**MATH 3100 Introduction to Modern Analysis I (I)**
- **MATH 3200 Introduction to Modern Analysis II (II)**
- **Math 4061 Modern Analysis I (I)**
- **Math 4062 Modern Analysis II (II)**
- **Math 4310 Intro to Modern Algebra I (I)**
- **Math 4320 Intro to Modern Algebra II (II)**
- **Math 6050 Modern Algebra (I)**
- **Math 6052 Modern Algebra (II)**
- **Math 6054 Modern Algebra (III)**

**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 to Modern Algebra I (I)
- MATH GU4042 Intro to Modern Algebra II (II)
- MATH GU4061 Intro to Modern Analysis I (I)
- MATH GU4062 Introduction to 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 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 UN2100
- MATH GU4001
- APMA E4901
- APMA E4903
- APMA E3900

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

- MATH UN2500
- MATH UN3007
- MATH UN3027
- MATH UN2010
- MATH UN3028
- MATH GU4032
- APMA E4300
- APMA E4101
- APMA E4150

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 UN1201
- MATH UN2010
- MATH UN2000
- MATH UN2030

or MATH UN3027

Possible further courses selected from the following:

- MATH UN1202
- MATH UN2500
- MATH UN3020
- MATH UN3025

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

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
- MATH UN1102
- MATH UN1201
- MATH UN2010
- MATH UN2500
- MATH UN1207
- MATH UN1208
- MATH UN2500

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 UN2952**: 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: Introduction to Combinatorics and Graph Theory
- **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

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 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.

<table>
<thead>
<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 1003</td>
<td>002/12023</td>
<td>T Th 11:40am - 12:55pm 407 Mathematics Building</td>
<td>Yier Lin</td>
<td>3</td>
<td>10/30</td>
</tr>
<tr>
<td>MATH 1003</td>
<td>003/00993</td>
<td>M W 6:10pm - 7:25pm 302 Barnard Hall</td>
<td>Lindsay Piechnik</td>
<td>3</td>
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<td>Alexander Pieloch</td>
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<tr>
<td>MATH 1003</td>
<td>002/11291</td>
<td>T Th 2:40pm - 3:55pm Room TBA</td>
<td>Mrudul Thatte</td>
<td>3</td>
<td>9/30</td>
</tr>
</tbody>
</table>
MATH UN1101 Calculus I. 3 points.
Prerequisites: (see Courses for First-Year Students). Functions, limits, derivatives, introduction to integrals, or an understanding of pre-calculus will be assumed.

The Help Room in 333 Milbank Hall (Barnard College) is open during the day, Monday through Friday, to students seeking individual help from the teaching assistants. (SC)

Spring 2020: MATH UN1101
Course Number Section/Call Number Times/Location Instructor Points Enrollment
MATH 1101 001/13846 M W 11:40am - 12:55pm 407 Mathematics Building Cailan Li 3 20/30
MATH 1101 002/12024 M W 2:40pm - 3:55pm 203 Mathematics Building Akash Sengupta 3 72/110
MATH 1101 003/12025 M W 6:10pm - 7:25pm 407 Mathematics Building Gerhardt Hinkle 3 20/30
MATH 1101 004/12026 T Th 10:10am - 11:25am 203 Mathematics Building Alexandra Florea 3 85/110
MATH 1101 005/12027 T Th 11:40am - 12:55pm 203 Mathematics Building William Chen 3 43/110

Fall 2020: MATH UN1101
Course Number Section/Call Number Times/Location Instructor Points Enrollment
MATH 1101 002/11292 M W 10:10am - 11:25am Room TBA Daniele Alessandrini 3 8/116
MATH 1101 003/11293 M W 11:40am - 12:55pm Room TBA Daniele Alessandrini 3 6/116
MATH 1101 004/11294 M W 1:10pm - 2:25pm Room TBA Akash Sengupta 3 23/110
MATH 1101 005/11295 M W 2:40pm - 3:55pm Room TBA Akash Sengupta 3 21/110
MATH 1101 006/11296 M W 4:10pm - 5:25pm Room TBA Chung Hang Kwok 3 5/30
MATH 1101 007/11297 T Th 10:10am - 11:25am Room TBA George Dragomir 3 23/100
MATH 1101 008/11298 T Th 11:40am - 12:55pm Room TBA Robin Zhang 3 20/30
MATH 1101 009/11299 T Th 1:10pm - 2:25pm Room TBA George Dragomir 3 14/100
MATH 1101 010/11300 T Th 4:10pm - 5:25pm Room TBA 3 4/100

