software Engineering or Introduction to Computer Systems |
| or CSCI 1010 | Theory of Computation |
| Three 1000-level Mathematics courses | 3 |
| Three advanced courses in Computer Science | 3 |
| Three additional courses different from any of the above chosen from Mathematics, Computer Science, Applied Mathematics, or related areas | 3 |
| A capstone course in Computer Science or Mathematics | 1 |

On completion of each professional experience, the student must write and upload to ASK a reflective essay about the experience addressing the following prompts, to be approved by the student’s concentration advisor:

- Which courses were put to use in your summer’s work? Which topics, in particular, were important?
- In retrospect, which courses should you have taken before embarking on your summer experience? What are the topics from these courses that would have helped you over the summer if you had been more familiar with them?
- Are there topics you should have been familiar with in preparation for your summer experience, but are not taught at Brown? What are these topics?
- What did you learn from the experience that probably could not have been picked up from course work?
- Is the sort of work you did over the summer something you would like to continue doing once you graduate? Explain.
- Would you recommend your summer experience to other Brown students? Explain.

---

### Mathematics-Economics Concentration Requirements

The Mathematics-Economics concentration is designed to give a background in economic theory plus the mathematical tools needed to analyze and develop additional theoretical constructions. The emphasis is on the abstract theory itself. Students may choose either the standard or the professional track, both award a Bachelor of Arts degree.

#### Standard Mathematics-Economics Concentration

<table>
<thead>
<tr>
<th>Economics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ECON 1130</td>
<td>Intermediate Microeconomics (Mathematical)</td>
</tr>
<tr>
<td>ECON 1210</td>
<td>Intermediate Macroeconomics</td>
</tr>
<tr>
<td>ECON 1630</td>
<td>Econometrics I</td>
</tr>
</tbody>
</table>

Two courses from the “mathematical-economics” group:

<table>
<thead>
<tr>
<th>Economics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ECON 1170</td>
<td>Welfare Economics and Social Choice Theory</td>
</tr>
<tr>
<td>ECON 1225</td>
<td>Advanced Macroeconomics: Monetary, Fiscal, and Stabilization Policies</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Economics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ECON 1465</td>
<td>Market Design: Theory and Applications</td>
</tr>
<tr>
<td>ECON 1470</td>
<td>Bargaining Theory and Applications</td>
</tr>
<tr>
<td>ECON 1640</td>
<td>Econometrics II</td>
</tr>
<tr>
<td>ECON 1650</td>
<td>Financial Econometrics</td>
</tr>
<tr>
<td>ECON 1660</td>
<td>Big Data</td>
</tr>
<tr>
<td>ECON 1750</td>
<td>Investments II</td>
</tr>
<tr>
<td>ECON 1759</td>
<td>Data, Statistics, Finance</td>
</tr>
<tr>
<td>ECON 1810</td>
<td>Economics and Psychology</td>
</tr>
<tr>
<td>ECON 1820</td>
<td>Theory of Behavioral Economics</td>
</tr>
<tr>
<td>ECON 1850</td>
<td>Theory of Economic Growth</td>
</tr>
<tr>
<td>ECON 1860</td>
<td>The Theory of General Equilibrium</td>
</tr>
<tr>
<td>ECON 1870</td>
<td>Game Theory and Applications to Economics</td>
</tr>
</tbody>
</table>

One course from the “data methods” group:

