

## Spring 2023 Course Descriptions as of 01/04/2023 08:09 PM

Information in Browse Course Catalog is subject to change. Information is term specific. Please refer to the appropriate term when searching for course content. Key to Course Descriptions may be found at: [http://rcs.registrar.arizona.edu/course\\_descriptions\\_key](http://rcs.registrar.arizona.edu/course_descriptions_key).

### Mathematics Main (MATH)

#### **MATH 100: Math Lab** (3 units)

**Description:** The main purpose of this course is to serve as a preparation for MATH 105, MATH 106, MATH 107, and MATH 112, with an emphasis on problem-solving techniques and graphing technology. Content includes the following topics: linear, quadratic, polynomial, rational, and absolute value equations and inequalities, algebraic expressions, graphing techniques, factoring techniques, exponents and basic data analysis. Students who wish to continue to higher level math courses will have the option to work with additional course material in algebra and trigonometry to facilitate this preparation. This course by itself cannot be used to satisfy the foundations math requirement for any degree program. Examinations are proctored.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Flat Fee:** \$100

**Course Components:**    Discussion                      May Be Offered  
   Laboratory                      Required

**Equivalent to:** MATH 100B

**Course typically offered:**

Main Campus: Fall, Winter, Spring, Summer

Online Campus: Fall, Winter, Spring, Summer

**Enrollment requirement:** For students who need review or do not place into Math 106, 107, 108, 112 or other required courses.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 105: Mathematics in Modern Society** (3 units)

**Description:** This course will examine how the mathematics learned in high school is applied to real life situations. Topics may include personal finance, statistics, elections, symmetry, and scheduling. Some of the applications may be how the site of the Olympic Games is chosen, why spirals occur in nature, and how statistical data is collected and how it can be used to mislead the public. The course is designed for elementary education majors, fine arts majors, humanities majors, and those social and behavioral science majors whose further courses do not require College Algebra as a prerequisite. Except as per University policy on repeating a course, credit will not be given for this course if the student has credit in a higher level math course. Such students may be dropped from the course. Examinations are proctored.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 122

**Course typically offered:**

Main Campus: Fall, Spring

**Enrollment requirement:** PPL 30+ or MCLG 40+ or SAT I MSS 530+ or ACT MATH 21+ . Test scores expire after 1 year. Some students may need to take Math 100 first.

**MATH 106: Exploring and Understanding Patterns, Functions, and Modeling for Elementary Teachers** (3 units)

**Description:** This course explores algebraic thinking from early childhood through middle school, with a focus on the different conceptions of algebra, including generalized arithmetic; patterns and functions; and modeling. Students will examine the different topics in K-8 algebra from an advanced perspective. Examinations are proctored.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall, Spring

**Enrollment requirement:** PPL 30+ or MCLG 40+ or SAT I MSS 530+ or ACT MATH 21+ . Test scores expire after 1 year. Some students may need to take Math 100 first.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 107: Exploring and Understanding Data** (3 units)

**Description:** The main purpose of this course is to help students understand, interpret, and represent data in a useful way to prepare students for courses in statistics. The course will provide students with the knowledge of basic mathematical and software tools and concepts which they can utilize to interpret quantitative information they encounter in their daily life. With the knowledge they gain, students will be able to better understand and assess the validity of quantitative information they receive through the web, newspaper, television, etc. Course topics will include creating various data summaries and descriptive statistics, probability, normal distributions, linear and other regression models, applying techniques to real world data sets. Examinations are proctored.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall, Spring, Summer

Online Campus: Fall, Spring, Summer

**Enrollment requirement:** PPL 30+ or MCLG 40+ or SAT I MSS 530+ or ACT MATH 21+ . Test scores expire after 1 year. Some students may need to take Math 100 first.

**MATH 108: Modeling with Algebraic and Trigonometric Functions** (4 units)

**Description:** The main purpose of this course is to help students use algebraic and trigonometric functions to model real-life situations. Particular emphasis will be placed on applications relevant to Architecture and Speech, Language, and Hearing Sciences majors. Course topics will include ratios and proportions, functions and graphs, linear and quadratic functions and equations, trigonometric functions and equations, sinusoidal curve-fitting, exponential and logarithmic functions and equations, all with an emphasis on applications. Examinations are proctored.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall, Spring

**Enrollment requirement:** PPL 40+ or MCLG 55+ or SAT I MSS 560+ or ACT MATH 24+. Test scores expire after 1 year. Some students may need to take Math 100 first.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 109C: Applied College Algebra with Data Analysis (3 units)**

**Description:** College algebra course that emphasizes data analysis. Topics include functions, rates of change, linear functions, systems of equations, exponential & logarithmic functions, and quadratic functions. Graphing calculators and spreadsheets will be used. It is not intended for students planning to take MATH 122A/B, and it will not serve as a prerequisite for that course. Except as per University policy on repeating a course, credit will not be given for this course if the student has credit in a higher level math course. Such students may be dropped from the course. Examinations are proctored. Credit will be allowed for only one of the following courses: MATH 109, MATH 109C, MATH 110, or MATH 112.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 109, MATH 110, MATH 112

**Course typically offered:**

Main Campus: Fall, Spring

**Enrollment requirement:** Proctored/Prep for Calculus 40+ or Proctored/Prep for College Algebra 55+.

**MATH 111: Plane Trigonometry (2 units)**

**Description:** Topics include right triangle trigonometry, trigonometric functions and graphs, trig identities, inverse trig functions, law of sines, and law of cosines. A graphing calculator is required for this course. We recommend the TI-83 or TI-84 models. Calculators that perform symbolic manipulations, such as the TI-89, NSpire CAS, or HP50g, cannot be used. Not applicable to the mathematics major or minor. Except as per University policy on repeating a course, credit will not be given for this course if the student has credit in a higher level math course. Such students may be dropped from the course. Examinations are proctored.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Enrollment requirement:** PPL 50+ or MCLG 88+ or SAT I MSS 590+ or ACT MATH 24+ or Math 112 or Math 113. Test scores expire after 1 year. Some students may need to take Math 100, then Math 112, then Math 111.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 112: College Algebra Concepts and Applications** (3 units)

**Description:** Topics include properties of functions and graphs, linear and quadratic equations, polynomial functions, exponential and logarithmic functions with applications. A graphing calculator is required for this course. We recommend the TI-83 or TI-84 models. Calculators that perform symbolic manipulations, such as the TI-89, NSpire CAS, or HP50g, cannot be used. Except as per University policy on repeating a course, credit will not be given for this course if the student has credit in a higher level math course. Such students may be dropped from the course. Examinations are proctored.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 109, MATH 109C, MATH 110

**Course typically offered:**

Main Campus: Fall, Winter, Spring, Summer

Online Campus: Fall, Spring, Summer

**Recommendations and additional information:** Credit allowed for only one of the following courses: MATH 110 or MATH 112.

**Enrollment requirement:** PPL 40+ or MCLG 55+ or SAT I MSS 560+ or ACT MATH 24+. Test scores expire after 1 year. Some students may need to take Math 100 first.

**Shared Unique Number:** SUN# MAT 1151

**MATH 113: Elements of Calculus** (3 units)

**Description:** Introductory topics in differential and integral calculus. Students are expected to have a graphing calculator. Except as per University policy on repeating a course, credit will not be given for this course if the student has credit in a higher level math course. Such students may be dropped from the course. Examinations are proctored.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 116

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Enrollment requirement:** PPL 60+ or SAT I MSS 640 or ACT MATH 26+ or recent Math 108(C or higher), Math 112(C or higher) or one recent course from MATH 113, 116, or 120R. Test scores expire after 1 year. Some students may need to take Math 100, then Math 112 first.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 116: Calculus Concepts for Business** (3 units)

**Description:** Introductory topics in differential and integral calculus, with particular emphasis on understanding the principal concepts and their applications to business. Microsoft Excel and graphing calculators will be used as tools for further understanding these concepts. Except as per University policy on repeating a course, credit will not be given for this course if the student has credit in a higher level math course. Such students may be dropped from the course.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 113

**Course typically offered:**

Main Campus: Fall, Spring, Summer

Online Campus: Fall, Spring, Summer

**Enrollment requirement:** PPL 60+ or SAT I MSS 640+ or ACT MATH 26+ or one course from MATH 108 (C or higher), 112 (C or higher), 113, or 120R. Either MIS 111 or ABE 120. Test scores expire after 1 year. Some students need to take Math 100, then Math 112 first.

**MATH 119A: Mathematics of Biological Systems: a calculus based approach** (4 units)

**Description:** A course using real examples developing and studying models of biological dynamical systems using concepts from calculus. Students taking this course will learn how to interpret and develop calculus-based models of biological systems that describe how quantities change in realistic and relevant settings drawn from physiology, neuroscience, ecology and evolution. They will also learn the rudiments of a programming language sufficient to graph functions, plot data and simulate systems of differential equations. This course is intended for students in the biological sciences or those interested in pursuing a career in medicine and does not require any prior knowledge of calculus or of programming.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Discussion May Be Offered  
Lecture Required

**Course typically offered:**

Main Campus: Fall, Spring

**Field trip:** None

**Enrollment requirement:** PPL 60+ or SAT I MSS 640+ or ACT MATH 26+ or one recent course from MATH 112, 113, 116, 120R, or 122A. Test scores expire after 1 year. Some students may need to take Math 100, then Math 112 first.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 120R: Calculus Preparation** (4 units)

**Description:** Review of algebra and trigonometry; study of functions including polynomial, rational, exponential, logarithmic and trigonometric. A graphing calculator is required for this course. We recommend the TI-83 or TI-84 models. Calculators that perform symbolic manipulations, such as the TI-89, NSpire CAS, or HP50g, cannot be used. For students who have high school credit in college algebra and trigonometry but have not attained a sufficient score on the UA Math Placement Test to enter calculus. Except as per University policy on repeating a course, credit will not be given for this course if the student has credit in a higher level math course. Such students may be dropped from the course. Examinations are proctored.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Discussion                      May Be Offered  
Lecture    Required

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Enrollment requirement:** PPL 60+ or SAT I MSS 640+ or ACT MATH 26+ or one recent course from MATH 108, 112, 113, 116, 120R, or 122A. Test scores expire after 1 year. Some students may need to take Math 100, then Math 112 first.

**MATH 121A: Precalculus Functions and Models, Part I** (3 units)

**Description:** This is the first in a sequence of courses designed to lead to Calculus I. It serves a prerequisite for Math 121B. Topics covered include: functions and graphs, rates of change, transformations, inverse functions, quadratic and polynomial functions, rational functions, trigonometric functions. Examinations are proctored.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture                                      Required

**Course typically offered:** Online Campus: Fall, Spring, Summer

**Enrollment requirement:** PPL 60+ or SAT I MSS 640+ or ACT MATH 26+ or one recent course from MATH 112, 113, 116, or 120R. Test scores expire after 1 year. Some students may need to take Math 100, then Math 112 first.

**MATH 121B: Precalculus Functions and Models, Part II** (3 units)

**Description:** This is the second in a sequence of courses designed to lead to Calculus I. Topics covered include: trigonometric functions and identities, exponential and logarithmic functions and models, limits. Examinations are proctored.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture                                      Required

**Course typically offered:** Online Campus: Fall, Spring, Summer

**Enrollment requirement:** Grade of C or higher in Math 121A

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 122A: Functions for Calculus** (1 unit)

**Description:** Elementary functions, their properties, and uses in modeling. A graphing calculator is required for this course. We recommend the TI-83 or TI-84 models. Calculators that perform symbolic manipulations, such as the TI-89, NSpire CAS, or HP50g, cannot be used.

**Grading basis:** Student Option ABCDE/PF

**Career:** Undergraduate

**Course Components:** Lecture Required

**Repeatable:** Course can be repeated a maximum of 2 times.

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Enrollment requirement:** PPL 75+ or SAT I MSS 660+ or ACT MATH 28+ or recent MATH 120R with C or higher, or MATH 122A. Test scores expire after 1 year. Some students may need to take Math 100, then Math 112, then Math 120R first.

**Approved Grading:** Pass/Fail Option

**MATH 122B: First-Semester Calculus** (4 units)

**Description:** An introduction to first-semester calculus for engineering, science and math students, from rates of change to integration, with an emphasis on understanding, problem solving, and modeling. Topics covered include key concepts of derivative and definite integral, techniques of differentiation, and applications, using algebraic and transcendental functions. A graphing calculator is required for this course. We recommend the TI-83 or TI-84 models. Calculators that perform symbolic manipulations, such as the TI-89, NSpire CAS, or HP50g, cannot be used. Examinations are proctored. Except as per University policy on repeating a course, credit will not be given for this course if the student has credit in a higher level math course. Such students may be dropped from the course.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 124, MATH 125

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Recommendations and additional information:** MATH 122A.

