Another requirement for majors is participation in an undergraduate seminar, usually in the junior or senior year. In these seminars, students gain experience in learning an advanced topic and lecturing on it. In order to be eligible for departmental honors, majors must write a senior thesis.

Courses for First-Year Students

The systematic study of mathematics begins with one of the following three alternative calculus and linear algebra sequences:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH UN1101</td>
<td>Calculus I</td>
</tr>
<tr>
<td>- MATH UN1102</td>
<td>Calculus II</td>
</tr>
<tr>
<td>- MATH UN1201</td>
<td>Calculus III</td>
</tr>
<tr>
<td>- MATH UN1202</td>
<td>Calculus IV</td>
</tr>
<tr>
<td>- MATH UN2010</td>
<td>Linear Algebra</td>
</tr>
<tr>
<td>MATH UN1101</td>
<td>Calculus I</td>
</tr>
<tr>
<td>- MATH UN1102</td>
<td>Calculus II</td>
</tr>
<tr>
<td>- MATH UN1205</td>
<td>Accelerated Multivariable Calculus</td>
</tr>
<tr>
<td>- MATH UN2010</td>
<td>Linear Algebra</td>
</tr>
<tr>
<td>MATH UN1201</td>
<td>Accelerated Multivariable Calculus</td>
</tr>
<tr>
<td>- MATH UN1102</td>
<td>Calculus II</td>
</tr>
<tr>
<td>- MATH UN1207</td>
<td>Honors Mathematics A</td>
</tr>
<tr>
<td>- MATH UN1208</td>
<td>Honors Mathematics B</td>
</tr>
</tbody>
</table>

Credit is allowed for only one calculus and linear algebra sequence.

Calculus I, II is a standard course in single-variable differential and integral calculus; Calculus III, IV is a standard course in multivariable differential and integral calculus; Accelerated Multivariable Calculus is an accelerated course in multivariable differential and integral calculus.

While Calculus II is no longer a prerequisite for Calculus III, students are strongly urged to take it before taking Calculus III. In particular, students thinking of majoring or concentrating in mathematics or one of the joint majors involving mathematics should take Calculus II before taking Calculus III. Note that Calculus II is a prerequisite for Accelerated Multivariable Calculus, and both Calculus II and Calculus III are prerequisites for Calculus IV.

The third sequence, Honors Mathematics A-B, is for exceptionally well-qualified students who have strong Advanced Placement scores. It covers multivariable calculus (MATH UN1201 Calculus III-MATH UN1202 Calculus IV) and linear algebra (MATH UN2010 Linear Algebra), with an emphasis on theory.

MATH UN1003 College Algebra and Analytic Geometry does not count toward the degree. Students who take this course do not receive college credit.

Advanced Placement

The department grants 3 credits for a score of 4 or 5 on the AP Calculus AB exam provided students complete MATH UN1102 Calculus II or MATH UN1201 Calculus III with a grade of C or better. The department grants 3 credits for a score of 4 on the AP Calculus BC exam provided students complete MATH UN1102 Calculus II or MATH UN1201 Calculus III with a grade of C or better. The department grants 6 credits for a score of 5 on the AP Calculus BC exam provided students complete MATH UN1201 Calculus III or MATH UN1205 Accelerated Multivariable Calculus MATH UN1207 Honors Mathematics A with a grade of C or better. Students can receive credit for only one calculus sequence.
Placement in the Calculus Sequences

Calculus I

Students who have essentially mastered a precalculus course and those who have a score of 3 or less on an Advanced Placement (AP) exam (either AB or BC) should begin their study of calculus with MATH UN1101 CALCULUS I.

Calculus II and III

Students with a score of 4 or 5 on the AB exam, 4 on the BC exam, or those with no AP score but with a grade of A in a full year of high school calculus may begin with either MATH UN1102 Calculus II or MATH UN1201 Calculus III. Note that such students who decide to start with Calculus III may still need to take Calculus II since it is a requirement or prerequisite for other courses. In particular, they MUST take Calculus II before going on to MATH UN1202 Calculus IV. Students with a score of 5 on the BC exam may begin with Calculus III and do not need to take Calculus II.

Those with a score of 4 or 5 on the AB exam or 4 on the BC exam may receive 3 points of AP credit upon completion of Calculus II with a grade of C or higher. Those students with a score of 5 on the BC exam may receive 6 points of AP credit upon completion of Calculus III with a grade of C or higher.

Accelerated Multivariable Calculus

Students with a score of 5 on the AP BC exam or 7 on the IB HL exam may begin with MATH UN1205 Accelerated Multivariable Calculus. Upon completion of this course with a grade of C or higher, they may receive 6 points of AP credit.

Honors Mathematics A

Students who want a proof-oriented theoretical sequence and have a score of 5 on the BC exam may begin with MATH UN1207 Honors Mathematics A, which is especially designed for mathematics majors. Upon completion of this course with a grade of C or higher, they may receive 6 points of AP credit.

