INTRODUCTION

The Department of Mathematics offers a standard undergraduate major program in mathematics with concentrations in pure mathematics, applied mathematics, probability and statistics and teaching mathematics. Courses are provided to satisfy the needs of:

- Students planning graduate study in mathematics or related disciplines
- Students planning to use mathematics in a career in business, industry or government
- Students planning to teach at the elementary or secondary level
- Students majoring in a discipline using mathematics as an analytic or descriptive tool

LEARNING GOALS AND STUDENT LEARNING OUTCOMES

The following goals and learning outcomes have been established for students pursuing a degree in Mathematics:

Broad Concepts
- All majors should achieve mastery of basic mathematical ideas and techniques ranging across the following fields: single and multivariate calculus, algebra, analysis, probability/statistics, differential equations and mathematical modeling
- All majors should achieve an understanding of the nature of proof

Specific Skills
- Demonstrate the ability to think analytically and critically and to formulate problems, solve them and interpret their solutions
- Demonstrate the ability to use technological tools, e.g., algebraic and visualization software, statistical packages, a high-level programming language
- Demonstrate the ability to apply knowledge from one branch of mathematics to another and from mathematics to other disciplines
- Demonstrate the ability to communicate mathematics both orally and in writing

Mastery of Information Competence Skills
- Determine the nature and extent of information needed
- Access information through both print and electronic data systems
- Analyze and evaluate the credibility and completeness of information sources
- Select, integrate and synthesize information to accomplish a purpose
- Acknowledge copyrighted material and intellectual property
- Communicate the product effectively to others
**BACHELOR OF ARTS IN MATHEMATICS (120 UNITS)**

The Bachelor of Arts in Mathematics requires 61-65 units in the major, plus 51 units of General Education and 4-6 units of electives. Each course required for the major must be completed with a “C” (2.0) or better, and may not be taken on a Credit/No Credit basis.

**Core Requirements (25 units)**

- MATH 150A,B Calculus I,II (8)
- MATH 250A Calculus III (4)
- MATH 250B Introduction to Linear Algebra and Differential Equations (4)
- MATH 280 Strategies of Proof (3)
- MATH 307 Linear Algebra (3)
- MATH 350 Advanced Calculus I (3)

**Additional Requirements (21-23 units)**

Complete one of the following concentrations:

**Pure Mathematics Concentration (21 units)**

- MATH 302 Modern Algebra (3)
- MATH 414 Topology (3)
- MATH 450 Advanced Calculus II (3)

Plus four of the following – MATH 407, 412, 425, 430, 471

**Applied Mathematics Concentration (21 units)**

Select one of the following tracks:

*Modeling and Computational Applied Mathematics Track*

- MATH 306 Vector and Tensor Analysis (3)
- MATH 310 Ordinary Differential Equations (3)
- MATH 335 Mathematical Probability (3)
- MATH 340 Numerical Analysis (3)
- MATH 370 Mathematical Model Building (3)

Plus two of the following – MATH 406, 440, 470

*Classical Applied Mathematics Track*

- MATH 302 Modern Algebra (3)
- MATH 306 Vector and Tensor Analysis (3)
- MATH 310 Ordinary Differential Equations (3)
- MATH 406 Introduction to Partial Differential Equations (3)
- MATH 425 Differential Geometry (3)

Plus two of the following – MATH 412, 414, 450

**Probability and Statistics Concentration (23 units)**

- MATH 335 Mathematical Probability (3)
- MATH 338 Statistics Applied to Natural Sciences (4)
- MATH 435 Mathematical Statistics (3)
- MATH 436 Advanced Applied Statistics (4)
- MATH 438 Introduction to Stochastic Processes (3)

MATH 439 Intermediate Data Analysis (3)

Plus one of the following – MATH 340, 370, 390

**Teaching Mathematics Concentration (21-22 units)**

- MATH 302 Modern Algebra (3)
- MATH 335 Mathematical Probability (3)
- MATH 370 Mathematical Model Building (3)
  OR MATH 338 Statistics Applied to Natural Sciences (4)
  OR MATH 375 Discrete Dynamical Systems and Chaos (3)
- MATH 401 Algebra and Probability for the Secondary Teacher (3)
- MATH 402 Logic and Geometry for the Secondary Teacher (3)

