A candidate for a master’s degree must satisfy each of the following requirements:

1. Earn at least two semesters of residency credit and complete all requirements within five years.
2. Demonstrate computer programming ability by passing an approved undergraduate or graduate course in programming, or by passing an exam administered by the Department of Mathematics.
3. Perform satisfactorily in 30 hours of graduate work in a program approved by the director of graduate studies. At least 15 of these hours must be in Department of Mathematics courses numbered 600 or above.
4. Complete a master’s project or thesis for a master of science degree or a master’s thesis for a master of arts degree.
5. Pass an oral examination upon completion of the master’s project or master’s thesis. The exam will cover coursework as well as the project or thesis.
6. A master’s candidate must pass one of the written comprehensive exams given to doctoral students.

A candidate for a Ph.D. degree must satisfy each of the following requirements:

1. Earn at least four semesters of residency credit and complete all requirements within eight years.
2. Satisfy the same computer programming requirement as a master’s student.
3. Demonstrate reading competence in one approved foreign language by passing an approved course or by passing a translation exam administered by the Department of Mathematics.
4. Complete either the Pure Math option or the Applied Math option for qualifying examinations by the beginning of the sixth semester.
5. Pass at least six courses from the following two lists: a) the second tier courses or b) first-year comprehensive courses that are not basic qualifying examinations by the beginning of the sixth semester.
6. Pass the Teaching Assistant Teaching Seminar and perform a minimum of two semesters of instructional service.
7. Pass a preliminary oral exam on the chosen Ph.D. specialty area.
8. Write a Ph.D. thesis and defend it successfully during a final oral exam chaired by the thesis advisor.

The student/faculty ratio of about 2/1 makes it possible for graduate students to take reading courses from individual faculty members that are tailored to meet the student’s needs.

Minor in Mathematics

Graduate students in other departments who plan to offer mathematics as a (complete or partial) minor field for the Ph.D. should consult the director of graduate studies in mathematics for approval of their programs and for assignment of an advisor in the Department of Mathematics. This should be done at the earliest possible time in order to prevent disappointment for the student.

Following the faculty member’s name is a section number that students should use when registering for independent studies, reading, research, and thesis and dissertation courses with that particular professor.
Profs:  
I. Assani 45, Dynamical Systems, Nonlinear Waves, Solitons, Fiber Flows of Complex Fluids  
Prakash Belkale 57, Algebraic Geometry  
Roberto Camassa 16, Mathematical Modeling, Nonlinear Waves, Propagation, Dynamical Systems  
Ivan Cherednik 48, Representation Theory, Mathematical Physics, Algebraic Combinatorics  
M. Gregory Forest 7, Nonlinear Waves, Solitons, Fiber Flows of Complex Fluids  
Jane M. Hawkins 38, Ergodic Theory, Dynamical Systems  
Jingfang Huang 51, Integral Equation Methods and Fast Algorithms  
Christopher K.R.T. Jones 55, Applications of Dynamical Systems, Nonlinear Partial Differential Equations, Ocean Dynamics, Nonlinear Optics  
Shrawan Kumar 46, Representation Theory, Geometry of Flag Varieties  
Richard McLaughlin 50, Fluid Dynamics and Turbulent Transport  
Sorin Mitran 58, Computational Methods for Partial Differential Equations, Continuum-Kinetic Methods, Fluid Dynamics, Biological Fluid Dynamics and Mechanics  
Peter J. Mucha 60, Network Analysis, Fluid Dynamics, Computer-Generated Animation  
Robert A. Proctor 43, Combinatorics, Representation Theory  
Richard Rimanyi 59, Topology, Geometry, Singularities  
Lev Rozansky 52, Three-Dimensional Topology  
Michael E. Taylor 40, Partial Differential Equations, Harmonic Analysis, Operator Theory  
Alexandre N. Varchenko 47, Geometry, Mathematical Physics  
Jonathan M. Wahl 28, Algebraic Geometry  
Mark Williams 36, Partial Differential Equations  

Assoc Profs:  
David Adalsteinsson 1, Applied Mathematics and Scientific Computation  
Hans Christianson 8, Semiclassical Analysis and Partial Differential Equations  
Jeremy Marzuola 9, Partial Differential Equations  
Jason Metcalfe 61, Partial Differential Equations  
Laura Miller 22, Mathematical Biology, Biomechanics, and Fluid Dynamics  
Justin Sawon 64, Differential Geometry  

