QUALIFYING EXAMINATION FOR THE PH.D. IN MATHEMATICAL SCIENCES
COMPREHENSIVE EXAMINATION FOR THE M.S. IN MATHEMATICAL SCIENCES

These written examinations are given three times each year, just before the start of each semester (mid-January, mid-June, and mid-August). The following individual exams are available: A (Algebra); B (Real and Complex Analysis); C (Functional Analysis and Topology); D (Differential Equations); E (Numerical Mathematics); F (Mathematics Education: Foundations and Research); G (Mathematics Education: Theories of Learning and Teaching); H (Statistics: Probability and Inference); I (Statistics: Linear Models and Bayesian Statistics); and J (Statistics: Advanced Statistical Methods and Statistical Consulting). All exams are three hours in length, except for Exam F (a take-home exam) and Exam J (a take-home exam).

For doctoral students (and also for master’s students who are considering the possibility of going on for a doctorate), the following guidelines apply. Each doctoral student must successfully complete three of these exams, as follows:

**Mathematics:** Two exams chosen from the set {A, B, C}; and any other exam in the list A-I.

**Mathematics Education:** One exam chosen from the set {A, B, C}; and exams F and G.

**Statistics:** Three exams H, I, and J.

A doctoral student will be expected to attempt at least two of the individual exams within two years of entering the program, and is encouraged to attempt three. On the first attempt, at least two of the individual exams must be taken. On the basis of the outcome, the Graduate Studies Committee will recommend to the student that they (a) continue in the doctoral program; (b) complete a master’s degree and leave the program; or (c) leave the program.

The student may petition the committee to retake one or more parts of the qualifying exam. The committee may, at its direction, allow a maximum of two attempts to pass any individual exam, and a maximum of three attempts to pass the entire qualifying exam. The student must take at least two individual exams at any given time, unless only one remains to be passed.

Master’s students who are considering the possibility of continuing for a doctorate should note that:

- Successful performance on Exams A and B is considered to meet the requirement for a Master’s Comprehensive Exam in Pure Mathematics.
- Successful performance on Exams B and D is considered to meet the requirement for a Master’s Comprehensive Exam in Applied Mathematics.
- Successful performance of Exams B and E is considered to meet the requirement for a Master’s Comprehensive Exam in Computational Mathematics.
- Successful performance on either Exam A or Exam B is considered to meet the mathematics requirement portion for a Master’s Comprehensive Exam in Mathematics Education.
- Successful performance on Exam F or Exam G is considered to meet the mathematics education requirement portion for a Master’s Comprehensive Exam in Mathematics Education.
Students in Statistics should consult the Director of the Division of Statistics for advice as to how Exams H and I may be applied to the Master’s Comprehensive Exam in Applied Probability and Statistics.

Students who are only pursuing a terminal master’s degree will proceed as follows. Two appropriate parts of the examination must be passed. On the first attempt, both parts must be taken at the same session. In the event that the examination is not passed on the first attempt, it may be repeated once. If the candidate passes one part of the examination on the first attempt, and if the examination is repeated within one academic year, then it is only necessary to repeat that part of the examination which was previously failed. In all circumstances in which the student is taking the examination for the second time, both parts must be repeated.

An exception to this rule is that a master’s student in Mathematics Education may, with departmental approval, take the mathematics portion of the comprehensive examination after completing the mathematics course requirement of their program. If the student passes the mathematics part of the examination, then it is not required that the student pass the education part within one year. If the student fails the mathematics part on the first attempt, then such a student must take both parts of the examination at the time of the second attempt, and pass the mathematics part. If needed, the student may repeat the education part of the examination, provided this is done within one year of the previous attempt.

**M.S. in Pure Mathematics:** The two-hour version of Exam A and Exam B.

**M.S. in Applied Mathematics:** The two-hour version of Exam B and Exam D.

**M.S. in Mathematics Education:** The mathematics portion is one of the following choices: The two-hour version of Exam A; the two-hour version of Exam B; a two-hour exam over statistical inference; or a two-hour general examination involving four different mathematics courses the student has taken for graduate credit. The education portion is a three-hour exam covering Math 610 and at least two courses selected from Math 611, 612, 613, 614, 615, and 617, depending on what the student has taken. Any student in this program should consult with the Director of Graduate Studies to determine the exact nature of their examinations.