Plus two of the following – MATH 407, 414, 417, 430, 471

**Cognates (9-11 units)**

Each student is required to complete one of the following cognates:

**Actuarial Cognate (9 units)**

- FIN 320 Business Finance (3) AND
  - Two of the following:
    - FIN 321 Theory of Corporate Finance (3)
    - FIN 340 Introduction to Investments (3)
    - FIN 360 Principles of Insurance (3)
  OR
  - Both of the following:
    - ISDS 361B Quantitative Business Analysis: Statistics and Management Science (3)
    - ISDS 440 Integrative Decision Tools for Business Operations (3)

**Computer Science Cognate (10 units)**

- CPSC 131 Data Structures Concepts (3)
- Any one of the CPSC 223 courses (3)
- CPSC 240 Computer Organization and Assembly Language (3)
  OR CPSC 332 File Structures and Database Systems (3)
- CPSC 253U Workshop in UNIX (1)

**Economics Cognate (9 units)**

- ECON 201 Principles of Microeconomics (3)
- ECON 202 Principles of Macroeconomics (3)

One of the following:

- ECON 310, 320, 440, 441

**Information Systems and Decision Sciences Cognate (9 units)**

Three from the following:

- ISDS 422, 465, 467, 472, 474, 475, 490

**Physics Cognate (11 units)**

- PHYS 225 Fundamental Physics: Mechanics (3)
- PHYS 225L Fundamental Physics: Laboratory (1)
- PHYS 226 Fundamental Physics: Electricity and Magnetism (3)
PHYS 226L  Fundamental Physics: Laboratory (1)
PHYS 227  Fundamental Physics: Waves, Optics and Modern Physics (3)

Chemistry Cognate (10 units)
CHEM 120A General Chemistry (5)
CHEM 120B General Chemistry (5)

Civil Engineering Cognate (9 units)
EGCE 201 Statics (3)
EGCE 301 Mechanics of Materials (3)
One of the following:
EGCE 302, 325

Mathematics Cognate (9 units)
Three upper-division courses in Mathematics from one of the four concentrations of the Mathematics major other than the student's own concentration.

Research Cognate (9 units)
MATH 491 Research Seminar (1)
MATH 497 Undergraduate Research (3,3)
MATH 498 Senior Thesis (2)

Computer Programming Requirement (3 units)
MATH 320 Introduction to Mathematical Computation
OR CPSC 120 Introduction to Programming
OR CPSC 121 Programming Concepts

Writing Requirement
MATH 380 will satisfy the university's upper-division writing requirement for mathematics majors.

INTERNSHIPS IN MATHEMATICS
Students should contact the Mathematics Department internship coordinator, MH-154.

MINOR IN MATHEMATICS (25 UNITS)
The mathematics minor must include MATH 150A,B, 250A,B and at least nine units of upper-division mathematics. MATH 303A,B, 380, 401, 402, 403A,B, 495, 496 or 499 may not be used to fulfill the requirements for the minor in mathematics. All courses must be completed with a "C" (2.0) or better.

MINOR IN MATHEMATICS FOR TEACHER EDUCATION (20-22 UNITS)
- For elementary education, the minor consists of 20 units of coursework offered by the Department of Mathematics. The courses must include MATH 150B or 338 and MATH 303A,B. All courses must be completed with a "C" (2.0) or better.
- For secondary education, the minor consists of 22 units of coursework offered by the Department of Mathematics. The courses must include MATH 250B and six units of upper-division courses in mathematics. All courses must be completed with a "C" (2.0) or better.

SINGLE SUBJECT TEACHING REQUIREMENT IN MATHEMATICS
The Department of Mathematics offers coursework meeting the requirements for the California Single Subject Credential in mathematics.

MASTER OF ARTS IN MATHEMATICS (30 UNITS)
The M.A. in Mathematics provides advanced study for students with one or more of the following interests: a Ph.D. program in mathematics or mathematics education, teaching in high school or community college, or using mathematical analysis in government, business or industry. The M.A. program includes a Teaching Option, Applied Mathematics Option and Special Topics Option.

