WASHINGTON STATE UNIVERSITY

Department of Mathematics & Statistics
Graduate Student Handbook

M.S. in Mathematics
M.S. in Statistics
PhD in Mathematics
PhD in Statistical Science

Last Updated: Oct 2022

1 TABLE OF CONTENTS

2 INTRODUCTION

This handbook offers guidance to students working toward advanced degrees in mathematics and statistics at Washington State University. In all of our degree programs we attempt to combine a sound general core of fundamental mathematics and statistics with electives that reflect individual interests, needs, and opportunities. Students can obtain an M.S. or Ph.D. in Mathematics, with optional areas of emphasis in applied mathematics, computational finance, and teaching in mathematics. The department also offers an M.S. in Statistics and a Ph.D. in Statistical Science.

Graduate students should accept much of the responsibility for their own training. This includes planning a meaningful program of study, studying for courses and examinations, and writing a dissertation or completing a project.

It is important to note that some of the regulations and requirements mentioned are from the Graduate School and are university-wide in scope, while others originate in the Department of Mathematics and Statistics and pertain only to mathematics and statistics students. The Graduate School determines the procedures regarding the Master's and Doctoral Final Oral Examinations, the Doctoral Preliminary Examination, total hours required for each degree, and the format for a thesis or dissertation. Specific course requirements and rules governing the Graduate Qualifying Examination and the Doctoral Qualifying Examination originate with the Department.

There are many more resources and important information available at the Graduate School website (gradschool.wsu.edu). On that site, be sure that you consult the page about New and Current Students and the current version of the Graduate School Policies and Procedures Manual. That manual is the definitive source for information on Graduate School regulations and requirements, while this guide is the official source of information concerning departmental regulations and requirements valid on the date of issue. For an up-to-date list and description of Mathematics and Statistics courses offered, consult the University Catalog (catalog.wsu.edu).

Departmental policies pertaining to graduate programs are set by the graduate faculty of the Department of Mathematics and Statistics. The departmental Graduate Studies Committee serves as an intermediary between the graduate students and the graduate faculty. Questions concerning the content of this document and petitions requesting a possible waiver or modification of any rule of departmental origin should be directed to this committee. Students should feel free to seek advice or assistance from any member of the mathematics faculty, and especially from the Chair of the Department, the Associate Chair of the Department, and the members of the Graduate Studies Committee. In addition, students should not hesitate to seek assistance from the Graduate Program Coordinator on administrative matters pertinent to the graduate programs of the Department.

3 PREREQUISITES FOR ADMISSION

All graduate students are expected to have a background in mathematics or statistics equivalent to that provided by an undergraduate degree. Normally this means that a student has taken advanced, upper-division courses typical of a mathematics or statistics major course of study. Specifics classes that are expected prerequisites for each degree are listed below. Students admitted with a deficient background are expected to make up these deficiencies at the earliest opportunity.

For applicants to the **MS and PhD Mathematics** program, a student's background in mathematics would ideally include familiarity with the material covered in Math 401 Introduction to Analysis, Math 402 Introduction to Analysis II, Math 420 Linear Algebra, Math 421 Algebraic Structures, and some experience with computer programming.

For applicants to the **PhD Statistical Science** program, a student's background in statistics would ideally include a course in probability theory, similar to Stat 443 Applied Probability, and a course in mathematical statistics or statistical theory, similar to Stat 456/556 Introduction to Statistical Theory.

Students considering the **M.S. in Statistics** should have a major in Mathematics, Statistics, or a field in which statistics is heavily used. Minimum admission requirements for the M.S. in Statistics include three semesters of calculus (including one semester of multivariate calculus), Linear Algebra (similar to Math 220), a course in computer programming, and at least one upper division course in probability in statistics (similar to Stat 360, Stat 412, Stat 423).

For students already registered to a doctoral program at Washington State University who are interested in completing an M.S. in Statistics concurrently, please see The MS in Statistics section for information on that process.

4 MASTER OF SCIENCE IN MATHEMATICS & STATISTICS: POLICIES AND PROCEDURES

The Department of Mathematics & Statistics offers an M.S. degree in Mathematics and an M.S. degree in Statistics, with possible Mathematics options including Applied, Computational Finance, and Teaching. A full-time graduate student typically takes two years to complete the program. Completing the M.S. degree requires four components, including:

Coursework – Each option has specific requirements, but at minimum, a student must complete 26 hours of graded coursework, 4 hours of Math 702 Directed Study to pursue an individual and/or group project, and 1 hour of Math 500 Proseminar, to be taken the week before the student's first fall semester. Additionally, teaching assistants are required to take three semesters of Math 533 Teaching College Mathematics.

Administrative paperwork – To assess progress and accomplishments, students must complete an annual review each spring. The semester before they graduate, all M.S. graduate students are required to submit a *Program of Study* (paper) and then an *Application for Degree* (online in the student's MyWSU portal by the deadlines listed by the Graduate School, normally the seventh week of final semester).

The *Program of Study* includes the signatures of all committee members and the department chair, and indicates that the committee approves the student's coursework to fulfill the requirements for the degree. Adjustments to the program of study and changes to the student's committee can be submitted to the Graduate School when necessary.

> *Committee Composition:* An M.S. graduate committee must consist of at least three WSU faculty members. At least two (including the chair of the committee) must be graduate faculty in the Department of Mathematics & Statistics. An optional 4th or 5th member may be from outside the University. For more information on forming an M.S. committee, see the Graduate School Policies and Procedures Manual and the graduate program bylaws.

The *Application for Degree* cannot be filed until an approved Program of Study is on file with the Graduate School. It is advised that students apply for their degree the semester before intended graduation so the student is notified of requirements to be completed their final semester. Candidates may not schedule a *final examination* until an Application for Degree has been filed.

Final Exam – All Master's degree students must complete a final oral examination that may cover all of the student's coursework including Math 702. The student's advisory committee may conduct the examination when all requirements of the Department and the Graduate School have been satisfied. Scheduling forms are available online at the Graduate School website and must be turned in at least four weeks before the end of the semester of graduation and at least two weeks (10 working days) before the exam date.

The format for M.S. examinations varies by discipline and project; students should work with their committee chair to determine the expectations for the exam.

Extracurricular activities – Besides meeting the requirements needed to obtain a degree, students should voluntarily and energetically devote time to additional courses, outside reading of both books and journals, attend colloquia and special lectures by local and visiting speakers, work on assigned problems, and participate actively in seminars and professional meetings. Participating in these activities may be a crucial part of obtaining desirable employment after graduation.

Course Policies and Procedures

Prerequisites – Students pursuing an M.S. in Mathematics are expected to have a background equivalent to that provided by our undergraduate degree in mathematics. Ideally, this would include familiarity with the material covered in Math 401 and 402 (Introduction to Analysis), Math 420 and 421 (Linear Algebra and Algebraic Structures), and some experience with computer programming. Students with a deficient background are expected to make up these deficiencies at the earliest opportunity.

Students considering the M.S. in Statistics should have a major in Mathematics, Statistics, or a field in which statistics is heavily used. Minimum admission requirements for the M.S. in Statistics include three semesters of calculus, Math 220 (Linear Algebra), a course in computer programming, and at least one upper-division course in probability and statistics (e.g. Stat 360, Stat 412, Stat 423).

Transfer Credit – Up to eight hours of transfer credit may be given for suitable coursework done elsewhere in the pure, applied, and computational finance options. Up to six hours may be requested in the mathematics teaching option. Transfer credit is requested by listing the courses on the program of study and attaching the course syllabus; approval of the program of study implies approval of transfer credit. Courses taken toward a completed M.S. degree may NOT be used toward another M.S. degree at WSU. All other graded graduate-level course work (with a grade of B or higher) taken as a graduate student, but not taken toward a completed graduate degree, may be used toward an M.S. degree at WSU. Other general regulations regarding transfer credit can be found in Chapter 6 of the Graduate School Policies and Procedures Manual.

Note: The departmental graduate handbooks are in a transitional period while we continue to update the PhD programs. Please do not hesitate to ask if you have questions about any policies or procedures for your degree.

5 THE M.S. IN MATHEMATICS

Description and Learning Outcomes – This broadly defined program provides flexibility for students to design a course of study according to their interests, particularly in pure mathematics. It can also lay a solid foundation for further doctoral study in Mathematics, working in industry, or for teaching at the high school, community college, or university level as an instructor. This M.S. program is designed to lead the student to the following learning outcomes:

- Problem Solving: Students will be able to identify mathematical and computational methods in order to solve problems.
- Deductive Thinking: Students will be able to read and write logical arguments in order to prove advanced mathematical results.
- Effective Communication: Students will be able to effectively communicate mathematical concepts, problems and their solutions in written and oral form.

For admission to this program, please consult for prerequisites.

Courses – The M.S. in Mathematics requires at least 32 semester hours of approved graduate work. Math 501, Math 500, and four hours of Math 702 are the only required courses for the degree; the remaining 24 hours must be graded coursework selected from the options listed below. At least 18 of these hours must be from the approved list of mathematics and statistics graduate electives below. The remaining 6 hours of graded credit are elective and may be taken in other departments with approval of the advisor through the submission of a program of study. These may include 500-level courses, a maximum of two 400-level courses, and up to one 300-level course (if in another department).

Required courses: (5 credits)	Math 500 Math 702	Proseminar (1 credit) Directed Study (4+ credits)
Core Courses: (3 credits)	Math 501	Real Analysis (3 credits)
Math/Stat Electives (18+ credits)	6 courses	chosen from: Math 502-574, Math 586 Stat 508-577, including Stat 443 and excluding Stat 511. A maximum of 2 Statistics courses can be counted.
Additional Electives (6 credits)	2 courses	Any Department

Math 702 and M.S. Examination – The four required hours of Math 702 involve independent study under the guidance of a faculty member, normally the chair of the student's advisory committee. The results of this study are often summarized in a paper,

but this is not mandatory. In addition, students must complete a final oral examination, covering the content of the student's coursework including Math 702, 401, 402, 420, and 421 (Analysis, Linear Algebra, and Abstract Algebra). The format for the final examination is at the discretion of the student's committee, and it is the student's responsibility to be aware of their requirements. The student's committee will conduct this examination when all other requirements for graduation have been fulfilled.

6 THE M.S. IN MATHEMATICS – APPLIED MATHEMATICS OPTION

Description and Learning Outcomes – This is a two-year professional degree specifically designed to train mathematicians and scientists/engineers with strong mathematics backgrounds in up-to-date applied mathematical, computational and statistical skills. Such training is intended to produce individuals who can confidently undertake interdisciplinary research. The focus will be in preparing individuals to face the mathematical and other research challenges in business and/or industrial sectors. In order to achieve these goals the program requires:

- A broad background in the areas of Numerical Analysis/Optimization, Modeling/Simulation, and Statistical Analysis;
- A concentration in one of the above areas or one that matches the student's interests;
- Development of an individual project;
- A strong computing component.

