MATHEMATICS (MATH)

MATH 2: Elementary Geometry With Problem Solving

4 Credits

Geometric congruence, similarity, area, surface area, volume, introductory trigonometry; emphasis on logical reasoning skills and the solution of applied problems. This course may not be used to satisfy the basic minimum requirements for graduation in any baccalaureate degree program.

MATH 3: Basic Skills

3 Credits

Natural numbers; integers; rational numbers; decimals; ratio, proportion; percent; graphs; applications. Students who have passed MATH 001 may not schedule this course for credit. This course may not be used to satisfy the basic minimum requirements for graduation in any baccalaureate degree program.

Enforced Prerequisite at Enrollment: Satisfactory performance on the mathematics placement examination.

MATH 4: Intermediate Algebra

3 Credits

Algebraic expressions; linear, absolute value equations and inequalities; lines; systems of linear equations; integral exponents; polynomials; factoring. This course may not be used to satisfy the basic minimum requirements for graduation in any baccalaureate degree program.

Enforced Prerequisite at Enrollment: MATH 3 or satisfactory performance on the mathematics placement examination.

MATH 10: Preparation Skills for Success in Mathematics

1 Credits/Maximum of 4

A foundation course that emphasizes study skills and reviews basic mathematical principles.

Concurrent: math 003-201

MATH 21: College Algebra with Analytic Geometry with Applications I

3 Credits

This course satisfies the General Education Qualification. Topics covered include visualizing and graphing data; evaluating the average rate of change; solving linear equations and inequalities; solving linear absolute value equations and inequalities; modeling with linear functions and discussion of interpolation; solving quadratic equations using different solution methods; solving quadratic inequalities; modeling with quadratic functions.

Enforced Prerequisite at Enrollment: MATH 4 or satisfactory performance on the mathematics placement examination.
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Effective Communication
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Integrative Thinking
GenEd Learning Objective: Key Literacies

MATH 22: College Algebra With Analytic Geometry and Applications II

3 Credits

This course covers topics that include functions and their representations; distinguishing between types of functions; evaluating the average rate of change; factoring polynomials of general degree; solving polynomial inequalities; solving rational equations and inequalities; solving radical equations; modeling with polynomial and rational functions; finding and interpreting the meaning of inverse functions; solving exponential and logarithmic equations; modeling with exponential and logarithmic functions.

Enforced Prerequisite at Enrollment: MATH 21 or satisfactory performance on the mathematics placement examination.
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Effective Communication
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Integrative Thinking
GenEd Learning Objective: Key Literacies

MATH 26: Plane Trigonometry and Applications of Trigonometry

3 Credits

This course satisfies the General Education Qualification. Topics covered include angles and their measures; right triangle trigonometry; all six trigonometric functions and their representations; angle addition/subtraction and double angle identities; modeling with sine and cosine; applications of trigonometric functions; simple harmonic motions and other applications of trigonometric functions; inverse trigonometric functions; solving trigonometric equations; verifying identities; law of sines and law of cosines; vectors; polar equations; trigonometric form of complex numbers; other related topics as time permits.

Enforced Prerequisite at Enrollment: MATH 21 or satisfactory performance on the mathematics placement examination.
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Effective Communication
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Integrative Thinking
GenEd Learning Objective: Key Literacies

MATH 26H: Plane Trigonometry

3 Credits

Trigonometric functions; solutions of triangles; trigonometric equations; identities.

General Education: Quantification (GQ)
Honors

MATH 30: Problem Solving

3 Credits

Concepts in problem solving; reducing new problems to old ones; techniques for attacking problems; building mathematical models.

Bachelor of Arts: Quantification

MATH 32: Math for Allied Health Professions

3 Credits

This course is intended to build the specific quantitative reasoning skills needed by workers in Allied Health Professions, such as nurses or therapists. Students will become fluent in proportional reasoning in a variety of contexts, including unit conversion, drug dosage calculations, probability, and logarithmic scales. Students gain the tools to communicate and reason about covariation in scenarios such as exponential growth and decay. Student will also apply tools of probability and descriptive statistics to gain literacy in risk and uncertainty in health settings, such as making sense of effect sizes in research literature.

Enforced Prerequisite at Enrollment: MATH 4 or satisfactory performance on the math placement exam
General Education: Quantification (GQ)
GenEd Learning Objective: Effective Communication
GenEd Learning Objective: Key Literacies

MATH 33: Mathematics for Sustainability

3 Credits

Mathematical analysis of sustainability: measurement, flows, networks, rates of change, uncertainty and risk, applying analysis in decision making; using quantitative evidence to support arguments; examples. MATH 033 Mathematics for Sustainability (3) (GQ) This course is one of several offered by the mathematics department with the goal of helping students from non-technical majors partially satisfy their general education quantification requirement. It is designed to provide an introduction to various mathematical modeling techniques, with an emphasis on examples related to environmental and economic sustainability. The course may be used to fulfill three credits of the GQ requirement for some majors, but it does not serve as a prerequisite for any mathematics courses and should be treated as a terminal course. The course provides students with the mathematical background and quantitative reasoning skills necessary to engage as informed citizens in discussions of sustainability related to climate change, resources, pollution, recycling, economic change, and similar matters of public interest. Students apply these skills through writing projects that require quantitative evidence to support an argument. The mathematical content of the course spans six key areas: "measuring" (representing information by numbers, problems of measurement, units, estimation skills); "flowing" (building and analyzing stock-flow models, calculations using units of energy and power, dynamic equilibria in stock-flow systems, the energy balance of the earth-sun system and the greenhouse effect); "connecting" (networks, the bystander effect, feedbacks in stock-flow models); "changing" (out-of-equilibrium stock-flow systems, exponential models, stability of equilibria in stock-flow systems, sensitivity of equilibria to changes in a parameter, tipping points in stock-flow models); "risking" (probability, expectation, bayesian inference, risk vs uncertainty; "deciding" (discounting, uses and limitations of cost-benefit analysis, introduction to game theory and the tragedy of the commons, market-based mechanisms for pollution abatement, ethical considerations).

RECOMMENDED PREPARATIONS: ENGL 15
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Effective Communication
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies
GenEd Learning Objective: Soc Resp and Ethic Reason

MATH 34: The Mathematics of Money

3 Credits

This course will provide students with the mathematical background and quantitative skills needed to make sound financial decisions. This course introduces personal finance topics including simple interest, simple discount, compound interest, annuities, investments, retirement plans, inflation, depreciation, taxes, credit cards, mortgages, and car leasing. Students will learn how to use linear equations, exponential and logarithmic equations, and arithmetic and geometric sequences to solve real world financial problems. Students will answer questions such as, What is the most they can afford to pay for a car? How much do they need to invest in their 401(k) account each month to retire comfortably? What credit card is the best option? In a society where consumers are presented with a vast array of financial products and providers, students are enabled to evaluate options and make informed, strategic decisions. This course may be used by students from non-technical majors to satisfy 3 credits of their General Education Quantification (GQ) requirement. This course does not serve as a prerequisite for any mathematics courses and should be treated as a terminal course.

Enforced Prerequisite at Enrollment: MATH 4 or satisfactory performance on the mathematics placement exam
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 35: General View of Mathematics

3 Credits

This course presents a general view of a number of mathematical topics to a non-technical audience, often relating the mathematical topics to a historical context, and providing students with an opportunity to engage with the mathematics at an introductory level. Although some variation in topics covered may take place among different instructors at different campuses, an example of such a course focuses on a number theory theme throughout the course, beginning with the Greeks' view of integers, the concept of divisors, the calculation of greatest common divisors (which originates with Euclid), the significance of the prime numbers, the infinitude of the set of prime numbers (also known to the ancient Greeks), work on perfect numbers (which continues to be a topic of research today), and the work of Pythagoras and his famous Theorem. The course then transitions to the work of European mathematicians such as Euler and Gauss, including work on sums of two squares (which generalizes the Pythagorean Theorem), and then considering Euler's phi function, congruences, and applications to cryptography.

Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 36: Insights Into Mathematics

3 Credits

This course will provide students the mathematical background and quantitative skills in various mathematical applications in such areas which are related to voting, fair divisions which includes apportionment methods, and the understanding and application of basic graph theory such as Euler and Hamilton circuits. This course may be used by students from non-technical majors to satisfy 3 credits of their General Education Quantification (GQ) requirement. This course does not serve as a prerequisite for any mathematics courses and should be treated as a terminal course.

Prerequisite: one unit of algebra or MATH 004
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 37: Finite Mathematics

3 Credits

Finite math includes topics of mathematics which deal with finite sets. Sets and formal logic are modern concepts created by mathematicians in the mid 19th and early 20th centuries to provide a foundation for mathematical reasoning. Sets and formal logic have lead to profound mathematical discoveries and have helped to create the field of computer science in the 20th century. Today, sets and formal logic are taught as core concepts upon which all mathematics can be built. In this course, students learn the elementary mathematics of logic and sets. Logic is the symbolic, algebraic way of representing and analyzing statements and sentences. While students will get just a brief introduction to logic, the mathematics used in logic are found at the heart of computer programming and in designing electrical circuits. Problems of counting various kinds of sets lead to the study of combinatorics, the art of advanced counting. For example, if a room has twenty chairs and twelve people, in how many ways can these people occupy the chairs? And are you accounting for differences in who sits in particular chairs, or does it only matter whether a chair has a body in it? These kinds of counting problems are the basis for probability. In order to calculate the chance of a particular event occurring you must be able to count all the possible outcomes. MATH 37 is intended for students seeking core knowledge in combinatorics, probability and mathematical logic but not requiring further course work in mathematics. Students entering the class will benefit from having some experience with basic algebra and solving word problems. The course may be used to fulfill three credits of the quantification portion of the general education requirement for some majors, but does not serve as a prerequisite for any mathematics courses and should be treated as a terminal course. Class size, frequency of offering, and evaluation methods will vary by location and instructor. For these details check the specific course syllabus.

Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 38: Elementary Linear Algebra

3 Credits

Many problems we have to solve in day-to-day practice require the simultaneous determination of several different but interrelated unknowns. Although many problems of this form have been studied throughout the long history of mathematics, only in the early 20th century did the systematic approach we now refer to as linear algebra emerge. Matrices and linear algebra are now accepted as the single most essential tool need for the solution of these problems. In addition, linear algebra provides students their first introduction to the concept of dimension in an abstract setting where things with 4, 5, or even more dimensions are often encountered. In the simplest situations, many of these problems can be represented as A x = b, where x is our vector of unknowns, A is a matrix, and b is a vector of constants. MATH 38 is intended for students requiring some understanding of the concepts of linear algebra for their major, but not requiring any calculus course work. Students who are also required to take calculus course work should instead take MATH 220 after completion of an appropriate prerequisite.

Prerequisite: 2 units of high school mathematics
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 40: Algebra, Trigonometry, and Analytic Geometry

5 Credits

Concepts of algebra; equations; inequalities; functions; graphs; polynomial and rational functions; exponential and logarithmic functions; trigonometry; analytic geometry; complex numbers.

Enforced Prerequisite at Enrollment: Satisfactory performance on the mathematics placement examination.
Bachelor of Arts: Quantification
General Education: Quantification (GQ)

MATH 41: Trigonometry and Analytic Geometry

4 Credits

Topics covered include functions and their representations; distinguishing between types of functions; evaluating the average rate of change; graphs and rate of change; end behavior of graphs; modeling with polynomial and rational functions and discussing extrema; finding and interpreting the meaning of inverse functions; solving exponential and logarithmic equations; modeling with exponential and logarithmic functions; angles and their measures; right triangle trigonometry; all six trigonometric functions and their representations; modeling with sine and cosine; applications of trigonometric functions; simple harmonic motion and other applications of trigonometric functions; inverse trigonometric functions; solving trigonometric equations; verifying identities; law of sines and law of cosines; and further topics, such as elementary limits, as time permits.

Enforced Prerequisite at Enrollment: MATH 21 or satisfactory performance on the mathematics placement examination.
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Effective Communication

GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Integrative Thinking
GenEd Learning Objective: Key Literacies

MATH 81: Technical Mathematics I

3 Credits

Math 81 is the first course in an applied mathematics sequence. The course includes a review of algebra, study of functions, study of systems of linear equations, and an introduction to trigonometry. It addresses the needs of engineering technology majors, and emphasizes technology and applications.

Prerequisite: MATH 004 or satisfactory performance on the mathematics placement examination
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Integrative Thinking
GenEd Learning Objective: Key Literacies

MATH 82: Technical Mathematics II

3 Credits

Exponents, radicals, complex numbers, theory of equations, inequalities, half angle and double angle formulas, inverse trigonometric functions, exponential, logarithm, conic sections.

Enforced Prerequisite at Enrollment: MATH 81
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Integrative Thinking
GenEd Learning Objective: Key Literacies

MATH 83: Technical Calculus

4 Credits

Math 83 is the third course in an applied mathematics sequence. Math 81; Math 82; Math 83; Math 210; Math 211. It addresses the needs of engineering technology majors, and emphasizes technology and applications. Math 83 is an introduction to differential and integral calculus, with some differential equations. Specific course topics include: limits: derivatives; implicit differentiation; related rates and extrema problems; curve sketching; numerical and symbolic integration; applications of differentiation; and differential equations.

Enforced Prerequisite at Enrollment: MATH 82 or MATH 41
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Integrative Thinking
GenEd Learning Objective: Key Literacies

MATH 97: Special Topics

1-9 Credits/Maximum of 9

Formal courses given infrequently to explore, in depth, a comparatively narrow subject which may be topical or of special interest.

MATH 97G: Special Topics - GenEd

1-9 Credits/Maximum of 9

Formal course given on a topical or special interest subject offered infrequently; several different topics may be taught in one year or semester. This is a Special Topics GenEd course.

General Education: Quantification (GQ)

MATH 97N: Special Topics - InterDomain

1-9 Credits/Maximum of 9

Formal course given on a topical or special interest subject offered infrequently; several different topics may be taught in one year or semester. This Special Topics is an GenEd course.

MATH 102: Bridge to Calculus

3-4 Credits

This summer course aims to provide incoming students with the tools needed to be successful wherever they place in the calculus sequence. Specific content is tailored to individual students, based on their existing skill set and expected entry point in the calculus sequence, but ranges from algebra and trigonometry to the real analysis which underlies calculus. The course emphasizes teamwork, communication skills, growth mindset, self-assessment (e.g., metacognition) and building a community of scholars. This is achieved through evidence-based, student-centered pedagogical practices such as collaborative and active learning, scaffolded instruction, extensive group work, metacognitive reflections, and exploratory projects and presentations.

MATH 110: Techniques of Calculus I

4 Credits

Business Calculus is a critical component in the education of any business, financial, or economics professional who uses quantitative analysis. This course introduces and develops the mathematical skills required for analyzing change, and the underlying mathematical behaviors that model real-life economics and financial applications. The primary goal of our business calculus courses is to develop the students' knowledge of calculus techniques, and to use a calculus framework to develop critical thinking and problem solving skills. The concept of a limit of a function/model is central to differential calculus; MATH 110 begins with a study of this concept, its geometric and analytical interpretation, and its use in the definition of the derivative. Differential calculus topics include: derivatives and their applications to rates of change, related rates, optimization, and graphing techniques. Target applications focus mainly on business applications, e.g. supply/demand models, elasticity, logistical growth, and marginal analysis within Cost, Revenue, and Profit models. Integral Calculus begins with the Fundamental Theorem of Calculus, integrating the fields of differential and integral calculus. Antidifferentiation techniques are used in applications focused on finding areas enclosed by functions, consumer and producer surplus, present and future values of income streams, annuities, and perpetuities, and the resolution of initial value problems within a business context. Students may only take one course for credit from MATH 110, 140, 140A, 140B, and 140H.

Enforced Prerequisite at Enrollment: MATH 22 or MATH 40 or MATH 41 or satisfactory performance on the mathematics placement examination.

Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 111: Techniques of Calculus II

2 Credits

MATH 111 is the second course in a sequence of calculus content tailored primarily to first year business students with an emphasis on economics, business, social science, and/or ecology applications. Although it provides standalone instruction in the core elements of differential and integral calculus, applications are chosen to dovetail with typical models discussed in first year finance, economics, social science and/or ecology coursework.

Enforced Prerequisite at Enrollment: MATH 110
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 140: Calculus With Analytic Geometry I

4 Credits

Calculus is an important building block in the education of any professional who uses quantitative analysis. This course introduces and develops the mathematical skills required for analyzing change and creating mathematical models that replicate real-life phenomena. The goals of our calculus courses include to develop the students' knowledge of calculus techniques and to use the calculus environment to develop critical thinking and problem solving skills. The concept of limit is central to calculus; MATH 140 begins with a study of this concept. Differential calculus topics include derivatives and their applications to rates of change, related rates, linearization, optimization, and graphing techniques. The Fundamental Theorem of Calculus, relating differential and integral calculus begins the study of Integral Calculus. Antidifferentiation and the technique of substitution is used in integration applications of finding areas of plane figures and volumes of solids of revolution. Trigonometric functions are included in every topic. Students may only take one course for credit from MATH 110, 140, 140A, 140B, and 140H.

Enforced Prerequisite at Enrollment: Math 22 and Math 26 or Math 26 and satisfactory performance on the mathematics placement examination or Math 40 or Math 41 or satisfactory performance on the mathematics placement examination.
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 140B: Calculus and Biology I

4 Credits

Calculus is an important building block in the education of any professional who uses quantitative analysis. This course introduces and develops the mathematical skills required for analyzing change and creating mathematical models that replicate real-life phenomena. The goals of our calculus courses include to develop the students' knowledge of calculus techniques and to use the calculus environment to develop critical thinking and problem solving skills. The concept of limit is central to calculus; this concept is studied early in the course. Differential calculus topics include derivatives and their applications to rates of change, related rates, linearization, optimization, and graphing techniques. The Fundamental Theorem of Calculus, relating differential and integral calculus begins the study of Integral Calculus. Antidifferentiation and the technique of substitution is used in integration applications of finding areas of plane figures and volumes of solids of revolution. Trigonometric functions are included in every topic. Students may only take one course for credit from MATH 110, 140, 140A, 140B, and 140H.

Enforced Prerequisite at Enrollment: Math 22 and Math 26 or Math 26 and satisfactory performance on the mathematics placement examination or Math 40 or Math 41 or satisfactory performance on the mathematics placement examination.
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 140E: Calculus with Engineering Applications I

4 Credits

Calculus is an important building block in the education of any professional who uses quantitative analysis. This course introduces and develops the mathematical skills required for analyzing change and creating mathematical models that replicate real-life phenomena. The goals of our calculus courses include to develop the students' knowledge of calculus techniques and to use the calculus environment to develop critical thinking and problem solving skills. The concept of limit is central to calculus; MATH 140E begins with a study of this concept. Differential calculus topics include derivatives and their applications to rates of change, related rates, linearization, optimization, and graphing techniques. The Fundamental Theorem of Calculus, relating differential and integral calculus begins the study of Integral Calculus. Antidifferentiation and the technique of substitution is used in integration applications of finding areas of plane figures and volumes of solids of revolution. Trigonometric functions are included in every topic.

Enforced Prerequisite at Enrollment: Math 22 and Math 26 or Math 26 and satisfactory performance on the mathematics placement examination or Math 40 or Math 41 or satisfactory performance on the mathematics placement examination.
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 140G: Calculus with Earth and Mineral Sciences Applications I

4 Credits

This course is the first in a sequence of three calculus courses designed for students in the earth and mineral sciences and related fields. Topics include limits of functions, continuity; the definition of the derivative, various rules for computing derivatives (such as the product rule, quotient rule, and chain rule), implicit differentiation, higher-order derivatives, solving related rate problems, and applications of differentiation such as curve sketching, optimization problems, and

Newton's method; the definition of the definite integral, computation of areas, the Fundamental Theorem of Calculus, integration by substitution, and various applications of integration such as computation of areas between two curves, volumes of solids, and work.

