Mathematics

Degrees Offered

• Master of Science
• Doctor of Philosophy

Nature of the Program

The Department of Mathematics offers graduate programs leading to the Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees. The master’s degree program offers specializations in pure and applied mathematics. The Ph.D. program provides for a common core of fundamental mathematics followed by specialized studies culminating in an original research dissertation directed by a faculty advisor. Depending on the student's program and interests, there are diverse career opportunities available in education, government, and industry.

Financial Support

Many graduate students receive financial support in the form of a graduate teaching assistantship, which provides a stipend and a full waiver of university tuition. These are awarded taking into account primarily the student's academic record along with the letters of recommendation and any supplementary information reflecting on the student's potential for success in the program. In some cases, teaching experience and/or the potential for outstanding teaching can be a consideration. Teaching assistants have the opportunity to work with the faculty in the Department's Institute for Mathematics Learning (IML). A small number of research assistantships are also available, usually through external funding.

Applications to the graduate program received by the January 15 deadline will receive full consideration for financial support for the subsequent fall semester. Late applications are accepted, but students are advised to check with the graduate director as to the availability of assistantships. Other financial aid includes partial university tuition waivers and part-time positions such as grading assisting in the instructional computer labs. TOEFL/IELTS scores are required for international students whose native language is not English, and passing the university SPEAK test is required for international students to be awarded teaching assistantships.

FACULTY

DIRECTOR

• Earl Scime - Ph.D. (University of Wisconsin-Madison)
  Plasma Physics

PROFESSORS

• Ian Christie - Ph.D. (University of Dundee)
  Emeritus, Numerical Partial Differential Equations
• Krzysztof Ciesielski - Ph.D. (Warsaw University)
  Analysis, Topology, Set Theory
• Marjorie Darrah - Ph.D. (West Virginia University)
  Educational technology, algorithms
• Jessica Deshler - Ph.D. (University of New Mexico)
  Undergraduate Mathematics Education
• Harvey Diamond - Ph.D. (MIT)
  Approximation Theory, Applied Mathematics
• Harry Gingold - D.Sc. (Israel Institute of Technology)
  Differential Equations, Asymptotic Methods
• John Goldwasser - Ph.D. (University of Wisconsin-Madison)
  Combinatorics, Graph Theory
• Henry W. Gould - M.A. (University of Virginia)
  Emeritus, Combinatorics, Number Theory, Special Functions
• Harumi Hattori - Ph.D. (Rensselaer Polytechnic Institute)
  Differential Equations, Continuum Mechanics
• Snehalata Huzurbazar - Ph.D. (Colorado State University)
  Statistics, Data Science
• Hong-Jian Lai - Ph.D. (Wayne State University)
  Associate Chair, Graph Theory, Matroid Theory
• Dening Li - Ph.D. (Fudan University)
Partial Differential Equations
- Rong Luo - Ph.D. (West Virginia University)
- David Miller - Ph.D. (Oklahoma State University)
  Undergraduate mathematics education
- Robert Mnatsakanov - Ph.D. (Moscow Inst. of Electronics and Mathematics)

Statistics
- Laura Pyzdrowski - Ed.D. (West Virginia University)
  Mathematics Education, Instructional Technology
- Michael E. Mays - Ph.D. (Penn. State University)
  Emeritus, Number Theory
- Sherman D. Riemenschneider - Ph.D. (Syracuse University)
  Emeritus, Approximation Theory, Wavelet Theory
- Adrian Tudorascu - Ph.D. (Carnegie Mellon University)
  Partial Differential Equations
- Jerzy Wojciechowski - Ph.D. (University of Cambridge)
  Combinatorics, Graph Theory
- Cun-Quan Zhang - Ph.D. (Simon Fraser University)
  Graph Theory, Combinatorics

