

# Requirements: Mathematics and Statistics

## Natural Sciences

For more than 2,000 years, mathematics has been a part of the human search for understanding. Mathematical discoveries have come from both the attempt to describe the natural world and the desire to arrive at a form of inescapable truth through careful reasoning that begins with a small set of self-evident assumptions. These remain fruitful and important motivations for mathematical thinking, but in the last century mathematics and statistics have been successfully applied to many other aspects of the human world: voting trends in politics, dating of ancient artifacts, analysis of automobile traffic patterns and long-term strategies for the sustainable harvest of deciduous forests, to mention a few. Today, statistics as a mode of thought and expression is more valuable than ever before. Learning to think in mathematical terms is an essential part of becoming a liberally educated person.

Mathematics and statistics are engaging fields, rich in beauty, with powerful applications to other subjects. Thus we strive to ensure that Kenyon students encounter and learn to solve problems using a number of contrasting but complementary mathematical perspectives: continuous and discrete, algebraic and geometric, deterministic and stochastic, theoretical and applied. In our courses, we stress mathematical and statistical thinking and communication skills. In courses where it makes sense to incorporate technological tools, our students learn to solve problems using computer algebra systems, statistical packages and computer programming languages.

*The Kenyon College faculty voted to change from Kenyon units to semester hours. This change will go into effect for all students who start at the College in the fall of 2024. Both systems will be used throughout the course catalog with the Kenyon units being listed first.*

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## New Students

Those students interested only in an introduction to mathematics or statistics or a course to satisfy a distribution requirement may select from MATH 105, 111, 128, STAT 106, 116 and COMP 118.

First-year students who are interested in majoring in mathematics or statistics are encouraged to enroll in MATH 100.

Students wanting to continue the study of mathematics or statistics beyond one year, by pursuing a major or minor or a foundation for courses in other disciplines, usually begin with the calculus sequence MATH 111, 112 and 213.

Students who have already had calculus or want to take more than one math course may choose to begin with STAT 106 and 206 or COMP 118. A few well-prepared students may take MATH 222 or 224 in their first year. Please see the department chair for further information.

MATH 111 is an introductory course in calculus. Students who have completed a substantial course in calculus might qualify for one of the successor courses, MATH 112 or 213. STAT 106 is an introduction to statistics, which focuses on quantitative reasoning skills and the analysis of data. COMP 118 introduces students to computer programming.

To facilitate proper placement in calculus courses, the department offers tests that help students decide which level of calculus is appropriate for them. This and other entrance information is used during Orientation to give students advice about course selection in mathematics and statistics. We encourage all students who do not have Advanced Placement credit to take the placement exam that is appropriate for them. Students who have Advanced Placement credit for STAT 106 should consider enrolling in STAT 206 or 216.

The ready availability of powerful computers has made the computer one of the primary tools of the mathematician and absolutely indispensable for the statistician. Students are expected to use appropriate computer software in many of the mathematics and statistics courses. However, no experience with the software packages or programming is expected, except in advanced courses that presuppose earlier courses in which use of the software or programming was taught.

### Pass/D/Fail Policy

In addition to requiring that majors take all MATH/STAT courses for a letter grade, we require that students who wish to declare a MATH/STAT major must petition to have any grades of P in MATH/STAT courses numbered 222 (Foundations) or above changed to a letter grade in order to count the course toward the math/stat major requirements.

### Requirements for the Majors

All courses for the major must be taken for a letter grade.

There are three different areas of emphasis within the major: classical mathematics, applied mathematics and statistics. Regardless of one's concentration, all math majors are required to complete the same eight core courses.

**Core Requirements**

A student must have credit for the following core courses:

- Three semesters of calculus (MATH 111, 112, 213 or the equivalent)
- One semester of statistics (STAT 106, 116 or the equivalent)
- One semester of computer programming (COMP 118 or PHYS 270)
- MATH 222: Foundations
- MATH 224: Linear Algebra
- MATH 480 Senior Seminar in Mathematics

Beyond the core are three other types of requirements: the "area of focus" requirement, the "depth" requirement and the "breadth" requirement. It is the "area of focus" requirement that determines a student's emphasis within the math major.

**Area of Focus Requirement**

Every math major is required to take at least three courses from a single column in the table given below. Additionally, at least one of those courses must be a MATH or STAT course at or above the 300 level. (Note: special topics courses may also count toward a major's area of focus, even though they are not listed in the table; the department chair signs off on such courses when appropriate.)

Category I		Category II		
A. Algebraic	B. Continuous/ Analytic	C. Discrete/ Combinatorial	D. Computational/ Modeling/ Applied	E. Statistical/ Data Science
MATH 335	MATH 341	MATH 336	COMP 218	STAT 206
Abstract Algebra I	Real Analysis I	Probability	Data Structures	Data Analysis

MATH 435 Abstract Algebra II	MATH 441 Real Analysis II	MATH 328 Coding Theory	MATH 233 Introduction to Differential Equations	STAT 436 Mathematical Stats
MATH 327 Number Theory	MATH 360 Topology	MATH 327 Number Theory	MATH 258 Mathematical Biology	STAT 416 Linear Regression
MATH 328 Coding Theory	MATH 230 Geometry	MATH 227 Combinatorics	MATH 325 Applied Linear Algebra	STAT 216 Nonparametric Statistics
MATH 322 Mathematical Logic	MATH 352 Complex Functions		MATH 330 Principles of Applied Math	STAT 226 Statistical Computing in R
	MATH 336 Probability		MATH 333	STAT 306 Topics in Statistics

			Applied Differential Equations	
			MATH 347 Mathematical Modeling	

The major's choice of column determines both the area of emphasis and the area of focus within the major.

