Mathematics

Professors: *Banerji (Emeritus), Fillebrown, Gowdy (Emeritus), Hecker, Klingsberg, Rash, Smith (Chair), Tapp*
Associate Professors: *Berezovski, Cavaliere, Costello (Emeritus), Foley (Emeritus), Hall, Laison, Lurie (on sabbatical Fall '15), Regis*
Assistant Professors: *Terry*
Visiting Assistant Professors: *Bobo, DeLiberato, Manco*

The Department of Mathematics offers a B.S. degree in mathematics, a B.S. degree in actuarial science and a five-year B.S./M.S. program in mathematics and secondary mathematics education. The objective of the bachelor's degree program in mathematics is to prepare students for professional careers in a variety of industries and for graduate programs leading to the M.S. and Ph.D. Students also may opt for advanced degrees in education, business administration, law, or medicine. A creative imagination is required for success.

B.S. in Mathematics

Learning Goals and Objectives for the B.S. in Mathematics

Learning Goal 1: Students will gain a general knowledge of the field of mathematics including knowledge of the application of mathematics to other fields.

Objective 1.1: Students will know the mathematical theory underlying fundamental developments in mathematics.

Objective 1.2: Students will understand the nature of mathematical proof.

Objective 1.3: Students will have knowledge of the diverse branches of mathematics.

Objective 1.4: Students will have knowledge of areas closely related to mathematics including Computer Science and at least one branch of the Natural Sciences.

Learning Goal 2: Students will master specific skills in mathematics.

Objective 2.1: Students will be able to perform basic computations such as calculating derivatives, integrals and various operations with matrices.

Objective 2.2: Students will be able to identify and apply the appropriate method to solve a specific mathematical problem.

Objective 2.3: Students will be able to identify and apply the appropriate proof technique to prove a mathematical statement.

Requirements for the Mathematics Major

GEP Signature Courses (See Curricula): six courses

GEP Variable Courses (See Curricula): six to nine courses, including

Mathematics:
MAT 161 Calculus I

Natural Science:
one semester of any lab-based natural science course

GEP Overlays (See Curricula): three courses

GEP Integrative Learning Component: three courses

Natural Science:
one semester of any lab-based major-level natural science course

Open ILC courses:
Any two additional CAS courses that relate to the major. Advisor and Chair approval required in advance.

GEP Electives: seven courses

Major Concentration: fifteen courses
CSC 120 Computer Science I (or CSC 110 Virtual Worlds and Robots)
MAT 162 Calculus II
MAT 180 Theory of Numbers
MAT 213 Calculus III
MAT 225 The Fundamental Ideas of Mathematics (*or CSC 140 with permission*)
MAT 226 Introduction to Linear Algebra
MAT 403 Abstract Algebra
MAT 409 Real Analysis

one elective chosen from MAT 404, 410, 415, or 418, and any other six MAT courses approved by advisor and chair.

Minor in Mathematics
Advisor: *Dr. Klingsberg*

With the approval of the department, students may minor in mathematics. Upon acceptance, they will be assigned an advisor within the department who will assist the students in selecting courses appropriate for their area of interest.

Students desiring a minor in mathematics must take or receive AP credit for six courses at the level of MAT 161 or higher. The course being used to satisfy the GEP math requirement may not be used toward the minor. The grade in each course must be C+ or better, or the average of the six classes must be at least 2.7.

Learning Goals and Objectives for the minor in Mathematics

Learning Goal 1: Students will gain a general knowledge of the field of mathematics including knowledge of the application of mathematics to other fields.

Objective 1.1: Students will know the mathematical theory underlying fundamental developments in mathematics.

Objective 1.2: Students will understand the nature of mathematical proof.

Objective 1.3: Students will gain knowledge of applications of mathematics to other fields.

Learning Goal 2: Student will master specific skills in mathematics.

Objective 2.1: Students will be able to perform basic computations from calculus such as derivatives and integrals.

Objective 2.2: Students will be able to identify and apply the appropriate method to solve a specific mathematical problem.

The Five-Year Combined B.S. in Mathematics, M.S. in Secondary Mathematics Education Option

Program Director: *Dr. Berezovski*

This program offers students the opportunity to complete an undergraduate major in mathematics, receive Commonwealth of Pennsylvania Secondary Teacher Certification in mathematics, and earn a M.S. in Secondary Mathematics Education. This curriculum emphasizes the unique character of mathematics learning theory, technology, and techniques for effective teaching in the discipline. The program strengthens the traditional certification programs by incorporating modern teaching/learning strategies and an opportunity to participate in research in the field.

