

# Mathematics

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## Administration:

Head of the Department: Brooke Shipley  
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## Program Codes:

20FS1901DA (DA)  
20FS0439MS (MS)  
20FS0290MST (MST)  
20FS0439PHD (PhD)

The Department of Mathematics, Statistics, and Computer Science offers work leading to degrees in Mathematics at both the master's and doctoral levels. Study and research is available in the general areas of pure mathematics, applied mathematics, probability and statistics, mathematical computer science, and the teaching of mathematics. Additional information, guidelines, and requirements are published annually in the department's Graduate Handbook. All teaching assistants are required to take MATH 589 before or concurrently with their initial teaching assignments.

## Admission and Degree Requirements

- [MS in Mathematics](#)
- [MST in Mathematics](#)
- [DA in Mathematics](#)
- [PhD in Mathematics](#)

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## Mathematics Courses

### MATH 410. Advanced Calculus I. 3 or 4 hours.

Functions of several variables, differentials, theorems of partial differentiation. Calculus of vector fields, line and surface integrals, conservative fields, Stokes's and divergence theorems. Cartesian tensors. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 210.

### MATH 411. Advanced Calculus II. 3 or 4 hours.

Implicit and inverse function theorems, transformations, Jacobians. Point-set theory. Sequences, infinite series, convergence tests, uniform convergence. Improper integrals, gamma and beta functions, Laplace transform. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 410.

### MATH 414. Analysis II. 3 or 4 hours.

Riemann-Stieltjes integration. Topology of metric spaces with emphasis on  $\mathbb{R}^n$ . (Uniform) Continuity of functions on metric spaces. Multi-dimensional differentiation theory. Implicit and Inverse Function Theorem and applications. Introduction to Lebes. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade C or better in MATH 313 and MATH 310, or MATH 320.

### MATH 417. Complex Analysis with Applications. 3 or 4 hours.

Complex numbers, analytic functions, complex integration, Taylor and Laurent series, residue calculus, branch cuts, conformal mapping, argument principle, Rouche's theorem, Poisson integral formula, analytic continuation. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade C or better in MATH 210.

### MATH 419. Models in Applied Mathematics. 3 or 4 hours.

Introduction to mathematical modeling; scaling, graphical methods, optimization, computer simulation, stability, differential equation models, elementary numerical methods, applications in biology, chemistry, engineering and physics. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 220 and grade of C or better in MCS 260.

### MATH 425. Linear Algebra II. 3 or 4 hours.

Canonical forms of a linear transformation, inner product spaces, spectral theorem, principal axis theorem, quadratic forms, special topics such as linear programming. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 320.

### MATH 430. Formal Logic I. 3 or 4 hours.

First order logic, syntax and semantics, completeness-incompleteness. Course Information: 3 undergraduate hours. 4 graduate hours. Credit is not given for MATH 430 if the student has credit for PHIL 416. Prerequisite(s): Grade of C or better in CS 202 or grade of C or better in MCS 261 or grade of C or better in MATH 215.

### MATH 431. Abstract Algebra II. 3 or 4 hours.

Further topics in abstract algebra: Sylow Theorems, Galois Theory, finitely generated modules over a principal ideal domain. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 320 and grade of C or better in MATH 330.

### MATH 435. Foundations of Number Theory. 3 or 4 hours.

Primes, divisibility, congruences, Chinese remainder theorem, primitive roots, quadratic residues, quadratic reciprocity, and Jacobi symbols. The Euclidean algorithm and strategies of computer programming. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 215.

### MATH 436. Number Theory for Applications. 3 or 4 hours.

Primality testing methods of Lehmer, Rumely, Cohen-Lenstra, Atkin. Factorization methods of Gauss, Pollard, Shanks, Lenstra, and quadratic sieve. Computer algorithms involving libraries and nested subroutines. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 435.

### MATH 442. Differential Geometry of Curves and Surfaces. 3 or 4 hours.

Frenet formulas, isoperimetric inequality, local theory of surfaces, Gaussian and mean curvature, geodesics, parallelism, and the Gauss-Bonnet theorem. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 320.

**MATH 445. Introduction to Topology I. 3 or 4 hours.**

Elements of metric spaces and topological spaces including product and quotient spaces, compactness, connectedness, and completeness. Examples from Euclidean space and function spaces. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 313.

**MATH 446. Introduction to Topology II. 3 or 4 hours.**

Topics in topology chosen from the following: advanced point set topology, piecewise linear topology, fundamental group and knots, differential topology, applications to physics and biology. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 445.

**MATH 480. Applied Differential Equations. 3 or 4 hours.**

Linear first-order systems. Numerical methods. Nonlinear differential equations and stability. Introduction to partial differential equations. Sturm-Liouville theory. Boundary value problems and Green's functions. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 220.

**MATH 481. Applied Partial Differential Equations. 3 or 4 hours.**

Initial value and boundary value problems for second order linear equations. Eigenfunction expansions and Sturm-Liouville theory. Green's functions. Fourier transform. Characteristics. Laplace transform. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 220.

**MATH 494. Special Topics in Mathematics. 3 or 4 hours.**

Course content is announced prior to each term in which it is given. Course Information: 3 undergraduate hours. 4 graduate hours. May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the department.

**MATH 496. Independent Study. 1-4 hours.**

Reading course supervised by a faculty member. Course Information: May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the instructor and the department. Class Schedule Information: This course counts toward the limited number of independent study hours accepted toward the degree and the major.

**MATH 502. Mathematical Logic. 4 hours.**

First order logic, completeness and incompleteness theorems, introduction to model theory and computability theory. Course Information: Same as PHIL 562. Prerequisite(s): MATH 430 or consent of the instructor.

**MATH 504. Set Theory. 4 hours.**

Naive and axiomatic set theory. Independence of the continuum hypothesis and the axiom of choice. Course Information: Same as PHIL 565. Prerequisite(s): MATH 430 or MATH 502 or PHIL 562.

**MATH 506. Model Theory I. 4 hours.**

Elementary embeddings, quantifier elimination, types, saturated and prime models, indiscernibles, Morley's Categoricity Theorem. Course Information: Same as PHIL 567. Prerequisite(s): MATH 502 or PHIL 562.