Enforced Prerequisite at Enrollment: Math 22 and Math 26 or Math 26 and satisfactory performance on the mathematics placement examination or Math 40 or Math 41 or satisfactory performance on the mathematics placement examination.
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 140H: Honors Calculus with Analytic Geometry I

4 Credits

Calculus is an important building block in the education of any professional who uses quantitative analysis. This course introduces and develops the mathematical skills required for analyzing change and creating mathematical models that replicate real-life phenomena. The goals of our calculus courses include to develop the students' knowledge of calculus techniques and to use the calculus environment to develop critical thinking and problem solving skills. The concept of limit is central to calculus; MATH 140 begins with a study of this concept. Differential calculus topics include derivatives and their applications to rates of change, related rates, linearization, optimization, and graphing techniques. The Fundamental Theorem of Calculus, relating differential and integral calculus begins the study of Integral Calculus. Antidifferentiation and the technique of substitution is used in integration applications of finding areas of plane figures and volumes of solids of revolution. Trigonometric functions are included in every topic. Students may only take one course for credit from MATH 110, 140, 140A, 140B, and 140H.

Enforced Prerequisite at Enrollment: Math 22 and Math 26 or Math 26 and satisfactory performance on the mathematics placement examination or Math 40 or Math 41 or satisfactory performance on the mathematics placement examination.
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
Honors
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 141: Calculus with Analytic Geometry II

4 Credits

MATH 141 is the second course in a two- or three-course calculus sequence for students in science, engineering and related fields. Calculus is an important building block in the education of any professional who uses quantitative analysis. This course further introduces and develops the mathematical skills required for analyzing growth and change and creating mathematical models that replicate reallife phenomena. The goals of our calculus courses include to develop the students' knowledge of calculus techniques and to use the calculus environment to develop critical thinking and problem solving skills. This course covers the following topics: logarithms, exponentials, and inverse trigonometric functions; applications of the definite integral and techniques of integration; sequences and series; power series and Taylor polynomials; parametric equations and polar functions. Students may take only one course for credit from MATH 141, 141B, and 141H.

Enforced Prerequisite at Enrollment: MATH 140 or MATH 140A or MATH 140B or MATH 140E or MATH 140G or MATH 140H.
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 141B: Calculus and Biology II

4 Credits

Techniques of integration and applications to biology; elementary matrix theory, limits of matrices, Markov chains, applications to biology and the natural sciences; elementary and separable differential equations, linear rst-order differential equations, linear systems of differential equations, the Lotka-Volterra equations. Students may take only one course for credit from MATH 141, 141B, and 141H.

Enforced Prerequisite at Enrollment: MATH 140 or MATH 140A or MATH 140B or MATH 140E or MATH 140G or MATH 140H.
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 141E: Calculus with Engineering Applications II

4 Credits

MATH 141E is the second course in a two- or three-course calculus sequence for students in science, engineering and related fields. Calculus is an important building block in the education of any professional who uses quantitative analysis. This course further introduces and develops the mathematical skills required for analyzing growth and change and creating mathematical models that replicate reallife phenomena. The goals of our calculus courses include to develop the students' knowledge of calculus techniques and to use the calculus environment to develop critical thinking and problem solving skills. This course covers the following topics: logarithms, exponentials, and inverse trigonometric functions; applications of the definite integral and techniques of integration; sequences and series; power series and Taylor polynomials; parametric equations and polar functions.

Enforced Prerequisite at Enrollment: MATH 140 or MATH 140A or MATH 140B or MATH 140E or MATH 140G or MATH 140H.
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 141G: Calculus with Earth and Mineral Sciences Applications II

4 Credits

This course is the second in a sequence of three calculus courses designed for students in the earth and mineral sciences and related fields. Topics include inverse functions of exponential, logarithmic, and trigonometric functions; indeterminate forms and L'Hopital's rule; various techniques of integration, including integration by parts, trigonometric integrals, trigonometric substitution, and partial fractions; improper

integration; infinite sequences and series, tests for convergence and divergence of infinite series, including the integral test, comparison tests, ratio test, root test; power series, Taylor and MacLaurin Series.

Enforced Prerequisite at Enrollment: MATH 140 or MATH 140A or MATH 140B or MATH 140E or MATH 140G or MATH 140H.
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 141H: Honors Calculus with Analytic Geometry II

4 Credits

MATH 141 is the second course in a two- or three-course calculus sequence for students in science, engineering and related fields. Calculus is an important building block in the education of any professional who uses quantitative analysis. This course further introduces and develops the mathematical skills required for analyzing growth and change and creating mathematical models that replicate reallife phenomena. The goals of our calculus courses include to develop the students' knowledge of calculus techniques and to use the calculus environment to develop critical thinking and problem solving skills. This course covers the following topics: logarithms, exponentials, and inverse trigonometric functions; applications of the definite integral and techniques of integration; sequences and series; power series and Taylor polynomials; parametric equations and polar functions. Students may take only one course for credit from MATH 141, 141B, and 141H.

Enforced Prerequisite at Enrollment: MATH 140 or MATH 140A or MATH 140B or MATH 140E or MATH 140G or MATH 140H.
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
Honors
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 197: Special Topics

1-9 Credits/Maximum of 9

Formal courses given infrequently to explore, in depth, a comparatively narrow subject which may be topical or of special interest.

Bachelor of Arts: Quantification

MATH 197N: Special Topics - InterDomain

1-9 Credits/Maximum of 9

Formal course given on a topical or special interest subject offered infrequently; several different topics may be taught in one year or semester. This Special Topics is an Inter-Domain GenEd course.

MATH 198: Special Topics

1-9 Credits/Maximum of 9

Formal courses given infrequently to explore, in depth, a comparatively narrow subject which may be topical or of special interest.

MATH 199: Foreign Studies

1-12 Credits/Maximum of 12

Courses offered in foreign countries by individual or group instruction.

Bachelor of Arts: Quantification
International Cultures (IL)

MATH 200: Problem Solving in Mathematics

3 Credits

Fundamental concepts of arithmetic and geometry, including problem solving, number systems, and elementary number theory. For elementary and special education teacher certification candidates only. A student who has passed EDMTH 444 may not take MATH 200 for credit.
MATH 200 Problem Solving in Mathematics (3) (GQ) This is a course in mathematics content for prospective elementary school teachers. Students are assumed to have successfully completed two years of high school algebra and one year of high school geometry. Students are expected to have reasonable arithmetic skills. The content and processes of mathematics are presented in this course to develop mathematical knowledge and skills and to develop positive attitudes toward mathematics. Problem solving is incorporated throughout the topics of number systems, number theory, probability, and geometry, giving future elementary school teachers tools to further explore mathematical content required to convey the usefulness, beauty and power of mathematics to their own students.

Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 201: Problem Solving in Mathematics II

3 Credits

This course studies the foundations of elementary school mathematics with an emphasis on problem solving. MATH 201 Problem Solving in Mathematics II (3) (GQ) Problem Solving in Mathematics II studies the foundations of elementary school mathematics with an emphasis on problem solving. Mathematical ways of thinking are integrated throughout the study of probability, statistics, graphing, geometric shapes, and measurement. This course is designed for prospective teachers not only to gain the ability to explain the mathematics in elementary school courses, but also to help them comprehend the underlying mathematical concepts. Gaining a deeper understanding will enable them to assist their young students in the classroom since effective mathematical teaching requires understanding what students know, what they need to learn, and then helping them to learn it well.

General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 210: Calculus with Engineering Technology Applications

3 Credits

Topics in calculus with an emphasis on applications in engineering technology. MATH 210 Calculus with Engineering Technology

Applications (3) is a three-credit course to be taken either after the MATH 81, MATH 82, MATH 83 sequence or after a semester of college-level calculus. The content of the course is geared toward the needs of engineering technology majors and places a large emphasis on technology and applications. The course provides mathematical tools required in the upper division engineering technology courses. A primary goal is to have students use technology to solve more realistic problems than the standard simplistic ones that can be solved by "pencil and paper." Student evaluation will be performed through exams, quizzes, graded assignments, and a cumulative final exam. It is expected that MTHBD 210 will be offered every semester with an enrollment of 44-80 students.

Enforced Prerequisite at Enrollment: MATH 83 or MATH 140
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Integrative Thinking
GenEd Learning Objective: Key Literacies

MATH 211: Intermediate Calculus and Differential Equations with Applications

3 Credits

Topics in ordinary differential equations, linear algebra, complex numbers, Eigenvalue solutions and Laplace transform methods. MATH 211 Intermediate Calculus and Differential Equations with Applications (4) MATH 211 is a three-credit course to be taken after MATH 210. The content of the course is geared toward the needs of engineering technology majors and places a large emphasis on technology and applications. The course provides mathematical tools required in the engineering technology courses at the sixth semester and above. A primary goal is to have students use technology to solve more realistic problems than the standard simplistic ones that can be solved by "pencil and paper." Student evaluation will be performed through exams, quizzes, graded assignments, and a cumulative final exam.

Enforced Prerequisite at Enrollment: MATH 210
Bachelor of Arts: Quantification
General Education: Quantification (GQ)

MATH 220: Matrices

2-3 Credits

Systems of linear equations; matrix algebra; eigenvalues and eigenvectors; linear systems of differential equations. MATH 220 Matrices (2-3) (GQ) (BA) This course meets the Bachelor of Arts degree requirements.Systems of linear equations appear everywhere in mathematics and its applications. MATH 220 will give students the basic tools necessary to analyze and understand such systems. The initial portion of the course teaches the fundamentals of solving linear systems. This requires the language and notation of matrices and fundamental techniques for working with matrices such as row and column operations, echelon form, and invertibility. The determinant of a matrix is also introduced; it gives a test for invertibility. In the second part of the course the key ideas of eigenvector and eigenvalue are developed. These allow one to analyze a complicated matrix problem into simpler components and appear in many disguises in physical problems. The course also introduces the concept of a vector space, a crucial element in future linear algebra courses. This course is completed by a wide variety of students across the university, including students majoring in engineering programs, the sciences, and mathematics. (In case of many of these students, MATH 220 is a required course in their degree program.)

