

# **A Handbook for Current Graduate Students**

**(For Academic Year 2017 – 2018)**

**Department of Mathematical Sciences  
University of Wisconsin-Milwaukee**

**The Department's Graduate Committee will update this Handbook each academic year. While every attempt will be made to update the relevant information at various departmental webpages simultaneously, it is inevitable that some of the information at these webpages do not get updated timely. If you have questions, please contact the Associate Chair for the Graduate Program.**

# Table of Contents

## 1. Overview

## 2. Administration of the Graduate Program

## 3. Who to Contact if You Have Questions

## 4. General Policies and Regulations

4.1 GPA Requirement

4.2 Credit Requirement

4.3 Transfer Credit

4.4 Change Program of Study

4.5 Promotion from M.S. to Ph.D.

4.6 Dismissal and Appeal of Dismissal

## 5. Financial Support

5.1 Assistantship and Fellowship

5.2 Awards

5.3 Tuition Remission

5.4 Summer Support

5.5 Financial Support and Award Authority

5.6 Maximum Number of Years of Support

5.7 Ph.D. Milestone Progress Requirement for Support

## 6. Teaching Assistant Policies and Regulations

6.1 [Link to UWM's Graduate Assistant Policies and Regulations](#)

6.2 English Proficiency for International Teaching Assistants

6.3 Departmental Policies

6.4 [Link to MAA Math TA Resource](#)

## 7. Other Departmental Awards

7.1 Graduate Student Conference Travel Award Program

7.2 Morris and Miriam Marden Award in Mathematics

7.3 Ernst Schwandt Teaching Award

7.4 Dharendra Sikdar Scholarship in Atmospheric Science

7.5 Mark Lawrence Teply Award

## 8. Master's Requirements

A. Standard Mathematics Option

B. Industrial Mathematics Option

C. Atmospheric Sciences Option

D. Statistics Option

- E. Actuarial Science Option
  - F. Foundations of Advanced Studies Option
- Dual Master's Degree

## **9. Ph.D. Requirements**

- 9.1 Major Professor Advisor
- 9.2 Course of Study
- 9.3 Foreign Language
- 9.4 Computer Proficiency
- 9.5 Residence
- 9.6 Doctoral Preliminary Examination
- 9.7 Doctoral Dissertation Proposal Hearing
- 9.8 Dissertation
- 9.9 Dissertation Defense
- 9.10 Time Limit
- 9.11 Minor Area for Other Ph.D. Majors

## **10. MS Exam Information**

## **11. MS Graduation Procedure**

## **12. Ph.D. Milestone Procedure**

- 12.1 Preliminary Exam
- 12.2 Proposal Hearing
- 12.3 Apply for Dissertator Status
- 12.4 Apply for Dissertation Defense and Graduation

## **13. Graduate Program Forms**

## **14. Courses**

- 14.1 Atmospheric Sciences Courses
- 14.2 Mathematical Sciences Courses
- 14.3 Mathematical Statistics Courses

## **1. Overview**

The Department of Mathematical Sciences offers graduate programs of study in mathematics and atmospheric sciences with specializations in the fields of algebra, analysis, topology, applied mathematics, probability, statistics, actuarial science, atmospheric science, and industrial mathematics.

The programs of study at the master's level are designed to suit both the student intending to continue toward a Ph.D. as well as the student who wishes to begin a professional career upon completion of the master's program.

The student in the Ph.D. program may prepare for a career in teaching at the college level and for a career in research in the academic, industrial, government, or business communities.

## **2. Administration of the Graduate Program**

The Associate Chair for the Graduate Program and the Graduate Committee are responsible for the programs. The Associate Chair for the Graduate Program and the Graduate Program Assistants manage the day-to-day operations.

## **3. Who to Contact if You Have Questions**

Graduate Study Related Issues (selection of courses, checking degree requirements, transfer of credits, etc.): The Associate Chair for the Graduate Program.

Teaching Related Issues (add/drop students from your classes, verifying your students' prerequisites, etc.): Your Course Coordinator (if you have one), or the Associate/Assistant Chair for Undergraduate Study. As a TA, your supervisor is the Department's Chair.

International Student Issue (visa etc.): Center for International Education or Katie Wehrheim.

## **4. General Policies & Regulations**

### **[UWM Graduate School Academic Policies and Procedures](#)**

#### **4.1 GPA Requirement**

UWM requires a minimum of cumulative 3.0 GPA (4.0 basis) in all work taken toward the degree. The student will receive an academic warning if the semester grade point average falls below 3.0. The student will receive a "Graduate Dean's OK Required to Continue" if the cumulative grade point average falls below 3.0. If the

semester GPA and cumulative GPA are both below 3.0, the Graduate Dean's OK will take precedence over an Academic Warning. The student will be prevented from further registration unless the student petitions the Graduate School and receives a positive recommendation from the student's graduate program unit.

## 4.2 Credit Requirement

Graduate students enrolled for a minimum of 8 credits per semester or 6 credits during a summer session are considered full time, with the exceptions described below. Fellowship recipients are subjected to different fellowship requirements depending on the fellowships; refer to the award descriptions of the fellowships.

Teaching and Research Assistants (TAs and RAs) who are employed for one-third (33%) time or more must enroll for a minimum of 6 credits per semester. They are considered full-time with this minimum enrollment.

In addition, the Department of Mathematical Sciences requires its graduate students who are employed for 33% time or more as TAs or RAs to complete a minimum of 15 credits of graduate courses offered by the Department of Mathematical Sciences per academic year.

## 4.3 Transfer Credit

**Master's:** The maximum number of transfer credits allowable is the higher of (a) 12 semester credits or (b) 40% of the total number of credits required for graduation. To qualify, the work must meet the following criteria:

- Graduate level, from an accredited institution.
- Taken within five years of admission to your UWM degree program.
- Not have been used to meet previous degree requirements.
- Grade of B or better (B- is not acceptable).
- Approved by the Associate Chair for the Graduate Program.

To transfer credits, the student must first discuss the transferability of the credits with the Associate Chair for the Graduate Program, and then submit a [Graduate Transfer Credit Evaluation Form](#) to the Graduate School for processing.

**Ph.D.:** If you earned a Master degree before enrolling in the Ph.D. program in our Department, you may qualify for an automatic 27 credit transfer. Contact the Associate Chair for the Graduate Program for more information.

## 4.4 Change Program of Study

To change the program of study, such as change from an M.S. program in Physics to an M.S. program in Mathematics, the student needs to formally apply for admission

to the graduate program into which the student wishes to change. There is no transfer between programs at UWM.