**MATH 507. Model Theory II. 4 hours.**

Stability theory: forking and independence, stable groups, geometric stability. Course Information: Same as PHIL 568. Prerequisite(s): MATH 506 or PHIL 567.

**MATH 511. Descriptive Set Theory. 4 hours.**

Polish spaces and Baire category; Borel, analytic and coanalytic sets; infinite games and determinacy; coanalytic ranks and scales; dichotomy theorems. Course Information: Recommended background: MATH 445 or MATH 504 or MATH 533 or MATH 539.

**MATH 512. Advanced Topics in Logic. 4 hours.**

Advanced topics in modern logic; e.g. large cardinals, infinitary logic, model theory of fields, o-minimality, Borel equivalence relations. Course Information: Same as PHIL 569. May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the department.

**MATH 514. Number Theory I. 4 hours.**

Introduction to classical, algebraic, and analytic, number theory. Euclid's algorithm, unique factorization, quadratic reciprocity, and Gauss sums, quadratic forms, real approximations, arithmetic functions, Diophantine equations.

**MATH 515. Number Theory II. 4 hours.**

Introduction to classical, algebraic, and analytic number theory. Algebraic number fields, units, ideals, and P-adic theory. Riemann Zeta-function, Dirichlet's theorem, prime number theorem. Course Information: Prerequisite(s): MATH 514.

**MATH 516. Second Course in Abstract Algebra I. 4 hours.**

Structure of groups, Sylow theorems, solvable groups; structure of rings, polynomial rings, projective and injective modules, finitely generated modules over a PID. Course Information: Prerequisite(s): MATH 330 and MATH 425.

**MATH 517. Second Course in Abstract Algebra II. 4 hours.**

Rings and algebras, polynomials in several variables, power series rings, tensor products, field extensions, Galois theory, Wedderburn theorems. Course Information: Prerequisite(s): MATH 516.

**MATH 518. Representation Theory. 4 hours.**

Major areas of representation theory, including structure of group algebras, Wedderburn theorems, characters and orthogonality relations, idempotents and blocks. Course Information: Prerequisite(s): MATH 517.

**MATH 520. Commutative and Homological Algebra. 4 hours.**

Commutative rings; primary decomposition; integral closure; valuations; dimension theory; regular sequences; projective and injective dimension; chain complexes and homology; Ext and Tor; Koszul complex; homological study of regular rings. Course Information: Prerequisite(s): MATH 516 and MATH 517; or consent of the instructor.

**MATH 525. Advanced Topics in Number Theory. 4 hours.**

Introduction to topics at the forefront of research in number theory. Topics will vary and may include elliptic curves, automorphic forms, diophantine geometry or sieve methods. Course Information: May be repeated. Prerequisite(s): MATH 515; or consent of the instructor.

**MATH 531. Advanced Topics in Algebra. 4 hours.**

Researchlevel topics such as groups and geometries, equivalencies of module categories, representations of Lie-type groups. Course Information: May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the department.

**MATH 533. Real Analysis I. 4 hours.**

Introduction to real analysis. Lebesgue measure and integration, differentiation, L-p classes, abstract integration. Course Information: Prerequisite(s): MATH 411 or MATH 414 or the equivalent.

**MATH 534. Real Analysis II. 4 hours.**

Continuation of MATH 533. Course Information: Prerequisite(s): MATH 417.

**MATH 535. Complex Analysis I. 4 hours.**

Analytic functions as mappings. Cauchy theory. Power Series. Partial fractions. Infinite products. Course Information: Prerequisite(s): MATH 411.

**MATH 536. Complex Analysis II. 4 hours.**

Normal families, Riemann mapping theorem. Analytic continuation, Harmonic and subharmonic functions, Picard theorem, selected topics. Course Information: Prerequisite(s): MATH 535.

**MATH 537. Introduction to Harmonic Analysis I. 4 hours.**

Fourier transform on  $L(p)$  spaces, Wiener's Tauberian theorem, Hilbert transform, Paley Wiener theory. Course Information: Prerequisite(s): MATH 533; and MATH 417 or MATH 535.

**MATH 539. Functional Analysis I. 4 hours.**

Topological vector spaces, Hilbert spaces, Hahn-Banach theorem, open mapping, uniform boundedness principle, linear operators in a Banach space, compact operators. Course Information: Prerequisite(s): MATH 533.

**MATH 546. Advanced Topics in Analysis. 4 hours.**

Subject may vary from semester to semester. Topics include partial differential equations, several complex variables, harmonic analysis and ergodic theory. Course Information: May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the department.

**MATH 547. Algebraic Topology I. 4 hours.**

The fundamental group and its applications, covering spaces, classification of compact surfaces, introduction to homology, development of singular homology theory, applications of homology. Course Information: Prerequisite(s): MATH 330 and MATH 445.

**MATH 548. Algebraic Topology II. 4 hours.**

Cohomology theory, universal coefficient theorems, cohomology products and their applications, orientation and duality for manifolds, homotopy groups and fibrations, the Hurewicz theorem, selected topics. Course Information: Prerequisite(s): MATH 547.

**MATH 549. Differentiable Manifolds I. 4 hours.**

Smooth manifolds and maps, tangent and normal bundles, Sard's theorem and transversality, embedding, differential forms, Stokes's theorem, degree theory, vector fields. Course Information: Prerequisite(s): MATH 445; and MATH 310 or MATH 320 or the equivalent.

**MATH 550. Differentiable Manifolds II. 4 hours.**

Vector bundles and classifying spaces, Lie groups and Lie algebras, tensors, Hodge theory, Poincaré duality. Topics from elliptic operators, Morse theory, cobordism theory, deRham theory, characteristic classes. Course Information: Prerequisite(s): MATH 549.

**MATH 551. Riemannian Geometry. 4 hours.**

Riemannian metrics and Levi-Civita connections, geodesics and completeness, curvature, first and second variation of arc length, comparison theorems. Course Information: Prerequisite(s): MATH 442 and MATH 549.

**MATH 552. Algebraic Geometry I. 4 hours.**

Basic commutative algebra, affine and projective varieties, regular and rational maps, function fields, dimension and smoothness, projective curves, schemes, sheaves, and cohomology, positive characteristic.