<table>
<thead>
<tr>
<th>Economics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ECON 1301</td>
<td>Economics of Education I</td>
</tr>
<tr>
<td>ECON 1305</td>
<td>Economics of Education: Research</td>
</tr>
<tr>
<td>ECON 1310</td>
<td>Labor Economics</td>
</tr>
<tr>
<td>ECON 1360</td>
<td>Health Economics</td>
</tr>
<tr>
<td>ECON 1410</td>
<td>Urban Economics</td>
</tr>
<tr>
<td>ECON 1480</td>
<td>Public Economics</td>
</tr>
<tr>
<td>ECON 1510</td>
<td>Economic Development</td>
</tr>
<tr>
<td>ECON 1520</td>
<td>The Economic Analysis of Institutions</td>
</tr>
</tbody>
</table>
The requirements for the professional track include all those of the Economics and Data methods requirement. Students must complete two two-to-four month full-time professional experiences, doing work that is relevant to their concentration programs. Such work is normally done within an industrial organization, but may also be at a university under the supervision of a faculty member. On completion of each professional experience, the student must write an honors thesis in senior year following the procedures specified by the concentration (see Economics Department website).

**Honors and Capstone Requirement:**

Admission to candidacy for honors in the concentration is granted on the following basis: 3.7 GPA for Economics courses, and 3.5 GPA overall. To graduate with honors, a student must write an honors thesis in senior year following the procedures specified by the concentration (see Economics Department website).

### Professional Track

The requirements for the professional track include all those of the standard track, as well as the following:

Students must complete two two-to-four month full-time professional experiences, doing work that is relevant to their concentration programs. Such work is normally done within an industrial organization, but may also be at a university under the supervision of a faculty member. On completion of each professional experience, the student must write and upload to ASK a reflective essay about the experience addressing the following prompts, to be approved by the student's concentration advisor:

- Which courses were put to use in your summer's work? Which topics, in particular, were important?
- In retrospect, which courses should you have taken before embarking on your summer experience? What are the topics from these courses that would have helped you over the summer if you had been more familiar with them?
- Are there topics you should have been familiar with in preparation for your summer experience, but are not taught at Brown? What are these topics?
- What did you learn from the experience that probably could not have been picked up from course work?
- Is the sort of work you did over the summer something you would like to continue doing once you graduate? Explain.

Would you recommend your summer experience to other Brown students? Explain.

### Mathematics Graduate Program

The department of Mathematics offers a graduate program leading to the Doctor of Philosophy (Ph.D.) degree. Ph.D. students may also earn a transitional A.M. or Sc.M. en route to the Ph.D.

For more information on admission and program requirements, please visit the following website:

http://www.brown.edu/academics/gradschool/programs/mathematics

### Courses

**MATH 0010A. First Year Seminar: A Taste of the Infinite.**

The concept of infinity occurs in many disciplines - philosophy, mathematics, physics, religion, art, and so on. This class will focus on the mathematical aspects of infinity, surveying some of the ways that the infinite arises in mathematics. Topics will include: the sizes of infinity, rates of growth, computational complexity, construction of the real numbers, the notion of compactness, geometric spaces, transcendental numbers, and fractal sets. I will not assume any prior knowledge of mathematics beyond a good grounding in high school algebra and geometry.

**MATH 0010B. Exploring the Fourth Dimension.**

This interdisciplinary seminar explores all the mathematics students have seen or ever will see, concentrating on an engaging topic that begins with elementary geometry and branches out to literature, history, philosophy, and art as well as physics and other sciences. Guideposts to the fourth dimension include Salvador Dalí's Corpus Hypercubicus, Edwin Abbott Abbott's Flatland, and Jeff Weeks' The Shape of Space. Students will investigate new mathematical topics such as combinatorics, regular polytopes, topology, and non-Euclidean geometry. Although students will use computers for visualization, no computer experience is required. There are no specific mathematical prerequisites except curiosity and a willingness to participate actively. Students considering concentrations in humanities, social sciences, and the arts are especially invited to this first-year seminar. Enrollment limited to 19 first year students.

**MATH 0010C. From 'Flatland' to the Fourth Dimension.**

No description available. Enrollment limited to 15 first year students. Instructor permission required, after initial placement of students.