Within the Department of Mathematical Sciences, there are three (3) distinguished graduate programs at the M.S. level: Actuarial Science, Atmospheric Sciences, and Mathematical Sciences. Though all graduate students in these programs are students in the Department of Mathematical Sciences, in order to change the program of study among these programs, a student must apply for admission to the program into which the student wishes to change. However, this does not apply to change the options of study within the Mathematical Sciences group of options (Standard Mathematics, Industrial Mathematics, Statistics, Foundations of Advanced Studies, and Dual Master's Degree), as students can change (or select) their option(s) without further application. However, an option should be decided early so the student can follow the requirements to complete the degree within the time limits. See **Master's Requirement** and **Maximum Number of Years of Support** for further information.

There are two graduate programs at the Ph.D. level: Atmospheric Sciences and Mathematical Sciences. A change of field of study within Mathematical Sciences does not require a formal application but needs to be approved by the student's Ph.D. advisor. See [UWM Graduate School Academic Policies and Procedures](#) for further information.

#### **4.5 Promotion from M.S. to Ph.D.**

An M.S. student who wishes to pursue a Ph.D. degree (in the same or a different program) needs to apply for admission to the Ph.D. program without paying the application fee. The student submits the application in the semester the student expects to complete the M.S. degree, and the Departmental Admission Committee makes the decision on whether or not an admission is granted. An M.S. student who is promoted to the Ph.D. program must be conferred the M.S. degree (the degree conferred date is shown on the student's transcript in PAWS) before officially becomes a Ph.D. student.

#### **4.6 Dismissal and Appeal of Dismissal**

Students who are not making satisfactory progress towards fulfilling the requirements for a Master's or Ph.D. degree are subject to dismissal from the program. The Associate Chair for the Graduate Program and the Graduate Committee make this decision and hear the appeals.

### **5. Financial Support**

Financial supports in the form of Fellowships, Teaching Assistantships, and Research Assistantships are awarded on a competitive basis. All applicants to the

program are automatically considered for each of these types of awards. Awards are renewable for students making satisfactory progress in their degree programs. In a typical year, 20-30 of these awards are given to new students entering the program. In addition, students may apply for other forms of financial aid such as loans by contacting the [Department of Financial Aid](#) or a third party.

## 5.1 Assistantship and Fellowship

- **Graduate Teaching Assistants:**

Most students are supported as Teaching Assistants (TAs). These half-time teaching positions include a remission of all tuition and the opportunity for health insurance coverage. The TA stipend for the 2017-2018 academic year ranged from \$12,850 to \$16,595 depending on the degree program and progress toward the degree.

- **Research/Project Assistantships:**

Some faculty members have support for research assistants (RA) or project assistants (PA) as part of their research funding. These positions pay a semester, academic year, or full-year stipend, have remission of tuition, and offer health insurance. The duties of the positions are determined by the faculty members. These faculty members select who they want for their positions from among current students and admitted applicants. There is no separate application for these positions.

- **Graduate School Fellowships:**

Student with excellent records may apply for a Graduate School Fellowship. The UWM Graduate School currently offers two fellowships for full-time study: The Distinguished Graduate Student Fellowship, which is for new and continuing UWM graduate students; and the Distinguished Dissertation Fellowship, which is for current UWM Ph.D. students who have either achieved dissertator status or will achieve dissertator status during the award year. These fellowships pay a 9-month stipend, remit all tuition, offer health insurance, provide a modest travel stipend, and do not require any teaching during the year. The fellowships are not renewable. Application deadline is January 15 each year. For more information, visit

<http://uwm.edu/graduateschool/types-of-funding/>

- **Advanced Opportunity Program (AOP) Fellowships:**

These fellowships are available to qualified new and continuing graduate students who are members of groups underrepresented in graduate study, students with disabilities, and/or students who are first-generation college graduates with demonstrated financial need. This fellowship is renewable for up to two years for M.S. and three years for Ph.D. students. More information is available at the [program website](#). Application deadline is January 15 each year.

## 5.2 Awards

The Department uses the Chancellor's Graduate Student Award and the Research Excellence Award as supplements to other support to form a whole package of financial support for the student. Should the financial support offer change, such as changing from a Teaching Assistantship to a Research Assistantship, the department may also change these awards in the new financial support offer.

- **Chancellor's Graduate Student Award:**

Depending on fund availability, the department offers Chancellor Graduate Student Award, ranging from \$1,000 to \$6,000 as supplements to the student's other support. These awards are renewable for up to five (5) years, depending on satisfactory progress being made toward the degree. No application is necessary; every applicant or current graduate student is automatically considered for the award.

- **Research Excellence Award:**

The Research Excellence Award (REA) program is designed to incentivize growth of extramural support for graduate students. The department offers this award to high-quality, talented graduate students. Subject to fund availability, new applicants and current graduate students with excellent records are offered REA as supplements to their other support. No application is necessary; every applicant or current student is automatically considered for the award. Preference may be given to graduate students who have made excellent progress in research.

## 5.3 Tuition Remission

Graduate assistants who hold appointments at 33% of full time or more are eligible for tuition remission for the semester(s) of appointment. Courses covered by the remission must be relevant to the student's program of study.

**Note on fees:** Payment of segregated fees or special course fees are the responsibility of the student. Graduate Assistants can arrange for the payment of these fees through payroll deduction.

## 5.4 Summer Support

Summer support, usually in the form of TA, is available upon applications and depends on the available TA positions. The Department may use other funds in addition to TA positions to provide summer supports for the student. Preference is given to Ph.D. students. The Department sends out summer support request forms to all current students each spring semester.

## 5.5 Financial Support Award Authority



The Associate Chair for the Graduate Program and the Graduate Committee oversee the award of financial supports for all graduate students.

The Chair of the Department appoints the TAs upon the recommendation of the Graduate Committee. The Chair of the Department also supervises the TAs. The Associate Chair for the Graduate Program, with input from the Graduate Committee, allocates the Chancellor's Graduate Student Award and the Research Excellence Award funds, and is responsible for nominating graduate students for Graduate School Fellowships.

Faculty members who have RA funds in their research grants select and award their RAs.

## **5.6 Maximum Number of Years of Support**

The maximum number of years of departmental financial supports (the total number of years of TA, RA, and other fellowships) is:

- two (2) for the M.S. student; and
- seven (7) for the Ph.D. student, regardless whether the student's initial enrollment is in the M.S. or the Ph.D. program.

