Calculus III or Honors Math A and completing with a grade of C or better. A grade of 5 will receive 4 points of credit or 6 points on placing into placement test for Calculus AB with a grade of 4 or 5 or BC with a grade of 5 on the Calculus BC test should start with Calculus III.

Advanced Placement: Students who have passed the advanced placement test for Calculus AB with a grade of 4 or 5 or BC with a grade of 5 will receive 4 points of credit or 6 points on placing into Calculus III or Honors Math A and completing with a grade of C or better.

Honors Mathematics A: Students who have passed the Calculus BC advanced placement test with a grade of 5, and who have strong mathematical talent and motivation, should start with Honors Mathematics A. This is the most attractive course available to well-prepared, mathematically talented first-year students, whether or not they intend to be mathematics majors. Students who contemplate taking this course should consult with the instructor. If this is not possible ahead of time, they should register and attend the first class.

Chair: Daniela De Silva (Professor)
Professors: Dave Bayer, Daniela De Silva, Dusa McDuff (Helen Lyttle Kimmel Chair)
Term Assistant Professor: Lindsay Piechnik
Professors Emeriti: Joan Birman, Walter Neumann

Links to other faculty of Columbia University offering courses in Mathematics:
Faculty by Rank: http://www.math.columbia.edu/people/faculty-by-rank/
Alphabetical Faculty Listing: http://www.math.columbia.edu/people/alphabetical-faculty-listing/

Requirements for the Major

The major programs in both Mathematics and Applied Mathematics are appropriate for students who plan to continue their training in graduate school. The major in Mathematical Sciences combines the elements of Mathematics, Computer Science and Statistics. It is designed to prepare students for employment in business, administration, and finance, and also give excellent background for someone planning graduate study in a social science field. Students who plan to obtain a teaching qualification in mathematics should plan their course of study carefully with an advisor, since courses that are too far from mathematics do not count towards certification.

For a major in Mathematics: 14 courses as follows:
Four courses in calculus or Honors Mathematics A-B, including Advanced Placement Credit. Six courses in mathematics numbered at or above 2000, and four courses in any combination of mathematics and cognate courses. The courses in mathematics must include:

- MATH UN2000 INTRO TO HIGHER MATHEMATICS
- MATH GU4061 INTRO MODERN ANALYSIS I (I)
- MATH GU4062 INTRO MODERN ANALYSIS II (II)
- MATH GU4042 INTRO MODERN ALGEBRA II (II)
- MATH GU4041 INTRO MODERN ALGEBRA I (I)
- MATH GU4062 INTRO MODERN ANALYSIS II (II)
- MATH UN3951 Undergraduate Seminars in Mathematics I (at least one term) or MATH UN3952 Undergraduate Seminars in Mathematics II

Note: It is strongly recommended that the sequences MATH GU4041 INTRO MODERN ALGEBRA I - MATH GU4062 INTRO MODERN ANALYSIS I and MATH GU4062 INTRO MODERN ANALYSIS II be taken in separate years.
However, students who are not contemplating graduate study in mathematics may replace one or both of the two terms of MATH GU4061 INTRO MODERN ANALYSIS I - MATH GU4062 INTRO MODERN ANALYSIS II by one or two of the following courses: MATH UN2500 ANALYSIS AND OPTIMIZATION, MATH UN3007 Complex Variables, or MATH GU4032 Fourier Analysis and may replace MATH GU4042 INTRO MODERN ALGEBRA II by one of MATH UN3020 Number Theory and Cryptography or MATH UN3025 Making, Breaking Codes. In exceptional cases, the chair will approve the substitution of certain more advanced courses for those mentioned above.

For a major in Applied Mathematics: 14 courses

Four courses in calculus or Honors Mathematics A-B, including Advanced Placement Credit.