Enforced Prerequisite at Enrollment: MATH 110 or MATH 140 or MATH 140B or MATH 140E or MATH 140G or MATH 140H
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 220H: Honors Matrices

2-3 Credits

Honors course in systems of linear equations; matrix algebra; eigenvalues and eigenvectors; linear systems of differential equations. MATH 220H Honors Matrices (2) (GQ)(BA) This course meets the Bachelor of Arts degree requirements. This course is intended as an introduction to linear algebra with a focus on solving systems for linear equations. Topics include systems of linear equations, row reduction and echelon forms, linear independence, introduction to linear transformations, matrix operations, inverse matrices, dimension and rank, determinants, eigenvalues, eigenvectors, diagonalization, and orthogonality.The typical delivery format for the course is two 50-minute lectures per week, with typical assessment tools including examinations, quizzes, homework, and writing assignments.In contrast to the non-honors version of this course, the honors version is typically more theoretical and will often include more sophisticated problems. Moreover, certain topics are often discussed in more depth and are sometimes expanded to include applications which are not visited in the non-honors version of the course.

Enforced Prerequisite at Enrollment: MATH 110 or MATH 140 or MATH 140B or MATH 140E or MATH 140G or MATH 140H
Bachelor of Arts: Quantification
General Education: Quantification (GQ)
Honors
GenEd Learning Objective: Crit and Analytical Think
GenEd Learning Objective: Key Literacies

MATH 230: Calculus and Vector Analysis

4 Credits

Three-dimensional analytic geometry; vectors in space; partial differentiation; double and triple integrals; integral vector calculus. Students who have passed either Math 231 or MATH 232 may not schedule Math 230 or MATH 230H for credit.

Enforced Prerequisite at Enrollment: MATH 141 or MATH 141B or MATH 141E or MATH 141G or MATH 141H
Bachelor of Arts: Quantification

MATH 230H: Honors Calculus and Vector Analysis

4 Credits

Honors course in three-dimensional analytic geometry; vectors in space; partial differentiation; double and triple integrals; integral vector calculus. Students who have passed either MATH 231 or MATH 232 may not schedule MATH 230 or MATH 230H for credit. MATH 230H Honors Calculus and Vector Analysis (4) This course is the third in a

sequence of three calculus courses designed for students in engineering, science, and related fields. Topics include vectors in space, dot products, cross products; vector-valued functions, modeling motion, arc length, curvature; functions of several variables, limits, continuity, partial derivatives, directional derivatives, gradient vectors, Lagrange multipliers; double integrals, triple integrals; line integrals, Green's Theorem, Stokes' Theorem, the Divergence Theorem.The typical delivery format for the course is four 50-minute lectures per week, with typical assessment tools including examinations, quizzes, homework, and writing assignments.In contrast to the non-honors version of this course, the honors version is typically more theoretical and will often include more sophisticated problems. Moreover, certain topics are often discussed in more depth and are sometimes expanded to include applications which are not visited in the non-honors version of the course.

Enforced Prerequisite at Enrollment: MATH 141 or MATH 141B or MATH 141E or MATH 141G or MATH 141H
Bachelor of Arts: Quantification
Honors

MATH 231: Calculus of Several Variables

2 Credits

Analytic geometry in space; partial differentiation and applications. Students who have passed MATH 230 or MATH 230H may not schedule this course.

Enforced Prerequisite at Enrollment: MATH 141 or MATH 141B or MATH 141E or MATH 141G or MATH 141H
Bachelor of Arts: Quantification

MATH 231H: Honors Calculus of Several Variables

2 Credits

Honors course in analytic geometry in space; partial differentiation and applications. Students who have passed MATH 230 or MATH 230H may not schedule this course. MATH 231H Honors Calculus of Several Variables (2) This course covers a subset of the material found in MATH 230. Topics include vectors in space, dot products, cross products; vector-valued functions, modeling motion, arc length, curvature; functions of several variables, limits, continuity, partial derivatives, directional derivatives, gradient vectors, Lagrange multipliers.The typical delivery format for the course is two 50-minute lectures per week, with typical assessment tools including examinations, quizzes, homework, and writing assignments.In contrast to the non-honors version of this course, the honors version is typically more theoretical and will often include more sophisticated problems. Moreover, certain topics are often discussed in more depth and are sometimes expanded to include applications which are not visited in the non-honors version of the course.

Enforced Prerequisite at Enrollment: MATH 141 or MATH 141B or MATH 141E or MATH 141G or MATH 141H
Bachelor of Arts: Quantification
Honors

MATH 232: Integral Vector Calculus

2 Credits

Multidimensional analytic geometry, double and triple integrals; potential fields; flux; Green's, divergence and Stokes' theorems. Students who have passed MATH 230 may not schedule this course for credit.

Enforced Prerequisite at Enrollment: MATH 231 or MATH 231H
Bachelor of Arts: Quantification

MATH 240: Mathematical Methods for Biology and the Life Sciences

4 Credits

This course will cover systems of differential equations, multivariable calculus, and applications to biology and the life sciences. Students will learn about complex numbers, and their relation to oscillations. Analysis of biologically relevant mathematical models will include the linear stability of couples nonlinear systems, and the method of separation of timescales. The course will also introduce probability theory in a biological context, including conditional probability, Bayes Theorem, probability distributions, and stochastic modeling in the life sciences.

Enforced Prerequisites at Enrollment: MATH141B or instructor approval

MATH 250: Ordinary Differential Equations

3 Credits

First- and second-order equations; special functions; Laplace transform solutions; higher order equations. Students who have passed MATH 251 may not schedule this course for credit.

Enforced Prerequisite at Enrollment: MATH 141 or MATH 141B or MATH 141E or MATH 141G or MATH 141H
Bachelor of Arts: Quantification

MATH 251: Ordinary and Partial Differential Equations

4 Credits

First- and second-order equations; special functions; Laplace transform solutions; higher order equations; Fourier series; partial differential equations.

Enforced Prerequisite at Enrollment: MATH 141 or MATH 141B or MATH 141E or MATH 141G or MATH 141H
Bachelor of Arts: Quantification

MATH 251H: Honors Ordinary and Partial Differential Equations

4 Credits

Honors course in first- and second-order equations; special functions; Laplace transform solutions; higher order equations; Fourier series; partial differential equations. MATH 251H Honors Ordinary and Partial Differential Equations (4) This course serves as an introduction to ordinary and partial differential equations. Topics include various techniques for solving first and second order ordinary differential equations, an introduction to numerical methods, solving systems of two ordinary differential equations, nonlinear differential equations and stability, Laplace transforms, Fourier series, and partial differential equations.The typical delivery format for the course is four 50-minute lectures per week, with typical assessment tools including examinations, quizzes, homework, and writing assignments.In contrast to the non-honors version of this course, the honors version is typically more

theoretical and will often include more sophisticated problems. Moreover, certain topics are often discussed in more depth and are sometimes expanded to include applications which are not visited in the non-honors version of the course.

Enforced Prerequisite at Enrollment: MATH 141 or MATH 141B or MATH 141E or MATH 141G or MATH 141H
Bachelor of Arts: Quantification
Honors

MATH 252: Partial Differential Equations

1 Credits

Fourier series; partial differential equations. Students who have passed MATH 251 may not schedule this course for credit. This course serves as the continuation of MATH 250 (Ordinary Differential Equations) and provides an elementary treatment of partial differential equations and Fourier series. Once a student completes both MATH 250 (3 credits) and MATH 252 (1 credit), the student will have completed all of the material in MATH 251 (4 credits). In particular, the student will be able to find solutions to given partial differential equations and will be able to utilize the tools from the field of Fourier series in the process.

MATH 296: Independent Studies

1-18 Credits/Maximum of 18

Creative projects, including nonthesis research, which are supervised on an individual basis and which fall outside the scope of formal courses.

Bachelor of Arts: Quantification

MATH 297: Special Topics

1-9 Credits/Maximum of 9

Formal courses given infrequently to explore, in depth, a comparatively narrow subject which may be topical or of special interest.

Bachelor of Arts: Quantification

MATH 310: Elementary Combinatorics

3 Credits

Fundamental techniques of enumeration and construction of combinatorial structures, permutations, recurrences, inclusion-exclusion, permanents, 0, 1- matrices, Latin squares, combinatorial designs.

Enforced Prerequisite at Enrollment: MATH 220 or MATH 220H
Bachelor of Arts: Quantification

MATH 310H: Honors Concepts of Combinatorics

3 Credits

Honors version of elementary and enumerative combinatorics.

Prerequisite: MATH 220
Bachelor of Arts: Quantification
Honors

MATH 311M: Honors Concepts of Discrete Mathematics

3 Credits

Basic methods of mathematical thinking and fundamental mathematical structures, primarily in the context of numbers, groups, and symmetries.

Bachelor of Arts: Quantification
Honors
Writing Across the Curriculum

MATH 311W: Concepts of Discrete Mathematics

3-4 Credits

Introduction to mathematical proofs; elementary number theory and group theory. Students who have passed CMPSC 360 may not schedule this course for credit.

Enforced Prerequisite at Enrollment: MATH 141 or MATH 141B or MATH 141E or MATH 141G or MATH 141H
Bachelor of Arts: Quantification
Writing Across the Curriculum

MATH 312: Concepts of Real Analysis

3 Credits

An introduction to rigorous analytic proofs involving properties of real numbers, continuity, differentiation, integration, and infinite sequences and series.