**MATH 0050. Analytic Geometry and Calculus.**

MATH 0050 and 0060 provide a slower-paced introduction to calculus for students who require additional preparation. Presents the same calculus topics as MATH 0090, together with a review of the necessary precalculus topics. Students successfully completing this sequence are prepared for MATH 0100. May not be taken for credit in addition to MATH 0070 or MATH 0090. S/NC only.

Fall MATH0050 S01 16381 TTh 10:30-11:50(13) (O. Mandelshtam)
Fall MATH0050 C01 16461 Arranged 'To Be Arranged'

**MATH 0060. Analytic Geometry and Calculus.**

A slower-paced introduction to calculus for students who require additional preparation. Presents the same calculus topics as MATH 0090, together with a review of the necessary precalculus topics. Students successfully completing this sequence are prepared for MATH 0100. Prerequisite: MATH 0050 or written permission. May not be taken for credit in addition to MATH 0070 or MATH 0090. S/NC only.

Spr MATH0060 S01 25273 MWF 10:00-10:50(03) 'To Be Arranged'
Spr MATH0060 C01 25274 Arranged 'To Be Arranged'

**MATH 0070. Calculus with Applications to Social Science.**

A survey of calculus for students who wish to learn the basics of calculus for application to social sciences or for cultural appreciation as part of a broader education. Topics include functions, equations, graphs, exponentials and logarithms, and differentiation and integration; applications such as marginal analysis, growth and decay, optimization, and elementary differential equations. May not be taken for credit in addition to MATH 0050 or MATH 0060 or MATH 0090. S/NC only.

Fall MATH0070 S01 16982 TTh 9:00-10:20(02) (A. Landman)
MATH 0090. Introductory Calculus, Part I.
An intensive course in calculus of one variable including limits, differentiation, maxima and minima, the chain rule, rational functions, trigonometric functions, and exponential functions. Introduction to integration with applications to area and volumes of revolution. MATH 0090 and MATH 0100 or the equivalent are recommended for all students intending to concentrate in the sciences or mathematics. May not be taken for credit in addition to MATH 0050 or MATH 0060 or MATH 0070. S/N/C only.

MATH 0100. Introductory Calculus, Part II.
A continuation of the material of MATH 0090 including further development of integration, techniques of integration, and applications. Other topics include infinite series, power series, Taylor's formula, polar and parametric equations, and an introduction to differential equations. MATH 0090 or the equivalent are recommended for all students intending to concentrate in the sciences or mathematics.

MATH 0170. Advanced Placement Calculus.
 Begins with a review of fundamentals of calculus and includes infinite series, power series, paths, and differential equations of first and second order. Placement in this course is determined by the department on the basis of high school AP examination scores or the results of tests given by the department during orientation week. May not be taken in addition to MATH 0100.

MATH 0180. Intermediate Calculus.
Three-dimensional analytic geometry. Differential and integral calculus for functions of two or three variables: partial derivatives, multiple integrals, line integrals, Green's Theorem, Stokes' Theorem. Prerequisite: MATH 0100, 0170, or 0190.

MATH 0190. Advanced Placement Calculus (Physics/Engineering).
Covers roughly the same material and has the same prerequisites as MATH 0170, but is intended for students with a special interest in physics or engineering. The main topics are: calculus of vectors and paths in two and three dimensions; differential equations of the first and second order; and infinite series, including power series and Fourier series. The extra hour is a weekly problem session.

MATH 0200. Intermediate Calculus (Physics/Engineering).
Covers roughly the same material as MATH 0180, but is intended for students with a special interest in physics or engineering. The main topics are: geometry of three-dimensional space; partial derivatives; Lagrange multipliers; double, surface, and triple integrals; vector analysis; Stokes' theorem and the divergence theorem, with applications to electrostatics and fluid flow. The extra hour is a weekly problem session. Recommended prerequisite: MATH 0100, 0170, or 0190.
MATH 0350. Honors Calculus.
A third-semester calculus course for students of greater aptitude and motivation. Topics include vector analysis, multiple integration, partial differentiation, line integrals, Green’s theorem, Stokes’ theorem, the divergence theorem, and additional material selected by the instructor. Prerequisite: Advanced placement or written permission.
Fall MATH0350 S01 16435 MWF 11:00-11:50(11) (B. Cole)
Fall MATH0350 S02 16436 MWF 2:00-2:50(07) ‘To Be Arranged’

