Mathematics

Natural Sciences Division

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For well over 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 from 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 has 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, mathematics 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.

Kenyon's program in mathematics endeavors to blend interrelated but distinguishable facets of mathematics: theoretical ideas and methods, modeling real-world situations, the statistical analysis of data, and scientific computing. The curriculum is designed to develop competence in each of these aspects of mathematics in a way that responds to the interests and needs of individual students.

New Students

For those students who want only an introduction to mathematics, or perhaps a course to satisfy a distribution requirement, selection from MATH 105, 106, 108, 110Y-111Y, 111, and 118 is appropriate. Students who think they might want to continue the study of mathematics beyond one year, either by pursuing a major or minor in mathematics or as 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 the Elements of Statistics (MATH 106) and Data Analysis (MATH 206) or Introduction to Computer Science (MATH 118). A few especially well-prepared students take Linear Algebra (MATH 224) or Foundations (MATH 222) in their first year. (Please see Professor Robert Milnikel for further information.)

Calculus with Elementary Functions (Math 110Y-111Y) is a year-long course that integrates an introduction to calculus with a thorough review of the necessary precalculus prerequisites. 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. MATH 106 is an introduction to statistics, which focuses on quantitative reasoning skills and the analysis of data. MATH 118 introduces students to computer programming.

Please read the course descriptions for further information concerning these courses, and look for the ◆ symbol, which designates those courses particularly appropriate for first-year students or upperclass students new to the mathematics curriculum. 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. We encourage all students who do not have advanced placement credit to take the placement exam that is appropriate for them.

The ready availability of powerful computers has made the computer one of the primary tools of the mathematician. Students will be expected to use appropriate computer software in many of the mathematics 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.

Course Requirements for the Major

There are two concentrations within the mathematics major: classical mathematics and statistics. The coursework required for completion of the major in each concentration is given below.

Classical Mathematics

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 (MATH 106 or 436)
MATH 118 Introduction to Programming
MATH 222 Foundations
MATH 224 Linear Algebra I
MATH 335 Abstract Algebra I or MATH 341 Real Analysis I

In addition, majors must have credit for at least three other courses selected with the consent of the department. MATH 110 may not be used to satisfy the requirements for the major.

Statistics

A student must have credit for the following core courses:

Three semesters of calculus (MATH 111, 112, 213 or the equivalent)
MATH 118 Introduction to Programming
MATH 222 Foundations
MATH 224 Linear Algebra I
MATH 336 Probability
MATH 341 Real Analysis I
MATH 416 Linear Regression Models or MATH 436 Mathematical Statistics

In addition to the core courses, majors must also have credit for two of the following:

MATH 106 Elements of Statistics
MATH 206 Data Analysis
MATH 216 Nonparametric Statistics
MATH 226 Design and Analysis of Experiments
MATH 416 Linear Regression Models
MATH 436 Mathematical Statistics

Additional Requirements for the Major

Majors should present to the department, through their advisor and prior to the start of the senior year, a proposal that says how their major program will meet expectations that go beyond the accumulation of units of credit, as follows:

1. Mathematics is a vital component in the methods used by other disciplines. Therefore, majors are expected to present a program of study that includes courses (at least 1 unit) that use mathematics in significant ways. While many such courses may be found in the natural sciences, suitable courses may also be found in other disciplines, such as economics.

2. Majors are expected to attain a depth of study within mathematics, as well as breadth. Therefore majors are expected to present a program of study that will fulfill these expectations. Ordinarily, depth of study results from election of a two-course, upper-level sequence chosen from the following: MATH 335 and 435 (Abstract Algebra I and II), MATH 341 and 441 (Real Analysis I and II), MATH 336 and 436 (Probability and Mathematical Statistics), or MATH 336 and 416 (Probability and Linear Regression). A concentration in statistics within the mathematics major will automatically meet the expectation of depth of study.

