Mathematics

The Department of Mathematics offers two master’s degrees, one in Mathematics and the other in Statistics, and two doctoral degrees, one in Mathematics and one in Statistics. To be admitted, an applicant should have, at the very minimum, the equivalent of two semesters of a rigorous advanced calculus course and two semesters of linear algebra or algebra. Most admitted students in the recent past have taken several more advanced courses. Because it is difficult to make up coherent programs for students entering in the middle of the year, students will ordinarily be admitted only in the fall.

The AM in Mathematics requires 36 semester hours of approved course work at the graduate level. In addition, a candidate for the master’s degree must pass two of the four PhD written qualifying examinations. A comprehensive AM examination based on Mathematical Analysis, Topology and Algebra may be substituted for the two written qualifying examinations.

The AM in Statistics requires 36 semester hours of approved course work, too, but also requires a thesis. Students earn 6 of the 36 credits for conducting thesis research. They defend their thesis in an oral examination.

The PhD in Mathematics requires 72 semester hours of approved course work at the graduate level, normally including courses on algebra, measure theory and functional analysis, complex analysis, and geometry/topology. With permission from the Director of Graduate Studies, a student may substitute courses on statistics for either complex analysis or geometry. In addition, students must demonstrate competence in English and one other major mathematical language and must take a qualifying examination. This exam includes four general written examinations, one on each of the four areas of required course work, and oral presentations on two topics. After passing the qualifying examinations, students research, write, defend, and submit their dissertations.

The PhD in Statistics requires 72 semester hours of approved course work at the graduate level, including course sequences in both mathematical statistics and linear statistical models, as well as two course sequences in pure mathematics, selected from algebra, measure theory and functional analysis, complex analysis and geometry. In addition, students must demonstrate competence in English and must take a qualifying examination. This exam includes four general written examinations, one on each of the four areas of required course work, and oral presentations on two topics. After passing the qualifying examination, students research, write, defend, and submit their dissertations.

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Affine Algebraic Geometry; Polynomial Automorphisms

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Ron Freiwald
Professor
PhD, University of Rochester
General Topology

Endowed Professor
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Spencer T. Olin Professor of Mathematics
PhD, University of California, Berkeley
Analysis; Operator Theory; One and Several Complex Variables

Professors
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PhD, Stanford University
Differential Geometry

Renato Feres
PhD, California Institute of Technology
Differential Geometry; Dynamical Systems

Jefferson M. Gill
Professor, Political Science; Courtesy appointment, Mathematics
PhD, American University

Steven G. Krantz
PhD, Princeton University
Several Complex Variables; Geometric Analysis

Rachel Roberts
PhD, Cornell University
Low-dimensional Topology

John Shareshian
PhD, Rutgers University
Algebraic and Topological Combinatorics

Edward Spitznagel
PhD, University of Chicago
Statistics; Statistical Computation; Application of Statistics to Medicine
Xiang Tang  
PhD, University of California, Berkeley  
Symplectic Geometry; Noncommutative Geometry; Mathematical Physics

Mladen Victor Wickerhauser  
PhD, Yale University  
Harmonic Analysis; Wavelets; Numerical Algorithms for Data Compression

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Representations of Lie Groups; Harmonic Analysis

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Statistics

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PhD, University of Illinois at Urbana-Champaign  
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Assistant Professor of Genetics, The Genome Institute, courtesy appointment Mathematics Department  
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Professors Emeriti

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PhD, University of Michigan  
Differential Geometry

Lawrence Conlon  
PhD, Harvard University  
Differential Topology

Gary R. Jensen  
PhD, University of California, Berkeley  
Differential Geometry

Robert McDowell  
PhD, Purdue University  
General Topology

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PhD, Harvard  
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Probability and Statistics; Population Biology, Mathematical Genetics

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AM Mathematics, Washington University
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Research

Faculty Research Projects
A significant measure of outside recognition of the mathematical activities at Washington University is the external grants awarded to its faculty. In the past five years, several dozen research, scholarly and computing projects conducted by Washington University faculty were funded by both federal and private agencies. These have included research grants, grants to purchase computing equipment, grants to run conferences, grants to develop educational projects, grants to develop software and algorithms, and grants to develop collaborations with engineering, statistics, the medical school, and other departments.