ASSOCIATE PROFESSORS
- Olgur Celikbas - Ph.D. (University of Nebraska)
  Commutative Algebra
- Gary H. Ganser
  Emeritus, Applied Mathematics, Fluid Mechanics, Numerical Analysis
- Adam Halasz - Ph.D. (State University of New York at Stony Brook)
  Mathematical Biology, Swarm Robotics
- Kevin Milans - Ph.D. (University of Illinois)
  Combinatorics, Graph Theory
- James E. Moseley - Ph.D. (Purdue University)
  Emeritus, Partial Differential Equations, Modeling
- Vicki Sealey - Ph.D. (Arizona State University)
  Mathematics Education
- Charis Tsikkou - Ph.D. (Brown University)
  Nonlinear PDE

ASSISTANT PROFESSORS
- Ela Celikbas - Ph.D. (University of Nebraska)
  Commutative Algebra, Representation Theory
- Qingtian Zhang - Ph.D. (Pennsylvania State University)
  Analysis of PDEs

PROFESSORS EMERITI
- Ian Christie - Ph.D. University of Dundee
  Numerical Partial Differential Equations
- Gary H. Ganser
  Applied Mathematics, Fluid Mechanics, Numerical Analysis
- Henry W. Gould - M.A. (University of Virginia)
  Combinatorics, Number Theory, Special Functions
- Michael E. Mays - Ph.D. (Penn State University)
  Number Theory
- James E. Moseley - Ph.D. (Purdue University)
  Partial Differential Equations, Modeling
- Sherman D. Riemenschneider - Ph.D. (Syracuse University)
  Approximation Theory, Wavelet Theory
Admissions

M.S. IN MATHEMATICS

Programs are available for students to study pure and applied mathematics. In addition to the university requirements for admission (http://catalog.wvu.edu/graduate/graduateeducationatwestvirginiauniversity/#classificationstext), applicants to the master’s program must have an undergraduate major in mathematics (or a strongly allied field), including at least one semester of advanced calculus (at WVU this course is Math 451 (http://catalog.wvu.edu/undergraduate/eberycollegeofartsandsciences/mathematics/#coursetext)) and courses in linear algebra and modern algebra. Students with deficiencies who also qualify for provisional admission (http://catalog.wvu.edu/graduate/graduateeducationatwestvirginiauniversity/#Provisional_Graduate_Students) may be admitted provisionally; deficiencies are expected to be made up in the first year of study. A minimum of three semesters of calculus is normally required for provisional admission, but students can often complete their remaining calculus courses during the summer prior to full-time enrollment.

As part of the graduate application, students must submit all official undergraduate transcripts, three letters of recommendation from individuals having experience with the applicant’s mathematical ability, and a personal statement. The personal statement should indicate the student’s mathematical interests and how those align with research interests of faculty within the department as well as any experience relevant to potential teaching opportunities.

PH.D. IN MATHEMATICS

In addition to the university requirements for admission (http://catalog.wvu.edu/graduate/graduateeducationatwestvirginiauniversity/#classificationstext), applicants to the Ph.D. program must have completed a graduate degree similar to the M.S. in Mathematics (http://catalog.wvu.edu/graduate/eberycollegeofartsandsciences/mathematics/#masterstext). Students lacking a master’s degree who have with an exceptionally strong undergraduate background who also qualify for provisional admission (http://catalog.wvu.edu/graduate/graduateeducationatwestvirginiauniversity/#Provisional_Graduate_Students) may sometimes be admitted provisionally, with twelve–eighteen credit hours of additional coursework required. These students would be expected to have completed a year of Advanced Calculus and Linear Algebra, with a cumulative GPA of 3.8 or higher.

As part of the graduate application, students must submit all official undergraduate and graduate transcripts, three letters of recommendation from individuals having experience with the applicant’s mathematical ability, and a personal statement. The personal statement should indicate the student’s mathematical interests and how those align with research interests of faculty within the department as well as any experience relevant to potential teaching opportunities. For students interested in admission to the Ph.D. without a M.S degree, the personal statement should also indicate how the student’s prior coursework has prepared them to pursue the doctorate without pursuing a master’s degree first.