The M.S. in Mathematics (Applied Option) is designed to meet the following learning outcomes:

- Problem Solving: Students will be able to identify mathematical and computational methods in order to solve problems.
- Deductive Thinking: Students will be able to read and write logical arguments in order to prove advanced mathematical results.
- Effective Communication: Students will be able to effectively communicate mathematical concepts, problems and their solutions in written and oral form.

For admission to this program, please consult Section 3 for prerequisites.

Courses – The M.S. in Mathematics (Applied Option) requires at least 35 hours of approved graduate course work from the list below, of which 26 hours are the core and required courses listed below. The remaining 9 credit hours of electives must include at least two courses in an emphasis area of the student's choice, subject to the advisory committee's approval. Please note that the electives must differ from the chosen core courses and that only three 400-level courses are permitted by the Graduate School for an M.S. degree.

Required courses: (5 credits)	Math 500 Proseminar (1 credit) Math 702 Directed Study (4+ credits)
Core Courses: (21 credits)	Math 464 Linear Optimization (3 credits) Math 516 Simulation Methods (3 credits) Math 540 Applied Mathematics I (3 credits) Math 548 Numerical Analysis (3 credits) Math 564 OR Math 566 – Optimization (3 credits)

Stat 443 Applied Probability (3 credits)
Stat 523 OR Stat 572 – Statistical Methods (3 credits)

Graduate Electives: (9 credits)	Three additional graduate level courses (of which one may be 400 level) including at least two from a chosen emphasis area. Examples of emphasis areas include (but are not limited to) two courses in Optimization (Math 564, 565, 566, 567, 574), Numerical Analysis (Math 545, 546), Modeling (570, 571, 579, 586), Data Analytics (Stat 435, 437, 536, 577, CptS 415, 570, 577), or any other focus. Courses from another department related to the student's research interests may be included.

Math 702 and M.S. Examination – Students must take at least four hours of Math 702. Ordinarily, the student must complete a project in Applied Mathematics under the direction of his or her advisor and committee. The final M.S. exam may also cover all of the student's coursework and the content of Math 401 & 402 Analysis, Math 420 Linear Algebra, and Math 421 Abstract Algebra. The student's advisory committee will conduct this examination when all other requirements for graduation have been fulfilled. The format of the final examination and project is at the discretion of the advisory committee.

Electives and Internships – During a standard two-year program, a student taking 10 credit hours (most students take more) will have time to include several elective courses in addition to the course work required. Students are strongly encouraged to take additional courses in math or other departments, spend a summer on an internship, and to attend seminars in applied mathematics. These elective courses, internship, and the project completed in Math 702 should form an effective combination in a particular area of interest to each student.

7 THE M.S. IN MATHEMATICS – MATHEMATICS TEACHING OPTION

Description and Learning Outcomes – This is a two-year professional degree designed to prepare teachers of mathematics at the community college, four-year college, or secondary levels. The program combines advanced work in mathematics with coursework in education and practice teaching, providing a foundation in both mathematical content and teaching methodology.

This M.S. program is designed to meet the following learning outcomes:

- Critical Thinking: Students will have developed the skills necessary to critically read and evaluate both practitioner and research articles in mathematics education journals.
- Pedagogical Content Knowledge: Students will have the mathematical knowledge necessary to teach upper secondary and lower level college mathematics.
- Effective Communication: Students will be able to speak effectively about mathematics, and write scholarly contributions to practitioner journals.

For admission to this program, please consult for prerequisites.

Courses – A candidate must complete 35 semester hours of approved graduate work, both in mathematical content and teaching methods. This must include 27 semester hours of graded course work and 8 semester hours of non-graded work.

Required Courses: (5 credits, nongraded)	Math 500 Proseminar (1 credit) Math 702 (4+ credits)
Core Courses: (15 credits, graded)	Math 501 Real Analysis (3 credits) Math 531 Intersections of Culture and Mathematics (3 credits) Math 532 Advanced Mathematical Thinking (3 credits) Math 533 Teaching College Mathematics (3 credits) Math 534 Theories of Learning in Mathematics (3 credits)
Practical Training: (3 credits, nongraded)	Math 597 Instruction Seminar (1 credit/semester, 3 semesters) One semester shadowing Math 251 or 252 Fundamentals of Mathematics for elementary teachers Two or more semesters teaching an undergraduate math course
Graduate Electives: (12 credits, graded)	Four courses from the following list; at least one course must be included from each of the three groups

Group 1: Algebra, Discrete Math, & Geometry	Math 505 Abstract Algebra Math 507 Advanced Theory of Numbers Math 553 Graph Theory Math 555 Topics in Combinatorics
Group 2: Probability & Statistics	Stat 443 Applied Probability Stat 510 Topics in Probability and Statistics Stat 519 Applied Multivariate Analysis Stat 544 Applied Stochastic Processes Stat 548 Statistical Theory I Stat 549 Statistical Theory II Stat 573 Reliability Stat 575 The Theory of Multivariate Analysis
Group 3: Applied & Numerical	Math 464 Linear Optimization Math 566 Optimization in Networks Math 508 Advanced Math Methods for Physics and Engineering Math 540 Applied Mathematics I Math 541 Applied Mathematics II Math 548 Numerical Analysis Math 563 Mathematical Genetics Math 564 Convex and Nonlinear Optimization Math 565 Nonsmooth Analysis and Optimization with Applications Math 567 Integer and Combinatorial Optimization Math 570/Math 571 Mathematical Foundations of Continuum Mechanics I & II Math 574 Topics in Optimization Math 579 Math Modeling in the Bio and Health Sciences Math 586 Math Modeling in the Natural Sciences

Math 702 and M.S. Examination – The four required hours of Math 702 involve independent study under the guidance of a faculty member, normally the chair of the student's advisory committee. The topic of the study must pertain to curricular and pedagogical issues relevant to teaching mathematics. The results of this study are often summarized in a paper, but this is not mandatory. In addition, students must complete a final oral examination, covering the student's coursework and the content of Math 702, 401, 402, 420, and 421. This will include an oral presentation on the results of the student's Math 702 project. The student's advisory committee will conduct this examination when all other requirements for graduation have been fulfilled. The format of the final examination, project, and/or paper is at the discretion of the advisory committee.

8   THE M.S. IN STATISTICS

Description and Learning Outcomes – This is a two-year degree designed to prepare students to work in industry or to apply to a PhD program by providing them with a broad statistical skill set. Students may enroll in the M.S. in Statistics program directly or while seeking a PhD in another field. Students can choose courses from five field areas: Statistical Theory, Applied Statistical Methods, Bioinformatics and Biostatistics, Econometrics and Time Series, and Data Analytics.

This M.S. program is designed to lead the student to the following learning outcomes:

- Problem solving skills: Students are expected to learn the fundamental tools of statistical modeling and implementation. Skills for identifying and solving statistical problems arising in various interdisciplinary areas is an important expected learning outcome associated with this degree.
- Ability to work individually or in groups: Statistical modeling can be pursued at an individual level or as part of a group effort with the group comprised of experts in various allied fields. Students are expected to develop such statistical skills so that modeling and analysis can be done in a timely and efficient manner.
- Communication skills: Students should develop good communication skills so that the interpretation and implications of the results obtained from analysis of a statistical model can be presented in an effective manner.

For admission to this program (if you are not already a doctoral student at WSU), please consult Section 3 for prerequisites.

For PhD Students in Other Departments – There are many disciplines and sub disciplines that require extensive advanced training in statistics to perform graduate research work. One natural avenue for students at WSU to obtain this advanced training is to pursue an M.S. in Statistics. It provides the skillset they need to perform research in their primary field of study and such a degree enhances their marketability. All students enrolled in a PhD program in Pullman are able to receive advanced statistical training at the Master of Science level. By pursuing this option, a student can simultaneously be enrolled in the M.S. in Statistics option and the program of their primary PhD degree-granting unit.

Normally, students will have taken several graduate level Statistics courses before adding the M.S. program to their PhD program. Once they have found an advisor and formed a committee, students will fill out an Add an Academic Program Degree Level form, to be submitted by the graduate coordinator in the Department of Mathematics & Statistics. There is no additional application fee. Students must obtain consent from their primary department and the Department of Mathematics & Statistics to submit this form. At the same time, the student should submit a completed Program of Study for the M.S. Statistics. Note that the Department of Mathematics & Statistics does not usually provide assistantships to students who are getting a PhD in another department. The degree must

be added at least one semester before the semester the student intends to complete the degree.

Courses – The M.S. in Statistics requires a total of 33 credit hours, including four credits of Stat 702, a written project, and passage of a comprehensive oral examination. Any changes to the requirements for a particular student can be made only with prior approval of the student's committee and the chair of the Graduate Studies Committee. Special topics covered in Stat 510 may be used to satisfy an elective with approval of the student's committee. Students who do not have a background in a field outside of statistics, mathematics, or computer science are encouraged to take at least two upper division courses in another substantive area. Those students who complete an undergraduate degree at Washington State University and receive a B or better in Stat 443 and Stat 456/556 may substitute other electives in place of that core requirement.

Core requirements account for 24 of the required credit hours; the remaining 9 hours must include three or more courses representing at least two field areas chosen from the table below. At most, two courses may be outside of the "STAT" or "DATA" prefix.

Required Courses: Stat 702 Master's Special Problems/Directed Study
(4+ hours)

Core Courses: Stat 443 AND Stat 556 Probability and Statistical Theory
(20 hours)   OR Stat 548 AND Stat 549 Statistical Theory (6 hours)
                       Stat 512 Analysis of Variance of Designed Experiments (3 hours)
                       Stat 536 Statistical Computing (3 hours)
                       Stat 530 OR Stat 535 Regression (3 hours)
                       Stat 575 The Theory of Multivariate Analysis (3 hours)
                       Stat 590 Statistical Consulting Practicum (2 hours)

Electives: Three courses from at least two field areas in the table below.
                       Students may select three courses from the Data Analytics field.
(9 hours)

Statistical Theory*	Stat 544 Applied Stochastic Processes
	Stat 548 Statistical Theory I
	Stat 549 Statistical Theory II
	Stat 577 Statistical Learning Theory
Applied Statistical Methods	Stat 519 Applied Multivariate Analysis
	Stat 572 Quality Control
	Stat 573 Reliability
	Stat 574 Linear and Nonlinear Mixed Models
	Stat 576 Bayesian Analysis
Bioinformatics and Biostatistics	Stat 520 Statistical Analysis of Qualitative Data
	Stat 522 Biostatistics and Statistical Epidemiology
	Stat 565 Analyzing Microarray and Genomic Data
	Math 563 Mathematical Genetics
	Crop_Sci 545 Statistical Genomics

Econometrics and Time Series	Stat 508 Environmental Spatial Statistics
	Stat 516 Time Series
	Econ 511 Econometrics I
	Econ 512 Econometrics II
	Econ 513 Econometrics III
Data Analytics	Stat 435 Statistical Modeling for Data Analytics
	Stat 437 High Dimensional Data Learning and Visualization
	MATH 566 Optimization in Networks
	CPTS 540 Artificial Intelligence
	CPTS 570 Machine Learning
	CPTS 575 Data Science
	CPTS 591 Elements of Network Science

*Stat 548 and 549 cannot be used in the field area if counted for the core requirements.