**MATH 553. Algebraic Geometry II. 4 hours.**

Divisors and linear systems, differentials, Riemann-Roch theorem for curves, elliptic curves, geometry of curves and surfaces. Course Information: Prerequisite(s): MATH 552.

**MATH 554. Complex Manifolds I. 4 hours.**

Holomorphic functions in several variables, Riemann surfaces, Sheaf theory, vector bundles, Stein manifolds, Cartan theorem A and B, Grauert direct image theorem. Course Information: Prerequisite(s): MATH 517 and MATH 535.

**MATH 555. Complex Manifolds II. 4 hours.**

Dolbeault Cohomology, Serre duality, Hodge theory, Kodaira vanishing and embedding theorem, Lefschetz theorem, Complex Tori, Kahler manifolds. Course Information: Prerequisite(s): MATH 517 and MATH 535.

**MATH 568. Topics in Algebraic Topology. 4 hours.**

Homotopy groups and fibrations. The Serre spectral sequence and its applications. Classifying spaces of classical groups. Characteristic classes of vector bundles. Course Information: May be repeated. Students may register in more than one section per term. Prerequisite(s): MATH 548 or consent of the instructor.

**MATH 569. Advanced Topics in Geometric and Differential Topology. 4 hours.**

Topics from areas such as index theory, Lefschetz theory, cyclic theory, KK theory, non-commutative geometry, 3-manifold topology, hyperbolic manifolds, geometric group theory, and knot theory. Course Information: Prerequisite(s): Approval of the department.

**MATH 570. Advanced Topics in Differential Geometry. 4 hours.**

Subject may vary from semester to semester. Topics may include eigenvalues in Riemannian geometry, curvature and homology, partial differential relations, harmonic mappings between Riemannian manifolds, hyperbolic geometry, arrangement of hyperplanes. Course Information: May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the department.

**MATH 571. Advanced Topics in Algebraic Geometry. 4 hours.**

Various topics such as algebraic curves, surfaces, higher dimensional geometry, singularities theory, moduli problems, vector bundles, intersection theory, arithmetical algebraic geometry, and topologies of algebraic varieties. Course Information: May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the department.

**MATH 576. Classical Methods of Partial Differential Equations. 4 hours.**

First and second order equations, method of characteristics, weak solutions, distributions, wave, Laplace, Poisson, heat equations, energy methods, regularity problems, Green functions, maximum principles, Sobolev spaces, imbedding theorems. Course Information: Prerequisite(s): MATH 410 and MATH 481 and MATH 533; or consent of instructor.

**MATH 577. Advanced Partial Differential Equations. 4 hours.**

Linear elliptic theory, maximum principles, fixed point methods, semigroups and nonlinear dynamics, systems of conservation laws, shocks and waves, parabolic equations, bifurcation, nonlinear elliptic theory. Course Information: Prerequisite(s): MATH 533 and MATH 576 or consent of the instructor.

**MATH 578. Asymptotic Methods. 4 hours.**

Asymptotic series, Laplace's method, stationary phase, steepest descent method, Stokes phenomena, uniform expansions, multi-dimensional Laplace integrals, Euler-MacLaurin formula, irregular singular points, WKB method. Course Information: Prerequisite(s): MATH 417 and MATH 481; or consent of instructor.

**MATH 580. Mathematics of Fluid Mechanics. 4 hours.**

Development of concepts and techniques used in mathematical models of fluid motions. Euler and Navier Stokes equations. Vorticity and vortex motion. Waves and instabilities. Viscous fluids and boundary layers. Asymptotic methods. Course Information: Prerequisite(s): Grade of C or better in MATH 410 and grade of C or better in MATH 417 and grade of C or better in MATH 481.

**MATH 581. Special Topics in Fluid Mechanics. 4 hours.**

Geophysical fluids with applications to oceanography and meteorology, astrophysical fluids, magnetohydrodynamics and plasmas. Course Information: Prerequisite(s): Grade of C or better in MATH 580.

**MATH 582. Linear and Nonlinear Waves. 4 hours.**

Analysis of partial differential equations describing (non-) linear wave phenomena. In particular, dispersive and hyperbolic equations. Analytical techniques include Fourier transformation and fixed point theorems. Course Information: Prerequisite(s): Graduate standing and MATH 533 and MATH 576 OR MATH 539 or consent of the instructor.

**MATH 584. Applied Stochastic Models. 4 hours.**

Applications of stochastic models in chemistry, physics, biology, queueing, filtering, and stochastic control, diffusion approximations, Brownian motion, stochastic calculus, stochastically perturbed dynamical systems, first passage times. Course Information: Prerequisite(s): MATH 417 and MATH 481 and STAT 401, or consent of the instructor.

**MATH 585. Ordinary Differential Equations. 4 hours.**

Introduction to ordinary differential equations, existence, uniqueness of solutions, dependence on parameters, autonomous and non-autonomous systems, linear systems, nonlinear systems, periodic solutions, bifurcations, conservative systems. Course Information: Prerequisite(s): MATH 313 or MATH 480 or approval of the department.

**MATH 586. Computational Finance. 4 hours.**

Introduction to the mathematics of financial derivatives; options, asset price random walks, Black-Scholes model; partial differential techniques for option valuation, binomial models, numerical methods; exotic options, interest-rate derivatives. Course Information: Prerequisite(s): Grade of C or better in MATH 220 and grade of C or better in STAT 381; or consent of the instructor.

**MATH 589. Teaching and Presentation of Mathematics. 2 hours.**

Strategies and techniques for effective teaching in college and for mathematical consulting. Observation and evaluation, classroom management, presenting mathematics in multidisciplinary research teams. Required for teaching assistants in MSCS. Course Information: No graduation credit awarded for students enrolled in the Master of Science in the Teaching of Mathematics degree program.

**MATH 590. Advanced Topics in Applied Mathematics. 4 hours.**

Topics from areas such as: elastic scattering, nonlinear problems in chemistry and physics, mathematical biology, stochastic optimal control, geophysical fluid dynamics, stability theory, queueing theory. Course Information: Prerequisite(s): Approval of the department.

