

DEPARTMENT OF MATHEMATICS

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GRADUATE PROGRAMS

The department offers programs leading to the Master of Science and Doctor of Philosophy degrees. At the master's and at the doctoral levels, there are two degrees: the degree of Master of Science in Mathematics and the degree of Master of Science in Applied Mathematics.

A student must satisfy all of the general requirements of the graduate school of the University as well as the more specific requirements of the Department to earn either a master's or doctoral degree. Each graduate student is assigned an advisory committee consisting of faculty members during the first year of study. The committee's primary responsibility is to help the student plan an appropriate and sufficiently broad program of course work and study, which will satisfy both the degree requirements and the special interests of the student. With the aid of the advisory committee, each student must present a study plan indicating how he or she intends to satisfy the requirements for a graduate degree.

The main requirements are as follows.

Master of Science in Mathematics

A minimum of 27 credit hours of approved course work, at least 18 of which must be at the 400 level or higher, is required for the M.S. degree in Mathematics. Courses in two of the following three basic areas must be included among the 27 credit hours required for graduation: Abstract Algebra (MATH 401 and MATH 402), Analysis (MATH 423 and one of MATH 424 or MATH 425), and Topology (MATH 461). The student must pass a comprehensive oral examination on three areas, two of which must be selected from the basic ones listed above (although no particular courses are specified). The third area for the examination may be any approved subject.

A student in the M.S. program in Mathematics may substitute the comprehensive exam examination requirement with an expository or original thesis, which will count as 6 credit hours of course work. The thesis will be defended in the course of an oral examination, during which the student will be questioned about the thesis and related topics. These two variants correspond to plan A and plan B in the Graduate School literature.

Master of Science in Applied Mathematics

The Department offers specialized programs in Applied Mathematics. For each of the programs, there is a minimum requirement of 27 credit hours of course work, at least 18 of which must be at the 400 level or higher. Students in the program must complete course work requirement in each of the following disjoint groups:

- At least 15 hours offered by the Department of Mathematics.
- At least 6 hours of courses offered outside the Department of Mathematics.
- 6 hours of thesis work (see below) or successfully passing a comprehensive exam.

Although individual programs of course work leading to a master's degree in Applied Mathematics cannot have a large common core of requirements because of the great diversity of topics used in applications, all

students pursuing a Master of Science in Applied Mathematics are strongly advised to take Introduction to Numerical Analysis (MATH 431) and Mathematical Modeling (MATH 441). In addition, to add breadth to the student's education, the set of courses taken within the Department must include three credit hours of approved course work in at least three of the following seven subjects. The courses listed are examples of suitable courses on the given subject. A course can be used to satisfy only one breadth area.

Applied Mathematics Breadth Areas

- **Analysis and Linear Analysis.** MATH 471 (not suitable for credit towards the Ph.D. requirements), MATH 423, or MATH 405
- **Probability and its Applications.** MATH 439 (Bayesian Scientific Computing), MATH 487 (Stochastic Processes in Engineering and Science), or MATH 491 (Probability)
- **Numerical Analysis and Scientific Computing.** MATH 431 (Intro to Numerical Analysis), MATH 432 (Numerical Differential Equations), or MATH 433 (Numerical Optimization)
- **Differential Equations.** MATH 435 (Ordinary Differential Equations), MATH 445 (Intro to Partial Differential Equations), MATH 448 (Applied Partial Differential Equations), or MATH 449 (Dynamical Systems for Biology and Medicine)
- **Inverse Problems and Imaging.** MATH 439 (Bayesian Scientific Computing), MATH 440 (Computational Inverse Problems), or MATH 475 (Mathematics of Imaging)
- **Logic and Discrete Mathematics.** MATH 406 (Math Logic and Model Theory), MATH 408 (Cryptology), or MATH 410 (Automata and Formal Languages)
- **Life Science.** MATH 441 (Mathematical Modeling), MATH 449 (Dynamical Systems for Biology and Medicine), MATH 478 (Computational Neuroscience), or MATH 487 (Stochastic Processes in Engineering and Science)

Other suitable courses for students in Applied Mathematics include MATH 413 (Graph Theory), MATH 424 (Functional Analysis), MATH 425 (Complex Analysis), MATH 427 (Convexity), MATH 428 (Fourier Analysis), MATH 444 (Data mining and Pattern Recognition), MATH 469 (Calculus of Variations), MATH 475 (Mathematics of Imaging), MATH 492 (Probability), and MATH 495 (Combinatorics).

