Department of Mathematics

The Department of Mathematics is engaged in teaching and in fundamental research in a wide variety of basic mathematical disciplines, and offers undergraduate and graduate students the opportunity to fashion a thorough program of study leading to professional competence in mathematical research or in an area of application.

The curriculum in mathematics includes opportunities for supervised individual study and research and is augmented by seminars and colloquia. It is designed to be compatible with curricular structures at other collegiate institutions in California in order to enable students transferring to UCI to continue their programs of mathematics study.

Undergraduate Program

The Department offers a B.S. degree in Mathematics. Within this program there are six tracks; besides the standard track, there are five specializations or concentrations (in Mathematical Biology, Mathematical Finance, Applied and Computational Mathematics, Mathematics for Education, and Mathematics for Education/Secondary Teaching Certification). In addition, the Department offers minors in Mathematics and Mathematics for Biology.

Undergraduate mathematics courses are of several kinds: courses preparatory to advanced work in mathematics, the exact sciences, and engineering; courses for students of the social and biological sciences; and courses for liberal arts students and those planning to enter the teaching field.

Admission to the Major

Students may be admitted to the Mathematics major upon entering the University as freshmen, via change of major, and as transfer students from other colleges and universities. Information about change of major policies is available in the Physical Sciences Student Affairs Office and at http://www.changeofmajor.uci.edu. For transfer student admission, preference will be given to junior-level applicants with the highest grades overall and who have satisfactorily completed the required course work of one year of approved calculus. Additional course work in multivariable calculus, linear algebra, and differential equations is strongly recommended.

Requirements for the B.S. Degree in Mathematics

All students must meet the University Requirements (catalogue.uci.edu/previouseditions/2013-14/informationforadmittedstudents/requirementsforabachelorsdegree).

School Requirements: None.

Core Requirements for all Mathematics Majors

Lower-Division Requirements:

A. Complete:

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 2A</td>
<td>Single-Variable Calculus and Single-Variable Calculus</td>
</tr>
<tr>
<td>MATH 2B</td>
<td></td>
</tr>
<tr>
<td>MATH 2D</td>
<td>Multivariable Calculus</td>
</tr>
<tr>
<td>or MATH H2D</td>
<td>Honors Multivariable Calculus</td>
</tr>
<tr>
<td>MATH 3A</td>
<td>Introduction to Linear Algebra</td>
</tr>
<tr>
<td>MATH 3D</td>
<td>Elementary Differential Equations</td>
</tr>
<tr>
<td>MATH 13</td>
<td>Introduction to Abstract Mathematics</td>
</tr>
</tbody>
</table>

B. Computing skills attained through one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I&amp;C SCI 31</td>
<td>Introduction to Programming</td>
</tr>
<tr>
<td>ENGR 10</td>
<td>Computational Methods in Electrical and Computer</td>
</tr>
<tr>
<td>EECS 10</td>
<td>Introduction to Programming</td>
</tr>
<tr>
<td>EECS 12</td>
<td>Introduction to Engineering Computations</td>
</tr>
<tr>
<td>ENGRMAE 10</td>
<td>Introduction to Engineering Computations</td>
</tr>
<tr>
<td>PHYSICS 53</td>
<td>Introduction to C and Numerical Analysis</td>
</tr>
</tbody>
</table>

C. Select one three-quarter lecture course sequence from the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 1A-1B-1C</td>
<td>General Chemistry and General Chemistry</td>
</tr>
<tr>
<td>PHYSICS 2-7C-7D</td>
<td>Introduction to Mathematical Methods for Physics and Classical Physics</td>
</tr>
<tr>
<td>PHYSICS 7C-7D-7E</td>
<td>Classical Physics and Classical Physics</td>
</tr>
</tbody>
</table>

Upper-Division Requirements:

A. Complete:

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 120A</td>
<td>Introduction to Abstract Algebra: Groups</td>
</tr>
<tr>
<td>MATH 121A</td>
<td>Linear Algebra</td>
</tr>
<tr>
<td>MATH 130A</td>
<td>Probability and Stochastic Processes</td>
</tr>
<tr>
<td>MATH 140A-140B</td>
<td>Elementary Analysis and Elementary Analysis</td>
</tr>
</tbody>
</table>

Requirements for the Pure Mathematics Major

Core requirements for all Mathematics majors plus:

Lower-Division Requirements:

A. Complete:

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 2E</td>
<td>Multivariable Calculus</td>
</tr>
<tr>
<td>or MATH H2E</td>
<td>Honors Multivariable Calculus</td>
</tr>
</tbody>
</table>

Upper-Division Requirements:

A. Complete:

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 120B</td>
<td>Introduction to Abstract Algebra: Rings and Fields</td>
</tr>
<tr>
<td>MATH 121B</td>
<td>Linear Algebra</td>
</tr>
</tbody>
</table>
MATH 147 Complex Analysis

B. Five additional four-unit MATH lecture courses numbered 100–189.

The Department offers two concentrations and three specializations. Note that all require the completion of an application and an interview with the faculty advisor for that concentration or specialization. Students must complete the basic "Core" requirements for the B.S. in Mathematics along with the lower- and upper-division requirements specified for each concentration and specialization.

Requirements for Mathematics Major with a Concentration in Mathematical Finance

Admission to this concentration requires approval in advance by the Mathematics Department. The admissions process begins with completing a form at the Department office and includes an interview with the Department’s advisor for the concentration. This approval should be applied for after the student has completed ECON 20A-ECON 20B, but no later than the end of the junior year.

Core requirements for all Mathematics majors plus:

Lower-Division Requirements:
A. Complete:
   MATH 2E Multivariable Calculus
   or MATH H2E Honors Multivariable Calculus

Upper-Division Requirements:
A. Complete:
   MATH 130B Probability and Stochastic Processes
   MATH 133A Statistical Methods with Applications to Finance
   MATH 176 Mathematics of Finance
B. Select three elective lecture courses from the following:
   MATH 105A-105B Numerical Analysis and Numerical Analysis (plus MATH 105LA-105LB)
   MATH 107 Numerical Differential Equations (plus MATH 107L)
   MATH 112A-112B-112C Introduction to Partial Differential Equations and Applications and Introduction to Partial Differential Equations and Applications and Introduction to Partial Differential Equations and Applications
   MATH 115 Mathematical Modeling
   MATH 121B Linear Algebra

C. Complete the following eight required Economics courses:
   ECON 20A-20B Basic Economics I and Basic Economics II
   ECON 105A-105B-105C Intermediate Quantitative Microeconomics and Macroeconomics I and Intermediate Quantitative Microeconomics and Macroeconomics II and Intermediate Quantitative Microeconomics and Macroeconomics III
   ECON 122A or ECON 123A Applied Econometrics I
   ECON 132A Introduction to Financial Investments
   ECON 134A Corporate Finance

Requirements for Mathematics Major with a Specialization in Applied and Computational Mathematics

Admission to this specialization requires approval in advance by the Mathematics Department. The admissions process begins with completing a form at the Department office, and includes an interview with the Department’s advisor for the specialization. This approval should be applied for no later than the end of the junior year.

Core requirements for all Mathematics majors plus:

Lower-Division Requirements:
A. Complete:
   MATH 2E Multivariable Calculus
   or MATH H2E Honors Multivariable Calculus

Upper-Division Requirements:
A. Six required lecture courses:
   MATH 105A-105B Numerical Analysis and Numerical Analysis (plus MATH 105LA-105LB)
   MATH 112A-112B Introduction to Partial Differential Equations and Applications and Introduction to Partial Differential Equations and Applications
   MATH 115 Mathematical Modeling
   MATH 121B Linear Algebra
B. Select three additional Mathematics courses from the following:
   MATH 107 Numerical Differential Equations (plus MATH 107L)
   MATH 112C Introduction to Partial Differential Equations and Applications
   MATH 117 Dynamical Systems
   MATH 118 The Theory of Differential Equations
   MATH 130B-130C Probability and Stochastic Processes and Probability and Stochastic Processes
   MATH 133A-133B Statistical Methods with Applications to Finance and Statistical Methods with Applications to Finance
Requirements for Mathematics Major with a Specialization in Mathematical Biology

Admission to this specialization requires approval in advance by the Mathematics Department. The admissions process begins with completing a form at the Department Office, and includes an interview with the Department’s advisor for the specialization. This approval should be applied for no later than the end of the junior year.

Core requirements for all Mathematics majors plus:  

Lower-Division Requirements:

A. Complete:
- MATH 2E or MATH H2E Multivariable Calculus  
- Honors Multivariable Calculus

B. Replace item C in the Core Requirements with the following:
- BIO SCI 93 From DNA to Organisms  
- BIO SCI 94 From Organisms to Ecosystems

and two courses selected from the following:
- CHEM 1A General Chemistry
- CHEM 1B General Chemistry
- PHYSICS 2 Introduction to Mathematical Methods for Physics
- PHYSICS 7C Classical Physics
- PHYSICS 7D Classical Physics
- BIO SCI 97 Genetics

Upper-Division Requirements:

A. Complete the following seven required upper-division lecture courses:
- MATH 105A- 105LA Numerical Analysis and Numerical Analysis Laboratory
- MATH 120B Introduction to Abstract Algebra: Rings and Fields
- MATH 130B Probability and Stochastic Processes
- MATH 150 Introduction to Mathematical Logic
- MATH 161 Modern Geometry
- MATH 180A Number Theory
- MATH 184- 184L History of Mathematics and History of Mathematics Lesson Lab

Plus one additional four-unit MATH course numbered 100–189.

B. Two additional elective courses, at least one from MATH courses numbered 100–189. The second elective may be either an upper-division MATH course or a four-unit upper-division Biological Sciences course with the advanced approval by the advisor for this specialization.

Requirements for Mathematics Major with a Concentration in Mathematics for Education/Secondary Teaching Certification

Admission to this concentration requires approval in advance. The admission process begins with completing an Intent form at the Cal Teach Resource and Advising Center.

Following completion of the Intent form, students must complete an application in the Mathematics Department office and an interview with the Department’s advisor for the concentration. These approvals should be applied for no later than the end of the sophomore year.

This concentration allows students pursuing the B.S. in Mathematics to earn a bachelor’s degree and complete the required course work and field experience for a California Preliminary Single Subject Teaching Credential at the same time. With careful, early planning, it
is possible for students to complete both in four years. For additional information about teacher certification requirements and enrollment procedures, see Preparation for Teaching Science and Mathematics (catalogue.ucI.edu/previouseditions/2013-14/schoolofphysicalsciences/undergraduateprogramstext) or contact the Cal Teach Resource and Advising Center. A Commission on Teacher Credentialing (CTC)-approved subject-matter program (SMP) in Mathematics can be satisfied in tandem with this concentration, and enables students to waive a subject matter exam for teachers. Specific SMP requirements and enrollment procedures are available from the Cal Teach Resource and Advising Center or the School of Education. Students interested in teaching at the high school level are encouraged to complete the course PHY SCI 106 in addition to the requirements listed below.

Core requirements for all Mathematics majors plus:

Lower-Division Requirements:
A. Complete:
MATH 8 Explorations in Functions and Modeling

Upper-Division Requirements:
A. Complete:
MATH 105A-105LA Numerical Analysis and Numerical Analysis Laboratory
MATH 120B Introduction to Abstract Algebra: Rings and Fields
MATH 130B Probability and Stochastic Processes
MATH 150 Introduction to Mathematical Logic
MATH 161 Modern Geometry
MATH 180A Number Theory
MATH 184-184L History of Mathematics and History of Mathematics Lesson Lab

Plus one additional four-unit MATH course numbered 100–189.