**1. Classical Mathematics**

To earn a math major with an emphasis in classical mathematics, the student must choose an area of focus within Category 1. For example, a math major taking three courses from the first column would have an emphasis in classical mathematics and a focus on algebra.

**2. Applied Mathematics**

To earn a math major with an emphasis in applied mathematics, the student must take three courses in column D. Applied mathematics is also the area of focus for this student.

**3. Statistics**

To earn a math major with an emphasis in statistics, the student must take three courses from column E. Statistics is also the area of focus for this student.

**Depth Requirement**

Majors are expected to attain a depth of study within mathematics or statistics. To this end, every major must take at least two MATH or STAT courses at or above the 300 level. At least one of these 300- or 400-level courses must be within the major's area of focus.

**Breadth Requirement**

Majors are also expected to attain a breadth of knowledge spanning pure and applied mathematics and statistics. Hence, every major must take courses in at least two different columns that are not the area of focus. (These courses must not also be listed within the area of focus.) A course listed in two columns may be counted only once. Additionally, every major must take at least one course from Category I and one course from Category II.

For instance, a student pursuing a major with an emphasis in classical mathematics and a continuous/analytic focus must choose a course from each of two columns besides column B, and at least one of these columns must be in Category II. Neither of these additional courses can be MATH 336 (Probability) because it is in the student's area of focus.

To summarize, a student earning a major in mathematics will take (or have credit for) at least 13 courses: eight core courses, three courses in an area of focus and two additional courses outside the area of focus and spanning Categories I and II. Students with AP credit can place out of some of the introductory core coursework, decreasing the number of required courses to fewer than 13.

**Senior Capstone**

The Senior Capstone begins promptly in the fall of the senior year with independent study on a topic of interest to the student and approved by the department. The independent study culminates in an oral presentation to department faculty in November and a poster presentation open to the Kenyon Community at the end of the fall semester. Juniors should begin thinking about possible topics before they leave for the summer. Evaluation of the Senior Capstone is based on the student's poster and oral presentation. Detailed information on the Senior Capstone is available on the [department website](#).

**Suggestions for Majoring**

Students wishing to keep open the option of a major in mathematics and statistics typically begin with the study of calculus and normally complete the calculus sequence, MATH 222 and either COMP 118 or STAT 106, by the end of the sophomore year. A major is usually declared no later than the second semester of the sophomore year. Those considering a mathematics and statistics major should consult with a member of the mathematics and statistics department to plan their course of study.

The requirements for the major are minimal. Anyone who is planning a career in the mathematical sciences or intends to read for honors is encouraged to consult with one or more members of the department concerning further appropriate studies. Similarly, any student who wishes to propose a variation of the major program is encouraged to discuss the plan with a member of the department prior to submitting a written proposal.

Students who are interested in teaching mathematics at the high-school level should take MATH 230 and 335, since these courses are required for certification in most states, including Ohio.

### **Honors**

To be eligible to enroll in the "Mathematics Honors Seminar" by the end of junior year, students must have:

Completed one of the following yearlong sequences: MATH 335/435, MATH 336/STAT 416, MATH 336/STAT 436 or MATH 341/441

Earned an overall Kenyon GPA of at least 3.33

A GPA in Kenyon mathematics and statistics courses of at least 3.6

In the estimation of the mathematics and statistics faculty, a reasonable expectation of fulfilling the requirements to earn honors (listed below)

To earn honors students must:

Indicate interest in pursuing honors in their capstone proposal

Complete two of the yearlong sequences: MATH 335/435, MATH 336/STAT 416, MATH 336/STAT 436 or MATH 341/441

Complete at least six courses in mathematics and statistics numbered 300 or above

Pass the Senior Capstone in the fall semester

Pass MATH 498 (Mathematics Honors Seminar) or STAT 498 (Statistics Honors Seminar)

Present the results of independent work in MATH 498 or STAT 498 to a committee consisting of an outside examiner and members of the mathematics and statistics department

Successfully complete an examination written by an outside examiner covering material from MATH 498 and previous mathematics or statistics courses

Maintain an overall Kenyon GPA of at least 3.33

Maintain a GPA in mathematics courses of at least 3.6

Based on performance in all of the above-mentioned areas, the department (in consultation with the outside examiner) can elect to award Honors, High Honors or Highest Honors, or not to award honors at all.

### **Requirements for the Minor**

There are two minors in mathematics and statistics. Each deals with core material of a part of the discipline, and each reflects the logically structured nature of the subject through a pattern of prerequisites. A minor consists of satisfactory completion of the following courses:

#### **Mathematics**

The calculus sequence MATH 111, 112, 213 or the equivalent  
Four other courses offered by the Department of Mathematics and Statistics.  
COMP 118 and/or COMP 218 may also be used toward this requirement. Of these four other courses, students may count at most one at the 100 level.

#### **Statistics**

STAT 106: Elements of Statistics, STAT 116: Statistics in Sports  
or an equivalent introductory statistics course

STAT 206: Data Analysis

Three courses from the following:

MATH 258: Mathematical Biology

MATH 336: Probability

STAT 216: Nonparametric Statistics

STAT 226: Statistical Computing with R

STAT 306: Topics in Statistics

STAT 416: Linear Regression Models

STAT 436: Mathematical Statistics

Students may count at most one statistics course from another department. ECON 205 or PSYC 200 may be substituted for one of the courses listed above.

