# **MATHEMATICS (MAT)**

## MAT 105 Exploring Mathematics 3

Introduction to modern mathematics through accessible tours of various topics, how they impact the real world, and how they are applied in a wide range of career paths. Example topics include fractals, data visualization, knot theory, and network science. Utilizing campus resources will also be covered.

## MAC: MAC Foundations

**Prerequisites:** Must have fewer than 60 credits to enroll or can enroll by Written Permission.

## MAT 110 Foundations of Calculus with Business Applications 3

Foundational concepts that supplement topics covered in Calculus with Business Applications.

Corequisites: MAT 120.

Notes: Grade: Pass/Not Pass (P/NP).

## MAT 112 Contemporary Topics in Mathematics 3

Introductory topics in mathematics, including set theory and reasoning in mathematical systems. Contemporary applications may include algorithms, consumer mathematics, cryptography, and geometry. **MAC:** MAC Quantitative Reasoning

Notes: Students may not receive credit for both MAT 112 and RCO 112.

## MAT 115 College Algebra 3

Algebraic expressions, exponents, radicals, factoring, solving equations and inequalities, graphing, polynomial and rational functions. **MAC:** MAC Quantitative Reasoning

**Notes:** Students who have prior credit for RCO 115 may not take MAT 115 for credit.

## MAT 118 Algebra with Business Applications 3

Introductory survey of algebra with emphasis on techniques and applications related to business and the social sciences. **MAC:** MAC Quantitative Reasoning

## MAT 120 Calculus with Business Applications 3

Introductory survey of differential calculus with emphasis on techniques and applications related to business and the social sciences. This course does not serve as a prerequisite for MAT 292 (Calculus II). This is a terminal course and not adequate preparation for MAT 292.

MAC: MAC Quantitative Reasoning

**Prerequisites:** An acceptable score on the MAT 120 placement test. a grade of C or better in one of MAT 115, MAT 118, MAT 150, MAT 151, MAT 183 or MAT 190; a Pass in MAT 110 or concurrent registration in MAT 110; or a score of 2 or better on the AP Calculus AB or BC exam.

## MAT 150 Precalculus I 3

Review of elementary algebra, equations, inequalities, relations, functions, transformations, graphing, complex numbers, polynomial and rational functions.

MAC: MAC Quantitative Reasoning

Notes: Credit can be earned for only one of MAT 115 or MAT 150.

# MAT 151 Precalculus II 3

Properties, graphs, and applications of exponential, logarithmic, trigonometric functions.

MAC: MAC Quantitative Reasoning

**Prerequisites:** An acceptable score on the mathematics placement test. or a grade of C or better in MAT 115 or MAT 150.

## MAT 181 Foundations of Calculus 3

Foundational concepts that supplement topics covered in Calculus I or Calculus A.

Corequisites: MAT 191 or MAT 196. Notes: Grade: Pass/Not Pass (P/NP).

## MAT 183 Mathematics for the Life Sciences 4

Functions and sets, descriptive statistics, probability, population genetics, matrices, discrete time modeling, and use of computational tools and visualization of data. MAC: MAC Quantitative Reasoning Corequisites: MAT 183L.

## MAT 183L Mathematics for Life Sciences Lab 0

Laboratory supporting MAT 183.

Corequisites: MAT 183.

**Notes:** No grade is awarded with this course number. Grades are awarded with the lecture course.

## MAT 184 Calculus for the Life Sciences 4

Limits and precision, change in quantities, derivatives, integration, concentration gradients, and modeling processes with differential equations.

**Prerequisites:** A grade of C or better in MAT 183 or MAT 190. **Corequisites:** MAT 184L.

## MAT 184L Calculus for the Life Sciences Lab 0

Laboratory supporting MAT 184.

Corequisites: MAT 184.

**Notes:** No grade is awarded with this course number. Grades are awarded with the lecture course.

## MAT 190 Precalculus 4

This course covers essential prerequisites for calculus. Topics include functions and graphs, equations and inequalities, polynomial and rational functions, trigonometry, functions of trigonometric, exponential, and logarithmic type.

MAC: MAC Quantitative Reasoning

**Prerequisites:** Acceptable score on the Calculus Readiness Diagnostic Test.

#### MAT 191 Calculus I 3

Limits and introductory differential calculus of the algebraic and transcendental functions of one variable.