Admission Requirements
Students must meet the CSU requirements for admission to a master’s degree program. Please consult the Graduate Admissions section in this catalog for complete information. In addition, applicants are admitted in conditionally classified standing with a grade-point average of 3.0 or better as undergraduate mathematics majors in all upper-division mathematics courses, or a combination of previous coursework and work experience approved as equivalent by the graduate committee of the Mathematics Department.

Classified Standing
A student’s status is changed to classified standing when the following requirements have been met:
- Completion of all prerequisites and/or deficiencies, including the University Writing Requirement
- Development of a study plan approved by the Mathematics Department and Academic Programs. The study plan should be developed prior to the completion of nine units

Teaching Option (30 units)
Designed for mathematics teachers, this option requires that at least 16 units must be 500-level mathematics courses. The following coursework must be included:
MATH 581 Studies in Geometry (3)
MATH 582 Studies in Algebra (3)
MATH 584 Studies in Analysis (3)
MATH 586 Studies in Discrete Mathematics (3)
MATH 587 Studies in Mathematical Problem Solving (3)
MATH 599 Independent Graduate Research (3-6)

Each student will be required to take adviser-approved mathematics electives to meet the 30-unit requirement, and pass a set of four comprehensive exams. Comprehensive exams may be taken no more than twice.
Applied Mathematics Option (30 units)
MA TH 489A,B Applicable Analysis and Linear Algebra (3,3)
MA TH 501A,B Numerical Analysis and Computation I and II (3,3)
MA TH 502A,B Probability and Statistics I and II (3,3)
MA TH 503A,B Mathematical Modeling I and II (3,3)
MA TH 597 Project (6)

Special Topics Option (30 units)
The Special Topics option requires a study plan approved by the graduate committee of the Mathematics Department. At least 16 units must be 500-level mathematics courses. Some of the 500-level courses may be accompanied by one unit of MA TH 599 Independent Graduate Research. Students will also be required to pass a set of comprehensive exams or complete a six-unit project.

MATHEMATICS COURSES
Courses are designated as MA TH in the class schedule.

030A Intermediate Algebra-ILE (3)
Prerequisite: A score of 30 or below on the ELM exam. For students who have taken but not passed the ELM exam. Equations and inequalities, algebraic expressions, functions, including polynomial functions. Degree credit is not awarded for these courses. Successful completion of MA TH 30A and 30B satisfies the ELM requirement.

030B Intermediate Algebra-ILE (3)
Prerequisite: MA TH 30A. For students who have taken but not passed the ELM exam. Continuation of MA TH 30A. Factoring, rational expressions and equations, exponents, radicals, quadratic functions and their graphs, logarithmic functions.

040 Intermediate Algebra (3)
Prerequisite: a score of 32-48 on the ELM exam. An intermediate algebra course designed specifically for students who have taken but not passed the ELM exam. Linear equations and inequalities, polynomial, rational and radical expressions, quadratic functions, exponential and logarithmic functions and sequences and series. Degree credit is not awarded for this course. Successful completion satisfies the ELM requirement.

045 Intermediate Algebra Minicourse (1)
Prerequisite: a score of 36-48 on the ELM exam. An intermediate algebra course designed specifically for students who have taken but not passed the ELM exam. Linear equations, polynomials, rational expressions, radical expressions, quadratic formulas, exponential functions and logarithmic functions. Degree credit is not awarded for this course. Successful completion satisfies the ELM requirement. Offered online only.

110 Mathematics for Liberal Arts Students (3)
Prerequisites: passing score on the ELM exam or exemption, and three years of high school mathematics, including two years of algebra and one year of geometry. Survey of traditional and contemporary topics in mathematics, such as elementary logic, counting techniques, probability, statistics and the mathematics of the social sciences. For non-science majors.

115 College Algebra (4)
Prerequisites: passing score on the ELM exam or exemption, and three years of high school mathematics, including two years of algebra and one year of geometry. For students planning to take MA TH 130 or 135. Equations, inequalities and systems of equations. Properties of functions and their graphs, including polynomial functions, rational functions, exponential and logarithmic functions, with applications. Sequences and series. If a student takes MA TH 115 and 125 and receives a “C” (2.0) or better in both courses, the second course receives credit. If the student receives a “C” (2.0) or better in one of the courses, credit is given for that course.

115W College Algebra Workshop (1)
Corequisite: MA TH 115. Supplementary problem-solving workshop in a collegial setting.