**Enrollment requirement:** C or better, or concurrent enrollment in MATH 122A, transfer credit not allowed.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.



### **MATH 125: Calculus I** (3 units)

**Description:** An accelerated version of MATH 122B. Introduction to calculus with an emphasis on understanding and problem solving. Concepts are presented graphically and numerically as well as algebraically. Elementary functions, their properties and uses in modeling; the key concepts of derivative and definite integral; techniques of differentiation, using the derivative to understand the behavior of functions; applications to optimization problems in physics, biology and economics. A graphing calculator is required for this course. We recommend the TI-83 or TI-84 models. Calculators that perform symbolic manipulations, such as the TI-89, NSpire CAS, or HP50g, cannot be used. Except as per University policy on repeating a course, credit will not be given for this course if the student has credit in a higher level math course. Such students may be dropped from the course. Examinations are proctored.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 122B, MATH 124

**Course typically offered:**

Main Campus: Fall, Spring

Online Campus: Spring

**Enrollment requirement:** PPL 92+ or SAT I MSS 730+ or ACT MATH 32+ or MATH 125 AP credit or UA Math 121B (UA Online) with C or higher. Test scores expire after 1 year.

**Special Exam:** Special Exam Credit Only

### **MATH 129: Calculus II** (3 units)

**Description:** Continuation of MATH 122B or MATH 125. Techniques of symbolic and numerical integration, applications of the definite integral to geometry, physics, economics, and probability; differential equations from a numerical, graphical, and algebraic point of view; modeling using differential equations, approximations by Taylor series. A graphing calculator is required for this course. We recommend the TI-83 or TI-84 models. Calculators that perform symbolic manipulations, such as the TI-89, NSpire CAS, or HP50g, cannot be used. Examinations are proctored.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 125B

**Course typically offered:**

Main Campus: Fall, Spring, Summer

Online Campus: Spring

**Enrollment requirement:** MATH 122B or 125 with C or higher.

**Special Exam:** Special Exam Credit Only

**Shared Unique Number:** SUN# MAT 2230

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 163: Basic Statistics (3 units)**

**Description:** Organizing data: displaying distributions, measures of center, measures of spread, scatterplots, correlation, regression, and their interpretation. Design of experiments: simple random samples and their sampling distribution, models from probability, normal distributions, and normal approximations. Statistical inference: confidence intervals and hypothesis testing, t procedures and chi-square tests. Not intended for those who plan further studies in statistics. Except as per University policy on repeating a course, credit will not be given for this course if the student has credit in a higher level math course. Such students may be dropped from the course. Examinations are proctored.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 263

**Course typically offered:**

Main Campus: Fall, Spring

**Enrollment requirement:** PPL 60+ or MCLG 88+ or SAT I MSS 640+ or ACT MATH 26+ or one recent course from MATH 108, 112, 113, 116, 119A, 122B, or 125. Test scores expire after 1 year. Some students may need to take Math 100, then Math 112 first.

**MATH 186J: College Algebra Supplemental Instruction Seminar (1 unit)**

**Description:** This course is designed as a complement to MATH 112. Students enrolled in the course will participate in a weekly problem session pertaining to material covered in MATH 112. Concurrent registration in MATH 112 is required.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Workshop Required

**Course typically offered:**

Main Campus: Fall, Spring

**Recommendations and additional information:** Concurrent enrollment in MATH 112.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 195M: Math and SDS Major Colloquium** (1 unit)

**Description:** Seminar-style course designed to introduce math department majors to the mathematical community at large, support new majors as they adjust to university life and expectations, and build students' written and oral communication skills, especially on math-related topics.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Colloquium Required

**Also offered as:** DATA 195M

**Course typically offered:**

Main Campus: Fall, Spring

**Recommendations and additional information:** Declared major in Mathematics or Statistics & Data Science

**Field trip:** There are no field trips as a group; however, students will be required to attend at least one event outside of class on their own, as detailed in the syllabus.

**Course Equivalencies:** Cross Listed

**Freshman Colloquia:** Freshman Colloquia

**MATH 196A: Tutoring in the Schools** (1 unit)

**Description:** This course is designed to introduce the mathematics teaching profession to mathematically talented college students. Students are given opportunities to observe and tutor in middle and high school mathematics classrooms. Additionally, class time will be dedicated to developing tutor techniques, examining learning styles, and exploring various methods of instruction. Readings, reflections, discussions, and group work will facilitate student understanding of the teaching and learning of mathematics. Students with a math placement level of calculus or higher will be given preference in the application process

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Seminar Required

**Course typically offered:**

Main Campus: Fall, Spring

**Recommendations and additional information:** Students must apply for the course. The application can be found at <http://crr.math.arizona.edu>. Students with a math placement level of calculus or higher will be given preference in the application process.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 196B: UA Math Bootcamp - Algebra Refresher (1 unit)**

**Description:** Get a head start for fall! This 3-week intensive will help you brush off the cobwebs and help solidify your algebra skills. Tutors will be available several hours a day to help you stay on track with ALEKS. ALEKS uses a highly sophisticated AI to help determine what you know well and what you still need to review. Start the year off right in your math or science courses. This course is intended for students who have placed below calculus on the Math Placement Test.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Seminar Required

**Repeatable:** Course can be repeated a maximum of 10 times.

**Course typically offered:**

Main Campus: Summer

**Field trip:** None

**MATH 196C: UA Math Bootcamp - Pre-calculus Refresher (1 unit)**

**Description:** For those of you daring to tackle the world's most pressing problems, this is the Bootcamp for you. We create an individualized plan that helps you refresh your pre-calculus skills so you can become a true master. Tutors will be available several hours a day to help you stay on track with ALEKS. ALEKS uses a highly sophisticated AI to help determine what you know well and what you still need to review. Start the year off right in your math or science courses. This course is intended for students who have placed into pre-calculus or calculus on the Math Placement Test.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Seminar Required

**Repeatable:** Course can be repeated a maximum of 10 times.

**Course typically offered:**

Main Campus: Summer

**Field trip:** None

**MATH 196K: Business Calculus Supplemental Instruction Seminar (1 unit)**

**Description:** This course is designed as a complement to MATH 116. Students enrolled in the course will participate in a weekly problem session pertaining to material covered in MATH 116. Concurrent registration in MATH 116 is required.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Seminar Required

**Repeatable:** Course can be repeated a maximum of 2 times.

**Course typically offered:**

Main Campus: Fall, Spring

**Recommendations and additional information:** Concurrent registration: MATH 116.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 196L: Precalculus Supplemental Instruction Seminar (1 unit)**

**Description:** This course is designed as a complement to MATH 120R. Students enrolled in the course will participate in a weekly problem session pertaining to material covered in MATH 120R. Concurrent registration in MATH 120R is required.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Seminar Required

**Repeatable:** Course can be repeated a maximum of 2 times.

**Course typically offered:**

Main Campus: Fall, Spring

**Recommendations and additional information:** Concurrent registration in MATH 120R.

**MATH 196M: Calculus I Supplemental Instruction Seminar (1 unit)**

**Description:** This course is designed as a complement to MATH 122B. Students enrolled in the course will participate in a weekly problem session pertaining to material covered in MATH 122B.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Seminar Required

**Repeatable:** Course can be repeated a maximum of 1 times.

**Course typically offered:**

Main Campus: Fall, Spring

**Enrollment requirement:** Concurrent registration in Math 122B required.

**MATH 196N: Calculus II Supplemental Instruction Seminar (1 unit)**

**Description:** This course is designed as a complement to MATH 129. Students enrolled in the course will participate in a weekly problem session pertaining to material covered in MATH129. Concurrent registration in MATH 129 is required.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Seminar Required

**Repeatable:** Course can be repeated for a maximum of 2 units.

**Course typically offered:**

Main Campus: Fall, Spring

**Recommendations and additional information:** Concurrent enrollment, MATH 129.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 196V: Vector Calculus Supplemental Instruction Seminar (1 unit)**

**Description:** This course is designed as a complement to Math 223. Students enrolled in the course will participate in a weekly problem session pertaining to material covered in Math 223. Concurrent registration in Math 223 is required.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Seminar Required

**Repeatable:** Course can be repeated a maximum of 2 times.

**Course typically offered:**

Main Campus: Fall, Spring

**Recommendations and additional information:** Concurrent enrollment, MATH 223.

**MATH 199: Independent Study (1 - 5 units)**

**Description:** Qualified students working on an individual basis with professors who have agreed to supervise such work.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Independent Study Required

**Repeatable:** Course can be repeated a maximum of 99 times.

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**MATH 199H: Honors Independent Study (1 - 5 units)**

**Description:** Qualified students working on an individual basis with professors who have agreed to supervise such work.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Independent Study Required

**Repeatable:** Course can be repeated a maximum of 99 times.

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Enrollment requirement:** Student must be active in the Honors College.

**Honors Course:** Honors Course

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 202: Introduction to Symbolic Logic** (3 units)

**Description:** Truth-functional logic and quantification theory; deductive techniques and translation into symbolic notation.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 202

**Also offered as:** LING 202, PHIL 202

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Home department:** Philosophy

**Course Equivalencies:** Cross Listed

**MATH 205: Teaching Secondary Mathematics** (3 units)

**Description:** This course is an introduction to secondary mathematics teaching. It is appropriate for students exploring secondary mathematics teaching as a career and required for students declaring a mathematics major in the mathematics education option. This is a mathematics pedagogy course in the Secondary Mathematics Education Program in the Department of Mathematics.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall, Spring

**Recommendations and additional information:** MATH 122B; Sophomore standing as math major with mathematics education option.

**Enrollment requirement:** Appropriate Math Placement Level or (MATH 124, 122B, 125 or 129 with C or higher).

**MATH 215: Introduction to Linear Algebra** (3 units)

**Description:** Introduction to Linear Algebra. Vector spaces, linear transformations and matrices including eigenvalues and eigenvectors. There is some emphasis on the writing of proofs. Examinations are proctored.

**Grading basis:** Student Option ABCDE/PF

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 313, MATV 313

**Enrollment requirement:** MATH 129, MATH 223, MATH 243, MATH 254, CSC 144, or CSC 245. Must not have taken MATH 310.

**Approved Grading:** Pass/Fail Option

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 223: Vector Calculus** (4 units)

**Description:** Math 223 Vector Calculus (4 semester credit hours) The course covers differential and integral calculus of functions of several variables. Topics include vector valued and scalar functions, partial derivatives, directional derivatives, chain rule, local optimization, double and triple integrals, the line integral, Green's theorem, Stokes' theorem and the Divergence theorem. Examinations are proctored.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall, Spring, Summer

Community Campus: Fall

**Enrollment requirement:** MATH 129 or Math 223 with C or better.

**Special Exam:** Special Exam Credit Only

**Shared Unique Number:** SUN# MAT 2241

**MATH 243: Discrete Mathematics** (3 units)

**Description:** Set theory, logic, discrete structures; induction and recursion; graphs and networks; techniques of proof. Examinations are proctored.

**Grading basis:** Student Option ABCDE/PF

**Career:** Undergraduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Recommendations and additional information:** Concurrent registration: MATH 129 or MATH 250A.

**Enrollment requirement:** MATH 122B or 124 or 125 or 129 (transfer credit ok).

**Approved Grading:** Pass/Fail Option

**Shared Unique Number:** SUN# MAT 2227

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.



**MATH 254: Introduction to Ordinary Differential Equations (3 units)**

**Description:** Solution methods for ordinary differential equations, qualitative techniques; includes matrix methods approach to systems of linear equations and series solutions. Examinations are proctored.

**Grading basis:** Student Option ABCDE/PF

**Career:** Undergraduate

**Course Components:** Discussion                      May Be Offered  
Lecture                                      Required

**Equivalent to:** MATH 250B, MATH 355, MATV 355

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Recommendations and additional information:** Credit allowed for only one of these courses: MATH 254, MATH 355 or MATH 250B.

**Enrollment requirement:** Math 129 or 223 with C or better.

**Approved Grading:** Pass/Fail Option

**Shared Unique Number:** SUN# MAT 2262

**MATH 263: Introduction to Statistics and Biostatistics (3 units)**

**Description:** Organizing data; distributions, measures of center and spread, scatterplots, nonlinear models and transformations, correlation, regression. Design of experiments: models from probability, discrete and continuous random variables, normal distributions, sampling distributions, the central limit theorem. Statistical inference; confidence intervals and test of significance, t procedures, inference for count data, two-way tables and chi-square procedures, inference for regression, analysis of variance. Examinations are proctored.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Discussion                      May Be Offered  
Lecture                                      Required

**Equivalent to:** MATH 163

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Enrollment requirement:** PPL 60+ or MCLG 88+ or SAT I MSS 640+ or ACT MATH 26+ or one recent course from MATH 108, 112, 113, 116, 119A, 122B, or 125. Test scores expire after 1 year. Some students may need to take Math 100, then Math 112 first.