**M.S. in Computational Mathematics:** The two-hour version of Exam B and Exam E.

**M.S. in Applied Probability and Statistics:** Students in Statistics should consult the Director of the Division of Statistics for advice as to the exact nature of their examinations.

Syllabi for Exams A, B, C, D, and E are attached. A student taking the two-hour version of Exam A will be responsible only for Part I of the syllabus. Approximately ¼ of this two-hour exam is devoted to linear algebra. A student taking the two-hour version of Exam B will be tested fully over advanced calculus, but will have a considerable choice of questions from real and complex analysis, and may avoid questions from one of these two areas entirely if desired. A student taking Exam E will be tested over Numerical Analysis, and either Numerical Linear Algebra or Numerical Differential Equations (the student must make this choice in advance).
SYLLABUS FOR EXAMINATION A

ALGEBRA

PART I

Groups: Groups, subgroups, normal subgroups, homomorphism theorems, Sylow theorems, structure theorem for finite abelian groups, Jordan-Hölder theorem, solvable groups.

Rings: Rings, ideals, homomorphism, field of fractions of an integral domain.

Fields and Galois theory: Characteristics, prime fields, algebraic and transcendental extensions, separability, perfect fields, normality, splitting fields, Galois group, fundamental theorem of Galois theory, solvability by radicals, structure of finite fields.

Linear algebra: Linear independence, basis, dimension, direct sums, linear transformations and their matrix representations, linear functions, dual spaces, determinants, rank, eigenvalue and eigenvector, minimal and characteristics polynomials, canonical forms.

PART II

Rings and Modules: Modules, simplicity, semisimplicity, chain conditions, tensor products, Jacobson radical, density theorem, Wedderburn-Artin theorem, finitely generated modules over a principal ideal domain, canonical forms.

Unique factorization, Euclidean domains, principal ideal domains, polynomial rings, maximal, prime, and primary ideals, Noetherian rings, Hilbert basis theorem, Lasker-Noether decomposition, integral elements, fractional ideals, Dedekind domains.

Primary Reference: Jacobson, Basic Algebra I, II
Hungerford, Algebra
Issacs, Algebra: A Graduate Course
Rotman, The Theory of Groups
Garling, A Course in Galois Theory
Friedberg, Insel, and Spence, Linear Algebra
Hoffman and Kunze, Linear Algebra
Clark, Elements of Abstract Algebra

Secondary References: Beachy and Blair, Abstract Algebra with a Concrete Introduction
Fraleigh, A First Course in Abstract Algebra
Herstein, Topics in Algebra
Anton, Elementary Linear Algebra
SYLLABUS FOR EXAMINATION B
REAL AND COMPLEX ANALYSIS

Advanced Calculus: Axioms for the real numbers and cardinality of sets. Sequences in one and several real variables. Topology of the line and Euclidean n-space. Limits, continuity, and differentiation of functions in one and several real variables. Integration in one and several real variables. Sequences and series of functions. Elementary functions of real variables and their properties.


References: Ahlfors, Complex Analysis
Apostol, Mathematical Analysis
Derrick, Complex Analysis and Applications
Fulks, Advanced Calculus
Gaughan, Introduction to Analysis
Kaplan, Advanced Calculus
Pennisi, Elements of Complex Variables
Royden, Real Analysis
SYLLABUS FOR EXAMINATION C

FUNCTIONAL ANALYSIS AND TOPOLOGY

Functional Analysis: Banach spaces, $l^p$, $L^p$, $C(K)$ products and quotients of normed linear spaces, dual spaces, Hahn-Banach Theorem, Stone-Weierstrass Theorem, Ascoli's Theorem, second dual space, weak and weak-star topologies, Alaoglu's Theorem, open mapping and closed graph theorems, projections, uniform boundedness, extreme points, Krein-Milman Theorem; inner product and Hilbert spaces, Bessel's inequality, Parseval's relation, adjoint operators, self-adjoint and normal operators, unitary operators; abstract measure theory, Hahn decomposition, Jordan decomposition, Radon-Nikodym Theorem, Riesz Representation Theorem for the dual of $C(K)$.