120 Introduction to Probability and Statistics (3)
Prerequisites: passing score on the ELM exam or exemption, and three years of high school mathematics, including two years of algebra and one year of geometry. Set algebra, finite probability models, sampling, binomial trials, conditional probability and expectation. Recommended for students of economics, business, and biological, geological and social sciences.

125 Precalculus (5)
Prerequisites: passing score on the ELM exam or exemption, and three years of high school mathematics, including two years of algebra and one year of geometry. For students planning to take MA TH 150A. Functions and their use in mathematical models, including linear functions, polynomial and rational functions, exponential and logarithmic functions and trigonometric functions. If a student takes MA TH 115 and 125 and receives a “C” (2.0) or better in both courses, the second course receives credit. If the student receives a “C” (2.0) or better in one of the courses, credit is given for that course.

125W Precalculus Workshop (1)
Corequisites: MA TH 125 and consent of instructor. Supplementary problem-solving workshop in a collegial setting.
130 A Short Course in Calculus (4)
Prerequisites: three years of high school mathematics, including two years of algebra and one year of geometry; a passing score on the ELM exam or exemption; and a passing score on the MQE or exemption. MATH 115 or MATH 125 (with a "C" (2.0) or better) is an MQE exemption. Survey of differential and integral calculus and applications. For students of biological and social sciences, business and economics. If a student takes MATH 130 and 135 and receives a “C” (2.0) or better in both courses, the second course receives credit. If the student receives a “C” (2.0) or better in one of the courses, credit is given for that course.

130W A Short Course in Calculus Workshop (1)
Corequisite: MATH 130. Supplementary problem-solving workshop in a collegial setting.

135 Business Calculus (3)
Prerequisites: three years of high school mathematics, including two years of algebra and one year of geometry; a passing score on the ELM exam or exemption; and a passing score on the MQE or exemption. MATH 115 or MATH 125 (with a “C” (2.0) or better) is an MQE exemption. Survey of differential and integral calculus with applications, including derivatives, integrals and max-min problems. For students of business and economics. If a student takes MATH 130 and 135 and receives a “C” (2.0) or better in both courses, the second course receives credit. If the student receives a “C” (2.0) or better in one of the courses, credit is given for that course. One or more sections offered online.

135W Business Calculus Workshop (1)
Corequisite: MATH 135. Supplementary problem-solving workshop in a collegial setting.

150A Calculus I (4)
Prerequisites: four years of high school mathematics, including geometry, two years of algebra and trigonometry; passing score on the ELM exam or exemption; passing score on the MQE or exemption. MATH 125 with a ”C” (2.0) or better is an MQE exemption. Properties of functions. The limit, derivative and definite integral concepts; applications of the derivative, and applications of integration. Six units of credit are given for both MATH 150A and MATH 130 or for both MATH 150A and MATH 135.

150B Calculus II (4)
Prerequisite: MATH 150A or equivalent. Techniques of integration, improper integrals and applications of integration. Introduction to differential equations. Parametric equations; sequences and series.

151A Calculus I Workshop (1)
Corequisites: MATH 150A and consent of instructor. Supplementary problem-solving in a collegial setting.

151B Calculus II Workshop (1)
Corequisites: MATH 150B and consent of instructor. Supplementary problem-solving in a collegial setting.

196 Student-to-Student Tutorials (1-3)
Consult “Student-to-Student Tutorials” in this catalog for more complete course description. May be taken Credit/No Credit only.

250A Calculus III (4)
Prerequisites: MATH 150A,B or equivalent. Calculus of functions of several variables. Partial derivatives and multiple integrals with applications. Parametric curves, vector-valued functions, vector fields, line integrals, Green’s Theorem, Stokes’ Theorem, Divergence Theorem, geometry of 3-space and vectors.

250B Introduction to Linear Algebra and Differential Equations (4)
Prerequisite: MATH 250A. Introduction to the solutions of ordinary differential equations and their relationship to linear algebra. Topics include matrix algebra, systems of linear equations, vector spaces, linear independence, linear transformations and eigenvalues.

270A Mathematical Structures I (3)
Prerequisites: four years of high school mathematics. First of two semesters of fundamental discrete mathematical concepts and techniques needed in computer-related disciplines. Logic, truth tables, elementary set theory, proof techniques, combinatorics and Boolean algebra.

