Courses for First-Year Students
The systematic study of Mathematics begins with one of the following alternative sequences:

Calculus I, II, III, IV
MATH UN1101 CALCULUS I
MATH UN1102 CALCULUS II
MATH UN1201 Calculus III
MATH UN1202 Calculus IV

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 INTRO 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)
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 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 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 II and MATH GU4061 INTRO MODERN ANALYSIS I - 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 FUNCTNS 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

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 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 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

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 UN3007 Complex Variables
- or MATH GU4065 Honors Complex Variables
- or APMA E4204 FUNCTNS 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

Statistics

Select one of the following sequences:

- MATH UN1101 and CALCULUS II
- MATH UN1201 and Calculus III
- 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

Computer Science

Select one of the following courses:
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 ALGEBRA-ANLYTC GEOMTRY, 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-ANLYTC GEOMTRY. 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

<table>
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<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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**Spring 2021: MATH UN1003**

**Fall 2021: MATH UN1003**

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**Spring 2021: MATH UN1003**

**Fall 2021: MATH UN1003**

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: 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 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.

**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.

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 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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<th>Times/Location</th>
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### Fall 2021: MATH UN1101

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### 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)

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<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
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### Fall 2021: MATH UN1102

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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)

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Fall 2021: MATH UN1201

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<td>MATH 1201</td>
<td>005/10646</td>
<td>T Th 11:40am - 12:55pm 207 Mathematics Building</td>
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<td>T Th 1:10pm - 2:25pm 312 Mathematics Building</td>
<td>Stephen Miller</td>
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<td>MATH 1201</td>
<td>007/10648</td>
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<td>T Th 4:10pm - 5:25pm 207 Mathematics Building</td>
<td>Inbar Klang</td>
<td>3</td>
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MATH UN1202 Calculus IV. 3.00 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>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
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<td>001/00084</td>
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<td>Daniela De Silva</td>
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<td>MATH 1202</td>
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Spring 2021: MATH UN1202

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<tr>
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<td>001/10650</td>
<td>M W 1:10pm - 2:25pm 203 Mathematics Building</td>
<td>Mu-Tao Wang</td>
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<td>Mikhail Smirnov</td>
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Fall 2021: MATH UN1202

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<td>001/10656</td>
<td>T Th 1:10pm - 2:25pm 417 Mathematics Building</td>
<td>4</td>
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</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)

Fall 2021: MATH UN1207

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<th>Course Number</th>
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<th>Times/Location</th>
<th>Instructor</th>
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<th>Enrollment</th>
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</table>

MATH UN1208 Honors Mathematics B. 4.00 points.
Prerequisites: (see Courses for First-Year Students). (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)

Spring 2021: MATH UN1208

<table>
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<th>Course Number</th>
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<th>Instructor</th>
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<tr>
<td>MATH 1208</td>
<td>001/12294</td>
<td>T Th 1:10pm - 2:25pm Online Only</td>
<td>Evan Warner</td>
<td>4</td>
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</table>
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).

Spring 2021: MATH UN2000
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 2000  001/12293  M W 10:10am - 11:25am  Online Only  Gus Schrader  3.00  28/100

Fall 2021: MATH UN2000
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 2000  001/00172  M W 10:10am - 11:25am  328 Milbank Hall  Dusa McDuff  3.00  28/55

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  David Bayer  3  38/40

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
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 2010  001/12292  M W 10:10am - 11:25am  Online Only  Konstantin Alekshin  3.00  21/100
MATH 2010  002/12291  M W 1:10pm - 2:25pm  Online Only  Gus Schrader  3.00  83/120
MATH 2010  003/12290  T Th 11:40am - 12:55pm  Online Only  Stephen Miller  3.00  73/100
MATH 2010  004/12289  T Th 1:10pm - 2:25pm  Online Only  Andrew Ahn  3.00  19/100
MATH 2010  005/12288  T Th 6:10pm - 7:25pm  Online Only  Elliott Stein  3.00  28/46
MATH 2010  AU4/19231  T Th 8:40am - 9:55am  Online Only  Andrew Ahn  3.00  1/5

Fall 2021: MATH UN2010
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 2010  001/00173  T Th 8:40am - 9:55am  328 Milbank Hall  David Bayer  3.00  28/58
MATH 2010  002/00174  T Th 10:10am - 11:25am  328 Milbank Hall  David Bayer  3.00  48/58
MATH 2010  003/10679  M W 10:10am - 11:25am  207 Mathematics Building  3.00  38/100
MATH 2010  004/10693  M W 11:40am - 12:55pm  312 Mathematics Building  3.00  30/100
MATH 2010  005/10698  T Th 4:10pm - 5:25pm  520 Mathematics Building  3.00  12/100

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. 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.
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)

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

MATH UN3028 PARTIAL DIFFERENTIAL EQUATIONS. 3.00 points.
Prerequisites: MATH UN3027 and MATH UN2010 or the equivalent
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 UN1101 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.

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 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.
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.

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.

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 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 soluble 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 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-Arzela theorem, Stone-Weierstrass theorem.

Spring 2021: MATH GU4061
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 4061  001/12278  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  203 Mathematics Building  0. FACULTY  3 38/100
MATH 4061  002/10770  T Th 4:10pm - 5:25pm  203 Mathematics Building  0. FACULTY  3 24/100

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  417 Mathematics Building  3.00 16/50

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  307 Mathematics Building  Julien Dubedat  3 13/20

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

Spring 2021: MATH GU4081
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 4081  001/00088  M W 10:10am - 11:25am  Room TBA  Dusa McDuff  3 15/40

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

Spring 2021: MATH GU4155
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 4155  001/12275  T Th 2:40pm - 3:55pm  203 Mathematics Building  Ioannis Karatzas  3 13/55

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

Spring 2021: MATH GU4392
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 4392  001/12274  T Th 4:10pm - 5:25pm  Online Only  Peter Woit  3.00 4/40

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, eigenvale 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)

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<th>Section/Call Number</th>
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<tr>
<td>COMS 3203</td>
<td>001/13030</td>
<td>M W 10:10am - 11:25am Online Only</td>
<td>Ansaf Salleb-Aouissi</td>
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<td>COMS 3203</td>
<td>001/12483</td>
<td>M W 4:10pm - 5:25pm B33 Seeley W. Mudd Building</td>
<td>Yining Liu</td>
<td>4.00</td>
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<tr>
<td>COMS 3203</td>
<td>002/12484</td>
<td>T Th 5:40pm - 6:55pm 207 Mathematics Building</td>
<td>Antonio Moretti</td>
<td>4.00</td>
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Industrial Engineering and Operations Research
CSOR E4010 Graph Theory: A Combinatorial View. 3 points.
Lect: 3. Not offered during 2021-22 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.