- MATH UN2010 LINEAR ALGEBRA (also satisfied by Honors Math A-B)
- MATH GU4061 INTRO MODERN ANALYSIS I
- APMA E4901 Seminar: Problem in Applied Mathematics
- APMA E4903 Seminar: Problems in Applied Mathematics
- APMA E3900 Undergraduate Research in Applied Mathematics (APMA E3900 may be replaced, with approval, by another technical elective for seniors that involves an undergraduate thesis or creative research report)

Additional electives, to be approved by the Applied Math Committee, e.g.:

- MATH UN2500 ANALYSIS AND OPTIMIZATION
- MATH UN3007 Complex Variables
- or MATH GU4065 Honors Complex Variables
- or APMA E4204 FUNCTS OF A COMPLEX VARIABLE
- MATH UN3027 Ordinary Differential Equations
- or MATH UN2030 ORDINARY DIFFERENTIAL EQUATION
- MATH UN3028 PARTIAL DIFFERENTIAL EQUATIONS
- or APMA E4200 Partial Differential Equations
- MATH GU4032 Fourier Analysis
- APMA E4300 Computational Math: Introduction to Numerical Methods
- APMA E4101 Introduction to Dynamical Systems
- APMA E4150 Applied Functional Analysis

For a major in Mathematical Sciences: 14 courses:

6 from Mathematics, 5 from a combination of Statistics and Computer Science and 3 electives from a combination of Mathematics, Statistics, Computer Science.

**Mathematics**

- **Six required courses:**
  - MATH UN1101 CALCULUS I
  - MATH UN1102 CALCULUS II
  - MATH UN1201 Calculus III
  - MATH UN2010 LINEAR ALGEBRA (also satisfied by Honors Math A-B)
  - MATH UN2000 INTRO TO HIGHER MATHEMATICS
  - MATH UN2030 ORDINARY DIFFERENTIAL EQUATION
  - MATH UN3027 Ordinary Differential Equations

Possible further courses selected from the following:

- MATH UN1202 CALCULUS IV
- MATH UN2500 ANALYSIS AND OPTIMIZATION
- MATH UN3020 Number Theory and Cryptography
- MATH UN3025 Making, Breaking Codes
- Any 3 credit MATH course numbered 2000 or above

**Statistics**

Select at least one of the following:

- STAT UN1101 Introduction to Statistics
- STAT UN1201 Calculus-Based Introduction to Statistics or equivalent

Other courses from the Statistics list (eg, STAT UN2102, STAT UN2103, STAT UN2104, STAT UN3105, STAT UN3106)

**Computer Science**

Select at least one of the following programming courses:

- COMS W1002 Computing in Context
- COMS W1004 Introduction to Computer Science and Programming in Java (preferred)
- COMS W1005 Introduction to Computer Science and Programming in MATLAB
- COMS W1007 Honors Introduction to Computer Science

Possible further courses selected from the following:

- Other classes from the Computer Science Core
- COMS W3203 DISCRETE MATHEMATICS
- COMS W3210 Scientific Computation
- ENGI E1006 Introduction to Computing for Engineers and Applied Scientists

More generally, electives may be any course with a prerequisite of at least one semester of Calculus, Statistics or Computer Science with the prior approval of the Mathematics Chair.

The Capstone Experience can be fulfilled by a significant thesis written under the supervision of faculty of any one of the three departments or by the Undergraduate Seminar in Mathematics.

**For a major in Mathematics-Statistics: 14 courses:**

- **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 UN1207 and Honors Mathematics A
  - MATH UN1208 and HONORS MATHEMATICS B
  - MATH UN2500 and ANALYSIS AND OPTIMIZATION

- **Statistics** Statistics required courses
  - STAT UN1201 Calculus-Based Introduction to Statistics
  - STAT GU4203 PROBABILITY THEORY
  - STAT GU4204 Statistical Inference
  - STAT GU4205 Linear Regression Models

And 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
COMS W1007  Honors Introduction to Computer Science
ENGI E1006  Introduction to Computing for Engineers and Applied Scientists

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 should plan to include a senior thesis or the Undergraduate Seminar in Mathematics in their program, in consultation with their advisors.

Note: Students must obtain approval from an adviser in each of the two departments before selecting electives. Students should take MATH UN2010 LINEAR ALGEBRA in the second semester of the second year.