270B Mathematical Structures II (3)
Prerequisite: MATH 270A. Second of two semesters of fundamental discrete mathematical concepts and techniques needed in computer-related disciplines. Graph theory, algebraic structures and linear algebra.

280 Strategies of Proof (3)
Prerequisite: MATH 250B. Logic, set theory and methods for constructing proofs of mathematical statements. A bridge to the rigor of upper-division mathematics courses containing significant abstract content.

302 Modern Algebra (3)
Prerequisites: MATH 250B, 280. Integers, rational numbers, real and complex numbers, polynomial domains, introduction to groups, rings, integral domains and fields.

303A Fundamental Concepts of Elementary Mathematics (3)
Prerequisite: completion of General Education (G.E.) Category B.4. Structure and form of the mathematics that constitutes the core of the K-8 mathematics curriculum, including number sense, number theory and problem solving.
303B Fundamental Concepts of Elementary Mathematics (3)
Prerequisites: completion of G.E. Category B.4 and a "C" (2.0) or better in MATH 303A. Structure and form of the mathematics that constitutes the core of the K-8 mathematics curriculum, including the real number system, geometry, probability and statistics, and problem solving.

306 Vector and Tensor Analysis (3)
Prerequisite: MATH 250B. Vector analysis, including coordinate bases, gradient, divergence and curl, Green’s, Gauss’ and Stokes’ theorems. Tensor analysis, including the metric tensor, Christoffel symbols and Riemann curvature tensor. Applications will be drawn from differential geometry, continuum mechanics, electromagnetism, general relativity theory.

307 Linear Algebra (3)

310 Ordinary Differential Equations (3)

320 Introduction to Mathematical Computation (3)

335 Mathematical Probability (3)
Prerequisite: MATH 250A. Probability theory; discrete, continuous and multivariate probability distributions, independence, conditional probability distribution, expectation, moment generating functions, functions of random variables and the central limit theorem.

337 Introduction to Experimental Design and Statistics in the Laboratory Sciences (3)
Prerequisites: passing score on the ELM exam or exemption; completion of one of the following: BIOL 241, 261; CHEM 120; or PHYS 211, 225. Graphical and numerical descriptive statistics; experimental design, randomization, replication, block designs, stratified samples, controlled experiments versus observational studies. Fundamental inference for proportions, means, variances. Analysis of variance, regression. Computer analysis of data from the laboratory sciences, e.g., biology, chemistry, geology.

338 Statistics Applied to Natural Sciences (4)
Prerequisite: MATH 130 or 150B or consent of instructor. Introduction to the theory and application of statistics. Elementary probability, estimation, hypothesis testing, regression, analysis of variance, non-parametric tests. Computer-aided analysis of real data. Graphical techniques, generating and interpreting statistical output, presentation of analysis (3 hours lecture, 2 hours activity).

340 Numerical Analysis (3)
Prerequisites: MATH 250B, and MATH 320, CPSC 120, 121 or equivalent. Approximate numerical solutions of systems of linear and nonlinear equations, interpolation theory, numerical differentiation and integration, numerical solution of ordinary differential equations. Computer coding of numerical methods.

350 Advanced Calculus I (3)
Prerequisites: MATH 250B, 280. Development of the theoretical foundations of calculus with an emphasis on mathematical rigor and formal proof. Algebraic and topological properties of the real numbers; limits of sequences and functions; continuity, differentiation and integration of functions of one variable; infinite series.

368 First Course in Symbolic Logic (3)
(Same as PHIL 368)

370 Mathematical Model Building (3)
Prerequisites: MATH 250B or consent of instructor, and MATH 320, CPSC 120, 121 or equivalent. Introduction to mathematical models in science and engineering; dimensional analysis, discrete and continuous dynamical systems, flow and diffusion models.

375 Discrete Dynamical Systems and Chaos (3)
Prerequisite: MATH 250B or consent of instructor. Analysis of the evolution of linear and nonlinear deterministic discrete systems with emphasis on long range behavior, stability and instability of stationary states and periodic orbits, chaotic orbits, strange attractors, fractional dimension and Lyapunov exponents; examples from current research literature.

