

# Mathematics and Statistics

## Natural Sciences Division

For more than two thousand years, mathematics has been a part of the human search for understanding. Mathematical discoveries have come both from the attempt to describe the natural world and from 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, the dating of ancient artifacts, the 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.

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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 SCMP 118.

Students wanting to continue the study of mathematics or statistics beyond one year, either 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 who want to take more than one math course may choose to begin with STAT 106 and 206 or SCMP 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. SCMP 118 introduces students to computer programming.

To facilitate proper placement of students in calculus courses, the department offers placement tests that help students decide which level of calculus course is appropriate for them. This and other entrance information is used during the orientation period 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 will be expected to use appropriate computer software in many of the mathematics and statistics courses. However, no prior 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.

## Students graduating in 2021-2022

Use the major requirements found in the [archived course catalog](#).

## Requirements for the Majors

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 or the equivalent)
- One semester of computer programming (SCMP 118 or PHYS 270)
- MATH 222 Foundations
- MATH 224 Linear Algebra
- MATH 480 Senior Seminar in Mathematics

Beyond the core requirements, there 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 will sign 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 Abstract Algebra I	MATH 341 Real Analysis I	MATH 336 Probability	MATH 347 Mathematical Modeling	STAT 206 Data Analysis
MATH 435 Abstract Algebra II	MATH 441 Real Analysis II	MATH 328 Coding Theory	MATH 258 Mathematical Biology	STAT 436 Mathematical Stats
MATH 327 Number Theory	MATH 360 Topology	MATH 327 Number Theory	SCMP 218 Data Structures	STAT 416 Linear Regression
MATH 328 Coding Theory	MATH 230 Geometry	MATH 227 Combinatorics	MATH 333 Applied Differential Equations	STAT 216 Nonparametrics
MATH 322 Mathematical Logic	MATH 352 Complex Functions		MATH 330 Principles of Applied Math	STAT 226 Statistical Computing in R
	MATH 336 Probability			STAT 306 Topics in Statistics

Additionally, (only) one of the following courses offered outside of the Department of Mathematics and Statistics may be counted towards Column D:

- ECON 357 Economics with Calculus
- ECON 375 Advanced Econometrics
- PHYS 340 Classical Mechanics
- PHYS 350 Electricity and Magnetism
- PHYS 360 Quantum Mechanics

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 residing within Category 1 in the above table. So, for example, a math major taking three courses from the first column would be a math major with 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 residing in column D. Applied mathematics will also be 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 will also be 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 reside 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 at least two different columns that are not the area of focus. (These courses must not also be listed within the area of focus.) Additionally, every major must take at least one course from Category I and one course from Category II.

For instance, a student that is 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 reside in Category II. Neither of these two additional courses can be Probability (MATH 336) because the course resides 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 (including the Senior Seminar), three courses in an area of focus and two additional courses outside the area of focus and spanning Categories I and II. Students with IB or AP credit can place out of some of the introductory core coursework, and this will decrease the number of required courses to a number less 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 the writing of a paper, which is due in November. While seniors will be studying their topics individually, all must be enrolled in the Senior Seminar during this fall semester as it will provide the structure and a timeline for completing the paper. Juniors are encouraged to begin thinking about possible topics before they leave for the summer. Students are required to take the Major Field Test in Mathematics produced by the Educational Testing Service.

Evaluation of the Senior Capstone is based on the student's performance on the paper and the standardized exam. 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 SCMP 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 who intends to read for honors, is encouraged to consult with one or more members of the department concerning further studies that would be appropriate.

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 for a decision by the department.

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 the following:

- One of the following year-long sequences: MATH 335/435, MATH 336/STAT 416, MATH 336/STAT 436 or MATH 341/441
- Have earned an overall Kenyon GPA of at least 3.33
- A GPA in Kenyon mathematics and statistics courses of at least 3.6
- The student also must have, in the estimation of the mathematics and statistics faculty, a reasonable expectation of fulfilling the requirements to earn honors (listed below)

To earn honors, a student must:

- Complete two of the year-long 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 the Mathematics Honors Seminar MATH 498 or the Statistics Honors Seminar STAT 498
- 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 minor 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. SCMP 118 and/or SCMP 218 may also be used toward this four-course requirement. Of these four other courses, students may count at most one at the 100 level.