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)

Spring 2020: MATH UN1102
Course Number Section/Call Number Times/Location Instructor Points Enrollment
MATH 1102 001/12029 M W 1:10pm - 2:25pm 207 Mathematics Building Yi Sun 3 43/125
MATH 1102 002/12030 M W 2:40pm - 3:55pm 407 Mathematics Building Semen Rezchikov 3 32/35
MATH 1102 003/12031 T Th 11:40am - 12:55pm 207 Mathematics Building Michael Woodbury 3 51/125
MATH 1102 004/12032 T Th 6:10pm - 7:25pm 407 Mathematics Building Iakov Kononov 3 18/30

Fall 2020: MATH UN1102
Course Number Section/Call Number Times/Location Instructor Points Enrollment
MATH 1102 001/11302 M W 11:40am - 12:55pm Room TBA Maithreya Sitaraman 3 12/30
MATH 1102 002/11303 M W 2:40pm - 3:55pm Room TBA Renata Picciotto 3 13/30
MATH 1102 003/11304 M W 4:10pm - 5:25pm Room TBA 3 1/110
MATH 1102 004/11305 T Th 10:10am - 11:25am Room TBA Elliott Stein 3 7/110
MATH 1102 005/00434 T Th 2:40pm - 3:55pm Room TBA Lindsay Piechnik 3 31/100
MATH 1102 006/11306 T Th 6:10pm - 7:25pm Room TBA Elliott Stein 3 17/45
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, gradients, surfaces, optimization, the method of Lagrange multipliers. (SC)

Prerequisites: MATH UN1102 and MATH UN1201 or the equivalent
MATH UN1202 Calculus IV.
Several variables, partial derivatives, gradients, surfaces, optimization, the rule, vector-valued functions of one variable, scalar-valued functions of exponential function with applications to differential equations, Cramer’s vectors in dimensions 2 and 3, complex numbers and the complex

MATH 1202
Number
Course
Fall 2020: MATH UN1202
Course Number Section/Call Number Times/Location Instructor Points Enrollment
MATH 1201 001/11389 M W 10:10am - 11:25am 207 Mathematics Building Konstantin 3 14/110
MATH 1201 002/11390 M W 11:40am - 12:55pm 602 Hamilton Hall Konstantin 3 8/110
MATH 1201 003/11394 M W 11:40am - 12:55pm 312 Mathematics Building Ovidiu Savin 3 7/110
MATH 1201 004/11398 T H 10:10am - 11:25am 312 Mathematics Building Carolyn Abbott 3 22/116
MATH 1201 005/11402 T H 11:40am - 12:55am 312 Mathematics Building Evan Warner 3 28/116
MATH 1201 006/11407 T H 2:40pm - 3:55pm Room TBA Inbar Klang 3 77/100
MATH 1201 007/11412 T H 4:10pm - 5:25pm Room TBA Inbar Klang 3 32/100
MATH 1201 008/11417 T H 6:10pm - 7:25pm Room TBA Guillaume Remy 3 5/116

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)

Spring 2020: MATH UN1207
Course Number Section/Call Number Times/Location Instructor Points Enrollment
MATH 1207 001/11430 T H 1:10pm - 2:25pm Room TBA Evan Warner 4 4/110

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).

Spring 2020: MATH UN2000
Course Number Section/Call Number Times/Location Instructor Points Enrollment
MATH 2000 001/00068 M W 2:40pm - 3:55pm 805 Altshul Hall Dusa McDuff 3 23/55

Fall 2020: MATH UN2000
Course Number Section/Call Number Times/Location Instructor Points Enrollment
MATH 2000 001/11446 M W 11:40am - 12:55pm Room TBA Gus Schrader 3 24/49

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.