The student must pass a comprehensive oral examination on three areas, two of which must be in the list for the breadth requirement (although no particular courses are specified). The third area for the examination may be any approved subject.

A student in the M.S. program in Applied Mathematics may substitute the comprehensive examination requirement with an expository or original thesis, which will count as 6 credit hours of course work. The thesis will be defended in the course of an oral examination, during which the student will be questioned about the thesis and related topics. These two variants correspond to plan A and plan B in the Graduate School literature.

Master of Science in Applied Mathematics, Entrepreneurial Track

The Master of Science in Applied Mathematics, Entrepreneurial Track, obtained through the Entrepreneurial Program in Mathematics and Computation, is a degree designed to provide training in applied mathematics for entrepreneurs who have a business idea that depends heavily on mathematics. They wish to learn enough mathematics to refine their business idea and, at the same time, acquire the business skills needed to bring this idea to the marketplace. The Master of Science in Applied Mathematics, Entrepreneurial Track, is also appropriate for industrial mathematicians who need to effectively utilize mathematical tools in a business context. It expands our basic Master of Applied Mathematics program by tightly integrating business training into the curriculum. The Entrepreneurial

Track provides instruction and real business-world experience to students who have a background in mathematics and a vision for new and growing ventures.

Candidates for the M.S. in Mathematics, Entrepreneurial Track, must complete at least 27 hours of course work and present a master's thesis. It is expected that a business plan be an integral part of the thesis. The two-year program includes these course requirements:

MATH 483-4 Mathematics for Innovation I and II, 6 hours
MATH 651 Thesis, 9 hours
ENTP 429 New Venture Creation, 3 hours
ENTP 441 Technology Entrepreneurship, 3 hours
Mathematics Technical Elective, 3 hours
Restricted Elective, 3 hours

The New Venture Creation and Technology Entrepreneurship courses will be offered by the Weatherhead School of Management. The Technical Elective is a 400-level or higher mathematics course or other technical elective appropriate to an individual student's program of study, as approved by the Mathematics Entrepreneurship Program Committee. The Restricted Elective is a course in mathematics, science, engineering, or management appropriate to an individual student's program of study, as approved by the Mathematics Entrepreneurship Program Committee.

Ph.D. Program

The doctorate is conferred not merely upon completion of a stipulated course of study, but rather upon clear demonstration of scholarly attainment and capability of original research work in mathematics. A doctoral student may plan either a traditional program of studies in mathematics (Mathematics track) or a program of studies oriented toward applied mathematics (Applied Mathematics track). In either case, each student must take 36 credit hours of approved courses with a grade average of B or better. For students entering with a master's degree in a mathematical subject compatible with our program, as determined by the Graduate Committee, this requirement is reduced to 18 credit hours of approved courses.

In addition to the course work, all Ph.D. students in both tracks must complete the following specific requirements:

- Pass the Ph.D. Qualifying Examination, which consists of examinations on three different subjects. All examinations are general proficiency examinations which may or may not be connected to specific courses. The topics for each subject are spelled out in a syllabus, periodically updated, which is available to the student. Students are expected to take the Qualifying Examination by the end of the second year of study and to successfully pass all parts of it by the beginning of their sixth semester in the Ph.D. program. Each track requires examination in a different set of subjects. More specifically:

Mathematics Track: A doctoral student in this track must take examinations on Abstract Algebra and Real Analysis. The third subject is to be selected from the following list: Complex Analysis, Control and Calculus of Variations, Differential Equations, Dynamical Systems, Functional Analysis, Geometry, Probability, and Topology. The choice of the examination subjects should be finalized by the end of the first year of study.

Applied Mathematics Track: A doctoral student in this track must take examinations in an area of Computational Mathematics and in an area of Mathematical Modeling. The third area of examination may be a more applied subject, including but not restricted to Fluid Mechanics, Statistical Mechanics, Epidemiology, Neuroscience, or a more traditional field of mathematics.