For a major in Mathematics-Computer Science 15 courses:

Mathematics
Four courses in calculus or Honors Mathematics A-B, including Advanced Placement Credit, and the 3 following courses:
MATH UN2010  LINEAR ALGEBRA (also satisfied by Honors Math A-B)
MATH GU4041  INTRO MODERN ALGEBRA I
MATH UN3951  Undergraduate Seminars in Mathematics I (at least one term)
or MATH UN3952  Undergraduate Seminars in Mathematics II

Computer Science
COMS W1004  Introduction to Computer Science and Programming in Java
COMS W3134  Data Structures in Java
COMS W3157  Advanced Programming
COMS W3203  DISCRETE MATHEMATICS
COMS W3261  Computer Science Theory
CSEE W3827  Fundamentals of Computer Systems

Note A: AP Computer Science with a grade of 4 or 5 or similar experience (e.g., COMS W1004) is a prerequisite for COMS W1007

Electives: 2 of the following:
CSOR W4231  Analysis of Algorithms I
COMS W4241  Numerical Algorithms and Complexity
MATH UN3020  Number Theory and Cryptography
MATH BC2006  Combinatorics
MATH GU4061  INTRO MODERN ANALYSIS I
MATH UN2500  ANALYSIS AND OPTIMIZATION
MATH UN3007  Complex Variables
MATH UN3386  Differential Geometry
MATH GU4051  Topology

Students seeking to pursue a Ph.D. program in either discipline are urged to take additional courses, in consultation with their advisers.

For a major in Economics and Mathematics, see the catalogue.

Requirement for the Minor in Mathematics
For a minor in Mathematics or Applied Mathematics: Six courses from any of the courses offered by the department except MATH UN1003 COLLEGE ALGBRA-ANLYTIC GEOMETRY, MATH UN1101 CALCULUS I / MATH UN1102 CALCULUS II. Some cognate courses are also acceptable with prior approval from the department chair.

Requirements for the Minor in Mathematical Sciences
The minor in Mathematical Sciences comprises 6 courses, at least two from Mathematics and one from each of Statistics and Computer Science. There should be a minimum of three courses in Statistics and Computer Science. Eligible courses are any listed in the Mathematical Sciences Major with the exception of Calculus I and II.

MATH UN1003 COLLEGE ALGEBRA-ANLYTIC GEOMETRY. 3.00 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. 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

Spring 2021: MATH UN1003
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 1003  001/12309  M W 1:10pm - 2:25pm  Nguyen Dung  3.00  14/35
MATH 1003  002/12310  T Th 6:10pm - 7:25pm  Shalin Parekh  3.00  20/35
MATH 1003  003/19220  T Th 9:10am - 10:25am  Nguyen Dung  3.00  1/5

Fall 2021: MATH UN1003
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 1003  001/10617  M W 6:10pm - 7:25pm  Room TBA  3.00  6/30
MATH 1003  002/10618  T Th 2:40pm - 3:55pm  Room TBA  3.00  14/30

Note: Students should consult with their advisers on the selection of courses.
### 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)

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<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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</thead>
<tbody>
<tr>
<td>MATH 1101</td>
<td>001/12308</td>
<td>M W 2:40pm - 3:55pm Online Only</td>
<td>Sayan Das</td>
<td>3.00</td>
<td>13/35</td>
</tr>
<tr>
<td>MATH 1101</td>
<td>002/12307</td>
<td>M W 4:10pm - 5:25pm Online Only</td>
<td>Kevin Smith</td>
<td>3.00</td>
<td>31/35</td>
</tr>
<tr>
<td>MATH 1101</td>
<td>003/12306</td>
<td>T Th 10:10am - 11:25am Online Only Panagiota Daskalopoulos</td>
<td>3.00</td>
<td>61/100</td>
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<tr>
<td>MATH 1101</td>
<td>004/12305</td>
<td>T Th 11:40am - 12:55pm Online Only George Dragomir</td>
<td>3.00</td>
<td>82/100</td>
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<tr>
<td>MATH 1101</td>
<td>005/12304</td>
<td>T Th 4:10pm - 5:25pm Online Only Tobias Schaefer</td>
<td>3.00</td>
<td>20/40</td>
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<tr>
<td>MATH 1101</td>
<td>AU1/19222</td>
<td></td>
<td>Sayan Das</td>
<td>3.00</td>
<td>1/5</td>
</tr>
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</table>

### MATH UN1102 CALCULUS II. 3.00 points.
Prerequisites: MATH UN1101 or the equivalent. Methods of integration, applications of the integral, Taylor’s theorem, infinite series. (SC)