### Statistics

- STAT 106 or an equivalent introductory statistics course
- STAT 206
- Three courses from the following:
  - MATH 236
  - MATH 258
  - MATH 336
  - STAT 216
  - STAT 226
  - STAT 306
  - STAT 416
  - STAT 436

- 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.

### Cross Listed Courses

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

- MATH 258 Mathematical Biology

## Courses in Mathematics

### First-Year Seminar in Mathematics

#### **MATH 100 CREDITS: 0.25**

The first-year seminar in mathematics provides an introduction to the rich and diverse nature of mathematics. Topics covered will vary from one semester to the next (depending on faculty expertise) but will 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: 1) to provide an overview of modern mathematics, which, while not exhaustive, will expose students to some exciting open questions and research problems in mathematics; 2) to introduce students to some of the mathematical research being done at Kenyon and; 3) to answer whatever questions students might have during their first semester here, while exposing them to useful resources and opportunities that are helpful in launching a meaningful college experience. Open only to first-year students. This course does not count towards any requirement for the major. Prerequisite or corequisite: MATH 112 (or equivalent) and concurrently enrolled in another MATH, STAT or SCMP course or permission of instructor. Offered every fall semester.

## Surprises at Infinity

### **MATH 105 CREDITS: 0.5 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 will 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 will be 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 will be 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. No prerequisite. Offered occasionally.

## Calculus I

### **MATH 111 CREDITS: 0.5 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 will study instantaneous rates of change from both a qualitative geometric and a quantitative analytic perspective. We will 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 will be introduced. The course will conclude 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 QR**

The second in a three-semester calculus sequence, this course has two primary foci. The first is integration, including techniques of integration, 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, 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 or permission of instructor. Offered every semester.



## History of Mathematics in the Islamic World

### **MATH 128 CREDITS: 0.5 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 will 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 Europe) 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.

## Introduction to Computer Science

### **MATH 138 CREDITS: 0.75 QR**

This course is an introduction to the intellectual scope of computer science and to the art of computer programming. This entry-level course is for students of all majors, including those with and without previous programming experience. We teach the Python programming language to introduce programming concepts. The course covers topics in abstraction, algorithms and program design, basic data structures, security, networking, privacy and history. Web technologies including HTML, CSS and Javascript are examined. Offered every semester.

## Calculus III

### **MATH 213 CREDITS: 0.5 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 will be 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 or permission of instructor. Offered every semester.

## Foundations

### **MATH 222 CREDITS: 0.5 QR**

This course introduces students to mathematical reasoning and rigor in the context of set-theoretic questions. The course will cover basic logic and set theory, relations — including

orderings, functions and equivalence relations — and the fundamental aspects of cardinality. The course will emphasize helping students read, write and understand mathematical reasoning. Students will be 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. Prerequisite: MATH 213 or permission of instructor. Offered every spring semester.

## Linear Algebra

### **MATH 224 CREDITS: 0.5 QR**

This course will focus 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 will 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 will be 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 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 will cover 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 or permission of instructor. Offered every other year.

## Euclidean and Non-Euclidean Geometry

### **MATH 230 CREDITS: 0.5 QR**

The "Elements" of Euclid, written over 2,000 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 in MATH 230 will consider Euclidean geometry from an advanced standpoint, but also will 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 or permission of instructor. Offered every other year.

## Mathematical Problem Solving

### **MATH 231 CREDITS: 0.25**

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 will build their problem-solving intuition and skills by working on challenging and fun mathematical problems. Common problem-solving techniques in mathematics will be covered in each class meeting, followed by collaboration and group discussions, which will be the central part of the course. The course will culminate 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 or permission of instructor.

