

DEPARTMENT OF MATHEMATICS

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The Department of Mathematics at Case Western Reserve University is an active center for mathematical research. Faculty members conduct research in Algebra, Analysis, Applied Mathematics, Convexity, Dynamical Systems, Geometry, Imaging, Inverse Problems, Life Sciences Applications, Mathematical Biology, Modeling, Numerical Analysis, Probability, Scientific Computing, Stochastic Systems, and other areas.

The department offers a variety of programs leading to both undergraduate and graduate degrees in traditional and applied mathematics. Undergraduate degrees are Bachelor of Arts, Bachelor of Science in Mathematics, and Bachelor of Science in Applied Mathematics. Graduate degrees are Master of Science and Doctor of Philosophy. The BS/MS program allows a student to obtain a Bachelor of Science in Applied Mathematics with a master's degree from Mathematics or another department in five years. The department, in cooperation with John Carroll University, offers a program for individuals interested in pre-college teaching. It also offers a specialized program with the Department of Physics.

Mathematics plays a central role in the physical, biological, economic, and social sciences. Because of this, employment prospects are always strong for individuals with degrees in mathematics, and there are excellent career opportunities. A bachelor's degree in mathematics offers a strong background for graduate school in many areas (including computer science, medicine, and law, in addition to mathematics and science) or a position in the private sector. A master's degree (in mathematics or applied mathematics, or an undergraduate degree in applied mathematics combined with a master's in a different area) is an excellent basis for employment in the private sector in a technical field. A Ph.D. degree is usually necessary for college teaching and research.

Students, both undergraduate and graduate, have opportunities to interact personally with faculty and other students, and research and other activities are available. In addition, undergraduates can obtain teaching experience via the Department's supplemental instruction program.

DEPARTMENT FACULTY

Daniela Calvetti, Ph.D.

(University of North Carolina)

Professor and Chair

Scientific computing; imaging, inverse problems; modeling and simulation in life science

James C. Alexander, Ph.D.

(Johns Hopkins University)

Levi Kerr Emeritus Professor

Dynamics; applied mathematics

Christopher Butler, M.S.

(Case Western Reserve University)

Instructor

Teaching of mathematics

David Gurarie, Ph.D.

(Hebrew University, Jerusalem, Israel)

Professor

Infectious diseases; epidemiology; mathematical biology; differential equations; gallery of fluid motions

Michael Hurley, Ph.D.

(Northwestern University)

Professor

Dynamical systems; dynamics of cellular automata; dynamics of numerical methods

Steven H. Izen, Ph.D.

(Massachusetts Institute of Technology)

Professor

Image reconstruction from projections, both theoretically and in applied situations

Peter Kotelenez, Ph.D.

(Universität Bremen)

Professor

Stochastic partial and ordinary differential equations; transitions from microscopic to macroscopic equations for particle systems; correlated Brownian motions and depletion phenomena in colloids; stochastic models in nanotechnology and complex systems

Joel Langer, Ph.D.

(University of California, Santa Cruz)

Professor

Static and dynamics of curves and related physical models; the interplay between geometry and integrable Hamiltonian systems; geometry of finite and infinite dimensional spaces of curves

Marshall J. Leitman, Ph.D.

(Brown University)

Professor

Continuum physics; integral equations; functional analysis; mechanics of materials

Elizabeth Meckes, Ph.D.

(Stanford University)

Assistant Professor

Quantitative limit theorems in probability; Stein's method; high-dimensional phenomena in probability; geometry; statistics

Mark Meckes, Ph.D.

(Case Western Reserve University)

Assistant Professor

Geometry in high dimensions; random matrix theory; geometry probability

David A. Singer, Ph.D.

(University of Pennsylvania)

Professor

Geometry; dynamical systems; variational problems

Erkki Somersalo, Ph.D.