B. Complete:
PHY SCI 5 California Teach 1: Introduction to Science and Mathematics Teaching
PHY SCI 105 California Teach 2: Middle School Science and Mathematics Teaching
CHEM 193 Research Methods
or PHYSICS 193 Research Methods
EDUC 55 Knowing and Learning in Mathematics and Science
EDUC 109 Reading and Writing in Secondary Mathematics and Science Classrooms
EDUC 143AW Classroom Interactions I
EDUC 143BW Classroom Interactions II
EDUC 148 Complex Pedagogical Design
EDUC 158 Student Teaching Mathematics and Science in Middle/High School (two quarters)

NOTE: Students may pursue either the concentration in Mathematics for Education/Secondary Teaching Certification or the specialization in Mathematics for Education, but not both.

Honors Program in Mathematics

The Honors Program in Mathematics is designed for students contemplating graduate work in mathematics. The program is open to junior and senior Mathematics majors who meet the minimum academic qualifications of a 3.5 GPA in Mathematics courses and a 3.2 GPA overall. It is highly recommended that students meet with the Honor’s advisor by the beginning of their junior year to begin planning courses. Students should officially apply for the Honors Program no later than the fall quarter of their senior year. Recognition for completing the program is conferred upon graduation.

In addition to completing the requirements for the major in Mathematics (in any one of its tracks), participants must meet the following requirements:

A. Select one of the following series:

| MATH 205A-205B-205C | Introduction to Graduate Analysis and Introduction to Graduate Analysis
| or | MATH 206A-206B-206C | Introduction to Graduate Algebra and Introduction to Graduate Algebra |

B. Complete the Honors Seminar, MATH H195A-B, or two quarters of MATH 199. One quarter of MATH 199 may be replaced by other research experience with the approval of the Honor’s Program advisor.

In order to prepare for independent study/independent research, it is highly recommended that students take at least one course sequence in the field they are interested in studying. The following list contains the major mathematical disciplines and the course work suggested for completion prior to doing independent study in that field:

- Applied Mathematics: MATH 117 and MATH 118
- Algebra: MATH 120A-MATH 120B-MATH 120C
- Probability and Statistics: MATH 130A-MATH 130B-MATH 130C, MATH 131A-MATH 131B
- Analysis: MATH 140A-MATH 140B-MATH 140C
- Logic: MATH 150 and MATH 151
- Geometry: MATH 162A-MATH 162B
- Number Theory: MATH 180A-MATH 180B

NOTE: These requirements are in addition to the math major requirements or requirements for any specialization/concentration. However, Math 206A-B-C in Item A may be used to satisfy upper-division electives or taken in place of MATH 120A-B-C and 121A-B, and MATH 205A-B-C may be used to satisfy upper-division electives or taken in place of MATH 140A-B-C requirements as described in the major.

If all requirements are completed and the student’s work and final GPA satisfies the program restrictions, the student will graduate with Honors in Mathematics, and this distinction is noted on the transcript.

Requirements for the Minor in Mathematics

A. Complete:

| MATH 13 | Introduction to Abstract Mathematics |
MATH 120A Introduction to Abstract Algebra: Groups
MATH 140A Elementary Analysis

B. Select five additional four-unit courses in MATH (plus the associated lab, where applicable) numbered 77–189.

NOTE: Nearly all upper-division courses in Mathematics have MATH 2A-MATH 2B as prerequisites, and many courses have additional prerequisites such as MATH 2D, MATH 2E, MATH 3A, and/or MATH 3D. Only one course from MATH 77A-MATH 77B-MATH 77C-MATH 77D (same as I&C SCI 77A-I&C SCI 77B-I&C SCI 77C-I&C SCI 77D) can be used toward the minor.

Requirements for the Minor in Mathematics for Biology

A. Complete:
MATH 13 Introduction to Abstract Mathematics
MATH 113A-113B-113C Mathematical Modeling in Biology and Mathematical Modeling in Biology

B. Select two of the following:
MATH 105A Numerical Analysis (plus MATH 105A)
MATH 112A Introduction to Partial Differential Equations and Applications
MATH 117 Dynamical Systems
MATH 118 The Theory of Differential Equations
MATH 119 Boundary Value Problems
MATH 121A Linear Algebra
MATH 131A Introduction to Probability and Statistics
MATH 140A Elementary Analysis

C. One additional four-unit upper-division lecture course in MATH numbered 100–189.

NOTE: Nearly all upper-division courses in Mathematics have MATH 2A-MATH 2B as prerequisites, and many courses have additional prerequisites such as MATH 2D, MATH 2E, MATH 3A, and/or MATH 3D.

Planning a Program of Study

For all Mathematics majors, or prospective majors, assistance in planning a program of study is available from the Mathematics Department Undergraduate Advisor and the advisors for the various tracks, as well as from the academic counselors for the School of Physical Sciences. The application process for the specializations and concentrations requires students to plan a program of study with the assistance of a faculty advisor. The following sample programs are only examples.

Those in the specialization for Education should note that MATH 184 may not be offered more than once every other year and thus should be taken when offered.

Sample Program — Pure Mathematics

<table>
<thead>
<tr>
<th>Freshman</th>
<th>Winter</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 2A</td>
<td>MATH 2B</td>
<td>MATH 2D</td>
</tr>
</tbody>
</table>

Sample Program — Mathematics Major Honors Program

<table>
<thead>
<tr>
<th>Sophomore</th>
<th>Winter</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 2B</td>
<td>MATH 2D</td>
<td>MATH 2E</td>
</tr>
<tr>
<td>PHYSICS 2</td>
<td>PHYSICS 7C-7LC</td>
<td>PHYSICS 7D-7LD</td>
</tr>
<tr>
<td>Gen. Ed./Elective</td>
<td>MATH 13</td>
<td>Gen. Ed./Elective</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Junior</th>
<th>Winter</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 3A</td>
<td>MATH 121A</td>
<td>MATH 121B</td>
</tr>
<tr>
<td>MATH 3D</td>
<td>I&amp;C SCI 31</td>
<td>Gen. Ed./Elective</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Senior</th>
<th>Winter</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 120A</td>
<td>MATH 120B</td>
<td>MATH 141</td>
</tr>
<tr>
<td>MATH 140A</td>
<td>MATH 140B</td>
<td>Gen. Ed./Elective</td>
</tr>
<tr>
<td>MATH 130A</td>
<td>MATH 147</td>
<td>Gen. Ed./Elective</td>
</tr>
</tbody>
</table>

Sample Program — Mathematics Major Concentrating in Mathematical Finance

<table>
<thead>
<tr>
<th>Freshman</th>
<th>Winter</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 2A</td>
<td>MATH 2B</td>
<td>MATH 2D</td>
</tr>
<tr>
<td>PHYSICS 2</td>
<td>PHYSICS 7C-7LC</td>
<td>PHYSICS 7D-7LD</td>
</tr>
<tr>
<td>Gen. Ed./Elective</td>
<td>MATH 13</td>
<td>Gen. Ed./Elective</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sophomore</th>
<th>Winter</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 2E</td>
<td>MATH 3A</td>
<td>MATH 3D</td>
</tr>
<tr>
<td>ECON 20A</td>
<td>ECON 20B</td>
<td>Gen. Ed./Elective</td>
</tr>
</tbody>
</table>
### Sample Program — Mathematics Major

#### Specializing in Applied and Computational Mathematics

**Freshman**
- Fall: MATH 2A, PHYSICS 2, Gen. Ed./Elective
- Winter: MATH 2B, PHYSICS 7C-7LC, Gen. Ed./Elective
- Spring: MATH 2D, PHYSICS 7D-7LD, Gen. Ed./Elective

**Sophomore**
- Fall: MATH 112A, MATH 121A, Gen. Ed./Elective
- Winter: MATH 121B, PHYSICS 105, Gen. Ed.
- Spring: MATH 121A, CHEM 193, Gen. Ed.

**Junior**
- Fall: MATH 130A, MATH 130B, Gen. Ed./Elective
- Winter: MATH 140A, MATH 120A, Gen. Ed./Elective
- Spring: MATH 140B, MATH 120B, Gen. Ed./Elective

**Senior**
- Fall: MATH 105A-105LA, MATH 180A, EDUC 143BW
- Spring: MATH 184-184L, MATH 150, Gen. Ed.

#### Specializing in Mathematical Biology

**Freshman**
- Fall: MATH 2A, BIO SCI 93, Gen. Ed.
- Spring: MATH 2D, BI 100, Gen. Ed.

**Sophomore**
- Fall: MATH 2E, CHEM 1A, I&C SCI 31
- Winter: MATH 3A, CHEM 1B, Gen. Ed./Elective
- Spring: MATH 3A, CHEM 193, Gen. Ed.

**Junior**
- Fall: MATH 113A
- Winter: MATH 113B
- Spring: MATH 113C

**Senior**
- Fall: MATH 105A-105LA, MATH 150, EDUC 143BW
- Winter: MATH 150, EDUC 158, Gen. Ed.
- Spring: MATH 150, EDUC 158, Gen. Ed.

#### Specializing in Mathematics for Education

**Freshman**
- Fall: MATH 2A, PHYSICS 2, Gen. Ed.
- Winter: MATH 2B, PHYSICS 7C-7LC, Gen. Ed.
- Spring: MATH 2D, PHYSICS 7D-7LD, Gen. Ed.

**Sophomore**
- Fall: MATH 3A, PHY SCI 5, Gen. Ed.
- Winter: MATH 3D, CHEM 193, Gen. Ed.
- Spring: MATH 3B, MATH 121A, I&C SCI 31

**Junior**
- Fall: MATH 130A, MATH 140A, Gen. Ed./Elective
- Winter: MATH 130B, MATH 120A, Gen. Ed./Elective
- Spring: MATH 140B, MATH 120B, Gen. Ed./Elective

**Senior**
- Fall: MATH 105A-105LA, MATH 180A, EDUC 143BW
- Spring: MATH 184-184L, MATH 150, Gen. Ed.
Graduate Program

Graduate courses are designed to meet the needs of students doing graduate work in mathematics and in those disciplines that require graduate-level mathematics for their study. Among the fields covered are analysis, algebra, applied and computational mathematics, mathematical biology, geometry and topology, probability, ordinary and partial differential equations, and mathematical logic.

In addition to formal courses, there are seminars for advanced study toward the Ph.D. in various fields of mathematics. Topics will vary from year to year. Each seminar is conducted by a faculty member specializing in the subject studied. Enrollment will be subject to the approval of the instructor in charge.

Master of Science in Mathematics

To earn the Master of Science degree, the student must satisfy course and residency requirements, and achieve two passes at the M.S. level among three exams in Real Analysis, Complex Analysis, and Algebra prior to the beginning of the second year.

The total number of required courses for the M.S. degree is 12, completed with satisfactory performance, that is, with a grade of B or better. Students are required to complete at least one series of the following courses:

MATH 210A- 210B- 210C  Real Analysis and Real Analysis and Real Analysis
or
MATH 220A- 220B- 220C  Analytic Function Theory and Analytic Function Theory and Analytic Function Theory
or
MATH 230A- 230B- 230C  Algebra and Algebra and Algebra

At most one undergraduate course may count as an elective course, provided it is sponsored by rank faculty and approved by the Graduate Advisor. At most one elective course (at least three units) is allowed outside the Department.

To satisfy exam requirements, students may take the Core Assessment Exam (offered in the spring of every year), the Comprehensive Exams (offered in the spring of every year), or the Qualifying Exams (offered before the start of each fall quarter) in Real Analysis, Complex Analysis, and Algebra. Students may not attempt to pass an exam in any particular area more than three times. Some students may require additional background before entering MATH 210 or MATH 230. This will be determined by assessment prior to the start of the students’ first year by the Vice Chair of Graduate Studies, upon consultation with the Graduate Studies Committee. Such students will be directed into MATH 205 and/or MATH 206 during their first year. They may pass one Comprehensive Exam in the areas of Analysis or Algebra in lieu of achieving an M.S. pass in one of the Core Assessment or Qualifying Exams that must be obtained prior to the start of their second year.