Topology: General topology (topological spaces, bases, products, subspaces, quotients, continuous maps); metric spaces (continuity, convergence, completion, Baire Category Theorem); compactness properties (compactness, local compactness, compactifications, compactness in metric spaces, Heine-Borel Theorem); covering properties (Lindelof property, paracompactness); separation and countability axioms; Urysohn's Lemma and the Tietze Extension Theorem; Tychonoff Theorem; connectivity (connectedness, path-connectedness, components); homotopy theory (homotopic maps, contractible spaces, deformation retracts); fundamental groups (functorial properties, calculations for euclidean spaces, spheres, relationship to covering spaces).

References: Croom, Principles of Topology
Dugundji, Topology
Goffman and Pedrick, First Course in Functional Analysis
Hewitt and Stromberg, Real and Abstract Analysis
Massey, Algebraic Topology: An Introduction
Munkres, Topology, A First Course
Pedersen, Analysis Now
Royden, Real Analysis
Rudin, Real and Complex Analysis
Simmons, Introduction to Topology and Modern Analysis
Singer and Thorpe, Lecture Notes on Elementary Geometry and Topology
Willard, General Topology
I. Ordinary Differential Equations:

Existence and uniqueness of solutions of systems of linear and nonlinear ordinary differential equations, successive approximations, explicit solutions of constant coefficient linear systems including matrix exponentials, variation of parameters method for solving nonhomogeneous systems, stability, oscillation, continuous dependence of solutions.

II. Partial Differential Equations:

Linear, quasi-linear, and nonlinear first-order equations; the classical mathematical models for the vibrating string, heat conduction and gravitational potential; characteristics, classification and canonical forms for second-order equations; the Cauchy problem and the Cauchy-Kovalevsky theorem; Holmgren's uniqueness theorem. Basic results for elliptic, parabolic and hyperbolic linear equations in one and several space dimensions; systems of linear and quasi-linear equations.

References:

I. Coddington and Levinson, Theory of Ordinary Differential Equations
   Jordan and Smith, Nonlinear Ordinary Differential Equations
   Waltman, A Second Course in Ordinary Differential Equations

II. John, Partial Differential Equations
   Weinberger, A First Course in Partial Differential Equations
SYLLABUS FOR EXAMINATION E

NUMERICAL MATHEMATICS

Numerical Analysis


Numerical Linear Algebra


Numerical Differential Equations

Initial value problems for ODE (Euler, multistep, backward difference and Runge-Kutta methods). Finite difference methods for elliptic PDE (numerical differentiation, discretization of elliptic operators, existence and uniqueness of solutions to the discrete problem, error estimates in the\(L_2\) norm and\(H_1\) norm for the solution of Poisson's equation). Iterative methods for solving systems of linear equations (Gauss-Seidel, Jacobi, steepest descent, conjugate gradient). Finite elements for elliptic PDE (variational formulation of elliptic BVP's, Galerkin approximation, changes of variable, trial functions of degree higher than 1, algorithm for constructing the discrete problem, structure of the stiffness matrix). Evolution equations (semidiscretization, parabolic equations using finite differences and finite elements, wave problem, transport equation, upwinding, Fourier
stability method, shooting method).

**References:**
Atkinson, An Introduction to Numerical Analysis
Burden and Faires, Numerical Analysis
Ciarlet, Numerical Analysis of the Finite Element Method
Conte and de Boor, Elementary Numerical Analysis
Golub and Van Loan, Matrix Computations
Hall and Porsching, Numerical Analysis of Partial Differential Equations
Sewell, The Numerical Solution of Ordinary and Partial Differential Equations
Stewart, Introduction to Matrix Computations
This is a take-home examination. Preparation for this examination requires the exploration of and reflection on a range of topics and issues related to mathematics education.

Graduate students are expected to have knowledge of individuals, groups, and organizations whose work has contributed to current understandings and perspectives of the learning and teaching of mathematics, mathematics curriculum and assessment, and mathematics education research. This includes, but is not limited to, the work of Bruner, Dewey, Gagne, Montessori, Piaget, Skinner, Thorndike, Vygotsky, plus Begle, Brownell, Dienes, Romberg, Skemp, Steffe, von Glasersfeld, as well as, the work of projects, (e.g., SMSG and DMP, and organizations such as NCTM, NCSM, and MAA).