Transfers Inside the Calculus Sequences

Students who wish to transfer from one calculus course to another are allowed to do so beyond the date specified on the Academic Calendar. They are considered to be adjusting their level, not changing their program. However, students must obtain the approval of the new instructor and their advising dean prior to reporting to the Office of the Registrar.

Grading

No course with a grade of D or lower can count toward the major, interdepartmental major, or concentration. Students who are doing a double major cannot double count courses for their majors.

Departmental Honors

In order to be eligible for departmental honors, majors must write a senior thesis. To write a senior thesis, students must register for MATH UN3999 Senior Thesis in Mathematics in the fall semester of their senior year. Normally no more than 10% of graduating majors receive departmental honors in a given academic year.

Professors

- Mohammed Abouzaid
- David A. Bayer (Barnard)
- Simon Brendle
- Ivan Corwin
- Panagiota Daskalopoulos
- Aise Johan de Jong
- Robert Friedman (Department Chair)
- Dorian Goldfeld
- Brian Greene
- Richard Hamilton
- Michael Harris
- Ioannis Karatzas
- Mikhail Khovanov
- Igor Krichever
- Chiu-Chu Liu
- Dusa McDuff (Barnard)
- Walter Neumann (Barnard)
- Andrei Okounkov
- D. H. Phong
- Henry Pinkham
- Ovidiu Savin
- Michael Thaddeus
- Eric Urban
- Mu-Tao Wang

Associate Professors

- Daniela De Silva (Barnard Chair)
- Julien Dubedat

Assistant Professors

- Amol Aggarwal
- Chao Li
- Francesco Lin
- Giulia Sacca
- Will Sawin

J.F. Ritt Assistant Professors

- Andrew Ahn
- Konstantin Aleshkin
- Evgeni Dimitrov
- Alexandra Florea
- Florian Johne
- Yash Jhaveri
- Inbar Klang
- Shotaro Makisumi
- Konstantin Matetski
- S. Michael Miller
- Henri Roesch
- Nicholas Salter
- Gus Schrader
- Akash Sengupta
Major in Mathematics

The major requires 40-42 points as follows:

Select one of the following three calculus and linear algebra sequences (13-15 points including Advanced Placement Credit):

1. MATH UN1101 - MATH UN1102 - MATH UN1201 - MATH UN1202 - MATH UN2010
   - CALCULUS I and Calculus II and Calculus III and Calculus IV and Linear Algebra

2. MATH UN1101 - MATH UN1102 - MATH UN1205 - MATH UN2010
   - CALCULUS I and Calculus II and Accelerated Multivariable Calculus and Linear Algebra

3. MATH UN1101 - MATH UN1102 - MATH UN1207 - MATH UN1208
   - CALCULUS I and Calculus II and Honors Mathematics A and Honors Mathematics B

15 points in the following required courses:

- MATH UN3951 - MATH UN3952
  - Undergraduate Seminars in Mathematics I and Undergraduate Seminars in Mathematics II (at least one term)

- MATH GU4041 - MATH GU4042
  - INTRO MODERN ALGEBRA I and INTRO MODERN ALGEBRA II

- MATH GU4061 - MATH GU4062
  - INTRO MODERN ANALYSIS I and Introduction To Modern Analysis II

12 points in any combination of mathematics and cognate courses. **

* Students who are not contemplating graduate study in mathematics may replace one or both of the two terms of MATH GU4061- MATH GU4062 by one or two of the following courses: MATH UN2500 Analysis and Optimization, MATH UN3007 Complex Variables, MATH UN3028 Partial Differential Equations, or MATH GU4032 Fourier Analysis.

** A course not taught by the Mathematics Department is a cognate course for the mathematics major if either (a) it has at least two semesters of calculus as a stated prerequisite and is a 2000-level (or higher) course, or (b) the subject matter in the course is mathematics beyond an elementary level, such as PHIL UN3411 Symbolic Logic, in the Philosophy Department, or COMS W3203 Discrete Mathematics: Introduction to Combinatorics and Graph Theory, in the Computer Science Department. In exceptional cases, the director of undergraduate studies may approve the substitution of certain more advanced courses for those mentioned above.

The program of study should be planned with a departmental adviser before the end of the sophomore year. Majors who are planning on graduate studies in mathematics are urged to obtain a reading knowledge of one of the following languages: French, German, or Russian.

Majors are offered the opportunity to write an honors senior thesis under the guidance of a faculty member. Interested students should contact the director of undergraduate studies.