MAC: MAC Quantitative Reasoning

**Prerequisites:** An acceptable score on the mathematics placement test or a grade of C or better in MAT 151 or MAT 190 or a Pass in MAT 181, or concurrent registration in MAT 181.

#### MAT 196 Calculus A 4

Limits, differential calculus, and introductory integral calculus of algebraic and transcendental functions of one variable. MAC: MAC Quantitative Reasoning

**Prerequisites:** An acceptable score on the Calculus Readiness Diagnostic Test. or a grade of C or better in one of MAT 120, MAT 151, MAT 184, or MAT 190; or a Pass in MAT 181; or concurrent registration in MAT 181; or a score of 2 or better in the AP Calculus AB or BC exam.

## MAT 220 Plane and Solid Analytic Geometry 3

Study of conic sections (including rotation of axes), graphing with polar coordinates, quadric surfaces, and vectors.

**Prerequisites:** Grade of C or better in MAT 151 (or equivalent). **Notes:** Hours do not count toward degree requirements for MATH major.

# MAT 253 Discrete Mathematical Structures 3

A rigorous introduction to discrete mathematical structures, proof techniques, and programming. Topics include sets, functions, sequences, relations, induction, propositional and predicate logic, modular arithmetic, and mathematical programming.

MAC: MAC Quantitative Reasoning

**Notes:** Only one of MAT 253 or MAT 295 can count toward degree requirements for MATH major.

#### MAT 292 Calculus II 3

Introductory integral calculus of the algebraic and transcendental functions of one variable, techniques of integration. **MAC:** MAC Quantitative Reasoning **Prerequisites:** Grade of C or better in MAT 191.

## MAT 293 Calculus III 3

Infinite sequences and series, conic sections, polar coordinates, vectors in dimensions two and three, vector-valued functions. **Prerequisites:** Grade of C or better in MAT 292.

## MAT 296 Calculus B 4

Integral calculus of algebraic and transcendental functions of one variable, techniques of integration, applications of integration, infinite sequences and series, conic sections, and calculus in polar coordinates. **MAC**: MAC Quantitative Reasoning

**Prerequisites:** Grade of C or better in MAT 196 or a passing grade in MAT 292.

## MAT 310 Elementary Linear Algebra 3

Linear systems, matrices, determinants, eigenvalues and eigenvectors, finite-dimensional vector spaces, linear transformations. **Prerequisites:** Grade of C or better in MAT 196 or MAT 253 or MAT 292.

## MAT 311 Introduction to Abstract Algebra 3

Sets and mappings, equivalence relations, mathematical induction, introduction to theory of groups, rings, and fields. **Prerequisites:** Grade of C or better in MAT 253 and MAT 310.

#### MAT 313 Historical Development of Mathematics 3

Study of the historical development of mathematics, not a history of persons involved in development.

CIC: CIC College Writing

Prerequisites: Grade of C or better in MAT 292 or MAT 296.

## MAT 320 Introduction to Topology 3

Metric spaces, continuity, equivalence of various types of definitions of continuity, convergence, compactness, connectedness, topological spaces.

**Prerequisites:** Grade C or better in MAT 293 or MAT 296 and grade C or better in MAT 253 or MAT 310 or CSC 250.

#### MAT 322 Linear Programming 3

Covers simplex computational procedure, minimum feasible solutions, artificial-basis technique, slack variables, perturbation techniques, cycling, parametric objective and dual problems, sensitivity analysis, and decomposition algorithms.

Prerequisites: Grade of C or better in MAT 310.

#### MAT 330 Axiomatic Foundations of Geometry 3

Axiomatic systems, logic and proof, incidence geometries, absolute geometries, Euclidean geometry, and an introduction to non-Euclidean geometries and transformational geometry.

Prerequisites: Grade C or better in MAT 196 or MAT 253 or MAT 292.

## MAT 349 Preparation for Industrial Careers in Mathematical Sciences 3

This course prepares mathematical sciences students for industrial careers by engaging them in research problems that come directly from industry.

Prerequisites: Permission of instructor.