Graduate students' preparation should also include an examination of the history of reform and change in mathematics education over the last 50 years. Along with this, graduate students should have an awareness of the effects of various reform movements on current trends in classroom practices, perspectives, and research paradigms in mathematics education, both in general and as they relate to particular contexts (e.g., the teaching of algebra or geometry).

Graduate students are expected to have had experience reading and evaluating original research, and to have developed an awareness of and an appreciation for various research methods and models in mathematics education. In preparing for this examination, graduate students are expected to analyze and synthesize research results in developing a broad perspective of quality research. Graduate students are also expected to have knowledge of other issues concerned with planning, conducting and evaluating research, and implementing and extending the existing body of research knowledge.

Suggested references and reading:


Lawrence Erlbaum Associates.


The National Assessment of Educational Progress results in Mathematics (NAEP).


See also various other publications from the NCTM including yearbooks, monographs, and journals, i.e., Arithmetic Teacher, Teaching Children Mathematics, Mathematics Teaching in the Middle School, Mathematics Teacher, and Journal for Research in Mathematics Education. In addition, other relevant publications may include articles from journals such as the following: American Educational Research Journal, Educational and Psychological Measurement, Educational Researcher, Educational Studies in Mathematics, Focus on Learning Problems in Mathematics, Journal of Educational Psychology, Journal of Educational Research, Journal of Mathematical Behavior, Review of Educational Research School Science and Mathematics.

**Suggested Coursework:** MATH 610, MATH 611, and at least TWO other Graduate-level mathematics education courses at the 600-level (such as MATH 602, MATH 612, MATH 613, MATH 614, or MATH 615), or at the 700-level (such as MATH 710A, or MATH 710B).
This is a three-hour written examination on the theories of learning and teaching of mathematics. Research-based literacy on students' and teachers' understandings of specific mathematical concepts is expected. Literacy with specific original research published in theses, dissertations, books, and periodicals is expected. Further, the graduate student is expected to link her/his knowledge about students' mathematical thinking and knowledge-building with how classroom instruction may be guided to enhance meaningful learning. Emphasis will be placed on the graduate student's in-depth analysis, synthesis and ability to extend the body of published research on the meaningful understanding and teaching of specific mathematical concepts and processes, at least, at any two of the following levels of education: elementary school, middle school, secondary school, and college level.

**Suggested References:**


JRME Research Monographs.


Piaget (A selection of his publications)


Literacy with specific original research studies published in theses, dissertations, and research periodicals. A selection of such periodicals is given below:


**Suggested Coursework:** MATH 513, MATH 514, and at least TWO other graduate-level mathematics education courses at the 600-level (such as MATH 602, MATH 610, MATH 611, MATH 612, or MATH 615), or at the 700-level (such as MATH 710A, or MATH 710B).
SYLLABUS FOR EXAMINATION H
STATISTICS: PROBABILITY AND THEORY OF STATISTICS

I. Probability: Probability spaces, Measures, measurable functions and algebra of events, Random variables, Expectations, Characteristic and moment generating functions, Discrete, continuous, mixed and multivariate probability distributions, Sequence of random variables and various modes of convergence, Borel-Cantelli Lemma and 0-1 laws, Weak and strong law of large numbers, Convergence in distributions and central limit theorems, conditional expectations and conditions distributions. Additional topics vary depending on the coverage in STAT 670 and may include Martingales, Brownian motion and other stochastic processes, Infinitely divisible and Stable distributions, Asymptotics, and various probability inequalities.

II. Theory of Statistics: Exponential families, Location and scale families, Hierarchical Models and mixture distributions, Sampling distributions, Properties of sample mean and variance from Normal distribution, Sufficiency principle, complete families, point estimation including unbiasedness, maximum likelihood and Bayesian estimation, Consistency, Hypothesis testing and Interval estimation. Additional topics vary depending on the coverage in STAT 672 and may include Statistical decision theory, Asymptotics, and Higher-order theory.

References:
I.

