# MATHEMATICS (MATH)

**MATH 511 - Probability (3 Credits)**
Probability and independence; discrete and continuous random variables; joint, marginal, and conditional densities, moment generating functions; laws of large numbers; binomial, Poisson, gamma, univariate, and bivariate normal distributions.
**Prerequisite or Corequisite:** C or better in MATH 241.

**Cross-listed course:** STAT 511

**MATH 514 - Financial Mathematics I (3 Credits)**
Probability spaces. Random variables. Mean and variance. Geometric Brownian Motion and stock price dynamics. Interest rates and present value analysis. Pricing via arbitrage arguments. Options pricing and the Black-Scholes formula.
**Prerequisites:** C or better in MATH 241.

**Cross-listed course:** STAT 522

**MATH 515 - Financial Mathematics II (3 Credits)**
Convex sets. Separating Hyperplane Theorem. Fundamental Theorem of Asset Pricing. Risk and expected return. Minimum variance portfolios. Capital Asset Pricing Model. Martingales and options pricing. Optimization models and dynamic programming.
**Prerequisites:** C or better in MATH 514 or STAT 522.

**Cross-listed course:** STAT 523

**MATH 520 - Ordinary Differential Equations (3 Credits)**
Differential equations of the first order, linear systems of ordinary differential equations, elementary qualitative properties of nonlinear systems.
**Prerequisites:** C or better in MATH 344 or MATH 544.

**MATH 521 - Boundary Value Problems and Partial Differential Equations (3 Credits)**
Laplace transforms, two-point boundary value problems and Green's functions, boundary value problems in partial differential equations, eigenfunction expansions and separation of variables, transform methods for solving PDE's, Green's functions for PDE's, and the method of characteristics.
**Prerequisites:** C or better in MATH 520 or in both MATH 241 and MATH 242.

**MATH 522 - Wavelets (3 Credits)**
Basic principles and methods of Fourier transforms, wavelets, and multiresolution analysis; applications to differential equations, data compression, and signal and image processing; development of numerical algorithms. Computer implementation.
**Prerequisites:** C or better in MATH 344 or MATH 544.

**MATH 523 - Mathematical Modeling of Population Biology (3 Credits)**
Applications of differential and difference equations and linear algebra modeling the dynamics of populations, with emphasis on stability and oscillation. Critical analysis of current publications with computer simulation of models.
**Prerequisites:** C or better in MATH 142, BIOL 301, or MSCI 311 recommended.

**MATH 524 - Nonlinear Optimization (3 Credits)**
Descent methods, conjugate direction methods, and Quasi-Newton algorithms for unconstrained optimization; globally convergent hybrid algorithm; primal, penalty, and barrier methods for constrained optimization. Computer implementation of algorithms.
**Prerequisites:** C or better in MATH 241 and one of MATH 344 or MATH 544.

**MATH 525 - Mathematical Game Theory (3 Credits)**
Two-person zero-sum games, minimax theorem, utility theory, n-person games, market games, stability.
**Prerequisites:** C or better in MATH 300 and in either MATH 344 or MATH 544.

**MATH 526 - Numerical Linear Algebra (4 Credits)**
Matrix algebra, Gauss elimination, iterative methods; overdetermined systems and least squares; eigenvalues, eigenvectors; numerical software. Computer implementation. Credit may not be received for both MATH 526 and MATH 544. Three lectures and one laboratory hour per week.
**Prerequisites:** C or better in MATH 142.

**MATH 527 - Numerical Analysis (3 Credits)**
Interpolation and approximation of functions; solution of algebraic equations; numerical differentiation and integration; numerical solutions of ordinary differential equations and boundary value problems; computer implementation of algorithms.
**Prerequisites:** C or better in MATH 520 or in both MATH 242 and MATH 344.

**Cross-listed course:** CSCE 561

**MATH 528 - Mathematical Foundation of Data Science and Machine Learning (3 Credits)**
Unconstrained and constrained optimization, gradient descent methods for numerical optimization, supervised and unsupervised learning, various reduced order methods, sampling and inference, Monte Carlo methods, deep neural networks.
**Prerequisites:** C or better in MATH 344 or MATH 544.