MATH 0420. Introduction to Number Theory.
An overview of one of the most beautiful areas of mathematics. Ideal for any student who wants a taste of mathematics outside of, or in addition to, the calculus sequence. Topics include: prime numbers, congruences, quadratic reciprocity, sums of squares, Diophantine equations, and, as time permits, such topics as cryptography and continued fractions. No prerequisites.
Spr MATH0420 S01 25311 MWF 10:00-10:50(03) (J. Kostik)

MATH 0520. Linear Algebra.
Vector spaces, linear transformations, matrices, systems of linear equations, bases, projections, rotations, determinants, and inner products. Applications may include differential equations, difference equations, least squares approximations, and models in economics and in biological and physical sciences. MATH 0520 or MATH 0540 is a prerequisite for all 1000-level courses in Mathematics except MATH 1260 or MATH 1610. Recommended prerequisite: MATH 0100 or equivalent. May not be taken in addition to MATH 0540.
Fall MATH0520 S01 16437 MWF 12:00-12:50(04) ‘To Be Arranged’
Fall MATH0520 S02 16438 TTh 9:00-10:20(04) ‘To Be Arranged’
Fall MATH0520 S03 16439 MWF 10:30-11:50(04) ‘To Be Arranged’
Spr MATH0520 S01 25312 MWF 9:00-9:50(16) ‘To Be Arranged’
Spr MATH0520 S02 25313 MWF 12:00-12:50(16) ‘To Be Arranged’
Spr MATH0520 S03 25314 TTh 9:00-10:20(16) (A. Landman)
Spr MATH0520 S04 25315 TTh 10:30-11:50(16) ‘To Be Arranged’
Spr MATH0520 S05 25316 TTh 1:00-2:20(16) ‘To Be Arranged’

MATH 0540. Honors Linear Algebra.
Linear algebra for students of greater aptitude and motivation, especially mathematics and science concentrators with a good mathematical preparation. Matrices, linear equations, determinants, and eigenvalues; vector spaces and linear transformations; inner products; Hermitian, orthogonal, and unitary matrices; and Jordan normal forms. Provides a more extensive treatment of the topics in MATH 0520. Recommended prerequisites: MATH 0100 or equivalent.
Fall MATH0540 S01 16440 MWF 1:00-1:50(06) (R. Ramadas)
Fall MATH0540 S02 16441 TTh 2:30-3:50(03) (A. Landman)
Spr MATH0540 S01 25317 TTh 10:30-11:50(09) (J. Silverman)
Spr MATH0540 S02 25318 TTh 2:30-3:50(16) (A. Landman)

MATH 0550. Problems from the History of Mathematics.
This course presents a history of mathematics through the lens of famous mathematical problems. Beginning in Ancient Greece and Babylon and continuing to the present, we discuss the problems that shaped the development of modern mathematics. Sample topics include the impossible constructions of Ancient Greece, paradoxes from the birth of calculus, the problems that gave rise to graph theory, and the rise of computer-assisted proofs.

MATH 0580. Mathematical Forms in Architecture.
This project will explore and advance innovative applications of mathematics to architecture using computational methods. Historically, architecture has been guided primarily by an intuitive creative process. In contrast to the end-results of intuitive design, many "optimal" forms--i.e. geometric shapes and configurations that satisfy extremal conditions--are unique because they are the result of systematic physical experiments or explicit mathematical study in addition to imaginative input. Classic questions for which human intuition alone has been incapable of finding a solution include: What is the exact shape of the optimal arch?, or What is the shape of a child's slide that minimizes the time of travel? The use of computational methods to generate solutions to these problems will be made considerably simpler via optimization libraries in Mathematica. The application to architecture in this project will provide students a unique concrete backdrop to visualize solutions to these problems.