380 History of Mathematics (3)
Prerequisite: MATH 250B. History of mathematics through its methods and concepts. Helps students become proficient in writing and reading mathematical literature. Satisfies the upper-division writing requirement for mathematics majors.

390 Introduction to Actuarial Science (3)
Prerequisite: MATH 150B. Corequisite: MATH 335, 338 or ISDS 361A. Fundamentals of actuarial science, including risk theory, interest theory, rate making, loss reserve and actuarial modeling. Selective corporate finance, investment and insurance topics, such as amortization, bonds, sinking funds, securities, annuities and pensions.
401 Algebra and Probability for the Secondary Teacher (3)
Prerequisites: 12 units of upper-division mathematics exclusive of MATH 303A,B and MATH 403A,B. Mathematical topics relevant to the teacher of secondary mathematics. Problem-solving approach to different areas, including algebra, number theory, combinatorics and probability, while maintaining an historical perspective.

402 Logic and Geometry for the Secondary Teacher (3)
Prerequisites: 12 units of upper-division mathematics exclusive of MATH 303A,B and MATH 403A,B. Parallel to MATH 401, but emphasizing Euclidean geometry, logic and problem solving from an historical perspective.

403A Fundamental Concepts of Middle School Mathematics I (3)
Prerequisite: MATH 303B. Content background in mathematics to help satisfy credentialing requirements for teaching mathematics at the middle school level. Focuses on gaining a thorough understanding of algebra, including patterns, functions and the use of technology.

403B Fundamental Concepts of Middle School Mathematics II (3)
Prerequisite: MATH 403A. Content background in mathematics to help satisfy credentialing requirements for teaching mathematics at the middle school level. Focuses on gaining a thorough understanding of advanced algebra, geometry, probability and statistics and the use of technology.

406 Introduction to Partial Differential Equations (3)

407 Abstract Algebra (3)
Prerequisite: MATH 302. Sets, mappings, groups, rings, modules, fields, homomorphisms, advanced topics in vector spaces and theory of linear transformations, matrices, algebras, ideals, field theory, Galois Theory.

412 Complex Analysis (3)
Prerequisite: MATH 350. Complex differentiation and integration, Cauchy's theorem and integral formulas, maximum modulus theorem, harmonic functions, Laurent series, analytic continuation, entire and meromorphic functions, conformal transformations and special functions.

414 Topology (3)
Prerequisite: MATH 350. Topological spaces and continuous functions, connectedness and compactness, metric spaces and function spaces.

417 Foundations of Geometry (3)
Prerequisite: MATH 307. Foundations of Euclidean and non-Euclidean geometries through transformations and formal axiomatics.

425 Differential Geometry (3)
Prerequisite: MATH 307. Differential geometry of curves and surfaces. Frenet-Serret formulas, Gauss-Weingarten equations, Gauss-Bonnet theorem.

430 Number Theory (3)
Prerequisite: MATH 302. Basic concepts of classical number theory with modern applications. Divisibility, congruences. Diophantine approximations and equations, primitive roots, continued fractions. Applications to public key cryptography, primality testing, factoring methods and check digits.

435 Mathematical Statistics (3)
Prerequisite: MATH 335. Statistical theory and its applications, based on the use of calculus.

436 Advanced Applied Statistics (4)
( Same as BIOL 436)

438 Introduction to Stochastic Processes (3)
Prerequisite: MATH 335. Stochastic processes, including Markov chains, Poisson Process, Wiener Process. Applications to birth and death processes and queuing theory.

439 Intermediate Data Analysis (3)
Prerequisites: MATH 250B or 270B, and 338. Simple and multiple linear regression, testing hypotheses, dummy variables, ANOVA, ANCOVA, confounding and interaction, diagnostics, influence and outliers, transformation and weighting and model selection. Introductory nonlinear and logistic regression. SAS statistical software will be used.

440 Advanced Numerical Analysis (3)
Prerequisite: MATH 340. Advanced topics in numerical analysis selected from iterative methods for linear systems, approximation of eigenvalues and eigenvectors, numerical methods for ordinary and partial differential equations, optimization methods and approximation theory. Error and convergence analysis and computer coding.