Assn Profs:  
Yaiza Canzani 18, Geometric Analysis, Semiclassical Analysis, Perturbation Theory  
Boye Griffith 10, Numerical Analysis, Mathematical Biology  
JiuZong Hong 13, Representation Theory  
Katie Newhall 12, Applied Mathematics, Stochastic Differential Equations  
Nancy Rodriguez 15, Partial Differential Equations, Stochastic Differential Equations  
David Rose 17, Categorification, Low-Dimensional Topology, Representation Theory  

EMs:  
Joseph A. Cima  
James N. Damon  
Patrick Eberlein  
Ladnor Gessinger  
Sue E. Goodman  
William H. Graves  

Robert G. Heyneman  
Norberto Kerzman  
Ancel C. Mewborn  
Karl Petersen  
John Pfaltzgraff  
Joseph Plante  
Michael Schlessinger  
William W. Smith  
Johann Sonner  
James Stasheff  
Warren R. Wogen  

MATH  
Advanced Undergraduate and Graduate-level Courses  
MATH 406. Mathematical Methods in Biostatistics. 1 Credit.  
Special mathematical techniques in the theory and methods of biostatistics as related to the life sciences and public health. Includes brief review of calculus, selected topics from intermediate calculus, and introductory matrix theory for applications in biostatistics.  
Requisites: Prerequisite, MATH 232.  
Gen Ed: Q1.  
Grading status: Letter grade.  

MATH 410. Teaching and Learning Mathematics. 4 Credits.  
Study of how people learn and understand mathematics, based on research in mathematics, mathematics education, psychology, and cognitive science. This course is designed to prepare undergraduate mathematics majors to become excellent high school mathematics teachers. It involves field work in both the high school and college environments.  
Gen Ed: EE-Field Work.  
Grading status: Letter grade.  

MATH 411. Developing Mathematical Concepts. 3 Credits.  
Permission of the instructor. An investigation of various ways elementary concepts in mathematics can be developed. Applications of the mathematics developed will be considered.  
Gen Ed: Q1.  
Grading status: Letter grade.  

MATH 418. Basic Concepts of Analysis for High School Teachers. 3 Credits.  
An examination of high school mathematics from an advanced perspective, including number systems and the behavior of functions and equations. Designed primarily for prospective or practicing high school teachers.  
Requisites: Prerequisites, MATH 233 and 381.  
Gen Ed: Q1.  
Grading status: Letter grade.  

MATH 515. History of Mathematics. 3 Credits.  
A general survey of the history of mathematics with emphasis on elementary mathematics. Some special problems will be treated in depth.  
Requisites: Prerequisite, MATH 381.  
Gen Ed: Q1.  
Grading status: Letter grade.  

MATH 521. Advanced Calculus I. 3 Credits.  
A grade of A- or better in STOR 215 may substitute for MATH 381. The real numbers, continuity and differentiability of functions of one variable, infinite series, integration.  
Requisites: Prerequisites, MATH 233 and 381.  
Gen Ed: Q1.  
Grading status: Letter grade.
MATH 521H. Advanced Calculus I. 3 Credits.
A grade of A- or better in STOR 215 may substitute for MATH 381. The real numbers, continuity and differentiability of functions of one variable, infinite series, integration.
Requisites: Prerequisites, MATH 233 and 381.
Gen Ed: QI.
Grading status: Letter grade.

MATH 522. Advanced Calculus II. 3 Credits.
Functions of several variables, the derivative as a linear transformation, inverse and implicit function theorems, multiple integration.
Requisites: Prerequisites, MATH 383 and 521.
Gen Ed: QI.
Grading status: Letter grade.

MATH 522H. Advanced Calculus II. 3 Credits.
Functions of several variables, the derivative as a linear transformation, inverse and implicit function theorems, multiple integration.
Requisites: Prerequisites, MATH 383 and 521.
Gen Ed: QI.
Grading status: Letter grade.

