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 mathematics education faculty of the Department’s Institute for Mathematics Learning (IML). A small number of research assistantships are also available. Applications from students requesting financial aid should be received no later than February 15 to ensure full consideration 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. Applications for admission (alone) can also be considered at other times, but for best consideration, particularly for the Ph.D. program, students should adhere to the February 15 deadline. 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, with a university minimum requirement of 79 on the TOEFL iBT and 6.5 on the IELTS.

FACULTY

INTERIM CHAIR

- Marjorie Darrah - Ph.D. (West Virginia University)
  Educational Technology, Algorithms

PROFESSORS

- Ian Christie - Ph.D. (University of Dundee)
  Emeritus, Numerical Partial Differential Equations
- Krzysztof Ciesielski
  Analysis, Topology, Set Theory
- Marjorie Darrah - Ph.D. (West Virginia University)
  Educational technology, algorithms
- Harvey Diamond - Ph.D. (MIT)
  Approximation Theory, Applied Mathematics
- Harry Gingold - D.Sc. (Israel Institute of Technology)
  Differential Equations, Asymptotic Methods
- John Goldwasser
  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
- Hong-Jian Lai
  Associate Chair, Graph Theory, Matroid Theory
- Dening Li
  Partial Differential Equations
- Rong Luo - Ph.D. (West Virginia University)
  Discrete Mathematics
- 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
- Jerzy Wojciechowski - Ph.D. (University of Cambridge)
  Combinatorics, Graph Theory
- Cun-Quan Zhang
  Graph Theory, Combinatorics

ASSOCIATE PROFESSOR

- Jessica Deshler - Ph.D. (University of New Mexico)
  Undergraduate Mathematics Education
- Nicole Engelke-Infante - Ph.D. (Arizona State University)
  Undergraduate Mathematics Educaiton
- 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
- Adrian Tudorascu - Ph.D. (Carnegie Mellon University)
  Partial Differential Equations

ASSISTANT PROFESSOR

- Olgur Celikbas - Ph.D. (University of Nebraska)
  Commutative Algebra
- Zachariah Etienne - Ph.D. (University of Illinois)
  Computational relativity

Admissions

MASTER'S ADMISSION INFORMATION

Admission to the M.S. program requires a WVU admission application and submission of applicable transcripts. International students must supply a passing TOEFL score or other acceptable evidence of English proficiency. Students seeking financial aid should also supply an assistantship application and three letters of recommendation. GRE scores are not required.

Programs are available for students to study pure and applied mathematics. For regular admission (http://catalog.wvu.edu/graduate/graduateeducationatwestvirginiauniversity/#classificationstext) to the M.S. program, students should have the equivalent of an undergraduate major in mathematics, including at least one semester of advanced calculus (Math 451 or equivalent) and courses in linear algebra and modern algebra. Students with deficiencies 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.

PH.D. ADMISSION REQUIREMENTS

For regular admission (http://catalog.wvu.edu/graduate/graduateeducationatwestvirginiauniversity/#classificationstext), applicants for the Ph.D. program must have completed a graduate degree similar to the M.S. in mathematics. Students with an exceptionally strong undergraduate background may sometimes be admitted provisionally, with twelve–eighteen credit hours of additional coursework required.

The following materials should be submitted:

- A WVU admission application
- Official undergraduate and graduate transcripts
- Three letters of recommendation from individuals having experience with the applicant's mathematical ability
- TOEFL or IELTS scores for students whose native language is not English

Master of Science

DEGREE REQUIREMENTS

- **Credit Hours**: Students are required to complete a minimum of 31 credit hours in Mathematics at the 400, 500 or 600 levels. While some courses may fulfill several degree requirements, the same course cannot be used to fulfill more than one requirement.
- **Grade Point Average:** Students must earn a minimum overall GPA of 2.75, a minimum grade of B- in all courses applied to the degree with the exception of elective courses, and a minimum GPA of 3.0 in all coursework applied to the degree.
- **Area of Emphasis:** Students must select between a Pure Mathematics or an Applied Mathematics area of emphasis by the end of their first year of study.
- **Master's Thesis:** all students who have earned an overall GPA of 3.25 or higher may decide to write a thesis.
- **Completion Requirements:**
    - Pure Mathematics AoE: In addition to completion of required coursework, students must pass the M. S. Advanced Exam by passing two subject areas from among Real Analysis, Algebra, Topology, and Differential Equations. Any exam can only be attempted three times.
    - Applied Mathematics AoE: In addition to completion of required coursework, students must present a project under the supervision of a faculty member, complete an internship and present an internship report, or complete a thesis.