450 Advanced Calculus II (3)
Prerequisite: MATH 350. Sequences and series of functions. Continuity, differentiation and integration of functions of several variables. Advanced topics in analysis, such as Lebesgue integration or the theory of metric spaces.
470 Advanced Mathematical Model Building (3)
Prerequisites: MATH 307, 335, 370. A capstone course for students with strong mathematical preparation. Topics may include stochastic models, Monte Carlo integration, simulation of discrete event systems, simulation software and further studies in dynamic systems and flow and diffusion models.

471 Combinatorics (3)
Prerequisite: MATH 302 or 307. Analysis of discrete structures, including existence, enumeration and optimization. Permutations and combinations, combinatorial identities, the inclusion-exclusion principle, recurrence relations, Polya counting. Basic definitions and properties of graphs, Eulerian and Hamiltonian graphs, trees, graph colorings and chromatic number, planar graphs.

480M MARC Proseminar (1)
(Same as BIOL 480M)

489A Applicable Linear Algebra (3)
Prerequisites: linear algebra, advanced calculus and consent of instructor. Corequisite: MATH 489B. Topics from linear algebra useful in graduate studies in applied mathematics. Finite and infinite dimensional vector spaces, linear transformations and matrices. Introduction to Hilbert spaces. Projection theorem and some of its applications.

489B Applicable Analysis (3)
Prerequisites: undergraduate calculus, linear algebra, advanced calculus and consent of instructor. Corequisite: MATH 489A. Topics from analysis useful in graduate studies in applied mathematics. Topics may include initial and boundary value problems, including series solutions, eigenvalues and eigenfunctions, Fourier analysis, generalized functions, an introduction to the calculus of variations, and transform methods.

491 Research Seminar (1)
Prerequisite: consent of instructor. Corequisite: MATH 497 or 498. Students are required to attend the weekly undergraduate research seminars and give at least one seminar presentation as determined by the faculty adviser. May be repeated for credit.

495 Internship in Applied Mathematics (1-3)
Prerequisites: 15 units of upper-division mathematics and consent of instructor. Work experience in advanced mathematics through positions in business, industry or government.

496 Student-to-Student Tutorials (1-3)
Consult “Student-to-Student Tutorials” in this catalog for more complete course description. May be taken Credit/No Credit only.

497 Undergraduate Research (1-3)
Prerequisites: nine units of upper-division math and consent of instructor. Methods of research in the mathematical sciences through a research project supervised by a departmental faculty. May be repeated for up to 6 units towards major.

498 Senior Thesis (2)
Prerequisites: six units MATH 497 (up to 2 units concurrently) and consent of instructor. Preparation, presentation and defense of thesis. Topic approved by the undergraduate research committee. Thesis formatted in accordance with journal in field. May not be repeated for credit.

499 Independent Study (1-3)
Prerequisite: consent of instructor. Special topic in mathematics, selected in consultation with and completed under supervision of instructor.

501A Numerical Analysis and Computation I (3)

501B Numerical Analysis and Computation II (3)

502A Probability and Statistics I (3)
Prerequisites: MATH 335, 489A,B. Corequisite: MATH 502B. Theory and applications of probability models including univariate and multivariate distributions; expectations and transformations of random variables. Must be taken prior to or concurrently with MATH 502B.

502B Probability and Statistics II (3)
Prerequisites: MATH 335, 489A,B. Corequisite: MATH 502A. Theory and applications of sampling theory, statistical estimation and hypothesis testing. Must be taken after or concurrently with MATH 502A.

503A Mathematical Modeling I (3)
Prerequisites: MATH 489A,B, 501A,B. Mathematical modeling concepts. Topics may include: dimensional analysis, scaling and sensitivity; system concepts, state space, observability, controllability and feedback; dynamical systems, models and stability analysis; optimization models.

503B Mathematical Modeling II (3)
Prerequisite: MATH 503A. Development and analysis of mathematical models in such areas as mechanics, economic planning, operations management, environmental and ecological sciences, biology and medicine.
504A Simulation Modeling and Analysis (3)
Prerequisites: MATH 501A, B, 502A, B, 503A, B. Advanced techniques of simulation modeling, including the design of Monte Carlo, discrete event and continuous simulations. Topics may include output data analysis, comparing alternative system configurations, variance-reduction techniques and experimental design and optimization.