## Mathematical Biology

### **MATH 258 CREDITS: 0.5 QR**

In biological sciences, mathematical models are becoming increasingly important as tools for turning biological assumptions into quantitative predictions. In this course, students will learn how to fashion and use these tools to explore questions ranging across the biological sciences. We will 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 will be encouraged to work together on many aspects of the course. Coursework will include homework, problem-solving exercises and short computational projects. Final independent projects will require the development and extension of an existing biological model selected from the primary literature. This course will build on (but not be 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 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**

This course is a mathematical examination of the formal language most common in mathematics: predicate calculus. We will examine various definitions of meaning and proof for this language and will consider its strengths and inadequacies. We will 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 will be discussed as time permits. This counts toward the Algebraic (Column A) elective for the major. Prerequisite: MATH 222 or PHIL 201 or permission of instructor. Offered occasionally.

## Linear Algebra II

### **MATH 324 CREDITS: 0.5 QR**

This course builds on the concepts that arise in MATH 224. Topics will vary and will likely include some of the following: abstract vector spaces, inner product spaces, linear mappings and canonical forms, linear models, linear codes, the singular value decomposition and wavelets. Prerequisite: MATH 224. Offered every other year.

## Number Theory Seminar

### **MATH 327 CREDITS: 0.5 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 will get a glimpse at both the old and the new. In the first two-thirds of the semester, we will 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 will explore some of the current questions and applications of number theory. We will study the famous RSA cryptosystem, and students will 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 QR**

Coding theory, or the theory of error-correcting codes, and cryptography are two recent applications of algebra and discrete mathematics to information and communications systems. The goals of this course are to introduce students to these subjects and to understand some of the basic mathematical tools used. 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 discs. Cryptography is a key technology in electronic security systems. Topics likely to be covered include basics of block coding, encoding and decoding, linear codes, perfect codes, cyclic codes, BCH and Reed-Solomon codes, and classical and public-key cryptography. Other topics may be included depending on the availability of time and the background and interests of the students. Other than some basic linear algebra, the necessary mathematical background (mostly abstract algebra) will be 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 224 or permission of instructor. Offered every other year.

## Principles of Applied Mathematics

### **MATH 330 CREDITS: 0.5**

This course provides a survey of several techniques used in applied mathematics. We will discuss the mathematical formulation of models for a variety of processes that arise in the natural and social sciences. We will 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 will 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 and sophomore standing or permission of instructor. Offered every other year.

## Applied Differential Equations

### **MATH 333 CREDITS: 0.5 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 will be used. This counts toward the Computation/Modeling/Applied (Column D) elective requirement for the major. Prerequisite: MATH 224 or PHYS 245 or permission of instructor. Offered every other year.

## Abstract Algebra I

### **MATH 335 CREDITS: 0.5 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 Abstract Algebra I, 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. In this course, we will 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 will be an emphasis on examples, many of them coming from calculus, linear algebra, discrete math and elementary number theory. There also will be 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 will be 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 or permission of instructor. Offered every other fall.

## Probability

### **MATH 336 CREDITS: 0.5 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 QR**

This course is a first introduction to real analysis. "Real" refers to the real numbers. Much of our work will revolve around the real number system. We will 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 also will be a major theme of the course. In the context of a general metric space (a space in which we can measure distances), we will 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 QR**

This course introduces students to the concepts, techniques and power of mathematical modeling. Both deterministic and probabilistic models will be 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 or permission of instructor. Offered every other year.

## Software and System Design

### **MATH 348 CREDITS: 0.5**

A study of software design project that requires planning, analysis, design, implementation, testing and maintenance. Different methods of planning, definition, requirements analysis and cost estimation are considered. A central component of the course is a semester long team project which engages a team of three to five students in the analysis, design, implementation and documentation of a significant applied project. The goal of this team project is for the students to engage with the material as they work to solve a real-world problem. These projects are real needs of organizations in the surrounding community (including Gambier, Knox county and, at times, beyond). Prerequisite: MATH 138, SCMP 118, 218 or 318.