## MAT 353 Introduction to Discrete Mathematics 3

Elementary graph theory, combinatorics, partially ordered sets. **Prerequisites:** Grade of C or better in MAT 253 or CSC 250.

## MAT 390 Ordinary Differential Equations 3

First order differential equations and linear equations of finite order, Laplace transforms, undetermined coefficients, variation of parameters, applications, numerical methods.

Prerequisites: Grade of C or better in MAT 292 or MAT 296.

## MAT 394 Calculus IV 3

Multivariable functions, partial differentiation, multiple integrals, vector calculus.

Prerequisites: Grade of C or better in MAT 293.

# MAT 395 Introduction to Mathematical Analysis 3

Properties of real numbers, sequences, limits of sequences and functions, continuity, differentiation, Riemann integral. **Prerequisites:** Grade C or better in MAT 293 or MAT 296 and a grade C or better in MAT 253 and MAT 310.

## MAT 396 Calculus C 4

Vectors in dimensions two and three, vector-valued functions, partial differentiation, multiple integrals, vector calculus. **Prerequisites:** Grade of C or better in MAT 293 or MAT 296.

#### MAT 399 Internship 3-6

Supervised pre-approved work experience in which students apply mathematics and statistics to solve real world problems. Students discuss progress and experiences with peers in regular meetings with the instructor.

**Prerequisites:** Internship proposal approved by the Department of Mathematics and Statistics.

Notes: May be repeated for up to a total of six (6) credits.

# MAT 405 Foundations of Mathematics for Teaching I 3

Capstone survey of topics including functions; calculus concepts; geometry; probability; data analysis; and discrete mathematics. Special teaching problems and procedures for secondary education topics in relation to their mathematical foundations.

**Prerequisites:** Grade of C (2.0) or better in MAT 310. Admission to Teacher Education Program or permission of instructor.

## MAT 406 Foundations of Mathematics for Teaching II 4

Capstone survey of topics including functions; calculus concepts; geometry; probability; data analysis; and discrete mathematics. Special teaching problems and procedures for secondary education topics related to their mathematical foundations, including 50-hour internship in secondary math classroom.

**Prerequisites:** Minimum grade of C (2.0) in MAT 405 and minimum grade of C (2.0) in one of either MAT 311 or MAT 395. Admission to the Teacher Education Program.

## MAT 414 Theory of Numbers 3

An introductory course to both multiplicative and additive number theory. Divisibility, prime numbers, congruencies, linear and nonlinear Diophantine equations (including Pell's equation), quadratic residues, number-theoretic functions, and other topics.

Prerequisites: Grade of C or better in either MAT 311 or MAT 395.

## MAT 415 Mathematical Logic 3

Formal languages, recursion, compactness, and effectiveness. First-order languages, truth, and models. Soundness and completeness theorems. Models of theories.

Prerequisites: Grade of C or better in MAT 311 (or MAT 353).

## MAT 416 Intermediate Abstract Algebra 3

Rings, integral domains, fields, division algorithm, factorization theorems, zeros of polynomials, greatest common divisor, formal derivatives, prime polynomials, Euclidean domains, the fundamental theorem of algebra. **Prerequisites:** Grade of C or better in MAT 311.

## MAT 417 Theory of Groups 3

Elementary properties of groups and homomorphisms, quotients and products of groups, the Sylow theorems, structure theory for finitely generated abelian groups.

## MAT 419 Intuitive Concepts in Topology 3

Basic concepts, vector fields, the Jordan curve theorem, surfaces, homology of complexes, continuity.

Prerequisites: Grade of C or better in MAT 311 (or MAT 395).

# MAT 420 Non-Euclidean Geometry 3

Fifth postulate, hyperbolic geometries, elliptic geometries, consistency of non-Euclidean geometries, models for geometries, elements of inversion. **Prerequisites:** Grade of C or better in MAT 311 (or MAT 395).

## MAT 421 Projective Geometry 3

Transformation groups and projective, affine and metric geometries of the line, plane, and space. Homogeneous coordinates, principles of duality, involutions, cross-ratio, collineations, fixed points, conics, models, and Euclidean specializations.

Prerequisites: Permission of instructor.

#### MAT 422 Introductory Functional Analysis 3

Basic concepts in Banach spaces, Hilbert spaces, linear operators, and their applications.