Also, Washington University mathematics faculty members are frequent speakers and visitors at other universities around the world. Our faculty members conduct seminars, host colloquia, and organize conferences having to do with their research interests. For more information about our faculty, please visit our website: http://wumath.wustl.edu/our-people.

A list of recent publications by members of our faculty can be found at http://libguides.wustl.edu/math/pubs.

A few of the research activities recently supported by grants from or contracts with the National Science Foundation or similar agencies:

- Collaborative research in Hodge Theory, Moduli, and Representation Theory (Matthew Kerr, NSF).
- Collaborative research in geometric numerical analysis (Ari Stern, Simon). The cross-disciplinary topic of geometric numerical analysis lies at the intersection of geometry, analysis, and computation. This project proposes to use insights from geometry in order to develop novel numerical methods for differential equations, along with techniques to analyze them.
- Multivariable Operator Theory and Applications (McCarthy, NSF). Holomorphic functions of a single variable can easily be applied to matrices whose spectrum lies in the domain of a function, and this has developed into a very successful and important theory. McCarthy is studying functions of several variables applied to matrices. The theory immediately splits into the commutative and non-commutative cases. In the former, he is investigating when functions of several variables preserve the natural order structure on matrices, and what happens when the size of the matrices becomes infinite (the operator case). Conversely, he is using tools from operator theory to understand functions of several variables, such as characterizing asymptotic expansions of functions in the Pick class (this is called the Hamburger problem in one variable). In the non-commutative case, he is investigating how non-commutative holomorphic functions can be obtained as limits of non-commutative polynomials. He is also working on applying analytic techniques to improve ultrasound imaging.
- Geometry of projective varieties (Roya Beheshti-Zavareh, Simons). The focus of this project is to investigate questions on moduli spaces of rational curves contained in smooth projective varieties in particular smooth hypersurfaces. The study of geometric properties of these moduli spaces sheds light on the arithmetic and geometric properties of hypersurfaces, and plays an important role in modern enumerative geometry as well as in birational and higher dimensional geometry.
- Noncommutative Geometry of Orbifolds (Xiang Tang, NSA). Orbifolds are interesting geometric objects showing up naturally in the study of many branches of mathematics. In this project, we will use noncommutative geometry tools to study orbifolds. In particular, we will study the deformation theory of orbifold algebras and its connections to the geometry and topology of orbifolds.
- Geometry of projective varieties (Roya Beheshiti-Zavareh, SIMONS). The focus of this project is to investigate questions on moduli spaces of rational curves contained in smooth projective varieties in particular smooth hypersurfaces. The study of geometric properties of these moduli spaces sheds light on the arithmetic and geometric properties of hypersurfaces, and plays an important role in modern enumerative geometry as well as in birational and higher dimensional geometry.
• Hodge theory, algebraic cycles, and arithmetic (Matt Kerr, Algebra and Number Theory Program, NSF). This project studies aspects of the theory of period domains and generalized algebraic cycles related to Calabi-Yau varieties and degenerations thereof. It has a particular focus on problems with applications to number theory and physics: automorphic cohomology; irrationality proofs; string dualities; and asymptotics of instanton numbers.

• Symplectic and Spectral Theory of Integrable Systems (Alvaro Pelayo, Geometric Analysis Program, NSF). Investigation of classical and quantum semitoric systems: verifying that the semiclassical joint spectrum of a quantum semitoric system determines completely the system (this is the Spectral Conjecture, widely considered the most spectacular problem in the area); furthering the study of semitoric systems in a more general context, in particular as it regards to the study of the convexity and connectivity properties of the singular Lagrangian fibrations which semitoric systems induce, and which are of special interest in mirror symmetry.

• Problems in Function Theory and Operator Theory (Richard Rochberg, Analysis Program, NSF). This group is working on specific problems in the operator theoretic function theory of spaces of holomorphic functions which are subspaces of potential spaces.