Fall 2020: MATH BC2001
Course Number Section/Call Number Times/Location Instructor Points Enrollment
MATH 2001 001/00116 T H 6:10pm - 7:25pm Room TBA Dusa McDuff 1 8/40

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 2020: MATH BC2006
Course Number Section/Call Number Times/Location Instructor Points Enrollment
MATH 2006 001/00068 M W 2:40pm - 3:55pm 805 Altshul Hall Dusa McDuff 3 23/55

Fall 2020: MATH BC2006
Course Number Section/Call Number Times/Location Instructor Points Enrollment
MATH 2006 001/11446 M W 11:40am - 12:55pm Room TBA Gus Schrader 3 24/49
Mathematics

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

<table>
<thead>
<tr>
<th>Spring 2020: MATH UN2010</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<td>MATH 2010 001/12050</td>
<td>M W 10:10am - 11:25am 203 Mathematics Building</td>
<td>Alexis Drouot</td>
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<td>MATH 2010 002/12051</td>
<td>M W 11:40am - 12:55pm 203 Mathematics Building</td>
<td>Gus Schrader</td>
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<tr>
<td>MATH 2010 003/12062</td>
<td>T Th 10:10am - 11:25am 312 Mathematics Building</td>
<td>Henry Pinkham</td>
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<tr>
<td>MATH 2010 004/12053</td>
<td>T Th 2:40pm - 3:55pm 207 Mathematics Building</td>
<td>Nathan Dowlin</td>
<td>3</td>
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<tr>
<td>MATH 2010 005/12064</td>
<td>T Th 6:10pm - 7:25pm 520 Mathematics Building</td>
<td>Elliott Stein</td>
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<td>T Th 8:40am - 9:55am Room TBA</td>
<td>David Bayer</td>
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<td>MATH 2010 002/00118</td>
<td>T Th 10:10am - 11:25am Room TBA</td>
<td>David Bayer</td>
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<td>MATH 2010 003/11450</td>
<td>M W 4:10pm - 5:25pm Room TBA</td>
<td>Francesco Lin</td>
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<tr>
<td>MATH 2010 004/11453</td>
<td>M W 11:40am - 12:55pm Room TBA</td>
<td>Kyle Hayden</td>
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<td>61/100</td>
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<tr>
<td>MATH 2010 005/11455</td>
<td>T Th 6:10pm - 7:25pm Room TBA</td>
<td>Giulia Sacca</td>
<td>3</td>
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</tbody>
</table>

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

Prerequisites: MATH UN1201. A more extensive treatment of the material in MATH UN2010, with increased emphasis on proof. Not to be taken in addition to MATH UN2010 or MATH UN1207-MATH UN1208.

**MATH UN2030 Ordinary Differential Equations. 3 points.**
Prerequisites: MATH UN102 and MATH UN1201 or the equivalent. Special differential equations of order one. Linear differential equations with constant and variable coefficients. Systems of such equations. Transform and series solution techniques. Emphasis on applications.

<table>
<thead>
<tr>
<th>Spring 2020: MATH UN2030</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
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<tr>
<td>MATH 2030 001/12103</td>
<td>T Th 4:10pm - 5:25pm 312 Mathematics Building</td>
<td>Kyler Siegel</td>
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<tr>
<td>MATH 2030 002/12104</td>
<td>T Th 6:10pm - 7:25pm 312 Mathematics Building</td>
<td>Kyler Siegel</td>
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<th>Instructor</th>
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<tr>
<td>MATH 2030 001/11457</td>
<td>M W 1:10pm - 2:25pm Room TBA</td>
<td>Florian Johne</td>
<td>3</td>
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<tr>
<td>MATH 2030 002/11461</td>
<td>M W 2:40pm - 3:55pm Room TBA</td>
<td>Florian Johne</td>
<td>3</td>
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</table>

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

<table>
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<tr>
<th>Spring 2020: MATH UN2500</th>
<th>Times/Location</th>
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<td>Kanstantsin Matetski</td>
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<tr>
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<td>Kanstantsin Matetski</td>
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<tr>
<td>MATH 2500 002/11466</td>
<td>T 2:40pm - 3:55pm 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)

<table>
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<tr>
<th>Fall 2020: MATH UN3007</th>
<th>Times/Location</th>
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<td>M W 2:40pm - 3:55pm Room TBA</td>
<td>Nicholas Salter</td>
<td>3</td>
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</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.

