MATHEMATICS

332G Milbank Hall
212-854-3577
Department Assistant: Marsha Peruo

General Information

Students who have special placement problems, or are unclear about their level, should make an appointment with a faculty member or the Chair.

Two help rooms, one in 404 Mathematics and one in 502 Milstein Center, are available. Hours will be posted on the door and on https://math.barnard.edu/math-tutoring-schedules/ for students seeking individual help and counseling from Barnard tutors and Columbia teaching assistants. No appointments are necessary. Both Barnard and Columbia students are welcome. NOTE: Changes to tutoring schedules and remote tutoring can occur in response to COVID-19.

Courses for First-Year Students

The systematic study of Mathematics begins with one of the following alternative sequences:

<table>
<thead>
<tr>
<th>Calculus I, II, III, IV</th>
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<tbody>
<tr>
<td>MATH UN1101 CALCULUS I</td>
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<tr>
<td>MATH UN1102 Calculus II</td>
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<td>MATH UN1201 Calculus III</td>
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<td>MATH UN1202 Calculus IV</td>
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</tbody>
</table>

Honors Math A-B

| MATH UN1207 Honors Mathematics A |
| MATH UN1208 Honors Mathematics B |

Credit is allowed for only one of the calculus sequences. The calculus sequence is a standard course in differential and integral calculus. Honors Mathematics A-B is for exceptionally well-qualified students who have strong advanced placement scores. It covers second-year Calculus (MATH UN1201 Calculus III – MATH UN1202 Calculus IV) and MATH UN2010 Linear Algebra, with an emphasis on theory.

Calculus II is NOT a prerequisite for Calculus III, so students who plan to take only one year of calculus may choose between I and II or I and III. The latter requires a B or better in Calculus I and is a recommended option for some majors.

MATH UN2000 An Introduction to Higher Mathematics is a course that can be taken in their first or second year by students with an aptitude for mathematics who would like to practice writing and understanding mathematical proofs.

Placement in the Calculus Sequence

College Algebra and Analytical Geometry is a refresher course for students who intend to take Calculus but do not have adequate background for it.

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 4 receive 3 points of credit. Those who passed Calculus 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.

Calculus I, II, III: Students who have not previously studied calculus should begin with Calculus I. Students with 4 or higher on the Calculus AB or BC advanced placement test may start with Calculus II. Students with 5 on the Calculus BC test should start with Calculus III.

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), Walter Neumann
Term Assistant Professor: Lindsay Piechnik
Research Professor and Professor Emerita: Joan Birman

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 UN2010 Linear Algebra (also satisfied by Honors Math A-B) |
| MATH GU4041 INTRO MODERN ALGEBRA I (I) |
| MATH GU4042 INTRO MODERN ALGEBRA II (II) |
| MATH GU4061 INTRO MODERN ANALYSIS I (I) |
| MATH GU4062 Introduction To Modern Analysis II (II) |
| MATH UN3951 Undergraduate Seminars in Mathematics I (at least one term) |
| MATH UN3952 Undergraduate Seminars in Mathematics II |

Note: It is strongly recommended that the sequences MATH GU4041 INTRO MODERN ALGEBRA I - MATH GU4062 Introduction To Modern Analysis II and MATH GU4061 INTRO MODERN ANALYSIS I - MATH GU4062 Introduction To 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 Introduction To 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 Functions of a Complex Variable
- MATH UN3027 Ordinary Differential Equations or MATH UN2030 Ordinary Differential Equations
- 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

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:**

Select one of the following sequences:

- MATH UN1101 - MATH UN1102 - MATH UN2010 - MATH UN2500 CALCULUS I and Calculus II and Linear Algebra and Analysis and Optimization
- MATH UN1207 - MATH UN1208 - MATH UN2500 Honors Mathematics A and Honors Mathematics B and Analysis and Optimization

Statistics

Statistics required courses

- STAT UN1101 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:

- 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 (e.g., 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

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 - MATH UN1102 - MATH UN2010 - MATH UN2000 - MATH UN2030 - MATH UN3027 CALCULUS I and Calculus II and Linear Algebra and An Introduction to Higher Mathematics and Ordinary Differential Equations and Ordinary Differential Equations

Possible further courses selected from the following:

- MATH UN1207 - MATH UN1208 - MATH UN2500 Honors Mathematics A and Honors Mathematics B 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:

- 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
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

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 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 Algebra and Analytic 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 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)

For a major in Computer Science and Programming in Java

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.
### MATH UN1102 Calculus II. 3 points.
Prerequisites: MATH UN1101 or the equivalent.
Methods of integration, applications of the integral, Taylor’s theorem, infinite series. (SC)