<table>
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<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 1102</td>
<td>001/12303</td>
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<td>Maithreya Sitaraman</td>
<td>3.00</td>
<td>12/35</td>
</tr>
<tr>
<td>MATH 1102</td>
<td>002/12302</td>
<td>M W 4:10pm - 5:25pm Online Only</td>
<td>Yier Lin</td>
<td>3.00</td>
<td>14/35</td>
</tr>
<tr>
<td>MATH 1102</td>
<td>003/12301</td>
<td>T Th 11:40am - 12:55pm Online Only Evgeni Dimitrov</td>
<td>3.00</td>
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<td>MATH 1102</td>
<td>004/12300</td>
<td>T Th 1:10pm - 2:25pm Online Only Evgeni Dimitrov</td>
<td>3.00</td>
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<td>MATH 1102</td>
<td>AU1/19280</td>
<td></td>
<td>Maithreya Sitaraman</td>
<td>3.00</td>
<td>1/5</td>
</tr>
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</table>

### MATH UN1101 Course Offerings
Spring 2021:
- **MATH 1101**
  - 001/12308: M W 2:40pm - 3:55pm Online Only
  - 002/12307: M W 4:10pm - 5:25pm Online Only
  - 003/12306: T Th 10:10am - 11:25am Online Only Panagiota Daskalopoulos
  - 004/12305: T Th 11:40am - 12:55pm Online Only George Dragomir
  - 005/12304: T Th 4:10pm - 5:25pm Online Only Tobias Schaefer
  - AU1/19222: M W 6:10pm - 7:25pm Online Only

### MATH UN1102 Course Offerings
Spring 2021:
- **MATH 1102**
  - 001/12303: M W 11:40am - 12:55pm Online Only
  - 002/12302: M W 4:10pm - 5:25pm Online Only
  - 003/12301: T Th 11:40am - 12:55pm Online Only
  - 004/12300: T Th 1:10pm - 2:25pm Online Only
  - AU1/19280: M W 6:10pm - 7:25pm Online Only

### MATH UN1101 Fall 2021
- **MATH 1101**
  - 001/10622: M W 10:10am - 11:25am Room TBA
  - 002/10623: M W 1:10pm - 2:25pm Room TBA
  - 003/10624: M W 2:40pm - 3:55pm Room TBA
  - 004/10625: M W 4:10pm - 5:25pm Room TBA
  - 005/10626: T Th 10:10am - 11:25am Room TBA
  - 006/10628: T Th 11:40am - 12:55pm Room TBA
  - 007/00170: M W 6:10pm - 7:25pm Room TBA
  - 008/10629: T Th 11:40am - 12:55pm Room TBA
  - 009/10630: T Th 4:10pm - 5:25pm Room TBA
  - 011/00171: T Th 2:40pm - 3:55pm Room TBA

### MATH UN1102 Fall 2021
- **MATH 1102**
  - 001/10631: M W 1:10pm - 2:25pm Room TBA
  - 002/10632: M W 2:40pm - 3:55pm Room TBA
  - 003/10634: M W 4:10pm - 5:25pm Room TBA
  - 004/10635: T Th 10:10am - 11:25am Room TBA
  - 005/10636: T Th 11:40am - 12:55pm Room TBA
  - 006/10638: T Th 6:10pm - 7:25pm Room TBA
  - 007/10639: T Th 6:10pm - 7:25pm Room TBA
  - 008/10640: T Th 11:40am - 12:55pm Room TBA
  - 009/10641: T Th 1:10pm - 2:25pm Room TBA
  - 010/10642: T Th 4:10pm - 5:25pm Room TBA
  - 011/10643: T Th 2:40pm - 3:55pm Room TBA
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)

Prerequisites: MATH UN1102 and MATH UN1201 or the equivalent
MATH UN1202 CALCULUS IV.

MATH 2006 COMBINATORICS.

Prerequisites: MATH V2010 or the equivalent
Honors-level introductory course in enumerative combinatorics.
Pigeonhole principle, binomial coefficients, permutations and
combinations, Polya enumeration, inclusion-exclusion principle,
generating functions and recurrence relations.

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.