**MATH 529 - Introduction to Deep Neural Networks (3 Credits)**
Review of relevant concepts of linear algebra, Fourier transform and convolution, Fast Fourier Transform (FFT), mean and variance, covariance matrices and joint probabilities, gradient descent and stochastic gradient descent, structure of deep neural networks and convolutional neural networks, applications to image processing.
**Prerequisites:** C or better in MATH 328, MATH 344, or MATH 544.

**MATH 531 - Foundations of Geometry (3 Credits)**
The study of geometry as a logical system based upon postulates and undefined terms. The fundamental concepts and relations of Euclidean geometry developed rigorously on the basis of a set of postulates. Some topics from non-Euclidean geometry.
**Prerequisites:** C or better in MATH 300.

**MATH 532 - Modern Geometry (3 Credits)**
Projective geometry, theorem of Desargues, conics, transformation theory, affine geometry, Euclidean geometry, non-Euclidean geometries, and topology.
**Prerequisites:** C or better in MATH 300.

**MATH 533 - Elementary Geometric Topology (3 Credits)**
Topology of the line, plane, and space, Jordan curve theorem, Brouwer fixed point theorem, Euler characteristic of polyhedra, orientable and non-orientable surfaces, classification of surfaces, network topology.
**Prerequisites:** C or better in MATH 241 and MATH 300.

**MATH 534 - Elements of General Topology (3 Credits)**
Elementary properties of sets, functions, spaces, maps, separation axioms, compactness, completeness, convergence, connectedness, path connectedness, embedding and extension theorems, metric spaces, and compactification.
**Prerequisites:** C or better in MATH 241 and MATH 300.

**MATH 540 - Modern Applied Algebra (3 Credits)**
Finite structures useful in applied areas. Binary relations, Boolean algebras, applications to optimization, and realization of finite state machines.
**Prerequisites:** MATH 300.

**MATH 541 - Algebraic Coding Theory (3 Credits)**
Error-correcting codes, polynomial rings, cyclic codes, finite fields, BCH codes.
**Prerequisites:** C or better in MATH 300 and in either of MATH 344 or MATH 544.

**MATH 544 - Linear Algebra (3 Credits)**
Vectors, vector spaces, and subspaces; geometry of finite dimensional Euclidean space; linear transformations; eigenvalues and eigenvectors; diagonalization. Throughout there will be an emphasis on theoretical concepts, logic, and methods. MATH 544L is an optional laboratory course where additional applications will be discussed.
**Prerequisites:** C or better in MATH 241 and MATH 300.

**MATH 546 - Algebraic Structures I (3 Credits)**
Permutation groups; abstract groups; introduction to algebraic structures through study of subgroups, quotient groups, homomorphisms, isomorphisms, direct product; decompositions; introduction to rings and fields.
**Prerequisites:** C or better in MATH 300 and 544.

**MATH 547 - Algebraic Structures II (3 Credits)**
Rings, ideals, polynomial rings, unique factorization domains; structure of finite groups; topics from: fields, field extensions, Euclidean constructions, modules over principal ideal domains (canonical forms).
**Prerequisites:** C or better in MATH 546.

**MATH 548 - Geometry, Algebra, and Algorithms (3 Credits)**
Polynomials and affine space, Grobner bases, elimination theory, varieties, and computer algebra systems.
**Prerequisites:** C or better in MATH 300 and in one of MATH 344 or MATH 544.

**MATH 550 - Vector Analysis (3 Credits)**
Vector fields, line and path integrals, orientation and parametrization of lines and surfaces, change of variables and Jacobians, oriented surface integrals, theorems of Green, Gauss, and Stokes; introduction to tensor analysis.
**Prerequisites:** C or better in MATH 241.

**MATH 551 - Introduction to Differential Geometry (3 Credits)**
Parametrized curves, regular curves and surfaces, change of parameters, tangent planes, the differential of a map, the Gauss map, first and second fundamental forms, vector fields, geodesics, and the exponential map.
**Prerequisites:** C or better in MATH 241 and MATH 300.

**MATH 552 - Applied Complex Variables (3 Credits)**
Complex integration, calculus of residues, conformal mapping, Taylor and Laurent Series expansions, applications.
**Prerequisites:** C or better in MATH 241.