**MATH 591. Seminar on Mathematics Curricula. 4 hours.**

Examination of research and reports on mathematics curricula. Analysis of research in teaching and learning mathematics. Developments in using technology in mathematics teaching. Course Information: Prerequisite(s): Enrollment in the Doctor of Arts program in mathematics or consent of the instructor.

**MATH 592. Seminar on Mathematics: Philosophy and Methodology. 4 hours.**

Problems related to teaching and learning mathematics. Analysis of work of Piaget, Gagne, Bruner, Ausabel, Freudenthal, and others and their relation to mathematics teaching. Course Information: Prerequisite(s): Enrollment in the Doctor of Arts program in mathematics or consent of instructor.

**MATH 593. Graduate Student Seminar. 1 hour.**

For graduate students who wish to receive credit for participating in a learning seminar whose weekly time commitment is not sufficient for a reading course. This seminar must be sponsored by a faculty member. Course Information: Satisfactory/Unsatisfactory grading only. May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the department.

**MATH 594. Internship in Mathematics. 0-8 hours.**

Under the direction of a faculty adviser, students work in government or industry on problems related to their major field of interest. At the end of internship, the student must present a seminar on the internship experiences. Course Information: Satisfactory/Unsatisfactory grading only. May be repeated to a maximum of 8 hours. Only 4 credit hours count toward the 32 credit hours required for the M.S. in MISI degree. Does not count toward the 12 credit hours of 500-level courses requirement. Prerequisite(s): Completion of the core courses in the degree program in which the student is enrolled and approval of the internship program by the graduate adviser and the graduate studies committee.

**MATH 595. Research Seminar. 1 hour.**

Current developments in research with presentations by faculty, students, and visitors. Course Information: Satisfactory/Unsatisfactory grading only. May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the department.

**MATH 596. Independent Study. 1-4 hours.**

Reading course supervised by a faculty member. Course Information: May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the instructor and the department.

**MATH 598. Master's Thesis. 0-16 hours.**

Research work under the supervision of a faculty member leading to the completion of a master's thesis. Course Information: Satisfactory/Unsatisfactory grading only. Prerequisite(s): Approval of the department.

**MATH 599. Thesis Research. 0-16 hours.**

Research work under the supervision of a faculty member. Course Information: Satisfactory/Unsatisfactory grading only. May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the department.

## Mathematical Computer Science Courses

**MCS 401. Computer Algorithms I. 3 or 4 hours.**

Design and analysis of computer algorithms. Divide-and-conquer, dynamic programming, greedy method, backtracking. Algorithms for sorting, searching, graph computations, pattern matching, NP-complete problems. Course Information: Same as CS 401. 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MCS 360; or Grade of C or better in CS 251.

**MCS 411. Compiler Design. 3 or 4 hours.**

Language translation: lexical analysis, parsing schemes, symbol table management, syntax and semantic error detection, and code generation. Development of fully-functional compiler. Course Information: Same as CS 473. 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in CS 301 or Grade of C or better in MCS 441; and Grade of C or better in CS 251 or Grade of C or better in MCS 360; and Grade of C or better in CS 261.

**MCS 415. Programming Language Design. 3 or 4 hours.**

Definition, design, and implementation of programming languages. Syntactic and semantic description; variable bindings, control and data structures, parsing, code generation, optimization; exception handling; data abstraction. Course Information: Same as CS 476. 3 undergraduate hours. 4 graduate hours. Prerequisite(s): MCS 360; or CS 341.

**MCS 421. Combinatorics. 3 or 4 hours.**

The pigeonhole principle, permutations and combinations, binomial coefficients, inclusion/exclusion principle, recurrence relations and generating functions, special counting sequences, Polya theory of counting. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 215; and Grade of C or better in MATH 310 or Grade of C or better in MATH 320; or consent of the instructor.

**MCS 423. Graph Theory. 3 or 4 hours.**

Basic concepts of graph theory including Eulerian and hamiltonian cycles, trees, colorings, connectivity, shortest paths, minimum spanning trees, network flows, bipartite matching, planar graphs. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 215; and Grade of C or better in MATH 310 or Grade of C or better in MATH 320; or consent of the instructor.

**MCS 425. Codes and Cryptography. 3 or 4 hours.**

Mathematics of communications theory, basic information theory necessary to understand both coding theory and cryptography, basic ideas and highlights for both coding theory and cryptography, including public-key cryptosystems. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 215; and Grade of C or better in MATH 310 or Grade of C or better in MATH 320; or consent of the instructor.

**MCS 441. Theory of Computation I. 3 or 4 hours.**

Introduction to formal languages; relations between grammars and automata; elements of the theory of computable functions. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): MATH 215.

**MCS 451. Object-Oriented Programming in C++. 3 or 4 hours.**

C++ as an object-oriented language, classes and member functions, access control, class scope, constructors, destructors, overloading, conversions, streams, derived classes, polymorphism through virtual functions, templates, class libraries. Course Information: 3 undergraduate hours. 4 graduate hours. Credit is not given for MCS 451 if the student has credit for CS 474. Extensive computer use required. Prerequisite(s): Grade of C or better in MCS 360 or the equivalent or consent of the instructor.

**MCS 471. Numerical Analysis. 3 or 4 hours.**

Introduction to numerical analysis; floating point arithmetic, computational linear algebra, iterative solution to nonlinear equations, interpolation, numerical integration, numerical solution of ODEs, computer subroutine packages. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MCS 260; or grade of C or better in CS 107 or CS 109 or CS 111; or consent of instructor.

**MCS 472. Introduction to Industrial Math and Computation. 3 or 4 hours.**

Technical writing and oral presentations in preparation for industrial projects. Topics include quality control, operations research, cost-benefit analysis, differential equations, using scientific software. Course Information: Extensive computer use required. Prerequisite(s): Grade of C or better in MCS 471 or consent of the instructor. Recommended background: Designed for students with a desire to explore mathematics via practical field work.

**MCS 481. Computational Geometry. 3 or 4 hours.**

Algorithmic problems on sets of points, rectangles, intervals, arcs, chords, polygons. Counting, reporting, location, intersection, pairing; static and dynamic data structures. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MCS 401 or consent of the instructor.