MATH 0750. Introduction to Higher Mathematics.
This year-long class will expose students to six fundamental areas of mathematics. It will be team taught by six members of the faculty. Fall topics will include logic, combinatorics, and analysis. Spring topics will include number theory, algebra, and geometry. Approximately 4 weeks will be devoted to each topic. S/NC
Fall MATH0750 S01 16442 TTh 1:00-2:20(08) ‘To Be Arranged’

MATH 0760. Introduction to Higher Mathematics.
This year-long class will expose students to six fundamental areas of mathematics. It will be team taught by six members of the faculty. Fall topics will include logic, combinatorics, and analysis. Spring topics will include number theory, algebra, and geometry. Approximately 4 weeks will be devoted to each topic.
Spr MATH0760 S01 25319 TTh 1:00-2:20(08) ‘To Be Arranged’

MATH 1010. Analysis: Functions of One Variable.
Completeness properties of the real number system, topology of the real line. Proof of basic theorems in calculus, infinite series. Topics selected from ordinary differential equations. Fourier series, Gamma functions, and the topology of Euclidean plane and 3-space. Prerequisite: MATH 0180, 0200, or 0350. MATH 0520 or 0540 may be taken concurrently. Most students are advised to take MATH 1010 before MATH 1130.
Spr MATH1010 S01 25320 MWF 1:00-1:50(06) (J. Kostik)

MATH 1040. Fundamental Problems of Geometry.
This class discusses geometry from a modern perspective. Topics include hyperbolic, projective, conformal, and affine geometry, and various theorems and structures built out of them. Prerequisite: MA 0520, MA 0540, or permission of the instructor.
Spr MATH1040 S01 25321 TTh 10:30-11:50(09) ‘To Be Arranged’

The study of curves and surfaces in 2- and 3-dimensional Euclidean space using the techniques of differential and integral calculus and linear algebra. Topics include curvature and torsion of curves, Frenet-Serret frames, global properties of closed curves, intrinsic and extrinsic properties of surfaces, Gaussian curvature and mean curvature, geodesics, minimal surfaces, and the Gauss-Bonnet theorem.
Fall MATH1060 S01 16443 TTh 10:30-11:50(13) (G. Daskalopoulos)

MATH 1110. Ordinary Differential Equations.
Ordinary differential equations, including existence and uniqueness theorems and the theory of linear systems. Topics may also include stability theory, the study of singularities, and boundary value problems.
Fall MATH1110 S01 16444 TTh 2:30-3:50(03) (H. Nguyen)

MATH 1120. Partial Differential Equations.
The wave equation, the heat equation, Laplace’s equation, and other classical equations of mathematical physics and their generalizations. Solutions in series of eigenfunctions, maximum principles, the method of characteristics, Green's functions, and discussion of well-posedness. Prerequisites: MATH 0520 or MATH 0540, or instructor permission.
Spr MATH1120 S01 25322 TTh 2:30-3:50(11) (N. Kapouleas)
MATH 1140. Functions Of Several Variables. See Functions Of Several Variables (MATH 1130) for course description. Prerequisite: MATH 1130 or instructor permission.
Spr MATH1140 S01 25323 MWF 2:00-2:50(07) (B. Cole)

MATH 1150. Machine Learning for Scientific Modeling: Data-Driven Discovery of Differential Equations. This junior/senior level course will explore the use of Machine Learning to automate the discovery and calibration of models involving differential equations directly from data. After introducing the basic machine learning tools (Gaussian Processes and Neural Networks) we will see how they can be combined with ODE and PDE computational methods to generate models in physics, medicine, and finance. The course will progress to a survey of recent research works on the topic. No prior knowledge of machine learning is required.