Enforced Prerequisite at Enrollment: MATH 141 or MATH 141B or MATH 141E or MATH 141G or MATH 141H
Bachelor of Arts: Quantification

MATH 312H: Honors Concepts of Real Analysis

3 Credits

Basic methods of mathematical thinking and fundamental structures, primarily in the context of infinite sets, real numbers, and metric spaces.

Enforced Prerequisite at Enrollment: MATH 141 or MATH 141B or MATH 141E or MATH 141G or MATH 141H
Bachelor of Arts: Quantification
Honors

MATH 313H: Concepts of Geometry

3 Credits

Development thorough understanding and technical mastery of foundations of modern geometry. MATH 313H Concepts of Geometry (3) The central aim of this course is to develop thorough understanding and technical mastery of foundations of modern geometry. Basic high school geometry is assumed; axioms are mentioned, but not used to deduce theorems. Approach in development of the Euclidean geometry of the plane and the 3-dimensional space is mostly synthetic with an emphasis on groups of transformations. Linear algebra is invoked to clarify and generalize the results in dimension 2 and 3 to any dimension. It culminates in the last part of the course where six 2-dimensional geometries and their symmetry groups are discussed. This course is a a part of a new "pre-MASS" program (PMASS)aimed at freshman/sophomore level students, which will operate in steady state in the spring semesters. This course is directly linked with a proposed course Math 313R, its 1-credit recitation component. It is highly recommended to all

mathematics, physics and natural sciences majors who are graduate school bound, and is a great opportunity for all Schreyer Scholars. The following topics will be covered: Euclidean geometry of the plane (distance, isometries, scalar product of vectors, examples of isometries: rotations, reflections, translations, orientation, symmetries of planar figures, review of basic notions of group theory, cyclic and dihedral groups, classification of isometries of Euclidean plane, discrete groups of isometries and crystallographic restrictions. similarity transformations, selected results from classical Euclidean geometry}; Euclidean geometry of the 3-dimensional space and the sphere (distance, isometries, scalar product of vectors, planes and lines in the 3-dimensional space, normal vectors to planes, classification of pairs of lines, isometries with a fixed point: rotations and reflections, orientation, isometries of the sphere, classification of orientation-reversing isometries with a fixed point, finite groups of isometries of the 3-dimensional space, existence of a fixed point, examples: cyclic, dihedral, and groups of symmetries of Platonic solids, classification of isometries without fixed point: translations and screw-motions, intrinsic geometry of the sphere, elliptic plane: a first example of non-Euclidean geometry); Elements of linear algebra and its application to geometry in 2, 3, and n dimension (real and complex vector spaces. linear independence of vectors, basis and dimension, eigenvalues and eigenvectors, diagonalizable matrices, classification of matrices in dimension 2: elliptic, hyperbolic and parabolic matrices, orthogonal matrices and isometries of the n-dimensional space); Six 2-dimensional geometries (Projective geometry, affine geometry, inversions and conformal geometry, Euclidean geometry revisited, geometry of elliptic plane, hyperbolic geometry). The achievement of educational objectives will be assessed through weekly homework, class participation, and midterm and final exams.

Enforced Prerequisite at Enrollment: MATH 140H and MATH 311M or
Concurrent: MATH 312H
Honors

MATH 316: Upperclass Seminar: Careers, Graduate Study, and Opportunities in Mathematics

1 Credits

This course is designed to prepare sophomore, junior and senior mathematics majors to take advantage of opportunities provided by the mathematics department and university in selecting and pursuing a career path. Some class sessions will involve professional development activities and information about career-related resources; others will consist of presentations and discussions with guest lecturers chosen to represent possible career pathways in mathematics and related fields.

Enforced Prerequisite at Enrollment: thirds-semester standing

MATH 318: Elementary Probability

3 Credits

Combinatorial analysis, axioms of probability, conditional probability and independence, discrete and continuous random variables, expectation, limit theorems, additional topics. Students who have passed either MATH(STAT) 414 or 418 may not schedule this course for credit.

Enforced Prerequisite at Enrollment: MATH 141
Cross-listed with: STAT 318
Bachelor of Arts: Quantification

MATH 319: Elementary Mathematical Statistics

3 Credits

Statistical inference: principles and methods, estimation and testing hypotheses, regression and correlation analysis, analysis of variance, computer analysis. Students who have passed STAT (MATH) 415 may not schedule this course for credit.

Enforced Prerequisite at Enrollment: MATH 318 or STAT 318 or MATH 414 or STAT 414 or STAT 418 or MATH 418
Cross-listed with: STAT 319
Bachelor of Arts: Quantification

MATH 397: Special Topics

1-9 Credits/Maximum of 9

Formal courses given infrequently to explore, in depth, a comparatively narrow subject which may be topical or of special interest.

Bachelor of Arts: Quantification

MATH 399: Foreign Studies

1-12 Credits/Maximum of 12

Courses offered in foreign countries by individual or group instruction.

Bachelor of Arts: Quantification
International Cultures (IL)

MATH 400: Teaching in Mathematics

1-2 Credits/Maximum of 6

Mathematics Learning Assistants will participate in the instruction of undergraduate mathematics courses. In MATH 400 Teaching in Mathematics (1-2), students will learn about and gain experience in leading and facilitating in-class and out-of-class group discussions and group problem-solving sessions. Students will be members of a teaching community, interact with a supervising mathematics faculty member, and learn teaching strategies on how to facilitate and help engage undergraduate students in discussions and group work.

Enforced Prerequisite at Enrollment: 4 credits in mathematics and permission of the department Concurrent Course: SC 220

MATH 401: Introduction to Analysis I

3 Credits

Review of calculus, properties of real numbers, infinite series, uniform convergence, power series. Students who have passed Math. 403 may not schedule this course.

Enforced Prerequisite at Enrollment: MATH 230 or MATH 231
Bachelor of Arts: Quantification

MATH 403: Classical Analysis I

3 Credits

Topology of Rn, compactness, continuity of functions, uniform convergence, Arzela-Ascoli theorem in the plane, Stone-Wierstrass theorem.

Enforced Prerequisite at Enrollment: MATH 312

Bachelor of Arts: Quantification

MATH 403H: Honors Classical Analysis I

3 Credits

Development of a thorough understanding and technical mastery of foundations of classical analysis in the framework of metric spaces. MATH 403H Honors Classical Analysis I (3)The central aim of this course is to develop thorough understanding and technical mastery of foundations of classical analysis in the framework of metric spaces rather than multidimensional Euclidean spaces. This level of abstraction is essential since it is in the background of functional analysis, a fundamental tool for modern mathematics and physics. Another motivation for studying analysis in this wider context is that many general results about functions of one or several real variables are more easily grasped at this more abstract level, and, besides, the same methods and techniques are applicable to a wider class of problems, e.g. to the study of function spaces. This approach also brings to high relief some of the fundamental connections between analysis on one hand and (higher) algebra and geometry on the other. This course is a sequel to Math 312H; it is highly recommended to all mathematics, physics and natural sciences majors who are graduate school bound, and is a great opportunity for all Schreyer Scholars. The following topics will be covered: Metric spaces (topology, convergence, Cauchy sequences and completeness); Maps between metric spaces (continuous maps and homeomorphisms, stronger continuity properties:uniform continuity, Hoelder and Lipschitz continuity, contraction mapping principle, points of discontinuity and the Baire Category Theorem); Compact metric spaces (continuity and compactness, connectedness, total boundedness, coverings and Lebesgue number, perfect metric spaces, characterization of Cantor sets, fractals); Function spaces (spaces of continuous maps, uniform continuity and equicontinuity,Arzela-Ascoli Theorem, uniform approximation by polynomials. Stone-Weierstrass Theorem).

Enforced Prerequisite at Enrollment: MATH 311M and MATH 312H
Bachelor of Arts: Quantification
Honors

MATH 404: Classical Analysis II

3 Credits

Differentiation of functions from Rn to Rm, implicit function theorem, Riemann integration, Fubini's theorem, Fourier analysis.

Enforced Prerequisite at Enrollment: MATH 403
Bachelor of Arts: Quantification

MATH 405: Advanced Calculus for Engineers and Scientists I

3 Credits

Vector calculus, linear algebra, ordinary and partial differential equations. Students who have passed MATH 411 or 412 may not take this course for credit.

Enforced Prerequisite at Enrollment: (MATH 230 or MATH 231) and (MATH 250 or MATH 251)
Bachelor of Arts: Quantification

MATH 406: Advanced Calculus for Engineers and Scientists II

3 Credits

Complex analytic functions, sequences and series, residues, Fourier and Laplace transforms. Students who have passed MATH 421 may not take this course for credit.

Enforced Prerequisite at Enrollment: MATH 405
Bachelor of Arts: Quantification

MATH 410: Complex Analysis for Mathematics and Engineering

3 Credits

Complex analytic functions; Cauchy-Riemann equations; complex contour integrals; Cauchy's integral formula; Taylor and Laurent series; residue theory; applications in engineering. MATH 410 Complex Analysis for Mathematics and Engineering (3) A succinct stand-alone course description (up to 400 words) to be made available to students through the on-line Bulletin and Schedule of Courses. This is a complex analysis course designed for students in mathematics, applied mathematics, engineering, science, and related fields. Topics include complex numbers; analytic functions, complex differentiability, and the Cauchy-Riemann equations; complex exponential, logarithmic, power, and trigonometric functions; complex contour integrals; Cauchy's theorem; Cauchy's integral formula; Taylor and Laurent series; residue theory; and various applications in areas of science and engineering. This course focuses on the definitions, concepts, calculation techniques, supporting theory, and examples of applications suited to the usage of complex analysis in mathematics, applied mathematics, science, and engineering. Students who have passed MATH 406 or MATH 421 may not take this course for credit.

Enforced Prerequisite at Enrollment: MATH 230 or MATH 232

MATH 411: Ordinary Differential Equations

3 Credits

Linear ordinary differential equations; existence and uniqueness questions; series solutions; special functions; eigenvalue problems; Laplace transforms; additional topics and applications.