Students who fail to pass the required examinations satisfactorily within the period specified will be recommended for academic disqualification by the Graduate Dean.

MATH 199, MATH 297, MATH 298, MATH 299, and MATH 399 may not be used to fulfill course requirements.

The residency requirement ordinarily is satisfied by full-time enrollment for three quarters immediately preceding the award of the M.S. degree. When appropriate, a leave of absence may be granted between matriculation and the final quarters of study.

If the candidate is not advanced before the beginning of the quarter in which all requirements are completed, the degree will not be conferred until the end of the following quarter. Deadlines for submission of the Application for Advancement to Candidacy are published on the Graduate Division Web site under filing fees and deadlines.

Master of Science in Mathematics with a Teaching Credential

In cooperation with the UCI School of Education, the Department of Mathematics sponsors a coordinated program for the M.S. degree in Mathematics and the California Single Subject Teaching Credential. The requirements for this option are the same as the Master of Science in Mathematics requirements listed above.

The student will complete the requirements for the Master’s degree with the Mathematics Department (generally a two-year commitment) and then will petition with the UCI School of Education to take the School of Education’s credential courses (generally a one-year commitment). The student must meet the requirements of the School of Education for the CBEST, CSET, TB test, and Certificate of Clearance. Prospective graduate students interested in this program should so indicate on their applications. A detailed description of the program can be requested from the School of Education.

Advancement to M.S. Candidacy

All Master’s students must be advanced to candidacy for the degree prior to the beginning of their final quarter of enrollment. An application for Advancement to Candidacy must be completed by the student and submitted for approval to the Department. The approved application must be submitted to the Graduate Division by the deadline published on the Graduate Division (http://www.grad.uci.edu) Web site. Advancement to M.S. Candidacy must occur one quarter prior to the degree conferral quarter.

Filing fee information can be located on the Graduate Division (http://www.grad.uci.edu) Web site.

Doctor of Philosophy in Mathematics

When accepted into the doctoral program, the student embarks on a program of formal courses, seminars, and individual study courses to prepare for the Ph.D. written examinations, Advancement to Candidacy examination, and dissertation.

Upon entering the program, students are expected to take MATH 210, MATH 220, and MATH 230, which must be passed with a grade of B or better. Students must complete these sequences by the end of the second year.

By the start of the second year, students must achieve at least two passes at the M.S. level among three exams in Real Analysis, Complex Analysis, and Algebra. By the start of the third year, students must achieve two Ph.D. level passes among three exams in Real Analysis, Complex Analysis, and Algebra.
To satisfy the exam requirements, students may take the Core Assessment Exams (offered in spring of every year) or the Qualifying Exams (offered before the start of the fall quarter) in these areas. Students may not attempt to take an exam in a particular subject area more than three times. A student who passes a Qualifying Examination at the Ph.D. level prior to taking the corresponding course will be exempted from taking the course.

Some students may require additional background prior to entering MATH 210 and MATH 230. This will be determined by assessment prior to the start of the students’ first year by the Vice Chair for Graduate Studies, upon consultation with the Graduate Studies Committee. Such students will be directed into MATH 205 and/or MATH 206, or equivalent, during their first year. These students may pass one Comprehensive Exam in the areas of Algebra or Analysis in lieu of achieving an M.S. pass on one Core Assessment or Qualifying Exam that must be obtained prior to the start of the students’ second year. Comprehensive Exams in Analysis and Algebra will be offered once per year in the spring quarter.

By the end of their second year, students must declare a major specialization from the following areas: Algebra, Analysis, Applied and Computational Mathematics, Geometry and Topology, Logic, or Probability. Students are required to take two series of courses from their chosen area. (Students who later decide to change their area must also take two series of courses from the new area.) Additionally, all students must take two series outside their declared major area of specialization. Special topics courses within certain areas of specialization and courses counted toward the M.S. degree, other than MATH 205A-MATH 205B-MATH 205C and MATH 206A-MATH 206B-MATH 206C, will count toward the fulfillment of the major specialization requirement.

By the beginning of their third year, students must have an advisor specializing in their major area. With the advisor’s aid, the student forms a committee for the Advancement to Candidacy oral examination. This committee will be approved by the Department on behalf of the Dean of the Graduate Division and the Graduate Council and will consist of five faculty members. At least one, and at most two, of the members must be faculty from outside the Department. Before the end of the third year, students must have a written proposal, approved by their committee, for the Advancement to Candidacy examination. The proposal should explain the role of at least two series of courses from the student’s major area of specialization that will be used to satisfy the Advancement to Candidacy requirements. The proposal should also explain the role of additional research reading material as well as providing a plan for investigating specific topics under the direction of the student’s advisor(s). Only one of the courses MATH 210A-MATH 210B-MATH 210C, MATH 220A-MATH 220B-MATH 220C, and MATH 230A-MATH 230B-MATH 230C may count for the course requirement for Advancement to Candidacy Examinations. After the student meets the requirements, the Graduate Studies Committee recommends to the Dean of the Graduate Division the advancement to candidacy for the Ph.D. degree. Students should advance to candidacy by the beginning of their fourth year.

After advancing to candidacy, students are expected to be fully involved in research toward writing their Ph.D. dissertation. Ideally, students should keep in steady contact/interaction with their Doctoral Committee.

Teaching experience and training is an integral part of the Ph.D. program. All doctoral students are expected to participate in the Department’s teaching program.

The candidate must demonstrate independent, creative research in Mathematics by writing and defending a dissertation that makes a new and valuable contribution to mathematics in the candidate’s area of concentration. Upon Advancement to Candidacy a student must form a Thesis Committee, a subcommittee of the Advancement Examination Committee, consisting of at least three faculty members and chaired by the student’s advisor. The committee guides and supervises the candidate’s research, study, and writing of the dissertation; conducts an oral defense of the dissertation; and recommends that the Ph.D. be conferred upon approval of the Doctoral Dissertation. The normative time for completion of the Ph.D. is five years, and the maximum time permitted is seven years. Completion of the Ph.D. degree must occur within nine quarters of Advancement to Ph.D. candidacy.

**Examinations**

Ph.D. examinations are given in Algebra, Complex Analysis, and Real Analysis. All students seeking the Ph.D. degree must successfully complete two examinations before the end of the third year of entering the graduate program. Only two attempts are allowed for a Ph.D. student on each exam.

**Area Requirements**

Ph.D. students will choose from one of six areas of specialization in the Mathematics Department, which determines course work requirements. Each area of specialization will have a core course, which the Department will do its best to offer each year. The Department will offer other courses every other year, or more frequently depending on student demands and other Department priorities.

**Algebra**

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>MATH 230A- 230B- 230C</td>
<td>Algebra and Algebra (core)</td>
</tr>
<tr>
<td>MATH 232A- 232B- 232C</td>
<td>Algebraic Number Theory and Algebraic Number Theory</td>
</tr>
<tr>
<td>MATH 233A- 233B- 233C</td>
<td>Algebraic Geometry and Algebraic Geometry</td>
</tr>
<tr>
<td>MATH 234B- 234C</td>
<td>Topics in Algebra and Topics in Algebra</td>
</tr>
<tr>
<td>MATH 235A- 235B- 235C</td>
<td>Mathematics of Cryptography and Mathematics of Cryptography</td>
</tr>
<tr>
<td>MATH 239A- 239B- 239C</td>
<td>Analytic Methods in Arithmetic Geometry and Analytic Methods in Arithmetic Geometry</td>
</tr>
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</table>

**Analysis**

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<tr>
<th>Course</th>
<th>Description</th>
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<tbody>
<tr>
<td>MATH 210A- 210B- 210C</td>
<td>Real Analysis and Real Analysis (core)</td>
</tr>
<tr>
<td>MATH 211A- 211B- 211C</td>
<td>Topics in Analysis and Topics in Analysis</td>
</tr>
<tr>
<td>MATH 220A- 220B- 220C</td>
<td>Analytic Function Theory and Analytic Function Theory (core)</td>
</tr>
<tr>
<td>Course Code</td>
<td>Course Title</td>
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</tr>
<tr>
<td>MATH 260A-260B-260C</td>
<td>Functional Analysis and Functional Analysis</td>
</tr>
<tr>
<td>MATH 296</td>
<td>Topics in Partial Differential Equations</td>
</tr>
</tbody>
</table>

**Applied and Computational Mathematics**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>MATH 227A-227B</td>
<td>Mathematical and Computational Biology and Mathematical and Computational Biology</td>
</tr>
<tr>
<td>MATH 291C</td>
<td>Topics in Applied and Computational Math</td>
</tr>
</tbody>
</table>

**Geometry and Topology**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>MATH 218A-218B-218C</td>
<td>Introduction to Manifolds and Geometry and Introduction to Manifolds and Geometry and Introduction to Manifolds and Geometry (core)</td>
</tr>
<tr>
<td>MATH 222A-222B-222C</td>
<td>Several Complex Variables and Complex Geometry and Several Complex Variables and Complex Geometry and Several Complex Variables and Complex Geometry</td>
</tr>
<tr>
<td>MATH 240A-240B-240C</td>
<td>Differential Geometry and Differential Geometry and Differential Geometry</td>
</tr>
<tr>
<td>MATH 245A-245C-245C</td>
<td>Topics in Differential Geometry and Topics in Differential Geometry and Topics in Differential Geometry</td>
</tr>
<tr>
<td>MATH 250A-250B-250C</td>
<td>Algebraic Topology and Algebraic Topology and Algebraic Topology</td>
</tr>
</tbody>
</table>

**Logic**

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<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tbody>
<tr>
<td>MATH 280A-280B-280C</td>
<td>Mathematical Logic and Mathematical Logic</td>
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</table>

**Probability**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>MATH 210A-210B-210C</td>
<td>Real Analysis and Real Analysis and Real Analysis</td>
</tr>
<tr>
<td>MATH 211A-211B-211C</td>
<td>Topics in Analysis and Topics in Analysis and Topics in Analysis</td>
</tr>
<tr>
<td>MATH 270A-270B-270C</td>
<td>Probability and Probability and Probability (core)</td>
</tr>
<tr>
<td>MATH 271A-271B-271C</td>
<td>Stochastic Processes and Stochastic Processes and Stochastic Processes (core)</td>
</tr>
<tr>
<td>MATH 272A-272B-272C</td>
<td>Probability Models and Probability Models and Probability Models (core)</td>
</tr>
<tr>
<td>MATH 274</td>
<td>Topics in Probability</td>
</tr>
</tbody>
</table>

**Graduate Program in Mathematical and Computational Biology**

The graduate program in Mathematical and Computational Biology (MCB) is a one-year “gateway” program designed to function in concert with selected department programs, including the Ph.D. in Mathematics. Detailed information is available online at [http://mcsb.bio.uci.edu/](http://mcsb.bio.uci.edu/) and in the School of Biological Sciences ([catalogue.uci.edu/previouseditions/2013-14/schoolofbiologicalsciences/#graduatetext](catalogue.uci.edu/previouseditions/2013-14/schoolofbiologicalsciences/#graduatetext)) section of the *Catalogue*.