Undergraduate mathematics majors at Saint Joseph's University who apply for the five-year combined B.S./M.S. program will be evaluated for acceptance into the program after the completion of the first semester of their junior year. A cumulative grade point average of 3.0 or better is normally required. For more information, contact the Department of Mathematics or the Graduate Arts and Sciences office. Requirements of the program and course offerings are listed in the Graduate Catalog under Mathematics Education. Courses in mathematics education are designated by MED and may be taken for undergraduate credit with the approval of advisor and chair.

Students interested in the five year program should speak to Dr. Fillebrown as early in their academic careers as possible.

Five-year BS/MS in Mathematics and Mathematics Education

Learning Goals and Objectives for the Five-year BS/MS in Mathematics and Mathematics Education

Students in the Five-year BS/MS in Mathematics and Mathematics Education Program complete all requirements of the undergraduate Mathematics major in the first four years and all requirements of the Secondary Education major by the end of the fifth year. In addition to the goals and objectives for those two programs, students in the 5-Yr Math and Math Education program will meet the following.

Learning Goal 1: Students will demonstrate knowledge of the mathematical content required for teaching secondary mathematics.

Objective 1.1: Students will know how to solve mathematical problems using multiple

representations and using multiple mathematical approaches.

Objective 1.2: Students will understand the nature of proof and the sequence of observing examples, making conjectures and proving or disproving mathematical statements in a variety of mathematical disciplines.

Learning Goal 2: Students will be able to plan and align curriculum and assessment according to Pennsylvania State standards, Common Core State Standards and the standards put forth by the National Council of Teachers of Mathematics.

Objective 2.1: Students will be aware of current issues in and the evolving nature of mathematics education including the use of technology.

Objective 2.2: Students will be able to draw on a variety of resources including the research literature in mathematics education to enhance their teaching and examine curricular change.

Teacher Certification for Secondary Schools
Advisor: *Dr. Berezovski*
Students who are pursuing Secondary Teacher Certification in Mathematics and who do not want to pursue a graduate degree, double major in Mathematics and Secondary Education. Their primary major is Mathematics. If they complete their student teaching during their senior year, they are exempt from one of the mathematics elective courses required for the Mathematics major. For more information on this option and the required courses, consult the department's web page, the Secondary Education sequence listed in the Education section of the Catalog, and consult with the Departmental advisor, Dr. Fillebrown.

Actuarial Science
Actuarial Science is an inter-college major with combined coursework from the Haub School of Business and the College of Arts and Sciences. The program director is Dr. Lurie. Please see the separate major listing "Actuarial Science" at the beginning of the College of Arts and Sciences section of this catalogue. A minor in Actuarial Science is also available.

Overlapping Course Groupings
MATH Students may not take overlapping courses for credit. Please note the following five overlapping course groupings.

1.	MAT 106	MAT 119	MAT 123	MAT 155	MAT 161 (formerly MAT 106
2.	MAT 156	MAT 162			
3.	MAT 118	MAT 128			
4.	MAT 225	CSC 140			
5.	MAT 139	MAT 150 Art, Poetry, Mathematics and Society			

College Honors Requirements

To receive College Honors credit, students undertake two consecutive semesters of course-based research and study that culminates in a senior thesis. For students in the Honors Program, these two courses may be counted toward the eight- course Honors requirement. To be eligible for College Honors a student must have a GPA of 3.5 or higher. If you are interested in completing the College Honors project during your senior year, please be in touch with the department chair early in the Spring of your junior year. Specific requirements for the College Honors thesis may be found under "Honors Program".