MATH 523. Functions of a Complex Variable with Applications. 3 Credits.
The algebra of complex numbers, elementary functions and their mapping properties, complex limits, power series, analytic functions, contour integrals, Cauchy's theorem and formulae, Laurent series and residue calculus, elementary conformal mapping and boundary value problems, Poisson integral formula for the disk and the half plane.
Requisites: Prerequisite, MATH 383.
Gen Ed: QI.
Grading status: Letter grade.

MATH 524. Elementary Differential Equations. 3 Credits.
Linear differential equations, power series solutions, Laplace transforms, numerical methods.
Requisites: Prerequisite, MATH 383.
Gen Ed: QI.
Grading status: Letter grade.

MATH 525. Mathematical Methods for the Physical Sciences I. 3 Credits.
Theory and applications of Laplace transform, Fourier series and transforms, Sturm-Liouville problems. Students will be expected to do some numerical calculations on either a programmable calculator or a computer. This course has an optional computer laboratory component: MATH 525L.
Requisites: Prerequisite, MATH 383.
Gen Ed: QI.
Grading status: Letter grade.

MATH 525L. Laboratory for Mathematical Methods for the Physical Sciences I. 1 Credit.
Training in the use of symbolic and numerical computing packages and their application to the MATH 525 lecture topics. Students will need a CCI-compatible computing device.
Requisites: Prerequisite, MATH 383; pre- or corequisite, MATH 529.
Grading status: Letter grade.

MATH 529M. Laboratory for Mathematical Methods for the Physical Sciences II. 1 Credit.
A grade of A- or better in STOR 215 may substitute for MATH 381. Divisibility, Euclidean algorithm, congruence classes, Euler's function, primitive roots, Chinese remainder theorem, quadratic residues, number-theoretic functions, Farey and continued fractions, Gaussian integers.
Requisites: Prerequisite, MATH 381.
Gen Ed: QI.
Grading status: Letter grade.

MATH 532. Advanced Calculus II. 3 Credits.
Functions of several variables, the derivative as a linear transformation, inverse and implicit function theorems, multiple integration.
Requisites: Prerequisites, MATH 383 and 521.
Gen Ed: QI.
Grading status: Letter grade.

MATH 533. Elementary Theory of Numbers. 3 Credits.
A grade of A- or better in STOR 215 may substitute for MATH 381. Divisibility, Euclidean algorithm, congruence classes, residue classes, Euler's function, primitive roots, Chinese remainder theorem, quadratic residues, number-theoretic functions, Farey and continued fractions, Gaussian integers.
Requisites: Prerequisite, MATH 381.
Gen Ed: QI.
Grading status: Letter grade.

MATH 534. Elements of Modern Algebra. 3 Credits.
Binary operations, groups, subgroups, cosets, quotient groups, rings, polynomials.
Requisites: Prerequisite, MATH 383.
Gen Ed: QI.
Grading status: Letter grade.

MATH 535. Introduction to Probability. 3 Credits.
Introduction to mathematical theory of probability covering random variables; moments; binomial, Poisson, normal and related distributions; generating functions; sums and sequences of random variables; and statistical applications.
Requisites: Prerequisite, MATH 233.
Gen Ed: QI.
Grading status: Letter grade
Same as: STOR 435.

MATH 547. Linear Algebra for Applications. 3 Credits.
Algebra of matrices with applications: determinants, solution of linear systems by Gaussian elimination, Gram-Schmidt procedure, eigenvalues. MATH 416 may not be taken for credit after credit has been granted for MATH 547.
Requisites: Prerequisite, MATH 233 or 283.
Gen Ed: QI.
Grading status: Letter grade.

MATH 548. Combinatorial Mathematics. 3 Credits.
Counting selections, binomial identities, inclusion-exclusion, recurrences, Catalan numbers. Selected topics from algorithmic and structural combinatorics, or from applications to physics and cryptography.
Requisites: Prerequisite, MATH 381 or STOR 215.
Gen Ed: QI.
Grading status: Letter grade.

MATH 550. Topology. 3 Credits.
Introduction to topics in topology, particularly surface topology, including classification of compact surfaces, Euler characteristic, orientability, vector fields on surfaces, tessellations, and fundamental group.
Requisites: Prerequisites, MATH 233 and 381; co-requisite, MATH 383; A grade of A- or better in STOR 215 may substitute for MATH 381.
Gen Ed: QI.
Grading status: Letter grade.
MATH 551. Euclidean and Non-Euclidean Geometries. 3 Credits.
A grade of A- or better in STOR 215 may substitute for MATH 381. Critical study of basic notions and models of Euclidean and non-Euclidean geometries: order, congruence, and distance.
Requisites: Prerequisite, MATH 381.
Gen Ed: QI.
Grading status: Letter grade.