**Faculty**

- Takeo Akasaki, Ph.D. University of California, Los Angeles, Professor Emeritus of Mathematics (ring theory)
- Vladimir Baranovsky, Ph.D. University of Chicago, Associate Professor of Mathematics (algebraic geometry, representation theory)
- Frank B. Cannonito, Ph.D. Adelphi University, Professor Emeritus of Mathematics (group theory)
- Long Chen, Ph.D. Pennsylvania State University, Associate Professor of Mathematics (numerical analysis, scientific computing, finite element methods, computational geometry)
- Michael C. Cranston, Ph.D. University of Minnesota, Professor of Mathematics (probability)
- Donald Darling, Ph.D. California Institute of Technology, Professor Emeritus of Mathematics
Sarah Eichorn, Ph.D. University of Arizona, Assistant Vice Chair of Undergraduate Studies and Lecturer with Potential Security of Employment, Department of Mathematics (applied mathematics, mathematics education)

Paul C. Eklof, Ph.D. Cornell University, Professor Emeritus of Mathematics (logic and algebra)

Germán A. Enciso Ruiz, Ph.D. Rutgers University, Assistant Professor of Mathematics (dynamical systems, mathematical and computational biology)

Catherine Famiglietti, Ph.D. Princeton University, Lecturer in Mathematics (calculus, numerical methods)

Aleksandr Figotin, Ph.D. Tashkent University, Professor of Mathematics (applied mathematics, photonic crystals, foundations of electromagnetism)

Mark Finkelstein, Ph.D. Stanford University, Professor Emeritus of Mathematics (analysis)

Matthew D. Foreman, Ph.D. University of California, Berkeley, Professor of Mathematics and of Logic and Philosophy of Science (logic, ergodic theory)

Michael D. Fried, Ph.D. University of Michigan, Professor Emeritus of Mathematics (arithmetic geometry, complex variables)

Anton Gorodetski, Ph.D. Moscow State University, Associate Professor of Mathematics (dynamical systems)

Patrick Guidotti, Ph.D. University of Zürich, Department Vice Chair for Graduate Studies and Professor of Mathematics (partial differential equations, applied mathematics)

Hamid Hezari, Ph.D. Johns Hopkins University, Assistant Professor of Mathematics (analysis, partial differential equations, inverse problems)

Svetlana Jitomirskaya, Ph.D. Moscow State University, UCI Chancellor's Fellow and Professor of Mathematics (mathematical physics, dynamical systems)

Abel Klein, Ph.D. Massachusetts Institute of Technology, Professor of Mathematics (mathematical physics, random Schrödinger operators)

Natalia L. Komarova, Ph.D. University of Arizona, Professor of Mathematics and of Ecology and Evolutionary Biology (applied mathematics, mathematical biology)

Rachel Lehman, Ph.D. University of California, Irvine, Lecturer in Mathematics (mathematics education, probability)

Peter Li, Ph.D. University of California, Berkeley, UCI Chancellor's Professor Emeritus of Mathematics (differential geometry)

Song-Ying Li, Ph.D. University of Pittsburgh, Professor of Mathematics (several complex variables, nonlinear partial differential equations, harmonic analysis)

John S. Lowengrub, Ph.D. New York University, UCI Chancellor's Professor of Mathematics, Biomedical Engineering, and Chemical Engineering and Materials Science (mathematical materials science, mathematical fluid dynamics, mathematical biology, computational mathematics, cancer modeling, nanomaterials, quantum dots, complex fluids)

Zhiqin Lu, Ph.D. New York University, Department Vice Chair for Undergraduate Studies and Professor of Mathematics (differential geometry)

Penelope Maddy, Ph.D. Princeton University, UCI Distinguished Professor of Logic and Philosophy of Science and of Mathematics (philosophy of mathematics and logic, meta-philosophy)

Caryl Margulies, Ph.D. University of California, Irvine, Lecturer in Mathematics (cryptography, graph theory, partial differential equations, linear algebra)

Eric D. Mjolsness, Ph.D. California Institute of Technology, Professor of Computer Science and Mathematics (applied mathematics, mathematical biology, modeling languages)

Charles Newman, Ph.D. Princeton University, UCI Distinguished Professor of Mathematics (probability, mathematical physics, statistical physics)

Qing Nie, Ph.D. Ohio State University, Professor of Mathematics and Biomedical Engineering (computational mathematics, systems biology, cell signaling and stem cell)

Alessandra Pantano, Ph.D. Princeton University, Lecturer with Potential Security of Employment, Department of Mathematics (representation theory, mathematical education)

David L. Rector, Ph.D. Massachusetts Institute of Technology, Professor Emeritus of Mathematics (algebraic topology, computer algebra)

Robert C. Reilly, Ph.D. University of California, Berkeley, Professor Emeritus of Mathematics (differential geometry)

Karl C. Rubin, Ph.D. Harvard University, Professor of Mathematics and Edward and Vivian Thorp Chair in Mathematics (number theory)

Bernard Russo, Ph.D. University of California, Los Angeles, Professor Emeritus of Mathematics (functional analysis)

Donald G. Saari, Ph.D. Purdue University, Director of the Institute for Mathematical Behavioral Sciences and UCI Distinguished Professor of Economics and Mathematics (dynamical systems with an emphasis on the Newtonian N-body problem and issues coming from the mathematical social and behavioral sciences)

Martin Schechter, Ph.D. New York University, Professor of Mathematics (partial differential equations, functional analysis, critical point theory)

Stephen Scheinberg, Ph.D. Princeton University; M.D. University of California, Irvine, Professor Emeritus of Mathematics (analysis)

Alice Silverberg, Ph.D. Princeton University, Professor of Mathematics (number theory, arithmetic algebraic geometry, cryptography)

William H. Smoke, Ph.D. University of California, Berkeley, Professor Emeritus of Mathematics (homological algebra)

Knut Solna, Ph.D. Stanford University, Professor of Mathematics (applied mathematics, mathematical finance)

Ronald J. Stern, Ph.D University of California, Los Angeles, Professor Emeritus of Mathematics (geometry and topology)

Jeffrey Streets, Ph.D. Duke University, Assistant Professor of Mathematics (geometric analysis)
Chuu-Lian Terng, Ph.D. Brandeis University, Professor of Mathematics (differential geometry, integrable systems)

Edriss S. Titi, Ph.D. Indiana University, Professor of Mathematics and of Mechanical and Aerospace Engineering (applied and computational mathematics, nonlinear partial differential equations)

Li-Sheng Tseng, Ph.D. University of Chicago, Assistant Professor of Mathematics (symplectic topology, mathematical physics and geometry)

Howard G. Tucker, Ph.D. University of California, Berkeley, Professor Emeritus of Mathematics (probability and statistics)

Daqing Wan, Ph.D. University of Washington, Professor of Mathematics (number theory, coding theory and computational complexity)

Frederic Yui-Ming Wan, Ph.D. Massachusetts Institute of Technology, Professor of Mathematics and of Mechanical and Aerospace Engineering (applied mathematics, mathematical biology; plate, shell, and elasticity theory; resource economics)

Robert W. West, Ph.D. University of Michigan, Professor Emeritus of Mathematics (algebraic topology)

Joel J. Westman, Ph.D. University of California, Los Angeles, Professor Emeritus of Mathematics (analysis)

Robert J. Whitley, Ph.D. New Mexico State University, Professor Emeritus of Mathematics (analysis)

Janet L. Williams, Ph.D. Brandeis University, Professor Emerita of Mathematics (probability and statistics)

Dominik Wodarz, Ph.D. University of Oxford, Professor of Ecology and Evolutionary Biology and of Mathematics (mathematical biology; infectious disease and cancer)

Liang Xiao, Ph.D. Massachusetts Institute of Technology, Assistant Professor of Mathematics (arithmetic geometry, number theory)

Jack Xin, Ph.D. New York University, Professor of Mathematics (applied mathematics, signal processing)

James J. Yeh, Ph.D. University of Minnesota, Professor Emeritus of Mathematics (real analysis, stochastic analysis)

Yifeng Yu, Ph.D. University of California, Berkeley, Associate Professor of Mathematics (nonlinear partial differential equations)

Martin Zeman, Ph.D. Humboldt University, Associate Professor of Mathematics (logic, set theory)

Hong-Kai Zhao, Ph.D. University of California, Los Angeles, Department Chair and Professor of Mathematics (computational and applied mathematics)

Weian Zheng, Ph.D. Université de Strasbourg, Professor Emeritus of Mathematics (probability theory and financial engineering)

Courses

MATH 1A. Pre-Calculus. 0 Units.
Basic equations and inequalities, linear and quadratic functions, and systems of simultaneous equations. Course may be offered online.

MATH 1B. Pre-Calculus. 4 Units.
Preparation for calculus and other mathematics courses. Exponentials, logarithms, trigonometry, polynomials, and rational functions. Satisfies no requirements other than contribution to the 180 units required for graduation. Course may be offered online.

Prerequisite: MATH 1A or placement into MATH 1B via the Calculus Placement exam, or a score of 450 or higher on the Mathematics section of the SAT Reasoning Test.

MATH 1B, Pre-Calculus. 4 Units.
Preparation for calculus and other mathematics courses. Exponentials, logarithms, trigonometry, polynomials, and rational functions. Satisfies no requirements other than contribution to the 180 units required for graduation. Course may be offered online.

Prerequisite: MATH 1A or placement into MATH 1B via the Calculus Placement exam, or a score of 450 or higher on the Mathematics section of the SAT Reasoning Test.

MATH 2A. Single-Variable Calculus. 4 Units.
Introduction to derivatives, calculation of derivatives of algebraic and trigonometric functions; applications including curve sketching, related rates, and optimization. Exponential and logarithm functions.

Prerequisite: MATH 1B or placement into MATH 2A via the Calculus Placement exam (fee required), or a score of 3 on the AP Calculus AB exam, or a score of 600 or higher on the Mathematics section of the SAT Reasoning Test. MATH 1B with a grade of C or better.

Restriction: School of Physical Sciences, School of Engineering, and School of Information and Computer Sciences majors have first consideration for enrollment.

(Vb)

MATH 2B. Single-Variable Calculus. 4 Units.
Definite integrals; the fundamental theorem of calculus. Applications of integration including finding areas and volumes. Techniques of integration. Infinite sequences and series. Parametric and polar equations.

Prerequisite: MATH 2A.

Restriction: School of Physical Sciences, School of Engineering, and School of Information and Computer Sciences majors have first consideration for enrollment.

(Vb)

MATH 2D. Multivariable Calculus. 4 Units.
Differential and integral calculus of real-valued functions of several real variables, including applications. Polar coordinates.

Prerequisite: MATH 2A and MATH 2B.

Overlaps with MATH H2D.

Restriction: School of Physical Sciences, School of Engineering, and School of Information and Computer Sciences majors have first consideration for enrollment.

(Vb)

MATH 2E. Multivariable Calculus. 4 Units.
The differential and integral calculus of vector-valued functions. Implicit and inverse function theorems. Line and surface integrals, divergence and curl, theorems of Greens, Gauss, and Stokes.

Prerequisite: MATH 2D.

Overlaps with MATH H2E.

Restriction: School of Physical Sciences and School of Engineering majors have first consideration for enrollment.
MATH 2J. Infinite Series and Basic Linear Algebra. 4 Units.
Systems of linear equations: matrix operations; determinants; eigenvalues, and eigenvectors. Infinite sequences and series. Complex numbers.
Prerequisite: MATH 2A and MATH 2B.
Overlaps with MATH 2C.
Restriction: Schools of Physical Sciences and School of Engineering majors have first consideration for enrollment.
(Vb)

MATH H2D. Honors Multivariable Calculus. 4 Units.
Differential and integral calculus of real-valued functions of several real variables, including applications. Polar coordinates. Covers the same material as MATH 2D-E, but with a greater emphasis on the theoretical structure of the subject matter.
Prerequisite: MATH 2B or a score of 4 or 5 on the AP Calculus BC exam. MATH 2B with a grade of B or better.
Overlaps with MATH 2D.
(Vb)

MATH H2E. Honors Multivariable Calculus. 4 Units.
Differential and integral calculus of real-valued functions of several real variables, including applications. Polar coordinates. Covers the same material as MATH 2D-E, but with a greater emphasis on the theoretical structure of the subject matter.
Prerequisite: MATH H2D. MATH H2D with a grade of C or better.
Overlaps with MATH 2E.
(Vb)

MATH 3A. Introduction to Linear Algebra. 4 Units.
Systems of linear equations, matrix operations, determinants, eigenvalues and eigenvectors, vector spaces, subspaces and dimension.
Prerequisite: MATH 2B.
Overlaps with MATH 6G, I&C SCI 6N.
Restriction: School of Physical Sciences and School of Engineering majors have first consideration for enrollment.