**MCS 494. Special Topics in Computer Science. 3 or 4 hours.**

Topics in mathematical computer science, such as symbolic computation, automated reasoning, cryptography or geometric algorithms. Course Information: 3 undergraduate hours. 4 graduate hours. May be repeated to a maximum of 12 hours. Students may register in more than one section per term. Prerequisite(s): Approval of the department.

**MCS 496. Independent Study. 1-4 hours.**

Reading course supervised by a faculty member. Course Information: May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the instructor and the department. Class Schedule Information: This course counts toward the limited number of independent study hours accepted toward the degree and the major.

**MCS 501. Computer Algorithms II. 4 hours.**

Continuation of MCS 401 (same as CS 401). Advanced topics in algorithms. Lower bounds. Union-find problems. Fast Fourier transform. Complexity of arithmetic, polynomial, and matrix calculations. Approximation algorithms. Parallel algorithms. Course Information: Same as CS 501. Prerequisite(s): MCS 401 or CS 401.

**MCS 507. Mathematical, Statistical and Scientific Software. 4 hours.**

The design, analysis, and use of mathematical, statistical, and scientific software. Course Information: Prerequisite(s): Grade of B or better in MCS 360 or the equivalent or consent of instructor.

**MCS 521. Combinatorial Optimization. 4 hours.**

Combinatorial optimization: network flows, bipartite matching, Edmonds algorithm for non-bipartite matching, the matching polytope, matroids, greedy algorithm, matroid union and intersection algorithms, matroid polyhedra, polymatroids. Course Information: Prerequisite(s): MCS 423 and STAT 471.

**MCS 541. Computational Complexity. 4 hours.**

Time and space complexity of computations, classification of mathproblems according to their computational complexity, P not equal NP problem. Course Information: Prerequisite(s): Consent of the instructor.

**MCS 548. Mathematical Theory of Artificial Intelligence. 4 hours.**

Valiant's learning model, positive and negative results in learnability, automation inference, perceptrons, Rosenblatt's theorem, convergence theorem, threshold circuits, inductive inference of programs, grammars and automata. Course Information: Prerequisite(s): MCS 541.

**MCS 549. Mathematical Foundations of Data Science. 4 hours.**

Topics will include random graphs, small world phenomena, random walks, Markov chains, streaming algorithms, clustering, graphical models, singular value decomposition, and random projections. Course Information: Prerequisite(s): MCS 401 and MCS 441; or consent of the instructor.

**MCS 563. Analytic Symbolic Computation. 4 hours.**

Analytic computation, including integration algorithms, differential equations, perturbation theory, mixed symbolic-numeric algorithms, and other related topics. Course Information: Prerequisite(s): Grade of C or better in MCS 460 or the equivalent, and MATH 480 or consent of the instructor.

**MCS 565. Mathematical Theory of Databases. 4 hours.**

Abstract systems for databases, syntax and semantics of operational languages, dependencies and normal forms, axiomatizations, queries and query optimization, null values, algebraic interpretations.

**MCS 571. Numerical Analysis of Partial Differential Equations. 4 hours.**

Numerical analysis of Finite Difference methods for PDE of mathematical physics: Wave, heat, and Laplace equations. Introduction to numerical analysis of the Finite Element method. Course Information: Prerequisite(s): MATH 481 and MCS 471 or consent of the instructor.

**MCS 572. Introduction to Supercomputing. 4 hours.**

Introduction to supercomputing on vector and parallel processors; architectural comparisons, parallel algorithms, vectorization techniques, parallelization techniques, actual implementation on real machines. Course Information: Prerequisite(s): MCS 471 or MCS 571 or consent of the instructor.

**MCS 573. Topics in Numerical Analysis of Partial Differential Equations. 4 hours.**

Topics in numerical analysis of partial differential equations which may include: High-order Finite Element methods, Discontinuous Galerkin methods, Spectral methods, or Integral Equation methods. Course Information: May be repeated if topics vary. Prerequisite(s): MATH 481 and MCS 471; and consent of the instructor.

**MCS 582. The Probabilistic Method. 4 hours.**

Introduction to the probabilistic method, which includes a range of applications to address various problems that arise in combinatorics. Prerequisite(s): MCS 421 and 423, or consent of the instructor.

**MCS 583. Extremal Combinatorics. 4 hours.**

Extremal combinatorics, including extremal graph and set theory, Ramsey theory, the linear algebra method, and applications to computer science. Prerequisite(s): MCS 421 and MCS 423, or consent of the instructor.

**MCS 584. Enumerative Combinatorics. 4 hours.**

Enumerative methods in combinatorics, including inclusion/exclusion, recursion, partitions, Latin squares and other combinatorial structures. Prerequisite(s): MCS 421 and MCS 423, or consent of the instructor.

**MCS 590. Advanced Topics in Computer Science. 4 hours.**

Topics in areas such as: mathematical aspects of artificial intelligence, symbolic methods in mathematics, mathematical cryptography, automated reasoning. Topics may vary from term to term. Course Information: May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the department.

**MCS 591. Advanced Topics in Combinatorial Theory. 4 hours.**

Some of the following topics: combinatorial enumeration, designs, graph theory, matroid theory, combinatorial matrix theory, Ramsey theory. Contents vary from year to year. Course Information: May be repeated. Prerequisite(s): MCS 423.

**MCS 593. Graduate Student Seminar. 1 hour.**

For graduate students who wish to receive credit for participating in a learning seminar whose weekly time commitment is not sufficient for a reading course. This seminar must be sponsored by a faculty member. Course Information: Satisfactory/Unsatisfactory grading only. May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the department.

**MCS 595. Graduate Seminar. 1 hour.**

Current developments in research with presentations by faculty, students, and visitors. Course Information: Satisfactory/Unsatisfactory grading only. May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the department.

**MCS 596. Independent Study. 1-4 hours.**

Reading course supervised by a faculty member. Course Information: May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the instructor and the department.

**MCS 598. Master's Thesis. 0-16 hours.**

Research work under the supervision of a faculty member leading to the completion of a master's thesis. Course Information: Satisfactory/Unsatisfactory grading only. Prerequisite(s): Approval of the department.