**MATH 554 - Analysis I (3 Credits)**
Least upper bound axiom, the real numbers, compactness, sequences, continuity, uniform continuity, differentiation, Riemann integral and fundamental theorem of calculus.
**Prerequisites:** C or better in MATH 241 and two 500-level classes requiring MATH 300: MATH 525, MATH 531, MATH 532, MATH 533, MATH 534, MATH 540, MATH 541, MATH 544, MATH 546, MATH 548, MATH 551, MATH 561, MATH 570, MATH 574, MATH 575, or MATH 580.

**MATH 555 - Analysis II (3 Credits)**
Riemann-Stieltjes integral, infinite series, sequences and series of functions, uniform convergence, Weierstrass approximation theorem, selected topics from Fourier series or Lebesgue integration.
**Prerequisites:** C or better in MATH 554.

**MATH 561 - Introduction to Mathematical Logic (3 Credits)**
Syntax and semantics of formal languages; sentential logic, proofs in first order logic; Godel's completeness theorem; compactness theorem and applications; cardinals and ordinals; the Lowenheim-Skolem-Tarski theorem; Beth's definability theorem; effectively computable functions; Godel's incompleteness theorem; undecidable theories.
**Prerequisites:** C or better in MATH 300.

**MATH 562 - Theory of Computation (3 Credits)**
Basic theoretical principles of computing as modeled by formal languages and automata; computability and computational complexity.
**Prerequisites:** C or better in CSCE 350 or MATH 300.

**Cross-listed course:** CSCE 551

**MATH 570 - Discrete Optimization (3 Credits)**
Discrete mathematical models. Applications to such problems as resource allocation and transportation. Topics include linear programming, integer programming, network analysis, and dynamic programming.
**Prerequisites:** C or better in MATH 300 and in one of MATH 544 or MATH 344.

**MATH 572 - Mathematical Foundation of Network Science (3 Credits)**
Graphs and probability, Web graphs, random graphs, models for complex graphs, graph searching algorithms, eigenvalues, PageRank.
**Prerequisites:** C or better in MATH 374 or MATH 574; C or better in MATH 344 or MATH 544.

**MATH 574 - Discrete Mathematics I (3 Credits)**
Mathematical models; mathematical reasoning; enumeration; induction and recursion; tree structures; networks and graphs; analysis of algorithms.
**Prerequisites:** C or better in MATH 300.

**MATH 575 - Discrete Mathematics II (3 Credits)**
A continuation of MATH 574. Inversion formulas; Polya counting; combinatorial designs; minimax theorems; probabilistic methods; Ramsey theory; other topics.
**Prerequisites:** C or better in MATH 574.

**MATH 576 - Combinatorial Game Theory (3 Credits)**
Winning in certain combinatorial games such as Nim, Hackenbush, and Domineering. Equalities and inequalities among games, Sprague-Grundy theory of impartial games, games which are numbers.
**Prerequisites:** C or better in MATH 300 or MATH 374.

**MATH 580 - Elementary Number Theory (3 Credits)**
Divisibility, primes, congruences, quadratic residues, numerical functions. Diophantine equations.
**Prerequisites:** C or better in MATH 300.

**MATH 587 - Introduction to Cryptography (3 Credits)**
Design of secret codes for secure communication, including encryption and integrity verification: ciphers, cryptographic hashing, and public key cryptosystems such as RSA. Mathematical principles underlying encryption. Code-breaking techniques. Cryptographic protocols.
**Prerequisites:** C or better in CSCE 145 or MATH 241, and at least one of CSCE 355, MATH 300, or MATH 374.

**Cross-listed course:** CSCE 557

**MATH 599 - Topics in Mathematics (1-3 Credits)**
Recent developments in pure and applied mathematics selected to meet current faculty and student interest.

**MATH 602 - An Inductive Approach to Geometry (3 Credits)**
This course is designed for middle-level pre-service mathematics teachers. This course covers geometric reasoning, Euclidean geometry, congruence, area, volume, similarity, symmetry, vectors, and transformations. Dynamic software will be utilized to explore geometry concepts. This course cannot be used for credit toward a major in mathematics.
**Prerequisites:** C or better in MATH 122 or MATH 141 or equivalent.