II.
Exam I is a three hour in-class exam.

**I. Linear Models:** Multivariate normal distribution, Distribution of quadratic forms, Linear models and design matrix of less than full rank, Estimation and distribution theory, Generalized least squares, Hypothesis testing and distribution theory for F-test, Confidence interval and regions, Multiple comparisons, Analysis of variance. Additional topics vary depending on the coverage in STAT 673 and may include Polynomial regression, Departure from assumptions and diagnostics, Prediction, and model selection.

**II. Bayesian Statistics:** Topics include Bayesian inference, Loss function and risk, one parameter models and posterior inference, conjugate priors, non-informative priors, multi-parameter models, Bayesian computation, Gibbs sampling, Markov chain Monte Carlo methods and applications in different areas. Additional topics may include decision theory, theoretical and convergence properties of Markov chain samplers, Bayesian model checking, model selection and assessment criteria, hierarchical models, Bayesian survival analysis.

**References:**

I.  

II.  
SYLLABUS FOR EXAMINATION J
STATISTICS: ADVANCED STATISTICAL METHODS AND STATISTICAL CONSULTING

Exam J is a take-home exam. The student will have to turn-in the completed exam within 7 days of when the exam is given to the student. Exam J emphasizes methodologies, real data analysis, implementation in software, professional quality reporting, and engaged learning.

Statistics, as a subject and discipline, covers a spectrum with statistical methods in the middle and theory and applications on the two sides. The goal of Exam J is to judge the student’s expertise in methods and applications and the student’s ability to transition (in either direction) between methods and applications.

Exam J, with its two components, will ask the student(s) to answer specific questions and will not be an open-ended research project. One goal of Exam J is to evaluate the student’s skill-set for statistical methods and applications. These skills may become necessary for the student in future collaborative (and possibly interdisciplinary) research projects, though this not the only purpose Exam J is designed to serve. Exam J will follow the standard setting of an examination where the answers will be judged against (at least one set of) established solutions (or approaches or methods).

I. Advanced Statistical Methods: Varied topics on recent statistical methodologies and applications. Topics vary depending on the coverage in STAT 679 and may include Generalized Linear Models, Linear mixed models, Generalized linear mixed models, Statistical methods for modeling and analyzing longitudinal data, Methods for analyzing missing data, Resampling methods, and Multivariate and categorical data analysis. Statistical data mining, analysis of high dimensional data, statistical bioinformatics.

This part of the exam will carry 50% weight to the overall score for Exam J.

This part of the exam may include theory and methodological questions where the students are asked to make methodological developments and possibly establish theoretical properties of the method(s). The student may also be asked to modify a method appropriately so that it fits the need of a specific application, establish the properties of the modified method, and then apply to the modified method to the application.

II. Statistical Consulting: Topics vary depending on the coverage in STAT 691 and may include techniques for problem formulation; identification of parameters and solutions; ill-posed problems and their formulation.

Note that the Statistical Consulting course is an engaged learning course where the students use statistical methodologies in real world problems.

This part of the exam will carry 50% weight to the overall score for Exam J.

This part of the exam will focus on analysis of real data. The Exam may utilize data from the following sources and others.

1. Data which are already published in statistical and other scientific literature. In this case, the analysis reported in the publication may serve as a standard or baseline against which the student’s answer will be judged.

2. Data which were brought in to the Statistical Consulting Center (SCS) by a client, for which the client provides written permission for use in the Qualifying exam and whose analysis the instructor of STAT 691 deems complex enough to be asked in Qualifying Exam J. In this case, the statistical analysis already done
by SCS may serve as a standard or baseline against which the student’s answer will be judged.

3. Data from other sources. For example, Sanjib, while teaching STAT 691, used an extensive dataset (under permission from the study investigators to use these data in the course) on longitudinal measurements from 902 heart patients in a clinical trial. In this case, the statistical analysis already done on the data may serve as a standard or baseline against which the student’s answer will be judged.

The goals of this part of the exam are the following:

1. To judge the student’s readiness, skill-set and expertise in handling real data

2. To judge the student’s readiness, skill-set and expertise in formulating scientific question(s) into statistical question(s)

3. To judge the student’s readiness, skill-set and expertise in formulating a statistical model, in choosing appropriate statistical methodologies and in modifying statistical methodologies to meet the intricacies of the data.