## Complex Functions

### **MATH 352 CREDITS: 0.5 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

$$\lim_{z \rightarrow z_0} \frac{f(z) - f(z_0)}{z - z_0}$$

exists. Subsequently, we will study the amazing results that come from making such a seemingly innocent assumption. Differentiability for functions of one complex variable turns out to be a very different thing from differentiability in functions of one real variable. Topics covered will 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 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, continuity and 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 will touch 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.

## Design and Analysis Algorithms

### **MATH 368 CREDITS: 0.5**

This course introduces students to the analysis and design of computer algorithms. Upon completion of this course, students will be able to do the following: 1) analyze the asymptotic performance of algorithms; 2) demonstrate a familiarity with major algorithms and data structures; 3) apply important algorithmic design paradigms and methods of analysis, and; 4) synthesize efficient algorithms in common engineering design situations. Prerequisite: MATH 222 and SCMP 118 or PHYS 270 or equivalent.

## Abstract Algebra II

### **MATH 435 CREDITS: 0.5 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, unique factorization domains; the Gaussian integers; factorization techniques and irreducibility criteria. The final block of the semester will serve 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 will be an emphasis on examples, many of them coming from calculus, linear algebra, discrete math and elementary number theory. There also will be 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 QR**

This course follows MATH 341. Topics will 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**

The senior seminar in mathematics will guide students through the process of writing their senior capstone paper — a comprehensive, expository manuscript about mathematical/statistical content that delves deeper into one of these fields than the level of content presented in their coursework. Some sessions will introduce students to tools for success such as literature searches, good note-taking strategies, proper use of citations and mathematical typesetting for large documents. Other sessions will be used to provide structure and a timeline for completing the capstone paper, and will include a short talk by each student based on the required paper outline, peer review sessions and time in class to work on the manuscript. Additionally, several sessions will be used to prepare students to take the Educational Testing Service Major Field Test in Mathematics, which mathematics majors must pass to graduate. This counts toward the core course requirement for the major and is only open to senior mathematics majors. Offered every fall.

## Individual Study

### **MATH 493 CREDITS: 0.25 - 0.5**

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 0.25–0.50 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, will create a tentative syllabus (including a list of readings and/or problems, goals and tasks) and describe 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 preferably the semester before, so that there is time to devise the proposal and seek departmental approval before the registrar's deadline. Individual study course 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 QR**

This course will consist 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 will culminate 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

### AP Statistics

#### **STAT 0 CREDITS: 0.5**

### Elements of Statistics

#### **STAT 106 CREDITS: 0.5 QR**

This is a basic course in statistics. The topics to be 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 will be 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 will be used throughout the course, and students will be engaged 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 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 will be on the proper application of statistical models in sports. Students will 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, of home field advantage in football, of technological improvements in golf or cycling, and of training methods in marathon running. Although the sport and question of interest will change, the focus on proper applications of appropriate statistical methods will remain the same. Students will analyze data and present their results to the class. Oral and written reports will be expected. This will count toward the core requirement for the major. Students with credit for STAT 106 cannot take STAT 116 for credit. No prerequisite. Offered every other year.

## Data Analysis

### **STAT 206 CREDITS: 0.5 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 will provide the foundation for the course. Classical inference methods that rely on the normality of the error terms will be thoroughly discussed, and general approaches for dealing with data where such conditions are not met will be provided. For example, distribution-free techniques and computer-intensive methods, such as bootstrapping and permutation tests, will be presented. Students will use statistical software throughout the course to write and present statistical reports. The culminating project will be 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 and will also count toward an elective for the math and statistics minor. Prerequisite: STAT 106 or 116 or a score of 4 or 5 on the Statistics AP exam. Offered every semester.