MATH 3D. Elementary Differential Equations. 4 Units.
Linear differential equations, variation of parameters, constant coefficient cookbook, systems of equations, Laplace tranforms, series solutions.
Prerequisite: MATH 2D and MATH 3A.
Restriction: School of Physical Sciences and School of Engineering majors have first consideration for enrollment.

MATH 4. Mathematics for Economists. 4 Units.
Topics in linear algebra and multivariable differential calculus suitable for economic applications.
Prerequisite: MATH 2B.
Overlaps with MATH 2D, MATH 2J, MATH 3A.
Restriction: MATH 4 may not be taken for credit if taken after MATH 2D and either MATH 2J or MATH 3A.
(Vb)

MATH 6G. Linear Algebra. 4 Units.
Linear equations, vector spaces and subspaces, linear functions and matrices, linear codes, determinants, scalar products.
Prerequisite: High school mathematics through trigonometry.
Overlaps with MATH 3A, I&C SCI 6N.
(Vb)

MATH 8. Explorations in Functions and Modeling. 4 Units.
Explorations of applications and connections in topics in algebra, geometry, calculus, and statistics for future secondary math educators. Emphasis on nonstandard modeling problems.
Corequisite: MATH 2A.

MATH 13. Introduction to Abstract Mathematics. 4 Units.
Introduction to formal definition and rigorous proof writing in mathematics. Topics include basic logic, set theory, equivalence relations, and various proof techniques such as direct, induction, contradiction, contrapositive, and exhaustion.
Prerequisite: MATH 2A or I&C SCI 6D.
Restriction: Mathematics majors have first consideration for enrollment.

MATH 77A. Topics in Mathematics and Computation in the Digital Age. 4 Units.
Signals in Matlab; blurring, filtering; elements of linear algebra, statistics, optimization; blind matrix inversion; de-correlation method, stochastic gradient descent method, applications to sounds and images.
Corequisite: MATH 2J or MATH 6G
Prerequisite: MATH 2A and MATH 2B and (I&C SCI 21 or CSE 21 or IN4MATX 41)
Same as I&C SCI 77A.
Restriction: Prerequisite required and Lower division only
(II, Va)
MATH 77B. Topics in Mathematics and Computation in the Digital Age. 4 Units.
Basic concepts of collaborative filtering; Clustering; Matrix factorization & Principal Components Analysis; Regression; Classification: naive Bayes classifier, decision trees, Perceptron (neural networks).
Corequisite: MATH 2J or MATH 6G
Prerequisite: MATH 2A and MATH 2B and (I&C SCI 21 or CSE 21 or IN4MATX 41)

Same as I&C SCI 77B.
Restriction: Prerequisite required and Lower division only

MATH 77C. Topics in Mathematics and Computation in the Digital Age. 4 Units.
Image de-noising, de-blurring, low pass filtering; image segmentation and classification; Sparse representation; visualization.
Corequisite: MATH 2J or MATH 6G
Prerequisite: MATH 2A and MATH 2B and (I&C SCI 21 or CSE 21 or IN4MATX 41)

Same as I&C SCI 77C.
Restriction: Prerequisite required and Lower division only

MATH 77D. Topics in Mathematics and Computation in the Digital Age. 4 Units.
Combinatorial Game Theory - game classification, tree graphs, strategy analysis, Sprague Grundy functions, Bouton's Theorem; Zero-Sum and General-Sum Game Theory - pay off matrices, Minimax Theorem, NACH equilibrium; Machine learning - Search algorithms.
Corequisite: MATH 2J or MATH 6G
Prerequisite: MATH 2A and MATH 2B and (I&C SCI 21 or CSE 21 or IN4MATX 41)

Same as I&C SCI 77D.
Restriction: Prerequisite required and Lower division only

MATH 105A. Numerical Analysis. 4 Units.
Introduction to the theory and practice of numerical computation. Floating point arithmetic, roundoff; solving transcendental equations; quadrature; linear systems, eigenvalues, power method.
Corequisite: MATH 105LA.
Prerequisite: MATH 3A. Some acquaintance with computer programming.
Overlaps with ENGRMAE 185.

MATH 105B. Numerical Analysis. 4 Units.
Introduction to the theory and practice of numerical computation. Lagrange interpolation, finite differences, splines, Padé approximations; Gaussian quadrature; Fourier series and transforms.
Corequisite: MATH 105LB.
Prerequisite: MATH 105A.

MATH 105LA. Numerical Analysis Laboratory. 1 Unit.
Provides practical experience to complement the theory developed in Mathematics 105A.
Corequisite: MATH 105A.

MATH 105LB. Numerical Analysis Laboratory. 1 Unit.
Provides practical experience to complement the theory developed in Mathematics 105B.
Corequisite: MATH 105B.

MATH 107. Numerical Differential Equations. 4 Units.
Theory and applications of numerical methods to initial and boundary-value problems for ordinary and partial differential equations.
Corequisite: MATH 107L.
Prerequisite: MATH 3D and MATH 105A and MATH 105B.

MATH 107L. Numerical Differential Equations Laboratory. 1 Unit.
Provides practical experience to complement the theory developed in Mathematics 107.
Corequisite: MATH 107.

MATH 112A. Introduction to Partial Differential Equations and Applications. 4 Units.
Introduction to ordinary and partial differential equations and their applications in engineering and science. Basic methods for classical PDEs (potential, heat, and wave equations). Classification of PDEs, separation of variables and series expansions, special functions, eigenvalue problems.
Prerequisite: MATH 2D and MATH 3D.

MATH 112B. Introduction to Partial Differential Equations and Applications. 4 Units.
Introduction to partial differential equations and their applications in engineering and science. Basic methods for classical PDEs (potential, heat, and wave equations). Green functions and integral representations, method of characteristics.
Prerequisite: MATH 2E and MATH 112A.

MATH 112C. Introduction to Partial Differential Equations and Applications. 4 Units.
Nonhomogeneous problems and Green's functions, Sturm-Liouville theory, general Fourier expansions, applications of partial differential equations in different areas of science.
Prerequisite: MATH 3D and MATH 2D and MATH 3A.

MATH 113A. Mathematical Modeling in Biology. 4 Units.
Discrete mathematical and statistical models: difference equations, population dynamics, Markov chains, and statistical models in biology.
Prerequisite: MATH 2B.

MATH 113B. Mathematical Modeling in Biology. 4 Units.
Linear algebra; differential equations models; dynamical systems; stability; hysteresis; phase plane analysis; applications to cell biology, viral dynamics, and infectious diseases.
Prerequisite: MATH 113A.
MATH 113C. Mathematical Modeling in Biology. 4 Units.
Partial differential equations models in biology such as one dimensional blood flow, morphogen gradients, and tumor growth; stochastic models in cancer and epidemiology.
Prerequisite: MATH 113B.

MATH 114A. Applied Complex Analysis. 4 Units.
Introduction to complex functions and their applications to engineering and science. Complex numbers, elementary functions; analytic functions; complex integration; power series; residue theory; conformal maps; applications.
Prerequisite: MATH 2D and MATH 3A.
Overlaps with MATH 147.

MATH 115. Mathematical Modeling. 4 Units.
Mathematical modeling and analysis of phenomena that arise in engineering physical sciences, biology, economics, or social sciences.
Prerequisite: Corequisite or prerequisite: MATH 112A or ENGRMAE 140. MATH 2D and (MATH 3A or MATH 6G) and MATH 3D.

MATH 117. Dynamical Systems. 4 Units.
Introduction to the modern theory of dynamical systems including contraction mapping principle, fractals and chaos, conservative systems, Kepler problem, billiard models, expanding maps, Smale's horseshoe, topological entropy.
Prerequisite: MATH 3D and MATH 140A.
Overlaps with MATH 118B.

MATH 118. The Theory of Differential Equations. 4 Units.
Existence and uniqueness of solutions, continuous dependence of solutions on initial conditions and parameters, Lyapunov and asymptotic stability, Floquet theory, nonlinear systems, and bifurcations.
Prerequisite: MATH 3D and MATH 140A.

MATH 119. Boundary Value Problems. 4 Units.
Introduction to boundary value problems including Green's function representations, maximum principle, variational formulations, Sturm-Liouville problems, eigenfunction expansions, existence and uniqueness for nonlinear problems, method of shooting, finite difference methods.
Prerequisite: MATH 3D and MATH 140A.

MATH 120A. Introduction to Abstract Algebra: Groups. 4 Units.
Axioms for group theory; permutation groups, matrix groups. Isomorphisms, homomorphisms, quotient groups. Advanced topics as time permits. Special emphasis on doing proofs.
Prerequisite: (MATH 3A OR MATH 6G) and MATH 13. MATH 13 with a grade of C- or better.
Restriction: Mathematics majors have first consideration for enrollment.

MATH 120B. Introduction to Abstract Algebra: Rings and Fields. 4 Units.
Basic properties of rings; ideals, quotient rings; polynomial and matrix rings. Elements of field theory.
Prerequisite: MATH 120A.
Restriction: Mathematics majors have first consideration for enrollment.

MATH 120C. Introduction to Abstract Algebra: Galois Theory. 4 Units.
Galois Theory: proof of the impossibility of certain ruler-and-compass constructions (squaring the circle, trisecting angles); nonexistence of analogues to the "quadratic formula" for polynomial equations of degree 5 or higher.
Prerequisite: MATH 120B.
Restriction: Mathematics majors have first consideration for enrollment.

MATH 121A. Linear Algebra. 4 Units.
Prerequisite: (MATH 3A OR MATH 6G) and MATH 13. MATH 13 with a grade of C- or better.
Restriction: Mathematics majors have first consideration for enrollment.

MATH 121B. Linear Algebra. 4 Units.
Introduction to modern abstract linear algebra. Special emphasis on students doing proofs. Canonical forms; inner products; similarity of matrices.
Prerequisite: MATH 121A.

MATH 130. Probability and Stochastic Processes. 4 Units.
Introductory course emphasizing applications.
Prerequisite: MATH 2A and MATH 2B and MATH 2C
Restriction: Prerequisite required

MATH 130A. Probability and Stochastic Processes. 4 Units.
Basic concepts of random variables, distributions, independence, correlations, moments, limit theorems, conditional probability. Markov chains, gambler's ruin, branching process, birth and death processes, numerical simulations in Matlab.
Prerequisite: MATH 2A and MATH 2B and (MATH 3A or MATH 6G).
Overlaps with MATH 131A, MATH 132A, STATS 120A.

MATH 130B. Probability and Stochastic Processes. 4 Units.
Exponential distributions, Poisson processes, continuous time Markov chains, renewal theory, insurance ruin and claim problems, numerical simulations in Matlab.
Prerequisite: MATH 130A OR MATH 131A or STATS 120A.
MATH 130C. Probability and Stochastic Processes. 4 Units.
Martingales, Invariance Principle, Brownian motions and applications
in option pricing, stationary processes and applications in Wiener filter,
umerical simulations in Matlab.
Prerequisite: MATH 130B.