• Operator Theory and Complex Analysis (John McCarthy, Analysis Program, NSF). This group studies the interaction between operator theory and complex analysis in one and several variables. Operator theory can shed light on problems like the boundary behavior of holomorphic functions. Conversely, one can use a combination of function theory and operator theory to help analyze functions that are matrix monotone or matrix convex.

• Noncommutative Geometry: Its Applications to Geometry and Analysis (Xiang Tang, Geometric Analysis Program, NSF). This group studies various problems in geometry using noncommutative geometric tools. This includes index theory on singular spaces, duality of gerbes on orbifolds, Rankin-Cohen deformations and Hopf algebras.

• Algebraic, topological and enumerative combinatorics (John Shareshian, Algebra, number theory, and combinatorics Program, NSF). This group examines a class of lattices appearing in a conjecture that specializes both Shareshian's topological conjecture that there is some finite lattice L such that there is no finite group G whose subgroup lattice contains an interval isomorphic with L, and a combinatorial conjecture of M. Aschbacher.

• Statistical Aggregation in Massive Data Environments (Nan Lin, Statistics Program, NSF). This group develops statistically sound compression and aggregation methods for advanced statistical analysis of data cubes and data streams, uses the compression-then-aggregation strategy to improve computational efficiency of certain statistical analyses, and develops associated asymptotic theories.

Degree Requirements
Graduate Programs in Mathematics and Statistics

• Areas of study (Math): Algebra, Algebraic Geometry, Real and Complex Analysis, Differential Geometry, Topology

• Areas of study (Statistics): Mathematical Statistics, Survival Analysis, Modeling, Statistical computing for massive data, Bayesian regularization, Bioinformatics, Longitudinal and Functional Data Analysis, Statistical computation, application of Statistics to Medicine

Degree Programs and Requirements

PhD students at Washington University are required to demonstrate proficiency in Algebra, Real Analysis, Complex Analysis, and Geometry. Most students satisfy these requirements by taking a yearlong (two semester) course in each subject, capped by a final exam that serves as a "qualifier." Students with strong backgrounds may be excused from some of these courses.

The result of this broad and uniform requirement is two-fold. First, graduate students have an opportunity when they first arrive to share common concerns and to become acquainted. One of the most attractive features of our program is the friendly and supportive atmosphere among the graduate students. Second, advanced courses in the Washington University math department can build on the common background shared by all students. As a result these courses are richer and nearer to the level of PhD work than advanced courses regularly taught at other good mathematics departments.

Typically, it takes two years for a student to complete the written qualifying exam phase of the program. By the end of the second year, the student usually has some idea of which area of specialization to choose. By that time the student is also acquainted with several faculty and feels comfortable asking one to direct his or her research.

Once the qualifying exams are passed and a thesis adviser engaged, the next step in the program is for the student to prepare a “minor oral presentation” and a “major oral presentation.” Topics for these orals are chosen in consultation with their thesis adviser, and culminate in two public lectures. These should be completed by the end of the year following completion of the written qualifying exams as well as satisfying their language requirement.

After these preliminaries, the essential part of a student’s graduate work — the thesis — begins. Unlike class and exam work, a PhD thesis in mathematics involves producing
a substantial piece of new research. The work is difficult, protracted, and frustrating. But in the end the rewards are great.

While working on their orals and their research, students have the opportunity to take a variety of advanced courses. These vary from semester to semester. See our current course schedule and WebSTAC for details.

When the research is completed the student prepares a thesis, which is the detailed writeup of the new results obtained. This writeup may range from 50 to a few hundred pages and is the formal record of the student's achievement in the graduate program. The final official step is for the student to defend the thesis in a public lecture followed by questions from a panel of appointed faculty members of the university in a closed session.

Students typically complete the PhD program in five years. A student who comes here with advanced preparation may finish in less time. On the other hand, some students find that it is advisable for them to take preparatory work before attempting the qualifying courses. In special cases, the time schedule may be lengthened accordingly. Students should plan to develop a close relationship with their thesis advisers so that they may have a realistic idea of their progress.