MATH 553. Mathematical and Computational Models in Biology. 3 Credits.
This course introduces analytical, computational, and statistical techniques, such as discrete models, numerical integration of ordinary differential equations, and likelihood functions, to explore various fields of biology.
Requisites: Prerequisites, BIOL 201 and 202, MATH 231, and either MATH 232 or STOR 155; Co-requisite, BIOL 553L/MATH 553L; permission of the instructor for students lacking the prerequisites.
Gen Ed: QI.
Grading status: Letter grade
Same as: BIOL 553.

MATH 553L. Mathematical and Computational Models in Biology Laboratory. 1 Credit.
This lab introduces analytical, computational, and statistical techniques, such as discrete models, numerical integration of ordinary differential equations, and likelihood functions, to explore various fields of biology.
Requisites: Prerequisites, BIOL 201 and 202, MATH 231, and either MATH 232 or STOR 155; Co-requisite, BIOL 553/MATH 553; Permission of the instructor for students lacking the prerequisites.
Grading status: Letter grade

MATH 555. Introduction to Dynamics. 3 Credits.
Topics will vary and may include iteration of maps, orbits, periodic points, attractors, symbolic dynamics, bifurcations, fractal sets, chaotic systems, systems arising from differential equations, iterated function systems, and applications.
Requisites: Prerequisite, MATH 383.
Gen Ed: QI.
Grading status: Letter grade

MATH 556. Introduction to Numerical Analysis. 3 Credits.
Requires some knowledge of computer programming. Iterative methods, interpolation, polynomial and spline approximations, numerical differentiation and integration, numerical solution of ordinary and partial differential equations.
Requisites: Prerequisite, MATH 383.
Gen Ed: QI.
Grading status: Letter grade.

MATH 577. Linear Algebra. 3 Credits.
Vector spaces, linear transformations, duality, diagonalization, primary and cyclic decomposition, Jordan canonical form, inner product spaces, orthogonal reduction of symmetric matrices, spectral theorem, bilinear forms, multilinear functions. A much more abstract course than MATH 416 or 547.
Requisites: Prerequisites, MATH 381 and 383; A grade of A- or better in STOR 215 may substitute for MATH 381.
Gen Ed: QI.
Grading status: Letter grade.

MATH 580. Algebraic Structures. 3 Credits.
Permutation groups, matrix groups, groups of linear transformations, symmetry groups; finite abelian groups. Residue class rings, algebra of matrices, linear maps, and polynomials. Real and complex numbers, rational functions, quadratic fields, finite fields.
Requisites: Prerequisite, MATH 547 or 577.
Gen Ed: QI.
Grading status: Letter grade.

MATH 590. Topics in Mathematics. 3 Credits.
Permission of the instructor. Topics may focus on matrix theory, analysis, algebra, geometry, or applied and computational mathematics.
Repeat rules: May be repeated for credit; may be repeated in the same term for different topics; 12 total credits. 4 total completions.
Grading status: Letter grade.

MATH 594. Nonlinear Dynamics. 3 Credits.
Interdisciplinary introduction to nonlinear dynamics and chaos. Fixed points, bifurcations, strange attractors, with applications to physics, biology, chemistry, finance.
Requisites: Prerequisite, MATH 383; permission of the instructor for students lacking the prerequisite.
Grading status: Letter grade
Same as: PHYS 594.

MATH 635. Probability. 3 Credits.
Requisites: Prerequisite, STOR 634; permission of the instructor for students lacking the prerequisite.
Grading status: Letter grade
Same as: STOR 635.

MATH 641. Enumerative Combinatorics. 3 Credits.
Basic counting; partitions; recursions and generating functions; signed enumeration; counting with respect to symmetry, plane partitions, and tableaux.
Requisites: Prerequisite, MATH 578.
Grading status: Letter grade.
MATH 643. Combinatorial Structures. 3 Credits.
Graph theory, matchings, Ramsey theory, extremal set theory, network flows, lattices, Moebius inversion, q-analogs, combinatorial and projective geometries, codes, and designs.
Requisites: Prerequisite, MATH 578.
Grading status: Letter grade.