Our goal is to provide a solid introduction to basic statistical methods, including data analysis, design and analysis of experiments, statistical inference, and statistical models using professional software.



Deviations from the list of approved minor courses must be approved by the department. Students considering a minor in mathematics or statistics are urged to speak with a member of the department about the selection of courses.

### **Transfer Credit**

Transfer credit from other institutions, and the applicability of this credit to the major or minor, must be approved by the department chair. Majors may count off-campus studies courses toward the major, with approval of the department chair. Ordinarily, no more than one unit of such credit is allowed. Moreover, transfer credit ordinarily does not count as one of the two 300- or 400-level courses required for the depth requirement or the area of focus.

### **Cross-listed Courses**

The following course is cross-listed in biology and satisfies the natural science requirement:

MATH 258: Mathematical Biology

## **Courses in Mathematics**

### **Seminar in Contemporary Mathematics**

MATH 100 Credits: 0.25/2

The seminar in contemporary mathematics provides an introduction to the rich and diverse nature of mathematics. Topics covered vary from one semester to the next (depending on faculty expertise) but typically span algebra and number theory, dynamical systems, probability and statistics, discrete mathematics, topology, geometry, logic, analysis and applied math. The course includes guest lectures from professors at Kenyon, a panel discussion with upper-class math majors and opportunities to learn about summer experiences and careers in mathematics. The course goals are threefold: to provide an overview of modern mathematics, which, while not exhaustive, exposes students to some exciting open questions and research problems in mathematics; to introduce students to some of the mathematical research being done at Kenyon; and to expose students to useful resources and opportunities (at Kenyon and beyond) that are helpful in launching a meaningful college experience. This course does not count toward any requirement for the major. Prerequisite or corequisite: MATH 112 (or equivalent) and concurrent enrollment in another MATH, STAT or COMP course. Open only to first- or second-year students. Offered every fall semester.

### **Surprises at Infinity**

MATH 105 Credits: 0.5/4 QR

Our intuitions about sets, numbers, shapes and logic all break down in the realm of the infinite. Seemingly paradoxical facts about infinity are the subject of this course. We discuss what infinity is, how it has been viewed through history, why some infinities are bigger than others and how a finite shape can have an infinite perimeter. This very likely is quite different from any mathematics course you have ever taken. This course focuses on ideas and reasoning rather than algebraic manipulation, though some algebraic work will be required to clarify big ideas. The class is a mixture of lecture and discussion, based on selected readings. Students can expect essay tests, frequent homework and writing assignments. This course does not count toward any major requirement. Students who have credit for MATH 222 may not receive credit for this course. No prerequisite. Offered occasionally.

### Calculus I

MATH 111 Credits: 0.5/4 QR

The first in a three-semester calculus sequence, this course covers the basic ideas of differential calculus. Differential calculus is concerned primarily with the fundamental problem of determining instantaneous rates of change. In this course, we study instantaneous rates of change from both a qualitative geometric and a quantitative analytic perspective. We cover in detail the underlying theory, techniques and applications of the derivative. The problem of anti-differentiation, identifying quantities given their rates of change, also is introduced. The course concludes by relating the process of anti-differentiation to the problem of finding the area beneath curves, thus providing an intuitive link between differential calculus and integral calculus. Those who have had a year of high school calculus but do not have Advanced Placement credit for MATH 111 should take the calculus placement exam to determine whether they are ready for MATH 112. Students who have 0.5 units of credit for calculus may not receive credit for MATH 111. This counts toward the core course requirement for the major. Prerequisite: solid grounding in algebra, trigonometry and elementary functions. Offered every semester.

### Calculus II

MATH 112 Credits: 0.5/4 QR

The second in a three-semester calculus sequence, this course has two primary foci. The first is integration, including Riemann sums, techniques of integration, and numerical methods and applications of integration. This study leads into the analysis of differential equations by separation of variables, Euler's method and slope fields. The second focus is the notion of convergence, as manifested in improper integrals, and sequences and series, particularly Taylor series. This counts toward the core course requirement for the major. Prerequisite: MATH 111 or AP score of 4 or 5 on Calculus AB exam or an AB sub-score of 4 or 5 on the Calculus BC exam. Offered every semester.

### History of Mathematics in the Islamic World

MATH 128 Credits: 0.5/4 QR

This course examines an important and interesting part of the history of mathematics and, more generally, the intellectual history of humankind: the history of mathematics in the Islamic world. Some of the most fundamental notions in modern mathematics have their roots here, such as the modern number system, the fields of algebra and trigonometry, and the concept of algorithm, among others. In addition to studying specific contributions of medieval Muslim mathematicians in the areas of arithmetic, algebra, geometry and trigonometry in some detail, we examine the context in which Islamic science and mathematics arose, and the role of religion in this development. The rise of Islamic science and its interactions with other cultures (e.g., Greek, Indian and Renaissance European) tell us much about larger issues in the humanities. Thus, this course has both a substantial mathematical component (60-65 percent) and a significant history and social science component (35-40 percent), bringing together three disciplines: mathematics, history and religion. The course counts toward the Islamic Civilization and Cultures concentration but does not count toward any math major requirement. Prerequisite: solid knowledge of algebra and geometry.