Graduate study in mathematics is not for everyone. Entering students usually find that the time and effort required to succeed goes well beyond anything they encountered as undergraduates. Success requires both ample mathematical ability and the determination to grapple with a subject for many days or weeks until the light of understanding shines through. The experience can be daunting. Those who continue in their studies are largely those for whom the pleasure in attaining that understanding more than compensates the required effort. For such persons, the life of a mathematician can be richly rewarding.

**AM in Mathematics**

**General requirements:** The minimum residence requirement is one full academic year of graduate study. 36 semester hours of graduate-level course work is required, with or without thesis, but 6 units may be for thesis research. If the department consents, a student may transfer up to 6 hours from other universities. A grade point average of "B" or better must be maintained in graduate course work.

**Course requirements:** There are four basic graduate courses in pure mathematics: 5021-5022, 5031-5032, 5041-5042, and 5051-5052. A candidate for the AM in Mathematics must include two of these sequences (12 hours) in the required 36 hours. The student, in consultation with his or her adviser, will select the remaining 24 hours according to the student's interests and needs.

**The AM examination:** Candidates for the AM degree must pass at least two of the four PhD qualifying exams. Under exceptional circumstances, the graduate committee may allow the student to substitute the PhD qualifying exams mentioned above with a comprehensive examination on the contents of Math 411-412, 417-418, and 429-430.

**AM in Statistics**

**General requirements:** 36 units of course work and a thesis. 6 units may be for thesis research. The minimum residence requirement is one full academic year of graduate study. A grade point average of "B" or better must be maintained in graduate course work.

**Course requirements:** The student must take (or have taken) the following five required courses in mathematics or their equivalents: Math 493 Probability and Math 494 Mathematical Statistics, or 5061 and 5062 (theory of statistics); Math 429 Linear Algebra or Math 4392 Advanced Linear Statistical Models; Math 439 Linear Statistical Models; and Math 475 Statistical Computation or a suitable substitute elective approved by the department. In the case that an equivalent course has been taken and also proficiency in the course material has been demonstrated, other 400-level and above electives may be substituted in consultation with the adviser.

Additional 400-level or higher electives will be chosen by the student in consultation with his or her adviser to make up the 36 units. Typically, at most two electives shall be chosen from outside the mathematics department. If not taken before, a course in C programming is strongly recommended but cannot be included among the courses used to satisfy the 36 units requirement.

**Possible electives include:**

- Math 4111 Introduction to Analysis (F)
- Math 4121 Introduction to Lebesgue Integration (S)
- Math 420 Experimental Design (SE)
- Math 4301 Multilevel Modeling (Pol Sci 584C) (F)
- Math 434 Survival Analysis (FO)
- Math 4392 Advanced Linear Statistical Models (SO)
- Math 449 Numerical Applied Mathematics (F)
- Math 459 Bayesian Statistics (S)
- Math 495 Stochastic Processes (SO)
- Math 5061-62 Theory of Statistics I,II (F),(S)
- Math 523C Information Theory and Statistics (ESE 523)
- Math 5021 Complex Analysis I (F)
- Math 5022 Complex Analysis II (S)
- Math 5031 Algebra I (F)
- Math 5032 Algebra II (S)
- Math 5041 Geometry I (F)
- Math 5042 Geometry II (SE)
- Math 5051 Measure Theory and Functional Analysis I (F)
- Math 5052 Measure Theory and Functional Analysis II (S)
- Math 551 Advanced Probability I
- Math 552 Advanced Probability II
- Biol 4181 Population Genetics
- Biol 5483 01 Human Linkage and Association Analysis
- Biol 5495 01 Computational Molecular Biology
- CSE 514A Data Mining
MEC 670 Seminar in Econometrics  
ESE 522 Random Variables and Stochastic Processes II

Please note: Not all courses are offered each year. Courses are listed in numerical order. The letters in parentheses after the name of a course mean:

• F = offered each fall  
• FO = offered each fall in odd-numbered years  
• FE = offered each fall in even-numbered years  
• S = offered each spring  
• SO = offered each spring in odd-numbered years  
• SE = offered each spring in even-numbered years

Math courses listed without one of these codes are offered based on demand.

PhD in Mathematics

No one can earn a doctorate merely by completing a specified course of study; the doctoral candidate must demonstrate high scholarship and the ability to perform significant original research in mathematics.