MATH 1230. Graph Theory. This course covers important material about graph theory, such as spanning trees, network flow problems, matching problems, coloring problems, planarity, Cayley graphs, spectral theory on graphs, and Ramsey Theory. The emphasis will be on a combination of theory and algorithms. Depending on the instructor, connections to such fields as combinatorics, geometry, or computer science might be emphasized. Prerequisite: MATH 0180, 0200 or 0350 and MATH 0520 or 0540 are recommended. Enrollment limited to 40.
Spr MATH1230 S01 25327 TTh 2:30-3:50(11) (R. Schwartz)

MATH 1260. Complex Analysis. Examines one of the cornerstones of mathematics. Complex differentiability, Cauchy-Riemann differential equations, contour integration, residue calculus, harmonic functions, geometric properties of complex mappings. Prerequisite: MATH 0180, 0200 or 0350 and MATH 0520 or 0540 are required. Fall MATH1260 S01 16446 TTh 1:00-2:20(06) (J. Holmer)

MATH 1270. Topics in Functional Analysis. Infinite-dimensional vector spaces with applications to some or all of the following topics: Fourier series and integrals, distributions, differential equations, integral equations, calculus of variations. Prerequisite: At least one 1000-level course in Mathematics or Applied Mathematics, or permission of the instructor.

MATH 1410. Topology. Topology of Euclidean spaces, winding number and applications, knot theory, fundamental group and covering spaces. Euler characteristic, simplicial complexes, classification of two-dimensional manifolds, vector fields, the Poincaré-Hopf theorem, and introduction to three-dimensional topology. Prerequisites: MATH 0520 or MATH 0540, or instructor permission.
Spr MATH1410 S01 25914 TTh 9:00-10:20(01) 'To Be Arranged'

MATH 1530. Abstract Algebra. An introduction to the principles and concepts of modern abstract algebra. Topics include groups, rings, and fields; applications to number theory, the theory of equations, and geometry. MATH 1530 is required of all students concentrating in mathematics.
Fall MATH1530 S01 16449 MWF 11:00-11:50(16) (J. Silverman)
Spr MATH1530 S01 25324 MWF 11:00-11:50(04) (R. Ramadas)

MATH 1540. Topics in Abstract Algebra. Galois theory together with selected topics in algebra. Examples of subjects which have been presented in the past include algebraic curves, group representations, and the advanced theory of equations. Prerequisite: MATH 1530.
Spr MATH1540 S01 25325 TTh 10:30-11:50(09) (T. Goodwillie)

MATH 1560. Number Theory. A basic introduction to the theory of numbers. Unique factorization, prime numbers, modular arithmetic, quadratic reciprocity, quadratic number fields, finite fields, Diophantine equations, and additional topics. Prerequisite: MATH 1530 or written permission.
Spr MATH1560 S01 25326 TTh 1:00-2:20(08) 'To Be Arranged'

MATH 1580. Cryptography. The main focus is on public key cryptography. Topics include symmetric ciphers, public key ciphers, complexity, digital signatures, applications and protocols. MATH 1530 is not required for this course. What is needed from abstract algebra and elementary number theory will be covered. Prerequisite: MATH 0520 or MATH 0540.
Fall MATH1580 S01 16450 MWF 10:00-10:50(14) (R. Ramadas)

MATH 1610. Probability. Basic probability theory. Sample spaces; random variables; normal, Poisson, and related distributions; expectation; correlation; and limit theorems. Applications in various fields (biology, physics, gambling, etc.). Prerequisites: MATH 0180, 0200 or 0350.
Fall MATH1610 S01 16451 MWF 1:00-1:50(06) (J. Holmer)

MATH 1810A. Applied Algebraic Topology. Topology is a powerful tool for identifying, describing, and characterizing the essential features of functions and spaces. In the recent years some of these methods have been adapted to study the shape of data collected from a range of different fields, including graphics and visualization, computational biology, etc. This course is an introduction to the basic concepts and topological structures behind these developments, focusing on persistent homology and mapper. Projects will involve using these methods to analyze and describe the shape of concrete data sets.