Senior Exercise

The Senior Exercise 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. (Juniors are encouraged to begin thinking about possible topics before they leave for the summer.) Students are also required to take the Major Field Test in Mathematics produced by the Educational Testing Service. Evaluation of the Senior Exercise is based on the student's performance on the paper and the standardized exam. A detailed guide on the Senior Exercise is available on the math department Web site under the link "mathematics academic program." The department's homepage is accessible via Kenyon's site, www.kenyon.edu.

Suggestions for Majoring in Mathematics

Students wishing to keep open the option of a major in mathematics typically begin with the study of calculus and normally complete the calculus sequence, MATH 222 (Foundations of Analysis) and either MATH 118 or MATH 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 major should consult with a member of the mathematics 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 (Geometry), since this course is required for certification in most states, including Ohio.

Honors in Mathematics

The Honors Program in mathematics requires three semesters of honors work: the Junior Honors Seminar in the spring of the junior year and two semesters of Senior Honors. The purpose of the Junior Honors Seminar is to allow honors students to explore widely so as to broaden their mathematical horizons and at the same time decide on a topic (or topics) on which to concentrate during their senior year. Students must have the consent of the department to undertake honors work. To be considered for the honors program, students must have an excellent academic record both in their mathematics courses and overall, and they must show promise for continued in-depth study of mathematics. Furthermore, they must complete at least two upper-level courses (numbered 300 or above) before admission to the honors program.

Requirements for the Minors

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

Mathematics

The calculus sequence MATH 111, 112, 213, and four courses from the following: MATH 105, 106, 108, 118, 222, 224, 227, 230, 233, 324, 327, 333, 335, 336, 341, 347, 352, 435, 441, 460. (Students may count at most one of the following: MATH 105, 106, 108, and 118.) Other courses numbered 200 or above (e.g., special-topics courses) may be counted with the consent of the department.

Statistics

Five courses in statistics from the following: MATH 106, 206, 216, 226, 316, 336, 436. (Students may count at most one statistics course from another department. For example, ECON 375 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 such as Minitab, SAS, and Maple.

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

Year Courses

Calculus/Elementary Functions

◆ QR MATH 110Y-111Y (.5 unit)
Schumacher

This course is a year-long introduction to calculus that integrates an extensive review of algebra and elementary functions with the topics taught in Calculus A (MATH 111). The course is intended for students who need to strengthen their quantitative and algebraic precalculus skills in order to learn calculus more effectively. Topics include functions and their properties (including exponential, logarithmic, and trigonometric functions), limits and continuity, and a thorough introduction to the study of rates of change, called differential calculus. The course will end with a brief introduction to integral calculus (the problem of finding areas) and the connection between integral and differential calculus. Students who have credit for MATH 111 may not take this course. Enrollment limited.

First-Semester Courses

Elements of Statistics

◆ QR MATH 106 (.5 unit)
Hartlaub, Frazier

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. Minitab, a statistical software package, will be used, and students will be engaged in a wide variety of hands-on projects. Enrollment limited.

Calculus A

◆ QR MATH 111 (.5 unit)
Jones, Schumacher

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, will also 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 .5 unit of credit for calculus may not receive credit for MATH 111. Prerequisites: solid grounding in algebra, trigonometry, and elementary functions.

Students who have credit for MATH 110Y-111Y may not take this course. Enrollment limited.

Calculus B

◆ QR MATH 112 (.5 unit)
Milnikel

The second in a three-semester calculus sequence, this course is concerned primarily with the basic ideas of integral calculus and the Riemann sums that serve as its foundation. We will cover in detail the ideas of integral calculus, including integration and the fundamental theorem, techniques of integration, numerical methods, and applications of integration. Analysis of differential equations by separation of variables, Euler's method, and slope fields will be a part of the course, as will the ideas of convergence related to improper integrals, sequences, series and Taylor Series. Prerequisite: MATH 111 or MATH 110Y-111Y, or permission of the instructor. Enrollment limited.