• General requirements: Completion of the PhD requires four full years of graduate study (72 hours), with at least 48 hours spent in residence at Washington University. The student must spend at least one academic year as a full-time student; this requirement cannot be met wholly by summer sessions or part-time study. The student may, with departmental permission, transfer a part of the 72 hours from other universities. The typical load is 9 credit hours per semester. A grade point average of "B" or better is required in graduate course work.

Graduate students in mathematics may ordinarily expect up to five years of support. Continuation of support each year is dependent upon normal progress toward the degree and satisfactory performance of duties.

For the well-prepared student, "normal progress" usually means: At the end of his or her second year, the student should have successfully completed the four qualifying exam course sequences; at the end of the third year, the student should have completed the major and minor oral exams and the language requirement; by the end of the fourth year, the student should have completed the 72-hour course requirement, and should be making substantial progress on a thesis.

Please note, however, that the sequence outlined above is for "well-prepared" students. The exact point at which any student enters the sequence depends upon his or her ability and background. When warranted, we will deviate from the normal sequence, and tailor a program that fits the student's ability and background.

• Specific course requirements: The 72 hours of course work must include four basic graduate sequences: Math 5021-5022, 5031-5032, 5041-5042, 5051-5052. In exceptional circumstances, departmental permission may be requested to replace one of these sequences with a suitable alternative. The student may also petition the department to waive one or more of the sequences because of work done previously.

It is in each student's best interest to take the four sequences that contain the material covered in the qualifying exams as soon as their individual program allows. Sequels to these courses, at the 500 level, are frequently offered; the qualifying exam courses are generally prerequisites to these 500-level courses.

• Language requirement: Most research literature in mathematics is written in English, French, German, or Russian. Consequently the department requires two of these languages for the PhD. If the student's native language is English, then he or she must demonstrate competence in one of the other three languages by either:

  • submitting an undergraduate transcript showing one year of one of these languages passed with a grade of C or better;  
  • taking a one-semester course in one of these languages while a graduate student at Washington University, and passing with a grade of "B" or better; or  
  • passing one of the annual written exams given by the department in mathematical French or German or Russian; to pass, the student must translate a passage in the language from a mathematics journal or book.

• Qualifying examinations: The qualifying exam is in two parts. One is a series of four written tests covering a range of topics, and one is an oral exam on two selected topics.

The written tests cover the material in the four basic course sequences: 5021-5022, 5031-5032, 5041-5042, and 5051-5052. Each spring, at the end of each sequence, all students enrolled in the course take a two-hour final exam; this exam usually covers the second half of the sequence. Doctoral candidates take an additional one-hour exam which covers the entire sequence. To pass the qualifying exam in one of the four areas, the student must pass the three hour combined exam.

Because each sequence varies somewhat in content from year to year, it is recommended that the student take each set of exams at the conclusion of the sequence in which he or she is enrolled. No advantage is gained by delaying the exam for a year. It is desirable to make every effort to finish all four exams by the end of the second year of study.

Some students will enter the PhD program with previously acquired expertise in one or more of the four basic
sequences. This sometimes happens with students who transfer from other PhD programs or who come from certain foreign countries. Such students may formally petition the Chairman of the Graduate Committee to be exempted from the appropriate course from and from its qualifying exam. The petition must be accompanied by hard evidence (e.g., published research, written testimony from experts, records of equivalent courses, or examinations and the grades achieved on them). The Graduate Committee will make the final judgment on all exemption requests.

Once the written phase of the qualifying process is complete, the student is ready to begin specialized study. The oral component of the qualifying exam is designed to expedite this process. Along with a committee of at least two faculty members, the student selects one major and one minor topic, and a body of literature dealing with each. The student then usually spends a semester studying the selected material. At the end of this period the student demonstrates mastery of each of the two selected topics by means of satisfactory oral expositions to a faculty committee. One member of this committee will in all likelihood become the student's thesis adviser and may have already agreed to be the adviser. The preparatory work for the presentation often becomes the foundation on which the thesis is constructed.

Following the oral and language exams, work on the thesis begins.