### Calculus III

MATH 213 Credits: 0.5/4 QR

The third in a three-semester calculus sequence, this course examines differentiation and integration in three dimensions. Topics of study include functions of more than one variable, vectors and vector algebra, partial derivatives, optimization and multiple integrals. Some of the following topics from vector calculus also are covered as time permits: vector fields, line integrals, flux integrals, curl and divergence. This counts toward the core course requirement for the major. Prerequisite: MATH 112 or a score of 4 or 5 on the BC calculus AP exam. Offered every semester.

### Foundations

MATH 222 Credits: 0.5/4 QR

This course introduces students to mathematical reasoning and rigor in the context of set-theoretic questions. The course covers basic logic and set theory, relations — including orderings, functions and equivalence relations — and the fundamental aspects of cardinality. The course emphasizes helping students read, write and understand mathematical reasoning. Students are actively engaged in creative work in mathematics. Students interested in majoring in mathematics should take this course no later than the spring semester of their sophomore year. Advanced first-year students interested in mathematics are encouraged to consider taking this course in their first year. This counts toward the core course requirement for the major. This course cannot be taken pass/D/fail. Prerequisite: MATH 213. Offered every semester.

### Linear Algebra

MATH 224 Credits: 0.5/4 QR

This course focuses on the study of vector spaces and linear functions between vector spaces. Ideas from linear algebra are useful in many areas of higher-level mathematics. Moreover, linear

algebra has many applications to both the natural and social sciences, with examples arising in fields such as computer science, physics, chemistry, biology and economics. In this course, we use a computer software system, such as Maple or Matlab, to investigate important concepts and applications. Topics to be covered include methods for solving linear systems of equations, subspaces, matrices, eigenvalues and eigenvectors, linear transformations, orthogonality and diagonalization. Applications are included throughout the course. This counts toward the core course requirement for the major. Prerequisite: MATH 213. Generally offered three out of four semesters.

### Combinatorics

MATH 227 Credits: 0.5/4 QR

Combinatorics is, broadly speaking, the study of finite sets and finite mathematical structures. A great many mathematical topics are included in this description, including graph theory; combinatorial designs; partially ordered sets; networks; lattices and Boolean algebras; and combinatorial methods of counting, including combinations and permutations, partitions, generating functions, recurring relations, the principle of inclusion and exclusion, and the Stirling and Catalan numbers. This course covers a selection of these topics. Combinatorial mathematics has applications in a wide variety of nonmathematical areas, including computer science (both in algorithms and in hardware design), chemistry, sociology, government and urban planning; this course may be especially appropriate for students interested in the mathematics related to one of these fields. This counts toward the discrete/combinatorial (column C) elective requirement for the major. Prerequisite: MATH 112 or a score of 4 or 5 on the BC calculus AP exam. Offered every other year.

### Euclidean and Non-Euclidean Geometry

MATH 230 Credits: 0.5/4 QR

The "Elements" of Euclid, written over 2,000 years ago, is a stunning achievement. The "Elements" and the non-Euclidean geometries discovered by Bolyai and Lobachevsky in the 19th century form the basis of modern geometry. From this start, our view of what constitutes geometry has grown considerably. This is due in part to many new theorems that have been proved in Euclidean and non-Euclidean geometry but also to the many ways in which geometry and other branches of mathematics have come to influence one another over time. Geometric ideas have widespread use in analysis, linear algebra, differential equations, topology, graph theory and computer science, to name just a few areas. These fields, in turn, affect the way that geometers think about their subject. Students consider Euclidean geometry from an advanced standpoint but also have the opportunity to learn about non-Euclidean geometries. This counts toward the continuous/analytic (column B) elective requirement for the major. Prerequisite: MATH 222. Offered every other year.

### Mathematical Problem Solving

MATH 231 Credits: 0.25/2

Looking at a problem in a creative way and seeking out different methods toward solving it are essential skills in mathematics and elsewhere. In this course, students build their problem-solving intuition and skills by working on challenging and fun mathematical problems. Common problem-solving techniques in mathematics are covered in each class meeting, followed by collaboration and group discussions, which are the central part of the course. When offered in the fall semester, the course culminates with the Putnam exam on the first Saturday in December. Interested students who have a conflict with that date should contact the instructor. This does not count toward any requirement for the major. Prerequisite: MATH 112 or a score of 4 or 5 on the BC calculus exam.

#### Introduction to Differential Equations

MATH 233 Credits: 0.5/4

This course is an introduction to ordinary differential equations (ODEs). The course discusses techniques for finding, analyzing, and interpreting solutions of ODEs using exact methods, numerical methods, series solutions and qualitative approaches. We discuss first- and second-order differential equations, as well as first-order systems of differential equations. Applications are woven throughout the course. Other topics, as time permits. This course counts toward the computational/modeling (column D) elective requirement for the major. Prerequisite: MATH 224.