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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>001/11302</td>
<td>M W 11:40am - 12:55pm Online Only</td>
<td>Mathreya Sitaraman</td>
<td>3</td>
<td>16/30</td>
</tr>
<tr>
<td>MATH 1102</td>
<td>002/11303</td>
<td>M W 2:40pm - 3:55pm Online Only</td>
<td>Zachary Sylvan</td>
<td>3</td>
<td>95/100</td>
</tr>
<tr>
<td>MATH 1102</td>
<td>003/11304</td>
<td>M W 4:10pm - 5:25pm Online Only</td>
<td>Zachary Sylvan</td>
<td>3</td>
<td>40/110</td>
</tr>
<tr>
<td>MATH 1102</td>
<td>005/00434</td>
<td>T Th 2:40pm - 3:55pm Room TBA</td>
<td>Lindsay Pietročnik</td>
<td>3</td>
<td>97/100</td>
</tr>
<tr>
<td>MATH 1102</td>
<td>006/11306</td>
<td>T Th 6:10pm - 7:25pm Online Only</td>
<td>Elliott Stein</td>
<td>3</td>
<td>38/45</td>
</tr>
<tr>
<td>MATH 1102</td>
<td>007/21402</td>
<td>T Th 11:40am - 12:55pm Online Only</td>
<td>Renata Picciotto</td>
<td>3</td>
<td>31/33</td>
</tr>
</tbody>
</table>

### 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)

### 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)

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</thead>
<tbody>
<tr>
<td>MATH 1202</td>
<td>001/00421</td>
<td>T Th 1:10pm - 2:25pm Online Only</td>
<td>Stephen Miller</td>
<td>3</td>
<td>34/64</td>
</tr>
<tr>
<td>MATH 1202</td>
<td>002/00424</td>
<td>M W 6:10pm - 7:25pm Online Only</td>
<td>Mikhail Smirnov</td>
<td>3</td>
<td>27/116</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)

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<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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</thead>
<tbody>
<tr>
<td>MATH 1207</td>
<td>001/11430</td>
<td>T 1:10pm - 2:25pm Online Only</td>
<td>Evan Warner</td>
<td>4</td>
<td>55/110</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).

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<th>Instructor</th>
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<th>Enrollment</th>
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<tr>
<td>MATH 2000</td>
<td>001/11446</td>
<td>M W 10:10am - 11:25am Online Only</td>
<td>Dusa McDuff</td>
<td>3</td>
<td>32/49</td>
</tr>
</tbody>
</table>

### MATH BC2001 Perspectives in Mathematics. 1 point.
Prerequisites: some calculus or the instructor’s permission. Intended as an enrichment to the mathematics curriculum of the first years, this course introduces a variety of mathematical topics (such as three dimensional geometry, probability, number theory) that are often not discussed until later, and explains some current applications of mathematics in the sciences, technology and economics.
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.

Spring 2021: MATH BC2006
Course Number | Section/Call Number | Times/Location | Instructor | Points | Enrollment
--- | --- | --- | --- | --- | ---
MATH 2006 | 001/00086 | T Th 10:10am - 11:25am Room TBA | Florian Johne | 3 | 0/20

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

Fall 2020: MATH UN2010
Course Number | Section/Call Number | Times/Location | Instructor | Points | Enrollment
--- | --- | --- | --- | --- | ---
MATH 2010 | 001/00117 | T Th 8:40am - 9:55am Room TBA | David Bayer | 3 | 24/100
MATH 2010 | 002/00118 | T Th 10:10am - 11:25am Room TBA | David Bayer | 3 | 35/100
MATH 2010 | 003/11450 | M W 4:10pm - 5:25pm Online Only | Francesco Lin | 3 | 75/100
MATH 2010 | 004/11453 | M W 11:40am - 12:55pm Online Only | Kyle Hayden | 3 | 91/100
MATH 2010 | 005/11455 | M W 8:40am - 9:55am Online Only | Giulia Sacca | 3 | 47/100

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 UN2010-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.

Fall 2020: MATH UN2030
Course Number | Section/Call Number | Times/Location | Instructor | Points | Enrollment
--- | --- | --- | --- | --- | ---
MATH 2030 | 001/11457 | M W 1:10pm - 2:25pm Online Only | Florian Johne | 3 | 52/116
MATH 2030 | 002/11461 | M W 2:40pm - 3:55pm Online Only | Florian Johne | 3 | 28/116

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 | 28/64
MATH 2500 | 002/11466 | T Th 2:40pm - 3:55pm Online Only | Kanstantin Matetski | 3 | 39/64

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 | 59/64

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 UN1201 and MATH UN1208) 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 Goldfield | 3 | 87/116

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 | 35/116

MATH UN3028 Partial Differential Equations. 3 points.
Prerequisites: MATH UN3027 and MATH UN2010 or the equivalent. Introduction to partial differential equations. First-order equations. Linear second-order equations; separation of variables, solution by series expansions. Boundary value problems.
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, termstructure of interest rates.

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.

MATH UN3901 Supervised Readings in Mathematics I. 2-3 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.
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.