Mathematics Courses

MAT 111 The Mathematics of Patterns (3 credits)
This course focuses on mathematics as the science of identifying, understanding and describing patterns. Patterns that occur in nature and empirical studies can be identified and modeled using fundamental ideas such as functions (mathematical rules), probability (long term behavior), exploratory data analysis (statistics) and geometry. Through a series of guided investigations students will master the reasoning used to identify the patterns, the mathematical model used to describe the pattern and the computational techniques necessary to further explore and apply the pattern in new situations. This course is designed specifically for students intending to become elementary or middle school teachers. *However, the course is open to anyone and has no pre-requisites. This course does not fulfill the GEP Mathematics requirement.*

MAT 118 Introduction to Statistics (3 credits)
Introduction to statistics and probability: measures of central tendency, variability, correlation, regression, chance and randomness, random variables, probability distributions, law of large numbers, central limit theorem. Students will be required to use a computer software package to

solve various statistical problems. Designed for Social Science majors. *This course does not fulfill the GEP Mathematics requirement. Students may NOT receive credit for this course and for MAT 128.*

MAT 119 Applied Business Calculus (4 credits)
Review of mathematical models using polynomial, rational, exponential and logarithmic functions with business applications. Introduction to calculus including limits, rates of change and the derivative, optimization using the derivative, integration. *This course does not fulfill the GEP Mathematics requirement. Students may NOT receive credit for both this course and for any of the following courses: MAT 104 (formerly MAT 106), MAT 123, MAT 155, or MAT 161.*

MAT 120 Mathematics Used in Modeling (3 credits)
Algebra: factoring, simultaneous equations, polynomial, rational, and exponential functions, binomial theorem, word problems. Trigonometry: basic functions, formulae, graphs. Analytic Geometry: straight line, circle, conic sections. *This course does not fulfill the GEP Mathematics requirement.*

MAT 121 Mathematical Modeling for Middle School Teachers (3 credits)
Designed for students who will become middle school teachers, this course will explore mathematical topics in the context of building of building models to solve problems. The emphasis will be on using multiple representations to develop mathematical models that describe some phenomena and learning the mathematical techniques necessary for working with the model in order to use effectively to answer questions about the situation being modeled. Students will interpret results given the context of the model and develop their communication skills for explaining mathematics. *This course does not fulfill the GEP Mathematics requirement.*

MAT 123 Differential Calculus (3 credits)
Review of mathematical models using polynomial, rational, exponential and logarithmic functions with business applications Introduction to differential calculus including limits, rates of change and the derivative, optimization using the derivative. *This course does not fulfill the GEP Mathematics requirement. Students may NOT receive credit for both this course and for any of the following courses: MAT 104 (formerly MAT 106), MAT 119, MAT 155 or MAT 161.*

MAT 128 Applied Statistics (3 credits)
Introduction to statistics and probability: design of a study, measures of central tendency, variability, correlation, regression; probability, random variables, probability distributions, central limit theorem; inferential statistics, hypothesis testing, etc. Students will be required to use a computer software package to solve various statistical problems. Data analysis projects will be assigned. *This course does not fulfill the GEP Mathematics requirement. Students may NOT receive credit for both this course and for MAT 118.*

MAT 130 The Whole Truth About Whole Numbers (3 credit)
This course involves studying properties of natural numbers and integers. Topics include divisibility, prime numbers, the Euclidean Algorithm and the RSA Encryption system for putting messages into code.
This course fulfills the GEP Mathematics Requirement.

MAT 131 Linear Methods (3 credits)
This course studies basic properties and applications of matrices and vectors. Then, matrices and vectors will be used in a variety of applications, including solving word problems involving systems of linear equations, investigating Markov chains, and analyzing transformations of objects on the screen in computer graphics. Students in this course will be required to have a graphing calculator that can perform standard matrix operations. *This course fulfills the GEP Mathematics Requirement.*

MAT 132 Mathematics of Games and Politics (3 credits)
This course will focus on both computational and theoretical aspects of probability theory, game theory and social choice theory. Topics include expected value, counting methods and conditional probability, dominant strategies, combinatorial games, Nash equilibria, social dilemmas and, for zero sum games, saddle points and the Minimax theorem. Social choice theory topics include voting methods, weighted voting, fairness criteria and impossibility theorems.
This course fulfills the GEP Mathematics Requirement.

MAT 134 Mathematics of Uncertainty: Counting Rules and Probability (3 credits)
This course provides students with an in-depth introduction to probability and its many real-life applications. Students will study counting techniques including permutations, combinations, binomial coefficients, occupancy problems and runs within random orderings and will prove combinatorial identities. Students will study topics in probability including sample spaces, DeMorgan's Laws, conditional probability, independent events, Bayes Theorem, random variables and expected value. Students will examine many of the classical problems in probability theory including Prisoner's Dilema, Gambler's Ruin and the Birthday Problem as well as lotteries, card games and random walks.
This course fulfills the GEP Mathematics Requirement.