MATH UN2000 INTRO TO HIGHER MATHEMATICS. 3.00 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)

MATH BC2006 Combinatorics. 3 points.
Corequisites: MATH V2010 is helpful as a corequisite, but not required.
Honors-level introductory course in enumerative combinatorics.
Pigeonhole principle, binomial coefficients, permutations and
combinations, Polya enumeration, inclusion-exclusion principle,
generating functions and recurrence relations.

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<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
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<td>Nicholas Salter</td>
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<td>Mu-Tao Wang</td>
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<td>MATH 1202</td>
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<td>Konstantin Aleshkin</td>
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<td>MATH 1202</td>
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<td>MATH 1202</td>
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<td>MATH 1202</td>
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<td>MATH 1202</td>
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<td>Stephen Miller</td>
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<td>MATH 1202</td>
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<td>Inbar Klang</td>
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<td>44/100</td>
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<tr>
<td>MATH 1202</td>
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<td>Inbar Klang</td>
<td>3</td>
<td>28/100</td>
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<tr>
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<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<td>MATH 1207</td>
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<th>Times/Location</th>
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<tr>
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<td>001/12294</td>
<td>T Th 1:10pm - 2:25pm Online Only</td>
<td>Evan Warner</td>
<td>4.00</td>
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<tr>
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<th>Section/Call Number</th>
<th>Times/Location</th>
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<tr>
<td>MATH 2006</td>
<td>001/00086</td>
<td>T Th 10:10am - 11:25am Room TBA</td>
<td>3</td>
<td>38/40</td>
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</tbody>
</table>
MATH UN2010 LINEAR ALGEBRA. 3.00 points.
Prerequisites: MATH UN1201 or the equivalent.
Prerequisites: MATH UN1201 or the equivalent. Matrices, vector spaces, linear transformations, eigenvalues and eigenvectors, canonical forms, applications. (SC)

Spring 2021: MATH UN2010

<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>
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<tr>
<td>MATH 2010</td>
<td>001/12292</td>
<td>M W 10:10am - 11:25am Online Only</td>
<td>Konstantin Alekhnin</td>
<td>3.00</td>
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<tr>
<td>MATH 2010</td>
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<td>M W 1:10pm - 2:25pm Online Only</td>
<td>Gus Schrader</td>
<td>3.00</td>
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<td>MATH 2010</td>
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<td>T Th 11:40am - 12:55pm Online Only</td>
<td>Stephen Miller</td>
<td>3.00</td>
<td>73/100</td>
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<tr>
<td>MATH 2010</td>
<td>004/12289</td>
<td>T Th 1:10pm - 2:25pm Online Only</td>
<td>Andrew Ahn</td>
<td>3.00</td>
<td>19/100</td>
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<td>MATH 2010</td>
<td>005/12288</td>
<td>T Th 6:10pm - 7:25pm Online Only</td>
<td>Elliott Stein</td>
<td>3.00</td>
<td>28/45</td>
</tr>
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<td>3.00</td>
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Fall 2021: MATH UN2010

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<th>Times/Location</th>
<th>Instructor</th>
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<tr>
<td>MATH 2010</td>
<td>001/00017</td>
<td>T Th 8:40am - 9:55am Room TBA</td>
<td>David Bayer</td>
<td>3.00</td>
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<td>David Bayer</td>
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<tr>
<td>MATH 2010</td>
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<td>T Th 4:10pm - 5:25pm Room TBA</td>
<td>Henry Pinkham</td>
<td>3.00</td>
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</table>

MATH UN2020 Honors Linear Algebra. 3 points.
Not offered during 2021-22 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 UN1207-MATH UN1208.