**MATH 293: Internship (1 - 10 units)**

**Description:** Specialized work on an individual basis, consisting of training and practice in actual service in a technical, business, or government establishment.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Independent Study      Required

**Course typically offered:**

Main Campus: Fall, Spring, Summer

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 294A: Problem-Solving Laboratory** (1 unit)

**Description:** With the annual Putnam mathematical competition as motivation, students engage weekly with challenging mathematics problems that require creativity, innovative thinking, and new insights to solve. This problem-solving lab thereby aims to help students synthesize and apply the theory, concepts, and techniques gained throughout their mathematics education in novel ways that lie outside the usual curricula of the major.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Independent Study Required

**Repeatable:** Course can be repeated a maximum of 99 times.

**Course typically offered:**

Main Campus: Fall, Spring

**MATH 299: Independent Study** (1 - 5 units)

**Description:** Qualified students working on an individual basis with professors who have agreed to supervise such work.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Independent Study Required

**Repeatable:** Course can be repeated a maximum of 99 times.

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**MATH 299H: Honors Independent Study** (1 - 5 units)

**Description:** Qualified students working on an individual basis with professors who have agreed to supervise such work.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Independent Study Required

**Repeatable:** Course can be repeated a maximum of 99 times.

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Enrollment requirement:** Student must be active in the Honors College.

**Honors Course:** Honors Course

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 302A: Understanding Elementary Mathematics (A)** (3 units)

**Description:** Development of a basis for understanding the common processes in elementary mathematics related to whole numbers, fractions, integers, and probability. This course is for elementary education majors only. Examinations are proctored.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall, Spring

**Enrollment requirement:** PPL 60+ or MCLG 88+ or SAT I MSS 620+ or ACT MATH 26+ or one recent course from MATH 105, 106, 107, 108, 112, 113, 116, 119A, 120R, 122B, 125, 163, or 263. Some students may need to take Math 100, then Math 105/106/107 first.

**MATH 302B: Understanding Elementary Mathematics (B)** (3 units)

**Description:** Development of a basis for understanding the common processes in elementary mathematics related to estimation, graphing of functions, measurement, geometry, and data analysis. This course is for elementary education majors only. Examinations are proctored.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall, Spring

**Enrollment requirement:** Restricted to College of Education Majors requiring course for degree completion. MATH 302A.

**MATH 310: Applied Linear Algebra** (3 units)

**Description:** Applications and methods of linear algebra emphasizing matrices and systems of equations, determinants, eigenvectors and eigenvalues. This course is an excellent introduction to linear algebra for students who are interested in a math minor. It does not satisfy requirements for the math major. Students who might be interested in the math major should consider taking Math 313.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Recommendations and additional information:** Credit allowed for only one of the following: MATH 310, MATH 313.

**Enrollment requirement:** MATH 250B, 254 or 355. Must not have taken MATH 313.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 313: Introduction to Linear Algebra** (3 units)

**Description:** An algorithmic approach to solving systems of linear equations transitions into the study of vectors, vector spaces and dimension. Matrices are used to represent linear transformations and this leads to eigenvectors and eigenvalues. The precise use of definitions plays an important role. Examinations are proctored. This course is required in the math major and prepares students to take Math 323. It is a prerequisite to the majority of the higher level courses in mathematics.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 215, MATV 313

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Recommendations and additional information:** Credit is allowed for only one of the following courses: MATH 310 or MATH 313.

**Enrollment requirement:** MATH 129, MATH 223, MATH 243, MATH 254, CSC 144, or CSC 245. Must not have taken MATH 310.

**MATH 315: Introduction to Number Theory and Modern Algebra** (3 units)

**Description:** Divisibility properties of integers, primes, congruencies, quadratic residues, number-theoretic functions.

**Grading basis:** Student Option ABCDE/PF

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATV 315

**Course typically offered:**

Main Campus: Spring

**Enrollment requirement:** MATH 215 or 313.

**Approved Grading:** Pass/Fail Option

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 322: Mathematical Analysis for Engineers** (3 units)

**Description:** This course prepares students for working with linear systems that arise in engineering applications. Emphasis is placed on general principles of linearity and orthogonality. Topics include complex numbers and functions, matrix and vector algebra, linear systems of ODEs, Fourier series and transforms, separable partial differential equations.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Discussion                      May Be Offered  
Lecture    Required

**Equivalent to:** MATH 422

**Course typically offered:**

Main Campus: Fall, Spring

**Recommendations and additional information:** Credit allowed for only one of the following: MATH 322 or MATH 422.

**Enrollment requirement:** MATH 223 and (MATH 250B, 254 or 355).

**MATH 323: Formal Mathematical Reasoning and Writing** (3 units)

**Description:** Elementary real analysis as an introduction to abstract mathematics and the use of mathematical language. Elementary logic and quantifiers; manipulations with sets, relations and functions, including images and pre-images; properties of the real numbers; supreme and infimum; other topics selected from cardinality, the topology of the real line, sequence and limits of sequences and functions; the emphasis throughout is on proving theorems.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture                                      Required

**Equivalent to:** MATV 323

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Enrollment requirement:** ((Math 313 or 215) and (C or higher in (Math 243 or Math 315 or CSC 245))); OR C or higher in (Math 313 or Math 215) OR, Math Milestone level 8. Concurrent enrollment in Math 396L required if (Math 215 or (C or D in Math 313))

**Writing Emphasis:** Writing Emphasis Course

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 330: Topics in Geometry** (3 units)

**Description:** Topics to be selected from 2- and 3-dimensional combinatorial geometry, Euclidean transformational geometry, symmetry, geometric optimization (shortest path problems), theorem of the arithmetic and geometric means, isoperimetric problem, polyhedra, and 3- and... 2-dimensional crystallography.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATV 330

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** MATH 313 or MATH 310.

**Enrollment requirement:** MATH 313 or MATH 310.

**MATH 355: Analysis of Ordinary Differential Equations** (3 units)

**Description:** Linear and nonlinear equations; basic solution techniques; qualitative and numerical methods; systems of equations; computer studies; applications drawn from physical, biological and social sciences.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 250B, MATH 254, MATV 355

**Course typically offered:**

Main Campus: Fall, Spring

**Enrollment requirement:** (Math 215 or 313) and (Math 129 or 223).

**MATH 361: Elements of Statistics using Calculus** (3 units)

**Description:** Focusing on statistical inference, the course has two goals in addition to teaching the statistical techniques. One is theoretical: To explore the links between probability, statistics and calculus, showing students the mathematical underpinnings. The second is applied: Provides experience with real data sets, many bearing on education. Students who complete this course will be prepared to teach high school level statistics courses.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Also offered as:** DATA 361

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** Credit allowed for only one of MATH 361 or MATH 363 or DATA 363

**Enrollment requirement:** MATH 223.

**Approved Grading:** Pass/Fail Option

**Honors Course:** Honors Contract

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 362: Introduction to Probability Theory (3 units)**

**Description:** Sample spaces, random variables and their properties, with considerable emphasis on applications. Computer exercises and hands-on activities will be used in class to introduce the concepts.

**Grading basis:** Student Option ABCDE/PF

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATV 362

**Also offered as:** DATA 362

**Course typically offered:**

Main Campus: Fall

**Enrollment requirement:** MATH 223.

**Approved Grading:** Pass/Fail Option

**MATH 363: Introduction to Statistical Methods (3 units)**

**Description:** An applications-oriented calculus-based statistics course with an introduction to statistical software. Course topics: Organizing data numerically and visually. Axioms of probability, conditional probability and independence. Random variables and expectation with emphasis on parametric families. Law of large numbers and central limit theorem. Estimation, bias and variance, confidence intervals. Hypothesis testing, significance and power. Likelihood ratio tests such as proportion tests, t-tests, chi-square tests, and analysis of variance.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Also offered as:** DATA 363

**Course typically offered:**

Main Campus: Fall, Spring

**Recommendations and additional information:** Ability to program, preferably in Python.

**Home department:** Mathematics

**Enrollment requirement:** Math 223 and (CSC 110 or ISTA 130) and have completed Math 310, 313, or 215, or are registered for Math 310 or 313.

**Course Equivalencies:** Cross Listed

**Honors Course:** Honors Contract

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 391: Preceptorship** (1 - 6 units)

**Description:** Specialized work on an individual basis, consisting of instruction and practice in actual service to a department, program, or discipline.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Independent Study Required

**Repeatable:** Course can be repeated a maximum of 4 times.

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Student Engagement Activity:** Leadership

**Student Engagement Competency:** Professionalism

**MATH 392: Directed Research** (1 - 6 units)

**Description:** Individual research under the guidance of faculty.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Independent Study Required

**Repeatable:** Course can be repeated a maximum of 4 times.

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Student Engagement Activity:** Discovery

**Student Engagement Competency:** Innovation and Creativity

**MATH 393: Internship** (1 - 10 units)

**Description:** Specialized work on an individual basis, consisting of training and practice in actual service in a technical, business, or government establishment.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Independent Study Required

**Course typically offered:**

Main Campus: Fall, Spring, Summer

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-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.



**MATH 395M: Career Exploration in Mathematics and Data Science (1 unit)**

**Description:** Colloquium-style course designed to help advanced math and SDS majors with career preparation, applications to internships, research programs and graduate school. We will also introduce topics of current research interest in mathematics and data science.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Colloquium Required

**Also offered as:** DATA 395M

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** Students who are enrolled in or have completed a 400 level math course can add through the instructor.

**Enrollment requirement:** MATH 323 or 355 or MATH/DATA 363.

**Course Equivalencies:** Cross Listed

**MATH 396L: Wildcat Proofs Workshop (1 unit)**

**Description:** This course is designed as a complement to Math 323. Students enrolled in the course will participate in a weekly problem session pertaining to material covered in Math 323. The primary purpose of this course is to give students many opportunities to share their mathematical conjectures and their justifications to classmates. During class meetings students will debate the validity of mathematical statements and formal proofs. Concurrent registration in Math 323 is required.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Seminar Required

**Repeatable:** Course can be repeated a maximum of 5 times.

**Course typically offered:**

Main Campus: Fall, Spring

**Enrollment requirement:** Co-Requisite: MATH 323.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 396T: Topics in Undergraduate Mathematics** (3 units)

**Description:** Selected topics from modern mathematics. Content varies. The primary purpose of the course is to provide students the opportunity to gain knowledge, experience, and exposure to topics in modern mathematics beyond what is presented in the core subjects required for the math major.

**Grading basis:** Student Option ABCDE/PF

**Career:** Undergraduate

**Course Components:** Seminar Required

**Repeatable:** Course can be repeated a maximum of 3 times.

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** MATH 223 or MATH 313 or instructor permission.

**Enrollment requirement:** MATH 129 or Math 223 with C or better.

**MATH 399: Independent Study** (1 - 5 units)

**Description:** Qualified students working on an individual basis with professors who have agreed to supervise such work.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Independent Study Required

**Repeatable:** Course can be repeated a maximum of 99 times.

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**MATH 399H: Honors Independent Study** (1 - 5 units)

**Description:** Qualified students working on an individual basis with professors who have agreed to supervise such work.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Independent Study Required

**Repeatable:** Course can be repeated a maximum of 99 times.

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Enrollment requirement:** Student must be active in the Honors College.

**Honors Course:** Honors Course

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 401A: Symbolic Logic** (3 units)

**Description:** Intermediate propositional logic and quantificational theory, natural deduction, axiom systems, elementary metatheorems, introduction to notions of modal logic, selected topics in philosophy of logic. Credit allowed for only one of these courses: PHIL 401A, PHIL 402.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** CSC 401A, MATH 401A

**Also offered as:** CSC 401A, PHIL 401A

**Co-convened with:**

**Course typically offered:**

Main Campus: Fall

**Home department:** Philosophy

**Course Equivalencies:** Cross Listed

**MATH 401B: Symbolic Logic** (3 units)

**Description:** Advanced propositional logic and quantification theory; metatheorems on consistency, independence, and completeness; set theory, number theory, and modal theory; recursive function theory and Goedel's incompleteness theorem.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** CSC 401B, MATH 401B

**Also offered as:** CSC 401B, PHIL 401B

**Co-convened with:**

**Course typically offered:**

Main Campus: Spring

**Home department:** Philosophy

**Course Equivalencies:** Cross Listed

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 402: Mathematical Logic** (3 units)

**Description:** [Taught Fall semester in even-numbered years] Sentential calculus, predicate calculus; consistency, independence, completeness, and the decision problem. Designed to be of interest to majors in mathematics or philosophy.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** CSC 402, CSCV 402, CSCV 402, MATV 402, PHIL 402

**Co-convened with:** MATH 502

**Course typically offered:**

Main Campus: Fall (even years only)

**Recommendations and additional information:** MATH 122B or MATH 125; experience with theoretical mathematical reasoning. Credit allowed for only one of these courses: MATH 402 or MATH 401A.