Major in Applied Mathematics

The major requires 38-40 points as follows:

Select one of the following three calculus and linear algebra sequences (13-15 points including Advanced Placement Credit):

1. MATH UN1101 - MATH UN1102 - MATH UN1201 - MATH UN1202 - MATH UN2010
   - CALCULUS I and Calculus II and Calculus III and Calculus IV and Linear Algebra

2. MATH UN1101 - MATH UN1102 - MATH UN1205 - MATH UN2010
   - CALCULUS I and Calculus II and Accelerated Multivariable Calculus and Linear Algebra

3. MATH UN1101 - MATH UN1102 - MATH UN1207 - MATH UN1208
   - CALCULUS I and Calculus II and Honors Mathematics A and Honors Mathematics B

Select one of the following three courses:

- MATH UN2500 Analysis and Optimization
- MATH GU4032 Fourier Analysis
- MATH GU4061 INTRO MODERN ANALYSIS I
- APMA E4901 Seminar: Problem in Applied Mathematics (junior year)
- APMA E4903 Seminar: Problems in Applied Mathematics (senior year)

18 points in electives, selected from the following (other courses may be used with the approval of the Applied Mathematics Committee):

- MATH UN2500 Analysis and Optimization
- MATH UN3007 Complex Variables
- MATH UN3007 or MATH GU4065 Honors Complex Variables
- MATH UN3028 Partial Differential Equations
- MATH UN3028 or APMA E4204 Functions of a Complex Variable
- MATH UN3027 Ordinary Differential Equations
- MATH UN3027 or APMA E4200 Partial Differential Equations
- MATH GU4062 Analytic methods for partial differential equations
- MATH GU4032 Fourier Analysis
- APMA E4300 Computational Math: Introduction to Numerical Methods
- APMA E4101 Introduction to Dynamical Systems
Major in Computer Science–Mathematics

The goal of this interdepartmental major is to provide substantial background in each of these two disciplines, focusing on some of the parts of each which are closest to the other. Students intending to pursue a Ph.D. program in either discipline are urged to take additional courses, in consultation with their advisers.

The major requires 20 points in computer science, 19-21 points in mathematics, and two 3-point electives in either computer science or mathematics.

Computer Science

COMS W1004  Introduction to Computer Science and Programming in Java

or COMS W1007  Honors Introduction to Computer Science

COMS W3134  Data Structures in Java

or COMS W3137  Honors Data Structures and Algorithms

COMS W3157  Advanced Programming

COMS W3203  Discrete Mathematics: Introduction to Combinatorics and Graph Theory

COMS W3261  Computer Science Theory

CSEE W3827  Fundamentals of Computer Systems

Mathematics

Select one of the following three calculus and linear algebra sequences (13-15 points including Advanced Placement Credit):

MATH UN1101  CALCULUS I

- MATH UN1102 and Calculus II

- MATH UN1201 and Calculus III

- MATH UN2010 and Linear Algebra

MATH UN1101  CALCULUS I

- MATH UN1102 and Calculus II

- MATH UN1205 and Accelerated Multivariable Calculus

- MATH UN2010 and Linear Algebra

MATH UN1101  CALCULUS I

- MATH UN1102 and Calculus II

- MATH UN1207 and Honors Mathematics A

- MATH UN1208 and Honors Mathematics B

- MATH UN3951 Undergraduate Seminars in Mathematics I

or MATH UN3952 Undergraduate Seminars in Mathematics II

MATH GU4041  INTRO MODERN ALGEBRA I

Electives

Select two of the following courses:

CSOR W4231  Analysis of Algorithms I

COMS W4241  Numerical Algorithms and Complexity

MATH BC2006  Combinatorics

MATH UN2500  Analysis and Optimization

MATH UN3007  Complex Variables

MATH UN3020  Number Theory and Cryptography

MATH UN3386  Differential Geometry

MATH GU4051  Topology

MATH GU4061  INTRO MODERN ANALYSIS I

Major in Economics-Mathematics

Major in Mathematics-Statistics

The program is designed to prepare the student for: (1) a career in industries such as finance and insurance that require a high level of mathematical sophistication and a substantial knowledge of probability and statistics, and (2) graduate study in quantitative disciplines. Students choose electives in finance, actuarial science, operations research, or other quantitative fields to complement requirements in mathematics, statistics, and computer science.

Mathematics

Select one of the following sequences:

MATH UN1101  CALCULUS I

- MATH UN1102 and Calculus II

- MATH UN1201 and Calculus III

- MATH UN2010 and Linear Algebra

- MATH UN2500 and Analysis and Optimization

MATH UN1101  CALCULUS I

- MATH UN1102 and Calculus II

- MATH UN1205 and Accelerated Multivariable Calculus

- MATH UN2010 and Linear Algebra

- MATH UN2500 and Analysis and Optimization

MATH UN1207  Honors Mathematics A

- MATH UN1208 and Honors Mathematics B

- MATH UN2500 and Analysis and Optimization (with approval from the adviser)

Statistics

Introductory Course

STAT UN1201  Calculus-Based Introduction to Statistics

Required Courses

STAT GU4203  PROBABILITY THEORY

STAT GU4204  Statistical Inference

STAT GU4205  Linear Regression Models

Select one of the following courses:

STAT GU4207  Elementary Stochastic Processes

STAT GU4262  Stochastic Processes for Finance

STAT GU4264  STOCHASTIC PROCESSES-APPLIC

STAT GU4265  Stochastic Methods in Finance

Computer Science

Select one of the following courses:

COMS W1004  Introduction to Computer Science and Programming in Java

COMS W1005  Introduction to Computer Science and Programming in MATLAB

ENGI E1006  Introduction to Computing for Engineers and Applied Scientists

COMS W1007  Honors Introduction to Computer Science

or an advanced computer science offering in programming

Electives

An approved selection of three advanced courses in mathematics, statistics, applied mathematics, industrial engineering and operations research, computer science, or approved mathematical methods courses in a quantitative discipline. At least one elective must be a Mathematics Department course numbered 3000 or above.
Students interested in modeling applications are recommended to take MATH UN3027 Ordinary Differential Equations and MATH UN3028 Partial Differential Equations.

Students interested in finance are recommended to take MATH GR5010 Introduction to the Mathematics of Finance, STAT GU4261 Statistical Methods in Finance, and STAT GU4221 Time Series Analysis.

Students interested in graduate study in mathematics or in statistics are recommended to take MATH GU4061 INTRO MODERN ANALYSIS I and MATH GU4062 Introduction To Modern Analysis II.

Students preparing for a career in actuarial science are encouraged to replace MATH UN1003 College Algebra and Analytic Geometry.

Concentration in Mathematics
The concentration requires the following:

Mathematics
Select one of the following three multivariable calculus and linear algebra sequences:

MATH UN1201 Calculus III
- MATH UN1202 and Calculus IV
- MATH UN2010 and Linear Algebra

MATH UN1205 Accelerated Multivariable Calculus
- MATH UN2010 and Linear Algebra

MATH UN1207 Honors Mathematics A
- MATH UN1208 and Honors Mathematics B

Additional Courses
Select at least 12 additional points from any of the courses offered by the department numbered 2000 or higher.

For mathematics courses taken in other departments, consult with the director of undergraduate studies.

Any course given by the Mathematics department fulfills the General Studies quantitative reasoning requirement when passed with a satisfactory letter grade.

MATH UN1003 College Algebra and Analytic Geometry. 3 points.
Prerequisites: score of 550 on the mathematics portion of the SAT completed within the last year or the appropriate grade on the General Studies Mathematics Placement Examination.
Columbia College students do not receive any credit for this course and must see their CSA advising dean. For students who wish to study calculus but do not know analytic geometry. Algebra review, graphs and functions, polynomial functions, rational functions, conic sections, systems of equations in two variables, exponential and logarithmic functions, trigonometric functions and trigonometric identities, applications of trigonometry, sequences, series, and limits.

MATH UN1101 CALCULUS I. 3.00 points.
Prerequisites: (see Courses for First-Year Students). Functions, limits, derivatives, introduction to integrals, or an understanding of pre-calculus will be assumed. (SC)

MATH UN1101 CALCULUS II. 3 points.
Prerequisites: MATH UN1101 or the equivalent. Methods of integration, applications of the integral, Taylor's theorem, infinite series. (SC)
MATH UN1201 Calculus III. 3 points.
Prerequisites: MATH UN1101 or the equivalent
Vectors in dimensions 2 and 3, complex numbers and the complex exponential function with applications to differential equations, Cramer’s rule, vector-valued functions of one variable, scalar-valued functions of several variables, partial derivatives, gradients, surfaces, optimization, the method of Lagrange multipliers. (SC)

<table>
<thead>
<tr>
<th>Fall 2020: MATH UN1201</th>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 1201</td>
<td>001/11389</td>
<td>M W 10:10am - 11:25am</td>
<td>Online Only</td>
<td>Konstantin Aleshkin</td>
<td>3</td>
<td>28/110</td>
</tr>
<tr>
<td>MATH 1201</td>
<td>002/11390</td>
<td>M W 11:40am - 12:55pm</td>
<td>Online Only</td>
<td>Konstantin Aleshkin</td>
<td>3</td>
<td>19/110</td>
</tr>
<tr>
<td>MATH 1201</td>
<td>003/11394</td>
<td>M W 1:10pm - 2:25pm</td>
<td>Online Only</td>
<td>Ovidiu Savin</td>
<td>3</td>
<td>19/110</td>
</tr>
<tr>
<td>MATH 1201</td>
<td>004/11398</td>
<td>T Th 10:10am - 11:25am</td>
<td>Online Only</td>
<td>Carolyn Abbott</td>
<td>3</td>
<td>40/116</td>
</tr>
<tr>
<td>MATH 1201</td>
<td>005/11402</td>
<td>T Th 11:40am - 12:55pm</td>
<td>Online Only</td>
<td>Evan Warner</td>
<td>3</td>
<td>30/116</td>
</tr>
<tr>
<td>MATH 1201</td>
<td>006/11407</td>
<td>T Th 2:40pm - 3:55pm</td>
<td>Online Only</td>
<td>Inbar Klang</td>
<td>3</td>
<td>100/100</td>
</tr>
<tr>
<td>MATH 1201</td>
<td>007/11412</td>
<td>T Th 4:10pm - 5:25pm</td>
<td>Online Only</td>
<td>Inbar Klang</td>
<td>3</td>
<td>71/100</td>
</tr>
</tbody>
</table>