MATH 653. Introductory Analysis. 3 Credits.
Requires knowledge of advanced calculus. Elementary metric space topology, continuous functions, differentiation of vector-valued functions, implicit and inverse function theorems. Topics from Weierstrass theorem, existence and uniqueness theorems for differential equations, series of functions.
Grading status: Letter grade.

MATH 656. Complex Analysis. 3 Credits.
A rigorous treatment of complex integration, including the Cauchy theory. Elementary special functions, power series, local behavior of analytic functions.
Requisites: Prerequisite, MATH 653.
Grading status: Letter grade.

MATH 657. Qualitative Theory of Differential Equations. 3 Credits.
Requires knowledge of linear algebra. Existence and uniqueness theorems, linear and nonlinear systems, differential equations in the plane and on surfaces, Poincare-Bendixson theory, Lyapunov stability and structural stability, critical point analysis.
Requisites: Prerequisite, MATH 653.
Grading status: Letter grade.

MATH 661. Scientific Computation I. 3 Credits.
Requires some programming experience and basic numerical analysis. Error in computation, solutions of nonlinear equations, interpolation, approximation of functions, Fourier methods, numerical integration and differentiation, introduction to numerical solution of ODEs, Gaussian elimination.
Grading status: Letter grade
Same as: ENVR 661.

MATH 662. Scientific Computation II. 3 Credits.
Theory and practical issues arising in linear algebra problems derived from physical applications, e.g., discretization of ODEs and PDEs. Linear systems, linear least squares, eigenvalue problems, singular value decomposition.
Requisites: Prerequisite, MATH 661.
Grading status: Letter grade
Same as: COMP 662, ENVR 662.

MATH 668. Methods of Applied Mathematics I. 3 Credits.
Requires an undergraduate course in differential equations. Contour integration, asymptotic expansions, steepest descent/stationary phase methods, special functions arising in physical applications, elliptic and theta functions, elementary bifurcation theory.
Grading status: Letter grade
Same as: ENVR 668.

MATH 669. Methods of Applied Mathematics II. 3 Credits.
Perturbation methods for ODEs and PDEs, WKBJ method, averaging and modulation theory for linear and nonlinear wave equations, long-time asymptotics of Fourier integral representations of PDEs, Green’s functions, dynamical systems tools.
Requisites: Prerequisite, MATH 668.
Grading status: Letter grade
Same as: ENVR 669.

MATH 676. Modules, Linear Algebra, and Groups. 3 Credits.
Requires knowledge of linear algebra and algebraic structures. Modules over rings, canonical forms for linear operators and bilinear forms, multilinear algebra, groups and group actions.
Repeat rules: May be repeated for credit. 6 total credits. 2 total completions.
Grading status: Letter grade.

MATH 677. Groups, Representations, and Fields. 3 Credits.
Internal structure of groups, Sylow theorems, generators and relations, group representations, fields, Galois theory, category theory.
Requisites: Prerequisite, MATH 676.
Grading status: Letter grade.

MATH 680. Geometry of Curves and Surfaces. 3 Credits.
Topics include (curves) Frenet formulas, isoperimetric inequality, theorems of Crofton, Fenchel, Fary-Milnor; (surfaces) fundamental forms, Gaussian and mean curvature, special surfaces, geodesics, Gauss-Bonnet theorem.
Requisites: Prerequisite, advanced calculus.
Grading status: Letter grade.

MATH 681. Introductory Topology. 3 Credits.
Requisites: Prerequisites, MATH 653 and 680.
Grading status: Letter grade.

MATH 690. Topics In Mathematics. 3 Credits.
Permission of the department. Directed study of an advanced topic in mathematics. Topics will vary.
Repeat rules: May be repeated for credit; may be repeated in the same term for different topics; 12 total credits. 4 total completions.
Grading status: Letter grade.

MATH 691H. Honors Research in Mathematics. 3 Credits.
Permission of the director of undergraduate studies. Readings in mathematics and the beginning of directed research on an honors thesis.
Gen Ed: EE-Mentored Research.
Grading status: Letter grade.