Stat 702 and M.S. Examination – There is no thesis requirement; however, an M.S. in Statistics student is required to do a written Masters project equivalent to 2-4 hours of Stat 702. Therefore, early in the students graduate program (by the second semester as recommended by the Graduate School), the student should obtain a project supervisor and form an M.S. committee. The student's project supervisor will normally serve as the chair of the M.S. committee, which will usually include two additional faculty with interest in Statistics. The student is required to make the final draft of the project report available to the M.S. committee at least two weeks prior to the final Masters oral exam. It is the committee's responsibility to give final approval to the project.

The student must select one of three M.S. project options in order to satisfy the project requirement. Selection of the project option must be made in consultation with the student's M.S. committee chair. The three project options are as follows:

1. The student can do an independent research project (advised by the supervisor). Acceptable topics for a project include an original data analysis or original research on a statistical problem. The student is required to write the final draft of the project report.
2. The student can thoroughly study a statistical modeling and methodology paper (suggested by the supervisor). The student then reads the selected paper, together with at least three other relevant papers and then prepares a comprehensive written report which includes, but is not limited to, the central objectives of the problem, modeling, methodology, implementation, results, and conclusions. The student is required to write a summary report on the topic and to include in the report the computer code for implementation of the methodology.
3. The student can complete an internship that is compatible with the student's chosen career specialization within statistics (approved by the supervisor). The internship should be a full-time affiliation for a period of not less than eight weeks duration and not less than 400 hours. A monthly report is required during the internship and a written report is to be turned in at the end of the internship.

For all three options, the student is required to write a final summary report on the subject and make it available to the M.S. committee at least two weeks prior to the final Master's Examination. It is the committee's responsibility to give final approval.

The final Masters oral exam is a two-hour oral exam conducted by the student's M.S. committee. The oral exam will consist of a (i) 30-minute presentation of the student's project/paper/internship, (ii) 15-minute period following the Master's project presentation for questions by the committee related to the results contained in the Masters project, and (iii) 75-minute period devoted to a comprehensive oral exam covering the material in Stat 443, Stat 512, Stat 530, and Stat 556, as well as material covered in additional course work. The student is expected to be thoroughly familiar with a wide array of statistical concepts contained in the list of topics and concepts obtained from the graduate coordinator. See Appendix III for a list of topics on the exam.

Suggested schedule for an MS Statistics student obtaining a PhD in another program:

Year 1

Fall: Stat 512 Analysis of Variance of Designed Experiments

        Stat 443 Applied Probability

Spring: Stat 556 Intro to Statistical Theory (prereq Stat 443)

        Stat 530 Applied Linear Models (name may be changing)

Year 2

Fall: Stat 575 Theory of Multivariate Analysis (prereq Stat 556)

        Stat 536 Statistical Computing (prereq Stat 556)

Spring: Stat 590 Statistical Consulting (at end of coursework)

        Stat Elective

Year 3

Fall: Stat Elective

        Stat Elective

Spring: Defense

Note: It is strongly recommended that students interested in the MS statistics program complete Stat 443 and Stat 512 first in the fall, then Stat 556 and Stat 530 the following spring. These courses will prepare the student for future electives and core requirements. Stat 443 should be considered a prerequisite for all other classes and must be taken before Stat 556. Please contact the graduate coordinator with any questions at mathstat.gradinfo@lists.wsu.edu

9 THE PhD IN MATHEMATICS

Description and Learning Outcomes – The degree of Doctor of Philosophy in Mathematics is awarded in recognition of distinctive scholarship and original contributions to knowledge. The PhD program is designed to lead the student to the following learning outcomes:

- Critical Thinking: Students will be able to think critically and creatively.
- Knowledge and Scholarship: Students will be able to identify and conduct original research and scholarship.
- Ethical and Responsible Research: Students will be able to conduct research in an ethical and responsible manner.
- Effective Communication: Students will be able to effectively communicate research work in written and oral form.

Departmental requirements and regulations for the PhD in Mathematics are specified below. The regulations of the Graduate School for doctoral programs are available in the Graduate School Policies and Procedures Manual (gradschool.wsu.edu/policies-procedures/). Appeals requesting waiver or modification of any rule of departmental origin may be submitted to the Graduate Studies Committee.

For admission to this program, please consult Section 3 for prerequisites.

Courses and Hours – This section contains information on course work requirements. A student must successfully complete 72 hours of approved course work. Twenty-four hours of course work must be chosen from the five groups below. This must ordinarily include at least two courses from each of three groups.

> Group 0: Math 501, 502, 503, 504, 525
> Group 1: Math 505, 507, 511, 550, 555
> Group 2: Math 508, 512, 560, 561, 570, 571, 586
> Group 3: Math 543, 544, 545, 546, 564, 565, 567, 574
> Group 4: Math 563, 568, 569; Stat 533, 536, 544, 572, 573

At least four additional graded 400 or 500 level courses are required to meet the Graduate School requirement of 34 semester hours of graded course work beyond the bachelor's degree. Finally, all doctoral students are required to take one hour of Math 500 (to be taken before the student's first Fall semester) and at least 20 total hours of Math 800. Teaching assistants are required to take three semesters of Math 533 (Teaching College Mathematics).
Please reach out to the Graduate Coordinator if you are interested in taking a course not listed in one of the groups above.

10 THE PHD IN MATHEMATICS – APPLIED MATHEMATICS OPTION

Description and Learning Outcomes – The specialization of modern academic disciplines provides both a challenge to those who wish to do research at the interface of mathematics and its areas of application and many opportunities to make valuable contributions. The Applied Mathematics Option allows students from a range of backgrounds to pursue a traditional applied mathematics program, while retaining the option to thoroughly learn an area of application. Entering students may not have a bachelor's degree in Mathematics. However, they will be required to demonstrate a grasp of the core areas of advanced calculus and linear algebra at the level of a bachelor's degree in Mathematics. They will then be given great latitude to take specialized courses in Mathematics and their area of application.
The learning outcomes for this degree are the same as in The PhD in Mathematics.

Departmental requirements and regulations for the Applied Mathematics Option are specified below. The regulations of the Graduate School for doctoral programs are available in the Graduate School Policies and Procedures Manual. Appeals requesting waiver or modification of any rule of departmental origin may be submitted to the Graduate Studies Committee.

For admission to this program, please consult Section 3 for prerequisites.

Courses and Hours – The course work requirements for the Applied Mathematics Option shall be as follows. A candidate must complete 34 semester hours of graded course work. These courses must be numbered 500 or above (except for up to 9 hours of non-graduate level graded course work). Twelve hours of course work must be chosen from the two groups below and must ordinarily include at least two courses from each group. A course appearing in more than one group may only count towards fulfilling the requirement in one of those groups.

> **Modelling and Applied Analysis:** Math 415, 508, 512, 523, 540, 541, 560, 561, 563, 568, 568, 570, 571, 574, 579, 586; Stat 533, 572, 573

> **Computational Mathematics and Optimization:** Math 464, 543, 544, 545, 546, 548, 564, 565, 566, 567, 574; Stat 533, 536, 544

In addition to the 12 hours chosen from the two groups, 12 further hours of Mathematics courses must be taken. These 12 further hours must be numbered 400 and above. Of this total 24 hours of required course work in Mathematics, at least 18 hours must be numbered 500 and above. Conjoint courses shall count as 400 level courses for these requirements. Exception to these requirements may be recommended by the student's Doctoral Committee and must be approved by the Graduate Studies Committee.

All doctoral students are required to take one hour of Math 500 (to be taken before the student's first Fall semester), which will include short presentations by faculty on their

research areas, and 20 total hours of Math 800. Teaching assistants are required to take three semesters of Math 533 Teaching College Mathematics. Further course work may be required by the Program of Study, which will be assembled in consultation with the student's Doctoral Committee. Students are strongly encouraged to participate in the Applied Mathematics Seminar throughout their graduate studies.

11 THE PhD IN MATHEMATICS WITH EDUCATION EMPHASIS

Description and Learning Outcomes – the degree of PhD in Mathematics with Education Emphasis is awarded in recognition of scholarship and original contributions to the teaching and learning of mathematics. The main difference from other PhD choices is in the research focus. The requirements for this PhD include competence in core mathematics as well as study in the research methodologies applicable to research in mathematics education.

This PhD program is designed to lead the student to the following learning outcomes:

1. Critical Thinking: Students will have a working knowledge of the literature in mathematics education research. They will understand different theories of learning mathematics and styles of research.

2. Knowledge and Scholarship: Students will have mastered the tools and knowledge (both mathematical and educational) necessary to conduct original research in mathematics education that will lead to a publishable quality dissertation.

3. Ethical and Responsible Research: Students will have completed the necessary training in ethical research and will fully understand and have experience with the issues involved in conducting educational research.

4. Effective Communication: Students will be experienced in writing research-based journal articles, making research presentations at conferences and speaking frequently in front of their peers.

Departmental requirements and regulation for the PhD in Mathematics are specified below. The regulations of the Graduate School for doctoral programs are available in the Graduate School Polices and Procedures Manual. Appeals requesting waiver or modification of any rule of departmental origin may be submitted to the Graduate Studies Committee.

For admission to this program, please consult Section 3 for prerequisites.

Courses and Hours – The course work for the PhD in Mathematics with Education Emphasis shall be as follows. A candidate must successfully complete 72 hours of approved coursework. At least 34 semester hours must be graded coursework and numbered 500 or above (except for up to 9 hours of 400-level graded course work). All doctoral students are required to take one hour of Math 500 (to be taken before the student's first Fall semester) and 20 total hours of Math 800. Teaching assistants are required to take three semesters of Math 533 Teaching College Mathematics.

The rest of the coursework must include the following courses:

> **Core:** Math 501, 511, 531, 532
>
> **Foundation in Mathematics (5 courses from the following):** Math 502, 503, 504, 505, 507, 512, 525, 543, 544, 553, 555, and 564. Alternative courses may be selected in consultation with your advisor. The intent here is to provide breadth of background in mathematics.

Educational Foundations, Research Methodologies, and Statistical Analysis:
Math 534, 535, Ed Res 564, and Stat 520 OR Stat 530

It is also recommended that the student participate in the joint WSU/UI Mathematics Education Seminar each semester and take two or more additional graded math courses numbered 500 or above to strengthen the mathematical foundations.