MATH UN1202 Calculus IV. 3 points.
Prerequisites: MATH UN1102 and MATH UN1201 or the equivalent
Multiple integrals, Taylor’s formula in several variables, line and surface integrals, calculus of vector fields, Fourier series. (SC)

<table>
<thead>
<tr>
<th>Fall 2020: MATH UN1202</th>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 1202</td>
<td>001/11421</td>
<td>T Th 10:10am - 11:25am</td>
<td>Online Only</td>
<td>Stephen Miller</td>
<td>3</td>
</tr>
<tr>
<td>MATH 1202</td>
<td>002/11424</td>
<td>M W 6:10pm - 7:25pm</td>
<td>Online Only</td>
<td>Mikhail Smirnov</td>
<td>3</td>
</tr>
</tbody>
</table>

MATH UN1205 Accelerated Multivariable Calculus. 4 points.
Prerequisites: (MATH UN1101 and MATH UN1102)
Vectors in dimensions 2 and 3, vector-valued functions of one variable, scalar-valued functions of several variables, partial derivatives, gradients, optimization, Lagrange multipliers, double and triple integrals, line and surface integrals, vector calculus. This course is an accelerated version of MATH UN1201 - MATH UN1202. Students taking this course may not receive credit for MATH UN1201 and MATH UN1202.

<table>
<thead>
<tr>
<th>Fall 2020: MATH UN1205</th>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 1205</td>
<td>001/11425</td>
<td>M W 8:40am - 9:55am</td>
<td>Online Only</td>
<td>Guillaume Remy</td>
<td>4</td>
</tr>
</tbody>
</table>

MATH UN1207 Honors Mathematics A. 4 points.
Prerequisites: (see Courses for First-Year Students). The second term of this course may not be taken without the first. Multivariable calculus and linear algebra from a rigorous point of view. Recommended for mathematics majors. Fulfills the linear algebra requirement for the major. (SC)

<table>
<thead>
<tr>
<th>Fall 2020: MATH UN1207</th>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 1207</td>
<td>001/11430</td>
<td>T Th 1:10pm - 2:25pm</td>
<td>Online Only</td>
<td>Evan Warner</td>
<td>4</td>
</tr>
</tbody>
</table>

MATH UN1208 Honors Mathematics B. 4 points.
Prerequisites: (see Courses for First-Year Students).
The second term of this course may not be taken without the first. Multivariable calculus and linear algebra from a rigorous point of view. Recommended for mathematics majors. Fulfills the linear algebra requirement for the major. (SC)

MATH UN2000 An Introduction to Higher Mathematics. 3 points.
Introduction to understanding and writing mathematical proofs. Emphasis on precise thinking and the presentation of mathematical results, both in oral and in written form. Intended for students who are considering majoring in mathematics but wish additional training. CC/GS: Partial Fulfillment of Science Requirement. BC: Fulfillment of General Education Requirement: Quantitative and Deductive Reasoning (QUA).

<table>
<thead>
<tr>
<th>Fall 2020: MATH UN2000</th>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 2000</td>
<td>001/11446</td>
<td>M W 10:10am - 11:25am</td>
<td>Online Only</td>
<td>Dusa McDuff</td>
<td>3</td>
</tr>
</tbody>
</table>

MATH UN2010 Linear Algebra. 3 points.
Prerequisites: MATH UN1201 or the equivalent.
Matrices, vector spaces, linear transformations, eigenvalues and eigenvectors, canonical forms, applications. (SC)

<table>
<thead>
<tr>
<th>Fall 2020: MATH UN2010</th>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 2010</td>
<td>001/00117</td>
<td>T Th 8:40am - 9:55am</td>
<td>Room TBA</td>
<td>David Bayer</td>
<td>3</td>
</tr>
<tr>
<td>MATH 2010</td>
<td>002/00118</td>
<td>T Th 10:10am - 11:25am</td>
<td>Room TBA</td>
<td>David Bayer</td>
<td>3</td>
</tr>
<tr>
<td>MATH 2010</td>
<td>003/11450</td>
<td>M W 4:10pm - 5:25pm</td>
<td>Online Only</td>
<td>Francesco Lin</td>
<td>3</td>
</tr>
<tr>
<td>MATH 2010</td>
<td>004/11453</td>
<td>M W 11:40am - 12:55pm</td>
<td>Online Only</td>
<td>Kyle Hayden</td>
<td>3</td>
</tr>
<tr>
<td>MATH 2010</td>
<td>005/11455</td>
<td>M W 8:40am - 9:55am</td>
<td>Online Only</td>
<td>Giulia Sacca</td>
<td>3</td>
</tr>
</tbody>
</table>

MATH UN2020 Honors Linear Algebra. 3 points.
Not offered during 2020-21 academic year.