MATH 692H. Honors Thesis in Mathematics. 3 Credits.
Permission of the director of undergraduate studies. Completion of an honors thesis under the direction of a member of the faculty. Required of all candidates for graduation with honors in mathematics.
Gen Ed: EE-Mentored Research.
Grading status: Letter grade.

Graduate-level Courses

MATH 751. Introduction to Partial Differential Equations. 3 Credits.
Basic methods in partial differential equations. Topics may include: Cauchy-Kowalewski Theorem, Holmgren's Uniqueness Theorem, Laplace's equation, Maximum Principle, Dirichlet problem, harmonic functions, wave equation, heat equation.
Requisites: Prerequisite, MATH 653.

MATH 753. Measure and Integration. 3 Credits.
Lebesgue and abstract measure and integration, convergence theorems, differentiation, Radon-Nikodym theorem, product measures, Fubini theorem, Lebesgue spaces, invariance under transformations, Haar measure and convolution.
Requisites: Prerequisite, MATH 653; permission of the instructor for students lacking the prerequisite.
MATH 754. Introductory Functional Analysis. 3 Credits.
Hahn-Banach and separation theorems. Normed and locally convex spaces, duals of spaces and maps, weak topologies; closed graph and open mapping theorems, uniform boundedness theorem, linear operators. Spring.
Requisites: Prerequisite, MATH 753.

MATH 755. Advanced Complex Analysis. 3 Credits.
Laurent series; Mittag-Leffler and Weierstrass Theorems; Riemann mapping theorem; Runge's theorem; additional topics chosen from: harmonic, elliptic, univalent, entire, meromorphic functions; Dirichlet problem; Riemann surfaces.
Requisites: Prerequisite, MATH 656.

MATH 756. Several Complex Variables. 3 Credits.
Elementary theory, the Cousin problems, domains of holomorphy, Runge domains and polynomial approximation, local theory, complex analytic structures, coherent analytic sheaves and Stein manifolds, Cartan's theorems.
Requisites: Prerequisite, MATH 656.

MATH 761. Numerical ODE/PDE, I. 3 Credits.
Single, multistep methods for ODEs: stability regions, the root condition; stiff systems, backward difference formulas; two-point BVPs; stability theory; finite difference methods for linear advection diffusion equations.
Requisites: Prerequisites, MATH 661 and 662.
Same as: ENVR 761, MASC 781.

MATH 762. Numerical ODE/PDE, II. 3 Credits.
Elliptic equation methods (finite differences, elements, integral equations); hyperbolic conservation law methods (Lax-Friedrich, characteristics, entropy condition, shock tracking/capturing); spectral, pseudo-spectral methods; particle methods, fast summation, fast multipole/vortex methods.
Requisites: Prerequisite, MATH 761.
Same as: ENVR 762, MASC 782.

MATH 768. Mathematical Modeling I. 3 Credits.
Nondimensionalization and identification of leading order physical effects with respect to relevant scales and phenomena; derivation of classical models of fluid mechanics (lubrication, slender filament, thin films, Stokes flow); derivation of weakly nonlinear envelope equations. Fall.
Requisites: Prerequisites, MATH 661, 662, 668, and 669.
Same as: ENVR 763, MASC 783.

MATH 769. Mathematical Modeling II. 3 Credits.
Current models in science and technology: topics ranging from material science applications (e.g., flow of polymers and LCPs); geophysical applications (e.g., ocean circulation, quasi-geostrophic models, atmospheric vortices).
Requisites: Prerequisites, MATH 661, 662, 668, and 669.
Same as: ENVR 764, MASC 784.

MATH 771. Commutative Algebra. 3 Credits.
Field extensions, integral ring extensions, Nullstellensatz and normalization theorem, derivations and separability, local rings, valuations, completions, filtrations and graded rings, dimension theory.
Requisites: Prerequisite, MATH 677.

MATH 773. Lie Groups. 3 Credits.
Lie groups, closed subgroups, Lie algebra of a Lie group, exponential map, compact groups, Haar measure, orthogonality relations, Peter-Weyl theorem, maximal torus, representations, Weyl character formula, homogeneous spaces.
Requisites: Prerequisites, MATH 676 and 781.

MATH 774. Lie Algebras. 3 Credits.
Nilpotent, solvable, and semisimple Lie algebras, structure theorems, root systems, Weyl groups, weights, classification of semisimple Lie algebras and their finite dimensional representations, character formulas.
Requisites: Prerequisite, MATH 676.