**MATH 603 - Inquiry Approach to Algebra (3 Credits)**
This course introduces basic concepts in number theory and modern algebra that provide the foundation for middle level arithmetic and algebra. Topics include: algebraic reasoning, patterns, inductive reasoning, deductive reasoning, arithmetic and algebra of integers, algebraic systems, algebraic modeling, and axiomatic mathematics. This course cannot be used for credit towards a major in mathematics.
**Prerequisites:** C or higher in MATH 122 or MATH 141 or equivalent.

**MATH 650 - AP Calculus for Teachers (3 Credits)**
A thorough study of the topics to be presented in AP calculus, including limits of functions, differentiation, integration, infinite series, and applications. Not intended for degree programs in mathematics.
**Prerequisites:** current secondary high school teacher certification in mathematics and a C or better in at least 6 hours of calculus.

**MATH 700 - Linear Algebra (3 Credits)**
Vector spaces, linear transformations, dual spaces, decompositions of spaces, and canonical forms. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 701 - Algebra I (3 Credits)**
Algebraic structures, sub-structures, products, homomorphisms, and quotient structures of groups, rings, and modules. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 701I - Foundations of Algebra I (3 Credits)**
An introduction to algebraic structures; group theory including subgroups, quotient groups, homomorphisms, isomorphisms, decomposition; introduction to rings and fields. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 241 or equivalent.

**MATH 702 - Algebra II (3 Credits)**
Fields and field extensions. Galois theory, topics from, transcendental field extensions, algebraically closed fields, finite fields. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 701.

**MATH 702I - Foundations of Algebra II (3 Credits)**
Theory of rings including ideals, polynomial rings, and unique factorization domains; structure of finite groups; fields; modules. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 701I or equivalent.

**MATH 703 - Analysis I (3 Credits)**
Compactness, completeness, continuous functions. Outer measures, measurable sets, extension theorem and Lebesgue-Stieltjes measure. Integration and convergence theorems. Product measures and Fubini's theorem. Differentiation theory. Theorems of Egorov and Lusin. Lp-spaces. Analytic functions: Cauchy-Riemann equations, elementary special functions. Conformal mappings. Cauchy's integral theorem and formula. Classification of singularities, Laurent series, the Argument Principle. Residue theorem, evaluation of integrals and series. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 703I - Foundations of Analysis I (3 Credits)**
The real numbers and least upper bound axiom; sequences and limits of sequences; infinite series; continuity; differentiation; the Riemann integral. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 241 or equivalent.

**MATH 704 - Analysis II (3 Credits)**
Compactness, completeness, continuous functions. Outer measures, measurable sets, extension theorem and Lebesgue-Stieltjes measure. Integration and convergence theorems. Product measures and Fubini's theorem. Differentiation theory. Theorems of Egorov and Lusin. Lp-spaces. Analytic functions: Cauchy-Riemann equations, elementary special functions. Conformal mappings. Cauchy's integral theorem and formula. Classification of singularities, Laurent series, the Argument Principle. Residue theorem, evaluation of integrals and series. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 704I - Foundations of Analysis II (3 Credits)**
Sequences and series of functions; power series, uniform convergence; interchange of limits; limits and continuity in several variables. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 703I or equivalent.

**MATH 705 - Analysis III (3 Credits)**
Signed and complex measures, Radon-Nikodym theorem, decomposition theorems. Metric spaces and topology, Baire category, Stone-Weierstrass theorem, Arzela-Ascoli theorem. Introduction to Banach and Hilbert spaces, Riesz representation theorems. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 703, MATH 704.

**MATH 708 - Foundations of Computational Mathematics I (3 Credits)**
Approximation of functions by algebraic polynomials, splines, and trigonometric polynomials; numerical differentiation; numerical integration; orthogonal polynomials and Gaussian quadrature; numerical solution of nonlinear systems, unconstrained optimization. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 554 or equivalent upper level undergraduate course in Real Analysis.