## **5.7 Ph.D. Milestone Progress Requirement for Support**

Making satisfactory progress in the degree program is a necessary condition for receiving financial support from the Department. The student in the Ph.D. program is expected to achieve the following milestones (see **Ph.D. Milestone Procedures** in this Handbook for more information):

1. Passing the Ph.D. Prelim Examination by
  - the end of the third academic year if the student was admitted into the Ph.D. program directly;
  - the end of the fourth academic year (including the years in the M.S. program) if the student was initially admitted into the M.S. program.
2. Achieving dissertator status by the beginning of the sixth academic year from the initial enrollment, regardless whether the student's initial enrollment is in the M.S. or the Ph.D. program.

Usually, students in the Ph.D. program can achieve these milestones a year earlier than the deadlines. It is possible for a well prepared Ph.D. student who has an M.S. degree from another institution to pass the prelim after one year of study in our program.

## **6. Teaching Assistant Policies & Regulations**

### **6.1 Graduate School's Graduate Assistant Policies and Procedures**

It is the student's responsibility to read the Graduate School's Graduate Assistant Policies and Procedures. These policies and procedures are available at:

<http://uwm.edu/graduateschool/graduate-assistant-policies-procedures/>

### **6.2 English Proficiency for International Teaching Assistants**

The UWM International Teaching Assistant Assessment (MITAA) is a requirement for some international teaching assistants who are non-native English speakers and who will be assigned classroom duties as part of a graduate teaching assistantship. A Department representative must be available to participate in the assessment. There is no charge for the MITAA.

Not all prospective international teaching assistants must take the MITAA. The assessment generally is not required if the student has one of the following recent standardized test scores:

- 23 or better on the Speaking section of the internet-Based TOEFL (iBT)
- 7.0 or better on the Speaking section of the IELTS

The assessment also might not be required for students who are graduates of an American university or college. For more information, contact the ESL Programs Office.

### **6.3 Departmental Policies**

Undergraduate teaching is one of the primary responsibilities of the Department of Mathematical Sciences; graduate students play an important role in this function. As a part of their training, and as a necessary condition for most forms of financial aid, all teaching assistants are involved with departmental teaching activities each semester they are in residence.

Balancing your roles as a student and a TA can be difficult, and we are here to help you navigate issues like these. Please do not hesitate to contact any member of the Department administration if you have questions.

#### **TA Responsibilities:**

As a TA in the Department of Mathematical Sciences at the University of Wisconsin-Milwaukee, your responsibilities are:

- teaching lectures and/or discussion sections in accordance with the outline and directives as provided by your course coordinator (if you have one)
- arriving to your classroom in a timely manner and teaching for the designated period of time
- familiarizing yourself with course material and preparing in advance for future classes
- managing the classroom to foster a positive learning environment
- managing online homework assignments (if they are being used)
- holding office hours for three hours per week on at least two different days
- attending lectures (if requested by your coordinator)
- attending meetings held by your coordinator
- proctoring and grading quizzes and exams, including make-up exams
- maintaining and managing grade data for each of your students
- entering grades in PAWS for each of your students
- submitting final exams and grade sheets to the department staff (Jane Miles)
- attendance at both the university and department TA orientation sessions
- attendance at ongoing department TA professional development activities
- for those who have not taught for the UWM Math Department before, enrollment in and satisfactory completion of MATH 799 – Teaching Mathematics to Undergraduates under the supervision of Drs. Kohlmetz or Van Harpen

In addition, the department sends out emails that contain information on class policies, procedures, and important dates, etc., to all instructional staff members of the department each semester. Please read it carefully and keep a copy for your reference.

### **More general guidelines:**

#### **Teaching tips:**

- 1) Know the subject matter of your lessons very well. Teach yourself anything that is new.
- 2) Visit your classroom before the semester starts to know its location and if it has a blackboard (chalk) or whiteboard (markers).
- 3) Get students to talk, not just raise hands, on day one. It is hard to fix later if they don't.
- 4) Dress nicely on day one to make a clear distinction between you and your students. Always practice good hygiene (daily showers; teeth brushed; clean clothes).
- 5) Always write on a board starting from the far left side rather than in the middle.
- 6) If something is important, write it on the board (e.g., the name of a new topic). If you speak for a while and write nothing on the board, nothing will go in student's notes!

- 7) Look at students more than the blackboard. Remember to turn around and face the class.
- 8) Do not lecture for more than 15 minutes without injecting an alternative activity (e.g., having the students work on a problem, ideally in pairs).
- 9) Illustrate new ideas with examples (wouldn't you like your teachers to do this too?).
- 10) Work out your examples before class and double-check your calculations.
- 11) Convey interest and confidence in what you're saying! If it comes across that you're bored or confused about the lesson, your students will stop paying attention.
- 12) When you ask the class if there are any questions, wait (perhaps count to 5 slowly in your head) before moving on. Time goes slower than you think at the front of the room.
- 13) If a student asks a question or makes a comment, don't suggest it is dumb even if it conveys an elementary misunderstanding. We have all misunderstood simple things.
- 14) If you tell a student "I don't know," follow up with "I'll find out." And then find out.
- 15) Do not yell at or make fun of students. It's hard to regain their respect once it is lost.

#### **What to do, administratively:**

- 1) Communicate! Reply in a timely manner to emails from coordinators, other instructors, other TAs, and students. In particular, you are expected to check your email regularly (at least twice a day).
- 2) Know dates and times of exams, and be here to proctor and grade; grading may be done at a common time. Mark exam weeks on your calendar and do not go away those weeks. In an emergency it is your duty to find a substitute that meets the instructor's approval.
- 3) Record exam and quiz grades before returning any exams or quizzes to the students.
- 4) Speak with the course coordinator or other TAs if you have questions about the course.
- 5) Speak with the course instructor if you have concerns about any of your students, especially if any student misses class for a week or if you suspect student cheating.
- 6) If you are unfamiliar with a topic in the course, review it before it is covered in class.
- 7) Start class on time, end class on time.
- 8) Tell students your office hours and try to include "by appointment" as an option.
- 9) Keep your door open during office hours, and leave a note on the door if you go away briefly.
- 10) Maintain a professional relationship with students; ignore any Facebook friend requests.