MAT 135 Sounding Number: Music and Mathematics from Ancient to Modern Times (3 credits)
Music has many connections to mathematics. The ancient Greeks discovered that chords with pleasing sounds are related to simple ratios of integers. Other connections include equations describing the sounds of musical instruments, the mathematics of digital recording, the use of symmetry in composition, and the systematic exploration of patterns by African and Indian drummers. This course introduces basic concepts in trigonometry, set and group theory, and combinatorics and investigates their applications in the analysis, recording, and composition of music. Along the way, we consider the role of creativity in mathematics and the ways in which mathematics has inspired musicians. The course will involve hands-on laboratory work in audio engineering and music composition.
This course fulfills the GEP Mathematics Requirement.

MAT 136 Mathematics and Visual Arts (3 credits)
This course will explore connections between mathematics and the arts. Mathematics - itself an aesthetic endeavor - has made fundamental contributions to art history and continues to be a source of inspiration to many contemporary artists. We will begin with the study of mathematical perspective, and of optical devices, such as the camera obscura, which assisted artists and illustrators in depicting the world around them. At the beginning of the twentieth century, artists turned to non-Euclidean geometries and higher dimensional spaces for inspiration and to break free from the constraints of linear perspective. We will take some time to understand these geometries as well. The remaining topics will be chosen according to the interests and talents of the students in the course. Possibilities include fractals, math and music, math and architecture, and advanced perspective topics.
This course fulfills the GEP Mathematics Requirement.

MAT 137 Ethnomathematics (3 credits)
This course aims to strengthen and expand students' understanding of fundamental mathematics – number systems, arithmetic, geometry, combinatorics, and mathematical reasoning – through study of the mathematics of world cultures. In addition, the course is designed to explore the connections between mathematics and the arts, to engage students' imagination and creativity, and to increase the diversity of offerings in the mathematics classroom.
This course fulfills the GEP Mathematics Requirement.

MAT 138 Symmetry (3 credits)
"Symmetry" is a ubiquitous concept in modern mathematics and science. Certain shapes and images seem more symmetric than others, yet is not immediately obvious how to best measure and understand an object's symmetry. In fact, the quest to more precisely quantify the concept of symmetry has been a driving force in science and mathematics, and will form the central theme of this course.
This course fulfills the GEP Mathematics Requirement.

MAT 139 Mathematics, Culture and Society (3 credits)
The course considers the relationship of mathematics to other areas of human thought and culture and to the society in which it develops. Several periods in the history of mathematics will be considered, from the beginnings of mathematics to modern times. This course fulfills the GEP Mathematics Requirement. *Students may NOT receive credit for both this course and for MAT 150 – Art, Poetry, Mathematics and Society (First Year Seminar).*

MAT 150 Art, Poetry, Mathematics and Society (First Year Seminar; 3 credits)
This course will consider several periods of human history and pre-history, and for each of them discuss the relationship of artistic and

mathematical production to each other, to the dominant modes of thought of the society, and to the social and economic base of the society. Periods will include: Paleolithic society in Africa; the Bronze Age in Egypt, Babylonia, China, and India; ancient Greece from Pythagoras to Plato; Medieval Arabic Society; Renaissance and early modern times in Europe; the Romantic period in Europe; the early twentieth century and the impact of Modernism. *This course does not fulfill the GEP Mathematics requirement. Students may NOT receive credit for both this course and for MAT 139– Mathematics, Culture and Society*

MAT 150 Fractals and Infinity (First Year Seminar; 3 credits)
Fractals are mathematical objects that exhibit self-similarity at different scales. They can be used to model many naturally occurring phenomena such as trees, mountain ranges, circulatory systems and river tributaries. They also occur frequently in pop-culture and some images such as the Mandelbrot Set, the Sierpinski Triangle and the Koch Snowflake decorate many calendars, t-shirts and book jackets. In this first year seminar we will study the mathematics behind these, and other, fractal images. Fractals are intimately related to the concept of infinity and so we will necessarily also spend some time examining exactly what do mathematics mean when they talk about quantities that are infinitely small or infinitely large or infinitely long. This course does not fulfill the GEP Mathematics requirement.