#### Mathematical Biology

MATH 258 Credits: 0.5/4 QR

In biological sciences, mathematical models are becoming increasingly important as tools for turning biological assumptions into quantitative predictions. In this course, students learn how to fashion and use these tools to explore questions ranging across the biological sciences. We survey a variety of dynamic modeling techniques, including both discrete and continuous approaches. Biological applications may include population dynamics, molecular evolution, ecosystem stability, epidemic spread, nerve impulses, sex allocation and cellular transport processes. The course is appropriate both for math majors interested in biological applications and for biology majors who want the mathematical tools necessary to address complex, contemporary questions. As science is becoming an increasingly collaborative effort, biology and math majors are encouraged to work together on many aspects of the course. Coursework includes homework, problem-solving exercises and short computational projects. Final independent projects require the development and extension of an existing biological model selected from the primary literature. This course builds on (but is not limited by) an introductory-level knowledge base in both math and biology. Interested biology and math majors lacking a prerequisite are encouraged to consult with the instructor. This counts toward the computational/modeling/applied (column D) elective requirement for the major. Prerequisite: STAT 106 or MATH 111 or 112 (or any math or statistics AP credit of 4 or 5), and either BIOL 115 or 116. Offered every other year.

### Mathematical Logic

MATH 322 Credits: 0.5/4

This course is a mathematical examination of the formal language most common in mathematics: predicate calculus. We examine various definitions of meaning and proof for this language and consider its strengths and inadequacies. We develop some elementary computability theory en route to rigorous proofs of Godel's Incompleteness Theorems. Concepts from model logic, model theory and other advanced topics are discussed as time permits. This counts toward the algebraic (column A) elective for the major. Prerequisite: MATH 222 or PHIL 201. Offered occasionally.

### Applied Linear Algebra

MATH 325 Credits: 0.5/4

This is a second course focusing on the use of linear algebra to solve large-scale data and image problems. Applications may include, but are not limited to, tomography to reconstruct a 3-D image of a brain, regression to model climate data, prediction of long-term behavior of populations, fractal generation, image-blurring and edge detection, algorithmic approaches to suggest movies to users, linear classifiers to identify cancer risk, and linear optimization for resource allocation. Linear algebra concepts and tools are developed as needed to address the presented problems. In addition to extensions of topics from the first linear algebra course, this course includes a selection of topics from the following list: abstract vector spaces, orthogonal subspaces and projection operators, norms and inner products, Markov matrices, matrix decompositions (LU, Cholesky, Schur, SVD), and support vector machines. Solutions to or simulations of the applied problems presented are implemented in Matlab or similar software. This course counts toward the algebraic focus (column A) elective for the major. Prerequisite: Math 224.

### Number Theory Seminar

MATH 327 Credits: 0.5/4 QR

Patterns within the set of natural numbers have enticed mathematicians for well over two millennia, making number theory one of the oldest branches of mathematics. Rich with problems that are easy to state but fiendishly difficult to solve, the subject continues to fascinate professionals and amateurs alike. In this course, we get a glimpse at both the old and the new. In the first two-thirds of the semester, we study topics from classical number theory, focusing primarily on divisibility, congruences, arithmetic functions, sums of squares and the distribution of primes. In the final weeks, we explore some of the current questions and applications of number theory. We study the famous RSA cryptosystem, and students read and present some current (carefully chosen) research papers. This counts toward either a discrete/combinatorial (column C) or an algebraic (column A) elective requirement for the major. Prerequisite: MATH 222. Offered every other year.

### Coding Theory and Cryptography

**MATH 328 Credits: 0.5/4 QR**

Coding theory (the theory of error-correcting codes), and cryptography are two important applications of algebra and discrete mathematics to information and communications systems. While coding theory is concerned with the reliability of communication, the main problem of cryptography is the security and privacy of communication. Applications of coding theory range from enabling the clear transmission of pictures from distant planets to quality of sound in compact disks and wireless communication. Error correcting codes play a key role in quantum computing. With the ever increasing role of digital communication, online transactions, the general dependence on electronic systems in modern life, and the emergence of quantum computers, the importance of these fields grows each day. In this course, students will learn the basic ideas of coding theory and cryptography, understand their mathematical foundations, and learn how mathematical tools can be used to devise useful error correcting codes and cryptographic systems. A selection of topics from these two disciplines will be discussed including basics of block coding, linear codes, Hamming codes, cyclic codes, symmetric-key and public-key cryptography, digital signatures, and code-based cryptography. Other than some basic linear algebra, the necessary mathematical background (mostly abstract algebra) is covered within the course. This counts toward either a discrete/combinatorial (column C) or an algebraic (column A) elective requirement for the major. Prerequisite: MATH 222 and MATH 224. Offered every other year.

**Principles of Applied Mathematics****MATH 330 Credits: 0.5/4**

This course provides a survey of several techniques used in applied mathematics. We discuss the mathematical formulation of models for a variety of processes that arise in the natural and social sciences. We derive the appropriate equations to describe these processes and use techniques from calculus, differential equations, linear algebra and numerical methods when needed. This course may touch on topics like dimensional analysis, scaling, kinetic equations and perturbation methods. Students have the opportunity to investigate applications within their fields of interest such as biology, medicine, physics, chemistry and finance. A strong background in calculus is essential; a familiarity with differential equations is recommended but not required. This counts toward the computation/modeling/applied (column D) elective requirement for the major. Prerequisite: MATH 213. Sophomore standing. Offered every other year.

**Applied Differential Equations****MATH 333 Credits: 0.5/4 QR**

Differential equations arise naturally to model dynamical systems such as often occur in physics, biology, chemistry and economics, and have given major impetus to other fields in mathematics, such as topology and the theory of chaos. This course covers basic analytic, numerical and qualitative methods for the solution and understanding of ordinary differential equations. Computer-based technology is used. This counts toward the

computation/modeling/applied (column D) elective requirement for the major. Prerequisite: MATH 224 or PHYS 245. Offered every other year.