MATH 1810B. A Second Course in Linear Algebra. We'll study various aspects of multilinear algebra, including tensors, differential forms and homological algebra, with emphasis on coordinate-free constructions and universal properties.

MATH 1820A. Introduction to Lie Algebras. Lie groups and Lie algebras are important, because they are the symmetries of structures such as quadratic forms, differential systems and smooth manifolds. The prototype of a Lie algebra is the space of 3-vectors together with their cross product, which is closely related to the Lie group of rotations. We will see how this basic example generalizes, mostly in the context of matrices. We'll examine special types of Lie algebras, such as nilpotent, solvable and semi-simple, study root systems and their diagrams, explore some representation theory, and end with the classification of the simple Lie algebras. Prerequisite: MATH 1530.

MATH 1970. Honors Conference. Collateral reading, individual conferences. Section numbers vary by instructor. Please check Banner for the correct section number and CRN to use when registering for this course.

MATH 2010. Differential Geometry. Introduction to differential geometry (differentiable manifolds, differential forms, tensor fields, homogeneous spaces, fiber bundles, connections, and Riemannian geometry), followed by selected topics in the field.
Spr MATH2010 S01 25328 TTh 9:00-10:20(01) (G. Daskalopoulos)
MATH 2420. Algebraic Topology
Complex manifolds and algebraic varieties, sheaves and cohomology, vector bundles, Hodge theory. Kähler manifolds, vanishing theorems, the Kodaira embedding theorem, the Riemann-Roch theorem, and introduction to deformation theory.
Fall MATH2420 S01 16452 MWF 2:00-2:50(07) (M. Chan)

MATH 2410. Topology
See Algebraic Geometry (MATH 2050) for course description.
Spr MATH2410 S01 25329 MWF 10:00-10:50(03) (D. Abramovich)

MATH 2110. Introduction to Manifolds.
Inverse function theorem, manifolds, bundles, Lie groups, flows and vector fields, tensors and differential forms, Sard's theorem and transversality, and further topics chosen by instructor.
Fall MATH2110 S01 16453 TTh 1:00-2:20(08) (N. Kapouleas)

MATH 2210. Real Function Theory.
Real numbers, outer measures, measures, Lebesgue measure, integrals of measurable functions, Holder and Minkowski inequalities, modes of convergence, $L^p$ spaces, product measures, Fubini's Theorem, signed measures, Radon-Nikodym theorem, dual space of $L^p$ and of $C$, Hausdorff measure.
Fall MATH2210 S01 16454 MWF 11:00-11:50(16) (B. Pausader)

MATH 2220. Real Function Theory.
The basics of Hilbert space theory, including orthogonal projections, the Riesz representation theorem, and compact operators. The basics of Banach space theory, including the open mapping theorem, closed graph theorem, uniform boundedness principle, Hahn-Banach theorem, Riesz representation theorem (pertaining to the dual of $C_0(X)$), weak and weak-star topologies. Various additional topics, possibly including Fourier series, Fourier transform, ergodic theorems, distribution theory, and the spectral theory of linear operators.
Spr MATH2220 S01 25330 MWF 11:00-11:50(04) (B. Pausader)

MATH 2250. Complex Function Theory.
Introduction to the theory of analytic functions of one complex variable. Content varies somewhat from year to year, but always includes the study of power series, complex line integrals, analytic continuation, conformal mapping, and an introduction to Riemann surfaces.
Fall MATH2250 S01 16455 MWF 1:00-1:50(06) (S. Treil)

MATH 2260. Complex Function Theory.
See Complex Function Theory (MATH 2250) for course description.
Spr MATH2260 S01 25331 MWF 1:00-2:20(08) (J. Kahn)