Prerequisites: Grade of C or better in MAT 395.

## MAT 425 Intermediate Mathematical Analysis 3

Integration, infinite series, sequences and series of functions. **Prerequisites:** Grade of C or better in MAT 395.

# MAT 427 Numerical Methods 3

Number systems and errors, solutions of non-linear and linear systems, interpolation, numerical differentiation and integration, solution of differential equations. Implementation of numerical methods using a high-level programming language.

Prerequisites: A grade of at least C in MAT 293 or MAT 296.

## MAT 428 Linear Programming and Optimization 3

This course is an introduction to linear programming and optimization including: the simplex method, degeneracy, efficiency, duality theory, convex analysis, game theory, financial applications, network flow problems, integer programming, quadratic programming. **Prerequisites:** Grade C or better in MAT 310.

# MAT 430 Computational Discrete Mathematics 3

Exact computations with mathematical structures. Topics include complexity analysis, multi precision arithmetic, matrix normal forms, graphs and networks, and fast Fourier transforms. **Prerequisites:** MAT 253 and MAT 310.

## MAT 431 Combinatorial Analysis 3

he pigeon-hole principle, permutations, combinations, generating functions, principle of inclusion and exclusion, distributions, partitions, recurrence relations.

**Prerequisites:** Grade of C or better in MAT 253 (or MAT 295 or MAT 311 or MAT 395). or permission of instructor.

#### MAT 432 Introductory Graph Theory 3

Basic concepts, graph coloring, trees, planar graphs, networks. **Prerequisites:** Grade of C or better in MAT 310 and any one of the courses MAT 253, MAT 295, MAT 311, MAT 395, MAT 431.

## MAT 435 Differential Equations and Orthogonal Systems 3

An introduction to Fourier series and orthogonal sets of functions, with applications to boundary value problems.

**Prerequisites:** Grade of C or better in MAT 293 or MAT 296 and grade C or better in MAT 390.

## MAT 436 Partial Differential Equations with Applications 3

Fourier integrals, Bessel functions, Legendre polynomials and their applications. Existence and uniqueness of solutions to boundary value problems.

Prerequisites: Grade of C or better in MAT 435.

## MAT 439 Topics in Applied Mathematics 3

Selected topics of current interest in applied mathematics. **Prerequisites:** Grade C or better in MAT 293 or MAT 296 and grade C or

better in MAT 390. **Notes:** May be repeated for credit with approval of the Department Head.

## MAT 440 Introductory Complex Analysis 3

The complex number system, holomorphic functions, power series, complex integration, representation theorems, the calculus of residues. **Prerequisites:** Grade of C or better in MAT 394 or MAT 396.

#### MAT 441 Stochastic Processes 3

Markov processes, Markov reward processes, queuing, decision making, graphs, and networks. Applications to performance, reliability, and availability modeling.

**Prerequisites:** Grade of C or better in MAT 394 and MAT 353. or equivalents.

#### MAT 442 Stochastic Processes 3

Markov processes, Markov reward processes, queuing, decision making, graphs, and networks. Applications to performance, reliability, and availability modeling.

**Prerequisites:** Grade of C or better in MAT 394 and MAT 353. or equivalents.

## MAT 451 Topological Data Analysis 3

This course covers persistent homology and topological data analysis. Topics include persistence modules, bar codes, stability, and the use of statistics and machine learning in topological data analysis. **Prerequisites:** C or better in MAT 310 and also a C or better in MAT 311 or CSC 350 or STA 301, or permission of instructor.

#### MAT 453 Foundations of Mathematical Data Science 3

This course is for students to build up a solid mathematical foundation in order to thrive in the rapidly growing field of data science. Students will learn essential mathematical topics in data science, including linear algebra, matrix decomposition, probability, stochastic process, analysis, optimization, geometry, and algebraic topology.

**Prerequisites:** Grade C or better in MAT 292 or MAT 296 and grade C or better in MAT 310.

# MAT 454 Intermediate Mathematical Data Science 3

Selected well-known machine learning algorithms will be studied in great mathematical detail in order for students to understand the mathematics behind them. General topics may include Regression, Dimension Reduction, Density Estimations, and Classification. Advanced topics may include Google PageRank algorithm, Manifold Learning, and the Mapper algorithm.