### Abstract Algebra I

MATH 335 Credits: 0.5/4 QR

Abstract algebra is the study of algebraic structures that describe common properties and patterns exhibited by seemingly disparate mathematical objects. The phrase "abstract algebra" refers to the fact that some of these structures are generalizations of the material from high school algebra relating to algebraic equations and their methods of solution. In this course, we focus entirely on group theory. A group is an algebraic structure that allows one to describe symmetry in a rigorous way. The theory has many applications in physics and chemistry. Since mathematical objects exhibit pattern and symmetry as well, group theory is an essential tool for the mathematician. Furthermore, group theory is the starting point in defining many other more elaborate algebraic structures including rings, fields and vector spaces. We cover the basics of groups, including the classification of finitely generated abelian groups, factor groups, the three isomorphism theorems and group actions. The course culminates in a study of Sylow theory. Throughout the semester there is an emphasis on examples, many of them coming from calculus, linear algebra, discrete math and elementary number theory. There also are a couple of projects illustrating how a formal algebraic structure can empower one to tackle seemingly difficult questions about concrete objects (e.g., the Rubik's cube or the card game SET). Finally, there is a heavy emphasis on the reading and writing of mathematical proofs. Junior standing is recommended. This counts toward the algebraic (column A) elective requirement for the major. Prerequisite: MATH 222. Offered every other fall.

### Probability

MATH 336 Credits: 0.5/4 QR

This course provides a calculus-based introduction to probability. Topics include basic probability theory, random variables, discrete and continuous distributions, mathematical expectation, functions of random variables and asymptotic theory. This counts toward either a discrete/combinatorial (column C) or continuous/analytic (column B) elective requirement for the major. Prerequisite: MATH 213. Offered every fall.

### Real Analysis I

MATH 341 Credits: 0.5/4 QR

This course is a first introduction to real analysis. "Real" refers to the real numbers. Much of our work revolves around the real number system. We start by carefully considering the axioms that describe it. "Analysis" is the branch of mathematics that deals with limiting processes. Thus the concept of distance is also a major theme of the course. In the context of a general metric space (a space in which we can measure distances), we consider open and closed sets, limits of sequences, limits of functions, continuity, completeness, compactness and connectedness. Other topics may be included if time permits. Junior standing is recommended. This counts



toward the continuous/analytic (column B) elective requirement for the major. Prerequisite: MATH 213 and 222. Offered every other fall.

### Mathematical Models

MATH 347 Credits: 0.5/4 QR

This course introduces students to the concepts, techniques and power of mathematical modeling. Both deterministic and probabilistic models are explored, with examples taken from the social, physical and life sciences. Students engage cooperatively and individually in the formulation of mathematical models and in learning mathematical techniques used to investigate those models. This counts toward the computational/modeling/applied (column D) elective requirement for the major. Prerequisite: STAT 106 and MATH 224 or 258. Offered every other year.

### Complex Functions

MATH 352 Credits: 0.5/4 QR

The course starts with an introduction to the complex numbers and the complex plane. Next, students are asked to consider what it might mean to say that a complex function is differentiable (or analytic, as it is called in this context). For a complex function that takes a complex number  $z$  to  $f(z)$ , it is easy to write down (and make sense of) the statement that  $f$  is analytic at  $z$  if

exists. Subsequently, we study the amazing results that come from making such a seemingly innocent assumption. Differentiability for functions of one complex variable turns out to be very different from differentiability in functions of one real variable. Topics covered include analyticity and the Cauchy-Riemann equations, complex integration, Cauchy's Theorem and its consequences, connections to power series, and the Residue Theorem and its applications. This counts toward the continuous/analytic (column B) elective requirement for the major. Prerequisite: MATH 224. Offered every other year.

### Topology

MATH 360 Credits: 0.5/4 QR

Topology is an area of mathematics concerned with properties of geometric objects that remain the same when the objects are "continuously deformed." Three of these key properties in topology are compactness, connectedness and continuity; the mathematics associated with these concepts is the focus of the course. Compactness is a general idea helping us to more fully understand the concept of limit, whether of numbers, functions or even geometric objects. For example, the fact that a closed interval (or square, or cube, or  $n$ -dimensional ball) is compact is required for basic theorems of calculus. Connectedness is a concept generalizing the intuitive idea that an object is in one piece: The most famous of all the fractals, the

Mandelbrot Set, is connected, even though its best computer-graphics representation might make this seem doubtful. Continuous functions are studied in calculus, and the general concept can be thought of as a way by which functions permit us to compare properties of different spaces or as a way of modifying one space so that it has the shape or properties of another. Engineering, chemistry and physics are among the subjects that find topology useful. The course touches on selected topics that are used in applications. This counts toward the continuous/analytic (column B) elective requirement for the major. Prerequisite: MATH 222 or permission of instructor. Generally offered every two to three years.