<table>
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<tr>
<th>Spring 2020: MATH UN3020</th>
<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
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<td>MATH 3020 001/12108</td>
<td>M W 10:10am - 11:25am 312 Mathematics Building</td>
<td>Shotaro Makisumi</td>
<td>3</td>
<td>94/116</td>
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</table>

**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.

<table>
<thead>
<tr>
<th>Fall 2020: MATH UN3025</th>
<th>Times/Location</th>
<th>Instructor</th>
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<tr>
<td>MATH 3025 001/11471</td>
<td>T Th 1:10pm - 2:25pm Room TBA</td>
<td>Dorian Goldfeld</td>
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</table>
MATH UN3027 Ordinary Differential Equations. 3 points.
Prerequisites: MATH UN102 and MATH UN101 or the equivalent.
Corequisites: MATH UN2010

<table>
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<tr>
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<td>MATH 3027</td>
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</table>

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

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<th>Spring 2020: MATH UN3028</th>
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<td>MATH 3028</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 UN102 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.

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<th>Spring 2020: MATH UN3050</th>
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<td>MATH 3050</td>
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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.

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<th>Fall 2020: MATH UN3386</th>
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<tr>
<td>Course Number</td>
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<td>MATH 3386</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.

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<th>Spring 2020: MATH UN3901</th>
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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.

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<th>Fall 2020: MATH UN3951</th>
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<tr>
<td>Course Number</td>
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<tr>
<td>MATH 3951</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.

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<th>Spring 2020: MATH UN3952</th>
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<td>MATH 3952</td>
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</table>

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.
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 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.

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<tr>
<th>Course Number</th>
<th>Section/Call Number</th>
<th>Times/Location</th>
<th>Instructor</th>
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<tbody>
<tr>
<td>MATH 1003</td>
<td>002/12023</td>
<td>T Th 11:40am - 12:55pm 407 Mathematics Building</td>
<td>Yier Lin</td>
<td>3</td>
<td>10/30</td>
</tr>
<tr>
<td>MATH 1003</td>
<td>003/00593</td>
<td>M W 6:10pm - 7:25pm 302 Barnard Hall</td>
<td>Lindsay Piechnik</td>
<td>3</td>
<td>26/36</td>
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Fall 2020: MATH UN1003

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<th>Course Number</th>
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<th>Instructor</th>
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<tbody>
<tr>
<td>MATH 1003</td>
<td>001/11290</td>
<td>M W 6:10pm - 7:25pm Room TBA</td>
<td>Alexander Friedman</td>
<td>3</td>
<td>7/30</td>
</tr>
<tr>
<td>MATH 1003</td>
<td>002/11291</td>
<td>T Th 2:40pm - 3:55pm Room TBA</td>
<td>Mudul Thate</td>
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<td>9/30</td>
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</table>

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 2020: MATH GU4007

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<th>Course Number</th>
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<tr>
<td>MATH 4007</td>
<td>001/12113</td>
<td>M W 2:40pm - 3:55pm 307 Mathematics Building</td>
<td>Evan Warner</td>
<td>3</td>
<td>4/20</td>
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</tbody>
</table>

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.