Teaching Experience – There are two additional requirements to those described in the section regarding Teaching Experience under PhD Policies and Procedures. First, most students graduating with this degree will be expected to teach the equivalent of Math 251 and 252 when they are hired as faculty members. Thus, students earning this degree are required to do an internship with a Math 251 or 252 instructor during which they will become familiar with the manipulatives used to teach these courses and gain experience teaching and assessing pre-service elementary teachers in an activity-based environment.

Second, they will teach a 200-300 level mathematics course with serious mentoring by their advisor or another faculty member approved by the advisor. The intent here is to help candidates develop all aspects of their teaching skills in a more autonomous environment than calculus.

12 THE PhD IN STATISTICAL SCIENCE

Description and Learning Outcomes – Students pursuing a PhD in Statistical Science will gain core knowledge in statistics and working knowledge in an allied interdisciplinary domain. Students will take core and elective statistics courses offered through the Department of Mathematics & Statistics, statistics courses offered through allied departments that have in-depth application of statistical methods, and at least two courses from one of the partnering allied departments. Students are also encouraged to have a faculty from an external department to serve on their PhD committee, and strongly encouraged to have that individual serve as co-chair of the student's PhD committee. The PhD dissertation will be focused on developing new statistical methods and solving problems for data challenges in a chosen field of interest.

This PhD program is designed to lead the student to the following learning objectives:
- Have knowledge of advanced statistical theory and statistical methodology
- Have a working knowledge of a domain that generates their problem
- Have knowledge in statistical computing and be familiar with commonly used statistical software such as R, S-PLUS, SAS, and data management programs
- Apply statistical knowledge to real life problems effectively and ethically, understanding the theoretical assumptions and practical limitations of the methodologies applied
- Communicate effectively the principles and methods of statistical science in both written and oral forms
- Conduct independent research in statistical sciences with focus on interdisciplinary research

Courses – Students pursuing a PhD in Statistical Science must complete a total of 72 credit hours. The curriculum is comprised of seven core statistics courses (21 credit hours), two fundamental applied statistics courses (6 credit hours), two general statistics electives (6 credit hours), and two elective courses in an external subject (6 credit hours), for a total of 39 graded credit hours. Examples of interdisciplinary, external subjects include Veterinary Medicine, Electrical Engineering, Computer Science, Economics, and Biological Sciences, but courses can be taken from any department as agreed upon by the student's PhD committee. Students must also take seven non-graded credit hours: Stat 590 (2 credit hours), Stat 591 Seminar (4 credit hours), and Math 500 (1 credit hour, taken their first fall semester). Additional credits can be obtained through Stat 800 (minimum of 20 credits of Stat 800 required). Teaching assistants are required to take three semesters of Math 533 (Teaching College Mathematics). The degree requirements are listed below:

Core Statistics:

(18 credits)

Stat 536	Statistical Computing
Stat 548	Statistical Theory I
Stat 549	Statistical Theory II
Stat 556	Introduction to Statistical Theory
Stat 574	Linear and Nonlinear Mixed Models
Stat 575	The Theory of Multivariate Analysis
Stat 577	Statistical Learning Theory

Core Applied Statistics:

(6 credits)

Stat 512	Analysis of Variance of Designed Experiments
Stat 530	Applied Linear Models

General Statistics Electives – 2 courses

(6 credits)

Stat 508	Environmental Spatial Statistics
Stat 516	Time Series
Stat 519	Applied Multivariate Analysis
Stat 520	Statistical Analysis of Qualitative Data
Stat 522	Biostatistics and Statistical Epidemiology
Stat 544	Applied Stochastic Processes
Stat 565	Analyzing Microarray and Other Genomic Data
Stat 572	Quality Control
Stat 573	Reliability
Stat 576	Bayesian Analysis

Interdisciplinary Electives – 2 courses, in consultation with PhD committee, at
(6 credits)   the 400-level or higher.

Practicum   Stat 590   Statistical Consulting Practicum
(2 credits)

Seminar   Stat 591   Seminar in Statistics
(4 credits – 4 semesters)

Proseminar   Math 500   Proseminar
(1 credit)

13 PHD POLICIES AND PROCEDURES

The proceeding parts of this guide outline the substance of the PhD graduate programs in mathematics and statistical science at WSU. Certain mechanisms and procedural rules are required, however, to implement individual programs. The present section summarizes the most important of these. These rules reflect both Graduate School and departmental policies. Refer to the Graduate School Policies and Procedures manual for a specification of the rules originating from the Graduate School.

The Department of Mathematics & Statistics offers a PhD degree in Mathematics and a PhD degree in Statistical Science, with possible Mathematics options including Applied and Education Emphasis. A full-time graduate student typically takes five years to complete the program. Completing the PhD degree requires four components, including:

1. Coursework – Each option has specific requirements, but at minimum, a student must complete 72 total credit hours, comprised of at least 34 hours of graded coursework, 20 hours of Math or Stat 800 Directed Study to pursue a dissertation topic, and 1 hour of Math 500 Proseminar, to be taken the week before the student's first fall semester. Additionally, teaching assistants are required to take three semesters of Math 533 Teaching College Mathematics.

2. Administrative Paperwork

Annual Review – completed each spring to assess progress and accomplishments, as well as set goals for the upcoming year.

Program of Study – includes the signatures of all committee members and the department chair, and indicates that the committee approves the student's coursework to fulfill the requirements for the degree. Adjustments to the program of study and changes to the student's committee can be submitted to the Graduate School when necessary. See PhD Policies and Procedures for information on doctoral advisory committee composition.

Application for Degree – Filed online through my.wsu.edu and cannot be filed until the preliminary exam has been completed. It is advised that students apply for their degree the semester before intended graduation so the student is notified of requirements to be completed their final semester. Candidates may not schedule a *final examination* until an application for degree has been filed.

Exam Scheduling Forms – Submission of scheduling forms is required for both the preliminary exam and the final exam. These are due to the graduate coordinator no less than ten business days from the date of the exam.

3. Research, Dissertation and Final Defense – see FDE for more information

4. Extracurricular Activities – besides meeting the requirements needed to obtain a degree, students should voluntarily and energetically devote time to additional courses, outside reading of both books and journals, attend colloquia and special lectures by local and visiting speakers, work on assigned problems, and participate actively in seminars and professional meetings. Participating in these activities may be a crucial part of obtaining desirable employment after graduation.

Summary of Doctoral Procedures

Procedure	Under Direction Of	Date
Obtain Advisor	Chair of Grad Studies Committee	As soon as possible
Online Training	Graduate School	As soon as possible after admission
GQE	Chair of Grad Studies Committee	See Doctoral Examination Str.
Submit Program of Study	Advisor and Doctoral Committee	During 2nd year
DQE	Doctoral Committee	Ideally end of 3rd year
Preliminary Examination	Doctoral Committee; Scheduled through Graduate School[a]	Ideally end of 4th year; at least four months prior to the Final Oral Examination
Application for Degree[b]	Graduate School	At least four months before graduation
Final Examination[c]	Graduate School	See Doctoral Examination Str.
Dissertation Submission[d]	Graduate School	5 days after defense

Notes
[a] Submit completed scheduling form with approved examination date, hour, and place to the Graduate School at least 10 business days prior to examination date.
[b] It is strongly advised that the application for degree be submitted one semester before the final oral examination is scheduled so that students can be notified of graduation requirements (to-do lists) before enrolling for their last semester.
[c] Submit completed scheduling form with approved examination date, hour, and place and a copy of the dissertation to the Graduate School at least 10 working days prior to the examination date. It is required that a copy of the dissertation be cleared by the Graduate School for compliance of format at the time of scheduling the final examination. A copy of the dissertation must be available for public inspection at least 5 working days prior to the final examination in the department office location designated by the department. The student must provide a copy of the dissertation to each member of the doctoral committee and to the Representative of the Graduate Studies Committee at least 5 working days before the date of the final examination.
[d] Doctoral students wishing to participate in Commencement must satisfy all requirements for the degree by the Wednesday preceding the Commencement.
All forms may be picked up in the Graduate School Office or downloaded at gradschool.wsu.edu.

13.1 SWITCHING BETWEEN STATISTICAL SCIENCE AND MATHEMATICS DOCTORAL PROGRAMS

In rare circumstances, the department may approve a student to switch between the Mathematics and Statistical Science doctoral programs. To apply, a student must first have a faculty member (typically a faculty member who is willing to be the student's PhD supervisor) indicate support for a change of program in a memo. The student should also work with this faculty member to propose a timeline to prepare and take the required GQE of their discipline, i.e., (1) when the student will take courses needed for the GQE and (2) when the student will attempt the GQE. Students who are approved to switch doctoral programs will normally have no more than a total of three attempts at the two forms of the GQE (not including the free try their first semester) and must pass the GQE by the end of their 5th academic semester (typically the Fall of the third year).

The above support memo, a personal statement by the student explaining the reason for the request, timeline, and a change of program form should be submitted to the Graduate Studies Committee for consideration. It should be noted that the student's PhD work should meet the learning objectives of the new PhD program.

The number of semesters a student is supported from departmental funding (e.g., Teaching Assistantship) is not extended due to switching programs.

13.2 COURSE POLICIES AND PROCEDURES

Prerequisites – (also in Section 3, above) All graduate students are expected to have a background in mathematics or statistics equivalent to that provided by an undergraduate degree. Students admitted with a deficient background are expected to make up these deficiencies at the earliest opportunity. For applicants to the **MS and PhD Mathematics** program, this would ideally include familiarity with the material covered in Math 401 Introduction to Analysis, Math 402 Introduction to Analysis II, Math 420 Linear Algebra, and Math 421 Algebraic Structures, and some experience with computer programming. For applicants to the **PhD Statistical Science** program, this includes a course in probability theory, similar to Stat 443 Applied Probability, and a course in mathematical statistics or statistical theory, similar to Stat 456/556 Introduction to Statistical Theory.

Transfer Credit – Graduate credit earned elsewhere (excluding extension work, special problems, workshops, etc.) may be applied as part of the program if the work is of "A" or "B" quality. Transfer credit is requested by listing the courses on the Program of Study; approval of the Program of Study implies approval of transfer of credit. Other general regulations regarding Transfer Credit can be found in the Graduate School Policies and Procedures Manual.

13.3 TEACHING EXPERIENCE

Most holders of graduate degrees in mathematics eventually teach in one way or another. Moreover, some experience with classroom teaching is useful in almost any mathematical career. The Department accordingly requires that each PhD student be responsible, under

supervision, for teaching at least one undergraduate course for a semester. Since this responsibility may be preceded by teaching experience of a less autonomous kind (grading papers, assisting teachers in other ways, conducting help sessions, etc.), every graduate student should have at least one year of teaching experience in the broad sense. The total experience may be considered an apprenticeship in teaching and should be treated as seriously and responsibly as any other part of the student's program.