Curriculum Requirements:

Foundation Courses		7
Real Analysis Requirement		
Select one of the following:		
MATH 452	Introduction to Real Analysis 2	
MATH 551	Real Variables 1	
Linear Algebra Requirement		
MATH 543	Linear Algebra	
MATH 694	Seminar	
Area of Emphasis		12
Select one option:		
Pure Mathematics		
Applied Mathematics		
Electives		12
Select four courses in consultation with adviser:		
MATH 521	Numerical Analysis	
MATH 522	Numerical Solution of PDE	
MATH 535	Foundations of Geometry	
MATH 541	Modern Algebra	
MATH 545	Number Theory 1	
MATH 551	Real Variables 1	
MATH 555	Complex Variables 1	
MATH 563	Mathematics Modeling	
MATH 564	Intermediate Differential Equations	
MATH 567	Advanced Calculus	
MATH 568	Advanced Calculus	
MATH 571	Combinatorial Analysis 1	
MATH 573	Graph Theory	
MATH 578	Applied Discrete Mathematics	
MATH 631	RUME 1: Introduction to Undergraduate Mathematics Education Research	
MATH 641	Modern Algebra 2	

MATH 645	Number Theory 2	
MATH 651	Real Variables 2	
MATH 681	Topology 2	
MATH 683	Set Theory and Applications	
MATH 697	Research *	
STAT 512	Statistical Methods 2 (or above,)	
STAT 513	Design of Experiments	
STAT 516	Forensic Statistics	
STAT 521	Statistical Analysis System Programming	
STAT 522	Advanced Statistical Analysis System Programming	
STAT 531	Sampling Theory and Methods	
STAT 545	Applied Regression Analysis	
STAT 555	Categorical Data Analysis	
STAT 561	Theory of Statistics 1	
STAT 562	Theory of Statistics 2	
CS 510	Formal Specification of Language	
CS 520	Advanced Analysis of Algorithms	
CS 525	Computational Complexity	
CS 572	Advanced Artificial Intelligence Techniques	
CS 573	Advanced Data Mining	
Total Hours		31

* 3 credits maximum of MATH 697 may be used for students writing a thesis

APPLIED MATHEMATICS AREA OF EMPHASIS

CORE COURSES:		9
MATH 521	Numerical Analysis	
MATH 563	Mathematics Modeling	
MATH 564	Intermediate Differential Equations	
COMPLEX VARIABLES ELECTIVE:		3
Select one course:		
MATH 456	Complex Variables	
MATH 555	Complex Variables 1	
MATH 568	Advanced Calculus	
Total Hours		12

PURE MATHEMATICS AREA OF EMPHASIS

CORE COURSES:		9
Select one sequence: *		
MATH 541 & Math 641	Modern Algebra and	
MATH 551 & Math 651	Real Variables 1 and	
MATH 581 & Math 681	Topology 1 and	
Select one course from the following: *		
MATH 541	Modern Algebra	
MATH 551	Real Variables 1	
MATH 651	Real Variables 2	
ELECTIVES: *		3
MATH 541	Modern Algebra	
MATH 545	Number Theory 1	
MATH 551	Real Variables 1	

MATH 555	Complex Variables 1
MATH 564	Intermediate Differential Equations
MATH 571	Combinatorial Analysis 1
MATH 573	Graph Theory
MATH 581	Topology 1
Total Hours	12

* May not use a course used for another requirement.