**MATH 709 - Foundations of Computational Mathematics II (3 Credits)**
Vectors and matrices; QR factorization; conditioning and stability; solving systems of equations; eigenvalue/eigenvector problems; Krylov subspace iterative methods; singular value decomposition. Includes theoretical development of concepts and practical algorithm implementation. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 544 or MATH 526, or equivalent upper level undergraduate courses in Linear Algebra.

**MATH 710 - Probability Theory I (3 Credits)**
Probability spaces, random variables and distributions, expectations, characteristic functions, laws of large numbers, and the central limit theorem. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** STAT 511, STAT 512, or MATH 703.

**Cross-listed course:** STAT 810

**MATH 711 - Probability Theory II (3 Credits)**
More about distributions, limit theorems, Poisson approximations, conditioning, martingales, and random walks.
**Cross-listed course:** STAT 811

**MATH 712I - Probability and Statistics (3 Credits)**
This course will include a study of permutations and combinations; probability and its application to statistical inferences; elementary descriptive statistics of a sample of measurements; the binomial, Poisson, and normal distributions; correlation and regression. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 720 - Applied Mathematics I (3 Credits)**
Modeling and solution techniques for differential and integral equations from sciences and engineering, including a study of boundary and initial value problems, integral equations, and eigenvalue problems using transform techniques, Green's functions, and variational principles. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 555 and MATH 520 or equivalent.

**MATH 721 - Applied Mathematics II (3 Credits)**
Foundations of approximation of functions by Fourier series in Hilbert space; fundamental PDEs in mathematical physics; fundamental equations for continua; integral and differential operators in Hilbert spaces. Basic modeling theory and solution techniques for stochastic differential equations. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 720.

**MATH 722 - Numerical Optimization (3 Credits)**
Topics in optimization; includes linear programming, integer programming, gradient methods, least squares techniques, and discussion of existing mathematical software. Graduate standing or consent of the department. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 723 - Differential Equations (3 Credits)**
Elliptic equations: fundamental solutions, maximum principles, Green's function, energy method and Dirichlet principle; Sobolev spaces: weak derivatives, extension and trace theorems; weak solutions and Fredholm alternative, regularity, eigenvalues and eigenfunctions. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 703/MATH 704.

**MATH 724 - Differential Equations II (3 Credits)**
Detailed study of the following topics: method of characteristics; Hamilton-Jacobi equations; conservation laws; heat equation; wave equation; linear parabolic equations; linear hyperbolic equations. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 723.

**MATH 725 - Approximation Theory (3 Credits)**
Approximation of functions; existence, uniqueness and characterization of best approximants; Chebyshev's theorem; Chebyshev polynomials; degree of approximation; Jackson and Bernstein theorems; B-splines; approximation by splines; quasi-interpolants; spline interpolation. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisite or Corequisite:** MATH 703.

**MATH 726 - Numerical Differential Equations I (3 Credits)**
Elliptic equations: fundamental solutions, maximum principles, Green's function, energy method and Dirichlet principle; Sobolev spaces: weak derivatives, extension and trace theorems; weak solutions and Fredholm alternative, regularity, eigenvalues and eigenfunctions. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 708/MATH 709.

**MATH 727 - Numerical Differential Equations II (3 Credits)**
Ritz and Galerkin weak formulation. Finite element, mixed finite element, collocation methods for elliptic, parabolic, and hyperbolic PDEs, including development, implementation, stability, consistency, convergence analysis, and error estimates.
**Prerequisites:** MATH 726.

**MATH 728 - Selected Topics in Applied Mathematics (3 Credits)**
All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 729 - Nonlinear Approximation (3 Credits)**
Nonlinear approximation from piecewise polynomial (spline) functions in the univariate and multivariate case, characterization of the approximation spaces via Besov spaces and interpolation, Newman's and Popov's theorems for rational approximation, characterization of the approximation spaces of rational approximation, nonlinear n-term approximation from bases in Hilbert spaces and from unconditional bases in Lp (p>1), greedy algorithms, application of nonlinear approximation to image compression.
**Prerequisites:** MATH 703.