Enforced Prerequisite at Enrollment: (MATH 230 or MATH 231) and (MATH 250 or MATH 251)
Bachelor of Arts: Quantification

MATH 412: Fourier Series and Partial Differential Equations

3 Credits

Orthogonal systems and Fourier series; derivation and classification of partial differential equations; eigenvalue function method and its applications; additional topics. MATH 412 Fourier Series and Partial Differential Equations (3) (BA) This course meets the Bachelor of Arts degree requirements.The purpose of MATH 412 is to introduce students to the origins, theory, and applications of partial differential equations. Several basic physical phenomena are considered - including flows, vibrations, and diffusions - and used to derive the relevant equations. The fundamentals of the mathematical theory of partial differential equations are motivated and developed for the students through the systematic exploration of these classic physical systems and their corresponding equations: the Laplace, wave, and heat equations. In addition to treating the physical origins of the equations, this course focuses on solving evolution equations as initial value problems on unbounded domains

(the Cauchy problem), and also on solving partial differential equations on bounded domains (boundary value problems). There is not one but many techniques for solving these equations, and the course presents some aspect of the expansion in orthogonal functions (including Fourier series), eigenvalue theory, functional analysis, and the use of separation of variables, Fourier transforms, and Laplace transforms to solve PDEs by converting them to ordinary differential equations. This course currently serves a cross-section of students at the university with interests or the need for this advanced subject mathematics, including students majoring in the engineering program, meteorology, physics, and mathematics. This typically includes the most advanced physics, engineering, and meteorology students, as well as mathematics majors with interests in applied mathematics.

Enforced Prerequisite at Enrollment: MATH 230 and (MATH 250 or MATH 251)
Bachelor of Arts: Quantification

MATH 414: Introduction to Probability Theory

3 Credits

STAT(MATH) 414 is an introduction to the theory of probability for students in statistics, mathematics, engineering, computer science, and related fields. The course presents students with calculus-based probability concepts and those concepts can be used to describe the uncertainties present in real applications. Topics include probability spaces, discrete and continuous random variables, transformations, expectations, generating functions, conditional distributions, law of large numbers, central limit theorems. Students may take only one course from STAT(MATH) 414 and 418.

Enforced Prerequisite at Enrollment: MATH 230 or Concurrent: MATH 232 or (MATH 231 and RM 214)
Cross-listed with: STAT 414

MATH 415: Introduction to Mathematical Statistics

3 Credits

A theoretical treatment of statistical inference, including sufficiency, estimation, testing, regression, analysis of variance, and chi-square tests.

Enforced Prerequisite at Enrollment: MATH 414 or STAT 414
Cross-listed with: STAT 415

MATH 416: Stochastic Modeling

3 Credits

Review of distribution models, probability generating functions, transforms, convolutions, Markov chains, equilibrium distributions, Poisson process, birth and death processes, estimation.

Enforced Prerequisite at Enrollment: (STAT 318 or MATH 318 or STAT 414 or MATH 414) and (MATH 230 or MATH 232)
Cross-listed with: STAT 416

MATH 417: Qualitative Theory of Differential Equations

3 Credits

Linear differential equations, stability of stationary solutions, ordinary bifurcation, exchange of stability, Hopf bifurcation, stability of periodic solutions, applications. MATH 417 Qualitative Theory of Differential Equations (3) (BA) This course meets the Bachelor of Arts degree requirements.The main objective of the course is the qualitative theory of ordinary differential equations such as existence and uniqueness of solutions, dependence on initial data and parameters, and basic stability of solutions for both linear and nonlinear equations. It is designed to introduce students to modern concepts including the bifurcation theory, intermittent (transitional) and chaotic behavior of solutions and dynamical system approach to differential equations. Along the way, a number of applications are discussed and students get familiar with some basic examples illustrating main principles of the theory, such as Lorenz attractor, predator-prey models, etc. The course is completed by students majoring in engineering programs, the sciences, and mathematics.

Enforced Prerequisite at Enrollment: MATH 220 and (MATH 250 or MATH 251)
Bachelor of Arts: Quantification

MATH 418: Introduction to Probability and Stochastic Processes for Engineering

3 Credits

Introduction to probability axioms, combinatorics, random variables, limit laws, and stochastic processes. Students may take only one course from MATH414 / STAT 414 and MATH 418 / STAT 418 for credit. STAT 418 / MATH 418 Introduction to Probability and Stochastic Processing for Engineering (3) This course gives an introduction to probability and random processes. The topics are not covered as deeply as in a semester-long course in probability only or in a semester-long course in stochastic processes only. It is intended as a service course primarily for engineering students, though no engineering background is required or assumed.The topics covered include probability axioms, conditional probability, and combinatorics; discrete random variables; random variables with continuous distributions; jointly distributed random variables and random vectors; sums of random variables and moment generating functions; and stochastic processes, including Poisson, Brownian motion, and Gaussian processes.

Enforced Prerequisite at Enrollment: MATH 230 or MATH 231
Cross-listed with: STAT 418

MATH 418H: Probability

3 Credits

Fundamentals and axioms, combinatorial probability, conditional probability and independence, probability laws, random variables, expectation; Chebyshev's inequality. Students may take only one course from MATH(STAT) 414 and 418 for credit.

Cross-Listed
Honors

MATH 419: Theoretical Mechanics

3 Credits

Principles of Newtonian, Lagrangian, and Hamiltonian mechanics of particles with applications to vibrations, rotations, orbital motion, and collisions. PHYS 419 / MATH 419 Theoretical Mechanics (3) A second course in classical mechanics, required of all physics majors who typically take it in their 5th or 6th semester. The course includes a review of relevant mathematics, detailed discussions of advanced topics in Newtonian mechanics, introductions to Lagrangian and Hamiltonian dynamics, and applications to such forced oscillations, orbital motion,

vibrational motion and normal modes, rigid body motion, and collisions.It is a prerequisite for Physics 461, which is a second semester extension. It is also a valuable background for most 400-level physics courses, especially Physics 410.

Enforced Prerequisite at Enrollment: (MATH 230 or MATH 231) and (MATH 250 or MATH 251) and PHYS 212 and PHYS 213 and PHYS 214
Cross-listed with: PHYS 419

MATH 421: Complex Analysis

3 Credits

Infinite sequences and series; algebra and geometry of complex numbers; analytic functions; integration; power series; residue calculus; conformal mapping, applications.

Enforced Prerequisite at Enrollment: (MATH 230 or MATH 232 or MATH 405) and (MATH 401 or MATH 403)
Bachelor of Arts: Quantification

MATH 422: Wavelets and Fourier Analysis: Theory and Applications

3 Credits

Fundamental mathematical issues of the theory of wavelets for senior undergraduate and graduate students in mathematics, engineering, physics, and computer science.

Bachelor of Arts: Quantification

MATH 425: Introduction to Operations Research

3 Credits

Nature of operations research, problem formulation, model construction, deriving solution from models, allocation problems, general linear allocation problem, inventory problems.

Enforced Prerequisite at Enrollment: MATH 141 and MATH 220
Bachelor of Arts: Quantification

MATH 426: Introduction to Modern Geometry

3 Credits

Plane and space curves; space surfaces; curvature; intrinsic geometry of surfaces; Gauss-Bonnet theorem; covariant differentiation; tensor analysis.

Enforced Prerequisite at Enrollment: MATH 401 or MATH 403
Bachelor of Arts: Quantification

MATH 427: Foundations of Geometry

3 Credits

Euclidean and various non-Euclidean geometries and their development from postulate systems. Students who have passed MATH 427 may not schedule MATH 471.

Enforced Prerequisite at Enrollment: MATH 230 or MATH 231
Bachelor of Arts: Quantification

MATH 428: Geometry for Teachers

1 Credits

Research in mathematics education using ideas from Euclidean and non-Euclidean geometry. Students who have passed MATH 471 may not schedule MATH 427. MATH 428 Geometry for Teachers (1) MATH 428 is designed to introduce students to mathematics education and research in education. The student will present topics in written and verbal classroom reports. Students will be evaluated on research papers and classroom presentations of those papers, classroom technology demonstration of geometry topics, and classroom demonstration of teaching geometry.This course supplements MATH 427 by providing the education component that is required by the state of Pennsylvania for obtaining certification in teaching mathematics. This course is offered only at Penn State Erie, The Behrend College.

Enforced Prerequisite at Enrollment: MATH 311W . Prerequisite or concurrent: MATH 427
Bachelor of Arts: Quantification

MATH 429: Introduction to Topology

3 Credits

Metric spaces, topological spaces, separation axioms, product spaces, identificaiton spaces, compactness, connectedness, fundamental group.

Enforced Prerequisite at Enrollment: MATH 311W
Bachelor of Arts: Quantification

MATH 430: Linear Algebra and Discrete Models I

3 Credits

Vector spaces, linear transformations, matrices determinants, characteristic values and vectors, systems of linear equations, applications to discrete models.

Enforced Prerequisite at Enrollment: MATH 220
Bachelor of Arts: Quantification

MATH 435: Basic Abstract Algebra

3 Credits

Elementary theory of groups, rings, and fields. Students who have passed MATH 435 may not schedule MATH 470.

Enforced Prerequisite at Enrollment: MATH 311W or MATH 315
Bachelor of Arts: Quantification

MATH 436: Linear Algebra

3 Credits

Vector spaces and linear transformations, canonical forms of matrices, elementary divisors, invariant factors; applications. Students who have passed MATH 436 may not schedule MATH 441.

Enforced Prerequisite at Enrollment: MATH 311W
Bachelor of Arts: Quantification

MATH 436H: Linear Algebra

3 Credits

Vector spaces and linear transformations, canonical forms of matrices, elementary divisors, invariant factors; applications.