MAT 150 From Chaos to the 4th Dimension (First Year Seminar; 3 credits)
This course investigates several beautiful topics within modern mathematics, including: prime numbers, the different sizes of infinity, the symmetry of the Platonic solids, the fourth dimension, fractals, chaos, probability, the math of voting and how to get rich. Students will develop sharper analytic skills and experience mathematics as an artistic endeavor which requires both imagination and creativity. *This course does not fulfill the GEP Mathematics requirement.*

MAT 150 Great Mathematical Discoveries - Elucidated by Reading and Writing (First Year Seminar; 3 credits)
This course introduces students to some of the great ideas in mathematics and to the mathematicians who made these great discoveries or created new theories. Students will read articles or chapters from an extensive reading list relevant to a variety of topics, including, but not limited to, historic information, modern applications of mathematics, biographies, careers using mathematics and other topics. Students will write summaries of or reflections on the articles. These topics vary from year to year and are chosen to match the interests and level of preparation of the students. Examples of topics include designing secret codes, optimal scheduling problems, algorithms and prime numbers.
This course does not fulfill the GEP Mathematics requirement.

MAT 155 Fundamentals of Calculus (3 credits)
This course covers the fundamentals of differential calculus (limit, continuity, and the derivative) and introduces the definite integral and its connection to the antiderivative. In addition, we discuss the historical roots of calculus and the challenges faced in establishing a rigorous logical foundation for its concepts.
This course fulfills the GEP Mathematics Requirement. Prerequisite: MAT 120 or adequate performance on calculus readiness test. Students may NOT receive credit for both this course and for any of the following courses: MAT 104 (formerly MAT 106), MAT 119, MAT 123 or MAT 161

MAT 156 Applied Calculus II (3 credits)
This course covers the definite integral, techniques of integration, solving differential equations and the calculus of several variables. The emphasis is on applications to the Business and Social Sciences.
Prerequisite: MAT 155 or MAT 161. This course does not fulfill the GEP Mathematics requirement. Students may NOT receive credit for both this course and for MAT 162.

MAT 161 Calculus I (4 credits)
Limits; slopes, rates of change and the derivative; techniques of differentiation; implicit differentiation; derivatives of transcendental functions; related rates; linear approximation; L'Hosptial's Rule; the Mean Value Theorem; applications of differentiation (including curve sketching and optimization); introduction to integration; the Fundamental Theorem of Calculus.
This course fulfills the GEP Mathematics Requirement.
Prerequisite: MAT 120 or adequate performance on calculus readiness test.
Students may NOT receive credit for both this course and for any of the following courses: MAT 104 (formerly MAT 106), MAT 119, MAT 123 or MAT 155.

MAT 162 Calculus II (4 credits)
Techniques of integration; applications of integration; improper integrals; exponential growth; infinite sequences and series; power series and Taylor series.
Prerequisite: a grade of C or better in MAT 161 or permission of department. This course fulfills the GEP Mathematics Requirement. Students may NOT receive credit for both this course and for MAT 156.

MAT 180 Theory of Numbers (3 credits)
Division Algorithm; Mathematical induction; Euclidean algorithm; fundamental theorem of arithmetic; linear Diophantine equations; modular arithmetic; number theoretic functions; prime numbers; Fermat's last theorem; quadratic residues, primitive roots, Chinese Remainder theorem. *This course fulfills the GEP Mathematics requirement but is at a more advanced level that courses in the MAT 130 - MAT 139 range.*

MAT 213 Calculus III (4 credits)
Vector geometry in R2 and R3; polar coordinates; introduction to the calculus of vector-valued functions (velocity, speed, acceleration, curvature, parametric equations); differentiation of functions of several variables (partial derivatives, the differential, chain rules, directional derivatives); applications of differentiation (linear approximation, optimization, the method of Lagrange multipliers); integrals of functions of several variables; applications of integration. Also, if time permits, cylindrical and spherical coordinates; some surface integrals; the Change of Variable theorem. *This course fulfills the GEP Mathematics Requirement.*
Prerequisite: a grade of C or better in MAT 162 or permission of department chairperson.

MAT 225 The Fundamental Ideas of Mathematics (3 credits)
An introduction to: (i) the basic ideas used throughout Mathematics—logic, sets, functions, relations — and (ii) the fundamental activity of mathematics—proving theorems. These ideas will be used to explore topics chosen from among: counting ideas in finite and infinite sets, construction of the real numbers, and abstract algebraic systems.
Prerequisite: MAT 162. Students may NOT receive credit for both this course and for CSC 140.