4. To judge the student’s readiness, skill-set and expertise in implementation, in developing appropriate code and software for implementing the modified methodologies.

5. To judge the student’s readiness, skill-set and expertise in appropriate presentation of the results from the statistical analysis in a readily interpretable and client-quality professional report.

As mentioned before, the students will be asked to answer specific scientific questions and the answers will be judged against established standards/solutions/approaches. The setting will be that of a take-home exam rather than an open-ended consultancy or research project.

References:
I and II.

NOTES TO PH.D. STUDENTS

A suggested timeline for students entering the Ph.D. program as full-time students is: 2 years to complete the core courses and pass the written Ph.D. Qualifying Exams; 1-2 years to take more advanced seminars and select a research area; and 1-2 years to construct a dissertation (total of 5 years). In general, a range of 4-6 years for full-time students should be anticipated.

As you plan your program of study, it is appropriate to keep some special requirements in mind.

1 PROBABILITY AND STATISTICS REQUIREMENT

The graduate catalog states that each student seeking admission to the Ph.D. program "is required to have completed an approved year-long sequence of courses in probability and statistics prior to admission to the program, or to take an approved sequence of graduate courses in probability and statistics as part of the doctoral program." Sequences that will meet this requirement include the traditional theoretical courses:

- **STAT 470 (3 hrs.)** INTRODUCTION TO PROBABILITY THEORY
- **STAT 472 (3 hrs.)** INTRODUCTION TO MATHEMATICAL STATISTICS

and the sequence of applications-oriented, computer-oriented courses:

- **STAT 473 (3 hrs.)** STATISTICAL METHODS AND MODELS I
- **STAT 473A (1 hr.)** STATISTICAL COMPUTING PACKAGES
- **STAT 474 (3 hrs.)** STATISTICAL METHODS AND MODELS II

Other sequences are also possible; consult the Director of Graduate Studies if in doubt.

2 CORE COURSES

All doctoral students will take 8 core courses: MATH 620, 630, 632, and 662, plus one of the following groups of courses:

- Core Group A (Mathematics): Four of MATH 621, 631, 636, 642, and 650;
- Core Group B (Mathematics Education): MATH 610, 611, 613, and 614;
- Core Group C (Statistics): STAT 673, 679, 680 and 691

The core group chosen identifies a doctoral student's general area of research (mathematics, mathematics education, or statistics).

Doctoral students are required to make a grade of B or higher in each of their core courses that is not explicitly tested on their qualifying examinations.

3 QUALIFYING EXAMINATIONS

The Department offers a written Ph.D. Qualifying Examination and Master’s Comprehensive Examination three times a year, in June, August, and January, just prior to the start of each semester. This is the only general written examination that students are required to pass. The qualifying examination consists of three individual examinations. The individual exams are listed below, along with the courses that students should take to prepare for each individual exam. Each is three hours in length, except for Exam F and Exam I.
A syllabus for each exam will be made available to interested students.

Exam A: Algebra (MATH 523, 620, 621)

Exam B: Real and Complex Analysis (MATH 530, 531, 630, 632)

Exam C: Functional Analysis and Topology (MATH 550, 631, 650)

Exam D: Differential Equations (MATH 636, 642)

Exam E: Numerical Mathematics (MATH 662, and either MATH 664 or MATH 666)

Exam F: Mathematics Education: Foundations and Research (MATH 610, 611) (This is a take-home exam.)

Exam G: Mathematics Education: Theories of Learning and Teaching (MATH 613, 614)

Exam H: Probability and Inference (STAT 670, 785)

Exam I: Linear Models and Bayesian Statistics (STAT 673, 680)

Exam J: Advanced Statistical Methods and Statistical Consulting (STAT 679, 691)

Each doctoral student must successfully complete three of these exams, as follows:

Area A: Applied, Computational, and Pure Mathematics. Two exams chosen from the set \{A, B, C\}; and any other exam in the list A-L.

Area B: Mathematics Education. One exam chosen from the set \{A, B, C\}; and exams F and G.

Area C: Statistics. H, I, and J.