Prerequisites: Grade of C or better in MAT 453.

## MAT 465 Student Teaching and Seminar-Secondary Mathematics 12

Supervised student teaching in senior high school under direction of university supervisor. Observation, participation, and appropriate classroom teaching experience on full-time teaching assignment for full semester with weekly seminar.

Prerequisites: MAT 406. Admission to the Teacher Education Program.

## MAT 486 Financial Mathematics for Actuaries 3

Measurement of interest, present and accumulated value, amortization, sinking funds, bonds, duration, immunization, and an introductory analysis of financial derivatives. Intended to help prepare for the FM/2 actuarial exam.

**Prerequisites:** Grade C or better in MAT 394 or MAT 396 or permission of instructor.

## MAT 488 Directed Study in Mathematics 1-3

Individual study in an appropriate area of mathematics, directed through regular conferences with the instructor.

Prerequisites: Permission of Instructor.

# MAT 490 Senior Seminar in Mathematics 3

Reading, formally writing, giving oral presentations on topics in mathematics, including current mathematics literature.

CIC: CIC College Writing

**Prerequisites:** Senior standing and mathematics major, or permission of instructor.

#### MAT 493 Honors Work 3-6

Honors Work.

**Prerequisites:** Permission of instructor. 3.30 GPA in the major, 12 s.h. in the major;

Notes: May be repeated for credit if the topic of study changes.

## MAT 494 Directed Study in Mathematics 1-3

Individual study in an appropriate area of mathematics, directed through regular conferences with the instructor.

Prerequisites: Permission of Instructor.

## MAT 497 Research Experience in Mathematics 1-3

Supervised research activity on contemporary research questions in the fields of mathematics and its applications.

**Notes:** May be repeated for up to a total of six (6) credits. Grade: Pass/ Not Pass (P/NP).

## MAT 503 Problem Solving in Mathematics 3

Investigates the nature of problem solving, covers procedures involved in problem solving, develops individual problem solving skills, and collects a set of appropriate problems. Required for middle grades mathematics concentration.

**Prerequisites:** Grade of at least C in MAT 191 and MAT 303 or permission of instructor.

**Notes:** Hours do not count toward degree requirements for Mathematics majors. This course cannot be applied toward the requirements for the M.A. degree in Mathematics.

## MAT 504 Foundations of Geometry for Teachers 3

Primarily for students seeking teacher certification. Includes logic and axiom systems, history, plane and solid Euclidean geometry, proof strategies, introduction to non-Euclidean geometries, and transformational geometry.

**Prerequisites:** Grade of C or better in MAT 292. or permission of instructor;

**Notes:** Hours do not count toward degree requirements for MATH major nor for the M.A. degree in Mathematics.

## MAT 505 Foundations of Mathematics for Teaching I 3

Capstone survey of topics including functions, calculus concepts, geometry, probability, data analysis, and discrete mathematics. Special teaching problems and procedures for secondary education topics related to their mathematical foundations.

**Prerequisites:** Admission to Masters of Arts in Teaching (M.A.T.) program.

## MAT 506 Foundations of Mathematics for Teaching II 3

Capstone survey course of mathematics topics including functions, calculus concepts, geometry, probability, data analysis, and discrete mathematics. Includes special teaching problems and procedures for secondary education topics related to their mathematical foundations. **Prerequisites:** Minimum grade of C (2.0) in MAT 505 and admission to the School of Education's Master of Arts in Teaching program.

## MAT 513 Historical Development of Mathematics 3

Study of the historical development of mathematics, not a history of persons involved in development.

Prerequisites: Grade of C or better in MAT 292 or MAT 296.

**Notes:** Credit hours do not count toward degree requirements for the M.A. in Mathematics.

## MAT 591 Advanced Abstract Algebra 3

Groups: homomorphisms, quotient groups, Sylow theorems, finitely generated abelian groups. Rings: homomorphisms, ideals, quotient rings, integral domains, Euclidean domains, factorization. Fields: algebraic extensions of fields, Galois theory.

Prerequisites: Grade of C or better in MAT 516.

#### MAT 593 Directed Study in Mathematics 1-3

Individual study in an appropriate area of mathematics, directed through regular conferences with the instructor. **Prerequisites:** Permission of Instructor.