### **What not to do, administratively:**

- 1) Do not disappear.
- 2) Do not miss any TA meetings without having a discussion in advance with the coordinator.
- 3) Do not schedule travel that will take you out of town while you have teaching duties without informing both the department administration and the course coordinator well in advance.
- 4) Do not cut special deals (e.g., on grades) with students before speaking to the course coordinator.
- 5) Do not accept excuses for missing major events (e.g., a midterm) without documentation. If something is questionable, ask the coordinator. The coordinator set the policy for the course and the ultimate decision regarding excuses lies with them!
- 6) Do not leave your phone's ringtone on in class.
- 7) Do not wait until the last minute to make copies of a quiz; the copy machine may be broken or may be being used by several other instructors!

## **6.4 Link to MAA Math TA Resource**

The Mathematical Association of America has developed an extensive handbook for Mathematics Teaching Assistants. We strongly recommend that all Teaching Assistants read this handbook and use it as a reference outlining aspirations for effective interactions in the classroom.

<http://www.maa.org/programs/students/student-resources/a-handbook-for-mathematics-teaching-assistants>

## **7. Other Departmental Awards**

### **7.1 Graduate Student Conference Travel Award Program**

The Department of Mathematical Sciences Travel Award program, subject to the availability of departmental funds, offers limited funding to our full time master's and doctoral students for presenting at and/or attending graduate program-related conferences. Such activities are an important part of the professional development of graduate students, offering opportunities to establish professional networks, contacts for collaborative research, and sources of potential future employment. The Department typically supports one trip per student per academic year.

#### **Eligibility**

- Full-time graduate student in the Department of Mathematical Sciences at UWM

- Travel must be discussed with and approved by the student's advisor
- Students must attempt to apply for funding from other sources, such as the UWM Graduate School Travel Support Program
- Submit application prior to the conference

## **Application**

Students are encouraged to submit applications at least 2 months *before* the event. Submit a paper copy of each of the following:

1. [Departmental application form](#)
2. Proof of application of additional support
3. Travel Approval Requests (2 Forms): [Campus Travel Form](#) & [L&S Travel Form](#)

If presenting at the conference, attach a printed copy of the abstract you are presenting from the conference's website.

## **Selection Process**

Preference will be given to:

- Students presenting at a conference (either oral or poster).
- Students who have not received a department conference travel award before.

## **Travel Guidelines**

Awardees must comply with the State and campus [travel policies and procedures](#) and any other Department instructions. Students planning to drive personal vehicles or rental cars must be registered and authorized by UWM. See the [Drivers and Vehicles](#) Web site.

## **7.2 Morris and Miriam Marden Award in Mathematics**

The Morris Marden Graduate Award will be given for a mathematical paper of high quality with respect to both exposition and mathematical content. The paper need not be written specifically for the Marden Award; papers originally written for coursework, independent study, professional reports, dissertation, or other reasons are acceptable.

Applicants must be UWM graduate students and should submit

1. a PDF file of the paper and
2. a letter of support from a faculty member describing the relevance and intellectual merits of the paper.

The length of the paper is expected to be between 10 and 25 pages, but these limits are not strict.

Students will receive email notification on how to apply for the award in spring from the award committee Chair.

### **7.5 Ernst Schwandt Teaching Award**

The Department of Mathematical Sciences annually recognizes demonstrated outstanding teaching performance by Mathematical Sciences Graduate Student Teaching Assistants through the Ernst Schwandt Award.

Nominations are accepted from members of the Department of Mathematical Sciences (faculty, TAs, lecturers, staff); self-nominations are accepted.

To nominate someone for the award, submit a letter of nomination describing how the nominee merits the award.

Students will receive email notification on how to apply for the award in spring from the award committee Chair.

### **7.6 Dhirendra Sikdar Scholarship in Atmospheric Science**

The Dhirendra Sikdar Memorial Scholarship Fund was established in 1989 to support graduate students in the atmospheric sciences masters or doctoral programs. The scholarship was established to honor a former UWM faculty member with a keen interest in meteorology. A committee of faculty members within the discipline will select students for this scholarship based on the quality of their overall academic record, including grade point average, research and other accomplishments, and the recommendation of faculty members.

Students will receive email notification on how to apply for the award in spring from the award committee Chair.

### **7.7 Mark Lawrence Teply Award**

The Department of Mathematical Sciences' Mark Lawrence Teply award is designed to recognize students who show remarkable potential in their research fields. The award is a memorial of Professor Teply's (b.1942-d. 2006) commitment to the graduate program. Along with this recognition, winners are awarded funding to be spent on books in their chosen field of research. The award is hoped to be given out each academic year in the Department of Mathematical Sciences at the University of Wisconsin-Milwaukee. Book purchases must be arranged through the department's staff during the six weeks following the spring awards ceremony.

Full-time graduate students in the UWM Department of Mathematical Sciences who have reached dissertator status, but have not yet defended their theses are eligible to submit a one page description of the books in their field which they would most like to add to their own reference libraries. Applicants are expected to be in good academic standing, and have a well defined research focus.

This merit based award is highly competitive. Winners must demonstrate outstanding potential as researchers in the mathematical sciences. Some specific criteria considered include the following.

1. Written statement of application (see above)
2. Reference from a graduate faculty member in the Department of Mathematical Sciences
3. Graduate GPA
4. Scholarly progress

#### Application Procedure

Submit the following by April 1 to the award committee Chair:

1. written statement of application;
2. an unofficial copy of your graduate transcripts; and
3. the name of a graduate faculty member in the Department of Mathematical Sciences whom you would want the selection committee to contact for a recommendation.

Students will receive email notification on how to apply for the award in spring from the award committee Chair.

## **8. Master's Requirements**

Six options for the master's degree are offered: the standard mathematics option (A), the industrial mathematics option (B), the atmospheric sciences option (C), the statistics option (D), the actuarial science option (E), and the foundations of advanced studies option (F).

In addition to these six options, the Department and the Department of Technomathematics of Fachhochschule Aachen (FHA), Germany, have a Dual Master's Degree Program in Mathematics. The students enrolled in this program will be able to earn Master's degrees from both institutions upon completion of the common course requirements.



Students who plan to continue for a Ph.D. degree with a focus on mathematics/statistics should elect an option from options A, B, D, and F, or the dual master's degree option; those who seek the Ph.D. in atmospheric sciences should elect option C.

## **A. Standard Mathematics Option**

### **Major Professor as Advisor**

The student must have a major professor to advise and supervise the student's studies as specified in Graduate School regulations. The entering graduate student is assigned a temporary advisor by the Associate Chair for the Graduate Program.