### Abstract Algebra II

MATH 435 Credits: 0.5/4 QR

This course picks up where MATH 335 ends, focusing primarily on rings and fields. Serving as a good generalization of the structure and properties exhibited by the integers, a ring is an algebraic structure consisting of a set together with two operations — addition and multiplication. If a ring has the additional property that division is well-defined, one gets a field. Fields provide a useful generalization of many familiar number systems: the rational numbers, the real numbers and the complex numbers. Topics to be covered include polynomial rings; ideals; homomorphisms and ring quotients; Euclidean domains, principal ideal domains and unique factorization domains; the Gaussian integers; factorization techniques; and irreducibility criteria. The final block of the semester serves as an introduction to field theory, covering algebraic field extensions, symbolic adjunction of roots, construction with ruler and compass, and finite fields. Throughout the semester there is an emphasis on examples, many of them coming from calculus, linear algebra, discrete math and elementary number theory. There also is a heavy emphasis on the reading and writing of mathematical proofs. This counts toward the algebraic (column A) elective requirement for the major. Prerequisite: MATH 335. Offered every other spring.

### Real Analysis II

MATH 441 Credits: 0.5/4 QR

This course follows MATH 341. Topics include a study differentiation and (Riemann) integration of functions of one variable, sequences and series of functions, power series and their properties, iteration and fixed points. Other topics may be included as time permits. For example: a discussion of Newton's method or other numerical techniques; differentiation and integration of functions of several variables; spaces of continuous functions; the implicit function theorem; and everywhere continuous, nowhere differentiable functions. This counts toward the continuous/analytic (column B) elective requirement for the major. Prerequisite: MATH 341. Offered every other spring.

### Senior Seminar in Mathematics

MATH 480 Credits: 0.25/2

The senior seminar in mathematics provides a structure to aid students in successfully completing the Mathematics and Statistics Capstone requirement. Students who participate in a 3-2 program ordinarily take this course in their junior year. Students with December anticipated graduation dates take the seminar in their sixth semester (in the third semester before graduation). This schedule makes it possible for students who do not succeed in their first try at the capstone to take full advantage of the “second chance” option without delaying their graduation timeline.

Students who do not successfully complete their capstone in the fall semester will be assigned NG (no grade) at the end of the senior seminar. This designation will change to a CR when the student successfully completes the capstone, usually at the end of the following semester. This course is a core requirement for the mathematics major. Prerequisite: MATH 222 and at least one 300+-level course in Mathematics or Statistics. The course is offered every fall semester., The course is credit/no credit.

#### Individual Study

MATH 493 Credits: 0.25-0.5/2-4

Individual study is a privilege reserved for students who want to pursue a course of reading or complete a research project on a topic not regularly offered in the curriculum. It is intended to supplement, not take the place of, coursework. Individual study cannot be used to fulfill requirements for the major. To qualify, a student must identify a member of the mathematics department willing to direct the project. The professor, in consultation with the student, creates a tentative syllabus (including a list of readings and/or problems, goals and tasks) and describes in some detail the methods of assessment (e.g., problem sets to be submitted for evaluation biweekly; a 20-page research paper submitted at the course's end, with rough drafts due at given intervals; and so on). The department expects the student to meet regularly with his or her instructor for at least one hour per week. All standard enrollment/registration deadlines for regular college courses apply. Because students must enroll for individual studies by the end of the seventh class day of each semester, they should begin discussion of the proposed individual study by the semester before, so that there is time to devise the proposal and seek departmental approval. Individual study courses may be counted as electives in the mathematics major, subject to consultation with and approval by the Department of Mathematics and Statistics. Permission of instructor and department chair required. No prerequisite.

#### Senior Honors

MATH 498 Credits: 0.25/2 QR

This course consists largely of an independent project in which students read several sources to learn about a mathematical topic that complements material studied in other courses, usually an already completed depth sequence. This study culminates in an expository paper and a public or semi-public presentation before an audience consisting of at least several members of the mathematics faculty as well as an outside examiner. Permission of department chair required.

Prerequisite: senior standing and the completion of at least one two-semester sequence at the junior-senior level.

## Courses in Statistics

### Elements of Statistics

STAT 106 Credits: 0.5/4 QR

This is a basic course in statistics. The topics covered are the nature of statistical reasoning, graphical and descriptive statistical methods, design of experiments, sampling methods, probability, probability distributions, sampling distributions, estimation and statistical inference. Confidence intervals and hypothesis tests for means and proportions are studied in the one- and two-sample settings. The course concludes with inference-regarding correlation, linear regression, chi-square tests for two-way tables and one-way ANOVA. Statistical software is used throughout the course, and students engage in a wide variety of hands-on projects. This counts toward the core course requirement for the major. Students with credit for STAT 116 cannot take STAT 106 for credit. No prerequisite. Offered every semester.

### Statistics in Sports

STAT 116 Credits: 0.5/4 QR

Appropriate applications of statistical methods have changed the way some Major League Baseball teams manage the game. (See "Moneyball: The Art of Winning an Unfair Game.") Statistics are used in other sports to evaluate the performance of individual players or teams. The focus of this course is on the proper application of statistical models in sports. Students use appropriate methods to examine interesting questions such as: Are there unusual patterns in the performance statistics of "steroid sluggers" such as Barry Bonds and Mark McGwire or pitchers such as Roger Clemens? Other possible topics include the impact of a penalty kick in soccer, home-field advantage in football, technological improvements in golf or cycling, and of training methods in marathon running. Although the sport and question of interest change, the focus on proper applications of appropriate statistical methods remains the same. Students analyze data and present their results to the class. Oral and written reports are expected. This counts toward the core course requirement for the major. Students with credit for STAT 106 cannot take STAT 116 for credit. No prerequisite. Offered occasionally.