The terms of many fellowships, traineeships, and other forms of graduate student support permit participation in teaching programs where required. If a student holds a grant which does not permit such participation, then the student will need to combine the period of the grant with at least a year on terms permitting teaching, e.g., as a teaching assistant. This may mean holding the grant for less than the normal period.

13.4 RESIDENCE

The period of study for doctoral degrees is at least three years (six semesters) beyond the baccalaureate degree. For students entering a doctoral program without a master's degree, at least two of these three years must be in residence at WSU (enrolled full-time and present on campus). For students entering a doctoral program with a master's degree, at least one of these three years must be in residence at WSU (enrolled full-time and present on campus).

13.5 RESPONSIBLE CONDUCT OF RESEARCH EDUCATION

All graduate students are required to complete web-based training Responsible Conduct of Research as soon as possible and inform the Graduate Program Coordinator of the department that training has been completed. This training is mandatory and must be repeated after a five year period.

13.6 GRADUATE STUDENT CODE OF RIGHTS AND RESPONSIBILITIES

This describes policies and guidelines pertaining to academic advancement and related grievance procedures, and provides links to important resources regarding student conduct, academic dishonesty, discrimination, sexual harassment, and drug and alcohol policies.

13.7 POLICY ON CONSENSUAL RELATIONSHIPS

According to the Executive Policy on Faculty-Student and Supervisor-Subordinate Relationships, faculty, graduate teaching and research assistants, as well as other supervisory employees in the WSU community accept responsibility to avoid any apparent or actual conflict of interest between their professional responsibilities and their personal relationships with students, or those whom they supervise, evaluate, or exercise other relationships of power or authority.

13.8 ENROLLMENT

An aspirant for a graduate degree at WSU must meet all requirements for that degree during a period of continuous enrollment. Normal course load is described below.

Students who do not wish to enroll for credit may enroll under graduate leave status. The student may not schedule examinations while being enrolled under graduate leave status.

Students not on appointment may carry reduced course loads during the final semesters of their programs of study. Students on appointment, however, must always carry the normal course load as described below, including in their first semester of study. See the Graduate Student Policies and Procedures Manual for a complete specification of enrollment categories. See the Graduate Coordinators for information on a reduced course load.

13.9 COURSE LOAD AND REGULATIONS

The following table indicates minimum and maximum numbers of credit hours for a graduate student at WSU stipulated by the Graduate School. Anything below the minimum is less than a full load and must be approved by the advisor; anything above the maximum is an overload and must be approved not only by the advisor but also by the Dean of the Graduate School.

Semester	Minimum – on assistantship	Minimum – without assistantship	Maximum (with/without assistantship)
Fall,Spring	12	10	18
Summer	0	0	9

The normal course load for a graduate student in the Department of Mathematics and Statistics must be consistent with the requirements in the table above, and in addition must satisfy the guidelines described in the next two paragraphs.

Students holding departmental assistantships during the academic year are expected to carry at least twelve (12) credit hours during the Fall and Spring semesters. Students holding assistantships during any session of summer are expected to carry the minimum course load during any one of the three summer sessions. Any credits in excess of three credits taken during the summer are the financial responsibility of the student. Students with no assistantships may carry a course load that satisfies the requirements in the table above.

In addition, the courses that a graduate student takes during any semester must satisfy the set of regulations below, where the phrase "graduate-level course means":

- Any course with the prefix Math and a number from 501-590 (inclusive) or
- Any course with the prefix Stat and a number from 507-590 (inclusive) or
- Courses taught outside the Department specifically mentioned in graduate program descriptions in this handbook, or
- Any course taught outside the Department (irrespective of number) vital to the student's program, if approved by the student's advisor.

Additional course regulations:

1. All full-time graduate students should register for 702 (MS) or 800 (doctoral) research credits each semester as follows:

a) If a student has a thesis advisor already and is working on a research project, they should enroll for one credit in the respective course under the advisor's supervision.
b) If a student does not have a thesis advisor yet and is not doing research, they should enroll for one credit in the respective course under the supervision of the Department Chair.
c) If students are taking preliminary or final exams, they must enroll in two research credits for that semester.
d) Until a doctoral student has passed the Graduate Qualifying Examination, they may **not** enroll in 800 credits beyond what is described above.

2. Each graduate student with an assistantship from the Department of Mathematics and Statistics must enroll in at least nine (9) hours of graduate level course work per semester (Fall and Spring), with the following exceptions:
a) A first-year student who finds it necessary to take an undergraduate course preparatory to taking a graduate level course, may substitute for a graduate-level course this undergraduate course (this may be done for more than once course);
a) A doctoral student, having passed the Graduate Qualifying Examination may substitute up to three (3) hours of Math 600 for graduate-level course credit;
b) A candidate for a doctoral degree who has passed the Doctoral Qualifying Examination is not required to enroll in any graded graduate-level course;
c) A master's student who is enrolled in at least three hours of Math/Stat 702 in the final semester of the master's program is not required to enroll in any graduate-level course.

13.10 SWITCHING TO OR ADDING A GRADUATE PROGRAM

Master's students who wish to change to a doctoral program must formally apply by the posted deadlines. If such a change of program is approved, it is subject to the following rules:
a) The outcome of any attempt to pass the GQE during the Master's course of studies is valid for the doctoral program and counts toward the maximum number of two attempts allowed to pass this exam.
b) If applicable, the student must use their remaining attempts to pass the GQE on the next two available opportunities following the semester in which the switch to the doctoral program is approved.
c) All other regulations and timing rules regarding the exams past the GQE (i.e., DQE, PDE, and FDE) apply as described in the doctoral program.
d) The total maximum period of financial support is as described in §4.5

Doctoral students who want to obtain a master's degree in the course of their studies must file a Plan and Degree Level Change Form to add the Master's program. Subsequently, a Program of Study must also be submitted (four months before the final Master's examination).

13.11 GRADES

In the grading system used at WSU, numerical equivalents of letter grades are:

| A = 4.0 | A- = 3.7 | B+ = 3.3 | B = 3.0 | B- = 2.7 | C+ = 2.3 |
| C = 2.0 | C- = 1.7 | D+ = 1.3 | D = 1.0 | D- = 1.0 | F = 0.0 |

The following rules govern grades for graduate students:

a) To earn any degree, a student must have a 3.0 cumulative grade point average and 3.0 program grade point average;

b) No course for which the student has received a grade below a B- may be dropped from a degree program; program courses for which a C- or below has been received must be repeated, but not on a Pass/Fail basis;

c) **Termination of enrollment** – the enrollment of a graduate student who fails to establish and maintain a cumulative GPA of 3.0 or above at the end of two semesters, one semester and one summer session, or two summer sessions will be terminated. The enrollment of a graduate student will be terminated if they fail to obtain a 2.75 cumulative GPA or above at the end of one semester or one summer session of graduate study.

d) **Reinstatement**
    i.   a graduate student who has completed only one semester or one summer session with a GPA below 2.75 may be reinstated upon favorable recommendation of the department/program chair and approval by the Dean of the Graduate School.
    ii. After a graduate student has completed two semesters, one semester and one summer session, or two summer sessions, the student must maintain at least a cumulative 3.0 GPA. If the GPA drops to the 2.75 to 2.99 range, the student may be reinstated by the Dean of the Graduate School only upon favorable recommendation of the department/program chair.

e) Courses outside the department and not in the student's minor department may be taken on a Pass/Fail basis; this should be arranged at the time of registration by submitting the appropriate forms; the grade in any such course will be "Pass" or "Fail".

13.12 ADVISOR AND ADVISORY/DOCTORAL COMMITTEE

The Chair of the Graduate Studies Committee assigns new graduate students an advisor, who, in consultation with appropriate people, helps the student prepare his/her program and recommend the composition of his/her doctoral committee. The composition of the Doctoral committee is governed by:

1. The Graduate School Policies and Procedures Manual

2. The Graduate Program in Mathematics and Statistics Bylaws, as to who is a member of the Graduate Faculty and who can serve on student committees.

The Graduate School has issued the following general guidelines for the formation of committees:

- The committee must have at least three WSU faculty members.
- All committee members must hold a doctoral degree.

- At minimum, the committee must have two tenured/tenure-track faculty who are members of the graduate faculty in the student's graduate program. The third member must be graduate faculty in a WSU graduate program, but is not required to be permanent tenure track faculty.
- 4th Committee Member:
  - Experts outside of WSU and faculty from other institutions may serve on committees as a fourth member.
  - If the statistics minor is chosen, a statistics faculty member must be represented as the fourth committee member.
- In all of the above cases, for any non-WSU member, or for any non-tenured/non-tenure track faculty outside of the student's graduate program, please attach a vitae and include a rationale to be reviewed for approval by the Dean of the Graduate School.
- Any exception to the composition noted above, or to program bylaws, requires a memo requesting an exception to policy (e.g. co-chair from another department, adjunct as co-chair, half or more of the committee composed of members outside Math/Stat).

The student usually has a definite voice in the formation of these committees and in exercising this privilege should consider the appropriateness of prospective members. An ideal committee should be made up of people all of whom have special reasons to be interested in the student's program, but represent varying viewpoints.

Committees are responsible for directing the student's program and conducting preliminary and final examinations of the student. Furthermore, the doctoral committee has the particularly important responsibility of guiding the student's thesis work and deciding on the acceptability of the finished thesis. Most of this responsibility usually falls on one member (normally the chair) of the doctoral committee, who, in this role, is called the student's thesis advisor or major professor.

Note: The departmental graduate handbooks are in a transitional period while we continue to update the PhD programs. Please do not hesitate to ask if you have questions about any policies or procedures for your degree.

14 DOCTORAL EXAMINATION STRUCTURE

The doctoral examination structure consists of four examinations: Graduate Qualifying Examination (GQE), Doctoral Qualifying Examination (DQE), Preliminary Doctoral Examination (PDE), and Final Doctoral Examination (FDE). The Graduate School Policy requires that all students can have two attempts to pass each examination. Note that if a student fails to pass an exam after the allowed number of attempts, the program will notify the Graduate School to recommend dismissal from the program. These examinations are described below.