### **Credits and Courses**

Minimum degree requirement is 30 or 36 credits, depending upon which option the student chooses: either 30 credits from Math and MthStat courses, at least 12 credits of which are numbered 700 or above; or at least 36 credits in Math and MthStat courses open for graduate credit.

Under the 36-credit option, no more than 12 credits below the 500 level from within the Department of Mathematical Sciences can be counted as program credits required for the degree.

Under the 30-credit option, up to 9 credits may be in approved courses from outside the Department. Under the 36 credit option, up to 12 credits may be taken in approved courses from outside the Department.

### **Thesis**

A thesis is optional. A student choosing the thesis option must enroll in Math 790. A maximum of 3 credits of thesis may be counted toward the degree requirements, however, thesis credits cannot be used to satisfy the 700 and above course credit requirement. An acceptable thesis will represent an original contribution and may involve applications, a novel exposition, or computational aspects of a mathematical problem or theory. The student must pass an oral defense of the thesis.

### **Examination or Project**

Each student who does not elect the thesis option must satisfy one of the following requirements:

(a) Pass a written comprehensive examination. See M.S. **Exam Information** in this Handbook for more information.

(b) Present a satisfactory oral and written report on a comprehensive project done under the supervision of a faculty advisor.

The project option is open only to students who complete the 36 credit graduation requirement. Students electing the project should register for 1 to 3 credits of the Master's Seminar 791. Students planning to continue for a Ph.D. should select the written comprehensive examination option.

### **Time Limit**

Under the 30 credit option, the student must complete all degree requirements within five (5) years of initial enrollment. Under the 36 credit option, the student must complete all degree requirements within seven (7) years of initial enrollment.

## **B. Industrial Mathematics Option**

### **Objective**

The objective of the master's program in industrial mathematics is to enable students to acquire the fundamentals of applied mathematics in areas of classical and numerical analysis, differential equations and dynamical systems, and probability and statistics. At the same time, the connection of these fields to modeling of physical, biological, and engineering phenomena will be stressed by requiring credits outside of the Department of Mathematical Sciences. Students are to obtain practical experience in mathematical modeling and analysis during an internship or industrial project that will culminate in a thesis.

### **Major Professor as Advisor**

The student must have a major professor to advise and supervise the student's studies. The entering graduate student is assigned an advisor by the chair of the Industrial Mathematics Committee. Depending on the thesis topic, the student may later change advisors.

### **General Requirements**

A student must have completed, either prior to entering the program or by the time of graduation, courses in advanced calculus, numerical analysis, and ordinary differential equations. In addition, students must complete courses involving Fourier series, linear algebra, linear programming, mathematical modeling, partial differential equations, probability, and calculus-based statistics.

### **Credits and Course Work**

At least 36 graduate credits in G or U/G courses at UWM are required, subject to the following regulations. A student must have:

1. At least 18 credits from the list of approved industrial mathematics courses, including Math 701, 715, and at least 6 additional credits at or above the 600 level.
2. At least 6 upper level (300 or above) credits of a coherent set of courses, approved by the advisor, in an application area (e.g., physics, engineering, business) outside of the Department. Students already proficient in an application area are expected to substitute mathematics courses.
3. Not more than 6 credits in any combination of independent study or seminar or thesis (Math 790, 791, 792, 799, or 990);
4. Not more than 12 credits below the 500 level from within the Department of Mathematical Sciences;
5. Demonstrated knowledge of an advanced scientific programming language approved by the Industrial Mathematics Committee; and
6. Advisor's prior written approval for every course.

### **Thesis**

A thesis in which the student solves a mathematical problem with an industrial source is required. The student must work with the advisor/major professor from the start of the thesis through its completion, receiving his/her approval. The student must pass an oral defense before three faculty members.

### **Time Limit**

Full-time students, without deficiencies, could be expected to complete the program in two years. All degree requirements must be completed within seven years of initial enrollment.

### **Special Recommendation**

It is recommended that, by the time of graduation, students master the material presented in the following courses, either prior to enrolling or through course work: Math 313, 314, 564, 571, 601, 602, 701, 702, and 715. Students must work closely with their advisors to ensure satisfaction of the General, Course Work, and Thesis requirements for timely graduation.

### **Approved Industrial Mathematics Courses**

#### **Applied Mathematics**

Math 307/308 Theoretical Mechanics

Math 320 Introduction to Differential Equations

Math 321 Vector Analysis

Math 322 Introduction to Partial Differential Equations  
Math 371 Introduction to Stochastic Models in Finance  
Math 405 Mathematical Models and Applications  
Math 520 Non-Linear Differential Equations  
Math 521/522 Advanced Calculus  
Math 525 Introductory Theory of Differential Equations  
Math 535 Linear Algebra  
Math 581 Introduction to the Theory of Chaotic Dynamical Systems  
Math 601/602 Advanced Engineering Mathematics I/II  
Math 621/622 Introduction to Analysis  
Math 623 Complex Analysis  
Math 701/702 Industrial Mathematics I/II  
Math 703 Boundary Value Problems  
Math 705 Mathematical Fluid Dynamics  
Math 709 Differential Geometry  
Math 716 Ordinary Differential Equations  
Math 719 Partial Differential Equations  
Math 726 Introduction to Functional Analysis  
Math 727 Calculus of Variations  
Math 728 Integral Equations  
Math 801 Topics in Applied Mathematics: (Subtitle)  
Math 816/817 Advanced Ordinary Differential Equations I/II  
Math 819/820 Advanced Partial Differential Equations I/II  
Math 827 Fourier Analysis

### **Numerical Analysis**

Math 313 Linear Programming and Optimization  
Math 314 Mathematical Programming and Optimization  
Math 413 Introduction to Numerical Analysis  
Math 414 Numerical Analysis  
Math 416 Computational Linear Algebra  
Math 715 Numerical Analysis  
Math 793 Scientific Computational Laboratory: (Subtitle)  
Math 813 Numerical Solution of Ordinary Differential Equations  
Math 814 Numerical Solution of Partial Differential Equations  
Math 815 Topics in Numerical Analysis: (Subtitle)

### **Probability and Statistics**

MthStat 361/362 Introduction to Mathematical Statistics I/II  
MthStat 461/462 Data Analysis and Graphing Using SAS-I/II  
Math 471 Introduction to the Theory of Probability  
MthStat 561 Analysis of Variance  
MthStat 562 Design of Experiments  
MthStat 563 Regression Analysis  
MthStat 564 Time Series Analysis  
MthStat 565 Nonparametric Statistics

MthStat 567 Statistical Methods in Reliability  
MthStat 568 Multivariate Statistical Analysis  
MthStat 569 Advanced Biostatistics  
Math 571 Introduction to Probability Models  
MthStat 761/762 Mathematical Statistics I/II  
Math 768 Applied Stochastic Processes  
MthStat 861/862 Decision Theory I/II  
MthStat 863 Hypothesis Testing  
MthStat 869 Advanced Topics in Mathematical Statistics  
Classes in Biostatistics at the Medical College of Wisconsin

## **C. Atmospheric Sciences Option**

### **Major Professor as Advisor**

The student must have a major professor to advise and supervise the student's studies as specified in Graduate School regulations. This advisor will formally be assigned upon enrollment in the program by the chair of the Atmospheric Science Program.