**MATH 404: History of Mathematics** (3 units)

**Description:** The development of mathematics from ancient times through the 17th century, with emphasis on problem solving. The study of selected topics from each field is extended to the 20th century.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Co-convened with:** MATH 504

**Course typically offered:**

Main Campus: Fall

**Enrollment requirement:** Prerequisite: Math 243 or 310 or 313 or 323.

**MATH 406A: Curriculum & Assessment in Secondary School Mathematics** (4 units)

**Description:** Examination of secondary school mathematics curricula with emphasis on the development of math topics; study of assessment with emphasis on its alignment with instruction; and practicum experiences with emphasis on curriculum analysis and implementation of assessment measures.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required  
Practicum Required

**Equivalent to:** MATH 406

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** This course is for Math Education majors only.

**Enrollment requirement:** MATH 205 and MATH 330 and EDP 301.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 406B: Methods of Teaching Mathematics in Secondary Schools** (4 units)

**Description:** Provides students with knowledge and experience to enable them to become effective secondary school mathematics teachers. Emphasis on modes of instruction, problem solving, use of technology, assessment, and national standards with special attention to the teaching of geometry, algebra, statistics, and discrete mathematics. Practicum experience focuses on effective teaching strategies and techniques used in secondary schools.

**Grading basis:** Regular Grades

**Career:** Undergraduate

<b>Course Components:</b>	Lecture	Required
	Practicum	Required

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** MATH 406A, STCH 310. This course is for Math Education majors only.

**Enrollment requirement:** MATH 406A. (No transfer credit allowed).

**MATH 407: Synthesis of Mathematical Concepts** (3 units)

**Description:** Math taught in secondary schools from an advanced perspective: Algebra, Geometry, and Discrete Math - with particular emphasis on modeling and investigating the deep mathematics behind "routine" problems.

**Grading basis:** Regular Grades

**Career:** Undergraduate

<b>Course Components:</b>	Lecture	Required
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**Course typically offered:**

Main Campus: Fall

**Enrollment requirement:** MATH 323 and ( MATH 315 or MATH 415A) and (MATH 330 or MATH 430).

**MATH 413: Linear Algebra** (3 units)

**Description:** Vector spaces, linear transformations and matrices, determinants, eigenvalues and diagonalization, bilinear forms, orthogonal and unitary transformations, Jordan canonical form.

**Grading basis:** Regular Grades

**Career:** Undergraduate

<b>Course Components:</b>	Lecture	Required
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**Equivalent to:** MATV 413

**Co-convened with:** MATH 513

**Course typically offered:**

Main Campus: Fall, Spring

**Enrollment requirement:** MATH 323.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 415A: Introduction to Abstract Algebra** (3 units)

**Description:** Introduction to groups, rings, and fields.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 415, MATV 415A

**Co-convened with:** MATH 515A

**Course typically offered:**

Main Campus: Fall

**Enrollment requirement:** MATH 323.

**MATH 415B: Second Course in Abstract Algebra** (3 units)

**Description:** A continuation of MATH 415A/515A. Topics may include finite groups, matrix groups, Galois theory, linear and multilinear algebra, finite fields and coding theory.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 416, MATV 415B

**Co-convened with:** MATH 515B

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** MATH 415A.

**Enrollment requirement:** MATH 415A.

**MATH 422: Advanced Applied Mathematics** (3 units)

**Description:** Applications of vector calculus, complex variables, and Sturm Liouville theory. Fourier series, Fourier and Laplace transforms, and separation of variables in classical partial differential equations. This course takes a more mathematical approach than Math 322.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 322

**Co-convened with:** MATH 522

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Recommendations and additional information:** Credit allowed for only one of the following: MATH 422 or MATH 322.

**Enrollment requirement:** (MATH 215 or 313 or 310 or 410) and MATH 223 and (MATH 254 or 355 or 250B).

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 424: Theory of Complex Variables (3 units)**

**Description:** Complex numbers, analytic functions, harmonic functions, elementary functions, complex integration, Cauchy's integral theorem, series representations for analytic functions, residue theory, conformal mapping, applications.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 421

**Co-convened with:** MATH 524

**Course typically offered:**

Main Campus: Spring

**Enrollment requirement:** MATH 250B, 254 or 355.

**MATH 425A: Real Analysis of One Variable (3 units)**

**Description:** Continuity and differentiation of functions of one variable. Riemann integration, sequences and series of functions and uniform convergence.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 425

**Co-convened with:** MATH 525A

**Course typically offered:**

Main Campus: Fall

**Enrollment requirement:** MATH 323.

**MATH 425B: Real Analysis of Several Variables (3 units)**

**Description:** Continuity and differentiation in higher dimensions, curves and surfaces; change of coordinates; theorems of Green, Gauss and Stokes; inverse and implicit function theorems.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 426

**Co-convened with:** MATH 525B

**Course typically offered:**

Main Campus: Spring

**Enrollment requirement:** MATH 425A.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 432: Topological Spaces** (3 units)

**Description:** Set theory (countability/uncountability), topological spaces and continuous maps, metric spaces, connectedness and compactness, separability axioms and Hausdorff spaces, Tychonoff product theorem, introductory topics from algebraic topology (homotopy, fundamental group) or category theory.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Co-convened with:** MATH 532

**Course typically offered:**

Main Campus: Spring

**Enrollment requirement:** MATH 323.

**MATH 443: Theory of Graphs and Networks** (3 units)

**Description:** [Taught Fall semester in even-numbered years] Undirected and directed graphs, connectivity, circuits, trees, partitions, planarity, coloring problems, matrix methods, applications in diverse disciplines.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** CSC 443, CSCV 443, CSCV 443, MATV 443

**Co-convened with:** MATH 543

**Course typically offered:**

Main Campus: Fall (even years only)

**Enrollment requirement:** MATH 323 or level 09 or ((MATH 243 or CSC 245) AND (Math 215 or Math 313 or Level 08))

**MATH 445: Introduction to Cryptography** (3 units)

**Description:** [Taught Spring semester in even-numbered years]. Introduction to cryptosystems and cryptanalysis. Basic number theory and finite fields. Basic complexity theory and probability. RSA and Diffie-Hellman protocols, factorization and discrete log attacks. Advanced encryption standard. Additional topics as times allows.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATV 445

**Course typically offered:**

Main Campus: Spring (even years only)

**Recommendations and additional information:** Ability to program in C, Java, or Python.

**Enrollment requirement:** Appropriate Math Placement Level or MATH 215 or MATH 313.

**Honors Course:** Honors Contract

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.



**MATH 446: Theory of Numbers** (3 units)

**Description:** [Taught Spring semester in odd-numbered years]. Divisibility properties of primes, congruences, quadratic residues, number-theoretic functions, primality, factoring, applications to cryptography, introduction to algebraic numbers.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** MATV 446

**Co-convened with:** MATH 546

**Course typically offered:**

Main Campus: Spring (odd years only)

**Enrollment requirement:** MATH 323.

**MATH 447: Combinatorial Mathematics** (3 units)

**Description:** [Taught Spring semester in odd-numbered years]. Enumeration and construction of arrangements and designs; generating functions; principle of inclusion-exclusion; recurrence relations; a variety of applications.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Co-convened with:** MATH 547

**Course typically offered:**

Main Campus: Spring (odd years only)

**Enrollment requirement:** MATH 215 or 313 or 243.

**MATH 454: Ordinary Differential Equations and Stability Theory** (3 units)

**Description:** General theory of initial value problems, linear systems and phase portraits, linearization of nonlinear systems, stability and bifurcation theory, an introduction to chaotic dynamics.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall, Spring

**Enrollment requirement:** (MATH 215 or 313 or 310 or 410) and (MATH 254 or 355 or 250B).

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 456: Applied Partial Differential Equations (3 units)**

**Description:** Properties of partial differential equations and techniques for their solution: Fourier methods, Green's functions, numerical methods.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Co-convened with:** MATH 556

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** Some exposure to linear algebra at the level of MATH 215, MATH 313, MATH 410, MATH 322, or MATH 422 is necessary.

**Enrollment requirement:** MATH 223 and (MATH 254 or MATH 355 or MATH 250B).

**MATH 462: Financial Math (3 units)**

**Description:** Analysis of cash flows from an actuarial viewpoint. Interest theory, annuities, bonds, loans, and related fixed income portfolios, rate of return, yield, duration, immunization, and related concepts.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Also offered as:** DATA 462

**Course typically offered:**

Main Campus: Spring

**Enrollment requirement:** MATH 223.

**Honors Course:** Honors Contract

**MATH 464: Theory of Probability (3 units)**

**Description:** Probability spaces, random variables, weak law of large numbers, central limit theorem, various discrete and continuous probability distributions.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** STAT 464

**Course typically offered:**

Main Campus: Fall, Spring

**Recommendations and additional information:** Students are expected to complete the prerequisites appropriate to their major/minor.

**Enrollment requirement:** (MATH 223 and MATH 323) or (MATH 313 and MATH/DATA 363).

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 466: Theory of Statistics** (3 units)

**Description:** Sampling theory. Point estimation. Limiting distributions. Testing Hypotheses. Confidence intervals. Large sample methods.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall, Spring

**Enrollment requirement:** MATH 464.

**MATH 468: Applied Stochastic Processes** (3 units)

**Description:** Applications of Gaussian and Markov processes and renewal theory; Wiener and Poisson processes, queues.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** STAT 468

**Also offered as:** DATA 468

**Co-convened with:** MATH 568

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** MATH 464.

**Enrollment requirement:** MATH 464.

**MATH 475A: Mathematical Principles of Numerical Analysis** (3 units)

**Description:** Analysis of errors in numerical computations, solution of linear algebraic systems of equations, matrix inversion, eigenvalues, roots of nonlinear equations, interpolation and approximation. The software package Matlab (or something similar) is used.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** CSC 475A, CSCV 475A, CSCV 475A, MATV 475A

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** Ability to program in C, Python, or Matlab.

**Enrollment requirement:** (MATH 254 or 355 or 250B) and (MATH 215 or 310 or 313 or 410).

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 475B: Mathematical Principles of Numerical Analysis (3 units)**

**Description:** Numerical integration, solution of systems of ordinary differential equations, initial value and boundary value problems.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Equivalent to:** CSC 475B, CSCV 475B, CSCV 475B, MATV 475B

**Course typically offered:**

Main Campus: Spring

**Enrollment requirement:** MATH 475A.

**MATH 481: Mathematical modeling of fluid flow through and around organs and organisms (3 units)**

**Description:** This course will focus on the mathematical modeling of fluid flows through and around organs and organisms, with an emphasis on topics of current medical and environmental interest. The natural world is replete with examples of cells, organs, and organisms whose shape influences flow to their benefit. For example, the shape of a maple seed generates lift which allows them to disperse farther. The design of the aortic valve prevents backflow during ventricular refilling while reducing disturbed regions of flow. The structure of a coral reef enhances the uptake of nutrients and the removal of wastes. A barracudas body shape reduces drag and allows it to quickly accelerate. In this course, we will mathematically describe the shape of organisms using 3D computer aided design (CAD). We will then use computational and experimental fluid dynamics to resolve the flow around 3D printed physical and numerical models. Mathematical topics will include the use of differential equations to describe fluid flow, numerical solutions of differential equations, image analysis, and the use of computational fluid dynamics software.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall

Online Campus: Fall

**Recommendations and additional information:** Math 223 is a required prerequisite, Math 254 or Math 355 are recommended.

**Enrollment requirement:** MATH 223 prerequisite.

**Honors Course:** Honors Contract

**Writing Emphasis:** Writing Emphasis Course

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 485: Mathematical Modeling** (3 units)

**Description:** Development, analysis, and evaluation of mathematical models for physical, biological, social, and technical problems; both analytical and numerical solution techniques are required.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Flat Fee:** \$21

**Course Components:** Lecture Required

**Co-convened with:** MATH 585

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** Ability to program in MATLAB, Python, C, or Java

**Enrollment requirement:** (MATH 215 or 313) and (MATH 254 or 355) and (MATH 422 or 454 or 456 or 464 or 475A).

**Student Engagement Activity:** Discovery

**Student Engagement Competency:** Professionalism

**Writing Emphasis:** Writing Emphasis Course

**MATH 488: Topics in Mathematical Physics** (3 units)

**Description:** Advanced topics in field theories, mathematical theory of quantum mechanics, mathematical theory of statistical mechanics; content varies

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Lecture Required

**Repeatable:** Course can be repeated a maximum of 5 times.

**Co-convened with:** MATH 588

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** MATH 425B preferred, knowledge of Special Relativity is necessary.