MATH UN2030 ORDINARY DIFFERENTIAL EQUATION. 3.00 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. (SC)

Spring 2021: MATH UN2030

<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>
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<tr>
<td>MATH 2030</td>
<td>001/12287</td>
<td>M W 2:40pm - 3:55pm Online Only</td>
<td>Igor Krichever</td>
<td>3.00</td>
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<tr>
<td>MATH 2030</td>
<td>002/12286</td>
<td>T Th 10:10am - 11:25am Online Only</td>
<td>Aleksander Doan</td>
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Fall 2021: MATH UN2030

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<th>Instructor</th>
<th>Points</th>
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<tr>
<td>MATH 2030</td>
<td>001/10718</td>
<td>M W 1:10pm - 2:25pm Room TBA</td>
<td>Florian Johne</td>
<td>3.00</td>
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<tr>
<td>MATH 2030</td>
<td>002/10719</td>
<td>T Th 2:40pm - 3:55pm Room TBA</td>
<td>Evgeni Dimitrov</td>
<td>3.00</td>
<td>60/100</td>
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</tbody>
</table>

MATH UN2500 ANALYSIS AND OPTIMIZATION. 3.00 points.
Prerequisites: MATH UN1102 and MATH UN1201 or the equivalent and MATH UN2010.
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)

Spring 2021: MATH UN2500

<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>
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<tr>
<td>MATH 2500</td>
<td>001/12285</td>
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<td>Yash Jhaveri</td>
<td>3.00</td>
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<tr>
<td>MATH 2500</td>
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<td>Yash Jhaveri</td>
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Fall 2021: MATH UN2500

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<th>Instructor</th>
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<th>Enrollment</th>
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<tr>
<td>MATH 2500</td>
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<td>T Th 10:10am - 11:25am Room TBA</td>
<td>Kanstantsin Matetski</td>
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<tr>
<td>MATH 2500</td>
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<td>T Th 11:40am - 12:55pm Room TBA</td>
<td>Kanstantsin Matetski</td>
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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 2021: MATH UN3007

<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>
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<tr>
<td>MATH 3007</td>
<td>001/10722</td>
<td>M W 2:40pm - 3:55pm Room TBA</td>
<td>Ovidiu Savin</td>
<td>3.00</td>
<td>34/60</td>
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</tbody>
</table>

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 MATH UN2010.
A concrete introduction to abstract algebra. Topics in abstract algebra used in cryptography and coding theory.

Fall 2021: MATH UN3025

<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>
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<tr>
<td>MATH 3025</td>
<td>001/10723</td>
<td>T Th 1:10pm - 2:25pm Room TBA</td>
<td>Dorian Goldfeld</td>
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<td>95/100</td>
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MATH UN3027 Ordinary Differential Equations. 3 points.
Prerequisites: MATH UN1102 and MATH UN1201 or the equivalent.
Corequisites: MATH UN2010

Fall 2021: MATH UN3027

<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>
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<tr>
<td>MATH 3027</td>
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<td>Elena Giorgi</td>
<td>3.00</td>
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MATH UN3028 PARTIAL DIFFERENTIAL EQUATIONS. 3.00 points.
Prerequisites: MATH UN3027 and MATH UN2010 or the equivalent.

Spring 2021: MATH UN3028

<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>
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<tr>
<td>MATH 3028</td>
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<td>Florian Johne</td>
<td>3.00</td>
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MATH UN3050 Discrete Time Models in Finance. 3 points.
Prerequisites: (MATH UN1102 and MATH UN1201) or (MATH UN101 and MATH UN1102 and MATH UN1201) 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.

Spring 2021: MATH UN3050

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
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<td>MATH 3050</td>
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<td>M W 6:10pm - 7:25pm</td>
<td>Mikhail Smirnov</td>
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</table>

MATH UN3386 Differential Geometry. 3 points.
Prerequisites: MATH UN1202 or the equivalent.
Local and global differential geometry of submanifolds of Euclidean 3-space. Frenet formulas for curves. Various types of curvatures for curves and surfaces and their relations. The Gauss-Bonnet theorem.

Fall 2021: MATH UN3386

<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>
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<td>MATH 3386</td>
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<td>T Th 11:40am - 12:55pm</td>
<td>Richard Hamilton</td>
<td>3</td>
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MATH UN3901 Supervised Readings in Mathematics I. 2-3 points.
Prerequisites: The written permission of the staff member who agrees to act as sponsor (sponsorship limited to full-time instructors on the staff list), as well as the permission of the Director of Undergraduate Studies. The written permission must be deposited with the Director of Undergraduate Studies before registration is completed. Guided reading and study in mathematics. A student who wishes to undertake individual study under this program must present a specific project to a member of the staff and secure his or her willingness to act as sponsor. Written reports and periodic conferences with the instructor.