## MAT 594 Directed Study in Mathematics 1-3

Individual study in an appropriate area of mathematics, directed through regular conferences with the instructor. **Prerequisites:** Permission of Instructor.

## MAT 601 Seminar in the Teaching of Mathematics I 1

Seminar on practices and principles of undergraduate teaching in mathematics and statistics. **Notes:** Required for all teaching assistants. Grade: Satisfactory/

Unsatisfactory (S/U).

## MAT 602 Seminar in Mathematical Software 3

Introduction to software and utilities for students in computational mathematics. Students implement algorithms, use software to compute mathematical objects, organize large computational tasks, and select the appropriate software to perform a given task.

Prerequisites: Knowledge of a programming language.

## MAT 603 Practicum in the Teaching of Mathematics 2

Practicum in teaching mathematics at the college/university level. Topics include course design, class materials, exams, grading, syllabus, choosing textbooks, dealing with difficult matters, and mathematical typesetting.

Corequisites: MAT 601.

## MAT 614 Theory of Numbers 3

An introductory course to both multiplicative and additive number theory. Divisibility, prime numbers, congruencies, linear and nonlinear Diophantine equations (including Pell's equation), quadratic residues, number-theoretic functions, and other topics.

#### MAT 616 Intermediate Abstract Algebra 3

Rings, integral domains, fields, division algorithm, factorization theorems, zeros of polynomials, greatest common divisor, formal derivatives, prime polynomials, Euclidean domains, the fundamental theorem of algebra.

#### MAT 617 Theory of Groups 3

Elementary properties of groups and homomorphisms, quotients and products of groups, the Sylow theorems, structure theory for finitely generated abelian groups.

# MAT 619 Intuitive Concepts in Topology 3

Basic concepts, vector fields, the Jordan curve theorem, surfaces, homology of complexes, continuity.

## MAT 620 Non-Euclidean Geometry 3

Fifth postulate, hyperbolic geometries, elliptic geometries, consistency of non-Euclidean geometries, models for geometries, elements of inversion.

## MAT 621 Projective Geometry 3

Transformation groups and projective, affine and metric geometries of the line, plane, and space. Homogeneous coordinates, principles of duality, involutions, cross-ratio, collineations, fixed points, conics, models, and Euclidean specializations.

Prerequisites: Permission of instructor.

## MAT 622 Introductory Functional Analysis 3

Basic concepts in Banach spaces, Hilbert spaces, linear operators, and their applications.

#### MAT 625 Intermediate Mathematical Analysis 3

Integration, infinite series, sequences and series of functions.

#### MAT 627 Numerical Methods 3

Number systems and errors, solutions of non-linear and linear systems, interpolation, numerical differentiation and integration, solution of differential equations. Implementation of numerical methods using a high-level programming language.

## MAT 628 Linear Programming and Optimization 3

This course is an introduction to linear programming and optimization including: simplex method, degeneracy, efficiency, duality theory, convex analysis, game theory, financial applications, network flow problems, integer programming, and quadratic programming.

## MAT 630 Computational Discrete Mathematics 3

Exact computations with mathematical structures. Topics include complexity analysis, multi precision arithmetic, matrix normal forms, graphs and networks, and fast Fourier transforms.

## MAT 631 Combinatorial Analysis 3

The pigeon-hole principle, permutations, combinations, generating functions, principle of inclusion and exclusion, distributions, partitions, recurrence relations.

## MAT 632 Introductory Graph Theory 3

Basic concepts, graph coloring, trees, planar graphs, networks.

## MAT 635 Differential Equations and Orthogonal Systems 3

An introduction to Fourier series and orthogonal sets of functions, with applications to boundary value problems.

#### MAT 636 Partial Differential Equations with Applications 3

Fourier integrals, Bessel functions, Legendre polynomials and their applications. Existence and uniqueness of solutions to boundary value problems.

Prerequisites: Grade of C or better in MAT 635 or permission of instructor.

#### MAT 639 Topics in Applied Mathematics 3

Selected topics of current interest in applied mathematics. **Prerequisites:** Permission of instructor.

#### MAT 640 Introductory Complex Analysis 3

The complex number system, holomorphic functions, power series, complex integration, representation theorems, the calculus of residues.