Prerequisites: MATH UN1201. A more extensive treatment of the material in MATH UN2010, with increased emphasis on proof. Not to be taken in addition to MATH UN2010 or MATH UN207-MATH UN1208.

MATH UN2030 Ordinary Differential Equations. 3 points.
Prerequisites: MATH UN1102 and MATH UN1201 or the equivalent. Special differential equations of order one. Linear differential equations with constant and variable coefficients. Systems of such equations. Transform and series solution techniques. Emphasis on applications.

<table>
<thead>
<tr>
<th>Fall 2020: MATH UN2030</th>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 2030</td>
<td>001/11457</td>
<td>M W 1:10pm - 2:25pm</td>
<td>Online Only</td>
<td>Florian Johne</td>
<td>3</td>
</tr>
<tr>
<td>MATH 2030</td>
<td>002/11461</td>
<td>M W 2:40pm - 3:55pm</td>
<td>Online Only</td>
<td>Florian Johne</td>
<td>3</td>
</tr>
</tbody>
</table>


MATH UN2500 Analysis and Optimization. 3 points.
Prerequisites: MATH UN1102 and MATH UN1201 or the equivalent and MATH UN2010. Mathematical methods for economics. Quadratic forms, Hessian, implicit functions. Convex sets, convex functions. Optimization, constrained optimization, Kuhn-Tucker conditions. Elements of the calculus of variations and optimal control. (SC)

Fall 2020: MATH UN2500
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 2500  001/11464  T Th 1:10pm - 2:25pm Online Only  Kanstantin Matetski  3  50/64
MATH 2500  002/11466  T Th 2:40pm - 3:55pm Online Only  Kanstantin Matetski  3  48/64

MATH UN3007 Complex Variables. 3 points.
Prerequisites: MATH UN1202. An elementary course in functions of a complex variable. Fundamental properties of the complex numbers, differentiability, Cauchy-Riemann equations. Cauchy integral theorem. Taylor and Laurent series, poles, and essential singularities. Residue theorem and conformal mapping. (SC)

Fall 2020: MATH UN3007
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 3007  001/11470  M W 2:40pm - 3:55pm Online Only  Nicholas Salter  3  60/64

MATH UN3020 Number Theory and Cryptography. 3 points.
Prerequisites: one year of calculus. Prerequisite: One year of Calculus. Congruences. Primitive roots. Quadratic residues. Contemporary applications.

MATH UN3025 Making, Breaking Codes. 3 points.
Prerequisites: (MATH UN1101 and MATH UN1102 and MATH UN1201) and and MATH UN2010.
A concrete introduction to abstract algebra. Topics in abstract algebra used in cryptography and coding theory.

Fall 2020: MATH UN3025
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 3025  001/11471  T Th 1:10pm - 2:25pm Online Only  Dorian Goldfeld  3  98/116

MATH UN3027 Ordinary Differential Equations. 3 points.
Prerequisites: MATH UN1102 and MATH UN1201 or the equivalent. Corequisites: MATH UN2010

Fall 2020: MATH UN3027
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 3027  001/11478  T Th 11:40am - 12:55pm Online Only  Simon Brendle  3  61/116

MATH UN3028 Partial Differential Equations. 3 points.
Prerequisites: MATH UN3027 and MATH UN2010 or the equivalent

MATH UN3050 Discrete Time Models in Finance. 3 points.
Prerequisites: (MATH UN1102 and MATH UN1201) or (MATH UN1101 and MATH UN1102 and MATH UN2010) and MATH UN2010
Recommended: MATH UN3027 (or MATH UN2030 and SIEO W3600).
Elementary discrete time methods for pricing financial instruments, such as options. Notions of arbitrage, risk-neutral valuation, hedging, term-structure of interest rates.

MATH UN3386 Differential Geometry. 3 points.
Prerequisites: MATH UN1102 or the equivalent.
Local and global differential geometry of submanifolds of Euclidian 3-space. Frenet formulas for curves. Various types of curvatures for curves and surfaces and their relations. The Gauss-Bonnet theorem.

Fall 2020: MATH UN3386
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 3386  001/11484  T Th 11:40am - 12:55pm Online Only  Richard Hamilton  3  36/49

MATH UN3951 Undergraduate Seminars in Mathematics I. 3 points.
Prerequisites: Two years of calculus, at least one year of additional mathematics courses, and the director of undergraduate studies' permission.
The subject matter is announced at the start of registration and is different in each section. Each student prepares talks to be given to the seminar, under the supervision of a faculty member or senior teaching fellow.