Introduction to Programming

◆ QR MATH 118 (.5 unit)
Aydin

This course presents an introduction to computer programming intended both for those who plan to take further courses in which a strong background in computation is desirable and for those who are interested in learning basic programming principles. The course will expose the student to a variety of applications where an algorithmic approach is natural and will include both numerical and non-numerical computation. The principles of program structure and style will be emphasized. Enrollment limited.

Calculus C

QR MATH 213 (.5 unit)
Holdener

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 will also be covered as time permits: vector fields, line integrals, flux integrals, curl, and divergence. Prerequisite: MATH 112 or permission of the instructor.

Foundations

QR MATH 222 (.5 unit)
Aydin

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. Emphasis will be placed on helping students in reading, writing, and understanding 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. (Please see a member of the mathematics faculty if you think you might want to do this.) Prerequisite: MATH 213 or permission of instructor.

Linear Algebra

QR MATH 224 (.5 unit)
Paquin

Linear algebra grew out of the study of the problem of organizing and solving systems of equations. Today, ideas from linear algebra are highly useful in most areas of higher-level mathematics. Moreover, there are numerous uses of linear algebra in other disciplines, including computer science, physics, chemistry, biology, and economics.
This course involves the study of vector spaces and matrices, which may be thought of as functions between vector spaces. In the past, linear algebra involved tedious calculations. Now we have computers to do this work for us, allowing us to spend more time on concepts and intuition. A computer algebra system such as Maple will likely be used. Prerequisite: MATH 213 or permission of instructor.

Special Topic: Random Structures

MATH 291 (.5 unit)
Jones

This course will explore the theory, structure, applications, and interesting consequences when probability is introduced to mathematical objects. Some of the core topics will be random graphs, random walks, and Markov processes, as well as randomness applied to sets, permutations, polynomials, functions, integer partitions, and binary codes. Previous study of all of these mathematical objects is not a prerequisite, as essential background will be covered during the course. In addition to studying the random structures themselves, a concurrent focus of the course will be the development of mathematical tools to analyze them, such as combinatorial concepts, indicator variables, generating functions, discrete distributions, laws of large numbers, asymptotic theory, and computer simulation. Prerequisite: MATH 112.

Combinatorics

MATH 317 (.5 unit)
Aydin

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 algebra, and combinatorial methods of counting, including combinations and permutations, partitions, generating functions, the principle of inclusion and exclusion, and the Stirling and Catalan numbers. This course will cover a selection of these topics. Combinatorics mathematics has applications in a wide variety of non-mathematical areas, including computer science (both in algorithms and hardware design), chemistry, sociology, government, and urban planning, and this course may be especially appropriate for students interested in the mathematics related to one of these fields. Prerequisite: MATH 222 or permission of instructor.

Abstract Algebra I

QR MATH 335 (.5 unit)
Holdener

The phrase "abstract algebra" correctly suggests some sort of a generalization of a topic most of us learned in high school, though it goes very much beyond that, of course. Three of the most important structures in abstract algebra are groups, rings, and fields; all three are, in fact, abstractions of familiar objects—the integers form a group or ring, while the real numbers give us an example of a field. Each of these structures has the property that any two of the subjects in the system may be "combined" in some way to produce a new object in the system. In the system of integers, for example, this "combining" might be addition or multiplication. Groups and rings are fundamental tools for any mathematician and many scientists, but these concepts are beautiful and worthy of study in their own right—group theory and ring theory currently are both very active areas of mathematical research.

In this course, the student examines the basics of groups and rings, with emphasis on the many examples of these algebraic structures. A possible example might be a study of symmetry with the aid of group theory. Prerequisite: MATH 222 or permission of the instructor. Junior standing is usually recommended.