A doctoral student is expected to attempt at least two of the individual exams within two years of entering the program, and is encouraged to attempt three. On the first attempt, at least two of the individual exams must be taken. On the basis of the outcome, the Graduate Studies Committee will recommend to the student that they (a) continue in the doctoral program; (b) complete a master’s degree and leave the program; or (c) leave the program.

The student may petition the committee to retake one or more parts of the qualifying exam. The committee may, at its discretion, allow a maximum of two attempts to pass any individual exam, and a maximum of three attempts to pass the entire qualifying exams.

The student must take at least two individual exams at any given time, unless only one remains to be passed.

Doctoral students are required to make a grade of B or higher in each of their core courses that is not explicitly tested on their set of exams.

4 SEMINARS and ELECTIVES

In addition to the core courses, doctoral students must take at least 21 semester hours of topics courses and seminars, and 12-18 hours of graduate-level electives. The topics courses and seminars are ordinarily chosen
from the 700-level courses listed in the Graduate Catalog, and may also include independent study courses (MATH 790x). At least one seminar course must be outside the student's area of study.

The additional electives usually include graduate courses at the 600 level and 700 level, and with department approval, may include some courses from other departments.

5 SEQUENCE REQUIREMENT

The graduate catalog states that the doctoral program of study shall contain "a coherent selection of 6 semester hours at the 600-level or above in the mathematical sciences, outside the student's broad area of study, or in a related discipline." We refer to this as the "Sequence Requirement." The sequence is approved by the department after the general area of research for the student's dissertation has been determined. The requirement is often satisfied by taking two MATH or STAT courses numbered 600 or above, both having the same course in the 8-course core as an essential prerequisite, and not in the student's major area of study.

Courses from the student's 8-course Ph.D. core cannot be used to meet the sequence requirement. Here are some examples of ways to satisfy the requirement:

MATH 640 and 642 (if you are not in applied mathematics),
MATH 664 and 666 (if you are not in computational mathematics),
MATH 613 and 614 (if you are not in mathematics education),
STAT 570 and 572 (if you are not in statistics).

The following examples could satisfy the sequence requirement while also meeting the catalog requirement that "one seminar must be elected outside the student's area of study."

MATH 622 (homology theory) and MATH 720 (topics in algebra), both relying on MATH 621;
MATH 637 (ordinary differential equations II) and MATH 740 (topics in ordinary differential equations), both relying on MATH 636;
MATH 664 (numerical linear algebra) and MATH 660 (topics in control theory), both relying on MATH 662;
MATH 730 (complex analysis II) and MATH 730 (Banach algebras and operator theory), both relying on MATH 632.

Many other sequences are also possible; consult the Director of Graduate Studies for further options.

6 FOREIGN LANGUAGE REQUIREMENT

The foreign language requirement for doctoral students can be met in one of two ways:

Demonstrate average reading proficiency in two of the languages French, German, and Russian.

Demonstrate average reading proficiency in one of the languages French, German, and Russian, and also satisfactorily translate a mathematical research paper in that language.
Average reading proficiency is demonstrated by either (a) completing the 6-credit scientific reading course offered by the Foreign Language Department in the summer with a satisfactory grade; or (b) pass the average reading proficiency test that is administered by the Office of Testing Services. In this test, the student must provide an acceptable translation of an excerpt from a mathematical book (at least 200 pages long) written in the language, with the aid of a dictionary. The book is chosen by the student and approved by the Director of Graduate Studies prior to its submission to the Office of Testing Services.

With the approval of the department, students whose undergraduate degree is from an institution in which the official language is French, German, or Russian can, with the approval of the department, automatically receive average reading proficiency in that language.

After demonstrating average reading proficiency in one language as defined above, the student can opt to translate a mathematical research paper in that language instead of demonstrating average reading proficiency in a second language. The mathematical research paper translation is administered by the department. The student will be expected to provide a translation of high quality (mathematically and linguistically) of a significant excerpt from a research article in the candidate's major area with the aid of a dictionary, but without access to the article in advance. The student may attempt this option at most once per academic term.