### **Credits and Courses**

The minimum degree requirement is 30 graduate credits, 12 of which must be in the atmospheric sciences 700 number sequence, 6 of which will be approved graduate elective credits, and 6 of which will be from either the mathematics sequences 521/522 or 601/602, atmospheric science sequence 500/950, or from two of the following courses: Math 703, Math 705, Math 801, and Atm Sci 750.

### **Thesis**

A thesis is optional. Students who choose the thesis option must enroll in Atm Sci 990 for the final 6 credits of the required total. An acceptable thesis will represent an original contribution to knowledge in the atmospheric sciences. Upon completion of the thesis, students must pass an oral examination to defend the thesis.

### **Comprehensive Examination**

In the non-thesis option, students must pass a written comprehensive examination that tests basic knowledge of the atmospheric sciences.

### **Time Limit**

Full-time students, without deficiencies, can be expected to complete the program within two years. Note that students seeking the M.S. degree are limited to a

maximum of two years of departmental financial support. All degree requirements must be completed within five years of initial enrollment.

## **D. Statistics Option**

### **Major Professor as Advisor**

The student must have a major professor to advise and supervise the student's studies as specified in Graduate School regulations. Each entering graduate student is assigned a temporary advisor by the Department Graduate Program Coordinator.

### **Credit and Courses**

The minimum requirement is 30 graduate credits. Students must complete the following:

1. Math 535 (or 631/632), 571, or 768.
2. Math 621/622 (or 711/712).
3. MthStat 563, 564, and the sequence 761/762.
4. At least one other 560-level MthStat course, such as MthStat 562, 565, or 568.

Students who already have taken some of these courses as undergraduates, or equivalent courses at another institution, should choose alternatives from the following list, subject to the advisor's approval:

- MthStat courses numbered 700 or above.
- Statistics course offered by the Division of Biostatistics of the Medical College of Wisconsin.
- Math 413, 414, 416, 711/712, 713, 714, 721, 768, or 771; MthStat 596/597.

### **Thesis Option**

Students have the option of writing a thesis, subject to the advisor's approval. Students who write a thesis are exempt from the Master's Proficiency Exam, and they earn 3 credits toward the degree by enrolling in Math 790. Students who choose the thesis option must pass an oral defense of the thesis.

### **Master's Proficiency Exam**

Students who do not complete the thesis option are required to pass a written comprehensive examination that tests basic knowledge of statistical theory and either mathematical analysis or algebra. See M.S. **Exam Information** in this Handbook for more information.

## **Time Limit**

Students must complete all degree requirements with 5 years of initial enrollment.

## **E. Actuarial Science Option**

### **Objective**

The program provides a mathematically rigorous education in actuarial science, prepares students for actuarial professional exams, and develops their economics and business reasoning skills. Students obtain thorough knowledge in the fundamentals of actuarial science such as applied probability models, applied statistics, credibility, financial economics, life contingencies, loss models, and risk theory. Emphasis is placed on developing skills that are highly valued by employers and thus are essential for a successful career as actuary. This program is intended for students who will seek employment as an actuary upon completion of the degree. Those interested in entering the department's Ph.D. program should consider a different Master's option.

### **Major Professor as Advisor**

The student must have a major professor, selected from the members of the Actuarial Science Committee, to advise and supervise the student's studies. The entering student is assigned an advisor by the chair of the committee. Before the start of studies, each student in the program must develop a plan of study in consultation with the Committee.

### **Credits and Course Work**

The minimum degree requirement is 30 credits. In order to graduate, the following requirements must be completed:

- Eighteen credits among MthStat 596, 597, 691, 692, 795, and either Math 571 or 768. Students already proficient in some of these areas may substitute up to six credits of other courses in actuarial science, probability or statistics at the 700 level or above. (All substitutions have to be approved by the Actuarial Science Committee and the Graduate Program Coordinator.)
- At least 12 credits from the following list: Math 311, 790, 792, 799, MthStat 563, 564, Econ 701, 702, BusMgmt 705. Students already proficient in these areas but having less than two actuarial exams passed must substitute at least six credits of other courses in probability or statistics at the 700 level or above. Credits for Math 790, 792 and 799 can be counted toward the degree requirement only for

students who have passed two actuarial professional exams and only when these courses cover topics in actuarial science, probability, or statistics.

Students who have completed program courses for undergraduate credit should discuss alternative graduate-level courses to substitute for those courses in their programs of study.

### **Thesis**

A thesis is not required for the actuarial science option. Rather, students must pass three departmental written proficiency exams, which are based on the learning objectives of the actuarial professional exams P/1, FM/2, and one of MFE/3F, MLC, C/4. Waivers for departmental exams are granted for students who have passed the corresponding professional exams.

### **Professional Development**

For future advancement in the field of actuarial science, "Validation by Educational Experience" (VEE) credits are required. VEE credits may be earned from the Society of Actuaries (SOA) and Casualty Actuarial Society (CAS) with a grade of B- or better in the following courses: MthStat 563, 564 (VEE-Applied Statistics); Econ 701, 702 (VEE-Economics); BusMgmt 705 (VEE-Corporate Finance). Courses taken at other universities may be used to meet the VEE requirement of the SOA/CAS.

### **Time Limit**

Full-time students are expected to complete the program in two years. Students must complete all degree requirements within five years of initial enrollment.

## **F. Foundations of Advanced Studies Option**

### **Objective**

This option is designed to prepare students for advanced-level graduate programs. It is structured so that students with basic preparation from their undergraduate institutions can complete the option in no more than two years. Some students with a higher level of preparation may transfer up to 12 graduate credits from the courses they completed previously; such students may advance more quickly through the program and complete the degree in only one year.