- **The dissertation and final oral exam:** The student's dissertation is the single most important requirement for the PhD degree: It must be an original contribution to mathematical knowledge. This is the student's opportunity to conduct significant independent research.

  It is the student's responsibility to find a thesis adviser who is willing to guide her or his research. Since the adviser should be part of the major and minor oral committee, the student should have engaged an adviser by the end of the third year of study.

  Once the department has accepted the dissertation (on the advice of the thesis adviser), the student is required to pass a final oral examination. Part of this procedure is a question/answer period in which the student is expected to "defend" the thesis.


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### PhD in Statistics

**Degree Requirements Summary**

Total of 72 graduate units required, consisting of:

- 24 required course work units total in fundamental topics and exam fields
- 12 elective course work units
- 6 course work units for staffing a walk-in statistical consulting center to be setup by the department
- 4 qualifying exams: 2 in statistics, 2 in mathematics
- Graduate School Teaching Requirement for PhD Students
- Major and minor oral presentation
- Dissertation research, thesis preparation, and defense (30 course work units)

**General Requirements:** Completion of the PhD requires four full years of graduate study (72 hours), with at least 48 hours spent in residence at Washington University. The student must spend at least one academic year as a full-time student; this requirement cannot be met wholly by summer sessions or part-time study. The student may, with departmental permission, transfer a part of the 72 hours from other universities. The typical load is 9 credit hours per semester. A grade point average of "B" or better is required in graduate course work.

Graduate students in statistics may ordinarily expect up to five years of support. Continuation of support each year is dependent upon normal progress toward the degree and satisfactory performance of duties. Teaching experience is an increasingly important component of graduate education for students who seek employment in academics. The PhD in Statistics program provides the opportunity for students to serve as teaching assistants to learn how to teach technical topics to students with a wide range of backgrounds.

For the well-prepared student, normal progress usually means: At the end of his or her second year, the student should have successfully completed the four qualifying exam course sequences (two on mathematical subjects, two on statistical subjects); at the end of the third year, the student should have completed the major exam in one of two statistics subjects, the minor oral exam in one of two pure mathematics subjects, and the language requirement; by the end of the fourth year, the student should have completed the 72-hour course requirement, and should be making substantial progress on a thesis.

Please note, however, that the sequence outlined above is for "well-prepared" students. The exact point at which any student enters the sequence depends upon his or her ability and background. When warranted, we will deviate from the normal sequence, and tailor a program that fits the student's ability and background.

**Specific course requirements:** The 72 hours of course work must include two basic graduate statistic sequences: Math
5061 Theory of Statistics I - Math 5062 Theory of Statistics II; Math 439 Linear Statistical Models - Math 4392 Advanced Linear Statistical Models; and any two of the following pure math sequences: Math 5021-5022, 5031-5032, 5041-5042, or 5051-5052. In exceptional circumstances, departmental permission may be requested to replace one of these sequences with a suitable alternative. The student may also petition the department to waive one or more of the sequences because of work done previously.

Prerequisites, if needed, are Math 429 Linear Algebra (0 credits towards the degree) and Math 233 Calculus III (0 credits towards the degree).

It is in each student's best interest to take the four sequences that contain the material covered in the qualifying exams as soon as their individual program allows. Sequels to these courses, at the 500 level, are frequently offered; the qualifying exam courses are generally prerequisites to these 500-level courses.

Electives allow students to develop their own tracks in advanced statistical theory, applied engineering, and biostatistics. Statistics elective courses include:

- Math 420 Experimental Design
- Math 425C, Multilevel Models in Quantitative Research
- Math 434 Survival Analysis
- Math 449 Numerical Applied Mathematics
- Math 456 Topics in Financial Mathematics
- Math 459 Bayesian Statistics
- Math 475 Statistical Computation
- Math 495 Stochastic Processes
- Math 523C, Information Theory and Statistics (ESE 523)
- Math 551, Advanced Probability I
- Math 552, Advanced Probability II
- ESE 405 Reliability and Quality Control
- ESE 407 Analysis and Simulation of Discrete Event Systems
- ESE 415 Optimization
- ESE 425 Random Processes and Kalman Filtering
- ESE 428, Probability
- ESE 520, Probability and Stochastic Processes
- ESE 521, Random Variables and Stochastic Processes I
- ESE 522, Random Variables and Stochastic Processes II
- ESE 523, Information Theory
- CSE 511A, Introduction to Artificial Intelligence
- CSE 514A, Data Mining
- CSE 517A, Machine Learning
- CSE 519T, Advanced Machine Learning
- CSE 541T, Advanced Algorithms
- Biostatistics M19-550, Randomized Controlled Trials
- Biostatistics M21-623, Advanced Topics in Biostatistics
- Econ 5145, Advanced Theoretical Econometrics

Language requirement: A student whose native language is not English must demonstrate proficiency in English. The student will also be expected to become fluent in spoken English. In particular, any student who expects to gain teaching experience while pursuing a degree will need to do this as soon as possible.

Ordinarily, otherwise qualified students who score less than 600 on the Test of English as a Foreign Language (TOEFL) are not admitted into the program. If English is not the student's native language, he or she must pass an oral English proficiency exam with a grade of "3" or better. If the student does not score a "3" the first time he or she takes the exam, the director of the English Language Program at the International Office will recommend taking one or more classes to improve reading, writing, pronunciation, listening or speaking skills. After the recommended classes have been completed, the student is required to retake the English proficiency exam. Once the student has demonstrated the ability to handle teaching a class (by scoring a "3" or better on the exam), he or she will qualify for a Teaching Assistantship or teaching duties. All students are expected to fulfill the language requirement during their first two years of graduate study.

Qualifying examinations: The qualifying exam is in two parts. One is a series of four written tests covering a range of topics, and one is an oral exam on two selected topics.

The written tests cover the material in the two basic statistics course sequences: Math 5061-5062, Math 439-4392, and the candidate's two chosen pure math sequences: Math 5021-5022, 5031-5032, 5041-5042, or 5051-5052. Each spring, at the end of each sequence, all students enrolled in the course take a two-hour final exam; this exam usually covers the second half of the sequence. Doctoral candidates take an additional one-hour exam which covers the entire sequence. To pass the qualifying exam in one of the four areas, the student must pass the three hour combined exam.

Because each sequence varies somewhat in content from year to year, it is recommended that the student take each set of exams at the conclusion of the sequence in which he or she is enrolled. No advantage is gained by delaying the exam for a year. It is desirable to make every effort to finish all four exams by the end of the second year of study.

Some students will enter the PhD program with previously acquired expertise in one or more of the four basic sequences. This sometimes happens with students who transfer from other PhD programs, or who come from certain foreign countries. Such students may formally petition the Chairman of the Graduate Committee to be exempted from the appropriate course and from its qualifying exam. The petition must be accompanied by hard evidence (e.g., published research, written testimony from experts, records of equivalent courses, or examinations and the grades achieved on them). The Graduate Committee will make the final judgment on all exemption requests.

Once the written phase of the qualifying process is complete, the student is ready to begin specialized study. The oral component of the qualifying exam is designed to expedite this process. Along with a committee of at least two faculty members, the student selects one major and one minor topic, and a body of literature dealing with each. The student then usually spends
a semester studying the selected material. At the end of this period the student demonstrates mastery of each of the two selected topics by means of satisfactory oral expositions to a faculty committee. One member of this committee will in all likelihood become the student's thesis adviser and may have already agreed to be the adviser. The preparatory work for the presentation often becomes the foundation on which the thesis is constructed.

Following the oral and language exams, work on the thesis begins.

The dissertation and final oral exam: The student's dissertation is the single most important requirement for the PhD degree. It must be an original contribution to statistical knowledge. This is the student's opportunity to conduct significant independent research.

It is the student's responsibility to find a thesis adviser who is willing to guide his or her research. Since the adviser should be part of the major and minor orals committee, the student should have engaged an adviser by the end of the third year of study.

Once the department has accepted the dissertation (on the advice of the thesis adviser), the student is required to pass a final oral examination. Part of this procedure is a question/answer period in which the student is expected to "defend" the thesis.