**Enrollment requirement:** (MATH 215 or 313 or 310 or 410) and MATH 223 and (MATH 254 or 355 or 250B).

**MATH 491: Preceptorship** (1 - 6 units)

**Description:** Specialized work on an individual basis, consisting of instruction and practice in actual service to a department, program, or discipline.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Independent Study Required

**Repeatable:** Course can be repeated a maximum of 4 times.

**Course typically offered:**

Main Campus: Fall, Spring, Summer

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 492: Directed Research** (1 - 6 units)

**Description:** Individual research under the guidance of faculty.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Independent Study      Required

**Repeatable:** Course can be repeated a maximum of 4 times.

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Student Engagement Activity:** Discovery

**Student Engagement Competency:** Innovation and Creativity

**MATH 493: Internship** (1 - 10 units)

**Description:** Specialized work on an individual basis, consisting of training and practice in actual service in a technical, business, or government establishment.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Independent Study      Required

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**MATH 494C: Secondary Mathematics Student Teaching Practicum** (15 units)

**Description:** This practicum is an internship that provides secondary mathematics teachers with student teaching experiences under the supervision of experienced classroom teachers and a university supervisor. Responsibility for teaching will increase gradually throughout the semester. A Student Teaching Placement Application must be completed and submitted the prior semester to student teaching. This practicum has student teaching seminars TBD by the mathematics education faculty prior to the semester.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Practicum      Required

**Repeatable:** Course can be repeated a maximum of 2 times.

**Course typically offered:**

Main Campus: Fall, Spring

**Recommendations and additional information:** MATH 406B. Pedagogy courses GPA greater or equal to 2.5. Overall GPA and Major GPA greater or equal to 2.0.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 496T: Advanced Topics in Undergraduate Mathematics (3 units)**

**Description:** Advanced topics from modern mathematics. Content varies. The primary purpose of the course is to provide students the opportunity to gain knowledge, experience, and exposure to advanced topics in modern mathematics beyond what is presented in the core subjects for the math major.

**Grading basis:** Student Option ABCDE/PF

**Career:** Undergraduate

**Course Components:** Seminar Required

**Repeatable:** Course can be repeated a maximum of 3 times.

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** MATH 323 or MATH 355 or instructor permission.

**Enrollment requirement:** MATH 313 or MATH 310.

**MATH 498: Senior Capstone (1 - 3 units)**

**Description:** A culminating experience for majors involving a substantive project that demonstrates a synthesis of learning accumulated in the major, including broadly comprehensive knowledge of the discipline and its methodologies. Senior standing required.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Independent Study Required

**Equivalent to:** MATV 498

**Course typically offered:**

Main Campus: Fall, Spring

**MATH 498H: Honors Thesis (3 units)**

**Description:** An honors thesis is required of all the students graduating with honors. Students ordinarily sign up for this course as a two-semester sequence. The first semester the student performs research under the supervision of a faculty member; the second semester the student writes an honors thesis.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Independent Study Required

**Repeatable:** Course can be repeated for a maximum of 9 units.

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Enrollment requirement:** Student must be active in the Honors College.

**Honors Course:** Honors Course

**Writing Emphasis:** Writing Emphasis Course

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 499: Independent Study** (1 - 5 units)

**Description:** Qualified students working on an individual basis with professors who have agreed to supervise such work.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Undergraduate

**Course Components:** Independent Study      Required

**Repeatable:** Course can be repeated a maximum of 99 times.

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**MATH 499H: Honors Independent Study** (1 - 5 units)

**Description:** Qualified students working on an individual basis with professors who have agreed to supervise such work.

**Grading basis:** Regular Grades

**Career:** Undergraduate

**Course Components:** Independent Study      Required

**Repeatable:** Course can be repeated a maximum of 99 times.

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Enrollment requirement:** Student must be active in the Honors College.

**Honors Course:** Honors Course

**MATH 500A: Research on the Learning of Mathematics for Teachers** (3 units)

**Description:** Research on student learning of mathematics with a focus on implications for classroom practice in the middle grades; topics include number/operation, algebraic reasoning, student motivation, and proportional reasoning.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture                                      Required

**Course typically offered:**

Main Campus: Summer

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.



**MATH 501A: Symbolic Logic** (3 units)

**Description:** Intermediate propositional logic and quantificational theory, natural deduction, axiom systems, elementary metatheorems, introduction to notions of modal logic, selected topics in philosophy of logic. Graduate-level requirements include an in-depth research project on a central theme or topic of the course. Courses for which students receive the grade of P (Pass) do not satisfy requirements for the M.A. or Ph.D. or minor in philosophy.

**Grading basis:** Student Option ABCDE/PF

**Career:** Graduate

**Course Components:** Lecture Required

**Equivalent to:** CSC 501A, MATH 501A

**Also offered as:** CSC 501A, PHIL 501A

**Co-convened with:** MATH 401A

**Course typically offered:**

Main Campus: Fall

**Home department:** Philosophy

**Course Equivalencies:** Cross Listed

**Approved Grading:** Pass/Fail Option

**MATH 501B: Symbolic Logic** (3 units)

**Description:** Advanced propositional logic and quantification theory; metatheorems on consistency, independence, and completeness; set theory, number theory, and modal theory; recursive function theory and Goedel's incompleteness theorem. Graduate-level requirements include an in-depth research project on a central theme or topic of the course. Courses for which students receive the grade of P (Pass) do not satisfy requirements for the M.A. or Ph.D. or minor in philosophy.

**Grading basis:** Student Option ABCDE/PF

**Career:** Graduate

**Course Components:** Lecture Required

**Equivalent to:** CSC 501B, MATH 501B

**Also offered as:** CSC 501B, PHIL 501B

**Co-convened with:** MATH 401B

**Course typically offered:**

Main Campus: Spring

**Home department:** Philosophy

**Course Equivalencies:** Cross Listed

**Approved Grading:** Pass/Fail Option

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 502: Mathematical Logic** (3 units)

**Description:** [Taught Fall semester in even-numbered years] Sentential calculus, predicate calculus; consistency, independence, completeness, and the decision problem. Designed to be of interest to majors in mathematics or philosophy. Graduate-level requirements include more extensive problem sets or advanced projects.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Equivalent to:** CSC 502, PHIL 502

**Also offered as:** CSC 502, PHIL 502

**Co-convened with:** MATH 402

**Course typically offered:**

Main Campus: Fall (even years only)

**Course Equivalencies:** Cross Listed

**MATH 504: History of Mathematics** (3 units)

**Description:** The development of mathematics from ancient times through the 17th century, with emphasis on problem solving. The study of selected topics from each field is extended to the 20th century. Graduate-level requirements include more extensive problem sets or advanced projects.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Co-convened with:** MATH 404

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** Not applicable to M.A., M.S., or Ph.D. degrees for math majors except for the M.A. teaching option.

**MATH 505C: Algebra for Elementary & Middle School Teachers** (3 - 4 units)

**Description:** This course focuses on the transition from arithmetic to algebraic thinking, particularly in grades 5-8. The pedagogical approach emphasizes problem-solving, use of technology and hands-on materials, communication, and strategies to work with English Language Learners.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (even years only)

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 505D: Data Analysis and Probability for K-8 Teachers** (3 - 4 units)

**Description:** The course focuses on developing a deep understanding of key ideas of probability and data analysis in grades K-8. Students will collect, represent and analyze data to make predictions in real-world situations. Experimental and theoretical probability will be discussed.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall (even years only)

**MATH 505E: Number and Operations for K-8 Teachers** (3 - 4 units)

**Description:** This course focuses on K-8 concepts about number systems (e.g., whole numbers, integers, rational numbers) and number operations (meanings and algorithms). The pedagogical approach emphasizes explorations, use of hands-on materials and communication of problem-solving strategies.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (odd years only)

**MATH 505F: Geometry and Measurement for K-8 Teachers** (3 - 4 units)

**Description:** The course focuses on developing a deep understanding of key ideas of geometry and measurement in grades K-8 (e.g., shape, transformations, different measurements). Students will construct models and use hands-on materials and technology to engage in geometric problem-solving.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall (odd years only)

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 506A: Research on the Learning of Mathematics** (3 units)

**Description:** [Taught Fall semester in even numbered years]. Research on learning theories and student learning of mathematics, including number/operation, spatial reasoning, algebra, proof, calculus and advanced topics; theories including constructivism, social, situated and enactivist perspectives, models/modeling, critical theory

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall (even years only)

**MATH 506B: Research Methods in Math Education** (3 units)

**Description:** [Taught Spring semester in odd-numbered years]. Evolution of mathematics education research methodology; examination of survey research, clinical interviews, teaching experiments, ethnographies, and standardized testing, etc; development of skills to review research and identify researchable questions in mathematics education.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (odd years only)

**MATH 506C: Research on the Teaching of Mathematics** (3 units)

**Description:** Examination of approaches to the study of mathematics teaching including evaluation of the theories and perspectives of mathematics instruction, the factors influencing instructional practice, studies of teachers' mathematical knowledge and beliefs, and research on teacher development and change.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (even years only)

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 507C: Problem Solving for Secondary Mathematics Teachers** (3 units)

**Description:** This course provides secondary teachers with the opportunity to explore open-ended problems in Mathematics. The teachers will be introduced to the algorithms, and the concepts that underlie the exploratory problems. They will write up their research and also present their findings to the class.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall (even years only)

**Recommendations and additional information:** Bachelors Degree.

**MATH 507D: Modern Algebra for Secondary Mathematics Teachers** (3 units)

**Description:** This course introduces secondary teachers to the structure and the theory behind algebra. It includes an in-depth study of polynomials; their factors, roots, and coefficients.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (odd years only)

**Recommendations and additional information:** Bachelors Degree.

**MATH 507E: Principles of Calculus for Secondary School Teachers** (3 units)

**Description:** This course investigates the concepts underlying calculus. The most fundamental of these limits of functions. Numerical, algebraic, and graphical properties of functions are analyzed.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall (odd years only)

**Recommendations and additional information:** Bachelors Degree.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 507F: Probability and Statistics for Secondary Math Teachers** (3 units)

**Description:** This course develops both statistical thinking that will help in analyzing data sets and drawing useful conclusions, and combinatorial principles that will help in understanding the concept of probability.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (even years only)

**Recommendations and additional information:** Bachelors Degree.

**MATH 509C: Statistics for Research** (3 units)

**Description:** Statistical concepts and methods applied to research in other scientific disciplines. Principles of estimation and hypothesis testing for standard one-and two-sample procedures. Correlation, linear regression. Contingency tables and analysis of variance.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Equivalent to:** GENE 509C, PCOL 509C

**Also offered as:** GENE 509C, PCOL 509C

**Course typically offered:**

Main Campus: Spring (even years only)

**Recommendations and additional information:** MATH 112.

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Global Change

**Grad Interdisciplinary Program:** Genetics

**Grad Interdisciplinary Program:** Physiological Sciences

**MATH 511A: Algebra** (3 units)

**Description:** Structure of groups, rings, modules, algebras; Galois theory.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** MATH 415A and MATH 415B, or MATH 413 and MATH 415A.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 511B: Algebra** (3 units)

**Description:** Structure of groups, rings, modules, algebras; Galois theory.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** MATH 511A.