MATH 131A. Introduction to Probability and Statistics. 4 Units.
Introductory course covering basic principles of probability and statistical
inference. Axiomatic definition of probability, random variables, probability
distributions, expectation.
Prerequisite: MATH 2A and MATH 2B and (MATH 2D or MATH 4).
Same as STATS 120A.
Overlaps with MATH 130A, MATH 132A.

MATH 131B. Introduction to Probability and Statistics. 4 Units.
Introductory course covering basic principles of probability and statistical
inference. Point estimation, interval estimating, and testing hypotheses,
Bayesian approaches to inference.
Prerequisite: (MATH 131A or STATS 120A) and (MATH 3A or MATH 6G
or MATH 4).
Same as STATS 120B.

MATH 131C. Introduction to Probability and Statistics. 4 Units.
Introductory course covering basic principles of probability and statistical
inference. Linear regression, analysis or variance, model checking.
Prerequisite: MATH 131B or STATS 120B.
Same as STATS 120C.

MATH 133A. Statistical Methods with Applications to Finance. 4 Units.
Introduction to Monte Carlo (MC) methods. Overview of probability,
statistics, financial concepts; linear and logistic regressions; time series
models; Brownian motion; MC simulations.
Prerequisite: MATH 130A or MATH 131A or STATS 120A or MATH 2D or
MATH 4.

MATH 133B. Statistical Methods with Applications to Finance. 4 Units.
Introduction to Monte Carlo (MC) methods. Elliptic and parabolic partial
differential equations; MC methods; vanilla and exotic derivatives; Greeks,
portfolio management, and value-at-risk.
Prerequisite: MATH 133A.

MATH 140A. Elementary Analysis. 4 Units.
Introduction to real analysis including convergence of sequences, infinite
series, differentiation and integration, and sequences of functions.
Students are expected to do proofs.
Prerequisite: MATH 140A.
Restriction: Mathematics majors have first consideration for enrollment.

MATH 140B. Elementary Analysis. 4 Units.
Introduction to real analysis including convergence of sequences, infinite
series, differentiation and integration, and sequences of functions.
Students are expected to do proofs.
Prerequisite: MATH 140A.

MATH 141. Introduction to Topology. 4 Units.
The elements of naive set theory and the basic properties of metric
spaces. Introduction to topological properties.
Prerequisite: MATH 140A.

MATH 146. Fourier Analysis. 4 Units.
Rigorous introduction to the theory of Fourier series and orthogonal
expansions. Fourier transform.
Prerequisite: MATH 3D and MATH 140A and MATH 140B.
Recommended: MATH 112A.

MATH 147. Complex Analysis. 4 Units.
Rigorous treatment of basic complex analysis: analytic functions, Cauchy
integral theory and its consequences, power series, residue calculus,
harmonic functions, conformal mapping. Students are expected to do
proofs.
Corequisite: MATH 140B.
Prerequisite: MATH 140B.
Overlaps with MATH 114A.
Restriction: MATH 114A may not be taken for credit after MATH 147.

MATH 150. Introduction to Mathematical Logic. 4 Units.
First order logic through the Completeness Theorem for predicate logic.
Prerequisite: MATH 13 or (I&C SCI 6B and I&C SCI 6D). MATH 13 with a
grade of C- or better.
Overlaps with LPS 105B, PHILOS 105B.

MATH 151. Set Theory. 4 Units.
Axiomatic development; infinite sets; cardinal and ordinal numbers.
Prerequisite: MATH 150.
Overlaps with SOC SCI 105A, LPS 105A.

MATH 152. Computability. 4 Units.
Computable functions; undecidability; Gödel's Incompleteness Theorem.
Prerequisite: MATH 150.
Overlaps with PHILOS 105C, LPS 105C.
MATH 161. Modern Geometry. 4 Units.
Euclidean Geometry; Hilbert's Axioms; Absolute Geometry; Hyperbolic Geometry; the Poincare Models; and Geometric Transformations.

Prerequisite: MATH 13 or (I&C SCI 6B and I&C SCI 6D). MATH 13 with a C- or better.

Restriction: Math majors have first consideration for enrollment.

MATH 162A. Introduction to Differential Geometry. 4 Units.
Applications of advanced calculus and linear algebra to the geometry of curves and surfaces in space.

Prerequisite: MATH 2E and MATH 3A and MATH 3D.

MATH 162B. Introduction to Differential Geometry. 4 Units.
Applications of advanced calculus and linear algebra to the geometry of curves and surfaces in space.

Prerequisite: MATH 162A.

MATH 171A. Mathematical Methods in Operations Research Linear Programming. 4 Units.
Simplex algorithm, duality, optimization in networks.

Prerequisite: MATH 3A or MATH 6G.

MATH 171B. Mathematical Methods in Operations Research Nonlinear Programming. 4 Units.
Conditions for optimality, quadratic and convex programming, search methods, geometric programming.

Prerequisite: MATH 2D and (MATH 3A or MATH 6G).

MATH 173A. Introduction to Cryptology. 4 Units.
Introduction to some of the mathematics used in the making and breaking of codes, with applications to classical ciphers and public key systems. The mathematics which is covered includes topics from number theory, probability, and abstract algebra.

Prerequisite: MATH 2B and (MATH 3A or MATH 6G) and (MATH 13 or (I&C SCI 6B and I&C SCI 6D)). MATH 13 with a grade of C- or better.

MATH 173B. Introduction to Cryptology. 4 Units.
Introduction to some of the mathematics used in the making and breaking of codes, with applications to classical ciphers and public key systems. The mathematics which is covered includes topics from number theory, probability, and abstract algebra.

Prerequisite: MATH 173A.

MATH 174A. Modern Graph Theory. 4 Units.
An introductory course emphasizing the fundamental concepts of graph theory by developing abilities to produce examples, following and devising simple proofs, and current applications of graph theory. Topics include coloring maps, plane graphs, vertices, and edges; Hadwiger's Conjecture; Hamilton Cycles; Ramsey Theory.

Prerequisite: MATH 174A.

MATH 175. Combinatorics. 4 Units.
Introduction to combinatorics including basic counting principles, permutations, combinations, binomial coefficients, inclusion-exclusion, derangements, ordinary and exponential generating functions, recurrence relations, Catalan numbers, Stirling numbers, and partition numbers.

Prerequisite: MATH 2B and MATH 13. MATH 13 with a grade of C- or better.

MATH 176. Mathematics of Finance. 4 Units.
After reviewing tools from probability, statistics, and elementary differential and partial differential equations, concepts such as hedging, arbitrage, Puts, Calls, the design of portfolios, the derivation and solution of the Black-Scholes, and other equations are discussed.

Prerequisite: MATH 3A.

Same as ECON 135.

Restriction: Mathematics, Economics, Quantitative Economics, and Business Economics majors have first consideration for enrollment.

MATH 180A. Number Theory. 4 Units.

Prerequisite: MATH 3A and MATH 13. MATH 13 with a grade of C- or better.

Restriction: Math majors have first consideration for enrollment.

MATH 180B. Number Theory. 4 Units.
Introduction to number theory and applications. Analytic number theory, character sums, finite fields, discrete logarithm, computational complexity. Introduction to coding theory. Other topics as time permits.

Prerequisite: MATH 180A.

Restriction: Mathematics majors have first consideration for enrollment.

MATH 184. History of Mathematics. 4 Units.
Topics vary from year to year. Some possible topics: mathematics in ancient times; the development of modern analysis; the evolution of geometric ideas. Students will be assigned individual topics for term papers.

Prerequisite: MATH 120A and MATH 140A.

Restriction: Math majors have first consideration for enrollment.
MATH 184L. History of Mathematics Lesson Lab. 1 Unit.
Aspiring math teachers research, design, present, and peer review middle school or high school math lessons that draw from history of mathematics topics.

Corequisite: MATH 184. 
Prerequisite: PHY SCI 5.

MATH 189. Special Topics in Mathematics. 4 Units.
Offered from time to time, but not on a regular basis. Content and prerequisites vary with the instructor.

Prerequisite: Prerequisites vary.
Repeatability: Unlimited as topics vary.

MATH 191. Mathematical Modeling Seminar. 2 Units.
Developing, testing, and presenting mathematical models for real world problems. Students will prepare for and participate in the Mathematical Contest in Modeling (MCM) in late February. Separate contest registration fee required.

Prerequisite: MATH 3D.
Repeatability: May be taken for credit 2 times.

MATH 192. Studies in the Learning and Teaching of Secondary Mathematics. 2 Units.
Focus is on historic and current mathematical concepts related to student learning and effective math pedagogy, with fieldwork in grades 6-14.

Prerequisite: MATH 2D and MATH 2J and MATH 3D and (MATH 13 or MATH 120A or MATH 140A).
Grading Option: Pass/no pass only.
Repeatability: May be taken for credit 2 times.
Restriction: Upper-division students only. Math majors with specialization in Mathematics for Education only.

MATH 193. SMPP Capstone. 2 Units.
Capstone course for the Mathematics Subject-Matter Preparation (SMPP) program. Engages students in reviewing and conducting current research on significant issues related to the teaching and learning of mathematics in the secondary classroom.

Corequisite: Recommended: MATH 192.
Repeatability: May be taken for credit 2 times.

MATH 194. Problem Solving Seminar. 2 Units.
Develops ability in analytical thinking and problem solving, using problems of the type found in the Mathematics Olympiad and the Putnam Mathematical Competition. Students taking the course in fall will prepare for and take the Putnam examination in December.

Grading Option: Pass/no pass only.
Repeatability: May be taken for credit 2 times.

MATH H195A. Honors Seminar. 4 Units.
Topics vary from year to year. Provides an integrative experience, including problem-solving and oral and written presentations. Required for the Honors Program in Mathematics and open to others with consent of instructor.

Restriction: Mathematics Honors Program students only.

MATH H195B. Honors Seminar. 4 Units.
Topics vary from year to year. Provides an integrative experience, including problem-solving and oral and written presentations. Required for the Honors Program in Mathematics and open to others with consent of instructor.

Restriction: Mathematics Honors Program students only.

MATH 199A. Special Studies in Mathematics. 2-4 Units.
Supervised reading. For outstanding undergraduate Mathematics majors in supervised but independent reading or research of mathematical topics.

Repeatability: Unlimited as topics vary.

MATH 199B. Special Studies in Mathematics. 2-4 Units.
Supervised reading. For outstanding undergraduate Mathematics majors in supervised but independent reading or research of mathematical topics.

Repeatability: Unlimited as topics vary.

MATH 199C. Special Studies in Mathematics. 2-4 Units.
Supervised reading. For outstanding undergraduate Mathematics majors in supervised but independent reading or research of mathematical topics.

Repeatability: Unlimited as topics vary.

MATH 205A. Introduction to Graduate Analysis. 5 Units.
Construction of the real number system, topology of the real line, concepts of continuity, differential and integral calculus, sequences and series of functions, equicontinuity, metric spaces, multivariable differential and integral calculus, implicit functions, curves and surfaces.

Prerequisite: MATH 2E and MATH 3A and MATH 13.

MATH 205B. Introduction to Graduate Analysis. 5 Units.
Construction of the real number system, topology of the real line, concepts of continuity, differential and integral calculus, sequences and series of functions, equicontinuity, metric spaces, multivariable differential and integral calculus, implicit functions, curves and surfaces.

Prerequisite: MATH 205A.

MATH 205C. Introduction to Graduate Analysis. 5 Units.
Construction of the real number system, topology of the real line, concepts of continuity, differential and integral calculus, sequences and series of functions, equicontinuity, metric spaces, multivariable differential and integral calculus, implicit functions, curves and surfaces.