Doctor of Philosophy

Degree Requirements

- **Credit Hours:** Students are required to complete a minimum number of 54 graduate credit hours in Mathematics at the 500 level or above, with a minimum of 18 credits at the 700 level (excluding seminar and MATH 797), with at least 12 from discrete mathematics, algebra, foundations, applied mathematics, and topology.
- **Grade Point Average:** Students must earn a minimum overall GPA of 2.75, and of 3.00 in coursework applied to their graduate program.
- **Program of Study:** The Ph.D. program assumes an M.S.-level background in graduate mathematics for admission. The program provides for a common core of fundamental mathematics followed by specialized studies culminating in an original research dissertation directed by a faculty advisor.
- **Comprehensive Examination:** The comprehensive examination consists of two parts. For students with research areas in discrete mathematics, algebra, foundations, analysis, applied mathematics, or topology, a written exam is given in the students research area, based on the corresponding course work and other specialized knowledge needed for the dissertation. Paired with the written exam is an oral exam, to be given within one week of the written exam and covering similar material. These exams are led by the dissertation supervisor in consultation with the student's committee. Students whose research area is in research in undergraduate mathematics education are assigned a written research project, whose results are examined at an oral presentation. The second part of the comprehensive examination is the public presentation of the dissertation prospectus, followed by questioning by the student's committee. The purpose of this is to demonstrate that the student has mastered the relevant literature in his or her field, and has developed a clear, realizable and program-suitable research topic, along with a research plan to achieve the desired results. The comprehensive exam is considered to have been passed when both parts have been successfully completed. In case a student fails to achieve a 3.5 GPA overall in one or both of their elective sequences, a written examination will be prepared in the corresponding elective courses, which the student must pass in the judgement of the committee.
- **Dissertation:** The research upon which the dissertation is based must conform to scholastic standards and constitute an original and publishable contribution to mathematics.
- **Benchmarks:** Students must demonstrate that they have mastered basic graduate mathematics by passing the Department's Ph.D. Entrance Examination by no later than the spring of their second full academic year in the program. The examination is over two subjects selected by the student from the four areas of algebra, real analysis, differential equations, and topology. The exams are given twice a year, in August and April. The student's dissertation committee is appointed after the Ph.D. Entrance Examination has been passed, and upon selection of an advisor, typically by the end of the second year. The Comprehensive Examination is normally taken at the end of the third year of study, or in the first semester of the fourth year. The dissertation defense should occur by the end of the fifth year in the program.
- **Additional Requirements:** Each Ph.D. student must demonstrate a reading knowledge of French, German, or Russian or another language as approved by the Graduate Programs Committee.

Curriculum Requirements

RESEARCH AREA CONCENTRATION	12
Discrete Mathematics, Algebra and Foundations *	
MATH 573 & MATH 773	Graph Theory and Advanced Topics in Graph Theory
MATH 683 & MATH 783	Set Theory and Applications and Set Theory and Applications
MATH 745 & MATH 746	Analytic Number Theory 1 and Analytic Number Theory 2
MATH 747 & 747	Advanced Topics in Modern Algebra and Advanced Topics in Modern Algebra
MATH 771 & MATH 772	Matroid Theory 1 and Matroid Theory 2
Analysis, Applied Mathematics, and Topology *	
MATH 751 & MATH 752	Functional Analysis 1 and Functional Analysis 2

MATH 757 & MATH 758	Theory of Partial Differential Equations 1 and Theory of Partial Differential Equations 2	
MATH 780	Seminar in Topology	
Research in Undergraduate Mathematic Education		
MATH 631	RUME 1: Introduction to Undergraduate Mathematics Education Research	
MATH 732	RUME 2: Learning Theories	
MATH 733	RUME 3: Advanced Learning Theories	
MATH 734	RUME 4: Research and Professional Preparation	
SEMINARS AND RESEARCH:		30
MATH 694	Seminar	
MATH 696	Graduate Seminar	
MATH 797	Research	
ELECTIVE COURSES **		12
Discrete Mathematics, Algebra and Foundations		
MATH 573 & MATH 773	Graph Theory and Advanced Topics in Graph Theory	
MATH 683 & MATH 783	Set Theory and Applications and Set Theory and Applications	
MATH 745 & MATH 746	Analytic Number Theory 1 and Analytic Number Theory 2	
MATH 747 & 747	Advanced Topics in Modern Algebra and Advanced Topics in Modern Algebra	
MATH 771 & MATH 772	Matroid Theory 1 and Matroid Theory 2	
Analysis, Applied Mathematics, and Topology		
MATH 751 & MATH 752	Functional Analysis 1 and Functional Analysis 2	
MATH 757 & MATH 758	Theory of Partial Differential Equations 1 and Theory of Partial Differential Equations 2	
Total Hours		54