**MATH 513: Linear Algebra** (3 units)

**Description:** Vector spaces, linear transformations and matrices, determinants, eigenvalues and diagonalization, bilinear forms, orthogonal and unitary transformations, Jordan canonical form. Graduate-level requirements include more extensive problem sets or advanced projects.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Co-convened with:** MATH 413

**Course typically offered:**

Main Campus: Fall, Spring

**Grad Interdisciplinary Program:** Global Change

**MATH 514A: Algebraic Number Theory** (3 units)

**Description:** [Taught Fall semester in odd-numbered years] Dedekind domains, complete fields, class groups and class numbers, Dirichlet unit theorem, algebraic function fields.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall (odd years only)

**Recommendations and additional information:** MATH 511B.

**MATH 514B: Algebraic Number Theory** (3 units)

**Description:** [Taught Spring semester in even numbered years] Dedekind domains, complete fields, class groups and class numbers, Dirichlet unit theorem, algebraic function fields.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (even years only)

**Recommendations and additional information:** MATH 514A.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 515A: Introduction to Abstract Algebra** (3 units)

**Description:** Graduate-level requirements include more extensive problem sets or advanced projects.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Co-convened with:** MATH 415A

**Course typically offered:**

Main Campus: Fall

**MATH 515B: Second Course in Abstract Algebra** (3 units)

**Description:** A continuation of MATH 415A/515A. Topics may include finite groups, matrix groups, Galois theory, linear and multilinear algebra, finite fields and coding theory. Graduate-level requirements include more extensive problem sets or advanced projects.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Co-convened with:** MATH 415B

**Course typically offered:**

Main Campus: Spring

**MATH 516: Commutative Algebra** (3 units)

**Description:** [Taught Spring semester in even-numbered years.] Commutative algebra is the foundation stone of modern algebraic geometry and this course should be viewed as a preparatory course for the Algebraic Geometry course (Math 536A/B) which is offered in the fall of every even numbered year. The course is designed with this purpose in mind. We will begin with the notion of localization of rings, notions of free, projective, injective modules, flat modules and move on to discuss prime and primary ideals and the primary decomposition theorem. After this we will introduce depth and dimension and prove the dimension theorem and introduce and study properties of local rings in some detail. The course will lead up to the characterization of regular local rings. This theorem, roughly speaking, lays the groundwork for the algebra-geometric analogue of the notion of smoothness. If time permits we will study the notion of Cohen-Macaulay and Gorenstein rings and some of their characterizations.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (even years only)

**Recommendations and additional information:** MATH 511A and MATH 511B.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.



**MATH 517A: Group Theory** (3 units)

**Description:** [Taught Fall semester in even numbered years] Selections from such topics as finite groups, abelian groups, characters and representations.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Repeatable:** Course can be repeated a maximum of 5 times.

**Course typically offered:**

Main Campus: Fall (even years only)

**Recommendations and additional information:** MATH 511B.

**MATH 517B: Group Theory** (3 units)

**Description:** [Taught Spring semester in odd-numbered years] Selections from such topics as finite groups, abelian groups, characters and representations.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Repeatable:** Course can be repeated a maximum of 5 times.

**Course typically offered:**

Main Campus: Spring (odd years only)

**Recommendations and additional information:** MATH 517A.

**MATH 518: Topics in Algebra** (3 units)

**Description:** Advanced topics in groups, rings, fields, algebras; content varies.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Repeatable:** Course can be repeated a maximum of 5 times.

**Course typically offered:**

Main Campus: Fall, Spring

**MATH 519: Topics in Number Theory and Combinatorics** (3 units)

**Description:** Advanced topics in algebraic number theory, analytic number theory, class fields, combinatorics; content varies.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Repeatable:** Course can be repeated a maximum of 5 times.

**Course typically offered:**

Main Campus: Fall, Spring

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 520A: Complex Analysis** (3 units)

**Description:** Analyticity, Cauchy's integral formula, residues, infinite products, conformal mapping, Dirichlet problem, Riemann mapping theorem.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** MATH 424.

**MATH 520B: Complex Analysis** (3 units)

**Description:** [Taught Spring semester in odd-numbered years.] Rudiments of Riemann surfaces.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** MATH 520A or MATH 582.

**MATH 521: Complex Variables with Applications** (3 units)

**Description:** Complex numbers, analytic functions, harmonic functions, elementary functions, complex integration, Cauchy's integral theorem, series representations for analytic functions, residue theory, conformal mapping, applications to steady-state temperature and oscillating systems. Graduate-level requirements include more extensive problem sets or advanced projects.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Co-convened with:** MATH 421

**Course typically offered:**

Main Campus: Fall, Spring, Summer

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 522: Advanced Applied Mathematics** (3 units)

**Description:** Applications of vector calculus, complex variables, and Sturm Liouville theory. Fourier series, Fourier and Laplace transforms, and separation of variables in classical partial differential equations. This course takes a more mathematical approach than Math 322. Graduate-level requirements include more extensive problem sets or advanced projects.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Co-convened with:** MATH 422

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**Grad Interdisciplinary Program:** Applied Biosciences

**MATH 523A: Real Analysis** (3 units)

**Description:** Lebesgue measure and integration, differentiation, Radon-Nikodym theorem, Lp spaces, applications.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** MATH 425A.

**Grad Interdisciplinary Program:** Statistics and Data Science

**MATH 523B: Real Analysis** (3 units)

**Description:** Lebesgue measure and integration, differentiation, Radon-Nikodym theorem, Lp spaces, applications.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** MATH 523A.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 524: Theory of Complex Variables** (3 units)

**Description:** Complex numbers, analytic functions, harmonic functions, elementary functions, complex integration, Cauchy's integral theorem, series representations for analytic functions, residue theory, conformal mapping, applications. Graduate-level requirements include more extensive problem sets or advanced project.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Co-convened with:** MATH 424

**Course typically offered:**

Main Campus: Spring

**MATH 525A: Real Analysis of One Variable** (3 units)

**Description:** Continuity and differentiation of functions of one variable. Riemann integration, sequences and series of functions and uniform convergence. Graduate-level requirements include more extensive problem sets or advanced projects.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Co-convened with:** MATH 425A

**Course typically offered:**

Main Campus: Fall

**MATH 525B: Real Analysis of Several Variables** (3 units)

**Description:** Continuity and differentiation in higher dimensions, curves and surfaces; change of coordinates; theorems of Green, Gauss and Stokes; inverse and implicit function theorems. Graduate-level requirements include more extensive problem sets or advanced projects.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Co-convened with:** MATH 425B

**Course typically offered:**

Main Campus: Spring

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 528A: Banach and Hilbert Spaces** (3 units)

**Description:** Introduction to the theory of normed spaces, Banach spaces and Hilbert spaces, operators on Banach spaces, spectral theory of operators on Hilbert spaces, applications.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** MATH 527B or MATH 523A.

**MATH 528B: Banach and Hilbert Spaces** (3 units)

**Description:** [Taught Spring semester in even-numbered years.] Introduction to the theory of normed spaces, Banach spaces and Hilbert spaces, operators on Banach spaces, spectral theory of operators on Hilbert spaces, applications.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (even years only)

**Recommendations and additional information:** MATH 528A.

**MATH 529: Topics in Modern Analysis** (3 units)

**Description:** Advanced topics in measure and integration, complex analysis in one and several complex variables, probability, functional analysis, operator theory; content varies.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall, Spring

**Grad Interdisciplinary Program:** Statistics and Data Science

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 532: Topological Spaces** (3 units)

**Description:** Set theory (countability/uncountability), topological spaces and continuous maps, metric spaces, connectedness and compactness, separability axioms and Hausdorff spaces, Tychonoff product theorem, introductory topics from algebraic topology (homotopy, fundamental group) or category theory. Graduate-level requirements include additional assignments and/or projects.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Co-convened with:** MATH 432

**Course typically offered:**

Main Campus: Spring

**MATH 534A: Topology-Geometry** (3 units)

**Description:** Point set topology, the fundamental group, calculus on manifolds. Homology, de Rham cohomology, other topics. Examples will be emphasized.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** MATH 415A, MATH 425A.

**MATH 534B: Topology-Geometry** (3 units)

**Description:** Point set topology, the fundamental group, calculus on manifolds. Homology, de Rham cohomology, other topics. Examples will be emphasized.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** MATH 534A.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 536A: Algebraic Geometry** (3 units)

**Description:** [Taught Fall semester in even numbered years] Affine and projective varieties, morphisms and rational maps. Dimension, degree and smoothness. Basic coherent sheaf theory and Cech cohomology. Line bundles, Riemann-Roch theorem.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall (even years only)

**Recommendations and additional information:** MATH 520A, MATH 534A.

**MATH 536B: Algebraic Geometry** (3 units)

**Description:** [Taught Spring semester in odd-numbered years] Affine and projective varieties, morphisms and rational maps. Dimension, degree and smoothness. Basic coherent sheaf theory and Cech cohomology. Line bundles, Riemann-Roch theorem.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (odd years only)

**Recommendations and additional information:** MATH 536A.

**MATH 537A: Global Differential Geometry** (3 units)

**Description:** [Taught Fall semester in odd-numbered years] Surfaces in  $R^3$ , structure equations, curvature. Gauss-Bonnet theorem, parallel transport, geodesics, calculus of variations, Jacobi fields and conjugate points, topology and curvature; Riemannian geometry, connections, curvature tensor, Riemannian submanifolds and submersions, symmetric spaces, vector bundles. Morse theory, symplectic geometry.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall (odd years only)

**Recommendations and additional information:** MATH 534A, MATH 534B.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 537B: Global Differential Geometry** (3 units)

**Description:** [Taught Spring semester in even-numbered years] Surfaces in  $R^3$ , structure equations, curvature. Gauss-Bonnet theorem, parallel transport, geodesics, calculus of variations, Jacobi fields and conjugate points, topology and curvature; Riemannian geometry, connections, curvature tensor, Riemannian submanifolds and submersions, symmetric spaces, vector bundles. Morse theory, symplectic geometry.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (even years only)

**Recommendations and additional information:** MATH 537A.

**MATH 538: Topics in Geometry and Topology** (3 units)

**Description:** Advanced topics in point set and algebraic topology, algebraic geometry, differential geometry; content varies.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Repeatable:** Course can be repeated a maximum of 5 times.

**Course typically offered:**

Main Campus: Fall, Spring

**MATH 539: Algebraic Coding Theory** (3 units)

**Description:** [Taught Spring semester in even-numbered years] Construction and properties of error correcting codes; encoding and decoding procedures and information rate for various codes.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Equivalent to:** ECE 539

**Also offered as:** ECE 539

**Course typically offered:**

Main Campus: Spring (even years only)

**Recommendations and additional information:** MATH 415A.

**Course Equivalencies:** Cross Listed

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.



**MATH 541: Introduction to Mathematical Physics** (3 units)

**Description:** Mathematical formulation and problems of statistical physics, quantum physics and field theory, relations between macroscopic and microscopic and between classical and quantum descriptions of physical systems, analytical, probabilistic and geometric methods. Contents vary.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Repeatable:** Course can be repeated a maximum of 3 times.

**Equivalent to:** PHYS 541

**Also offered as:** PHYS 541

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** MATH 523A, MATH 523B or MATH 527A, MATH 527B or consent of instructor.

**Course Equivalencies:** Cross Listed

**MATH 543: Theory of Graphs and Networks** (3 units)

**Description:** [Taught Fall semester in even-numbered years] Undirected and directed graphs, connectivity, circuits, trees, partitions, planarity, coloring problems, matrix methods, applications in diverse disciplines. Graduate-level requirements include more extensive problem sets or advanced projects.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Equivalent to:** CSC 543

**Also offered as:** CSC 543

**Co-convened with:** MATH 443

**Course typically offered:**

Main Campus: Fall (even years only)

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Statistics and Data Science

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 546: Theory of Numbers** (3 units)

**Description:** [Taught Spring semester in odd-numbered years]. Divisibility properties of primes, congruences, quadratic residues, number-theoretic functions, primality, factoring, applications to cryptography, introduction to algebraic numbers. Graduate-level requirements include more extensive problem sets or advanced projects.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Co-convened with:** MATH 446

**Course typically offered:**

Main Campus: Spring (odd years only)

**MATH 547: Combinatorial Mathematics** (3 units)

**Description:** [Taught Spring semester in odd-numbered years]. Enumeration and construction of arrangements and designs; generating functions; principle of inclusion-exclusion; recurrence relations; a variety of applications. Graduate-level requirements include more extensive problem sets or advanced projects.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Co-convened with:** MATH 447

**Course typically offered:**

Main Campus: Spring (odd years only)

**MATH 553A: Partial Differential Equations** (3 units)

**Description:** [Taught Fall semester in odd-numbered years] Theory and examples of linear equations; characteristics, well-posed problems, regularity, variational properties, asymptotics. Topics in nonlinear equations, such as shock waves, diffusion waves, and estimates in Sobolev spaces.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall (odd years only)

**Recommendations and additional information:** MATH 523B or MATH 527B or MATH 583B.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 553B: Partial Differential Equations** (3 units)

**Description:** [Taught Spring semester in even-numbered years] Theory and examples of linear equations; characteristics, well-posed problems, regularity, variational properties, asymptotics. Topics in nonlinear equations, such as shock waves, diffusion waves, and estimates in Sobolev spaces.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (even years only)

**Recommendations and additional information:** MATH 553A.

**MATH 554: Ordinary Differential Equations** (3 units)

**Description:** [Taught Spring semester in odd-numbered years.] General theory of linear systems, Foquet theory. Local theory of nonlinear systems, stable manifold and Hartman-Grobman theorems. Poincare-Bendixson theory, limit cycles, Poincare maps. Bifurcation theory, including the Hopf theorem.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (odd years only)