Prerequisite: MATH 205B.

MATH 206A. Introduction to Graduate Algebra. 5 Units.
Introduction to abstract linear algebra, including bases, linear transformation, eigenvectors, canonical forms, inner products, symmetric operators. Introduction to groups, rings, and fields including examples of groups, group actions, Sylow theorems, modules over principal ideal domains, polynomials and Galois groups.

Prerequisite: MATH 3A.
MATH 206B. Introduction to Graduate Algebra. 5 Units.
Introduction to abstract linear algebra, including bases, linear
transformation, eigenvectors, canonical forms, inner products, symmetric
operators. Introduction to groups, rings, and fields including examples
of groups, group actions, Sylow theorems, modules over principal ideal
domains, polynomials and Galois groups.
Prerequisite: MATH 206A.

MATH 206C. Introduction to Graduate Algebra. 5 Units.
Introduction to abstract linear algebra, including bases, linear
transformation, eigenvectors, canonical forms, inner products, symmetric
operators. Introduction to groups, rings, and fields including examples
of groups, group actions, Sylow theorems, modules over principal ideal
domains, polynomials and Galois groups.
Prerequisite: MATH 206B.

MATH 210A. Real Analysis. 4 Units.
Measure theory, Lebesgue integral, signed measures, Radon-Nikodym
theorem, functions of bounded variation and absolutely continuous
functions, classical Banach spaces, Lp spaces, integration on locally
compact spaces and the Riesz-Markov theorem, measure and outer
measure, product measure spaces.
Prerequisite: MATH 140C.

MATH 210B. Real Analysis. 4 Units.
Measure theory, Lebesgue integral, signed measures, Radon-Nikodym
theorem, functions of bounded variation and absolutely continuous
functions, classical Banach spaces, Lp spaces, integration on locally
compact spaces and the Riesz-Markov theorem, measure and outer
measure, product measure spaces.
Prerequisite: MATH 210A.

MATH 210C. Real Analysis. 4 Units.
Measure theory, Lebesgue integral, signed measures, Radon-Nikodym
theorem, functions of bounded variation and absolutely continuous
functions, classical Banach spaces, Lp spaces, integration on locally
compact spaces and the Riesz-Markov theorem, measure and outer
measure, product measure spaces.
Prerequisite: MATH 210B.

MATH 211A. Topics in Analysis. 4 Units.
Studies in selected areas of Real Analysis, a continuation of MATH 210A-
B-C. Topics addressed vary each quarter.
Prerequisite: MATH 210C.

MATH 211B. Topics in Analysis. 4 Units.
Studies in selected areas of Real Analysis, a continuation of MATH 210A-
B-C. Topics addressed vary each quarter.
Prerequisite: MATH 211A.

MATH 211C. Topics in Analysis. 4 Units.
Studies in selected areas of Real Analysis, a continuation of MATH 210A-
B-C. Topics addressed vary each quarter.
Prerequisite: MATH 211B.

MATH 218A. Introduction to Manifolds and Geometry. 4 Units.
General topology and fundamental groups, covering space; Stokes
theorem on manifolds, selected topics on abstract manifold theory.
Prerequisite: MATH 205C.

MATH 218B. Introduction to Manifolds and Geometry. 4 Units.
General topology and fundamental groups, covering space; Stokes
theorem on manifolds, selected topics on abstract manifold theory.
Prerequisite: MATH 218A.

MATH 218C. Introduction to Manifolds and Geometry. 4 Units.
General topology and fundamental groups, covering space; Stokes
theorem on manifolds, selected topics on abstract manifold theory.
Prerequisite: MATH 218B.

MATH 220A. Analytic Function Theory. 4 Units.
Standard theorems about analytic functions. Harmonic functions. Normal
families. Conformal mapping.
Prerequisite: MATH 140C.

MATH 220B. Analytic Function Theory. 4 Units.
Standard theorems about analytic functions. Harmonic functions. Normal
families. Conformal mapping.
Prerequisite: MATH 220A.

MATH 220C. Analytic Function Theory. 4 Units.
Standard theorems about analytic functions. Harmonic functions. Normal
families. Conformal mapping.
Prerequisite: MATH 220B.

MATH 222A. Several Complex Variables and Complex Geometry. 4
Units.
Several Complex variables, d-bar problems, mappings, Kaehler geometry,
de Rham and Dolbeault Theorems, Chern Classes, Hodge Theorems,
Calabi conjecture, Kahler-Einstein geometry, Monge-Ampere.
Prerequisite: MATH 218C and MATH 220C.

MATH 222B. Several Complex Variables and Complex Geometry. 4
Units.
Several Complex variables, d-bar problems, mappings, Kaehler geometry,
Le Rham and Dolbeault Theorems, Chern Classes, Hodge Theorems,
Calabi conjecture, Kahler-Einstein geometry, Monge-Ampere.
Prerequisite: MATH 222A.

MATH 222C. Several Complex Variables and Complex Geometry. 4
Units.
Several Complex variables, d-bar problems, mappings, Kaehler geometry,
Le Rham and Dolbeault Theorems, Chern Classes, Hodge Theorems,
Calabi conjecture, Kahler-Einstein geometry, Monge-Ampere.
Prerequisite: MATH 222B.
MATH 225A. Introduction to Numerical Analysis and Scientific Computing. 4 Units.
Introduction to fundamentals of numerical analysis from an advanced viewpoint. Error analysis, approximation of functions, nonlinear equations.
Prerequisite: MATH 3D and ((MATH 105A and MATH 105B) or (MATH 140A and MATH 140B)) and MATH 121A and (MATH 112A or ENGRMAE 140).
Restriction: Graduate students only.

MATH 225B. Introduction to Numerical Analysis and Scientific Computing. 4 Units.
Introduction to fundamentals of numerical analysis from an advanced viewpoint. Numerical linear algebra, numerical solutions of differential equations; stability.
Prerequisite: MATH 225A.
Restriction: Graduate students only.

MATH 225C. Introduction to Numerical Analysis and Scientific Computing. 4 Units.
Introduction to fundamentals of numerical analysis from an advanced viewpoint. Numerical linear algebra, numerical solutions of differential equations; stability.
Prerequisite: MATH 225B.
Restriction: Graduate students only.

MATH 226A. Computational Differential Equations. 4 Units.
Prerequisite: MATH 3D and (MATH 112A or ENGRMAE 140) and (MATH 140B or MATH 105B).

MATH 226B. Computational Differential Equations. 4 Units.
Prerequisite: MATH 226A.

MATH 226C. Computational Differential Equations. 4 Units.
Prerequisite: MATH 226B.

MATH 227A. Mathematical and Computational Biology. 4 Units.
Prerequisite: MATH 2A and MATH 2B and MATH 3A.

MATH 227B. Mathematical and Computational Biology. 4 Units.
Prerequisite: MATH 227A.

MATH 227C. Mathematical and Computational Biology. 4 Units.
Prerequisite: MATH 227A.
Same as COMPSCI 285.

MATH 230A. Algebra. 4 Units.
Elements of the theories of groups, rings, fields, modules. Galois theory. Modules over principal ideal domains. Artinian, Noetherian, and semisimple rings and modules.
Prerequisite: MATH 120A and MATH 121A and MATH 121B.

MATH 230B. Algebra. 4 Units.
Elements of the theories of groups, rings, fields, modules. Galois theory. Modules over principal ideal domains. Artinian, Noetherian, and semisimple rings and modules.
Prerequisite: MATH 230A.

MATH 232A. Algebraic Number Theory. 4 Units.
Algebraic integers, prime ideals, class groups, Dirichlet unit theorem, localization, completion, Cebotarev density theorem, L-functions, Gauss sums, diophantine equations, zeta functions over finite fields. Introduction to class field theory.
Prerequisite: MATH 230C.

MATH 232B. Algebraic Number Theory. 4 Units.
Algebraic integers, prime ideals, class groups, Dirichlet unit theorem, localization, completion, Cebotarev density theorem, L-functions, Gauss sums, diophantine equations, zeta functions over finite fields. Introduction to class field theory.
Prerequisite: MATH 232A.
MATH 232C. Algebraic Number Theory. 4 Units.
Algebraic integers, prime ideals, class groups, Dirichlet unit theorem, localization, completion, Cebotarev density theorem, L-functions, Gauss sums, diophantine equations, zeta functions over finite fields. Introduction to class field theory.
Prerequisite: MATH 232B.

MATH 233A. Algebraic Geometry. 4 Units.
Prerequisite: MATH 230C.

MATH 233B. Algebraic Geometry. 4 Units.
Prerequisite: MATH 233A.

MATH 233C. Algebraic Geometry. 4 Units.
Prerequisite: MATH 22B.

MATH 234B. Topics in Algebra. 4 Units.
Group theory, homological algebra, and other selected topics.
Prerequisite: MATH 230C.
Repeatability: May be repeated for credit unlimited times.

MATH 234C. Topics in Algebra. 4 Units.
Group theory, homological algebra, and other selected topics.
Prerequisite: MATH 234B.
Repeatability: May be repeated for credit unlimited times.

MATH 235A. Mathematics of Cryptography. 4 Units.
Mathematics of public key cryptography: encryption and signature schemes; RSA; factoring; primality testing; discrete log based cryptosystems, elliptic and hyperelliptic curve cryptography and additional topics as determined by the instructor.
Prerequisite: MATH 230C.

MATH 235B. Mathematics of Cryptography. 4 Units.
Mathematics of public key cryptography: encryption and signature schemes; RSA; factoring; primality testing; discrete log based cryptosystems, elliptic and hyperelliptic curve cryptography and additional topics as determined by the instructor.
Prerequisite: MATH 235B.

MATH 239A. Analytic Methods in Arithmetic Geometry. 4 Units.
Riemann zeta function, Dirichlet L-functions, prime number theorem, zeta functions over finite fields, sieves methods, zeta functions of algebraic curves, algebraic coding theory, L-Functions over number fields, L-functions of modular forms, Eisenstein series.
Prerequisite: MATH 220C and MATH 230C.

MATH 239B. Analytic Methods in Arithmetic Geometry. 4 Units.
Riemann zeta function, Dirichlet L-functions, prime number theorem, zeta functions over finite fields, sieves methods, zeta functions of algebraic curves, algebraic coding theory, L-Functions over number fields, L-functions of modular forms, Eisenstein series.
Prerequisite: MATH 239A.

MATH 239C. Analytic Methods in Arithmetic Geometry. 4 Units.
Riemann zeta function, Dirichlet L-functions, prime number theorem, zeta functions over finite fields, sieves methods, zeta functions of algebraic curves, algebraic coding theory, L-Functions over number fields, L-functions of modular forms, Eisenstein series.
Prerequisite: MATH 239B.

MATH 240A. Differential Geometry. 4 Units.
Riemannian manifolds, connections, curvature and torsion. Submanifolds, mean curvature, Gauss curvature equation. Geodesics, minimal submanifolds, first and second fundamental forms, variational formulas. Comparison theorems and their geometric applications. Hodge theory applications to geometry and topology.

MATH 240B. Differential Geometry. 4 Units.
Riemannian manifolds, connections, curvature and torsion. Submanifolds, mean curvature, Gauss curvature equation. Geodesics, minimal submanifolds, first and second fundamental forms, variational formulas. Comparison theorems and their geometric applications. Hodge theory applications to geometry and topology.
Prerequisite: MATH 240A.

MATH 240C. Differential Geometry. 4 Units.
Riemannian manifolds, connections, curvature and torsion. Submanifolds, mean curvature, Gauss curvature equation. Geodesics, minimal submanifolds, first and second fundamental forms, variational formulas. Comparison theorems and their geometric applications. Hodge theory applications to geometry and topology.
Prerequisite: MATH 240B.

