Northeastern

Mathematics

College *of* Science
Graduate Programs
2011-2012

Contents

Our Mission:
To educate students for a life of fulfillment and accomplishment.
To create and translate knowledge to meet global and societal needs.

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July 2011

Faculty

Interim Chair

Richard D. Porter, PhD, Yale University
Fields: Algebraic and differential topology, Massey products, deRham theory with applications to the fundamental group, group cohomology

Professors

Samuel J. Blank, PhD, Brandeis University
Field: Differential topology

Maxim Braverman, PhD, Tel Aviv University
Fields: Symplectic geometry, partial differential equations

Stanley J. Eigen, PhD, McGill University, Montreal, Canada
Fields: Ergodic theory, measure theory, number theory, dynamical systems

Terence Gaffney, PhD, Brandeis University
Fields: Singularities of mappings and its applications to algebraic, differential geometry

Arshag Hajian, PhD, Yale University
Fields: Ergodic theory, analysis

Anthony Iarrobino, PhD, Massachusetts Institute of Technology
Fields: Algebraic geometry, commutative rings and their deformations, singularities of maps, families of points on a variety, Gorenstein algebras

Christopher King, PhD, Harvard University
Fields: Quantum theory, statistical mechanics, probability theory

Venkatramani Lakshmibai, PhD, Tata Institute, Bombay, India
Fields: Algebraic geometry, algebraic groups, representation theory

Mikhail Malioutov, PhD, Moscow State University
Fields: Statistics, probability, experimental design, information theory

David Massey, PhD, Duke University
Fields: Complex analytic singularities, stratified spaces

Robert C. McOwen, PhD, University of California–Berkeley
Field: Partial differential equations with applications to problems in differential geometry

Egon Schulte, PhD, University of Dortmund
Fields: Discrete geometry, combinatorics, group theory, graph theory

Jayant M. Shah, PhD, Massachusetts Institute of Technology
Field: Computer vision

Alexandru Suciu, PhD, Columbia University
Fields: Algebraic topology, geometric topology

Gordana G. Todorov, PhD, Brandeis University
Fields: Representation theory of Artin algebras, noncommutative algebra

Jonathan Weitsman, Robert G. Stone Professor, PhD, Harvard University
Fields: Symplectic geometry, combinatorics, and mathematical physics

Jerzy Weyman, PhD, Brandeis University
Fields: Commutative algebra, algebraic geometry, representation theory

Andrei Zelevinsky, PhD, Moscow University
Fields: Representation theory, algebraic geometry, algebraic combinatorics, discrete geometry, special functions

Associate Professors

Robert W. Case, PhD, Yeshiva University
Fields: Mathematical logic, Socratic teaching of mathematics

Adam Ding, PhD, Cornell University
Fields: Artificial neural networks, statistics, biostatistics

Eugene H. Gover, PhD, Brandeis University
Fields: Commutative algebra, homology of local rings

Solomon M. Jekel, PhD, Dartmouth College
Fields: Classifying spaces, homeomorphism groups, homology of groups, foliations

Donald R. King, PhD, Massachusetts Institute of Technology
Fields: Lie groups, Lie algebras, Weyl groups, Lie algebra cohomology, noncommutative ring theory

Valerio Toledano Laredo, PhD, University of Cambridge
Fields: Lie groups, Lie algebras, representation theory

Ivan Losev, PhD, Moscow University
Field: Representations of algebraic groups

Alina Marian, PhD, Harvard University
Field: Algebraic Geometry

Alex Martsinkovsky, PhD, Brandeis University
Graduate Coordinator
Fields: Functorial and homological methods in representation theory, homological algebra, homotopy theory and applications, industrial mathematics

Mark B. Ramras, PhD, Brandeis University
Fields: Commutative algebra, graph theory

Martin Schwarz, Jr., PhD, Johns Hopkins University and the Courant Institute
Fields: Nonlinear analysis, nonlinear differential equations, mathematical problems in science

Thomas O. Sherman, PhD, Massachusetts Institute of Technology
Fields: Noncommutative harmonic analysis, symmetric spaces, Lie groups, numerical analysis