**Recommendations and additional information:** MATH 413 or consent of instructor.

**MATH 556: Applied Partial Differential Equations** (3 units)

**Description:** Properties of partial differential equations and techniques for their solution: Fourier methods, Green's functions, numerical methods. Graduate-level requirements include more extensive problem sets or advanced projects.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Co-convened with:** MATH 456

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** Some exposure to linear algebra at the level of MATH 215, MATH 410, MATH 322, or MATH 422 is necessary.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 557A: Dynamical Systems and Chaos** (3 units)

**Description:** [Taught Fall semester in odd-numbered years.] Qualitative theory of dynamical systems, phase space analysis, bifurcation, period doubling, universal scaling, onset of chaos. Applications drawn from atmospheric physics, biology, ecology, fluid mechanics and optics.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall (odd years only)

**Recommendations and additional information:** MATH 454 or (MATH 254 and MATH 422): and MATH 421 or MATH 424.

**MATH 557B: Dynamical Systems and Chaos** (3 units)

**Description:** [Taught Spring semester in even-numbered years.] Qualitative theory of dynamical systems, phase space analysis, bifurcation, period doubling, universal scaling, onset of chaos. Applications drawn from atmospheric physics, biology, ecology, fluid mechanics and optics.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (even years only)

**Recommendations and additional information:** MATH 557A.

**MATH 559A: Lie Groups and Lie Algebras** (3 units)

**Description:** [Taught Fall semester in even-numbered years]. Correspondence between Lie groups and Lie algebras, structure and representation theory, applications to topology and geometry of homogeneous spaces, applications to harmonic analysis.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall (even years only)

**Recommendations and additional information:** MATH 511A, MATH 523A, MATH 534A, MATH 534B or consent of instructor.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 559B: Lie Groups and Lie Algebras** (3 units)

**Description:** [Taught Spring semester in odd-numbered years]. Correspondence between Lie groups and Lie algebras, structure and representation theory, applications to topology and geometry of homogeneous spaces, applications to harmonic analysis.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (odd years only)

**Recommendations and additional information:** MATH 559A.

**MATH 563: Probability Math** (3 units)

**Description:** Random variables, expectation and integration, Borel-Cantelli lemmas, independence, sums of independent random variables, strong law of large numbers, convergence in distribution, central limit theorem, infinitely divisible distributions.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Equivalent to:** STAT 563

**Also offered as:** STAT 563

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** MATH 523B or MATH 527B or consent of instructor.

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Statistics and Data Science

**MATH 564: Theory of Probability** (3 units)

**Description:** Probability spaces, random variables, weak law of large numbers, central limit theorem, various discrete and continuous probability distributions. Graduate-level requirements include more extensive problem sets or advanced projects.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Equivalent to:** STAT 564

**Also offered as:** STAT 564

**Co-convened with:** MATH 464

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** Calculus through multivariable/vector calculus (at the level of MATH 125, MATH 129, MATH 223).

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Statistics and Data Science

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 565A: Stochastic Processes** (3 units)

**Description:** [Taught Spring semester in odd-numbered years]. Stochastic Processes in continuous time: Levy processes, Martingales, Markov processes, introduction to stochastic integrals.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (odd years only)

**Recommendations and additional information:** Strong probability background.

**Grad Interdisciplinary Program:** Statistics and Data Science

**MATH 565B: Stochastic Processes** (3 units)

**Description:** [Taught Fall semester in even-number years]. Stochastic processes in continuous time; Levy processes, martingales, Markov processes, introduction to stochastic integrals.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall (even years only)

**Recommendations and additional information:** MATH 565A.

**Grad Interdisciplinary Program:** Statistics and Data Science

**MATH 565C: Stochastic Differential Equations** (3 units)

**Description:** [Taught Spring semester in even-numbered years] Brownian motion, stochastic integrals, Ito formula, stochastic differential equations, diffusions, applications including: Partial differential equations, filtering, stochastic control

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (even years only)

**Recommendations and additional information:** MATH 565B, MATH 468/568 or consent of instructor.

**Grad Interdisciplinary Program:** Statistics and Data Science

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 566: Theory of Statistics** (3 units)

**Description:** Sampling theory. Point estimation. Limiting distributions. Testing Hypotheses. Confidence intervals. Large sample methods.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 566B, STAT 566, STAT 566A, STAT 566B

**Also offered as:** STAT 566

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** MATH 564.

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Statistics and Data Science

**MATH 567A: Theoretical Statistics I** (3 units)

**Description:** [Taught Spring semester in even-numbered years] Basic decision theory. Bayes' rules for estimation. Admissibility and completeness. The minimax theorem. Sufficiency. Exponential families of distributions. Complete sufficient statistics. Invariant decision problems. Location and scale parameters. Theory of nonparametric statistics. Hypothesis testing. Neyman-Pearson lemma. UMP and UMPU tests. Two-sided tests. Two-sample tests. Confidence sets. Multiple decision problems.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Equivalent to:** STAT 567A

**Also offered as:** STAT 567A

**Course typically offered:**

Main Campus: Spring (even years only)

**Recommendations and additional information:** MATH 563.

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Statistics and Data Science

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 567B: Theoretical Statistics II** (3 units)

**Description:** [Taught Fall semester in even-numbered years] Large sample theory of estimation: modes of convergence, central limit theorems, consistency and asymptotic distribution of estimators, asymptotic relative efficiencies of estimators, autoregressive time series, Cramer-Rao bounds and asymptotic efficiency of the MLE, asymptotic theory of Bayes estimators, semi-parametric linear regression, nonparametric regression and density estimation. Large sample theory of tests: likelihood ratio and Wald's tests in parametric models, the chi-square tests for multinomials, tests for goodness of fit, asymptotic relative efficiencies of tests, nonparametric one- and two-sample tests. Statistical computation: nonparametric bootstrap, Markov Chain Monte Carlo and Bayes theory, hierarchical models.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Equivalent to:** STAT 567B

**Also offered as:** STAT 567B

**Course typically offered:**

Main Campus: Fall (even years only)

**Recommendations and additional information:** MATH 567A.

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Statistics and Data Science

**MATH 568: Applied Stochastic Processes** (3 units)

**Description:** Applications of Gaussian and Markov processes and renewal theory; Wiener and Poisson processes, queues. Graduate-level requirements include more extensive problem sets or advanced projects.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Equivalent to:** STAT 568

**Co-convened with:** MATH 468

**Course typically offered:**

Main Campus: Spring

**Grad Interdisciplinary Program:** Statistics and Data Science

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.



**MATH 571A: Advanced Statistical Regression Analysis** (3 units)

**Description:** Regression analysis including simple linear regression and multiple linear regression. Matrix formulation and analysis of variance for regression models. Residual analysis, transformations, regression diagnostics, multicollinearity, variable selection techniques, and response surfaces. Students will be expected to utilize standard statistical software packages for computational purposes.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Equivalent to:** STAT 571A

**Also offered as:** STAT 571A

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** MATH 410 or MATH 413, or equivalent; MATH 461 or MATH 466, or equivalent. Graduate standing.

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Global Change

**Grad Interdisciplinary Program:** Statistics and Data Science

**MATH 571B: Design of Experiments** (3 units)

**Description:** Principles of designing experiments. Randomization, block designs, factorial experiments, response surface designs, repeated measures, analysis of contrasts, multiple comparisons, analysis of variance and covariance, variance components analysis.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Equivalent to:** STAT 571B

**Also offered as:** STAT 571B

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** MATH 223 or equivalent; MATH 571A.

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Applied Biosciences

**Grad Interdisciplinary Program:** Statistics and Data Science

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 573: Theory of Computation** (3 units)

**Description:** Chomsky hierarchy, undecidability; general recursive functions; recursion theory; computational complexity theory, NP-complete and provably intractable problems.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 573

**Also offered as:** CSC 573

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** CSC 473.

**Home department:** Computer Science

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Cognitive Science

**MATH 574E: Environmental Statistics** (3 units)

**Description:** Statistical methods for environmental and ecological sciences, including nonlinear regression, generalized linear models, temporal analyses, spatial analyses/kriging, quantitative risk assessment.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Equivalent to:** CPH 574E, MATH 574E

**Also offered as:** BIOS 574E, STAT 574E

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** MATH 571B, or PSYC 507C, or equivalent.

**Home department:** GIDP on Statistics

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Global Change

**Grad Interdisciplinary Program:** Statistics and Data Science

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 574G: Introduction to Geostatistics (3 units)**

**Description:** [Taught Spring semester in odd-numbered years] Exploratory spatial data analysis, random function models for spatial data, estimation and modeling of variograms and covariances, ordinary and universal kriging estimators and equations, regularization of variograms, estimation of spatial averages, non-linear estimators, includes use of geostatistical software. Application of hydrology, soil science, ecology, geography and related fields.

**Grading basis:** Regular Grades

**Career:** Graduate

**Flat Fee:** \$50

**Course Components:** Lecture Required

**Equivalent to:** MATH 574G, STAT 574G

**Also offered as:** GEOG 574G, STAT 574G

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** Linear algebra, basic course in probability and statistics, familiarity with DOS/Windows, UNIX.

**Home department:** School of Geography and Development

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Global Change

**Grad Interdisciplinary Program:** Remote Sensing & Spatial An.

**Grad Interdisciplinary Program:** Statistics and Data Science

**MATH 574M: Statistical Machine Learning (3 units)**

**Description:** Basic statistical principles and theory for modern machine learning, high dimensional data analysis, parametric and nonparametric methods, sparse analysis, shrinkage methods, variable selection, model assessment, model averaging, kernel methods, and unsupervised learning.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** Probability at the level of MATH 464, statistics at the level of MATH 363 or MATH 466, and linear algebra.

**Grad Interdisciplinary Program:** Statistics and Data Science

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 574T: Time Series Analysis** (3 units)

**Description:** Methods for analysis of time series data. Time domain techniques. ARIMA models. Estimation of process mean and autocovariance. Model fitting. Forecasting methods. Missing data. Students will be expected to utilize standard statistical software packages for computational purposes.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Equivalent to:** STAT 574T

**Also offered as:** STAT 574T

**Course typically offered:**

Main Campus: Fall, Spring

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Global Change

**Grad Interdisciplinary Program:** Statistics and Data Science

**MATH 576A: Numerical Analysis PDE** (3 units)

**Description:** [Taught Fall semester in even numbered years] Finite difference, finite element, and spectral discretization methods; semidiscrete, matrix, and Fourier analysis.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Fall (even years only)

**Recommendations and additional information:** MATH 413, MATH 456, MATH 575B.

**MATH 576B: Numerical Analysis PDE** (3 units)

**Description:** [Taught Spring semester in odd-numbered years] Well-posedness, numerical boundary conditions, nonlinear instability, time-split algorithms, special methods for stiff and singular problems.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (odd years only)

**Recommendations and additional information:** MATH 576A.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 577: Topics in Applied Mathematics** (3 units)

**Description:** Advanced topics in asymptotics, numerical analysis, approximation theory, mathematical theory of mechanics, dynamical systems, differential equations and inequalities, mathematical theory of statistics; content varies.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Repeatable:** Course can be repeated a maximum of 5 times.

**Equivalent to:** ATMO 577

**Course typically offered:**

Main Campus: Fall, Spring

**MATH 580: Mathematical Models in Biology** (3 units)

**Description:** For advanced undergraduates and graduate students in biological and ecological sciences, and math students: learn how to apply basic tools of mathematical tools (from simple back-of-the-envelope estimates to formal stability analysis using difference and differential equations) to biological problems including population dynamics, species coexistence, population genetics, links between ecosystems ecology and Global biogeochemistry, and biological scaling.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Also offered as:** ECOL 580

**Co-convened with:** ECOL 480

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** MATH 129.