**MCS 599. Thesis Research. 0-16 hours.**

Research work under the supervision of a faculty member leading to the completion of a doctoral thesis. Course Information: Satisfactory/Unsatisfactory grading only. May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the department.

## Mathematics Teaching Courses

**MTHT 400. Methods of Teaching Secondary Mathematics I. 3 or 4 hours.**

Philosophies, issues, techniques, and styles of teaching high school mathematics. Implications of psychological models. Mathematics in the evolving curriculum. Preparation of lessons. Course Information: 3 undergraduate hours. 4 graduate hours. To be taken in the year prior to student teaching. Prerequisite(s): Grade of C or better in MTHT 410, enrollment in B.S. or M.S. in the Teaching of Mathematics program in Secondary Mathematics Education, and a 2.50 grade point average in mathematics courses at the level of calculus or above.

**MTHT 401. Methods of Teaching Secondary Mathematics II. 3 or 4 hours.**

Philosophies, issues, techniques and styles of teaching high school mathematics. Preparation of diverse lessons. Supervised teaching experience. Course Information: 3 undergraduate hours. 4 graduate hours. To be taken in year prior to student teaching. Prerequisite(s): Grade of C or better in MATH 210 and enrollment in the B.S. or M.S. in the Teaching of Mathematics program in Secondary Mathematics Education; and a 2.50 grade point average in mathematics courses at the level of calculus or above.

**MTHT 411. Advanced Euclidean Geometry. 3 or 4 hours.**

Axioms for Euclidean geometry are developed based upon reflections. Further concepts in Euclidean geometry which arise from these axioms are explored. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 215.

**MTHT 420. Computers in Secondary School Mathematics. 3 or 4 hours.**

An overview of techniques, topics and tools for teaching secondary level mathematics using computers. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 210.

**MTHT 430. Real Analysis for Teachers I. 3 or 4 hours.**

Major topics include real number system with emphasis on the completeness axiom, limits of sequences and functions, derivatives, Riemann integrals and the Fundamental Theorem of Calculus. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 210 and Grade of C or better in MATH 215.

**MTHT 435. Abstract Algebra. 3 or 4 hours.**

Sets, properties of integers, groups, rings, fields. Focus on concepts applicable to high school teaching. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): MATH 210 and MATH 215.

**MTHT 438. Educational Practice with Seminar I. 6 hours.**

The first half of a two-segment sequence of practice teaching, including seminar, to meet certification requirements for teaching in grades six through twelve. Course Information: Graduate credit only with approval of the department. Prerequisite(s): 2.50 grade point average in mathematics courses at the level of calculus or above, successful completion of 100 clock hours of pre-student-teaching field experiences, and approval of the department. Class Schedule Information: To be properly registered, students must enroll in one Lecture-Discussion and one Practice.

**MTHT 439. Educational Practice with Seminar II. 6 hours.**

The second half of a two-segment sequence of practice teaching, including seminar, to meet certification requirements for teaching in grades six through twelve. Course Information: Graduate credit only with approval of the department. Prerequisite(s): Credit or concurrent registration in MTHT 438; and approval of the department and a 2.50 grade point average in mathematics courses at the level of calculus or above and successful completion of 100 clock hours of pre-student teaching field experiences. Class Schedule Information: To be properly registered, students must enroll in one Conference and one Practice.

**MTHT 450. Concepts and Methods in Elementary and Middle School Mathematics I. 3 or 4 hours.**

Advanced analysis of concept development and teaching methods. Sorting, classifying, counting, number tracks, addition, subtraction, group, place value, length, area and alternative teaching strategies. Course Information: 3 undergraduate hours. 4 graduate hours. For elementary school teachers. Prerequisite(s): Graduate standing and admission to the M.S. in the Teaching of Mathematics program (Option for Elementary School Teachers) or consent of the instructor.

**MTHT 465. Teaching Algebra for Understanding. 3 or 4 hours.**

Manipulatives and other representations of mathematical concepts used for teaching algebra to middle grade students. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Admission to the M.S. in the Teaching of Mathematics program (Option for Elementary School Teachers) or consent of the instructor.

**MTHT 466. Introduction to Calculus and the Graphing Calculator. 4 hours.**

Problem solving using derivatives, differentials, and their applications followed by integrals and their applications. Maximum/minimum problems solved directly by graphing, then by derivatives. Course Information: Prerequisite(s): Admission to the Mathematics Education Concentrators Program or consent of the instructor.

**MTHT 467. Introduction to Number Theory with Application. 4 hours.**

Classical topics of elementary number theory and how they pertain to teaching the upper grades. Primes, GCF, LCM, divisibility, floor and ceiling functions, Gaussian Residue, lattices. Course Information: Prerequisite(s): Admission to the Mathematics Education Concentrators Program or consent of the instructor.

**MTHT 468. Geometry with Applications for Middle Grade Teachers. 4 hours.**

Plane and solid figures and their properties. Polygons and polyhedra. Euler's formula. Volume versus surface area. Spatial visualization; two dimensional representations of three dimensional figures. Course Information: Prerequisite(s): Admission to the Mathematics Education Concentrators Program or consent of the instructor.

**MTHT 470. Teaching Mathematics with Science: An Activity Approach I. 3 or 4 hours.**

Introduction to basic variables (length, area, volume, mass, time) and the Scientific Method (picture, table, graph, questions). Extensive use of TIMS project curriculum. Course Information: 3 undergraduate hours. 4 graduate hours. For elementary school teachers. Prerequisite(s): Admission to the M.S. in the Teaching of Mathematics program (Option for Elementary School Teachers) or consent of the instructor.

**MTHT 490. Topics in Teaching Secondary Mathematics. 1-5 hours.**

Course content is announced prior to each term in which it is given. Course Information: May be repeated. Students may register in more than one section per term. Prerequisite(s): Prerequisites may vary according to topic.

**MTHT 491. Topics in Teaching Elementary/Junior High School Mathematics. 1-5 hours.**

Course content is announced prior to each term in which it is given. Course Information: May be repeated. Students may register in more than one section per term. Prerequisite(s): Prerequisites may vary according to topic.