Probability

QR MATH 336 (.5 unit)
Hartlaub

This course provides a mathematical introduction to probability. Topics include basic probability theory, random variables, discrete and continuous distributions, mathematical expectation, functions of random variables, and asymptotic theory. Prerequisite: MATH 213.

Mathematical Models

MATH 347 (.5 unit)
Paquin

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. Prerequisites: MATH 224 or permission of the instructor.

Individual Study

MATH 493 (.5 unit)
Staff

This course enables students to study a topic of special interest under the direction of a member of the mathematics department. Prerequisites: permission of instructor and department chair.

Senior Honors

QR MATH 497 (.5 unit)
Staff

The content of this course is variable and adapted to the needs of senior candidates for honors in mathematics. Prerequisite: permission of department.

Second-Semester Courses

Surprises at Infinity

◆ QR MATH 105 (.5 unit)
Milnikel

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, how a finite shape can have an infinite perimeter, and why some mathematical statements can be neither proved nor disproved. This will very likely be quite different from any mathematics course you have ever taken. Surprises at Infinity 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. You can expect essay tests, frequent homework and writing assignments. No prerequisites.

Elements of Statistics

◆ QR MATH 106 (.5 unit)
Hartlaub, Jones

See first-semester course description.

Calculus A

◆ QR MATH 111 (.5 unit)
Jones

See first-semester course description.

Calculus B

◆ QR MATH 112 (.5 unit)
Paquin

See first-semester course description.

Introduction to Programming

◆ QR MATH 118 (.5 unit)
Milnikel

See first-semester course description.

Data Analysis

QR MATH 206 (.5 unit)
Hartlaub

This course follows MATH 106 and focuses on (1) additional topics in statistics, including linear regression, nonparametric methods, discrete data analysis, and analysis of variance; (2) efficient use of statistical software in data analysis and statistical inference; and (3) writing and presenting statistical reports, including graphics. The MATH 106-206 sequence provides a foundation for statistical work in applied fields such as econometrics, psychology, and biology. It also serves as preparation for study of theoretical probability and statistics. Prerequisite: MATH 106.

Calculus C

QR MATH 213 (.5 unit)
Aydin

See first-semester course description.

Data Structures and Program Design

QR MATH 218 (.5 unit)
Aydin

This course is intended as a second course in programming, as well as an introduction to the concept of computational complexity and the major abstract data structures (such as arrays, stacks, queues, link lists, graphs, and trees), their implementation and application, and the role they play in the design of efficient algorithms. Students will be required to write a number of programs using a high-level language. Prerequisite: MATH 118.

Foundations

QR MATH 222 (.5 unit)
Schumacher

See first-semester course description.

Mathematical Biology

MATH 258 (.5 unit)
Kerkhoff

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 mathematics 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 mathematics majors will be encouraged to work together on many aspects of the course.

Course work 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, using mathematical software like Mathematica, Matlab, R, or Maple. Students will make a poster presentation of their results.

Prerequisites: This course will build on (but not be limited by) an introductory-level knowledge base in both subjects, including MATH 111 and either BIOL 112 or BIOL 113. Interested biology and math majors lacking one of the prerequisites are encouraged to consult with the instructor.

Differential Equations

QR MATH 333 (.5 unit)
Paquin

Differential equations arise naturally to model dynamical systems such as occur in physics, biology, 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. Prerequisite or co-requisite: MATH 213.

Real Analysis I

QR MATH 341 (.5 unit)
Schumacher

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 will also 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. Prerequisites: MATH 213 and MATH 222. Junior standing is usually recommended.

Complex Functions

QR MATH 352 (.5 unit)
Holdener

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

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

exists. In the course 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. Prerequisites: MATH 213 and 224.

Junior Honors

QR MATH 398 (.5 unit)
Staff

The goal of the Junior Honors Seminar is twofold: to develop a greater understanding of a broad selection of mathematical topics and to gain the experience of independent exploration in mathematics. Students will work under the close supervision of a faculty member on three areas of interest. Topics of study will be chosen by the student. As a culmination of the course, each student will write a proposal describing his or her plan of study for senior honors. Prerequisite: permission of department.