(University of Helsinki)

Professor

Modeling and simulation of complex biological systems; inverse problems and Bayesian scientific computing; medical imaging

Stanislaw J. Szarek, Ph.D.
(Mathematical Institute, Polish Academy of Science)
Professor

Geometric functional analysis and its applications to study of high-dimensional phenomena; asymptotic geometric analysis

Peter Thomas, Ph.D.
(University of Chicago)
Assistant Professor

Noise and reliability in neural spike time patterns; gradient sensing, signal transduction and information theory; pattern formation in the visual cortex

Catalin Turc, Ph.D.
(University of Minnesota, Minneapolis)
Assistant Professor

Numerical analysis; scientific computing, computational electromagnetism; partial differential equation

Elisabeth Werner, Ph.D.
(Université Pierre et Marie Curie, Paris IV)
Professor

Convex geometry; analysis; probability; applications to approximation theory, mathematical physics, quantum information theory

Secondary Faculty

Colin McLarty, Ph.D.
(Case Western Reserve University)
Associate Professor of Philosophy
Logic; philosophy of mathematics

Adjunct Faculty

Christophe Geuzaine, Ph.D.
(University of Liege, Belgium)
Adjunct Associate Professor
Numerical analysis; scientific computing; computational electromagnetism

Marvin E. Goldstein, Ph.D.
(University of Michigan)
Adjunct Professor; Chief Scientist, NASA-Lewis Research Center
Fluid mechanics; heat transfer

Carsten Schütt, Ph.D.
(Christian-Albrecht Universität, Kiel)
Adjunct Professor
Convex geometry; analysis; probability; applications to approximation theory, mathematical physics, quantum information theory

Richard Varga, Ph.D.
(Harvard University)

Adjunct Professor

Rational approximation; Riemann hypothesis; Gershgorin disks

UNDERGRADUATE PROGRAMS

Majors

A Bachelor of Arts in Mathematics, a Bachelor of Science in Mathematics, a Bachelor of Science in Mathematics and Physics, and a Bachelor of Science in Applied Mathematics are available to students at Case Western Reserve University. All undergraduate mathematics degrees are based on a four-course sequence in calculus and differential equations and a five-course mathematics core in analysis and algebra.

Bachelor of Arts in Mathematics

(1) Mathematics Requirements

The B.A. degree requires at least 38 hours of Mathematics courses, including:

- (a) MATH 121, 122, 223, and 224, or an equivalent sequence
- (b) Core Mathematics for the B.A.
 - (i) MATH 307, 308, 321, 322
 - (ii) MATH 324 or 425
- (c) Three approved technical electives (9 credit hours), no more than one of which can be from outside the department

(2) Non-Mathematics Requirements

A 3-credit hour course in Computer Science (ENGR 131 or other approved course)

TEACHING CERTIFICATION

High school teaching certification is available in the B.A. program in Mathematics through a joint program with John Carroll University. The requirements are:

- (a) Completion of the B.A. program in Mathematics, including MATH 150, MATH 304, and STAT 312 as the three approved technical electives.
- (b) The completion of a second major in Teacher Education. Students interested in this program should contact the director of teacher licensure for further information about eligibility and requirements.

Bachelor of Science in Mathematics

(1) Mathematics Requirements

The B.S. degree in Mathematics requires at least 50 hours of Mathematics courses, including:

- (a) MATH 121, 122, 223, and 224, or an equivalent sequence
- (b) Core Mathematics for the B.S. in Mathematics
 - (i) MATH 307, 308, 321, 322
 - (ii) MATH 324 or 425
- (c) 21 hours (normally seven courses) of approved technical electives, no more than 9 hours of which may be from outside the department

(2) Non-Mathematics Requirements

The B.S. degree in Mathematics requires the following non-mathematics courses:

- (a) PHYS 121, 122, 221, or an equivalent sequence

- (b) A two-course science sequence from the following list of physical sciences: ASTR 201-202, CHEM 105-106, CHEM 111-ENGR 145, GEOL 110 and either 115 or 210
- (c) A 3-credit hour course in Computer Science (ENGR 131 or other approved course).
- (d) An approved science lab (usually 2 credit hours) (BIOC 314, BIOL 111, CHEM 113, GEOL 119, or PHYS 203)

Bachelor of Science in Applied Mathematics

The B.S. degree in Applied Mathematics requires at least 50 hours of course work in mathematics and related subjects, in addition to a professional core that is specific to the area of application of interest to the student. A student in this degree program must design a program of study in consultation with his or her academic advisor. This program of study must explicitly list the technical electives and the professional core in the area of application.