Gilead Tadmor, PhD, Weizmann Institute of Science
Jointly appointed with Electrical and Computer Engineering
Fields: Basic system theory, control systems, medical imaging

Peter Topalov, PhD, Moscow State University
Fields: Hamiltonian PDEs and ODEs, dynamical systems, Riemannian and Symplectic geometry

Assistant Professors

Christopher E. Beasley, PhD, Princeton University
Fields: Theoretical math, mathematical physics, string theory

Benjamin Webster, PhD, University of California–Berkeley
Field: Geometric Representation Theory

Professors Emeritus

Mark Bridger, PhD, Brandeis University
Fields: Mathematics education, computer assisted instruction, numerical and constructive algebra, commutative algebra

Holland C. Filgo, Jr., PhD, Rice University
Fields: Complex analysis, computer-assisted instruction

John N. Frampton, PhD, Yale University
Fields: Artificial intelligence, natural language

Maurice E. Gilmore, PhD, University of California–Berkeley
Fields: Geometric topology, secondary mathematics education

Samuel Gutmann, PhD, Massachusetts Institute of Technology
Fields: Statistical decision theory, mathematical statistics, probability, quantum mechanics

Nishan Krikorian, PhD, Cornell University
Fields: Low-dimensional dynamical systems, numerical analysis

Marc N. Levine, PhD, Brandeis University
Fields: Algebraic geometry, algebraic K-theory

Jack Warga, PhD, New York University
Fields: Optimal control theory Laredo, optimization, nonsmooth analysis

The Department of Mathematics at Northeastern University is internationally known for its mathematical research and education. The graduate programs offer MS and PhD degrees in mathematics, an MS degree in Applied Mathematics, and an MS degree in Operations Research (in conjunction with the Mechanical, Industrial, and Manufacturing Engineering department). The programs are designed to provide students with a broad overview of current mathematics and a strong command of an area of specialization. Graduate students work with internationally recognized faculty in a range of research programs in both pure and applied mathematics. In addition, numerous seminars at Northeastern and in the Boston area give students ample opportunity to learn about important recent advances in mathematics.

The Graduate Programs

The department offers both full-time and part-time programs leading to the PhD, MS, MS in Industrial and Applied Mathematics, and MS in Operations Research. In addition to the course requirements, a dissertation is required for the PhD program. A thesis is optional, in place of two electives in the master's-level programs. See the sections on the PhD dissertation and the master's thesis for more details.

Research

The department has strong and active research mathematicians in a variety of areas. Following is a partial list of current research areas and some of the studies being undertaken, a rich cross-section of the whole of mathematics.

- Algebra, algebraic geometry, and algebraic groups: Commutative algebra, flag varieties, Schubert varieties, singularities, K-theory, moduli problems, group actions, homogeneous spaces, invariant theory, representation theory of algebraic, Kac-Moody, and quantum groups.

- Combinatorics: Studies in graph theory, algorithms, operations research, algebraic combinatorics, and combinatorial geometry.

- Differential geometry: Variational problems, geometry of submanifolds. Study of differential forms with applications to Lie groups and algebras and their cohomology.

- Lie theory: Structure and representations of Lie groups, noncommutative harmonic analysis on symmetric spaces.

- Ergodic theory: Studies in measure theoretic ergodic theory, applications to number theory, spectral analysis of ergodic transformations.

- Partial differential equations: Studies in linear and nonlinear partial differential

equations, elliptic equations on noncompact domains and manifolds, spectral theory of elliptic operators, index theory, geometric applications of partial differential equations.

- Topology: Singularities of maps, geometry of spaces with singularities, algebraic and differential topology.

- Statistics: Studies of statistical decision theory, design of experiments, theory of random functions, statistical inference of random functions, applications of statistics in natural sciences, public health, economy, and finance.