**MTHT 496. Independent Study. 1-4 hours.**

Reading course supervised by a faculty member. Course Information: May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the instructor and the department. Class Schedule Information: This course counts toward the limited number of independent study hours accepted toward the degree and the major.

**MTHT 510. Introduction to Higher Geometry. 4 hours.**

Projective geometry, as an extension of Euclidean geometry, treated synthetically and/or algebraically. Desargues' and Pappus' theorems, subgeometries, conics and the underlying skew field. Course Information: For graduate students in mathematics teacher education programs. Other students enroll in MATH 440. Prerequisite(s): Grade of C or better in MATH 330.

**MTHT 530. Mathematical Analysis for Teachers II. 4 hours.**

Derivatives, inverse functions, Riemann integral, trigonometric functions, logarithmic and exponential functions. Course Information: Prerequisite(s): Grade of C or better in MTHT 430 or consent of the instructor.

**MTHT 550. Concepts and Methods in Elementary and Middle School Mathematics II. 4 hours.**

Methods of teaching middle school mathematics: concept development; focus on classroom materials to promote learning. Area, volume, rational numbers, decimals, function machines. Course Information: Prerequisite(s): MTHT 450 or consent of the instructor.

**MTHT 560. Introduction to Analytic Geometry and Calculus. 4 hours.**

Programmable calculators used to investigate ideas and applications of analytic geometry, differential and integral calculus. Examples and ideas relevant to elementary mathematics and science curricula. Course Information: For elementary school teachers. Do not purchase a calculator until after the first day of class. Prerequisite(s): MTHT 460 or consent of the instructor.

**MTHT 565. Teaching Geometry: An Activity Approach. 4 hours.**

Informal geometry using manipulatives, elementary topological concepts, polygons, polyhedra, metric geometry, motion geometry, geometric constructions, spherical geometry, introduction to research on the learning of geometry. Course Information: For elementary school teachers. Prerequisite(s): Enrollment in the M.S. in the Teaching of Mathematics program (Option for Elementary School Teachers) or consent of the instructor.

**MTHT 575. Principles of Probability and Statistics. 4 hours.**

Probability, descriptive and inferential statistics, implications for teaching. Emphasis on collection and analysis of data, classroom activities and software. Course Information: For elementary school teachers. Prerequisite(s): Admission to the M.S. in the Teaching of Mathematics program (Option for Elementary School Teachers) or approval of the department.

**MTHT 589. Practicum in Teaching Elementary School Mathematics. 4 hours.**

Culminating experience for students in the M.S. in the Teaching of Mathematics (Option for Elementary School Teachers). Major project is required. Supervised weekly seminars. Course Information: Prerequisite(s): Admission to the M.S. in the Teaching of Mathematics program (Option for Elementary School Teachers) and consent of the instructor.

**MTHT 590. Topics in Teaching Secondary Mathematics. 1-5 hours.**

Course content is announced prior to each term in which it is given. Course Information: May be repeated. Students may register in more than one section per term. Prerequisite(s): Prerequisite may vary according to topic.

**MTHT 591. Topics in Teaching Elementary/Junior High School Mathematics. 1-5 hours.**

Course content is announced prior to each term in which it is given. Course Information: May be repeated. Students may register in more than one section per term. Prerequisite(s): Prerequisite may vary according to topic.

**MTHT 592. Topics in Advanced Mathematics for Teachers. 1-5 hours.**

Course content is announced prior to each term in which it is given. Course Information: May be repeated. Students may register in more than one section per term. For students in the M.S. in the Teaching of Mathematics program. Prerequisite(s): Prerequisite may vary according to topic.

**MTHT 596. Independent Study. 1-4 hours.**

Reading course supervised by a faculty member. Course Information: May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the instructor and the department.

## Statistics Courses

**STAT 401. Introduction to Probability. 3 or 4 hours.**

Probability spaces, random variables and their distributions, conditional distribution and stochastic independence, special distributions, sampling distributions, limit theorems. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 210; or approval of the department.

**STAT 411. Statistical Theory. 3 or 4 hours.**

Estimation, tests of statistical hypotheses, best tests, sufficient statistics, Rao-Cramer inequality, sequential probability ratio tests, the multivariate normal distribution, nonparametric methods. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in STAT 401.

**STAT 416. Nonparametric Statistical Methods. 3 or 4 hours.**

Distribution free tests for location and dispersion problems, one-way and two-way layouts, the independence problem, regression problems involving slopes, detecting broad alternatives, resampling methods. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in STAT 381 or STAT 411.

**STAT 431. Introduction to Survey Sampling. 3 or 4 hours.**

Simple random sampling; sampling proportions; estimation of sample size; stratified random sampling; ratio estimators; regression estimators; systematic and cluster sampling. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in STAT 411 or STAT 481.

**STAT 451. Computational Statistics. 3 or 4 hours.**

Modern computationally-intensive statistical methods including Monte Carlo integration and simulation, optimization and maximum likelihood estimation, EM algorithm, MCMC, sampling and resampling methods, non-parametric density estimation. Course Information: 3 undergraduate hours. 4 graduate hours. Extensive computer use required. Prerequisite(s): STAT 411.

**STAT 461. Applied Probability Models I. 3 or 4 hours.**

Computing probabilities and expectations by conditioning, Markov chains, Chapman-Kolmogorov equations, branching processes, Poisson processes and exponential distribution, continuous-time Markov chains, reversibility, uniformization. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in STAT 401.

**STAT 471. Linear and Non-Linear Programming. 3 or 4 hours.**

Linear programming, simplex algorithm, degeneracy, duality theorem sensitivity analysis, convexity, network simplex methods, assignment problems. Constrained and unconstrained minima. Quasi-Newton methods. Ellipsoidal methods of Kachian. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in MATH 310.

**STAT 473. Game Theory. 3 or 4 hours.**

Introduction to the basic ideas of game theory. Static and dynamic games; mixed strategies, imperfect information; economic, political and biological applications. Course Information: Same as ECON 473. 3 undergraduate hours. 4 graduate hours. Prerequisite(s): STAT 381; or ECON 270; or equivalents.

**STAT 475. Mathematics and Statistics for Actuarial Sciences I. 3 or 4 hours.**

Financial mathematics as it pertains to the valuation of deterministic cash flows. Basic concepts and techniques regarding the theory of interest. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Math 210.