14.1 GRADUATE QUALIFYING EXAMINATION (GQE)

Mathematics

The GQE is a two-part written exam. Problems written for the GQE are designed to assess the test-taker's knowledge of mathematical ideas spanning two areas: (1) advanced calculus (upper level calculus and introductory real analysis) and (2) linear algebra at the advanced undergraduate level. Each area is described in greater detail in Appendix I, including topics covered, courses offered in each area, and suggested study resources. The GQE will be prepared and graded by a committee of up to four faculty members chosen by the Chair of the Department. Rules concerning the GQE are:

- The GQE is given over a two-day period where students complete one part of the exam per day (linear algebra the first day and analysis the second). Each part of the exam is allotted a three-hour time block. The results of both parts of the GQE submitted by the student are considered in determining whether they pass.
- The GQE will consist of 10 problems, five from each area.
- Students can take the GQE in the first semester of enrollment and have at most two subsequent attempts to pass the GQE
- The GQE is typically given twice a year – the week before classes start fall and spring semester.
- Full-time students with a previous mathematics degree must pass the GQE by the end of their third semester in the program (not counting summer semesters). Students without a previous mathematics degree must pass the GQE by the end of their fourth semester in the program (not counting summer semesters), but still have at most two attempts after their first semester.
- Part-time students with a previous math degree must pass the GQE before completing 21 credit hours, and part-time students without a previous math degree must pass the GQE before completing 30 credit hours.
- Students who have not passed within the expected timeline can appeal for an additional attempt, but such appeals will rarely be granted. See below for information on the appeals process.

Statistical Science

The GQE is a two-part written exam. Problems written for the GQE are designed to assess the test-taker's knowledge of statistical ideas spanning two areas of statistics: (1) Statistical Theory (Probability and Mathematical Statistics) and (2) Statistical Methods

and Applications (Design of Experiments and Regression Analysis). The GQE will be set at the level of difficulty of senior undergraduate/first-year graduate level WSU statistics courses. Each area is described in greater detail in Appendix II, including topics covered, courses offered in each area, and suggested study resources.

The GQE will be prepared and graded by a committee of up to four faculty members chosen by the Chair of the Department. Rules concerning the GQE are:

- The GQE is given over a two-day period where students complete one part of the exam per day, theoretical statistics the first day and applied statistics the second. Each part of the exam is allotted a three-hour time block. The results of both parts of the GQE submitted by the student are considered in determining whether they pass.
- The GQE will consist of eight problems (four from Statistical Theory and four from Statistical Methods and Applications).
- Students can take the GQE in the first semester of enrollment and have at most two subsequent attempts to pass the GQE.
- The GQE is typically given twice a year – the week before Fall semester commences (regularly) and the week before Spring semester commences (as needed).
- Students can attempt the GQE their third and if necessary, their fourth semester.
- A typical student will take the four courses mentioned in Appendix B (Stat 512 and 443 in Fall, Stat 530 and 556 in the Spring) to prepare themselves for the exam.
- Part-time students must pass the GQE before completing 30 credit hours.
- Students who have not passed within the expected timeline can appeal for an additional attempt, but such appeals will rarely be granted. See below for information on the appeals process.

GQE Appeals

- **Appealing the grading of the GQE** – Requests by students to view the graded exams, inquiries, or any objections regarding the grading must be addressed to the Chair of the Graduate Studies Committee, who will act as a liaison between students and the GQE Committee.
- **Appealing for an additional attempt at the GQE** –In exceptional cases, a student may appeal for an additional attempt at the GQE. When considering an appeal, it is recommended the student talk to the Chair of the Graduate Studies Committee and/or their faculty advisor before submitting an appeal. The written appeal should be submitted to the Chair of the Graduate Studies Committee. A letter of support from a member of the Graduate Faculty, usually the faculty advisor, addressed to the Graduate Studies Committee often strengthens a student's request. Appeals are granted on a case-by-case basis by the Graduate Studies Committee. The Chair can solicit feedback from other relevant members of the department.

14.2 DOCTORAL QUALIFYING EXAMINATION (DQE)

The Doctoral Qualifying Examination (DQE) is a written and/or oral examination that demonstrates that a student has the ability to learn and apply advanced knowledge. The student's Doctoral Committee will define the material to be covered on the DQE and the format of the DQE, and they will compose and grade this examination. Rules concerning the DQE are:

- The format of the exam and scope of material covered in the exam must be communicated in writing to the student and all members of the DQE committee before the exam is given.
- An exam cannot be given over more than a 4 month time period.
- Students will have at most two attempts to pass the DQE.
- Students are expected to pass the DQE after passing the GQE and by the end of their third year.
- Part-time students are expected to pass the DQE before completing 42 credit hours.
- The DQE will be given at a time suitable for the student and the committee.
- The possible results for the DQE are (1) pass, (2) fail, (3) conditional pass. In the case of a conditional pass, the student's doctoral committee will provide a written plan and timeline that must be satisfied for a student to formally pass. All decisions will be communicated in writing to the student, committee members, and graduate coordinator.
- An approved Program of Study must be on file with the Graduate School before the DQE can be scheduled.

14.3 PRELIMINARY DOCTORAL EXAMINATION (PDE)

The Preliminary Doctoral Examination (PDE) is an oral examination that follows the Graduate School rules for Preliminary Doctoral Examinations. The PDE will begin with a presentation by the student to his/her doctoral committee on a dissertation research problem and a plan of research to be followed toward its solution. The examination will include questions and feedback from members of the doctoral committee on the student's presentation. Rules concerning the PDE are:

- The PDE will be given at a time suitable for the student and the committee, within the Graduate School regulations.
- Students will have at most two attempts to pass the PDE.
- Students should be aware that the PDE must be passed 4.5 months before the Final Doctoral Exam can be attempted. Therefore, students planning to complete their degree in five years need to complete the PDE by the end of their fourth year or early in their fifth year.

Once the Preliminary Examination has been passed, the student technically becomes a candidate for the PhD. This means that the student's primary focus should be on preparing and writing a dissertation, and they are considered All But Dissertation (ABD). ABD status is required to be eligible for many WSU scholarships and allows for flexibility to pursue employment opportunities outside WSU.

14.4 FINAL DOCTORAL EXAMINATION (FDE, DEFENSE)

Dissertation – The dissertation is a scholarly, original study that represents a significant contribution to the knowledge of the chosen discipline. The originality, importance and correctness of the dissertation should be comparable to what would appear in a peer-reviewed research journal. It is expected that a paper based on the student's work has been or will be submitted for publication.

Students must be aware of the dissertation format requirements as published by the Graduate School and be enrolled in research credits (800-level) while preparing and defending the dissertation. The committee should be kept informed of the student's research progress throughout the dissertation-writing process, and should discuss any potential problems with a student's research as soon as the problem is noticed. A draft of the dissertation containing all of the major results and implications should be provided to the committee members no later than four weeks before the exam so that committee members can provide feedback before officially scheduling the exam with the Graduate School. Submission of the scheduling exam form (two weeks before exam) with all committee signatures indicates that only minor revisions will be required for publication in the WSU dissertation database following the defense. This typed, approved dissertation draft must be submitted to the Graduate School when the defense is scheduled two weeks before the exam date. The student must pay any costs associated with graduation or preparation and duplication of the manuscript.

The Final Doctoral Examination – The FDE is an exam that is scheduled after the student has completed their dissertation and it has been approved by the student's Doctoral Committee. It will be an oral examination following the rules of the Graduate School and requires the submission of the Final Exam Scheduling Form and draft of the dissertation ten or more business days before the exam. The FDE is devoted mainly to a presentation of the content of the dissertation by the student and includes questions from members of the doctoral committee.

Rules concerning the FDE are:

- The FDE will be given at a time suitable for the student and the committee, within the Graduate School regulations.
- Students will have at most two attempts to pass the FDE
- For students on assistantship, please consult the Assistantship Section about timelines for departmental financial support.

Note that students who have not completed their doctoral degree (i.e., have not passed the FDE) within 3 years of the semester they passed their preliminary exam, or within 10 years from the beginning date of the earliest course applied toward the degree, must request from the Graduate School an Extension of their degree program.

15 ASSISTANTSHIPS AND OTHER AWARDS

Research and Teaching Assistantships serve three primary purposes:

1. To provide the assistant with financial aid while pursuing graduate studies
2. To give the assistant an opportunity for apprenticeship in research and teaching
3. To augment the research and teaching programs of the Department.

15.1 TERMS FOR RESEARCH AND TEACHING ASSISTANTSHIP

The normal appointment to a research or teaching assistantship is considered a half-time appointment, meaning 20 hours/week on average. Assistantship appointments are made on a semester-by-semester basis. Fall semester appointments begin on August 16th and end December 31, while spring semester appointments begin on January 1st and end May 15th. Summer appointments are sometimes available. If a doctoral student takes and passes the GQE, the salary will increase starting from the semester following the one in which the GQE took place.

The Graduate Studies Committee reviews current academic standing and the level of performance in assistantship duties of each graduate student at the end of each semester. Continued financial support in the form of a teaching or research assistantship is available to students who remain in good academic standing in the Department and perform their assistantship duties in a satisfactory manner.

15.2 MAXIMUM PERIODS OF SUPPORT

The usual maximum periods of support (from the time of first enrollment in graduate studies in the Department) are as follows.

- Students entering a doctoral program with a previous degree in mathematics or statistics typically have up to five years of financial support in pursuit of their degree.
- Students entering a doctoral program without a previous degree in mathematics or statistics typically have up to six years of financial support in pursuit of their degree.
- Students entering a Master's program are generally not fully funded; if they are, the maximum period of support for Master's students is two years (four semesters). For Master's candidates who decide to change to a doctoral program, the maximum period of support will be as if the student enrolled in the doctoral program on the date of first enrollment in the master's program.
- These maximums do not include summer semesters.

15.3 REQUEST FOR AN EXTENSION OF FINANCIAL SUPPORT

A student may submit a request for an extra semester or year of financial support, but it is rare that such a request will be granted. All requests must be sponsored by the student's doctoral advisor. The advisor and the student should each email a written request to the Chair of the Graduate Studies Committee. The student should include the reasons for the request and their academic goals and timeline, and the advisor's letter typically supports the student's extension request and provides context to the Committee regarding the student's progress. Extensions are granted on a case-by-case basis by the Graduate Studies Committee. The Chair can solicit feedback from other relevant members of the department as well. Requests are subject to available funds and current departmental need. Note that this extension request is for departmental funding only; a request to extend a student's program beyond the Graduate School regulations (six years for MS, ten years for PhD, three years from date of preliminary exam) must be submitted according to the Graduate School Policies and Procedures Manual.

15.4   DUTIES FOR RESEARCH AND TEACHING ASSISTANTS

Research Assistants – A research assistant is usually assigned to a particular member of the faculty, who then directs his/her work as assistant. In some departments, research assistants often literally assist the professor in research, but in mathematics this is seldom feasible and the research assistant is often engaged, in effect, on a separate project which may be more closely related to his/her thesis plans than anything else.

Teaching Assistants – Teaching assistants may perform a wide variety of tasks, ranging from relatively routine paper grading to having complete charge of an individual class. In general, an effort is made to provide teaching assistants with assignments that will be of greatest benefit to them without neglecting the needs of the undergraduate students with whom they deal.

It is not always easy for a teaching assistant to arrive at a balance between activities as a student and activities as a teacher. Undergraduate teaching is an important function of the Department, and teaching assistants have a large share in it; they should accordingly avoid slighting it, and bring to it as much conscientiousness and imagination as they can.