Admission Requirements

Applicants to the PhD program must have a master's degree in mathematics or a closely related field. Applicants to the MS program must have a bachelor's degree in mathematics or a closely related field. All applicants must submit scores from the general Graduate Record Exam (GRE). In addition, applicants to the PhD and the MS in Mathematics must submit scores from the subject GRE in mathematics. An applicant's undergraduate coursework should have included linear algebra, combinatorics, differential and integral calculus, differential equations, real analysis, and computer programming. Students deficient in any of these areas may be accepted provisionally if their overall college work is particularly strong, but they will be expected to eliminate the deficiency either before enrollment or within their first two semesters at Northeastern.

Applications

If applying for departmental financial aid, a candidate must apply for the fall semester as a regular full-time student. Deadline: February 1.

If not applying for departmental financial aid, candidates should refer to www.northeastern.edu/casgraduate for deadlines.

The priority deadline for fall admission is February 1. Applications must be submitted on-line at www.northeastern.edu/casgraduate. Unofficial transcripts, three letters of recommendation, and a personal essay are to be submitted on-line via the Apply Yourself system. Official Graduate Record Examination (GRE) General scores and GRE Subject scores (PhD and MS in Mathematics applicants only) are submitted electronically via Educational Testing Services and are required by February 1. The only code necessary is our institution code, 3682.

In addition, international applicants must provide proof of English proficiency as described on page 7.

International Student Application

Evidence of English proficiency may consist of one of the following:

- a minimum of 79–80 (Internet-based test) on the Test of English as a Foreign Language (TOEFL) or a minimum score of 6.5 on the International English Language Testing System (IELTS) exam.

- proof of completion of a degree program at an American college or university.

Some students may be required to be evaluated by the English Language Center prior to registration. Students who do not demonstrate adequate English proficiency will be required to enroll in the English Language Center Intensive Language Course for at least one semester before enrolling in a full academic program. Such students may be permitted, with approval of the director of the English Language Center and the academic adviser, to enroll in academic coursework at the same time they participate in Intensive English.

Admitted international students are required to have a Declaration and Certification of Finances form with original supporting documents and evidence of English proficiency on file with the Graduate School office at least sixteen weeks before the beginning of the semester in which they expect to begin a program.

Financial Awards

Each year, the Mathematics department offers a limited number of Teaching Assistantships (TAs), Research Assistantships (RAs) and Graduate Student Scholarships (GSSs). TA and RA awards include tuition, a stipend and health insurance, in exchange for 20 hours per week of work each semester. For this reason, international students receiving a Teaching Assistantship must meet the minimum score requirements as noted above and should be able to speak English fluently. A GSS covers tuition only. Additionally, the University awards need-based aid to graduate students through the Federal Perkins Loan, Federal Work-Study, and Federal Stafford Loan programs.

International Teaching Assistant Orientation

All international students receiving a Teaching Assistantship for the first time must participate in a week-long intensive orientation prior to the beginning of the fall semester. This orientation is intended to provide the teaching assistants with the opportunity to sharpen their speaking and presentation skills, as well as to introduce them to the culture of the American classroom. This orientation and the weekly seminars that are offered throughout the fall semester are mandatory for first-time international teaching assistants.

Part-Time Program

Nearly all graduate courses in the Mathematics department meet after 5:00 pm, Monday through Thursday, so that students who work during the day may take one or two courses each semester at night. Students in the part-time program may progress according to their abilities and available time, subject to the seven-year time limitation established by the University.

Special Student Status

Students with a bachelor's degree who are not matriculating in a degree program but would like to take a few graduate-level courses should also complete the application and must satisfy all admissions requirements, with the exception of taking the GRE. Also, students applying for special student status must submit two letters of recommendation.

Graduate Adviser

An adviser will monitor the student's progress and advise the student on the courses to take. Any courses taken outside the department and some courses from within the department will require approval from the adviser. An adviser should assist the PhD student in finding a thesis supervisor. The thesis supervisor will act as the adviser for the student and will also guide the student through the dissertation.

Satisfactory Academic Progress

Satisfactory progress means satisfying requirements in the Graduate School's General Regulations and in the regulations specified in the departmental booklet. The Graduate School sets minimum standards for all students to fulfill. Departments and programs may have additional requirements that exceed those of the Graduate School.