**STAT 481. Applied Statistical Methods II. 3 or 4 hours.**

Testing hypotheses, linear regression, analysis of variance, factorial design, and nested design. SAS and R applications. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): STAT 381. Students in the BS in Data Science may satisfy the prerequisite with IE 342 or ECE 341 instead of STAT 381.

**STAT 485. Intermediate Statistical Techniques for Machine Learning and Big Data. 3 or 4 hours.**

Modern techniques for statistical learning including linear models, subset selection, partial least squares; LDA; logistic regression; model selection; sampling theory with applications to big data analysis; applied nonparametric inference. Course Information: 3 undergraduate hours. 4 graduate hours. Extensive computer use required. Prerequisite(s): STAT 385 and STAT 411. Recommended background: STAT 481.

**STAT 486. Statistical Consulting. 3 or 4 hours.**

Introduction to statistical consulting methods and techniques. Handling and transformation of raw data sets in CMS. Statistical analysis of data sets with SAS and SPSSX. Course Information: 3 undergraduate hours. 4 graduate hours. Prerequisite(s): Grade of C or better in STAT 411 or STAT 481.

**STAT 494. Special Topics in Statistics, Probability and Operations Research. 3 or 4 hours.**

Course content announced prior to each semester in which it is given. Topics drawn from areas such as distribution theory; Bayesian inference; discrete optimization; applied probability models; resampling techniques; biostatistics; environmental sampling. Course Information: 3 undergraduate hours. 4 graduate hours. May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the department.

**STAT 496. Independent Study. 1-4 hours.**

Reading course supervised by a faculty member. Course Information: May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the instructor and approval of the department.

**STAT 501. Probability Theory I. 4 hours.**

Abstract measure theory, probability measures, Kolmogorov extension theorem, sums of independent random variables, the strong and weak laws of large numbers, the central limit theorem, characteristic functions, law of iterated logarithm, infinitely divisible laws. Course Information: Prerequisite(s): MATH 534 or consent of the instructor.

**STAT 502. Probability Theory II. 4 hours.**

Radon-Nikodym theorem, conditional expectations, martingales, stationary processes, ergodic theorem, stationary Gaussian processes, Markov chains, introduction to stochastic processes, Brownian motions. Course Information: Prerequisite(s): STAT 501.

**STAT 511. Advanced Statistical Theory I. 4 hours.**

Statistical models, criteria of optimum estimation, large sample theory, optimum tests and confidence intervals, best unbiased tests in exponential families, invariance principle, likelihood ratio tests. Course Information: Prerequisite(s): STAT 411.

**STAT 512. Advanced Statistical Theory II. 4 hours.**

Basic concepts in decision theory, prior and posterior distributions, Bayesian decision theory, hierarchical models, robustness, minimax analysis, invariance principle, sequential analysis, completeness. Course Information: Prerequisite(s): STAT 511.

**STAT 521. Linear Statistical Inference. 4 hours.**

Estimation and testing in linear models, generalized inverses of matrices,  $n$ -dimensional normal distribution, quadratic forms, likelihood ratio tests, best invariant tests, analysis of variance. Course Information: Prerequisite(s): STAT 411.

**STAT 522. Multivariate Statistical Analysis. 4 hours.**

Multivariate normal distribution, estimation of mean vector and covariance matrix, T-square statistic, discriminant analysis, general linear hypothesis, principal components, canonical correlations, factor analysis. Course Information: Prerequisite(s): STAT 521.

**STAT 531. Sampling Theory I. 4 hours.**

Foundations of survey design and inference for finite populations; the Horvitz-Thompson estimator; simple random, cluster, systematic survey designs; auxiliary size measures in design and inference. Course Information: Prerequisite(s): STAT 411.

**STAT 532. Sampling Theory II. 4 hours.**

Uses of auxiliary size measures in survey sampling; cluster sampling; systematic sampling; stratified sampling; superpopulation methods; randomized response methods; resampling; nonresponse; small area estimations. Course Information: Prerequisite(s): STAT 531.

**STAT 535. Optimal Design Theory I. 4 hours.**

Gauss-Markov theorem, optimality criteria, optimal designs for 1-way, 2-way elimination of heterogeneity models, repeated measurements, treatment-control; Equivalence theorem, approximate designs for polynomial regression. Course Information: Prerequisite(s): STAT 521.

**STAT 536. Optimal Design Theory II. 4 hours.**

Construction of optimal designs: BIB, Latin square and generalized Youden, repeated measurements, treatment-control studies; construction of factorial designs including orthogonal arrays. Course Information: Prerequisite(s): STAT 535 or consent of the instructor.

**STAT 591. Advanced Topics in Statistics, Probability and Operations Research. 4 hours.**

Special topics. Topics drawn from areas such as: Data analysis; Bayesian inference; Nonlinear models; Time series; Computer aided design; reliability models; game theory. Course Information: May be repeated. Prerequisite(s): Approval of the department.

**STAT 593. Graduate Student Seminar. 1 hour.**

For graduate students who wish to receive credit for participating in a learning seminar whose weekly time commitment is not sufficient for a reading course. This seminar must be sponsored by a faculty member. Course Information: Satisfactory/Unsatisfactory grading only. May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the department.

**STAT 595. Research Seminar. 1 hour.**

Current developments in research with presentations by faculty, students, and visitors. Researchers and practitioners from academia, industry and government will present talks on topics of current interest. Course Information: Satisfactory/Unsatisfactory grading only. May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the department.

**STAT 596. Independent Study. 1-4 hours.**

Reading course supervised by a faculty member. Course Information: May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the instructor and the department.

**STAT 598. Master's Thesis. 0-16 hours.**

Research work under the supervision of a faculty member leading to the completion of a master's thesis. Course Information: Satisfactory/Unsatisfactory grading only. Prerequisite(s): Approval of the department.

**STAT 599. Doctoral Thesis Research. 0-16 hours.**

Research work under the supervision of a faculty member leading to the completion of a doctoral thesis. Course Information: Satisfactory/Unsatisfactory grading only. May be repeated. Students may register in more than one section per term. Prerequisite(s): Approval of the department.