### **Major Professor as Advisor**

The student must have a major professor to advise and supervise the student's studies as specified in Graduate School regulations. The Associate Chair for the Graduate Program assigns a temporary advisor for the entering graduate student.



## **Credits and Courses**

Minimum degree requirement is 30 credits from mathematics/statistics courses, including Math 621/622 and 631/632. At least 12 credits must be taken in courses numbered 700 or above. Up to 6 credits may be in approved courses from outside the Department.

Students who already have taken Math 621/622 and/or Math 631/632 (or equivalent courses as another institution) as undergraduates may request permission to take alternatives from the following list:

1. Math 711/712
2. Math 713/714
3. Math 731/732
4. Math 751/752

## **Examination**

The student must pass a written comprehensive examination. See M.S. **Exam Information** in this Handbook for more information.

## **Time Limit**

The student must complete all degree requirements within 5 years of initial enrollment. Normally, the student can complete all degree requirements within 2 years of initial enrollment. Students who have prior graduate course work may be able to complete the degree requirements in 1 year.

## **Remark**

The Department of Mathematical Sciences does not offer financial support to students enrolled in this program.

## **Dual Master's Degree**

The program is designed in such a way that students typically will be able to complete all the course requirements within a two-year time period (one year at each institution). Within this program, students can choose courses that will allow them to concentrate in the areas of Statistics, Numerical Analysis or General Mathematics. Complete information on the admission policy and graduation requirements, including sample schedules, is available at the Department of Mathematical Sciences web page

<http://uwm.edu/math/graduate/>

## **9. Ph.D. Requirements**

### **9.1 Major Professor as Advisor**

The student must have a major professor to advise and supervise the student's studies as specified in Graduate School regulations. The entering graduate student is assigned a temporary advisor by the Associate Chair for the Graduate Program.

### **9.2 Course of Study**

Minimum degree requirement is 54 graduate credits beyond the bachelor's degree, at least 27 of which must be earned in residence at UWM. The student, in consultation with the major professor, must select both a primary and a secondary area of specialization. The primary area may be chosen from one of the following eight fields with minimum credit requirements as shown. The secondary area may be chosen from another of these fields or may be chosen from another appropriate department. Minimum course requirements for all work in both areas of specialization require approximately two full years of study.

#### **Algebra field**

- 12 credits in algebra
- 3 in complex analysis
- 3 in real analysis
- 3 in topology
- 3 in applied mathematics
- 3 outside the field (means not algebra, the same for the descriptions below)

#### **Analysis field**

- 3 credits in algebra
- 6 in complex analysis
- 6 in real analysis
- 3 in topology
- 3 in applied mathematics
- 3 outside the field

#### **Applied mathematics field**

- 3 credits in algebra
- 6 in complex analysis
- 3 in real analysis
- 12 in applied mathematics
- 3 outside the field

#### **Probability and statistics**

3 credits in complex analysis  
6 in real analysis  
12 in probability and statistics  
3 in applied mathematics

### **Topology field**

3 credits in algebra  
3 in complex analysis  
3 in real analysis  
12 in topology  
3 in applied mathematics  
3 outside the field

### **Industrial mathematics field**

3 credits in algebra or topology  
3 in complex analysis  
3 in real analysis  
9 in applied mathematics  
6 in probability and statistics  
6 in approved credits outside Math and MthStat.

### **Atmospheric sciences field**

12 credits in atmospheric sciences (synoptic, dynamic, cloud/radiative, air pollution)  
9 in applied mathematics or probability and statistics  
3 in analysis

### **Actuarial science field**

6 credits in actuarial science  
6 in applied mathematics  
6 in probability & statistics  
6 in real analysis  
3 in business or economics

*NOTE:* Admission to this program is limited to students who have made significant progress towards and are close to achieving a professional designation from an internationally recognized actuarial organization.

## **9.3 Foreign Language**

Except for students in the atmospheric sciences field, each student must pass a written examination in one foreign language; the examination is administered by the Department's Language Committee. Acceptable languages are French, German, and Russian; exceptions may be permitted upon written request of advisor.

## **9.4 Computer Proficiency**

The student shall pass an examination on a higher programming language and/or other appropriate advanced computer skills; the examination is administered by the Department's Computer Committee. The Computer Committee may accept advanced computer science course work in lieu of the examination.

## 9.5 Residence

The student must meet minimum [Graduate School residence requirements](#).

## 9.6 Doctoral Preliminary Examination

When the student is sufficiently prepared — normally when the student has earned 24 credits in specified areas above the 700 level — a doctoral preliminary examination to determine the student's knowledge and achievement is taken.

For students in mathematics, the exam is an oral exam consists of three (3) different fields. It evaluates the student's general knowledge of mathematics, as well as the student's knowledge of the major area of concentration. The student chooses three (3) different fields from these five (5) options: algebra, analysis, applied mathematics, probability and statistics, and topology, and selects three examination committee members whose expertise represent the three selected fields. The Associate Chair for the Graduate Program must approve both the selected fields and the committee members. See **Ph.D. Milestone Procedures** in this Handbook for more information.

Students in atmospheric sciences are examined in three areas: at least one from Atm Sci and at least one from Math or MthStat.

Students must pass this examination to continue in the program. With permission of the examination committee, the student may repeat this examination once. If the student does not have a master's degree in mathematics before this examination, the committee will determine whether the student's performance is sufficient to qualify for the master's degree.

## 9.7 Doctoral Dissertation Proposal Hearing

After passing the language requirements and the doctoral preliminary examination, the student participates in a doctoral dissertation proposal hearing. At this hearing, the student is examined on the student's chosen area of research and a dissertation topic is approved. See **Ph.D. Milestone Procedures** in this Handbook for more information.

## 9.8 Dissertation

The primary requirement for the Ph.D. in mathematics is the candidate's completion, under the supervision of the Department advisor, of an original and significant mathematical investigation presented in the form of a dissertation. The investigation is to be in the field of algebra, analysis, applied mathematics, probability and statistics, topology, atmospheric sciences, or actuarial science. A dissertation for the industrial mathematics field must involve an industrial problem requiring a mathematical solution.

## **9.9 Dissertation Defense**

The candidate must, as the final step toward the degree, present a colloquium based on the dissertation and must pass an oral examination in defense of the dissertation. If the candidate does not successfully defend a thesis within five years of admission to candidacy, the candidate may be required to take another doctoral preliminary examination and be readmitted to candidacy. See **Ph.D. Milestone Procedures** in this Handbook for more information.