Anything worth reading about college teaching in general, and about the teaching of college mathematics or statistics in particular, should be of potential interest to the teaching assistant. There exist some useful documents addressed directly to teaching assistants in mathematics, statistics, and kindred disciplines. A good place to start is the web site of the Mathematical Association of America. Information useful to the teaching assistants is provided at Math 500 Proseminar, a course offered to teaching assistants in the week before Fall semester begins. All new graduate teaching assistants are required to attend this seminar before they begin their assistantship duties. Math 597 Mathematics Instruction Seminar provides additional information useful for teaching assistants.

Teaching assistant appointments officially start on August 16th for fall semester and January 2nd for spring semesters. All teaching assistants are expected to be on campus a

minimum of four days (seven days for new teaching assistants) before the start of each semester. Teaching assistants must not make travel plans to arrive in Pullman after the Wednesday preceding the start of each semester. Because of scheduling complications, assignments for teaching assistants may not be available before the Wednesday preceding the start of each semester. Teaching assistants are expected to use the time remaining before the start of each semester to meet with course coordinators, prepare for teaching assignments, and prepare for coursework. Once teaching positions for each semester have started, all teaching assistants must be available for contact via email and/or an active telephone number.

Once the position has begun, the teaching assistant must maintain regular contact with his/her supervisor via email, phone, and/or office visits. If the position is primarily a grading position, the supervisor is the instructor for the associated course. If the position is a teaching or tutorial position, the supervisor is the course coordinator for the associated course. All teaching assistants are assigned a mailbox in Neill Hall outside the main office of the department. Teaching assistants must check their Neill Hall mail boxes and email frequently to ensure timely collection of student assignments, quizzes, or tests for grading, or other pertinent information. Graded material must be promptly returned to the supervisor by the agreed deadline. All grading must be completed following procedures and standards set by the supervisor. In case of an emergency that might prevent meeting a deadline, the supervisor must be notified as soon as possible.

All teaching assistants are expected to hold office hours. All teaching and tutorial teaching assistants must add one credit of Math 597 (Math Instruction Seminar) the first time that they teach/tutor a new course. There are separate Math 597 sections (led by course coordinators) for each of the primary teaching assistant assignment classes: Math 100, 103, 106, 108, 171, and 172.

Teaching assistants are expected to be on-campus until their teaching assistantship duties (including grading final examinations and submitting final course grades) for the semester are complete. Teaching assistants should not make travel plans at the end of the semester that result in departures prior to the completion of their teaching duties.

All teaching assistants are required to take three semesters of the one credit course Math 533 Teaching College Mathematics.

15.5 DEPARTMENTAL POLICIES REGARDING TEACHING ASSISTANTS

Teaching assistantships are critical to the existence of our graduate program. In many cases, the financial support they provide makes it possible for students to continue their education at the graduate level. With the assistantship comes the responsibility of conscientiously carrying out the TA duties. A major challenge for graduate students is to balance their own graduate studies with their TA duties.

The following guidelines have been developed to assist graduate students in achieving this balance:

- Whenever possible, first year graduate students will be assigned to either lead calculus tutorials or grade for a lower division class. These positions will give the

first year students slightly less responsibility and more time to adjust to graduate classes and to prepare for the GQE.

- In the final semester of their doctoral work, students will be given more flexible TA duties to allow for completion of their dissertations, job interviews, and presentations at professional meetings.
- Students in the middle of their doctoral program or the second year of their masters program will be assigned to teach courses in which they have more autonomy such as Math 105, 106, 107, 108, 201 or 202. Occasionally, more advanced courses such as 220, 273, and 315 will be available. This arrangement will give graduate students valuable teaching experience after they have acclimated to the graduate program and at a time when they have completed most of their course work.
- TA teaching requests will be honored whenever possible within the constraints above. This will include the opportunity to teach a variety of courses if the graduate student desires it.
- TAs will receive support from their Course Coordinators in the form of sample course materials, course administration, test scheduling and planning, teaching observations and feedback, resolution of student problems, final grade approval, and so forth. For multiple section courses, regular meetings may be required, but normally should not exceed once a week.

15.6 OTHER AWARDS

There exist fellowships, traineeships, and other kinds of support for graduate students; these are provided by state, federal and private agencies. Graduate students at WSU are automatically considered for those administered at WSU, as these become available. Applications for awards not administered through WSU are left to the individual student, who may, however, count on the cooperation of the Department in these matters.

The variety of these awards, and the rapidity with which their terms change, make it impractical to list them here. A file of relevant announcements, lists, and application forms is maintained in the department office, and students should feel free to ask for it. A booklet, Fellowship and Research Opportunities in Mathematics, has appeared annually in recent years and may be obtained from the Division of Mathematical Sciences, National Research Council, 2101 Constitutional Avenue, N.W., Washington, D.C. 20418. Announcements about fellowships, etc., frequently appear in the Notices of the American Mathematical Society. The WSU Office of Grant and Research Development located on the 4th floor of Neill Hall can also be helpful. It is also possible to obtain long- and short-term loans on very favorable terms. Inquiries should be made at the Student Financial Aid Office.

16 OTHER USEFUL INFORMATION

Annual Graduate Student Review – An annual progress review of each graduate student is performed at the end of the spring semester. The review takes place on a form with two parts provided by the department. Students complete part I of the form and his/her advisor completes part II. It is recommended that prior to completing this form, students meet with their advisors to discuss their progress.

Exceptions to Departmental Requirements and Regulations – Both the student and the student's committee have considerable latitude in meeting departmental and Graduate School requirements. When a waiver of a departmental requirement or suspension of a departmental regulation is desired, however, the student should transmit the request with a recommendation for action to the Graduate Studies Committee. A written statement of the decision of the Graduate Studies Committee will be sent to the Department Chair, members of the Advisory Committee, and all members of the departmental graduate faculty. Decisions of the Graduate Studies Committee in such matters can be overruled only through action of the departmental graduate faculty. A meeting of the departmental graduate faculty will be called by the Chair of the Graduate Studies Committee to act on an appeal of such a decision when requested in writing by five members of the graduate faculty. The student must make appeals within 10 days of the decision by the Graduate Studies Committee.

Attendance at Departmental Colloquia – The Department organizes a colloquium series during the academic year. The colloquium presentations are usually made by leading scholars. The Department considers attending and participating in departmental colloquia as a vital part of the education of graduate students. Therefore, all graduate students are expected to attend the departmental colloquia.

Library Privileges – Mathematics and Statistics books and journals are housed in the Owen Science and Engineering Library. Other materials may be obtained by special order or by interlibrary loan or photocopy; the science librarians can supply information about these services. The library of the University of Idaho, which has a generous policy toward off-campus borrowers, contains some items not available at WSU, such as runs of certain journals. Every graduate student should become familiar with the arrangement and facilities of the science library. In particular, they should become familiar with accessing library resources electronically. Advanced graduate students should form the habit of scanning the latest issues of journals for items relevant to their research projects.

Summer Program – The Department of Mathematics and Statistics at WSU has a limited summer program. Or formal offerings for graduate students usually consist of a reading course and one or two regularly scheduled graduate courses. There are sometimes also informal seminars, which are open to anyone who is willing to participate. We are, however, attempting to increase our summer offerings for the benefit of all concerned.

Professional Societies and Placement – One way a graduate student may express commitment to the profession and maintain contact with the rest of the mathematical world, is to join one or more professional societies. Most of these allow graduate students to enjoy all the privileges of memberships reduced rates. The organizations most likely to be of interest are probably:

- American Mathematical Society (research emphasis)
- Society for Industrial and Applied Mathematics (emphasis on applied math)
- American Statistical Association
- Mathematical Association of America (emphasis on collegiate mathematics)
- National Council of Teachers of Mathematics

Job opportunities for mathematicians are undergoing considerable evolution. General as well as specific information about employment opportunities for mathematicians is available from the American Mathematical Society, the Society for Industrial and Applied Mathematics, and the Mathematical Association of America.

Most students expect to move into a suitable position immediately after the last academic degree is obtained, if not before. This sometimes calls for early and aggressive effort. Members of the faculty are glad to provide their help and advice.

Hard copies of announcements of job openings for mathematicians are placed in the Department (Hacker) Lounge, Neill 216, just as soon as they come in. Such announcements received electronically are forwarded to all graduate students as soon as they are received.

In general, finding the first employer in one's mathematical career is a challenging and momentous matter. A great deal of help is available from institutions and individuals, but ultimately, the initiative and the crucial decisions must come from the individual student.

17 APPENDIX I: THE GRADUATE QUALIFYING EXAMINATION IN MATHEMATICS (GQE)

General Comments – The GQE is set by an examining committee appointed by the Department Chair. The Chair of the Graduate Studies Committee, or his/her representative, administers the examination. A unique ID number is assigned to each examinee and only these ID numbers identify the examination papers. The names of the students will be correlated with the examination papers only after the final outcome of the examination has been determined.

Graded copies of the examination papers will be made available in the department office for inspection by the graduate faculty. Each paper will be marked with a consensus score for each problem, a consensus total score, appropriate comments, and the recommended outcome of the examination. After the graduate faculty has had at least a day to weigh the recommendations of the examining committee, the Graduate Faculty will convene to decide the final outcome of the examination for all participating students. It is inappropriate for members of the examining committee or other faculty members to discuss the performance of an examinee with any student, including the examinee, prior to the final announcement of the examination results.

Topics for the Graduate Qualifying Examination – Here are listed topics that a student should know for passing the GQE. Courses at WSU cover most, if not all, of these topics, but this list is not intended as a syllabus for any course. It is the student's responsibility to prepare adequately.

Topics in Advanced Calculus: Metric spaces, Cauchy sequences and completeness, limits, continuity, Intermediate Value Theorem, differentiation, Mean Value Theorem, Taylor's Theorem, L'Hôpital's Rule, monotone functions, convexity and curvature, infinite series, sequences and series of functions, Fundamental Theorem of Calculus, Mean Value Theorem for integrals, improper integrals, partial and directional derivatives, Jacobian matrix, gradient vector, chain rule, Divergence Theorem, Stokes' Theorem, Inverse Function Theorem, Implicit Function Theorem, change of variables in multiple integrals, Lagrange multipliers.

References: This material is covered at the appropriate level, for example, in the following texts: T. Kaplan, Advanced Calculus, Addison-Wesley, 2002; A. Taylor and W. R. Mann, Advanced Calculus, Wiley, 1983; W. A. J. Kosmala, A Friendly Introduction to Analysis—Single and Multivariable, Pearson Prentice Hall, 2004.