GRADUATE TEACHING ASSISTANTSHIPS

All completed applications submitted by the January 15th deadline will automatically be considered for support in the form of a graduate teaching assistantship (GTA).

List of Admission Requirements for the M.S.:
- See the steps to apply for admissions and access the application here (https://graduateadmissions.wvu.edu/how-to-apply/)
- Transcripts from all institutions attended
- Three letters of recommendation from academic references
- Statement of purpose (personal statement)

List of Admission Requirements for the Ph.D.:
- See the steps to apply for admissions and access the application here (https://graduateadmissions.wvu.edu/how-to-apply/)
- Transcripts from all institutions attended
- Three letters of recommendation from academic references
- Statement of purpose (personal statement)

International Applicants:
- See the steps to apply for admissions and access the application here (https://graduateadmissions.wvu.edu/how-to-apply/)
- International applications should view additional requirements here (http://catalog.wvu.edu/graduate/graduateeducationatwestvirginiauniversity/#internationaltext) and here (https://graduateadmissions.wvu.edu/how-to-apply/apply-for-2020-2021/international-graduate-applicant/)
- Language proficiency is required in order to hold a graduate teaching assistantship. See here (https://elli.wvu.edu/testing-resources/english-proficiency-gtas/).

Application Deadlines:
- The Mathematics programs admit students for the Fall and Spring semesters
- For Fall admission, completed applications should be submitted no later than January 15th
- For Spring admission, completed applications should be submitted no later than October 15th
- Applications submitted after the deadline may be considered on a space-available basis
Exceptional Ph.D. applicants may be nominated by the Mathematics program for competitive University Fellowships. Qualified applicants will be notified if they are nominated. More information on WVU fellowships can be found here (https://graduateeducation.wvu.edu/fellowships/).

Certain application requirements may be waived based on a preliminary review of an application by the program.

Major Code: 1457

For specific information on the following program, please see the link to the right:

- Mathematics, M.S.

For specific information on the following program, please see the link to the right:

- Mathematics, Ph.D.

Degree Progress

All Students will have a plan of study and will receive, at minimum, a yearly letter of evaluation.

MASTER OF SCIENCE

The M.S. program usually requires two years of full-time study. In their first year, students will normally complete the Linear Algebra and the Real Analysis requirements. Ideally, students in the Pure Mathematics Area of Emphasis take at least one of the subject areas of the M.S. Advanced Exam by no later than August at the beginning of their second year. To be in good standing, a student is expected to maintain at least a 3.0 average (B) in mathematics courses and to present at least a 3.0 average in all work offered in fulfillment of the degree program.

ADVISING

Each student will be assigned to be advised by the Graduate Program Director upon entry to the program who will assist the student in designing a written plan of study that takes into account the student’s interests and needs as well as the aims of the department’s graduate programs. Later changes in the plan are possible only through mutual agreement of the student and the Director.

PROGRAMS

The student’s plan of study is developed in one of these areas of emphasis: pure mathematics or applied mathematics. The programs are designed either for students who intend to pursue a doctor of philosophy in mathematics or the mathematical sciences or for those planning to seek employment in education, government, or industry. At least thirty-one semester hours of approved coursework are required.

Note: MATH 590/690/696/697/790/797 may not be counted for credit to satisfy graduate course requirements.

EXAMINATIONS/THESIS/PROJECTS

Upon beginning graduate study, all M.S. students are given a basic exam in advanced calculus and linear algebra for purposes of course placement. Depending on the program chosen, students must complete examinations, a thesis, or a project as a graduation requirement.