Honors

MATH 437: Algebraic Geometry

3 Credits

Study of curves in the plane defined by polynomial equations p(x,y)= 0. Projective equivalence, singular points, classification of cubics. MATH 437 Algebraic Geometry (3)(BA) This course meets the Bachelor of Arts degree requirements. The geometric study of algebraic equations is one of the oldest and deepest parts of mathematics, and it lies at the heart of modern developments in geometry, algebra, number theory and physics. Students completing MATH 437 will understand many new algebraic and geometric ideas by studying examples of curves defined by equations of degrees 2 and 3 in the plane. Fist come conics (given by equations of degree 2 in two variables). Rigid motions, similarities, and affine transformations give different classifications of them. New ideas then show how to get a conic through any five points and prove Pascal's theorem about six points on a conic. Special cases suggest extension of the usual plane to the projective plane, with "points at infinity," homogeneous coordinates, and projective transformations.The main part of the course turns to equations of degree 3 and their singularities, flex points, tangents, and degeneracies. Several new ideas, both algebraic and analytic, are brought in to prove the existence of complex flex points on singular cubics and then real flex points on nonsingular real cubics. There is then a classification on complex projective cubics by a single parameter and finally a full classification of all real projective cubics.As time permits, relations to further topics are sketched: addition of points on a nonsingular cubic, Mordell's theorem, doubly periodic functions, and Fermat's last theorem.The course is typically taken by mathematics majors.

Enforced Prerequisite at Enrollment: (MATH 230 or MATH 231) and MATH 311W
Bachelor of Arts: Quantification

MATH 441: Matrix Algebra

3 Credits

Determinants, matrices, linear equations, characteristic roots, quadratic forms, vector spaces. Students who have passed Math 436 may not schedule this course.

Enforced Prerequisite at Enrollment: MATH 220
Bachelor of Arts: Quantification

MATH 448: Mathematics of Finance

3 Credits

The course provides a foundational knowledge of the mathematics and mathematical models of finance, primarily of option pricing, hedging, and portfolio optimization. The topics include the definition of various financial securities and instruments (e.g. bonds, stocks, forward contracts, and options), the theory of interest, the No-Arbitrage Principle, measures of return and volatility, the Markowitz model of portfolio theory, the Capital Asset Pricing Model, the pricing of forward contracts, option trading strategies, the pricing of options via binomial models and the Black-Scholes model, and principles of hedging.

Enforced Prerequisite at Enrollment: MATH 141 and (STAT 200 or STAT 301 or MATH 318 or STAT 318 or STAT 401 or MATH 414 or STAT 414)

MATH 449: Applied Ordinary Differential Equations

3 Credits

Differential and difference equations and their application to biology, chemistry, and physics; techniques in dynamical systems theory. MATH 449 Mathematical Modeling (3) Many phenomena that arise in the natural sciences, such as the motion of pendulum or signal conduction in neurons or oscillations in certain chemical reactions, can be modeled using nonlinear differential equations. This course will develop the mathematical techniques needed to investigate such differential equations. These techniques include the study of equilibria, stability, phase plane analysis, bifurcation analysis and chaos. The course will assume prior knowledge of ordinary differential equations at the MATH 250/251 level; this is the only prerequisite for the course. We will focus on understanding and interpreting the behavior of the solutions to the differential equation models rather than on deriving the model equations themselves. Evaluation will be based on midterm exams, a final exam, graded homework, and graded longer projects which may involve computer work. The course should be of interest to any science or engineering major and some models will be chosen to reflect the fields of interest of the class. The goal is for the students to be able to apply the techniques learned in the course to mathematical models that they will encounter in other classes or situations. The class will be offered every other year with an expected enrollment of 10-15 students.

Enforced Prerequisite at Enrollment: MATH 250 or MATH 251
Bachelor of Arts: Quantification

MATH 450: Mathematical Modeling

3 Credits

Constructing mathematical models of physical phenomena; topics include pendulum motion, polymer fluids, chemical reactions, waves, flight, and chaos. MATH 450 Mathematical Modeling (3) The purpose of the course is to introduce mathematical modeling, i.e., the construction of mathematical structures which capture relevant physical phenomena. The course will systematically explore mathematical ideas and tools used to study the natural world. Particular emphasis will be placed on the process of creating a mathematical model starting from a physical scenario. Typically this process will begin with an experiment either demonstrated in the W. G. Pritchard Lab or performed by the students in class.Once a particular model has been developed, students will use mathematical analysis and experimentation to determine the properties and relevance of the model, and to make predictions. Often the model can be satisfactory; however, many times one also finds new features of the system that are not adequately accounted for in the model, and the process begins again. It is this cycle the course will focus on. For a given phenomenon (e.g., flow of viscous fluid, pendulum motion) several models may be compared and contrasted, and possible simplifications will be discussed.A significant aspect of the course is its laboratory component, in which the students will perform experiments or observe demonstrations. However, the main emphasis will be placed on creating and rigorously analyzing the mathematical aspects of the models. Instead of presenting a finely tuned model for a given phenomenon, this course will try to convey some of the heuristic, intuitive, and mathematical ideas employed in modeling.Examples

of physical systems to be considered include: simple and compound pendulum motion, chemical oscillations, water waves, and elastic behavior of polymer solutions.The course is open to a wide range of undergraduate as well as graduate students with majors in mathematics, biology, chemistry, engineering, and physics. The course should be accessible to students with some basic knowledge of mathematical analysis and differential equations. Main topics include: modeling with ordinary differential equations; bifurcation theory and stability; traveling waves in epidemics, chemical reactions, free fluid surfaces, and polymer solutions; fluctuations in nature, stochastic differential equations and chaos.

Enforced Prerequisite at Enrollment: (MATH 315 and MATH 430) or MATH 405 or MATH 412
Bachelor of Arts: Quantification

MATH 451: Numerical Computations

3 Credits

ALGORITHMS FOR INTERPOLATION, APPROXIMATION, INTEGRATION, NONLINEAR EQUATIONS, LINEAR SYSTEMS, FAST FOURIER TRANSFORM, AND DIFFERENTIAL EQUATIONS EMPHASIZING COMPUTATIONAL PROPERTIES AND IMPLEMENTATION. STUDENTS MAY TAKE ONLY ONE COURSE FOR CREDIT FROM MATH 451 AND 455.

Enforced Prerequisite at Enrollment: (CMPSC 101 or CMPSC 121 or CMPSC 131 or CMPSC 200 or CMPSC 201) and (MATH 230 or MATH 231)
Cross-listed with: CMPSC 451
Bachelor of Arts: Quantification

MATH 452: Deep Learning Algorithms and Analysis

3 Credits

This is an undergraduate course on the introduction of basic mathematical, numerical and practical aspects of deep learning techniques. It will provide students with the mathematical background and also practical tools needed to understand, to analyze and to further develop numerical methods for deep learning and applications. The course is simultaneously geared towards math students who want to learn about the emerging technology of deep learning and also towards students from other fields who are interested in deep learning application but would like to strengthen their theoretical foundation and mathematical understanding. This course will allow students to fulfill 400-level math course requirement for Math Majors/Minors (or for other Majors as approved by student advisor). The course will cover some basic deep learning models such as the basic deep neural networks, convolutional neural networks, training algorithms such as stochastic gradient descent methods, popular data bases such as MNIST and CIFAR and specific applications such as image classifications. Traditional numerical methods such as finite element and multigrid method will also be introduced to motivate and to understand how and why deep neural networks work.

Enforced Prerequisite at Enrollment: MATH 220 and (MATH 230 or MATH 231) and (CMPSC 101 or CMPSC 121 or CMPSC 131 or CMPSC 200 or CMPSC 201)

MATH 455: Introduction to Numerical Analysis I

3 Credits

Floating point computation, numerical rootfinding, interpolation, numerical quadrature, direct methods for linear systems. Students may take only one course for credit from MATH 451 and MATH 455.

Enforced Prerequisite at Enrollment: (CMPSC 201 or CMPSC 202 or CMPSC 121 or CMPSC 131) and MATH 220 and (MATH 230 or MATH 231)
Cross-listed with: CMPSC 455
Bachelor of Arts: Quantification

MATH 455H: Introduction To Numerical Analysis I

3 Credits

FLOATING POINT COMPUTATION, NUMERICAL ROOTFINDING, INTERPOLATION, NUMERICAL QUADRATURE, DIRECT METHODS FOR LINEAR SYSTEMS. STUDENTS MAY TAKE ONLY ONE COURSE FOR CREDIT FROM MATH 451 AND MATH 455.

Cross-Listed
Honors

MATH 456: Introduction to Numerical Analysis II

3 Credits

Polynomial and piecewise polynomial approximation, matrix least squares problems, numerical solution of eigenvalue problems, numerical solution of ordinary differential equations.

Enforced Prerequisite at Enrollment: MATH 455
Cross-listed with: CMPSC 456
Bachelor of Arts: Quantification

MATH 457: Introduction to Mathematical Logic

3 Credits

Propositional logic, first-order predicate logic, axioms and rules of inference, structures, models, definability, completeness, compactness. Logic forms the foundation of all mathematical reasoning. To prove a mathematical theorems, one deduces them step by step from basic principles, called axioms, or from other statements previously deduced. Each step of a proof has to be a logically valid rule, such as, for example, the modus ponens: "If A holds, and A implies B, then B holds." In Math 457, students will learn how concepts such as axiom, theorem, proof, and truth can be formulated as a mathematical theory, that is, logical reasoning will be studied as a mathematical subject. The simplest kind of logical system is propositional logic. Here, the basic components are whole statements which are either true or false, and which can be combined using logical connectives such AND, OR, or NOT to form new statements. Its simple nature makes propositional logic a good system to introduce many of the basic ideas: syntax and semantics, proof systems, completeness and compactness. However, propositional logic does not capture mathematical reasoning adequately. Therefore, one considers (first-order) predicate logic. Students will learn how formulas are formed according to syntactical rules. They will also study how a mathematical theory is defined as a set of formulas, how a proof is formally defined, and what constitutes a proof system. The syntactical notions above are contrasted with mathematical semantics, which considers structures over which formulas can be interpreted. This way, one can rigorously define whether a formal statement is true in a given mathematical

structure, in which case we say the structure is a model of the statement. For example, the integers with addition are a model of the statement "for every x there exists a y such that x+y =0". A central goal of mathematical logic is to explore how the syntactical side (formulas, axioms, proof systems) and the semantical side (mathematical structures such as the additive group of integers) interact. Two fundamental results in this regard will be covered: the completeness theorem says that one can prove a statement from a set of axioms if and only if the statement is true in any structure satisfying all axioms. The compactness theorem, in turn, is an important consequence of the completeness theorem. It has profound implications for the existence and construction of mathematical structures. Students who would like to enroll in Math 457 are required to have some knowledge of mathematical proofs as provided in Math 311W.