Receipt of financial support administered by the Graduate School is contingent on satisfactory academic progress toward the degree and on meeting department-specific guidelines. See the Graduate School's General Regulations for further details.

The Doctor of Philosophy Degree

The Doctor of Philosophy degree is awarded to candidates who show evidence of high scholastic attainment and research ability in their major field.

Areas of Specialization

Algebra, Geometry/Topology, Geometric Analysis/PDE, Probability/Statistics, Combinatorics.

Course Requirements

A total of eight 4-semester-hour courses beyond the MS degree and two PhD dissertation courses leading to a dissertation topic are required. Two of the eight courses must be in a minor specialty, which is different from the thesis area. All master's level coursework must be completed by the end of the first year of the program. The 2 PhD thesis courses must be completed by the third year in the program. Candidates must also satisfy any additional course requirements specified by their thesis adviser. A minimum GPA of 3.000, equivalent to a grade of B, is required for degree qualification. Please refer to our web site for full details: www.math.neu.edu/grad.

Qualifying Exams

Qualifying exams are given several times each year—including late January, late April and late September. They cover algebra, analysis, and the student's specialized field. Students will be given an opportunity to practice on a sample test. Students must pass these exams by May of their second year in the PhD program in order to continue in the program.

Minor Specialty

Each doctoral candidate selects a specific mathematical subject of an advanced nature, which must be reasonably unrelated to the topic of the student's dissertation. The student should render work in this area equivalent to eight semester hours of coursework.

Language Requirement

Ability to read and translate mathematical texts and journals in one foreign language must be established by the candidate. The language may be chosen from French, German, and Russian; any other choice requires special approval. Students should notify the chair of the departmental Graduate Committee when they are prepared to be examined on a language. The examination is conducted

by a member of the faculty of the Mathematics department.

Teaching Requirement

Some teaching experience is required while in the program. This requirement may be satisfied by teaching an undergraduate course or presenting at least two talks in conferences or departmental seminars.

Residence Requirement

The residence requirement is satisfied by one year of full-time graduate work or two years of continuous registration for part-time work.

Doctoral Candidacy

Doctoral students must complete a minimum of 32 semester hours (8 Math courses) beyond the Master of Science degree and pass the Qualifying Exams. It is expected that students will pass the Qualifying Exams within one academic year of coursework completion.

Dissertation Requirement

Each doctoral student must complete a dissertation that embodies the results of extended research and makes an original contribution to the field. This work should give evidence of the candidate's ability to carry out independent investigation and interpret in a logical manner the results of the research. There are two stages to this process.

Stage 1: Students in the PhD program must have a thesis supervisor within two years after joining the PhD program. The department views the failure of a student to find a supervisor within two years of joining the PhD program with concern and considers this sufficient cause to review the student's status in the PhD program. The process of obtaining a thesis supervisor always involves two choices—the student chooses the supervisor, and the supervisor chooses the student. For this reason, the department does not guarantee a thesis supervisor for every student, but the department recognizes its responsibility to help the student find a satisfactory match. This aid is usually provided by the student's graduate adviser, who should be familiar with the student's progress in finding a thesis supervisor. The thesis supervisor guides the student's further education as well as directs the student's dissertation. The dissertation itself must represent an original solution of a problem in the chosen area of mathematics that makes a significant contribution to the mathematical knowledge in that area. Students in their 4th or 5th year are required to submit a written report on their thesis to the Graduate Committee.
Stage 2: The final oral examination on the dissertation is held in accordance

with the Graduate School regulations and given by a thesis committee of four faculty members (three from the university, including the supervisor, and one from outside Northeastern University). The thesis supervisor should propose this thesis committee to the Executive Committee for its approval. By the end of the third year in the PhD program, if the student has not succeeded in presenting the PhD thesis, he or she will be required to present the progress made to date and a plan of the remaining work to a committee of three faculty members. The committee evaluates the student's progress up to that point, and its report is placed in the student's file.