**MATH 730 - General Topology I (3 Credits)**
Topological spaces, filters, compact spaces, connected spaces, uniform spaces, complete spaces, topological groups, function spaces. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 731 - General Topology II (3 Credits)**
Topological spaces, filters, compact spaces, connected spaces, uniform spaces, complete spaces, topological groups, function spaces. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 732 - Algebraic Topology I (3 Credits)**
The fundamental group, homological algebra, simplicial complexes, homology and cohomology groups, cup-product, triangulable spaces. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 730 or MATH 705, and MATH 701.

**MATH 733 - Algebraic Topology II (3 Credits)**
The fundamental group, homological algebra, simplicial complexes, homology and cohomology groups, cup-product, triangulable spaces. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 730 or MATH 705, and MATH 701.

**MATH 734 - Differential Geometry (3 Credits)**
Differentiable manifolds; classical theory of surfaces and hypersurfaces in Euclidean space; tensors, forms and integration of forms; connections and covariant differentiation; Riemannian manifolds; geodesics and the exponential map; curvature; Jacobi fields and comparison theorems, generalized Gauss-Bonnet theorem. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 550.

**MATH 735 - Lie Groups (3 Credits)**
Manifolds; topological groups, coverings and covering groups; Lie groups and their Lie algebras; closed subgroups of Lie groups; automorphism groups and representations; elementary theory of Lie algebras; simply connected Lie groups; semisimple Lie groups and their Lie algebras. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 705 or MATH 730.

**MATH 736I - Modern Geometry (3 Credits)**
Synthetic and analytic projective geometry, homothetic transformations, Euclidean geometry, non-Euclidean geometries, and topology. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 241 or equivalent.

**MATH 737 - Introduction to Complex Geometry (3 Credits)**
Algebraic geometry over the complex numbers, using ideas from topology, complex variable theory, and differential geometry.
**Prerequisite or Corequisite:** MATH 701.

**MATH 738 - Selected Topics in Geometry and Topology (3 Credits)**
Course content varies and will be announced in the schedule of classes by title. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 739 - Introduction to Complex Geometry II (3 Credits)**
Algebraic geometry over the complex numbers, using ideas from topology, complex variable theory, and differential geometry.
**Prerequisites:** MATH 737.

**MATH 741 - Algebra III (3 Credits)**
Theory of groups, rings, modules, fields and division rings, bilinear forms, advanced topics in matrix theory, and homological techniques.
**Prerequisites:** MATH 702.

**MATH 742 - Representation Theory (3 Credits)**
Representation and character theory of finite groups (especially the symmetric group) and/or the general linear group, Young tableaux, the Littlewood Richardson rule, and Schur functors.
**Prerequisites:** MATH 702.

**MATH 743 - Lattice Theory (3 Credits)**
Sublattices, homomorphisms and direct products of lattices; freely generated lattices; modular lattices and projective geometries; the Priestley and Stone dualities for distributive and Boolean lattices; congruence relations on lattices. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 740.

**MATH 744 - Matrix Theory (3 Credits)**
Extremal properties of positive definite and hermitian matrices, doubly stochastic matrices, totally non-negative matrices, eigenvalue monotonicity, Hadamard-Fisher determinantal inequalities. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 700.

**MATH 746 - Commutative Algebra (3 Credits)**
Prime spectrum and Zariski topology; finite, integral, and flat extensions; dimension; depth; homological techniques, normal and regular rings. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 701.

**MATH 747 - Algebraic Geometry (3 Credits)**
Properties of affine and projective varieties defined over algebraically closed fields, rational mappings, birational geometry and divisors especially on curves and surfaces, Bezout's theorem, Riemann-Roch theorem for curves. All Non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 701.

**MATH 748 - Selected Topics in Algebra (3 Credits)**
Course content varies and will be announced in the schedule of classes by title. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 750 - Fourier Analysis (3 Credits)**
The Fourier transform on the circle and line, convergence of Fejer means; Parseval's relation and the square summable theory, convergence and divergence at a point; conjugate Fourier series, the conjugate function and the Hilbert transform, the Hardy-Littlewood maximal operator and Hardy spaces. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 703 and MATH 704.