Bachelor of Arts: Quantification

MATH 465: Number Theory

3 Credits

Elements, divisibility of numbers, congruences, residues, and forms. MATH 465 Number Theory (3) (BA) This course meets the Bachelor of Arts degree requirements.This course serves as an upper-level introduction to the fundamentals of elementary number theory. A major emphasis in the course is placed on the role that the prime numbers play in the study of properties of the integers along with the related topics of divisibility and factorization of integers. Additional topics covered in the course include congruences (and the theorems of Euler and Fermat which are classics in this area), properties of arithmetic functions including those which are multiplicative, and other topics such as Pythagorean triples and representations of numbers as sums of squares. This course is completed by a wide variety of students across the university, especially those majoring in mathematics. (In many of the options in the MTHBS degree, MATH 465 can be used to satisfy one of the major requirements.) The course is also taken quite frequently by non-mathematics majors who wish to use the course to satisfy an upper-level requirement for the mathematics minor.

Enforced Prerequisite at Enrollment: MATH 311W
Bachelor of Arts: Quantification

MATH 467: Factorization and Primality Testing

3 Credits

Prime sieves, factoring, computer numeration systems, congruences, multiplicative functions, primitive roots, cryptography, quadratic residues. Students who have passed MATH 465 may not schedule this course.

Enforced Prerequisite at Enrollment: CMPSC 360 or MATH 311W
Cross-listed with: CMPSC 467
Bachelor of Arts: Quantification

MATH 467H: Factorization and Primality Testing

3 Credits

Prime sieves, factoring, computer numeration systems, congruences, multiplicative functions, primitive roots, cryptography, quadratic residues. Students who have passed MATH 465 may not schedule this course.

Honors

MATH 468: Mathematical Coding Theory

3 Credits

Shannon's theorem, block codes, linear codes, Hamming codes, Hadamard codes, Golay codes, Reed-Muller codes, bounds on codes, cyclic codes.

Enforced Prerequisite at Enrollment: MATH 311W
Bachelor of Arts: Quantification

MATH 470: Algebra for Teachers

3 Credits

An introduction to algebraic structures and to the axiomatic approach, including the elements of linear algebra. Designed for teachers and prospective teachers. Students who have passed Math 435 may not schedule this course.

Enforced Prerequisite at Enrollment: MATH 311W
Bachelor of Arts: Quantification

MATH 471: Geometry for Teachers

4 Credits

Problem solving oriented introduction to Euclidean and non-Euclidean geometries; construction problems and geometrical transformations via "Geometer's Sketchpad" software. Intended primarily for those seeking teacher certification in secondary mathematics. Students who have passed MATH 427 may not schedule this course.

Enforced Prerequisite at Enrollment: MATH 311W
Bachelor of Arts: Quantification

MATH 475Y: History of Mathematics

3 Credits

A global survey of the history of mathematics as viewed as a human response to cultural, political, economic, and societal pressures. MATH 475W Introduction to the History of Mathematics (3) (DF) The primary goal of this course is to explore where mathematics comes from, how it was labored on, how ideas were preceived, and how theories developed. Development in algebra, geometry, arthimetic and calculus will be discussed.A second goal is to help students understand the importanct of written communication in mathematics and to provide opportunities for students to improve the quality of their writing. The primary means for accomplishing this goal will be four papers, 4-8 pages in length. These will be written for an audience of mathematically-knowledgeable readers. In addition, each quiz will contain at least one essay question.Students will be evaluated on quizzes, homework, papers, and a final exam. Quizzes will total 250 points, the papers 200 points, and the final exam 150 points.This course is a required course in the Mathematical Science (MA SC) BS curriculum. This course is also available as an elective for students in the Computer Science (COMP) program.No special facilities are required for this course. This course will be offered once per year, with an expected enrollment of 25-40 students.

Enforced Prerequisite at Enrollment: MATH 315 or MATH 311W
Bachelor of Arts: Quantification
International Cultures (IL)
United States Cultures (US)
Writing Across the Curriculum

MATH 479: Special and General Relativity

3 Credits

Mathematical description, physical concepts, and experimental tests of special and general relativity. MATH 479 / PHYS 479 Special and General Relativity (3) This course is intended as an elective course (within the undergraduate Physics program) for Physics majors to be taken in their senior year. Intended to be cross-listed with MATH, it can also be used in support of a Mathematics minor and, in some options, within the Math program as a program elective as well. The course significantly expands upon the introduction to Special Relativity (SR) seen in PHYS 237, including discussions of experimental tests of SR and applications to relativistic mechanics. It then introduces students to the mathematical machinery required to understand General Relativity (GR), starting with the description of curved spacetimes and geodesics. It discusses solutions to the Einstein equations and surveys the classic tests which established the validity of General Relativity. It concludes with applications of GR in such areas as black hold physics, the generation and detection of gravitational waves, other topics (such as cosmology, relativistic astrophysics, etc.).

Enforced Prerequisite at Enrollment: PHYS 237 and PHYS 400 and PHYS 419 and (MATH 250 or MATH 251) and (MATH 230 or MATH 231)
Cross-listed with: PHYS 479
Bachelor of Arts: Quantification

MATH 482: Mathematical Methods of Operations Research

3 Credits

Survey of linear and nonlinear programming; mathematics of optimization; queues; simulation.

Enforced Prerequisite at Enrollment: MATH 220 and MATH 230 and STAT 301
Bachelor of Arts: Quantification

MATH 484: Linear Programs and Related Problems

3 Credits

Introduction to theory and applications of linear programming; the simplex algorithm and newer methods of solution; duality theory.

Enforced Prerequisite at Enrollment: MATH 220 and (MATH 230 or MATH 231)
Bachelor of Arts: Quantification

MATH 485: Graph Theory

3 Credits

Introduction to the theory and applications of graphs and directed graphs. Emphasis on the fundamental theorems and their proofs.

Enforced Prerequisite at Enrollment: MATH 311W
Bachelor of Arts: Quantification

MATH 486: Mathematical Theory of Games

3 Credits

Basic theorems, concepts, and methods in the mathematical study of games of strategy; determination of optimal play when possible. MATH 486 Mathematical Theory of Games (3) This course covers several major classes of models and methods for analyzing multi-party strategic interactions, i.e. games. Specific topics include extensive and strategic form games, continuous games, cooperative games, strictly competitive games, repeated games and adaptive learning, and evolutionary models. The effects on outcomes of information, communication, and other modeling assumptions are discussed. Real-world examples drawn from economics, biology, anthropology, management and everyday life are discussed in detail. When appropriate, computer algebra systems are incorporated in the course. The course typically meets during either two 75-minute periods each week or three 50-minute periods each week. Evaluation methods may vary by instructor, but will typically include a combination of examinations, quizzes, homework, and projects.

Enforced Prerequisite at Enrollment: MATH 220
Bachelor of Arts: Quantification

MATH 490H: Honors Student Colloquium

1 Credits/Maximum of 6

The course comprises colloquium style weekly lectures by visitors and by Penn State faculty covering select topics in classical and contemporary mathematics. Some talks will describe math-intense jobs outside of academia and help the students to plan for their future career. The topics of the lectures will be quite advanced, distinguishing it as an honors course. In addition to attending the talks, toward the end of semester, the students will either give a presentation or write an essay on a mathematical topic of their choice or a topic covered in one of the colloquium talks.

Enforced Prerequisite at Enrollment: MATH 220 and MATH 230 and (MATH 250 or MATH 251) and (MATH 311W or MATH 311M)
Honors

MATH 494: Research Project

1-12 Credits/Maximum of 12

Supervised student activities on research projects identified on an individual or small-group basis.

Bachelor of Arts: Quantification

MATH 494H: Thesis Project

3 Credits/Maximum of 6

The honors thesis proposal must be approved by the thesis supervisor and the honors adviser and submitted to the Schreyer Honors College prior to scheduling this course. Honors students in Mathematics should register for Math 494H in one or both of their last two semesters. All Schreyer Scholars are required to complete an undergraduate honors thesis. This work represents the culmination of a student's honors experience. Through the thesis, the student demonstrates a command of relevant scholastic work and a personal contribution to that scholarship. The thesis document should capture the relevant background, methods and techniques, as well as describe the details of the completion of the individual project.

Bachelor of Arts: Quantification
Honors

MATH 495: Internship

1-18 Credits/Maximum of 18

Supervised off-campus, nongroup instruction including field experiences, practica, or internships. Written and oral critique of activity required.

Prerequisite: prior approval of proposed assignment by instructor
Bachelor of Arts: Quantification

MATH 496: Independent Studies

1-18 Credits/Maximum of 18

Creative projects, including research and design, which are supervised on an individual basis and which fall outside the scope of formal courses.

Bachelor of Arts: Quantification

MATH 496A: **SPECIAL TOPICS**

1-6 Credits

Bachelor of Arts: Quantification

MATH 496H: Independent Studies

1-18 Credits/Maximum of 18

Creative projects, including research and design, which are supervised on an individual basis and which fall outside the scope of formal courses.

Honors

MATH 497: Special Topics

1-9 Credits/Maximum of 999

Formal courses given infrequently to explore, in depth, a comparatively narow subject which may be topical or of special interest.

Bachelor of Arts: Quantification

MATH 499: Foreign Studies

1-12 Credits/Maximum of 12

Courses offered in foreign countries by individual or group instruction.

Bachelor of Arts: Quantification
International Cultures (IL)