- Write an acceptable thesis that constitutes an original contribution to mathematical knowledge. It is the responsibility of the student to find a thesis advisor who is willing to help plan a program and guide his or her research. This should be done immediately after passing the Qualifying Examination. A copy of a student's thesis is to be available no later than 10 days prior to the Final Oral Examination (see below), and the student is required to deliver an expository lecture on the subject of his or her thesis sometime prior to the Final Oral Examination. This lecture is open to all students and faculty.
- Pass a Final Oral Examination consisting of a defense of the thesis. The examination committee, which consists of not fewer than four members of the faculty, including one whose appointment is outside the Mathematics Department, is responsible for certifying that the material presented in the thesis meets acceptable scholarly standards. The examination may also include an inquiry into the student's competence in the major and related fields. All faculty members are welcome to attend.

Course work requirements

Mathematics Track: A student in the traditional Mathematics program must demonstrate knowledge of the basic concepts and techniques of Algebra, Analysis (Real and Complex), and Topology. This must be done by taking all courses in the three basic areas: Abstract Algebra (MATH 401-MATH 402), Analysis (MATH 423-MATH 424 and MATH 425), and Topology (MATH 461). In addition, the student is required to take a minimum of 18 credit hours of approved course work.

A student with a master's degree in a mathematical subject compatible with our program, as determined by the Graduate Committee, must take 18 credit hours of approved courses. The Graduate Committee will determine which of the specific course work requirements stated above have been satisfied by the master's course work.

Applied Mathematics Track: A student in the Applied Mathematics track must demonstrate knowledge of Scientific Computing, Mathematical Modeling, and Differential Equations. This may be done by taking:

- Introduction to Numerical Analysis (MATH 431) and at least one of Numerical Differential Equations (MATH 432) or Numerical Nonlinear Systems and Optimization (MATH 433);
- Mathematical Modeling (MATH 441) and at least one of Ordinary Differential Equations (MATH 435), Introduction to Partial Differential Equations (MATH 445), or Partial Differential Equations (MATH 448).

In addition, a student in this track must take at least 24 credit hours of approved courses, which must include at least 9 credit hours of courses offered outside the Department of Mathematics, and at least 9 credit hours offered by the Department of Mathematics.

A student with a master's degree in a mathematical subject compatible with our program, as determined by the Graduate Committee, must take 18 credit hours of approved courses, which must include at least 6 credit hours of courses offered outside the Department of Mathematics and at least 9 credit hours offered by the Department of Mathematics. The Graduate Committee will determine which of the specific course work requirements stated above have been satisfied by the master's course work.

Sample study plans for students with concentrations in Scientific Computing, Imaging, Mathematical Biology, and Stochastics follow. The Graduate Committee will entertain ideas for other serious study plans or qualifying exam subjects in addition to the most common variants specifically suggested.

Scientific Computing Concentrations

MATH 431	MATH 441	MATH 448	Application area
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MATH 432	MATH 445	MATH 487	Application area
MATH 433	MATH 439/440	MATH 449/469/478	Application area

Imaging Concentrations

MATH 431	MATH 441	MATH 445	PHYS 431
MATH 432	MATH 428	MATH 439/440	PHYS 460
MATH 433	MATH 475	MATH 444	EBME 410

Life Science Concentrations

MATH 431	MATH 441	MATH 445	Application area
MATH432	MATH 449	MATH 439/487	Application area
MATH 433	MATH 478	MATH440	Application area

Stochastics Concentrations

MATH 431	MATH 481	MATH 487	Application area
MATH 423	MATH 424	MATH 469	Application area
MATH 441	MATH 491	MATH 492	Application area

Ph.D. students entering with a bachelor's degree are also subject to the breadth requirements for students in the program for the M.S. degree in Applied Mathematics.

Petitions

Any exceptions to departmental regulations or requirements must have the formal approval of the Graduate Committee of the Department. Such exceptions are to be sought by a written petition, approved by the student's advisory committee or thesis advisor, to the Graduate Committee.

Any exception to University rules and regulations must be approved by the Dean of Graduate Studies. Such exceptions are to be sought by presenting a written petition to the Graduate Committee for departmental endorsement and approval prior to forwarding the petition to the Dean.