## Nonparametric Statistics

### **STAT 216 CREDITS: 0.5 QR**

This course will focus on nonparametric and distribution-free statistical procedures. These procedures will rely heavily on counting and ranking techniques. In the one and two sample settings, the sign, signed-rank and Mann-Whitney-Wilcoxon procedures will be discussed. Correlation and one-way analysis of variance techniques also will be investigated. A variety of special topics will be used to wrap up the course, including bootstrapping, censored data, contingency tables and the two-way layout. The primary emphasis will be on data analysis and the intuitive nature of nonparametric statistics. Illustrations will be from real data sets and students will be asked to locate an interesting data set and prepare a report detailing an appropriate nonparametric analysis. This counts toward the statistical data science elective for

the major. Prerequisite: STAT 106, 116 or a score of 4 or 5 on the Statistics AP exam or permission of instructor. Offered every other year.

## Statistical Computing in R

### **STAT 226 CREDITS: 0.5**

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 will 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 will be introduced. Case studies and projects will be independently completed throughout the semester. This counts toward the Statistical/Data Science (Column E) elective for the major and will also count toward an elective for the math and statistics minor. Prerequisite: STAT 106, STAT 116 or permission of instructor. Offered every other year.

## Topics in Statistics

### **STAT 306 CREDITS: 0.5**

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 will be examined. A large component of each offering will be intensive projects where students will be expected to determine which statistical methods are appropriate for a given setting before analyzing data. As part of these projects and daily activities, students will use R to analyze data to make inferences about the population characteristics of interest. Additionally, written and oral communication will be 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 and will also count toward an elective for the math and statistics minor. Prerequisite: any STAT course at the 200-level or higher or permission of the instructor. Offered every spring.

Additional Catalog information for different subfields:

#### STAT 306 Topics in Statistics: Bayesian Analysis

This course will focus on statistical inference using a Bayesian framework. Unlike many other statistical tools, Bayesian methods incorporate prior information with information derived through experimentation or observation. The course will begin with a review of the basic concepts of probability, which are critical to understanding the foundations of the subject. Other topics will include decision theory, loss functions, subjective and objective prior distributions, posterior distribution, estimation, testing, prediction, sensitivity analysis and hierarchical modeling. We will also compare and contrast Bayesian methods with classical methods. Students will use R regularly to make Bayesian inference from data.

### STAT 306 Topics in Statistics: Biostatistics

Statistical methods are often used in medical studies. All of the examples, exercises and projects will deal with data from public health sectors, the World Health Organization, the CDC, the FDA or prospective or retrospective studies on patients. Survival functions will be introduced and inference methods based on the Kaplan-Meier estimator will be studied. Cox regression models and accelerated failure time models will be examined if time permits. R statistical software will be used heavily throughout the course.

### STAT 306 Topics in Statistics: Sports Analytics

Sports analytics are being used more frequently to help managers and owners make important decisions. Billy Bean was one of the first general managers to implement statistical methods and models to MLB. Now, similar models and methods are being used in basketball, football, hockey, soccer, golf, swimming and other sports. Using data science techniques to scrape data from appropriate sources has been a game changer for many analysts who are always trying to get an advantage on their competitors. We will carefully examine the statistical methods that are being used. In addition to analyzing individual and team performance over time, we will look at the impact of rule changes and new guidelines or draft policies. Students will read current journal articles from sports statistics journals and analyze data to address open questions of interest. Oral and written communication about these technical models will be a regular part of the course. Students will regularly be using R to analyze data and make inferences. Statistical methods for analyzing time series data will be a major part of this course.

### STAT 306 Topics in Statistics: Experimental Design

This course will focus on the design and analysis of experiments. Complete and fractional factorial designs, completely random designs, an

## Linear Regression Models

### **STAT 416 CREDITS: 0.5 QR**

This course will focus on linear regression models. Simple linear regression with one predictor variable will serve as the starting point. Models, inferences, diagnostics and remedial measures for dealing with invalid assumptions will be examined. The matrix approach to simple linear regression will be presented and used to develop more general multiple regression models. Building and evaluating models for real data will be the ultimate goal 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 and MATH 224. Offered every other spring.

## Mathematical Statistics

### **STAT 436 CREDITS: 0.5 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 will accompany and corroborate many of the theoretical results. Course methods often will be 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**

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## Senior Honors

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