MAT 226 Introduction to Linear Algebra (4 credits)
Linear systems, vector spaces, dimension, linear transformations, matrices, inner product, orthogonality, characteristic polynomials, diagonalization, eigenvalues, and eigenvectors.
Prerequisite: MAT 225 or permission of the chair of Mathematics.

MAT 231 The Mathematics of Music (3 credits)
Music has many connections to mathematics. The ancient Greeks discovered that chords with a pleasing sound are related to simple ratios of integers. The mathematics of rhythm has also been studied for centuries—in fact, ancient Indian writers discovered the celebrated Fibonacci sequence in the rhythms of Sanskrit poetry. Other connections between math and music investigated in this course include the equations describing the sounds of musical instruments, the mathematics behind digital recording, the use of symmetry and group theory in composition, the exploration of patterns by African and Indian drummers, the application of chaos theory to modeling the behavior of melodies, and the representation of chords by exotic geometric objects called orbifolds. Along the way, we discuss the role of creativity in mathematics and the ways in which mathematics has inspired musicians.
Prerequisite: MAT 162 and some musical training (ART 1511 or equivalent). Students with exceptional performance in Calculus I (or AP) and musical training will be admitted on a case-by-case basis as determined by the chair of Mathematics.

MAT 232 Chaos, Fractals and Dynamical Systems (3 credits)
Introduction to dynamical systems: one dimensional dynamics; attracting, repelling, periodic and chaotic orbits; bifurcation; dynamics in the complex plane, Julia sets, the Mandelbrot set; two dimensional dynamics. Introduction to fractals: self-similarity, iterated function systems, fractal dimension.
Prerequisite: MAT 162.

MAT 233 History of Mathematics (3 credits)
Development of mathematical ideas over 2500 years, beginning with Greek geometry and including Euclid, Archimedes, Newton, Euler, Gauss, and Poincare.
Prerequisite: MAT 213 or permission of the chair of Mathematics.

MAT 238 Differential Equations (3 credits)
Solution of ordinary differential equations using analytic, numerical, and qualitative techniques.

Modeling via differential equations, systems of differential equations. Laplace transforms; discrete dynamical systems. Use of a computer software package is required.
Prerequisite: MAT 213 or equivalent.

MAT 239 Problem Solving (3 credits)
The course is designed to involve students in an active way in the mathematical process by having them participate in the major activity of both pure and applied mathematics: the solving of problems. Problems will be chosen from many areas of mathematics, and an attempt will be made to develop general approaches to and general paradigms for problem solving.
Prerequisite: MAT 225.

MAT 240 Advanced Calculus (4 credits)
This course covers three main groups of topics. I) Calculus of functions from Rn to Rk: Differentials, Inverse Function Theorem, Implicit Function Theorem, Jacobian, change of variables. II) Vector calculus. Vector fields, line and surface integrals, Green's Theorem, Stokes's Theorem, the Divergence Theorem. III) Sequences and series of functions. Pointwise and uniform convergence; continuity, differentiation and integration of sequences and series; Fourier series; Taylor series for functions of several variables.
Prerequisite: MAT 213 or equivalent.

MAT 311 Numerical Analysis and Computer Techniques (3 credits)
An introduction to numerical methods for solving a variety of problems. Included will be rootfinding, numerical integration and differentiation, polynomial approximation, systems of equations, ordinary differential equations, and discussion of convergence issues, error analysis and machine arithmetic.
Prerequisite: MAT 213. Concurrent enrollment in or prior completion of MAT 226 would be beneficial.

MAT 313 Mathematical Programming (3 credits)
The course covers basic ideas in optimization beginning with linear programming, the simplex method and duality and finishes with non-linear optimization and algorithms and conditions leading to a solution of non-linear problems.
Prerequisite: MAT 226 or permission of the chair of Mathematics.

MAT 316 Operations Research (3 credits)
The course will cover some of the basic models and techniques used in operations research. Topics include: linear programming, the simplex method, duality, network problems, transportation problems, and time permitting, game theory.
Prerequisite: MAT 226 or permission of the chair of Mathematics.

MAT 321 Probability (3 credits)
The first part of a two-semester sequence, this course includes discrete probability distributions and counting methods, continuous random variables, special probability distributions, joint distributions, expectation, variance, covariance and correlation, moment generating functions, conditional probability, Bayes's Theorem.
Prerequisites: MAT 213.