(1) Mathematics Requirements

- (a) MATH 121, 122, 223, and 224, or an equivalent sequence
- (b) Core Mathematics for Applied Mathematics
 - (i) MATH 304, 307, 321, 322, 330
 - (ii) MATH 324 or 425
- (c) Technical Electives: 18 credit hours (normally six courses) of technical electives as follows:
 - (i) Four approved courses, specific to the concentration area of interest to the student
 - (ii) Two other courses of MATH at the 300 level or higher

(2) Professional Core Requirement

The professional core requires 12 credit hours of course work specific to the area of application. This requirement is intended to promote scientific breadth and encourage application of mathematics to other fields.

(3) Non-Mathematics Requirements

The B.S. degree in applied mathematics requires the following non-mathematics courses:

- (a) PHYS 121, 122, 221, or an equivalent sequence
- (b) A two-course science sequence from the following list of physical sciences: ASTR 201-202, CHEM 105-106, CHEM 107-108, GEOL 110 and either 115 or 210
- (c) A 3-credit hour course in Computer Science (ENGR 131 or other approved course)
- (d) An approved science lab (usually 2 credit hours) (BIOC 314, BIOL 111, CHEM 113, GEOL 119, or PHYS 203)

Areas of research in applied mathematics well represented in the department include:

- Applied Dynamical Systems
- Applied Probability and Stochastic Processes
- Imaging
- Life Science
- Scientific Computing

Study plans with emphasis on areas of application closely related to Mathematics but centered in other departments will be also considered. Such areas might include Engineering Applications, Biology, Cognitive Science, or Economics.

Bachelor of Science in Mathematics and Physics

In contrast to an Applied Mathematics degree or the B.S. in Physics with a Mathematical Physics Concentration, this is a synergistic, coherent, and parallel education in Mathematics and Physics. To a close approximation, the challenging course work corresponds to combining the Mathematics and Physics

cores, with the Physics Laboratory cluster replaced by a single, fourth-year laboratory semester. A student in this new program may use either of two official advisors, one available from each department, who would also constitute a committee for the administration of the degree and the approval of curriculum petitions.

The total number of required credits is 126 (35 MATH, 38 PHYS, 6 senior project, 11-13 ENGR and CHEM). There are 14 to 16 credits of open electives.

Year 1	PHYS 121 or 123 Mechanics	4	PHYS 122 or 124 Electricity & Magnetism	4	MATH 121 or 123 Calculus I	4
Year 1	MATH 122 or 124 Calculus II	4	MATH 223 or 227 Calculus III	3	ENGR 131 CompProg	3
Year 1	CHEM 105 or 111 Intro Chemistry	3/4	CHEM 106 or ENGR 145 Intro Chemistry	3/4	CHEM 113 Chem Lab	2
Year 2	PHYS 221 Intro to Modern Physics	3	PHYS 310 Classical Mechanics	3	MP group I***	3
Year 2	MATH 224 Diff Eqs	3	MATH 307 Linear Algebra	3	MATH 308 or 330 Algebra or Scient. Comput.	3
Year 3	PHYS 313 Thermodynamics & Stat Mechanics	3	PHYS 331 or 481 Quantum I	3	PHYS 332 or 482 Quantum II	3
Year 3	MATH 321 Analysis I	3	MATH 322 Analysis II	3	MATH 324 Complex Analysis	3
Year 3	PHYS 3XX**	3	MP group II***	3	MP group III***	3
Year 4	PHYS 423 Adv Elec & Mag	3	PHYS 472 Grad Lab	3	MP group IV***	3
Year 4	PHYS 351 or MATH 351 Sr Project	4				