Abstract Algebra II

QR MATH 435 (.5 unit)
Holdener

This course picks up where MATH 335 ends. In this course, however, the focus is on using the tools considered in Abstract Algebra I. Mathematicians and scientists apply the fundamental algebraic notions of group, ring, and field to a wide variety of mathematical areas and scientific disciplines. In this course, the student explores these applications. The structure will be that of a topics course with a focus on classical problems that can be solved (and historically were solved) using algebraic structures as tools.

Topics that may be considered include insolvability of a quintic polynomial, the factoring of polynomials (just as in high school, but over arbitrary rings rather than the real numbers), the classification of finite simple groups (something proven very recently), special cases of

"Fermat's Last Theorem," Eisenstein's criterion for irreducibility, the beautiful subject of Galois theory, and more. The class may borrow knowledge from subjects including linear algebra, number theory, complex numbers, calculus, and computer programming, though all one needs to know about these subjects will be covered in class. Prerequisite: MATH 335.

Mathematical Statistics

QR MATH 436 (.5 unit)
Jones

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 will often be applied to real data sets. Prerequisite: MATH 336.

Individual Study

MATH 494 (.5 unit)
Staff

This course enables students to study a topic of special interest under the direction of a member of the department. Prerequisites: permission of instructor and department chair.

Senior Honors

QR MATH 498 (.5 unit)
Staff

The content of this course is variable and adapted to the needs of senior candidates for honors in mathematics. Prerequisite: permission of department.

Additional courses available another year include the following:

Models of Life

◆ QR MATH 108 (.5 unit)

This course will explore various areas of mathematics involved in modeling the growth and form of biological organisms and populations. In particular, we will ask such questions as: How can you model the growth of a population of animals? How can you model the fractal branching patterns exhibited by a tree? How can you model the spiraling growth of sunflowers and seashells? How might you model the surface patterns of a seashell? How do mathematicians quantify symmetry? The course will be a "hands-on" course and will make extensive use of the graphical capabilities of the computer software package Maple. The course will not involve significant amounts of symbolic manipulation. Rather, assignments will usually involve readings and computer projects, and there will be a large emphasis on visualization. The course will rely on ideas from a wide range of mathematical fields, including dynamical systems, geometry, linear algebra, mathematical modeling, and computer graphics. Prerequisites: Precalculus or permission of the instructor. Enrollment limited.

Nonparametric Statistics

QR MATH 216 (.5 unit)

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 will also 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. Prerequisites: MATH 106 or permission of instructor.

Design and Analysis of Experiments

QR MATH 226 (.5 unit)

This course will focus on standard methods of designing and analyzing experiments. Simple comparative designs, factorial designs, block designs, and appropriate post-hoc comparisons will be discussed. These techniques are commonly used by statisticians and experimental scientists in a wide variety of fields. Statistical software will be introduced and heavily used throughout the course. No prior experience with the software is necessary. Each student will be asked to design an experiment, conduct the experiment, and collect and analyze the appropriate data. Prerequisite: MATH 106 (6) or permission of instructor. Enrollment limited.

Euclidean and Non-Euclidean Geometry

QR MATH 230 (.5 unit)

The Elements of Euclid, written over two thousand years ago, is a stunning achievement. The Elements and the non-Euclidean geometries discovered by Bolyai and Lobachevsky in the nineteenth century formed 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 point of view, but will also have the opportunity to learn about several non-Euclidean geometries such as (possibly) the Poincare plane, geometries relevant to special relativity, or the geometries of Bolyai and Lobachevsky. In addition, the course may cover topics in differential geometry, topology, vector space geometry, mechanics, or other areas, depending on the interests of the students and the instructor. Prerequisite: MATH 222 or permission of instructor.