DOCTOR OF PHILOSOPHY

The doctor of philosophy is a research program in which the final product is an original, publishable research thesis. For students entering with regular admission status, the program requires a minimum of twenty-four hours of approved coursework along with research and graduate seminar requirements. As reflected in the interests and expertise of the faculty, students may specialize in a variety of areas of pure, applied, and discrete mathematics as well as research in undergraduate mathematics education. Beyond any coursework taken to remove deficiencies while a provisional student, a minimum of twenty-four hours of approved coursework (not including research or one-credit seminar courses) is required of all doctoral students, which must include a major area of four courses and two minor areas of two courses each. Certain level and distribution requirements apply to a student’s program. Six credits of seminar (Five credits of Math 696 and one credit of Math 694) are required.

DISSERTATION COMMITTEE

Students normally select a dissertation advisor at the end of their first year in the program, though this can also be done in the second year. Upon selecting a dissertation advisor, a student must request that the Director of Graduate Studies select a dissertation committee of at least five members (with a dissertation advisor as chairperson and one member from outside the department) for them.

EXAMINATIONS AND DISSERTATION

All doctoral students must demonstrate that they are prepared to undertake doctoral work and research by passing an entrance examination, given each year in April and August, within two years after enrolling. Specifically, students entering the program in a given calendar year must pass the entrance examinations by the end of the spring semester in the calendar year two years after. Students must pass examinations in two areas from among the four areas of algebra, real analysis, topology, and differential equations. During the fourth year after enrolling, the student is expected to pass a qualifying oral and written examination and present an approved dissertation prospectus. Any minor area in which the student has not achieved a GPA of at least 3.5 also requires a written examination. If the qualifying examination results are unsatisfactory, the dissertation committee may reexamine the student.
once. After the Qualifying Examination is successfully completed the student is considered a Candidate for the Ph.D. The dissertation typically requires from one to two years of research and writing, with the defense completed by the end of the fifth year.

**COURSES**

**MATH 521. Numerical Analysis. 3 Hours.**
PR: MATH 261 and computer language. Number systems and errors, interpolation by polynomials, linear systems, scalar algebraic equations and systems, optimization, approximation theory, integration initial, and boundary value problems.

**MATH 522. Numerical Solution of PDE. 3 Hours.**
PR: MATH 261 and computer language. Finite difference and finite element methods for elliptic, parabolic, and hyperbolic problems. Study of properties such as consistency, convergence, stability, conservation, and discrete maximum principles.

**MATH 534. Modern Algebra For Teachers 2. 3 Hours.**
PR: MATH 341 or MATH 533. Further investigation of algebraic structures begun in MATH 533. (Emphasis on topics helpful to secondary-school mathematics teachers.) Topics include Sylow theory, Jordan-Holder Theorem, rings and quotations, field extensions, Galois theory and solution by radicals.

**MATH 535. Foundations of Geometry. 3 Hours.**
PR: MATH 251 (Designed especially for secondary mathematics teachers; others admitted with departmental approval obtained before registration.) Incidence geometrics with models; order for lines and planes; separation by angles and by triangles; congruence; introduction to Euclidean geometry; geometry.

**MATH 541. Modern Algebra. 3 Hours.**
PR: MATH 341 Concepts from set theory and the equivalence of the Axiom of Choice. Zorn's Lemma and the Well-Ordering Theorem; a study of the structure of groups, rings, fields, and vector spaces; elementary factorization theory; extensions of ring and fields; modules and ideals; and lattices.

**MATH 543. Linear Algebra. 3 Hours.**
PR: MATH 441. Review of theory of groups and fields; linear vector spaces including the theory of duality; full linear group; bilinear and quadratic forms; and theory of isotropic and totally isotropic spaces.

**MATH 545. Number Theory 1. 3 Hours.**
PR: MATH 155 or MATH 156. Introduction to classical number theory covering such topics as divisibility, the Euclidean algorithm, Diophantine equations, congruencies, primitive roots, quadratic residues, number-theoretic functions, distribution of primes, irrationals, and combinatorial methods. Special numbers such as those of Bernoulli, Euler, and Stirling.