## MAT 641 Stochastic Processes I 3

The first half of a year long sequence in Stochastic Processes. Markov processes, Markov reward processes, queuing, decision making, graphs, and networks. Applications to performance, reliability, and availability modeling.

#### MAT 642 Stochastic Processes II 3

The second half of a year long sequence in Stochastic Processes. Markov processes, Markov reward processes, queuing, decision making, graphs, and networks. Applications to performance, reliability, and availability modeling.

Prerequisites: MAT 641.

#### MAT 651 Topological Data Analysis 3

This course covers persistent homology and topological data analysis. Topics include persistence modules, bar codes, stability, and the use of statistics and machine learning in topological data analysis.

## MAT 653 Foundations of Mathematical Data Science 3

This course is for students to build up a solid mathematical foundation in order to thrive in the rapidly growing field of data science. Students will learn essential mathematical topics in data science, including linear algebra, matrix decomposition, probability, stochastic process, analysis, optimization, geometry, and algebraic topology.

## MAT 654 Advanced Mathematical Data Science 3

Based on the specialty of the instructor, selected well-known machine learning algorithms will be studied in great mathematical detail. General topics may include Regression, Dimension Reduction, Density Estimations, and Classification. Advanced topics may include Google PageRank algorithm, Manifold Learning, and the Mapper algorithm. **Prerequisites:** MAT 653.

#### MAT 659 Advanced Topics in Mathematics 3

Topics vary according to interest and demand, and include algebra, applied mathematics, combinatorics, dynamics, mathematical logic, topology, and other topics.

Prerequisites: Permission of instructor.

Notes: May be repeated for credit when topic varies.

#### MAT 686 Financial Mathematics for Actuaries 3

Measurement of interest, present and accumulated value, amortization, sinking funds, bonds, duration, immunization, and an introductory analysis of financial derivatives. Intended to help prepare for the FM/2 actuarial exam.

**Prerequisites:** Minimum grade of C (2.0) in MAT 394 or permission of instructor. Graduate students in MA in Mathematics, Ph.D. students in Computational Mathematics, or undergraduate students in the accelerated BS to MA in Mathematics.

## MAT 687 Project in Mathematics 3

Directed research project in Mathematics. **Prerequisites:** Admission to the MA in Mathematics and Permission of Instructor.

## MAT 691 Abstract Algebra I 3

The first half of a year-long sequence in algebra. Topics include quotients and products of groups, the Sylow theorems, and structure theory for finitely generated abelian groups, representations of groups, and the basic theory of rings.

## MAT 692 Abstract Algebra II 3

The second half of a year-long sequence in algebra. Topics include integral domains, ideals, factorization, polynomial rings, quotient rings, finite fields, field extensions, and Galois theory.

Prerequisites: MAT 691 or permission of instructor.

## MAT 695 Mathematical Analysis 3

Real number axioms, metric spaces, sequences, series, continuity, differentiation, the Riemann-Stieltjes integral.

## MAT 696 Mathematical Analysis 3

Real number axioms, metric spaces, sequences, series, continuity, differentiation, the Riemann-Stieltjes integral.

## MAT 699 Thesis 1-6

Individual guidance in the development and examination of a research problem.

## MAT 701 Graduate Seminar in Computational Mathematics 3

Readings from the literature of computational mathematics. **Prerequisites:** Permission of instructor.

## MAT 709 Topics in Computational Mathematics 3

Advanced study in special topics in computational mathematics. **Prerequisites:** Permission of instructor.

## MAT 721 Mathematical Cryptography 3

Mathematics of cryptography with emphasis on public key systems. Applications of elliptic and hyperelliptic curves and lattice theory in attacking and evaluating the security of cryptographic systems. **Prerequisites:** Permission of instructor.

## MAT 723 Numerical Mathematics 3

Functional analytic treatment of computation, approximation, optimization, interpolation, smoothing equations, linear systems, differential equations. Emphasis on the mathematical development and analysis of numerical techniques.

#### MAT 726 Finite Element Methods 3

Introduce the fundamental concepts of the finite element method for approximating solutions to boundary and initial boundary value problems. Topics include modeling, mathematical formulations, convergence analysis, and computer implementation. **Prerequisites:** A grade of B or better in MAT 727.