**MATH 751 - The Mathematical Theory of Wavelets (3 Credits)**
The L1 and L2 theory of the Fourier transform on the line, bandlimited functions and the Paley-Weiner theorem, Shannon-Whittacker Sampling Theorem, Riesz systems, Mallat-Meyer multiresolution analysis in Lebesgue spaces, scaling functions, wavelet constructions, wavelet representation and unconditional bases, nonlinear approximation, Riesz's factorization lemma, and Daubechies' compactly supported wavelets.
**Prerequisites:** MATH 703.

**MATH 752 - Complex Analysis (3 Credits)**
Normal families, meromorphic functions, Weierstrass product theorem, conformal maps and the Riemann mapping theorem, analytic continuation and Riemann surfaces, harmonic and subharmonic functions. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 703, MATH 704.

**MATH 752I - Complex Variables (3 Credits)**
Properties of analytic functions, complex integration, calculus of residues, Taylor and Laurent series expansions, conformal mappings. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 241 or equivalent.

**MATH 754 - Several Complex Variables (3 Credits)**
Properties of holomorphic functions of several variables, holomorphic mappings, plurisubharmonic functions, domains of convergence of power series, domains of holomorphy and pseudoconvex domains, harmonic analysis in several variables. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 703 and MATH 704.

**MATH 755 - Applied Functional Analysis (3 Credits)**
Banach spaces, Hilbert spaces, spectral theory of bounded linear operators, Fredholm alternatives, integral equations, fixed point theorems with applications, least square approximation. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 703.

**MATH 756 - Functional Analysis I (3 Credits)**
Linear topological spaces; Hahn-Banach theorem; closed graph theorem; uniform boundedness principle; operator theory; spectral theory; topics from linear differential operators or Banach algebras. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 704.

**MATH 757 - Functional Analysis II (3 Credits)**
Linear topological spaces; Hahn-Banach theorem; closed graph theorem; uniform boundedness principle; operator theory; spectral theory; topics from linear differential operators or Banach algebras. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 704.

**MATH 758 - Selected Topics in Analysis (3 Credits)**
Course content varies and will be announced in the schedule of classes by title. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 760 - Set Theory (3 Credits)**
An axiomatic development of set theory: sets and classes; recursive definitions and inductive proofs; the axiom of choice and its consequences; ordinals; infinite cardinal arithmetic; combinatorial set theory. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 761 - The Theory of Computable Functions (3 Credits)**
Models of computation; recursive functions, random access machines, Turing machines, and Markov algorithms; Church's Thesis; universal machines and recursively unsolvable problems; recursively enumerable sets; the recursion theorem; the undecidability of elementary arithmetic. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 762 - Model Theory (3 Credits)**
First order predicate calculus; elementary theories; models, satisfaction, and truth; the completeness, compactness, and omitting types theorems; countable models of complete theories; elementary extensions; interpolation and definability; preservation theorems; ultraproducts. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 764 - Quantum Information (3 Credits)**
Fundamentals of quantum information theory and quantum communications. Topics include: Postulates of quantum mechanics, classical information and entropy, compression of classical information and classical typical sets, quantum entropy and quantum relative entropy, quantum states discrimination, Schumacher's theory of quantum compression and quantum typical subspace, communicating classical information using quantum channels, the Classical Capacity Theorem of a quantum channel.
**Prerequisites:** C or better in MATH 344 or MATH 544 or equivalent, or permission by the instructor; and C or better in MATH 511 or STAT 511 or equivalent, or permission by the instructor; knowledge of quantum mechanics is not required.

**Cross-listed course:** CSCE 764, PHYS 764

**MATH 768 - Selected Topics in Foundations of Mathematics (3 Credits)**
Course content varies and will be announced in the schedule of classes by title. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 770 - Discrete Optimization (3 Credits)**
The application and analysis of algorithms for linear programming problems, including the simplex algorithm, algorithms and complexity, network flows, and shortest path algorithms. No computer programming experience required. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 774 - Discrete Mathematics I (3 Credits)**
An introduction to the theory and applications of discrete mathematics. Topics include enumeration techniques, combinatorial identities, matching theory, basic graph theory, and combinatorial designs. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 775 - Discrete Mathematics II (3 Credits)**
A continuation of MATH 774. Additional topics will be selected from: the structure and extremal properties of partially ordered sets, matroids, combinatorical algorithms, matrices of zeros and ones, and coding theory. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 774.