**MATH 551. Real Variables 1. 3 Hours.**

**MATH 555. Complex Variables 1. 3 Hours.**
PR: MATH 451. Number systems, the complex plane and its geometry. Holomorphic functions, power series, elementary functions, complex integration, representation theorems, the calculus of residues, analytic continuation and analytic function, elliptic functions, Holomorphic functions of several complex variables.

**MATH 560. Introduction to Dynamical Systems and Applications. 3 Hours.**
This course is an introduction to the theory of dynamical systems, whose goal is to study the behavior of systems with known laws of evolution. We cover basic topics including fixed points, periodic orbits, linearization, local and global behavior of solutions, bifurcations, and chaos. The theory will be accompanied by applications from biology, chemistry, and physics.

**MATH 563. Mathematics Modeling. 3 Hours.**
PR: MATH 261 and MATH 465. This course is concerned with construction, analysis, and interpretation of mathematical models that shed light on important problems in the sciences. Emphasis is on the simplification, dimensional analysis, and scaling of mathematical models.

**MATH 564. Intermediate Differential Equations. 3 Hours.**

**MATH 566. Intermediate Partial Differential Equations. 3 Hours.**
The goal of this course is to study the behavior of mathematical models arising from applied sciences with known boundary and initial conditions. Basic topics include first and second order equations, well-posedness, method of characteristics, energy methods, maximum principle, Green's functions, Duhamel's principle and shock waves. Knowledge of ordinary differential equations is necessary for successful completion of this course.

**MATH 567. Advanced Calculus. 3 Hours.**
per semester. PR: MATH 261. Primarily for engineers and scientists. Functions of several variables, partial differentiation, implicit functions, transformations; line surface and volume integrals; point set theory, continuity, integration, infinite series and convergence, power series, and improper integrals.
MATH 568. Advanced Calculus. 3 Hours.
per semester. PR: MATH 567. Primarily for engineers and scientists. Functions of several variables, partial differentiation, implicit functions, transformations; line surface and volume integrals; point set theory, continuity, integration, infinite series and convergence, power series, and improper integrals.

MATH 571. Combinatorial Analysis 1. 3 Hours.
PR: One year of calculus. Permutations, combinations, generating functions, principle of inclusion and exclusion, distributions, partitions, compositions, trees and networks.

MATH 573. Graph Theory. 3 Hours.
PR: MATH 343 and MATH 283. Basic concepts of graphs and digraphs, trees, cycles and circuits, connectivity, traversibility, planarity, colorability, and chromatic polynomials. Further topics from among factorization, line graph, covering and independence, graph matrices and groups, Ramsey theory, and packing theory.

MATH 578. Applied Discrete Mathematics. 3 Hours.
PR: MATH 375 or MATH 378 or MATH 341 or MATH 343 or MATH 283. Topics may include combinatorial optimization, applied coding theory, integer programming, linear programming, matching, and network flows.

MATH 581. Topology 1. 3 Hours.
PR: MATH 452. A detailed treatment of topological spaces covering the topics of continuity, convergence, compactness, and connectivity; product and identification space, function spaces, and the topology in Euclidean spaces.

MATH 590. Teaching Practicum. 1-3 Hours.
PR: Consent. Supervised practice in college teaching of mathematics. Note: This course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. Grading will be P/F.

MATH 591. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

MATH 592. Directed Study. 1-6 Hours.
Directed study, reading, and/or research.

MATH 593. Special Topics. 1-6 Hours.
A study of contemporary topics selected from recent developments in the field.

MATH 595. Independent Study. 1-9 Hours.
Faculty supervised study of topics not available through regular course offerings.

MATH 631. RUME 1: Introduction to Undergraduate Mathematics Education Research. 3 Hours.
PR: (MATH 451 and MATH 452) or MATH 551 or MATH 567. Research literature will provide background for investigating issues in knowing and learning undergraduate mathematics. Students will be introduced to research design, data collection, and qualitative analysis related to investigating aspects of learning undergraduate mathematics.