### Data Analysis

STAT 206 Credits: 0.5/4 QR

This course focuses on choosing, fitting, assessing and using statistical models. Simple linear regression, multiple regression, analysis of variance, general linear models, logistic regression and discrete data analysis provide the foundation for the course. Classical interference methods that rely on the normality of the error terms are thoroughly discussed, and general approaches for dealing with data where such conditions are not met are provided. For example, distribution-free techniques and computer-intensive methods, such as bootstrapping and permutation tests, are presented. Students use statistical software throughout the course to

write and present statistical reports. The culminating project is a complete data analysis report for a real problem chosen by the student. The MATH 106–206 sequence provides a thorough foundation for statistical work in economics, psychology, biology, political science and many other fields. This counts toward the statistical/data science (column E) elective for the major. Prerequisite: STAT 106 or 116, or a score of 4 or 5 on the AP statistics exam. Offered every semester.

### Nonparametric Statistics

STAT 216 Credits: 0.5/4 QR

This course focuses on nonparametric and distribution-free statistical procedures. These procedures rely heavily on counting and ranking techniques. In the one- and two-sample settings, the sign, signed-rank and Mann-Whitney-Wilcoxon procedures are discussed. Correlation and one-way analysis of variance techniques also are investigated. A variety of special topics are used to wrap up the course, including bootstrapping, censored data, contingency tables and the two-way layout. The primary emphasis is on data analysis and the intuitive nature of nonparametric statistics. Illustrations come from real data sets, and students are asked to locate an interesting data set and prepare a report detailing an appropriate nonparametric analysis. This counts toward the statistical/data science (column E) elective for the major. Prerequisite: STAT 106 or 116, or a score of 4 or 5 on the AP statistics exam. Offered every other year.

### Statistical Computing in R

STAT 226 Credits: 0.5/4

This course provides a mathematical introduction to probability and statistics using R statistical software. The primary goal of the course is to learn and apply Monte-Carlo simulation techniques to a wide variety of problems. We focus on solving problems from a numerical point of view, with methods to complete numerical integration, root finding, curve fitting, variance reduction and optimization. Core knowledge of R and basic programming concepts are introduced. Case studies and projects are independently completed throughout the semester. This counts toward the statistical/data science (column E) elective for the major. Prerequisite: STAT 106 or STAT 116. Offered every other year.

### Topics in Statistics

STAT 306 Credits: 0.5/4

Each offering of this course approaches the study of variability using a particular set of statistical tools (such as Bayesian Analysis, biostatistics, sports analytics, experimental design or statistical machine learning). Specific statistical methodology within a subfield of the discipline is examined. A large component of each offering involves intensive projects in which students are expected to determine which statistical methods are appropriate for a given setting before analyzing data. As part of these projects and daily activities, students use R to analyze data to make inferences about the population characteristics of interest. Additionally, written and oral

communication are a regular part of the course. The course may be repeated for credit as long as the subfield is different. That is, students may receive credit for each specific subfield only once. This counts toward the statistical/data science (column E) elective for the major.

Prerequisite: any STAT course at the 200 level or higher. Offered every spring.

Additional information for different subfields:

<https://www.kenyon.edu/academics/departments-and-majors/mathematics-statistics/academic-program-requirements/courses-in-statistics/stat-306-topics/>

### Linear Regression Models

STAT 416 Credits: 0.5/4 QR

This course focuses on linear regression models. Simple linear regression with one predictor variable serves as the starting point. Models, inferences, diagnostics and remedial measures for dealing with invalid assumptions are examined. The matrix approach to simple linear regression is presented and used to develop more general multiple regression models. Building and evaluating models for real data are the ultimate goals of the course. Time series models, nonlinear regression models and logistic regression models also may be studied if time permits. This counts toward the statistical/data science (column E) elective for the major. Prerequisite: STAT 106 or 116, and MATH 224. Offered every other spring.

### Mathematical Statistics

STAT 436 Credits: 0.5/4 QR

This course follows MATH 336 and introduces the mathematical theory of statistics. Topics include sampling distributions, order statistics, point estimation, maximum likelihood estimation, methods for comparing estimators, interval estimation, moment-generating functions, bivariate transformations, likelihood ratio tests and hypothesis testing. Computer simulations accompany and corroborate many of the theoretical results. Course methods often are applied to real data sets. This counts toward the statistical/data science (column E) elective for the major.

Prerequisite: MATH 336. Offered every other spring.

### Individual Study

STAT 493 Credits: 0.25-0.5/2-4

Individual study is a privilege reserved for students who want to pursue a course of reading or complete a research project on a topic not regularly offered in the curriculum. It is intended to supplement, not take the place of, coursework. Individual study cannot be used to fulfill requirements for the major. Individual studies will earn 0.25-0.5 units of credit. To qualify, a student must identify a member of the mathematics department willing to direct the project. The professor, in consultation with the student, creates a tentative syllabus (including a list of readings and/or problems, goals and tasks) and describes in some detail the methods of assessment (e.g., problem sets to be submitted for evaluation biweekly; a 20-page research paper submitted at the course's end, with rough drafts due at given intervals; and so on). The

department expects the student to meet regularly with the instructor for at least one hour per week. All standard enrollment/registration deadlines for regular college courses apply. Because students must enroll for individual studies by the end of the seventh class day of each semester, they should begin discussion of the proposed individual study by the semester before, so that there is time to devise the proposal and seek departmental approval. Permission of instructor and department chair required. Individual study courses may be counted as electives in the major, subject to consultation with and approval by the Department of Mathematics and Statistics. No prerequisite.