Spring 2021: MATH UN3901

<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>
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<tbody>
<tr>
<td>MATH 3901</td>
<td>001/00175</td>
<td>Online Only</td>
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MATH UN3902 Supervised Readings in Mathematics II. 2-3 points.
Prerequisites: The written permission of the staff member who agrees to act as sponsor (sponsorship limited to full-time instructors on the staff list), as well as the permission of the Director of Undergraduate Studies. The written permission must be deposited with the Director of Undergraduate Studies before registration is completed. Guided reading and study in mathematics. A student who wishes to undertake individual study under this program must present a specific project to a member of the staff and secure his or her willingness to act as sponsor. Written reports and periodic conferences with the instructor.

Spring 2021: MATH UN3902

<table>
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<th>Course Number</th>
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<th>Instructor</th>
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<th>Enrollment</th>
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<td>MATH 3902</td>
<td>001/17763</td>
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<td>Francesco Lin</td>
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<td>Ivan Corwin</td>
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<td>Ioannis Karatzas</td>
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<td>Peter Wolf</td>
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<td>Mikhail Khovanov</td>
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MATH UN3901 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 2021: MATH UN3901

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
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MATH UN3951 Undergraduate Seminars in Mathematics II. 3 points.
Prerequisites: (MATH UN1102 and MATH UN1201) or (MATH UN101 and MATH UN1102 and MATH UN1201) and MATH UN2010
Recommended: MATH UN3027 (or MATH UN2030 and SIEO W3600).
The written permission of the staff member who agrees to act as sponsor (sponsorship limited to full-time instructors on the staff list), as well as the permission of the Director of Undergraduate Studies. The written permission must be deposited with the Director of Undergraduate Studies before registration is completed. Guided reading and study in mathematics. A student who wishes to undertake individual study under this program must present a specific project to a member of the staff and secure his or her willingness to act as sponsor. Written reports and periodic conferences with the instructor.

Spring 2021: MATH UN3951

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
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<tr>
<td>MATH 3951</td>
<td>001/00175</td>
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</table>
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.

Spring 2021: MATH UN3952
Course Number Section/Call Times/Location Instructor Points Enrollment
MATH 3952 001/00688 0 TTh 10:10am - 11:25am David Bayer 3 41/60

MATH UN3997 Supervised Individual Research. 3 points.
Prerequisites: The written permission of the faculty member who agrees to act as a supervisor, and the permission of the Director of Undergraduate Studies. For specially selected mathematics majors, the opportunity to write a senior thesis on a problem in contemporary mathematics under the supervision of a faculty member.

Spring 2021: MATH UN3997
Course Number Section/Call Times/Location Instructor Points Enrollment
MATH 3997 001/00749 0 TTh 11:40am - 12:55pm David Bayer 3 1/1

MATH UN3998 Supervised Individual Research. 3 points.
Prerequisites: The written permission of the faculty member who agrees to act as a supervisor, and the permission of the Director of Undergraduate Studies. For specially selected mathematics majors, the opportunity to write a senior thesis on a problem in contemporary mathematics under the supervision of a faculty member.

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.

Spring 2021: MATH GU4007
Course Number Section/Call Times/Location Instructor Points Enrollment
MATH 4007 001/12281 0 M W 10:10am - 11:25am Dorian Goldfeld 3 13/50

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.

Fall 2021: MATH GU4032
Course Number Section/Call Times/Location Instructor Points Enrollment
MATH 4032 001/10754 0 M W 10:10am - 11:25am Simon Brendle 3 30/50

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.

Spring 2021: MATH GU4041
Course Number Section/Call Times/Location Instructor Points Enrollment
MATH 4041 001/12280 0 M W 10:10am - 11:25am Online Only Daniele Alessandrini 3 35/100

Fall 2021: MATH GU4041
Course Number Section/Call Times/Location Instructor Points Enrollment
MATH 4041 001/12812 0 M W 2:40pm - 3:55pm Room TBA Robert Friedman 3 83/100

MATH GU4032 Fourier Analysis. 3 points.
Prerequisites: MATH UN3007

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.