MATH 245A. Topics in Differential Geometry. 4 Units.
Studies in selected areas of differential geometry, a continuation of MATH 240A-B-C. Topics addressed vary each quarter.
Prerequisite: MATH 240C.
Repeatability: Unlimited as topics vary.
MATH 245B. Topics in Differential Geometry. 4 Units.
Studies in selected areas of differential geometry, a continuation of MATH 240A-B-C. Topics addressed vary each quarter.
Prerequisite: MATH 245A.
Repeatability: Unlimited as topics vary.

MATH 245C. Topics in Differential Geometry. 4 Units.
Studies in selected areas of differential geometry, a continuation of MATH 240A-B-C. Topics addressed vary each quarter.
Prerequisite: MATH 245B.
Repeatability: Unlimited as topics vary.

MATH 250A. Algebraic Topology. 4 Units.
Provides fundamental materials in algebraic topology: fundamental group and covering space, homology and cohomology theory, and homotopy group.
Prerequisite: MATH 230A.

MATH 250B. Algebraic Topology. 4 Units.
Provides fundamental materials in algebraic topology: fundamental group and covering space, homology and cohomology theory, and homotopy group.
Prerequisite: MATH 250A.

MATH 250C. Algebraic Topology. 4 Units.
Provides fundamental materials in algebraic topology: fundamental group and covering space, homology and cohomology theory, and homotopy group.
Prerequisite: MATH 250B.

MATH 250A. Algebraic Topology. 4 Units.
Provides fundamental materials in algebraic topology: fundamental group and covering space, homology and cohomology theory, and homotopy group.
Prerequisite: MATH 230A.

MATH 250B. Algebraic Topology. 4 Units.
Provides fundamental materials in algebraic topology: fundamental group and covering space, homology and cohomology theory, and homotopy group.
Prerequisite: MATH 250A.

MATH 250C. Algebraic Topology. 4 Units.
Provides fundamental materials in algebraic topology: fundamental group and covering space, homology and cohomology theory, and homotopy group.
Prerequisite: MATH 250B.

MATH 250A. Algebraic Topology. 4 Units.
Provides fundamental materials in algebraic topology: fundamental group and covering space, homology and cohomology theory, and homotopy group.
Prerequisite: MATH 230A.

MATH 250B. Algebraic Topology. 4 Units.
Provides fundamental materials in algebraic topology: fundamental group and covering space, homology and cohomology theory, and homotopy group.
Prerequisite: MATH 250A.

MATH 250C. Algebraic Topology. 4 Units.
Provides fundamental materials in algebraic topology: fundamental group and covering space, homology and cohomology theory, and homotopy group.
Prerequisite: MATH 250B.

MATH 260A. Functional Analysis. 4 Units.
Normed linear spaces, Hilbert spaces, Banach spaces, Stone-Weierstrass Theorem, locally convex spaces, bounded operators on Banach and Hilbert spaces, the Gelfand-Neumark Theorem for commutative $C^*$-algebras, the spectral theorem for bounded self-adjoint operators, unbounded operators on Hilbert spaces.
Prerequisite: MATH 210C and MATH 220C.

MATH 260B. Functional Analysis. 4 Units.
Normed linear spaces, Hilbert spaces, Banach spaces, Stone-Weierstrass Theorem, locally convex spaces, bounded operators on Banach and Hilbert spaces, the Gelfand-Neumark Theorem for commutative $C^*$-algebras, the spectral theorem for bounded self-adjoint operators, unbounded operators on Hilbert spaces.
Prerequisite: MATH 260A.

MATH 260C. Functional Analysis. 4 Units.
Normed linear spaces, Hilbert spaces, Banach spaces, Stone-Weierstrass Theorem, locally convex spaces, bounded operators on Banach and Hilbert spaces, the Gelfand-Neumark Theorem for commutative $C^*$-algebras, the spectral theorem for bounded self-adjoint operators, unbounded operators on Hilbert spaces.
Prerequisite: MATH 260B.

MATH 270A. Probability. 4 Units.
Prerequisite: MATH 130C and MATH 210C.

MATH 270B. Probability. 4 Units.
Prerequisite: MATH 270A.

MATH 270C. Probability. 4 Units.
Prerequisite: MATH 270B.

MATH 271A. Stochastic Processes. 4 Units.
Processes with independent increments, Wiener and Gaussian processes, function space integrals, stationary processes, Markov processes.
Prerequisite: MATH 210C.
Overlaps with STATS 270.

MATH 271B. Stochastic Processes. 4 Units.
Processes with independent increments, Wiener and Gaussian processes, function space integrals, stationary processes, Markov processes.
Prerequisite: MATH 271A.
Overlaps with STATS 270.

MATH 271C. Stochastic Processes. 4 Units.
Processes with independent increments, Wiener and Gaussian processes, function space integrals, stationary processes, Markov processes.
Prerequisite: MATH 271B.
Overlaps with STATS 270.

MATH 272A. Probability Models. 4 Units.
Spin systems, Ising models, contact process, exclusion process, percolation, increasing events, critical probabilities, sub- and super-critical phases, scaling theory, oriented percolation, concentration of measure, Gaussian fields, Borell’s inequality, chaining, entropy.
Prerequisite: MATH 271C.

MATH 272B. Probability Models. 4 Units.
Spin systems, Ising models, contact process, exclusion process, percolation, increasing events, critical probabilities, sub- and super-critical phases, scaling theory, oriented percolation, concentration of measure, Gaussian fields, Borell’s inequality, chaining, entropy.
Prerequisite: MATH 272A.
MATH 272C. Probability Models. 4 Units.
Spin systems, Ising models, contact process, exclusion process, percolation, increasing events, critical probabilities, sub- and super-critical phases, scaling theory, oriented percolation, concentration of measure, Gaussian fields, Borell’s inequality, chaining, entropy.
Prerequisite: MATH 272B.

MATH 274. Topics in Probability. 4 Units.
Selected topics, such as theory of stochastic processes, martingale theory, stochastic integrals, stochastic differential equations.
Prerequisite: MATH 270C.
Repeatability: Unlimited as topics vary.

MATH 277A. Topics in Mathematical Physics . 4 Units.
Studies in selected areas of mathematical physics. Topics addressed vary each quarter.
Repeatability: May be repeated for credit unlimited times.

MATH 277B. Topics in Mathematical Physics . 4 Units.
Studies in selected areas of mathematical physics. Topics addressed vary each quarter.
Prerequisite: MATH 277A.
Repeatability: May be repeated for credit unlimited times.

MATH 277C. Topics in Mathematical Physics . 4 Units.
Studies in selected areas of mathematical physics. Topics addressed vary each quarter.
Prerequisite: MATH 277B.
Repeatability: May be repeated for credit unlimited times.

MATH 280A. Mathematical Logic. 4 Units.
Basic set theory; models, compactness, and completeness; basic model theory; Incompleteness and Gödel’s Theorems; basic recursion theory; constructible sets.

MATH 280B. Mathematical Logic. 4 Units.
Basic set theory; models, compactness, and completeness; basic model theory; Incompleteness and Gödel’s Theorems; basic recursion theory; constructible sets.
Prerequisite: MATH 280A.

MATH 280C. Mathematical Logic. 4 Units.
Basic set theory; models, compactness, and completeness; basic model theory; Incompleteness and Gödel’s Theorems; basic recursion theory; constructible sets.
Prerequisite: MATH 280B.

MATH 281B. Set Theory. 4 Units.
Ordinals, cardinals, cardinal arithmetic, combinatorial set theory, models of set theory, Gödel’s constructible universe, forcing, large cardinals, iterate forcing, inner model theory, fine structure.
Prerequisite: MATH 281A.

MATH 281C. Set Theory. 4 Units.
Ordinals, cardinals, cardinal arithmetic, combinatorial set theory, models of set theory, Gödel’s constructible universe, forcing, large cardinals, iterate forcing, inner model theory, fine structure.
Prerequisite: MATH 281B.

MATH 282A. Model Theory. 4 Units.
Prerequisite: MATH 280C.

MATH 282B. Model Theory. 4 Units.
Prerequisite: MATH 282A.

MATH 282C. Model Theory. 4 Units.
Prerequisite: MATH 282B.

MATH 285A. Topics in Mathematical Logic. 4 Units.
Studies in selected areas of mathematical logic, a continuation of MATH 280A-B-C. Topics addressed vary each quarter.
Prerequisite: MATH 280C.
Repeatability: Unlimited as topics vary.

MATH 285B. Topics in Mathematical Logic. 4 Units.
Studies in selected areas of mathematical logic, a continuation of MATH 280A-B-C. Topics addressed vary each quarter.
Prerequisite: MATH 285A.
Repeatability: Unlimited as topics vary.

MATH 285C. Topics in Mathematical Logic. 4 Units.
Studies in selected areas of mathematical logic, a continuation of MATH 280A-B-C. Topics addressed vary each quarter.
Prerequisite: MATH 285B.
Repeatability: Unlimited as topics vary.

MATH 290A. Methods in Applied Mathematics. 4 Units.
MATH 290B. Methods in Applied Mathematics. 4 Units.
Prerequisite: MATH 290A.

MATH 290C. Methods in Applied Mathematics. 4 Units.
Prerequisite: MATH 290B.

MATH 291C. Topics in Applied and Computational Math. 4 Units.
Studies in selected areas of applied and computational mathematics. Topics addressed vary each quarter.
Repeatability: May be repeated for credit unlimited times.

MATH 295A. Partial Differential Equations. 4 Units.
Prerequisite: MATH 210C and MATH 112B and MATH 112C.

MATH 295B. Partial Differential Equations. 4 Units.
Prerequisite: MATH 295A.

MATH 295C. Partial Differential Equations. 4 Units.
Prerequisite: MATH 295B.

MATH 296. Topics in Partial Differential Equations. 4 Units.
Studies in selected areas of partial differential equations, a continuation of MATH 295A-B-C. Topics addressed vary each quarter.
Prerequisite: MATH 295C.
Repeatability: Unlimited as topics vary.
Restriction: Graduate students only.

MATH 297. Mathematics Colloquium. 1 Unit.
Weekly colloquia on topics of current interest in mathematics.
Grading Option: Satisfactory/unsatisfactory only.
Repeatability: May be repeated for credit unlimited times.

MATH 298A. Seminar . 1-3 Units.
Seminars organized for detailed discussion of research problems of current interest in the Department. The format, content, frequency, and course value are variable.
Repeatability: Unlimited as topics vary.

MATH 298B. Seminar . 2 Units.
Seminars organized for detailed discussion of research problems of current interest in the Department. The format, content, frequency, and course value are variable.
Prerequisite: MATH 298A.
Repeatability: Unlimited as topics vary.

MATH 298C. Seminar . 2 Units.
Seminars organized for detailed discussion of research problems of current interest in the Department. The format, content, frequency, and course value are variable.
Prerequisite: MATH 298B.
Repeatability: Unlimited as topics vary.

MATH 299A. Supervised Reading and Research. 1-12 Units.
Supervised reading and research with Mathematics faculty.
Repeatability: May be repeated for credit unlimited times.

MATH 299B. Supervised Reading and Research. 1-12 Units.
Supervised reading and research with Mathematics faculty.
Prerequisite: MATH 299A.
Repeatability: May be repeated for credit unlimited times.

MATH 299C. Supervised Reading and Research. 1-12 Units.
Supervised reading and research with Mathematics faculty.
Prerequisite: MATH 299B.
Repeatability: May be repeated for credit unlimited times.

MATH 399. University Teaching. 1-4 Units.
Limited to Teaching Assistants.
Grading Option: Satisfactory/unsatisfactory only.
Repeatability: May be repeated for credit unlimited times.