SAGES	First and University Seminars	10
A&S SAGES	Breadth Requirements	12
Open Electives		14- 16

*Course usually taken in this year, offered only in F = fall, S = spring

**An advanced physics course to be selected from the following list: PHYS 315, 316, 326, 328, 336, 365.

***The "M&P group" of four courses corresponds to two physics courses and two mathematics courses. The physics courses would be chosen from P250, P349, and P350. The mathematics courses are subject to approval by the advisory committee and are thereby referred to as 'approved electives.' They may be chosen from the general list of mathematics courses at the 300 level or higher. Also subject to approval, students may choose a course from outside the mathematics and physics departments as a substitute in the M&P group.

****If approved by the M&P committee, other science sequence courses may be substituted.

****The number of open electives will vary depending on whether students choose 3-credit or 4-credit courses to fulfill the chemistry/science requirement

Integrated B.S./M.S. Programs in Mathematics and/or Applied Mathematics

The integrated B.S./M.S. Program is intended for highly motivated candidates for the B.S in Mathematics and Applied Mathematics who wish to pursue an advanced degree. Application to the B.S./M.S. program must be made after completion of 75 semester hours of course work and prior to attaining senior status (completion of 90 semester hours). Generally, this means that a student will submit the application during his/her sixth semester of undergraduate course enrollment and will have no fewer than two semesters of remaining B.S. requirements to complete. Applicants should consult the Dean of Undergraduate Studies.

A student admitted to the program may, in the senior year, take up to nine hours of graduate courses (400 level and above) that will count towards both B.S. and M.S. requirements. The courses to be double-counted must be specified at the time of application. Any undergraduate course work that is to be applied to the M.S. must be beyond that used to satisfy B.S. degree requirements and must conform to University, School, and Department rules. Students may petition to transfer graduate course work taken prior to application to the B.S./M.S. Program subject to the rules of the Graduate School.

Students for whom the master's project or thesis is a continuation and development of the senior project should register for MATH 651 Thesis (or the appropriate project course) during the senior year and are expected to complete all other courses for the B.S. before enrolling in further M.S. course work and thesis (continuing the senior project). Students for whom the master's thesis or project is distinct from the senior project will be expected to complete the B.S. degree before taking further graduate courses for the master's degree.

Integrated B.S./M.S. in Applied Mathematics and Another Discipline

There is the possibility of an integrated five-year study plan leading to a B.S. in Applied Mathematics and an M.S. in the area of application. In order to complete the requirements for the B.S./M.S. in five years, students must choose an area outside Mathematics that integrates well with Mathematics, such as Computing and Information Science, Operations Research, Systems Engineering, Control Theory, Biology, or Cognitive Science. The general academic requirements for Integrated B.S./M.S. programs must be followed. (Since the graduate courses required for the M.S. degree are determined by the respective department, each student in the dual-degree program should have a secondary advisor in that department, starting no later than the junior year, and consult with this advisor concerning requirements for the M.S. degree.)

Minors

A minor in Mathematics is available to all University undergraduates. It consists of 17 credit hours of approved course work in Mathematics. No more than two courses can be used to satisfy both minor requirements and the requirements of the student's major field (meaning departmental degree requirements, including departmental technical electives and common course requirements of the student's school). The 17 hours must be from among the following MATH courses: 121 or 123 or 125, 122 or 124 or 126, 223 or 227, 224 or 228, 150, 201, 301, 302, 303, 304, 307, 308, 321, 322, 323, 324, 331, 338, 343, 345, 380, or any 400-level MATH course (only one of 201, 307).

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 (Cryptography), 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 445), 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
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.