The Master of Science Degree

Total: 32 semester hours.
This program offers students with a bachelor's degree in mathematics or a related field an opportunity to broaden their knowledge in the several fields of mathematics and its applications. The program is designed to prepare graduates for careers in business, industry, or government, or for the PhD program in mathematics.

Areas of Specialization

Pure Mathematics, Discrete Mathematics, Probability and Statistics, Applied Analysis

Course Requirements

Eight 4-semester-hour graduate courses are required for the degree. To qualify for the degree, students must obtain a minimum cumulative average of 3.000, equivalent to a grade of B. Required courses for different specializations vary.

Concentration: Pure Mathematics
7 Required: Algebra 1, Analysis 1, Algebra 2, Analysis 2, Topology 1, Combinatorial Analysis/Representation Theory, Geometry 1/Algebraic Geometry. 1 Elective: Algebra 3, Geometry 2, Topology 2, or an advanced course in Analysis.

Concentration: Discrete Mathematics
7 Required: Algebra 1, Analysis 1, Algebra 2, Probability 1, Combinatorial Analysis, Discrete & Computational Geometry, Graph Theory. 1 Elective: Topology 1 or Probability 2.

Concentration: Probability/Statistics
7 Required: Algebra 1, Analysis 1, Analysis 2, Probability 1, Probability 2, Mathematical Statistics, Applied Statistics. 1 Elective: Regression, ANOVA and Design; Topics in Statistics; Nonparametric Methods in Statistics; or Time Series.

Concentration: Applied Analysis
7 Required: Algebra 1, Analysis 1, Analysis 2, Algebra 2, ODE 1, PDE 1, Numerical Analysis. 1 Elective: advanced course in Analysis or Geometry 1.

Thesis Options for All Master's Programs

At the end of their first year in the program, students in the master's-level programs may choose the option of a Master's Degree with Thesis. A student with the master's thesis option should register for a master's thesis course with the supervisor during one of the semesters of the final year of the student's master's program. The

written thesis may present original research or an original approach to a problem, or it can be expository in nature. After the supervisor's approval, the thesis will be reviewed by a referee. The student will make an oral presentation of the thesis before a committee of three faculty members, including the supervisor and the referee. A letter grade (A, B, or F) will be given for the thesis after the presentation. For students enrolled in the Northeastern MS degree program to be considered for admission to the PhD program, they must pass a series of qualifying exams (see the description of the PhD program).

The Master of Science Degree in Industrial and Applied Mathematics

Total: 32 semester hours

Eight graduate courses (32 semester hours of credit) are required for the degree: three required courses and five elective courses. The required courses provide a basic training in mathematical methods, and the elective courses include a wide variety of advanced topics. In addition, the program allows up to two of the elective courses to be taken outside the Mathematics Department.

Course Requirements

Required courses:

Three core courses: Introduction to Mathematical Methods and Modeling, Applied Statistics or Mathematical Statistics, Analysis 1 or Algebra 1 or Probability 1.

Five electives: Three must be graduate courses offered by the Department of Mathematics. With approval of the Graduate Coordinator, two may be graduate courses outside of the department.

The Master of Science Degree in Operations Research

Total: 32 semester hours

This program will provide training in the basic techniques and theory of operations research and their applications to real-world problems. Graduates should have developed their analytical skills to attack complex, large-scale optimization problems of both a deterministic and stochastic nature. Eight 4-semester-hour graduate courses are required for this degree. To qualify for the degree, a minimum cumulative average of 3.000, equivalent to a grade of B, must be obtained. Some courses listed for this program are offered in the Department of Mechanical, Industrial, and Manufacturing Engineering.

Course Requirements

Required courses:

Four core courses: Probability 1 or Engineering Probability and Statistics, Probability 2 or Probabilistic Operations Research, Deterministic Operations Research, Optimization. Four elective courses from the following list: Mathematical Statistics, Enumeration, Data structures, Stochastic Calculus and No-arbitrage Finance, Statistical decisions, Complexity Theory, Economic Decision Making, Multi-criteria Decision Making, Logistics, Warehousing and Scheduling, Reliability and Risk Assessment.