7 APPLICATIONS INVOLVEMENT COMPONENT (AIC)

Every doctoral student in Mathematical Sciences is required to complete an internship experience. Here are examples of such experiences drawn from the students who have fulfilled the requirement to date:

Argonne National laboratory in the southwest suburbs of Chicago. Argonne has extremely powerful computer resources. Our students who have gone there have worked extensively with computers in such areas as numerical linear algebra, robotics, and symbolic algebra software packages.

Allied Signal Corporation, Des Plaines, IL. Allied does chemical research. Our students who have worked there have applied mathematical techniques to the analysis of long-chain molecules.

Department of Education, State of Missouri. This student was involved with curriculum development in mathematics for the public schools in Missouri.

Mathematics 360 (Model-Building in Applied Mathematics) at NIU. This unique course, involving teams of students working on projects drawn from real-world problems, is required for all undergraduate math majors at NIU. The doctoral students working with this course developed project materials, helped to implement the Minitab software into the course, and taught the course under the supervision of a faculty member.

Many other types of internship experiences are possible. One option is to arrange a placement with another department on this campus. You should plan to confer with the AIC director soon after passing the written exam. The director is involved with arranging your placement with a governmental or industrial laboratory, if your experience is to be of this type.

During the semester in which the working phase of the AIC internship occurs, a doctoral student should register for at least 3 hours of credit in MATH 792. If the internship involves a research stipend paid by the employing company or laboratory, then the Graduate School will normally grant a tuition waiver.

Doctoral students should also register for one hour of credit in MATH 792 each semester that they are in residence on campus before the working phase of their AIC. During these semesters, it is expected that they will participate in all on-campus AIC activities (such as seminars given by visiting scientists, and oral presentations...
by students who have completed the working phase of their internship).

Students who need a placement within a given calendar year, but have not arranged one by January 1 of that year, will meet with Dr. Bellout for about one hour per week in the spring semester as a Math 792 seminar. Activities of this seminar will be designed to prepare these students for the AIC experience.

When a doctoral student has fulfilled the AIC requirement, they will not be required to register for MATH 792 in subsequent semesters. However, students are encouraged to continue to attend AIC activities even after they have completed the AIC requirement.

8 DISSERTATION ADVISER

By the time you take the written qualifying examination you should be thinking very seriously about which faculty member to work with for your dissertation research. This is a very important decision, and you should not hesitate to talk with several faculty members about this. The Director of Graduate Studies has a handout on research interests of the graduate faculty, which may be helpful. Note that a given faculty member is not required to accept you as a student if you request it; there is an element of choice here for both of you.

9 CANDIDACY EXAMINATION AND DISSERTATION PROPOSAL

When you and your dissertation adviser have identified a promising dissertation topic, and perhaps obtained some preliminary results, you will have your oral Ph.D. Candidacy Examination. This is an oral examination in the student's primary area of study. It must take place after the qualifying examination is passed, and should be scheduled as soon as the adviser is reasonably convinced that the research investigation is likely to be fruitful. It is not appropriate to delay the oral candidacy examination until the dissertation is virtually complete. The format for this exam will normally be as follows: The candidate, working closely with the dissertation adviser, draws up a written research proposal and submits it to the committee at least one week before the exam. The proposal should include:
   (i) a clear statement of the problem(s) which the student proposes to address;
   (ii) an indication of the methods and/or techniques with which the student proposes to attack the problem(s) mentioned in (i).

During the initial part of the exam (approximately 30-45 minutes), the candidate presents the proposal orally. The emphasis should be on the general framework of the proposal, relating it to major themes in the relevant research area, as opposed to presentation of a lot of technical detail. This part of the presentation will be open to anyone who wishes to attend. At this point, all but the candidate and the committee will be excused. The committee will proceed to question the candidate about the primary area of study. This part of the exam should normally last about one hour. The "primary area of study" mentioned above includes material in previous courses that leads into the proposed research. For example, a candidate in ring theory can be questioned about other areas of algebra that are necessary to develop the subject matter of the proposal. The faculty will interpret to the candidate what "primary area of study" means in their context, well before the oral exam itself.

After this period of questioning, the candidate will be excused and the committee will determine if the candidate should be passed, failed, or requested to return at a later time for additional questions. If a student has passed the oral exam and later changes to a different adviser with a substantial change in research area, then the committee can, at its discretion, require a new oral exam.