Fall 2020: MATH UN3951
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 3951  001/00120  M W 6:10pm - 7:25pm Room TBA  Daniela De Silva  3  36/64

MATH UN3952 Undergraduate Seminars in Mathematics II. 3 points.
Prerequisites: two years of calculus, at least one year of additional mathematics courses, and the director of undergraduate studies’ permission.
The subject matter is announced at the start of registration and is different in each section. Each student prepares talks to be given to the seminar, under the supervision of a faculty member or senior teaching fellow. Prerequisite: two years of calculus, at least one year of additional mathematics courses, and the director of undergraduate studies’ permission.

MATH GU4007 Analytic Number Theory. 3 points.
Prerequisites: MATH UN3007
A one semester course covering the theory of modular forms, zeta functions, L-functions, and the Riemann hypothesis. Particular topics covered include the Riemann zeta function, the prime number theorem, Dirichlet characters, Dirichlet L-functions, Siegel zeros, prime number theorem for arithmetic progressions, SL (2, Z) and subgroups, quotients of the upper half-plane and cusps, modular forms, Fourier expansions of modular forms, Hecke operators, L-functions of modular forms.
**MATH GU4032 Fourier Analysis. 3 points.**
Prerequisites: three terms of calculus and linear algebra or four terms of calculus.
Prerequisite: three terms of calculus and linear algebra or four terms of calculus. Fourier series and integrals, discrete analogues, inversion and Poisson summation formulae, convolution. Heisenberg uncertainty principle. Stress on the application of Fourier analysis to a wide range of disciplines.

**MATH GU4041 INTRO MODERN ALGEBRA I. 3 points.**
Prerequisites: MATH UN1102 and MATH UN1202 and MATH UN2010 or the equivalent.
The second term of this course may not be taken without the first.
Groups, homomorphisms, rings, ideals, fields, polynomials, field extensions, Galois theory.

**MATH GU4042 INTRO MODERN ALGEBRA II. 3 points.**
Prerequisites: MATH UN1102 and MATH UN1202 and MATH UN2010 or the equivalent.
The second term of this course may not be taken without the first. Rings, homomorphisms, ideals, integral and Euclidean domains, the division algorithm, principal ideal and unique factorization domains, fields, algebraic and transcendental extensions, splitting fields, finite fields, Galois theory.

**MATH GU4043 Algebraic Number Theory. 3 points.**
Prerequisites: MATH GU4041 and MATH GU4042 or the equivalent.
Algebraic number fields, unique factorization of ideals in the ring of algebraic integers in the field into prime ideals. Dirichlet unit theorem, finiteness of the class number, ramification. If time permits, p-adic numbers and Dedekind zeta function.

**MATH GU4044 Representations of Finite Groups. 3 points.**
Prerequisites: MATH UN2010 and MATH GU4041 or the equivalent.
Finite groups acting on finite sets and finite dimensional vector spaces. Group characters. Relations with subgroups and factor groups. Arithmetic properties of character values. Applications to the theory of finite groups: Frobenius groups, Hall subgroups and solvable groups. Characters of the symmetric groups. Spherical functions on finite groups.

**MATH GU4045 Algebraic Curves. 3 points.**
Prerequisites: (MATH GU4041 and MATH GU4042) and MATH UN3007
Plane curves, affine and projective varieties, singularities, normalization, Riemann surfaces, divisors, linear systems, Riemann-Roch theorem.

**MATH GU4051 Topology. 3 points.**
Prerequisites: (MATH UN1202 and MATH UN2010) and rudiments of group theory (e.g., MATH GU4041). MATH UN1208 or MATH GU4061 is recommended, but not required.

**MATH GU4053 Introduction to Algebraic Topology. 3 points.**
Prerequisites: MATH UN2010 and MATH GU4041 and MATH GU4051
The study of topological spaces from algebraic properties, including the essentials of homology and the fundamental group. The Brouwer fixed point theorem. The homology of surfaces. Covering spaces.

**MATH GU4061 INTRO MODERN ANALYSIS I. 3 points.**
Prerequisites: MATH UN1202 or the equivalent, and MATH UN2010.
The second term of this course may not be taken without the first. Real numbers, metric spaces, elements of general topology, sequences and series, continuity, differentiation, integration, uniform convergence, Ascoli-Arzela theorem, Stone-Weierstrass theorem.

**MATH GU4062 Introduction To Modern Analysis II. 3 points.**
 Prerequisites: MATH UN1202 or the equivalent, and MATH UN2010. The second term of this course may not be taken without the first. Real numbers, metric spaces, elements of general topology, sequences and series, continuity, differentiation, integration, uniform convergence, Ascoli-Arzela theorem, Stone-Weierstrass theorem.