Topics in Linear Algebra: Vector spaces, subspaces, linear independence, bases and dimension, inner product spaces, norms, triangle inequality, Cauchy-Schwarz inequality, orthogonality, orthonormal bases, orthogonal projections, basic matrix operations, matrix transpose, trace of a matrix, determinants and their properties, invertibility, eigenvalues and eigenvectors, characteristic polynomials, matrix equivalence, matrix similarity, diagonalizability, linear transformations, matrix representations of linear transformations, range and null space (kernel) of a linear transformation, symmetric and hermitian matrices or operators, unitary matrices, normal matrices.

References: This material is covered at the appropriate level, for example, in S. H. Friedberg, A. J. Insel, and L. E. Spence, Linear Algebra, Pearson Prentice Hall, 2003; P. J. Oliver and C. Shakiban, Applied Linear Algebra, Pearson Prentice Hall, 2006.

18 APPENDIX II: THE GRADUATE QUALIFYING EXAMINATION IN STATISTICAL SCIENCE (GQE)

General Comments – The GQE is set by an examining committee appointed by the Department Chair. The Chair of the Graduate Studies Committee, or his/her representative, administers the examination. A unique ID number is assigned to each examinee and only these ID numbers identify the examination papers. The names of the students will be correlated with the examination papers only after the final outcome of the examination has been determined.

Graded copies of the examination papers will be made available in the department office for inspection by the graduate faculty. Each paper will be marked with a consensus score for each problem, a consensus total score, appropriate comments, and the recommended outcome of the examination. After the graduate faculty has had at least a day to weigh the recommendations of the examining committee, the Graduate Faculty will convene to decide the final outcome of the examination for all participating students. It is inappropriate for members of the examining committee or other faculty members to discuss the performance of an examinee with any student, including the examinee, prior to the final announcement of the examination results.

Topics for the Graduate Qualifying Examination – Here are listed topics that a student should know for passing the GQE. Courses at WSU cover most, if not all, of these topics, but this list is not intended as a syllabus for any course. It is the student's responsibility to prepare adequately.

Topics in Statistical Theory

Probability*:* Discrete random variables, continuous random variables, expectation and moments, moment generating functions, bivariate and multivariate distributions, marginal and conditional distributions, independence, covariance and correlation, multivariate normal distributions (marginal and conditional distributions, bivariate normal), distributions of functions of random variables, order statistics, large sample theory, convergence in probability and distribution, central limit theorem.

Mathematical Statistics: Finite and large sample sampling distributions, method of moments estimation, maximum likelihood (ML) estimation, ML estimation for the multivariate normal distribution, properties of estimators, unbiased estimation, Bayes and minimax estimators, Cramér-Rao lower bound, best linear unbiased estimation, uniformly minimum variance unbiased estimator, sufficiency and completeness, Neyman factorization, Lehmann-Scheffé completeness theorem, regular exponential class, confidence intervals, tests of hypothesis, uniformly most powerful tests, generalized likelihood ratio tests, contingency tables and goodness of fit.

Reference: L.J. Bain and M. Engelhardt, Introduction to Probability and Mathematical Statistics, 2nd Edition, Duxbury Thomson Learning, 1992.

WSU Courses*:* Stat 443 Applied Probability & Stat 556 Introduction to Statistical Theory

Topics in Statistical Methods and Applications

Design of Experiments: Concepts and techniques in design of experiments for the completely randomized design, randomized complete block designs, split-plot designs, designs with repeated measures and the analysis of covariance. Development of statistical models for the experimental designs covered, including fixed and random effects (mixed models), inference and multiple comparison techniques.

Regression Analysis: Linear models, simple linear regression, multiple linear regression, weighted least squares, multicollinearity, robust regression, bootstrapping with linear models, qualitative predictors, nonlinear regression, logistic and Poisson regression.

References:

G. A. Milliken and D. E. Johnson, Analysis of Messy Data, Volume 1: Designed Experiments, Second Edition, CRC Press, 2009.

R. O. Kuehl, Design of Experiments: Statistical Principles of Research Design and Analysis, Second Edition, Brooks/Cole, Cengage Learning, 2000.

M. Kutner, C. Nachtscheim, J. Neter, and W. Li, Applied Linear Statistical Models, 5th ed., McGraw-Hill/Irwin, 2004.

WSU Courses: Stat 512 Analysis of Variance of Designed Experiments & Stat 530 Predictive Models: Foundations in Data Science

19 APPENDIX III: LIST OF TOPICS FOR THE M.S. STATISTICS ORAL COMPREHENSIVE EXAM

Stat 443 Applied Probability

Discrete Random Variables
      Binomial
      Negative binomial
      Geometric
      Poisson
      Hyper-geometric
Continuous Random Variables
      Uniform
      Exponential
      Gamma
      Normal
      Beta
      Weibull
Expectation and Moments
      Mean, variance
      Raw moments, central moments
      Chebysheff's inequality
      Moment generating functions
Bivariate and Multivariate Distributions
      Joint and marginal distributions
      Conditional distributions
      Covariance and correlation
      Independence
      Expectation and variance of linear combinations of random variables
      Conditional expectation and conditional variance
Transformations – Distributions of functions of random variables
      Univariate and bivariate transformations – Jacobian method
      Distributions of sums of random variables – method of moments
      Order statistics – distributions of maximum and minimum
Large Sample Theory
      Convergence in probability, weak law of large numbers
      Convergence in distribution, central limit theorem
      Normal approximation to binomial and Poisson
      Poisson approximation to binomial

Stat 556 – Intro to Statistical Theory

Sampling distributions

      Finite sample distributions of statistics
      Empirical distribution function

t, F, and beta distributions
Large sample distributions of statistics

Point Estimation
Method of moments estimators
Least squares estimators
Likelihood function and maximum likelihood estimators
Invariance property of MLEs
Unbiased estimators, Cramer-Rao lower bound
Best linear unbiased estimation (BLUE or MVLUE)
Rao-Blackwell theorem, UMVUEs
Consistency, asymptotic unbiasedness
Efficiency, asymptotic efficiency
Asymptotic properties of MLEs
Bayes and minimax estimators

Sufficiency and Completeness
Sufficiency and minimal sufficiency
Neyman factorization theorem, minimal sufficiency of MLEs
Completeness, Lehmann-Scheffe Completeness theorem
Exponential class, complete sufficient statistics

Interval Estimation
Confidence intervals - one-sided and two-sided
Confidence level of confidence intervals (interpretation)
Pivotal quantity
Location-scale parameters
Confidence interval estimators of mean and variance
Approximate confidence intervals
Two-sample confidence interval estimation
Bayes interval estimation

Tests of Hypotheses
Simple and composite hypotheses
Test statistic, critical region
Significance level, power function (interpretation)
p-value, one-sided and two-sided tests
Tests for mean and variance - sampling from a normal distribution
Binomial tests
Most powerful and uniformly most powerful tests
Neyman-Pearson fundamental lemma
MLR property of exponential families and UMP tests
UMP tests and Uniformly most accurate interval estimates (duality relationship)
Generalized likelihood ratio tests

Stat 533 Theory of Linear Models – **to be changed to Stat 575 or Stat 576**

Results in Linear Algebra
> Elementary results in linear and matrix algebra
> Generalized inverses g-inverse and c-inverse
> Application of generalized inverses to solutions of linear equations

The Multivariate Normal Distribution
> Joint, marginal and conditional distributions of the multivariate normal dist.
> Simple correlation, multiple correlation and partial correlation

Distributions of Quadratic Forms
> Noncentral chi-square, noncentral F, and noncentral t - distributions
> Distributions of quadratic forms of normal variables
> Independence of linear forms and quadratic forms
> Expected value of a quadratic form

The General Linear Model
> Definition of the general linear model - full rank, less than full rank
> Estimation of linear functions of model parameters, Gauss-Markov theorem
> Tests of linear hypotheses - normal case
> Confidence intervals for linear functions of parameters
> One at a time and simultaneous confidence intervals

Applications of the General Linear Model
> Prediction intervals
> The calibration problem
> Parallel, intersecting and identical simple linear models
> Testing for the equality of a set of linear models

The Design Models (less than full rank)
> Definition, estimation of the parameters
> Estimable functions, linearly independent estimable functions
> BLUEs of estimable functions
> Confidence intervals and tests of hypotheses for design models
> Linear contrasts and the one factor design model
> Tukey's method of simultaneous Cls for pairwise differences

Two Factor Design Models
> No interaction, one observation per cell model
> Multiple number observations per cell without interaction
> Equal number of observations per cell model with interaction
> Unequal number of observations per cell with interaction

Components of Variance Models
> Definition of a components of variance model
> One-factor components of variance model estimation, Cls and tests
> Two-factor components of variance model estimation, Cls and tests

Stat 530 Predictive Models: Foundations in Data Science

Linear Models
>   ANOVA, multiple regression, ANCOVA

Simple Linear Regression
>   Deterministic vs. stochastic relationship, estimation of the parameters
>   MLE vs. least squares, properties of the regression parameters
>   Assumptions, checking assumptions
>   Confidence intervals for a line
>   Calibration problem

Multiple Linear Regression
>   First order vs. higher order models, model building
>   Violations of assumptions
>   Properties of residuals, detection of outliers

Weighted Least Squares
>   Use, weight selection

Multicollinearity
>   Definition
>   Detection and application

Robust Regression
>   Definition, use
>   Weight selection

Bootstrapping
>   Use in linear models

Qualitative Predictors
>   Definition, use
>   Multiple regressions with dummies versus ANCOVA
>   Advantages and disadvantages
>   ANOVA as a special case of regression
>   one-way ANOVA, two-way ANOVA with or without interaction

Nonlinear Regression
>   Definition, use
>   Advantages and disadvantages

Generalized Linear Models
>   Definition, similarities and differences from general linear models
>   Advantages and disadvantages
>   Logistic and Poisson regression

Stat 512 – Analysis of Variance of Designed Experiments

Concepts and Techniques
      Treatment factors, treatments, and experimental units
      Randomization, replication, and blocking

Some Standard Designs and Corresponding Statistical Models
      Completely randomized designs
      Randomized complete block designs
      Incomplete block designs
      Split-plot designs
      Row-column designs (Latin square designs, Y ouden designs, etc)

One-Way ANOVA Model
      The model
      Estimation of treatment mean and the variance of the error term
      Inferences for a single contrast or a treatment mean
      Methods for multiple comparisons
      Experimentwise error rate
      Hypotheses and ANOV A
      Power of a test and sample size determination

Two-Way ANOVA Model
      The model and distributional assumptions
      The meaning of interaction
      Hypotheses testing and ANOVA
      Checking model assumptions
      Multiple comparisons

Mixed Effects Model
      Applications to different designs
      Inferences (estimation and hypothesis testing)
      ANOVA

Nested Models
      Estimation and hypothesis testing

Split-plot Designs
      Models and analysis of variance
      Contrasts within and between whole plots

Repeated Measures
      Different correlation structures of repeated measures
      Analysis of variance