* Select two pairs rather than four individual courses to satisfy the requirement.

** Choose at least one pair outside of Research Area Concentration. May not select courses already chosen to satisfy a Research Area Concentration requirement. Students who choose RUME as their research area must select at least two courses from the Discrete Mathematics, Algebra, and Foundation group, and two courses from the Analysis, Applied Mathematics, and Topology group.

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.

ADVISORY COMMITTEE

Each student will be assigned an advisory committee consisting of at least three members of the graduate faculty. This committee 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 committee.

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. Depending upon the program selected, thirty to thirty-three 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/THESES/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 examination 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. Within three years of 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.

Major Learning Outcomes

MATHEMATICS

The Department of Mathematics offers the M.S. and Ph.D. degrees and has programs emphasizing pure and applied mathematics (M.S., Ph.D.)

Major goals include the following:

Students in the M.S. program receive broad, rigorous training in areas fundamental to mathematics, with options depending on their post-graduation goals:

- Master's level students planning to continue graduate study will have a solid grounding in mathematics basic to their intended graduate programs.
- Students preparing for industry jobs will possess the breadth of applicable mathematical knowledge and experience needed for the challenges of mathematics in industry.
- Students preparing for teaching positions will have a broad based deep appreciation of the core of mathematics and effective pedagogy.

Ph.D. students continue advanced training with the following goals:

- Obtain specialized, advanced training in a major field giving them a research-level background and the ability to contribute in their field.
- Under the mentorship of their thesis supervisor, conduct independent, original research in mathematics leading to a significant contribution in their field of study.
- Become acquainted with mathematical research in a variety of fields through course work, seminars, colloquia, and conference presentations.
- Gain significant experience in teaching at the university level and in communicating mathematics.

Policies

M.S. EXAMINATIONS

Students in the Pure Mathematics area of emphasis must pass the M.S. Advanced Exam by passing two subject area exams at the MS level, taken from among Real Analysis, Algebra, Topology, and Differential Equations. No more than three attempts at any one subject area exam are permitted. The exams must be completed by the end of the third year after initial enrollment. The same exams are used for the Ph.D. Entrance Examination, with different expectations for the two degrees, characterized as "M.S. level pass" and "Ph.D. level pass". However any subject area exam may be taken in total at most three time while a graduate student in either program.

Students in the Applied Mathematics area of emphasis complete a project under the supervision of the chair of their committee. A written report together with a public presentation are required. An appropriate internship related to the area of study may also be used as approved by the committee.

PH.D. EXAMINATIONS

Students must pass the Ph.D. Entrance Examination by the end of their second year in the program. This entails passing two subject area exams at the Ph.D. level, from among Algebra, Real Analysis, Topology, and Differential equations. Any exam may be taken up to three times. Note that Graduate Teaching Assistants are expected to require at most two attempts to pass a subject area exam. Any subject area exam may be taken in total at most three times while a graduate student in either program.

Students must pass the Qualifying Examination by the end of their third year. Students are examined by their committee in their major area, via written and oral exam. Students whose dissertation area is Research in Undergraduate Mathematics Education will be provided by their committee with a research assignment, based on content areas and research techniques in the field, to be completed over a four-week period. The results will be presented in written form and orally examined by the student's committee. Students in any major area must present a satisfactory thesis prospectus. The student's committee must approve the outcome of both the exam (written and oral) and the prospectus.

For each minor area in which the GPA is not 3.5 or above, as part of the Qualifying Exam, the student must take an exam over the minor area to assess competency.