MATH 2370. Partial Differential Equations.
The theory of the classical partial differential equations; the method of characteristics and general first order theory. The Fourier transform, the theory of distributions, Sobolev spaces, and techniques of harmonic and functional analysis. More general linear and nonlinear elliptic, hyperbolic, and parabolic equations and properties of their solutions, with examples from physics, differential geometry, and the applied sciences. Semester II concentrates on special topics chosen by the instructor.
Fall MATH2370 S01 16456 TTh 9:00-10:20(02) 'To Be Arranged'

MATH 2410. Topology.
An introduction to algebraic topology. Topics include fundamental group, covering spaces, simplicial and singular homology, CW complexes, and an introduction to cohomology.
Fall MATH2410 S01 16456 TTh 9:00-10:20(02) 'To Be Arranged'

MATH 2420. Algebraic Topology.
This is a continuation of MATH 2410. Topics include cohomology, cup products, Poincare duality, and other topics chosen by the instructor.
Spr MATH2420 S01 25332 TTh 9:00-10:20(01) 'To Be Arranged'
MATH 2720A. Topics in Harmonic Analysis.
MATH 2720B. Multiple Dirichlet Series.
MATH 2720C. Curves on Surfaces and the Classification of Finitely Generated Kleinian Groups.
This is a course in the study of geometry and topology of hyperbolic 3-manifolds.
MATH 2720D. Piecewise Isometric Maps.
This class will cover a variety of topics, all more or less related to dynamical systems that are defined by piecewise isometric maps. Topics may include: polygonal billiards and flat cone surfaces; outer billiards; interval exchange maps; The Gauss map and continued fractions; aperiodic tilings, such as the Penrose tiling; cut and paste theorems about polyhedra; and Ashwin’s conjecture about piecewise rotation maps.
A fairly large part of the class will be devoted to the explanation of the instructor’s proof of the Moser-Neumann conjecture for outer billiards. For this part, the instructor will use his book on the subject. For other parts of the course, a variety of sources will be used.
MATH 2720E. Advanced Topics in Mathematics.
MATH 2720F. Topics in Geometric Analysis.
No description available.
Spr MATH2720F S01 25334 Arranged 'To Be Arranged'
MATH 2720G. Introduction to Hodge Structures.
No description available.
MATH 2720H. Discrete Groups, Ergodic Theory and Hyperbolic Geometry.
No description available.
MATH 2720I. Automorphic Representations for GL(2).
Graduate topics course in automorphic representations for GL(2).
MATH 2720N. Groups Acting on Trees.
This course will be an introduction to geometric group theory from the viewpoint of groups acting on trees. Some topics that may be covered included Bass-Serre theory, R-trees and the Rips machine and groups acting on quasi-trees.
MATH 2720P. Interfaces in Fluids.
The course will explore the description of the motion of interfaces in fluids from the points of view of modeling, numerical simulation and rigorous analysis. We will focus primarily on planar vortex sheets, but we also discuss other examples of interfaces.
MATH 2970. Preliminary Exam Preparation.
No description available.
Fall MATH2970 S01 15313 Arranged 'To Be Arranged'
Spr MATH2970 S01 24202 Arranged 'To Be Arranged'
MATH 2980. Reading and Research.
Independent research or course of study under the direction of a member of the faculty, which may include research for and preparation of a thesis. Section numbers vary by instructor. Please check Banner for the correct section number and CRN to use when registering for this course.
MATH 2990. Thesis Preparation.
For graduate students who have met the residency requirement and are continuing research on a full time basis.
Fall MATH2990 S01 15314 Arranged 'To Be Arranged'
Spr MATH2990 S01 24203 Arranged 'To Be Arranged'
Font Notice

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

Helvetica was used instead of Arial.
The editor may contact Leepfrog for a draft with the correct fonts in place.