Spring 2020: MATH GU4032

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<th>Course Number</th>
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<tr>
<td>MATH 4032</td>
<td>001/12115</td>
<td>M W 11:40am - 12:55pm 520 Mathematics Building</td>
<td>Peter Woit</td>
<td>3</td>
<td>21/50</td>
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</tbody>
</table>

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 2020: MATH GU4041

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<th>Instructor</th>
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<tr>
<td>MATH 4041</td>
<td>001/12116</td>
<td>T Th 10:10am - 11:25am 520 Mathematics Building</td>
<td>Michael Harris</td>
<td>3</td>
<td>42/55</td>
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Fall 2020: MATH GU4041

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<th>Course Number</th>
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<tr>
<td>MATH 4041</td>
<td>001/11487</td>
<td>M W 2:40pm - 3:55pm Room TBA</td>
<td>Robert Friedman</td>
<td>3</td>
<td>87/110</td>
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</tbody>
</table>

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 2020: MATH GU4042

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<th>Instructor</th>
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<tr>
<td>MATH 4042</td>
<td>001/12121</td>
<td>T Th 1:10pm - 2:25pm 417 Mathematics Building</td>
<td>Yihang Zhu</td>
<td>3</td>
<td>41/50</td>
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Fall 2020: MATH GU4042

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<th>Times/Location</th>
<th>Instructor</th>
<th>Points</th>
<th>Enrollment</th>
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<tr>
<td>MATH 4042</td>
<td>001/11488</td>
<td>M W 1:10pm - 2:25pm Room TBA</td>
<td>Mikhail Khovanov</td>
<td>3</td>
<td>17/35</td>
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</tbody>
</table>

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 2020: MATH GU4044
Course Number Section/Call Times/Location Instructor Points Enrollment
MATH 4044 001/11490 T Th 1:10pm - 2:25pm Room TBA Chao Li 3 13/19

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.

Spring 2020: MATH GU4045
Course Number Section/Call Times/Location Instructor Points Enrollment
MATH 4045 001/12122 M W 4:10pm - 5:25pm 528 Mathematics Building Akash Sengupta 3 9/20

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.

Fall 2020: MATH GU4051
Course Number Section/Call Times/Location Instructor Points Enrollment
MATH 4051 001/11491 T Th 11:40am - 12:55pm Room TBA Stephen Miller 3 37/64

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.

Spring 2020: MATH GU4053
Course Number Section/Call Times/Location Instructor Points Enrollment
MATH 4053 001/12123 T Th 2:40pm - 3:55pm 307 Mathematics Building Oleg Lazarev 3 8/50

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 2020: MATH GU4061
Course Number Section/Call Times/Location Instructor Points Enrollment
MATH 4061 001/12124 M W 1:10pm - 2:25pm 417 Mathematics Building Hui Yu 3 45/64
MATH 4061 002/12125 M W 4:10pm - 5:25pm 417 Mathematics Building Hui Yu 3 37/64

Fall 2020: MATH GU4061
Course Number Section/Call Times/Location Instructor Points Enrollment
MATH 4061 001/11494 T Th 2:40pm - 3:55pm Room TBA Henri Roesch 3 35/100
MATH 4061 002/11495 T Th 4:10pm - 5:25pm Room TBA Henri Roesch 3 20/100

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. Real numbers, metric spaces, elements of general topology. Continuous and differential functions. Implicit functions. Integration; change of variables. Function spaces.

Spring 2020: MATH GU4062
Course Number Section/Call Times/Location Instructor Points Enrollment
MATH 4062 001/12126 M W 1:10pm - 2:25pm 407 Mathematics Building Evgeni Dimitrov 3 22/65

Fall 2020: MATH GU4062
Course Number Section/Call Times/Location Instructor Points Enrollment
MATH 4062 001/11498 M W 4:10pm - 5:25pm Room TBA Hui Yu 3 29/49
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
MATH 4065  001/11503  T Th 10:10am - 11:25am  Julien Dubédat  3  20/20  Room TBA

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
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 GU4081
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 4081  001/00119  M W 10:10am - 11:25am  Dusa McDuff  3  14/40  Room TBA

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

Spring 2020: MATH GU4155
Course Number  Section/Call Number  Times/Location  Instructor  Points  Enrollment
MATH 4155  001/12127  T Th 4:10pm - 5:25pm  Ioannis Karatzas  3  24/55  520 Mathematics Building

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: Introduction to Combinatorics and Graph Theory. 3 points.
Lect: 3.
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.