MATH 641. Modern Algebra 2. 3 Hours.
PR: MATH 545. Concepts from set theory and the equivalence of the axiom of choice. Zorn's Lemma and the Well-Ordering Theorem; a study of the structure of groups, rings, fields, and vector spaces; elementary factorization theory; extensions of ring and fields; modules and ideals; and lattices.

MATH 645. Number Theory 2. 3 Hours.
PR: MATH 305. Introduction to classical number theory covering such topics as divisibility, the Euclidean algorithm, Diophantine equations, congruencies, primitive roots, quadratic residues, number-theoretic functions distribution of primes, irrationals, and combinatorial methods. Special numbers such as those of Bernoulli, Euler, and Stirling.

MATH 651. Real Variables 2. 3 Hours.
PR: MATH 551. A development of the Lebesgue integral, function spaces and differentiation, complex measures, the Lebesgue-Radon- Nikodym theorem.

MATH 681. Topology 2. 3 Hours.
PR: MATH 581. A detailed treatment of topological spaces covering the topics of continuity, convergence, compactness, and connectivity; product and identification space, function spaces, and the topology in Euclidean spaces.

MATH 683. Set Theory and Applications. 3 Hours.
PR: MATH 541 or MATH 551 or MATH 581. The course concentrates on the typical methods of set theory, transfinite induction, and Zorn's Lemma with emphasis on their applications outside set theory. The fundamentals of logic and basic set theory are included.

MATH 690. Teaching Practicum. 1-3 Hours.
PR: Consent. Supervised practice in college teaching of mathematics. Note: This course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It also provides a mechanism for students not on assistantships to gain teaching experience. (Grading will be S/U.).

MATH 691. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.
MATH 692. Directed Study. 1-6 Hours.
Directed study, reading, and/or research.

MATH 693. Special Topics. 1-6 Hours.
A study of contemporary topics selected from recent developments in the field.

MATH 694. Seminar. 1-6 Hours.
Special seminars arranged for advanced graduate students.

MATH 695. Independent Study. 1-9 Hours.
Faculty supervised study of topics not available through regular course offerings.

MATH 696. Graduate Seminar. 1-3 Hours.
PR: Consent. Each graduate student will present at least one seminar to the assembled faculty and graduate student body of his or her program.

MATH 697. Research. 1-9 Hours.
PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project or a dissertation. (Grading may be S/U).

MATH 698. Thesis or Dissertation. 1-6 Hours.
PR: Consent. This is an optional course for programs that wish to provide formal supervision during the writing of student reports (698), or dissertations (798). Grading is normal.

MATH 699. Graduate Colloquium. 1-6 Hours.
PR: Consent. For graduate students not seeking coursework credit but who wish to meet residency requirements, use of the University's facilities, and participate in academic and cultural programs. Note: Graduate students who are not actively involved in coursework or research are entitled, through enrollment in their department's 699/799 Graduate Colloquium to consult with graduate faculty, participate in both formal and informal academic activities sponsored by their program, and retain all of the rights and privileges of duly enrolled students. Grading is P/F; colloquium credit may not be counted against credit requirements for masters programs. Registration for one credit of 699/799 graduate colloquium satisfies the University requirement of registration in the semester in which graduation occurs.

MATH 732. RUME 2: Learning Theories. 3 Hours.
PR: MATH 631. Students will investigate learning theories related to undergraduate mathematics education research and use these learning theories to formulate research questions and to collect and analyze data.

MATH 733. RUME 3: Advanced Learning Theories. 3 Hours.
PR: MATH 732. Students will expand their understanding of learning theories related to undergraduate mathematics education research and their ability to use these learning theories to formulate research questions and to collect and analyze data.

MATH 745. Analytic Number Theory 1. 3 Hours.
PR: MATH 551 and MATH 645. Selected topics in analytic number theory such as the prime number theorem, primes in an arithmetical progression, the Zeta function, the Goldbach conjecture.