**MATH 776 - Graph Theory I (3 Credits)**
The study of the structure and extremal properties of graphs, including Eulerian and Hamiltonian paths, connectivity, trees, Ramsey theory, graph coloring, and graph algorithms. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 777 - Graph Theory II (3 Credits)**
Continuation of MATH 776. Additional topics will be selected from: reconstruction problems, independence, genus, hypergraphs, perfect graphs, interval representations, and graph-theoretical models. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 776.

**MATH 778 - Selected Topics in Discrete Mathematics (3 Credits)**
Course content varies and will be announced in the schedule of classes by title. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 780 - Elementary Number Theory (3 Credits)**
Diophantine equations, distribution of primes, factoring algorithms, higher power reciprocity, Schnirelmann density, and sieve methods. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 780I - Theory of Numbers (3 Credits)**
Elementary properties of integers, Diophantine equations, prime numbers, arithmetic functions, congruences, and the quadratic reciprocity law. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 241 or equivalent.

**MATH 782 - Analytic Number Theory I (3 Credits)**
The prime number theorem, Dirichlet's theorem, the Riemann zeta function, Dirichlet's L-functions, exponential sums, Dirichlet series, Hardy-Littlewood method partitions, and Waring's problem. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 580 and MATH 552.

**MATH 783 - Analytic Number Theory II (3 Credits)**
The prime number theorem, Dirichlet's theorem, the Riemann zeta function, Dirichlet's L-functions, exponential sums, Dirichlet series, Hardy-Littlewood method partitions, and Waring's problem. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 580 and MATH 552.

**MATH 784 - Algebraic Number Theory (3 Credits)**
Algebraic integers, unique factorization of ideals, the ideal class group, Dirichlet's unit theorem, application to Diophantine equations. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 546 and MATH 580.

**MATH 785 - Transcendental Number Theory (3 Credits)**
Thue-Siegel-Roth theorem, Hilbert's seventh problem, diophantine approximation. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.
**Prerequisites:** MATH 580.

**MATH 788 - Selected Topics in Number Theory (3 Credits)**
Course content varies and will be announced in the schedule of classes by title. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 790 - Graduate Seminar (1 Credit)**
Although this course is required of all candidates for the master's degree it is not included in the total credit hours in the master's program. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 791 - Mathematics Pedagogy I (0-1 Credits)**
First of two required math pedagogy courses for graduate assistants in the department. Pedagogical topics include assessment theory, discourse, theory, lesson planning, and classroom management. Applications assist graduate students with syllabusnesson/assessment creation, teacher questioning, midcourse evaluations, and student learning and engagement. This course will replace the University's requirement for GRAD 701. Restricted to Mathematics graduate students teaching at some capacity.

**MATH 792 - Mathematics Pedagogy II (0-1 Credits)**
Second of two required math pedagogy courses for graduate assistants in the department. Pedagogical topics include student-learning and reflection theories, sociomathematical norms, and constructivism. Applications assist graduates with lesson/revision/reflection, student-centered investigations, curriculum problem solving and metacognition. This course will replace the University's requirement for GRAD 701. Restricted to Mathematics graduate students teaching at some capacity. **Prerequisites:** Satisfactory grade in MATH 791.

**MATH 797 - Mathematics into Print (3 Credits)**
The exposition of advanced mathematics emphasizing the organization of proofs and the formulation of concepts; computer typesetting systems for producing mathematical theses, books, and articles.

**MATH 798 - Directed Readings and Research (1-6 Credits)**
Full admission to graduate study in mathematics. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 799 - Thesis Preparation (1-9 Credits)**
For master's candidates. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 890 - Graduate Seminar (1-3 Credits)**
A review of current literature in specified subject areas involving student presentations. Content varies and will be announced in the schedule of classes by title. Minimum of 3 credit hours required of all doctoral students. All non-degree students should request permission to register from the Graduate Director in the Mathematics Department.

**MATH 899 - Dissertation Preparation (1-12 Credits)**
For doctoral candidates.