Vector Calculus

QR MATH 232 (.5 unit)

Physical and natural phenomena depend on a complex array of factors, and to analyze these factors requires the understanding of geometry in two and three (or more) dimensions. This course will continue the study of multivariable calculus begun in MATH 213. Topics of study will include curves in space, vector fields, line and surface integrals, potential functions, classical vector analysis, and classical vector analysis, including Green's theorem, the divergence theorem, and Stokes' theorem. Computer labs will be incorporated throughout the course, and physical applications will be plentiful. Prerequisite: MATH 213.

Dynamical Systems

QR MATH 233 (.5 unit)

The theory of dynamical systems is the study of the behavior of physical or mathematical systems that change over time according to specific rules. Dynamical systems have applications to many areas of science and social science-research, including models of population growth and decline, interspecies relationships, traffic-flow problems, battles, river meanders, weather patterns, heartbeat rates, chemical reactions, and financial markets. In this course we will study both discrete and continuous time models, presenting the two approaches in a unified manner. Upon completion of the course, students should comprehend the basic concepts and recent developments in the field of dynamical systems, including the stability theory of equilibria and the theory of transitions to chaos. Students will develop the ability to analyze simple nonlinear discrete and continuous dynamical systems and to chart parameter regions of stability, periodicity, and chaos. Further, students will gain an appreciation for the power as well as the limitations of dynamical systems theory and chaos when applied to realistic systems such as ecologies and financial markets. Rather than taking a formal theorem-proof style, the course will be taught in a manner that stresses the geometry, intuition, and appreciation of dynamical systems. Computer technology will be used extensively to perform simulations and experiments. Prerequisite: MATH 111. Co-requisite: MATH 112.

Numerical Analysis

QR MATH 237 (.5 unit)

This course presents a study of the major topics of classical numerical analysis. These include the solution of nonlinear equations, interpolation and approximation, numerical integration, matrices and systems of linear equations, and the solution of differential equations. The course requires extensive use of the computer. Prerequisites: MATH 118 and MATH 213 or permission of department chair.

Linear Regression Models

QR MATH 316 (.5 unit)

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 may also be studied if time permits. Prerequisites: MATH 106 and MATH 224 or permission of instructor.

Linear Algebra II

QR MATH 324 (.5 unit)

This course deepens the studies begun in MATH 224. Topics will vary depending on the needs and interests of the students. However, the topics are likely to include some of the following: vector spaces over general fields, linear mappings and canonical forms, linear models and eigenvector analysis, complex inner product spaces. Prerequisite: MATH 224.

An Introduction to Coding Theory and Cryptography

QR MATH 328 (.5 unit)

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 materials from abstract algebra, elementary number theory, and computational complexity will be covered within the course.

This course is appropriate for math and science majors who are interested in seeing some of the practical applications of abstract mathematics. It is also useful for students interested in scientific computing to explore practical issues related to computational complexity and theory of computation. It can be used to fulfill a requirement in the scientific computing concentration.

Linear Regression Models

QR MATH 416 (.5 unit)

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 may also be studied if time permits. Prerequisites: MATH 106, MATH 213, and MATH 224 or permission of instructor.

Real Analysis II

QR MATH 441 (.5 unit)

As the name suggests, this course is a successor to Real Analysis I . The course 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, and differentiation of functions of several variables. Other topics may be included as time permits. For example, a discussion of Newton's method or other numerical techniques; integration of functions of several variables, spaces of continuous functions; the implicit function theorem; everywhere continuous, nowhere differentiable functions. Prerequisite: MATH 341.

Topology

QR MATH 460 (.5 unit)

Topology is a relatively new branch of geometry that studies very general properties of geometric objects, how these objects can be modified, and the relations between them. Three key concepts in topology are compactness, connectedness, and 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. Economics, chemistry, and physics are among the subjects that find topology useful. The course will touch on selected topics that are used in applications. Prerequisite: permission of instructor.