MAT 322 Mathematical Statistics (3 credits)
Random samples, statistics and sampling distributions, the Central Limit Theorem, point and interval estimation, hypothesis testing (one-sample and two-sample tests), analysis of variance, correlation, regression analysis and Chi Square goodness of fit and other nonparametric methods. Applications. Data analysis projects will be assigned.
Prerequisite: MAT 321

MAT 332 Geometry (3 credits)
An axiomatic treatment of the foundations of geometry. Axioms of incidence, order, congruence, Bolyai-Lobachevsky parallel axiom, angle of parallelism. A rigorous development of selected topics in non-Euclidean geometry.
Prerequisite: MAT 225.

MAT 334 Combinatorics and Graph Theory (3 credits)
Introduction to combinatorics and graph theory and to methods by which each theory is applied to the other. Topics include basic counting formulas; generating functions; the principle of inclusion-exclusion; counting labeled trees (Cayley's Theorem, Kirchhoff's Theorem, Prüfer's Theorem); directed Euler circuits; Pólya-deBrujin theory; Möbius inversion.
Prerequisite: MAT 162.

MAT 336 Logic and Foundations (3 credits)
Cantorian set theory and the crisis in foundations (Cantor's paradox, Russell's paradox); the intuitionist challenge and the formalist response; formal logic and meta mathematics (Propositional Calculus, Predicate Calculus, formal number

theory); Goedel's incompleteness theorems of 1931.
Prerequisite: MAT 162.

MAT 403 Abstract Algebra (3 credits)
Group theory, including finite groups, subgroups, cyclic groups, permutation groups, group isomorphisms, and cosets; introduction to rings and fields, including integral domains, polynomial rings, unique factorization domains and Euclidean domains.
Prerequisite: MAT 225.

MAT 404 Abstract Algebra II (3 credits)
A more in-depth treatment of rings and fields including integral domains, fields, field extensions, homomorphisms, and the insolvability of the quintic by radicals. Galois theory.
Prerequisite: MAT 403.

MAT 409 Real Analysis (3 credits)
Elementary topology of Euclidean spaces, including open, closed and compact sets; convergence of sequences and series; least upper bound axiom and its equivalents; sequences of functions, pointwise and uniform convergence, continuity, differentiation and integration of sequences. Topics which overlap MAT 240 will be covered in more depth in this course.
Prerequisite: MAT 213 and 225.

MAT 410 Complex Analysis (3 credits)
Analytic functions; complex integration; singularities.
Prerequisite: MAT 240, MAT 409, or permission of the chair of Mathematics.

MAT 415 Differential Geometry (3 credits)
Tangent vectors and directional derivatives; mappings and differential forms on E3; Frenet fields; covariant derivatives; frame fields; Cartan structural equations; orientation; Euclidean geometry; surfaces in R3; calculus on surfaces; integration of forms; shape operators; normal and Gaussian curvature; geometry of surfaces.
Prerequisite: MAT 409.

MAT 423 Applied Statistical Methods (3 credits)
Statistical models, design and analysis of experiments, regression, Monte Carlo methods, and other advanced topics in statistics.
Prerequisites: MAT 156 or 162; and MAT 128 or MAT 322.

MAT 418 Topology of Point Sets (3 credits)
Open and closed sets, closure and interior, continuity, metric spaces, connectivity, compactness; the Heine-Borel and Bolzano-Weierstrass Theorems. The Classification of Surfaces may also be covered.
Prerequisite: MAT 409 or equivalent.

MAT 370-470 Special Topics (formerly Independent Study) (3 or 6 credits)

MAT 491-492 Internship (3 credits)
The course goals are: to gain first-hand experience of the daily activities of professionals in mathematics and related fields, to verify an interest in a particular area of mathematics, to develop and hone skills required for mathematical professions, to establish contacts outside the academic community who will facilitate a career in mathematics. *An internship journal and an academic paper are also required.*

MAT 493-494 Research (6 credits)
Students need to complete the application form for independent study (available in the Dean's Office) and have the approval of the department chair and Associate Dean in order to register.

MAT 493-494 Honors Research (6 credits)
Must be elected in junior year to allow adequate research time. Students need to complete the application form for independent study (available in the Dean's Office) and have the approval of the department chair, Associate Dean and the Honors Program Director in order to register. Honors Students must complete this sequence.