Spring 2021: MATH GU4042
Course Number Section/Call Times/Location Instructor Points Enrollment
MATH 4042 001/12279 0 M W 2:40pm - 3:55pm Online Only Inbar Klang 3 42/100

Fall 2021: MATH GU4042
Course Number Section/Call Times/Location Instructor Points Enrollment
MATH 4042 001/10765 0 T Th 1:10pm - 2:25pm Room TBA 3 15/35

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.

Fall 2021: MATH GU4044
Course Number Section/Call Times/Location Instructor Points Enrollment
MATH 4044 001/10766 0 T Th 1:10pm - 2:25pm Room TBA Chao Li 3 15/20

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 W4046 Introduction to Category Theory. 3 points.
CC/GS: Partial Fulfillment of Science Requirement
Not offered during 2021-22 academic year.

Prerequisites: MATH W4041.
Categories, functors, natural transformations, adjoint functors, limits and colimits, introduction to higher categories and diagrammatic methods in algebra.

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 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.

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.
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-Arzelà theorem, Stone-Weierstrass theorem.

Spring 2021: MATH GU4061
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 4061  001/12276  M W 1:10pm - 2:25pm  Online Only  Hui Yu  3 39/100
MATH 4061  002/12277  M W 4:10pm - 5:25pm  Online Only  Hui Yu  3 30/100

Fall 2021: MATH GU4061
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 4061  001/10769  T Th 2:40pm - 3:55pm  Room TBA  Henri Roesch  3 35/100
MATH 4061  002/10770  T Th 4:10pm - 5:25pm  Room TBA  Henri Roesch  3 21/100

MATH GU4062 INTRO MODERN ANALYSIS II. 3.00 points.
Prerequisites: MATH UN1202 or the equivalent, and MATH UN2010. The second term of this course may not be taken without the first.
Prerequisites: MATH UN1202 or the equivalent, and MATH UN2010. The second term of this course may not be taken without the first. Power series, analytic functions, Implicit function theorem, Fubini theorem, change of variables formula, Lebesgue measure and integration, function spaces

Spring 2021: MATH GU4062
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 4062  001/12276  T Th 4:10pm - 5:25pm  Online Only  Henri Roesch  3.00 20/100

Fall 2021: MATH GU4062
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 4062  001/10771  M W 4:10pm - 5:25pm  Room TBA  3.00 19/50

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 2021: MATH GU4065
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 4065  001/10772  T Th 10:10am - 11:25am  Julien Dubedat  3 12/20
MATH GU4071 Introduction to the Mathematics of Finance. 3 points.
CC/GS: Partial Fulfillment of Science Requirement

Prerequisites: MATH UN1202 and MATH UN3027 and STAT W4150 and
SEIO W4150, or their equivalents.
The mathematics of finance, principally the problem of pricing of
derivative securities, developed using only calculus and basic probability.
Topics include mathematical models for financial instruments, Brownian
motion, normal and lognormal distributions, the Black-Scholes formula,
and binomial models.

MATH GU4081 Introduction to Differentiable Manifolds. 3 points.

Prerequisites: (MATH GU4051 or MATH GU4061) and MATH UN2010
Concept of a differentiable manifold. Tangent spaces and vector fields.
The inverse function theorem. Transversality and Sard’s theorem.
forms and Stokes’ theorem.

COMS W4150 Computational Linear Algebra. 3 points.
Not offered during 2021-22 academic year.

MATH GU4155 Probability Theory. 3 points.
Prerequisites: MATH GU4061 or MATH UN3007
A rigorous introduction to the concepts and methods of mathematical
probability starting with basic notions and making use of combinatorial
and analytic techniques. Generating functions. Convergence in
probability and in distribution. Discrete probability spaces, recurrence
and transience of random walks. Infinite models, proof of the law of large
numbers and the central limit theorem. Markov chains.

MATH GU4392 INTRO TO QUANTUM MECHANICS II. 3.00 points.
Not offered during 2021-22 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 4392

Cross-Listed Courses

Computer Science

COMS S3251 Computational Linear Algebra. 3 points.
Not offered during 2021-22 academic year.

Prerequisites: two terms of calculus.
Computational linear algebra, solution of linear systems, sparse linear
systems, least squares, eigenvalue problems, and numerical solution of
other multivariate problems as time permits.