MATH 775. Algebraic Geometry. 3 Credits.
Topics may include: algebraic varieties, algebraic functions, abelian varieties, projective and complete varieties, algebraic groups, schemes and the Grothendieck theory, Riemann-Roch theorem.
Requisites: Prerequisite, MATH 771.

MATH 776. Algebraic Topology. 3 Credits.
Homotopy and homology; simplicial complexes and singular homology; other topics may include cohomology, universal coefficient theorems, higher homotopy groups, fibre spaces.
Requisites: Prerequisites, MATH 676 and 681.

MATH 781. Differentiable Manifolds. 3 Credits.
Calculus on manifolds, vector bundles, vector fields and differential equations, Lie Groups, connections, de Rham cohomology.
Requisites: Prerequisites, MATH 653, 676, and 681.

MATH 782. Differential Geometry. 3 Credits.
Riemannian geometry, first and second variation of area and applications, effect of curvature on homology and homotopy, Chern-Weil theory of characteristic classes, Chern-Gauss-Bonnet theorem.
Requisites: Prerequisite, MATH 781.

MATH 853. Harmonic Analysis. 3 Credits.
Permission of the instructor. Subjects may include topological groups, abstract harmonic analysis, Fourier analysis, noncommutative harmonic analysis and group representation, automorphic forms, and analytic number theory.

MATH 854. Advanced Functional Analysis. 3 Credits.
Permission of the instructor. Subjects may include operator theory on Hilbert space, operators on Banach spaces, locally convex spaces, vector measures, Banach algebras.

MATH 857. Theory of Dynamical Systems. 3 Credits.
Permission of the instructor. Topics may include: ergodic theory, topological dynamics, stability theory of differential equations, classical dynamical systems, differentiable dynamics.

MATH 891. Special Topics. 1-3 Credits.
Advance topics in current research in statistics and operations research.
Repeat rules: May be repeated for credit; may be repeated in the same term for different topics.
Same as: GNET 891, BCB 891.

MATH 892. Topics in Computational Mathematics. 3 Credits.
Topics may include: finite element method; numerical methods for hyperbolic conservation laws, infinite dimensional optimization problems, variational inequalities, inverse problems.
Requisites: Prerequisites, MATH 661 and 662.

MATH 893. Topics in Algebra. 3 Credits.
Topics from the theory of rings, theory of bialgebras, homological algebra, algebraic number theory, categories and functions.
Requisites: Prerequisite, MATH 677.
MATH 894. Topics in Combinatorial Mathematics. 3 Credits.
Topics may include: combinatorial geometries, coloring and the critical problem, the bracket algebra, reduced incidence algebras and generating functions, binomial enumeration, designs, valuation module of a lattice, lattice theory.
Requisites: Prerequisite, MATH 641; permission of the instructor for students lacking the prerequisite.

MATH 895. Special Topics in Geometry. 3 Credits.
Topics may include elliptic operators, complex manifolds, exterior differential systems, homogeneous spaces, integral geometry, submanifolds of Euclidean space, geometrical aspects of mathematical physics.
Requisites: Prerequisite, MATH 781.

MATH 896. Topics in Algebraic Topology. 3 Credits.
Topics primarily from algebraic or differential topology, such as cohomology operations, homotopy groups, fibre bundles, spectral sequences, K-theory, cobordism, Morse Theory, surgery, topology of singularities.
Requisites: Prerequisite, MATH 776; permission of the instructor for students lacking the prerequisite.

MATH 920. Seminar and Directed Readings. 1-3 Credits.

MATH 921. Seminar. 3 Credits.

MATH 925. Practical Training Course in Mathematics. 3-5 Credits.
Required preparation, passed Ph.D. written comprehensive exam. An opportunity for the practical training of a graduate student interested in mathematics is identified. Typically this opportunity is expected to take the form of a summer internship.
Repeat rules: May be repeated for credit.

MATH 992. Master's (Non-Thesis). 3 Credits.

MATH 993. Master's Research and Thesis. 3 Credits.
This should not be taken by students electing non-thesis master's projects.
Repeat rules: May be repeated for credit.

MATH 994. Doctoral Research and Dissertation. 3 Credits.