MATH 746. Analytic Number Theory 2. 3 Hours.
PR: MATH 745. Selected topics in analytic number theory such as the prime number theorem, primes in an arithmetical progression, the Zeta function, the Goldbach conjecture.

MATH 747. Advanced Topics in Modern Algebra. 1-6 Hours.
This course will cover selected topics of modern algebra as an extension of the basic material covered in the 541-641 sequence. The topic will be selected from algebraic number theory, noncommutative rings and modules, representation theory, algebraic model theory, homological algebra. (May be repeated for credit with consent.).

MATH 751. Functional Analysis 1. 3 Hours.
PR: MATH 551. A study of Banach and Hilbert spaces; the Hahn-Banach theorem, uniform boundedness principle, and the open mapping theorem; dual spaces and the Riesz representation theorem; Banach algebras; and spectral theory.

MATH 752. Functional Analysis 2. 3 Hours.
PR: MATH 751. A study of Banach and Hilbert spaces; the Hahn-Banach theorem, uniform boundedness principle, and the open mapping theorem; dual spaces and the Riesz representation theorem; Banach algebras; C* algebras; spectral theory.

MATH 757. Theory of Partial Differential Equations 1. 3 Hours.

MATH 758. Theory of Partial Differential Equations 2. 3 Hours.

MATH 771. Matroid Theory 1. 3 Hours.
PR: MATH 541 or MATH 543) and (MATH 571 or MATH 573). Independent sets, circuits, bases, rank functions, closure operators and close sets, other axiom systems, geometric representations, duality and minors, linear and algebraic representability, connectivity, basics of partial ordered sets, flats and lattices, relationship between lattices and matroids.
MATH 772. Matroid Theory. 3 Hours.
PR: MATH 771. Matroid representability, representability over finite fields, algebraic matroids, matroid constructions, higher connectivity of matroids, binary and ternary matroids, the splitter theorem and its applications, submodular functions, matroid intersection theorem, matroids in combinatorial optimizations.

MATH 773. Advanced Topics in Graph Theory. 3 Hours.
PR: MATH 573. (May be repeated for credit toward graduation.) Topics may include: Algebraic graph theory, random graph theory, extremal graph theory, topological graph theory, and structural graph theory.

MATH 777. Advanced Topics in Combinatorics. 3 Hours.
PR: MATH 571. Topics may include: Combinatorics on finite sets, probabilistic methods in combinatorics, enumerations, Polya Theory, combinatorial matroid theory, coding theory, combinatorial identities, infinite combinatorics, transversal theory, and matroid theory. (May be repeated for credit with consent.).

MATH 780. Seminar in Topology. 1-12 Hours.

MATH 783. Set Theory and Applications. 3 Hours.
PR: MATH 683. The course elaborates on the applications of the transfinite induction, and combines recursion methods with other elements of modern set theory, including the use of additional axioms of set theory, introduction to the forcing method.

MATH 790. Teaching Practicum. 1-3 Hours.
PR: Consent. Supervised practice in college teaching of mathematics. Note: This course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading will be S/U.).

MATH 791. Advanced Topics. 1-6 Hours.
PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

MATH 792. Directed Study. 1-6 Hours.
Directed study, reading, and/or research.

MATH 793. Special Topics. 1-6 Hours.
A study of contemporary topics selected from recent developments in the field.

MATH 795. Independent Study. 1-9 Hours.
Faculty supervised study of topics not available through regular course offerings.

MATH 796. Graduate Seminar. 1-3 Hours.
PR: Consent. Each graduate student will present at least one seminar to the assembled faculty and graduate student body of his or her program.

MATH 797. Research. 1-9 Hours.
PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or dissertation. (Grading may be S/U.).

MATH 930. Professional Development. 1-6 Hours.
Professional development courses provide skill renewal or enhancement in a professional field or content area (e.g., education, community health, geology). These tuition-waived continuing education courses are graded on a pass/fail grading scale and do not apply as graduate credit toward a degree program.