## MAT 727 Linear Algebra 3

An introduction to vector spaces over general fields. Topics include linear transformations, dual spaces, inner product spaces, orthogonality, spectral theory, and Jordan normal form.

#### MAT 728 Numerical Linear Algebra 3

An introduction to numerical linear algebra. Topics include conditioning and stability, matrix factorizations, eigenvalue solvers, least-squares problems, and iterative methods as well as the implementation of various computational methods using a high-level programming language.

## MAT 735 Ordinary Differential Equations 3

Existence and uniqueness theorems for initial value problems, theory of linear equations, nonlinear equations, stability theory, boundary value problems.

## MAT 736 Partial Differential Equations 3

Derivation of partial differential equations (PDE) models and applications, linear first order PDE's, elliptic equations and Green's function, PDE's of parabolic and hyperbolic type.

Prerequisites: MAT 735 or permission of instructor.

## MAT 737 General Topology 3

Topological spaces, point set topology, product and quotient spaces, embedding and metrization, uniform spaces, function spaces, homotopy theory, simplicial complexes and homology, more algebraic topology, general homology theories.

## MAT 740 Algebra I: Groups and Rings 3

The first half of a year-long sequence in algebra. Topics include basic group and ring theory: quotients and products of groups, group actions, the Sylow theorems, structure theory for finitely generated abelian groups, domains, ideals, factorization, and polynomial rings.

## MAT 741 Algebra II: Modules and Fields 3

The second half of a year-long sequence in algebra. Topics include basic module and field theory: quotient modules, tensor products, exact sequences, structure theory for finitely generated modules over a PID, extension of scalars, finite fields, algebraic field extensions, and Galois theory.

Prerequisites: MAT 740 or permission of instructor.

## MAT 742 Computational Algebraic Number Theory 3

A constructive introduction to algebraic number theory. Topics include algebraic number fields, integral bases, ideal factorization, system of fundamental units, and the class group. **Prerequisites:** Permission of instructor.

#### MAT 743 Complex Analysis 3

The complex number system, holomorphic functions, power series, complex integration, representation theorems, the calculus of residues.

## MAT 745 Measure Theory 3

Lebesgue measure, and integration; existence of non-measurable sets; sigma-algebras; transfinite induction; abstract measure spaces, measurable functions, and integration; outer measures and Caratheodory's Extension Theorem; product measures; Fubini's Theorem; Egorov's Theorem; Fatou's Lemma; Dominated Convergence Theorem; modes of convergence, Borel-Cantelli Lemma.

## MAT 746 Real Analysis 3

Lebesque measure; the Lebesque integral; differentiation and integration, the classical Banach spaces; metric spaces, topological spaces, compact spaces; Banach spaces, measure and integration, measure and outer measure; the Daniell integral; mappings of measure spaces.

**Prerequisites:** Bachelor's degree with a major in mathematics. Credits equivalent to credits for mathematics MAT 310, MAT 311, MAT 595, and MAT 596, or permission of instructor and department head.

## MAT 747 Computational Topology 3

Triangulations and WRAP. Computing homology algorithmically. Morse theory and persistent homology. Computations on knots, braids, and links.

Prerequisites: Permission of instructor.

#### MAT 748 Computational Algebra 3

An introduction to basic subjects in computational algebra. Topics include fast arithmetic, algorithms for finite fields, matrix normal forms over rings, polynomial factorization, and lattice basis reduction.

## MAT 749 The Mathematics of Machine Learning 3

This course covers the underlying mathematical theory behind common machine learning methods: support vector machines, kernel methods, decision trees, nearest neighbor, clustering, stochastic gradient descent, and neural networks.

## MAT 751 Advanced Topological Data Analysis 3

This is an advanced course in topological data analysis. After covering persistent homology, bar codes, and stability, the course will move into research level topics drawn from recent papers.

## MAT 790 Directed Doctoral Research 1-6

Individual work on a dissertation research problem, which could also include original research or a review of current literature leading to a dissertation proposal.

Prerequisites: Permission of Director of Graduate Study.

MAT 799 Dissertation 1-12

MAT 801 Thesis Extension 1-3 Thesis Extension.

MAT 802 Dissertation Extension 1-3 Dissertation Extension.