**Home department:** Ecology & Evolutionary Biology

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Ecosystem Genomics

**Grad Interdisciplinary Program:** Global Change

**Grad Interdisciplinary Program:** Statistics and Data Science

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 581A: Methods of Applied Mathematics I** (3 units)

**Description:** Complex Analysis: variables; functions; analyticity; integrals; residue calculus; saddle-point method. Fourier Analysis: Fourier transform; Fourier series; delta-function; Riemann-Lebesgue lemma; Gibbs phenomenon. Ordinary Differential Equations: parameter variations; integrals of motion; phase portraits; perturbative analysis; Green's functions; Sturm-Liouville theory. Partial Differential Equations: method of characteristics; classification of second order linear (elliptic, hyperbolic, parabolic); separation of variables for boundary value problems; nonlinear examples. Other topics as chosen by the instructor.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Also offered as:** APPL 581A

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** Admission to Applied Math GIDP or Math 422 or Math 424 or Math 454 or Math 456 or equivalent

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Applied Mathematics

**MATH 581B: Methods of Applied Mathematics II** (3 units)

**Description:** Calculus of Variations: Euler-Lagrange; Classical Mechanics; Legendre-Fenchel; Elements of Convexity, Duality and Finite Dimensional Optimization; Lagrange multipliers. Optimal control and Dynamic Programming: Linear Quadratic Control; Bellman-Hamilton-Jacobi; Pontryagin Minimal Action Principle; DP in Optimal Control and Discrete Mathematics. Mathematics of Uncertainty: Basic Concepts from Statistics and Stochastic Processes. Inference and Learning Methods: exact and approximate inference and learning; sampling; Monte-Carlo methods; Graphical Models; Neural Networks. Other topics as chosen by the instructor.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Also offered as:** APPL 581B

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** Math 581A

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Applied Mathematics

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 582: Applied Complex Analysis** (3 units)

**Description:** [Taught Spring semester in even-numbered years.] Representations of special functions, asymptotic methods for integrals and linear differential equations in the complex domain, applications of conformal mapping, Wiener-Hopf techniques.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (even years only)

**Recommendations and additional information:** MATH 424.

**MATH 584A: Theoretical Foundations of Applied Mathematics I** (3 units)

**Description:** Analysis: Euclidean space; Metric spaces; Limits; Vector spaces; Norms; Basic inequalities of functional analysis. Convexity and Optimization: Convexity of sets, functions, optimization; Duality Theorem; Optimization Algorithm (convergence, uniqueness, complexity). Topology: open & closed sets; Metric topology; Completeness; Compactness; Contraction mapping. Integration: Riemann integral; Convergence; Multi-dimensional integrals; Flux; Flow; Conservation Laws; Divergence theorem. Other topics as chosen by the instructor.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Also offered as:** APPL 584A

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** Admission to Applied Math GIDP

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Applied Mathematics

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 584B: Theoretical Foundations of Applied Mathematics II** (3 units)

**Description:** Measure theory: Lebesgue measures; Lebesgue Integral; Convergence theorems; Product measures; Differentiation. Probability: Random numbers; Probability; Moments; Generating function; Independence; Law of large numbers; Central Limit Theorem; Large Deviation. Foundations of information theory: Multivariate distributions; Marginalization; Conditioning; Bayes theorem; Entropy; mutual information, comparison of probabilities; Shannon Theorem. Markov Chains: Transition probabilities; Steady-State Analysis; Perron-Frobenius theorem. Fourier Analysis: Fourier series and convergence; applications to PDEs. Other topics as chosen by the instructor.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Also offered as:** APPL 584B

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** Math 584A

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Applied Mathematics

**MATH 585: Mathematical Modeling** (3 units)

**Description:** Development, analysis, and evaluation of mathematical models for physical, biological, social, and technical problems; both analytical and numerical solution techniques are required. Graduate-level requirements include more advanced projects.

**Grading basis:** Regular Grades

**Career:** Graduate

**Flat Fee:** \$21

**Course Components:** Lecture Required

**Co-convened with:** MATH 485

**Course typically offered:**

Main Campus: Spring

**Grad Interdisciplinary Program:** Global Change

**Grad Interdisciplinary Program:** Neuroscience

**MATH 586: Case Studies in Applied Mathematics** (1 - 3 units)

**Description:** In-depth treatment of several contemporary problems or problem areas from a variety of fields, but all involving mathematical modeling and analysis; content varies.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Repeatable:** Course can be repeated for a maximum of 6 units.

**Course typically offered:**

Main Campus: Fall, Spring

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.



**MATH 587: Perturbation Methods in Applied Mathematics** (3 units)

**Description:** [Taught Spring semester in odd-numbered years]. Regular and singular perturbations, boundary layer theory, multiscale and averaging methods for nonlinear waves and oscillators.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Course typically offered:**

Main Campus: Spring (odd years only)

**Recommendations and additional information:** MATH 422; MATH 421 or MATH 454.

**MATH 588: Topics in Mathematical Physics** (3 units)

**Description:** Advanced topics in field theories, mathematical theory of quantum mechanics, mathematical theory of statistical mechanics; content varies. Graduate-level requirements include additional assignments and/or projects.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Repeatable:** Course can be repeated a maximum of 5 times.

**Co-convened with:** MATH 488

**Course typically offered:**

Main Campus: Fall, Spring

**MATH 589A: Algorithms of Applied Mathematics I** (3 units)

**Description:** Floating point arithmetic. Numerical linear algebra: Singular Value Decomposition, QR and LU factorizations. Eigenvalues and eigenvectors. Systems of non-linear equations: functional iteration, Newton's method. Numerical Differential Equations: basic integration schemes, order of accuracy. Initial Value Problem: Euler method, explicit-implicit methods, stability, Runge-Kutta methods, adaptive step size. Boundary Value Problem: shooting method, quasi-linearization. Other topics as chosen by the instructor.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Also offered as:** APPL 589A

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** Admission to Applied Math GIDP

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Applied Mathematics

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 589B: Algorithms of Applied Mathematics II** (3 units)

**Description:** Least squares problem. Unconstrained Optimization: gradient descent with backtracking, Newton method; constrained optimization: primal-dual Newton, interior point methods; linear programming. Inference and Learning Algorithms: sampling algorithms, Monte-Carlo method, importance sampling, stochastic optimization; regression, classification, clustering. Other topics as chosen by the instructor.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Also offered as:** APPL 589B

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** Math 589A

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Applied Mathematics

**MATH 593: Internship** (1 - 3 units)

**Description:** Specialized work on an individual basis, consisting of training and practice in actual service in a technical, business, or governmental establishment.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Graduate

**Course Components:** Independent Study Required

**Repeatable:** Course can be repeated a maximum of 99 times.

**Course typically offered:**

Main Campus: Fall, Spring

**MATH 595A: Math Instruction** (1 unit)

**Description:** The exchange of scholarly information and/or secondary research, usually in a small group setting. Instruction often includes lectures by several different persons. Research projects may or may not be required of course registrants.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Colloquium Required

**Repeatable:** Course can be repeated a maximum of 12 times.

**Course typically offered:**

Main Campus: Fall, Spring

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 595C: Research in Applied Mathematics** (1 unit)

**Description:** The exchange of scholarly information and/or secondary research, usually in a small group setting. Instruction often includes lectures by several different persons. Research projects may or may not be required of course registrants.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Graduate

**Course Components:** Colloquium Required

**Repeatable:** Course can be repeated a maximum of 5 times.

**Course typically offered:**

Main Campus: Fall, Spring

**MATH 595D: Research in Mathematics Education** (1 - 3 units)

**Description:** Readings and discussion of research in Mathematics education, usually in small group setting. Course includes presentations by different persons. Research projects may or may not be required of course registrants. Emphasis on exchange of scholarly information.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Colloquium Required

**Repeatable:** Course can be repeated for a maximum of 6 units.

**Course typically offered:**

Main Campus: Fall, Spring

**MATH 596A: Topics in Mathematics** (1 - 3 units)

**Description:** The development and exchange of scholarly information, usually in a small group setting. The scope of work shall consist of research by course registrants, with the exchange of the results of such research through discussion, reports, and/or papers.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Seminar Required

**Repeatable:** Course can be repeated for a maximum of 12 units.

**Course typically offered:**

Main Campus: Fall, Spring

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 596B: Mathematics Mentoring Methods** (1 unit)

**Description:** This course is designed to focus on adult learning theories in order that the participants can then assist other teachers to examine their own teaching practices so that lessons are designed and delivered to maximize student engagement and improve student achievement.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Seminar Required

**Course typically offered:**

Main Campus: Summer

**Recommendations and additional information:** Bachelors in Elementary Education or Secondary certified in Mathematics.

**MATH 596C: Mathematics Instruction for English Language Learners** (2 - 3 units)

**Description:** This course focuses on mathematics education and English Language Learners (e.g., sheltered mathematics teaching strategies, assessment). It addresses content and pedagogy around topics such as proportional reasoning, algebraic thinking, patterns and functions, and measurement.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Seminar Required

**Course typically offered:**

Main Campus: Spring

**MATH 596F: Topics in Math for Elementary and Middle School Teachers** (3 units)

**Description:** This course will focus on connections across key areas in K-8 mathematics (e.g., algebra, geometry, numbers and operations, data analysis and probability). The pedagogical approach will emphasize problem solving, use of technology, communication and hands-on materials.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Seminar Required

**Repeatable:** Course can be repeated a maximum of 6 times.

**Course typically offered:**

Main Campus: Fall

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 596G: Research Tutorial Group** (1 - 3 units)

**Description:** Introduction to research interests of the faculty. Required in Spring of first year in Ph.D. program in Mathematics and in the following Fall. Content varies.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Seminar Required

**Repeatable:** Course can be repeated a maximum of 2 times.

**Course typically offered:**

Main Campus: Fall, Spring

**Recommendations and additional information:** Ph.D student in Mathematics.

**MATH 597T: Professional Development Workshop in Teaching Mathematics** (1 unit)

**Description:** Introduction to the theory and practice of teaching lower-division college mathematics courses. This course is required of and intended only for Math and Applied Math graduate student GATs who are teaching in the Math Department for the first time.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Workshop Required

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** Math/Applied Math GAT - first year teaching in the Math Department.

**MATH 599: Independent Study** (1 - 6 units)

**Description:** Qualified students working on an individual basis with professors who have agreed to supervise such work. Graduate students doing independent work which cannot be classified as actual research will register for credit under course number 599, 699, or 799.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Graduate

**Course Components:** Independent Study Required

**Repeatable:** Course can be repeated a maximum of 99 times.

**Course typically offered:**

Main Campus: Fall, Spring, Summer

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 636: Information Theory** (3 units)

**Description:** [Taught alternate years 2000-2001] Definition of a measure of information and study of its properties; introduction to channel capacity and error-free communications over noisy channels; rate distortion theory; error detecting and correcting codes.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Lecture Required

**Equivalent to:** MATH 636

**Also offered as:** ECE 636

**Course typically offered:**

Main Campus: Fall

**Recommendations and additional information:** ECE 503.

**Home department:** Electrical & Computer Engr

**Course Equivalencies:** Cross Listed

**Grad Interdisciplinary Program:** Statistics and Data Science

**MATH 697B: Applied Mathematics Laboratory** (3 units)

**Description:** The practical application of theoretical learning within a group setting and involving an exchange of ideas and practical methods, skills, and principles.

**Grading basis:** Regular Grades

**Career:** Graduate

**Course Components:** Workshop Required

**Equivalent to:** MSE 697B, PHYS 697B

**Also offered as:** MSE 697B, PHYS 697B

**Course typically offered:**

Main Campus: Spring

**Recommendations and additional information:** Applied math core or equivalent.

**Course Equivalencies:** Cross Listed

**MATH 699: Independent Study** (1 - 6 units)

**Description:** Qualified students working on an individual basis with professors who have agreed to supervise such work. Graduate students doing independent work which cannot be classified as actual research will register for credit under course number 599, 699, or 799.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Graduate

**Course Components:** Independent Study Required

**Repeatable:** Course can be repeated a maximum of 99 times.

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.

**MATH 900: Research** (2 - 8 units)

**Description:** Individual research, not related to thesis or dissertation preparation, by graduate students.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Graduate

**Course Components:** Independent Study Required

**Repeatable:** Course can be repeated a maximum of 99 times.

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**MATH 910: Thesis** (1 - 6 units)

**Description:** Research for the master's thesis (whether library research, laboratory or field observation or research, artistic creation, or thesis writing). Maximum total credit permitted varies with the major department.

**Grading basis:** Alternative Grading: S, P, F

**Career:** Graduate

**Course Components:** Independent Study Required

**Repeatable:** Course can be repeated a maximum of 99 times.

**Course typically offered:**

Main Campus: Fall, Spring, Summer

**MATH 920: Dissertation** (1 - 9 units)

**Description:** Research for the doctoral dissertation (whether library research, laboratory or field observation or research, artistic creation, or dissertation writing).

**Grading basis:** Alternative Grading: S, P, F

**Career:** Graduate

**Course Components:** Independent Study Required

**Repeatable:** Course can be repeated a maximum of 99 times.

**Course typically offered:**

Main Campus: Fall, Spring, Summer

-SA represents a Student Abroad & Student Exchange offering

-CC represents a Correspondence Course offering

**May Be Offered** Departments may offer this component in some semesters. See the Schedule of Classes for term-specific offerings.