504B Applications of Simulation Modeling Techniques (3)
Prerequisites: MATH 501A, B; 502A, B; 503A, B. Corequisite: MATH 504A. Introduction to a modern simulation language and its application to simulation modeling. Topics will include development of computer models to demonstrate the techniques of simulation modeling, model verification, model validation and methods of error analysis.

534 Statistical Computing (3)
Prerequisites: MATH 502AB, 320, 307 or equivalent. Numerical methods in linear and nonlinear regression, including Gauss-Jordan, QR and Gauss-Newton algorithms. Maximum likelihood computation, including Newton, Fisher-scoring, quasi-Newton and EM algorithms. Bayesian computations, including numerical integration, Monte-Carlo integration, and Markov chain Monte Carlo. Nonparametric inference, including Bootstrap.

558 Bayesian Statistics (3)
Prerequisites: MATH 502AB, 534. Fundamentals of Bayesian inference, including informative and noninformative priors for single and multiparameter models, Bayesian asymptotics, hierarchical models, Metropolis Hastings and Gibbs sampler algorithms, model checking, Bayesian design of experiments, Bayesian linear models and generalized linear models, and neural networks.

539 Statistical Consulting (3)
Prerequisites: MATH 502AB, or equivalent. Ethics, communication aspects of consulting with clients, formulating statistical problems, recommendations of design protocols, selecting appropriate statistical methods, data analysis and interpreting results, including writing proper reports. Course will be based on case studies.

581 Studies in Geometry (3)
Prerequisites: MATH 307, graduate standing. Topics relating to the high school curriculum from an advanced standpoint, including the axiomatic method and non-Euclidean geometry.

582 Studies in Algebra (3)
Prerequisites: MATH 302, graduate standing. Topics relating to the high school curriculum from an advanced standpoint, including algorithms, fields and polynomials.

583 Studies in Statistics (3)
Prerequisites: MATH 338, graduate standing. Calculus-based course designed to teach appropriate strategies and tools to effectively address problems in statistics. Includes project design, exploratory data analysis and interpretation, and effective communication of results.

584 Studies in Analysis (3)
Prerequisites: MATH 350, graduate standing. Topics relating to the high school curriculum from an advanced standpoint, including limits, continuity, differentiation and integration.

586 Studies in Discrete Mathematics (3)
Prerequisites: MATH 335, graduate standing. Topics relating to the high school curriculum from an advanced standpoint, including induction, recursion, probability and combinatorics.

587 Studies in Mathematical Problem Solving (3)
Prerequisites: MATH 302, graduate standing. Problem solving via non-routine and enrichment-type problems from several different branches of mathematics.

597 Project (3-6)
Prerequisite: consent of instructor. May be repeated for credit. Students in the Applied Master's Program earn a total of 6 units.

599 Independent Graduate Research (1-3)
Prerequisites: graduate standing and consent of instructor. Normally taken in conjunction with required graduate courses. Also offered without being attached to any course. May be repeated for credit.
MATHEMATICS EDUCATION COURSES

Courses are designated as MAED in the class schedule

442 Teaching Mathematics in Secondary School (3)
Prerequisite: admission to Teacher Education Program in Mathematics. Corequisite: EDSC 440E. Research, standards, objectives, technology and methods for teaching mathematics. Required of mathematics majors for the general single subject credential. (2 hours lecture, 2 hours activity)

449E First Semester Student Teaching (3)
(Same as EDSC 449E)

449I Second Semester Student Teaching (10)
(Same as EDSC 449I)

449S Seminar in Secondary Teaching (3)
(Same as EDSC 449S)

499 Independent Study (1-3)
Prerequisite: consent of instructor. Special topic in mathematics education, selected in consultation with and completed under supervision of the instructor. May be repeated for credit.

532 Teaching Problem Solving in Middle School Mathematics (3)
Prerequisite: MATH 403B. Seminar to explore techniques of problem solving for mathematics teachers of grades 5-9. Review of research on problem solving at the middle school level. Review of state and national documents on middle school mathematics education. Emphasis on problem solving in algebra, geometry and probability.

542 Teaching Mathematics at the College Level (3)
Prerequisites: full-time graduate standing. Strengthens students' effectiveness in teaching mathematics at the college level. Strategies that promote student engagement, collaboration, retention and success, as well as appropriate use of technologies.