Fall 2020: MATH UN3901
Course Number Section/Call Number Times/Location Instructor Points Enrollment
MATH 3901 001/1484 T Th 11:40am - 12:55pm Online Only Richard Hamilton 3 26/49

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.

Fall 2020: MATH UN3902
Course Number Section/Call Number Times/Location Instructor Points Enrollment
MATH 3902 001/0503 T Th 11:40am - 12:55pm Online Only Dorian Goldfield 2 1/2
MATH 3901 002/24556 2/3 2/2
MATH 3901 003/24704 2/3 1/2
MATH 3901 004/24705 2/3 1/2
MATH 3901 005/24834 2/3 1/1
MATH 3901 006/24915 2/3 3/3
MATH 3901 007/25035 2/3 2/1

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 Lindsay Piechnik 3 8/15

Spring 2021: MATH UN3952
Course Number Section/Call Number Times/Location Instructor Points Enrollment
MATH 3952 001/00087 3 points

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 or not.

Fall 2020: MATH UN3997
Course Number Section/Call Number Times/Location Instructor Points Enrollment
MATH 3997 001/00576 3 points

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 or not.

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 theory, density of arithmetic progressions, SL (2, Z) and subgroups, points of the upper half-plane and cusp, 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 W4046 Introduction to Category Theory. 3 points.
CC/GS: Partial Fulfillment of Science Requirement
Not offered during 2020-21 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 $\mathbb{R}^3$, 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.

Fall 2020: MATH GU4041
Course Number | Section/Call Number | Times/Location | Instructor | Points | Enrollment
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MATH 4041 | 001/11487 | M W 2:40pm - 3:55pm | Robert Friedman | 3 | 68/110

Fall 2020: MATH GU4042
Course Number | Section/Call Number | Times/Location | Instructor | Points | Enrollment
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MATH 4042 | 001/11488 | M W 1:10pm - 2:25pm | Mikhail Khovanov | 3 | 13/35

Fall 2020: MATH GU4044
Course Number | Section/Call Number | Times/Location | Instructor | Points | Enrollment
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MATH 4044 | 001/11490 | T Th 1:10pm - 2:25pm | Chao Li | 3 | 10/19

Fall 2020: MATH GU4061
Course Number | Section/Call Number | Times/Location | Instructor | Points | Enrollment
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MATH 4061 | 001/11494 | T Th 2:40pm - 3:55pm | Henri Roesch | 3 | 36/100
MATH 4061 | 002/11495 | T Th 4:10pm - 5:25pm | Henri Roesch | 3 | 30/100
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.

Fall 2020: MATH GU4062
Course Number  | Section/Call Number | Times/Location  | Instructor  | Points | Enrollment
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MATH 4062   | 001/11498  | M W 4:10pm - 5:25pm | Hui Yu  | 3  | 25/49

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
Course Number  | Section/Call Number | Times/Location  | Instructor  | Points | Enrollment
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MATH 4065   | 001/11503  | T Th 10:10am - 11:25am | Julien Dubédat  | 3  | 17/45

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 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

Spring 2021: MATH GU4081
Course Number  | Section/Call Number | Times/Location  | Instructor  | Points | Enrollment
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MATH 4081   | 001/00088  | M W 10:10am - 11:25am | Dusa McDuff  | 3  | 8/20

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

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

Cross-Listed Courses

Computer Science

COMS S3251 Computational Linear Algebra. **3 points.**
Not offered during 2020-21 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.

COMS W4203 Graph Theory. **3 points.**
Lect: 3.
Prerequisites: (COMS W3203)
General introduction to graph theory. Isomorphism testing, algebraic specification, symmetries, spanning trees, traversability, planarity, drawings on higher-order surfaces, colorings, extremal graphs, random graphs, graphical measurement, directed graphs, Burnside-Polya counting, voltage graph theory.

COMS W3203 DISCRETE MATHEMATICS. **4.00 points.**
Lect: 3.
Prerequisites: Any introductory course in computer programming.
Prerequisites: Any introductory course in computer programming. Logic and formal proofs, sequences and summation, mathematical induction, binomial coefficients, elements of finite probability, recurrence relations, equivalence relations and partial orderings, and topics in graph theory (including isomorphism, traversability, planarity, and colorings)

Industrial Engineering and Operations Research

CSOR E4010 Graph Theory: A Combinatorial View. **3 points.**
Lect: 3.
Not offered during 2020-21 academic year.
Prerequisites: Linear Algebra, or instructor’s permission.
Graph Theory is an important part of the theoretical basis of operations research. A good understanding of the basic fundamentals of graph theory is necessary in order to apply the theory successfully in the future. This is an introductory course in graph theory with emphasis on its combinatorial aspects. It covers basic definitions, and some fundamental concepts in graph theory and its applications. Topics include trees and forests graph coloring, connectivity, matching theory and others. This course will provide a solid foundation for students in the IEOR department, on which further courses may build.