Sample Course Listing

The following is a sample listing of departmental course offerings. Please refer to www.northeastern.edu/registrar for course descriptions and relevant prerequisites.

Course Name	Credit (sh)
Analysis 1: Functions of One Variable	4
Analysis 2: Functions of Several Variables	4
Basics and Probability and Statistics	4
Basics of Statistics and Stochastic Processes	3
Basics of Complex Analysis	3
Basics of Number Theory	3
Methods for Teaching Math	3
Algebra 1	4
Algebra 2	4
Topology 1	4
Geometry 1	4
Introduction to Mathematical Methods and Modeling	4
Ordinary Differential Equations	4
Partial Differential Equations	4
Numerical Analysis	4
Complex Analysis	4
Algebra 3: Galois Theory	4
Topology 2	4
Geometry 2	4
Discrete Geometry 1	4
Combinatorial Analysis	4
Graph Theory	4
Optimization and Complexity	4
Probability 1	4
Statistics for Health Sciences	4
History of Mathematics	4
Functional Analysis	4
Partial Differential Equations 2	4
Complex Manifolds	4
Commutative Algebra	4
Lie Theory	4
Representations of Finite Groups	4
Algebraic Geometry 1	4
Algebraic Number Theory	4
Lie Algebras	4
Topology 3	4
Geometry 3	4
Differential Geometry 1	4

Course Name	Credit (sh)
Differential Geometry 2	4
Algebraic Combinatorics	4
Discrete3 Geometry 2	4
Statistics for Bioinformatics	4
Probability 2	4
Mathematical Statistics	4
Applied Statistics	4
Regression, ANOVA, and Design	4
Nonparametric Methods in Statistics	4
Time Series	4
Statistical Decision Theory	4
Categorical Data Analysis	4
Stochastic Calculus and Introduction to No-Arbitage Finance	4
Pseudo Differential Equations	4
Mathematical Methods of Classical Mechanics	4
Mathematical Methods of Quantum Mechanics	4
Atiyah-Singer Index Theory	4
Von Neumann Algebras and Applications	4
Topics in Differential Equations	4
Complex Analysis Several Variable	4
Topics in Complex Analysis	4
Potential Theory	1
Schemes	4
Topics in Algebra	4
Topics in Algebraic Geometry	4
Topics in Representation Theory	4
Morse Theory	4
Characteristic Classes	4
Topology of Complex Hypersurface	4
Riemannian Geometry and General Relativity	4
Discrete Geometry 2	4
Topics in Geometry	4
Topics in Topology	4
Topics in Differential Geometry	4
Topics in Combinatorics	4
Topics in Statistics	4
Directed Study	1-4
Mathematical Tapas Seminar	4
Graduate Research Seminar in Mathematics	4
Master's Research	2 or 4
Thesis	4
Thesis Continuation	0
Readings: Topology	4

Course Name	Credit (sh)
Readings: Algebraic Topology	4
Readings: Real Analysis	4
Readings: Coding Theory	4
Readings: Geometric Topology	4
Readings: Singularities	4
Readings: Combinatorics	4
Readings: Combinatorics and Algebra	4
Readings: Combinatorial Geometry	4
Readings: Graph Theory	4
Readings: Algebra	4
Readings: Algebraic Geometry	4
Readings: Discrete and Combinatorial Geometry	4
Readings: Commutative Algebra	4
Readings: Probability and Statistics	4
Readings: Analysis	4
Readings: Geometric Analysis	4
Readings: Ordinary Differential Equations	4
Readings: Partial Differential Equations	4
Readings: Geometry	4
Dissertation	0
Dissertation Continuation	0

Northeastern

Department of Mathematics

Graduate Coordinator
Department of Mathematics
567 Lake Hall
Northeastern University
360 Huntington Avenue
Boston, MA
02115-5000

617.373.2454 (phone)
617.373.5658 (fax)

mathdept@neu.edu (e-mail)
www.math.neu.edu