**MATH GU4052 Introduction to Knot Theory. 3 points.**
CC/GS: Partial Fulfillment of Science Requirement
Prerequisites: MATH GU4051 Topology and / or MATH GU4061
Introduction To Modern Analysis I (or equivalents). Recommended (can be taken concurrently): MATH UN2010 linear algebra, or equivalent.
The study of algebraic and geometric properties of knots in R^3, including but not limited to knot projections and Reidemeister's theorem, Seifert surfaces, braids, tangles, knot polynomials, fundamental group of knot complements. Depending on time and student interest, we will discuss more advanced topics like knot concordance, relationship to 3-manifold topology, other algebraic knot invariants.

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 4041</td>
<td>001/11487</td>
<td>M W 2:40pm - 3:55pm</td>
<td>Robert Friedman</td>
<td>3</td>
<td>101/110</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Online Only</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MATH 4042</td>
<td>001/11488</td>
<td>M W 1:10pm - 2:25pm</td>
<td>Mikhail Khovanov</td>
<td>3</td>
<td>18/35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Online Only</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MATH 4043</td>
<td>001/11490</td>
<td>T Th 1:10pm - 2:25pm</td>
<td>Chao Li</td>
<td>3</td>
<td>15/19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Online Only</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MATH 4044</td>
<td>001/11498</td>
<td>M W 4:10pm - 5:25pm</td>
<td>Hui Yu</td>
<td>3</td>
<td>34/49</td>
</tr>
</tbody>
</table>
MATH GU4065 Honors Complex Variables. 3 points.
Prerequisites: (MATH UN1207 and MATH UN1208) or MATH GU4061
A theoretical introduction to analytic functions. Holomorphic functions, harmonic functions, power series, Cauchy-Riemann equations, Cauchy’s integral formula, poles, Laurent series, residue theorem. Other topics as time permits: elliptic functions, the gamma and zeta function, the Riemann mapping theorem, Riemann surfaces, Nevanlinna theory.

Fall 2020: MATH GU4065

<table>
<thead>
<tr>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 4065</td>
<td>001/11503</td>
<td>T Th 10:10am - 11:25am</td>
<td>Julien Dubédat</td>
<td>3</td>
<td>29/45</td>
</tr>
<tr>
<td></td>
<td>Online Only</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MATH GU4081 Introduction to Differentiable Manifolds. 3 points.
Prerequisites: (MATH GU4051 or MATH GU4061) and MATH UN2010

MATH GU4155 Probability Theory. 3 points.
Prerequisites: MATH GU4061 or MATH UN3007

MATH GU4391 INTRO TO QUANTUM MECHANICS. 3 points.
This course will focus on quantum mechanics, paying attention to both the underlying mathematical structures as well as their physical motivations and consequences. It is meant to be accessible to students with no previous formal training in quantum theory. The role of symmetry, groups and representations will be stressed.

Fall 2020: MATH GU4391

<table>
<thead>
<tr>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 4391</td>
<td>001/14322</td>
<td>T Th 4:10pm - 5:25pm</td>
<td>Peter Woit</td>
<td>3</td>
<td>36/48</td>
</tr>
<tr>
<td></td>
<td>Room TBA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MATH GU4392 INTRO TO QUANTUM MECHANICS II. 3.00 points.
Not offered during 2020-21 academic year.

Continuation of GU4391. This course will focus on quantum mechanics, paying attention to both the underlying mathematical structures as well as their physical motivations and consequences. It is meant to be accessible to students with no previous formal training in quantum theory. The role of symmetry, groups and representations will be stressed.

MATH GR5010 Introduction to the Mathematics of Finance. 3 points.
Prerequisites: MATH UN1102 and MATH UN1201, or their equivalents.
Introduction to mathematical methods in pricing of options, futures and other derivative securities, risk management, portfolio management and investment strategies with an emphasis of both theoretical and practical aspects. Topics include: Arithmetic and Geometric Brownian motion processes, Black-Scholes partial differential equation, Black-Scholes option pricing formula, Ornstein-Uhlenbeck processes, volatility models, risk models, value-at-risk and conditional value-at-risk, portfolio construction and optimization methods.

Fall 2020: MATH GR5010

<table>
<thead>
<tr>
<th>Course</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 5010</td>
<td>001/12050</td>
<td>M W 7:40pm - 8:55pm</td>
<td>Mikhail Smirnov</td>
<td>3</td>
<td>73/140</td>
</tr>
<tr>
<td></td>
<td>Room TBA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Of Related Interest

Computer Science

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMS W3203</td>
<td>Discrete Mathematics: Introduction to Combinatorics and Graph Theory</td>
</tr>
<tr>
<td>COMS W3251</td>
<td>COMPUTATIONAL LINEAR ALGEBRA</td>
</tr>
<tr>
<td>COMS W4203</td>
<td>Graph Theory</td>
</tr>
</tbody>
</table>

Industrial Engineering and Operations Research

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSOR E4010</td>
<td>Graph Theory: A Combinatorial View</td>
</tr>
</tbody>
</table>