## **9.10 Time Limit**

All degree requirements must be completed within ten years from the date of initial enrollment in the doctoral program. Note that students seeking the Ph.D. degree are limited to a maximum of seven years, inclusive of time spent in pursuit of an initial M.S. degree, of departmental financial support.

## **9.11 Minor Area for Other Ph.D. Majors**

A doctoral student planning a physical science major other than mathematics may fulfill requirements for mathematics as the minor area of concentration by completing 12 credits of approved mathematics courses with a grade of B or better, at least 6 credits of which must be in courses 700 or above.

A doctoral student planning a non-physical science major may fulfill requirements for mathematics as the minor area of concentration by completing 12 credits with a grade of B or better in approved mathematics courses 300 or above.

## **10. M.S. Exam Information**

The Department's written comprehensive Master's Exam is given in three subjects: Algebra, Analysis, and Statistics. Master's students who choose to take the M.S. Exams to satisfy the capstone requirement (alternatives for the capstone requirement are a thesis or project, see **Master's Requirements** in this Handbook for detail) must pass any combination of two of these exams except those who choose the statistics option. Master's students who choose the M.S. Statistics option

must pass the M.S. Statistics exam and either the M.S. Algebra exam or the M.S. Analysis exam. Students can pass the exams one at a time; and there is no limitation on the number of times a student can take each exam. Each of the exams lasts three hours and is offered three times a year in one week in January, May/June, and August. The January and August M.S. exams are offered in the week preceding the first week of instruction, and the May/June M.S. exams are offered in the second week after the spring semester ends.

Students must sign up for the exams at least one week ahead of the scheduled exam dates. Approximately a month before the next scheduled exam week, the Department will send an email to inform the students about the coming M.S. exam and ask the students to sign up. If no students sign up for a particular subject exam, this subject exam will be cancelled. In the past, most students have taken the M.S. Algebra and the M.S. Analysis exams. Copies of past M.S. exams can be obtained from the Departmental main office, while example M.S. exams can be found using the links below.

### **MS Algebra Exam**

The M.S. Algebra exam is based on the course sequence Math 631 – 632 and it covers these topics: linear algebra, group theory, rings and modules.

#### **References:**

*Algebra*, M. Artin (2nd Ed): Chapters 1-4, Sections 6.7 – 6.11, 7.1 – 7.7, 7.9, 7.10, Chapter 8, Sections 11.1 – 11.8, Chapter 12, Sections 14.1, 14.2, 14.5, and 14.7;  
or

*Abstract Algebra*, Dummit & Foote (3rd ed): Chapters 1-5, 7-8, 9.1-9.4, 10.1-10.2, 11.1-11.4, and Chapter 12.

[MS Algebra Exam Example \(PDF\)](#)

### **MS Analysis Exam**

The M.S. Analysis exam is based on the course sequence Math 621-622 and it covers these topics: sequences, continuity, differentiation, integration, series and functions of several variables.

#### **References:**

*Principles of Mathematical Analysis*, Walter Rudin: Chapter 3-7 and Chapter 9;  
or

*A Friendly Introduction to Analysis*, Witold A. J. Kosmala: Chapter 2-8 and Chapter 10-11.

[MS Analysis Exam Example \(PDF\)](#)

### **MS Statistics Exam**

The M.S. Statistics exam is based on the course sequence MthStat 761–762 and it covers these topics: axiomatics of probability, random variables and vectors,

distributions, transformations, expected value and moments, asymptotics, point estimation, confidence intervals and hypothesis testing.

**References:**

*Statistical Inference*, G. Casella and R.L. Berger (2002, second edition);

or

*Modern Mathematical Statistics*, E.J. Dudewicz and S.N. Mishra (1988).

[MS Statistics Exam Example \(PDF\)](#)

## 11. M.S. Graduation Procedures

### For Graduate School Policies and Procedures, visit

<http://uwm.edu/graduateschool/masters-toolbox/>

### Before the semester in which you expect to graduate:

1. Meet with the [Associate Chair for the Graduate Program](#) to make sure you will meet the course and credit requirements by the end of the semester in which you intend to graduate. If your M.S. option is one of Actuarial Science, Atmospheric Sciences, Industrial Mathematics, or Statistics, you should also check the concentration requirement for your option.

See the Concentration Verification of Completion forms:

- 1) [Verification – Actuarial Science](#)
  - 2) [Verification – Atmospheric Science](#)
  - 3) [Verification – Industrial Mathematics](#)
  - 4) [Verification – Statistics](#)
2. If you plan to take the M.S. Exams for your M.S. capstone requirement (exit requirement), note that our department offers these exams three (3) times a year in January, May/June, and August, and plan accordingly.  
Note: You will need to pass two (2) out of these three (3) exams: Algebra Exam, Analysis Exam, and Statistics Exam. Our department will send out an email notice about the coming M.S. Exams. You can take these exams as many times as time permits, so you may want to take them as early as possible.
  3. If you plan a thesis/project for your M.S. capstone, it is advised that you find an advisor before the semester in which you plan to graduate. Note that some M.S. options (e.g. Industrial Mathematics) require a thesis, and the project option requires 36 credits.

4. Apply for graduation by the posted deadline for the semester in which you intend to graduate.
5. Information on registration requirements, application deadlines, and the online graduation application link are available [here](#).

**During the semester in which you expect to graduate (for those who are completing a thesis/project):**

1. Check the graduate school's deadlines, enrollment requirement, and other policies [here](#), and plan your defense/hearing accordingly.  
*Note: If you are completing a thesis, you must follow the graduate school's deadlines on formatting, defense, and submission. If any of these deadlines are not met, you must re-apply and graduate in the next semester. You will not be required to register for the next semester if your thesis has been defended, passed, and accepted by the Graduate School before the first day of classes for the next semester. The date of graduation, however, will be the next semester. If you are writing a project, you do not need to submit your project to the Graduate School, and you will just need to pass your project hearing by the end of the semester.*
2. Form your thesis/project committee at least two (2) weeks before your defense/hearing date and get approval from the Associate Chair for the Graduate Program. Three (3) graduate faculty members are required. Schedule your defense/hearing with your committee members, and reserve a room for your defense/hearing through the [departmental online room request system](#). You must include your advisor's name, defense/hearing title, and an abstract (for our departmental announcement) with your room request. You should schedule your defense/hearing for two (2) hours and make the room reservation accordingly.
3. Fill in and print the departmental [Masters Project or Thesis Report Form](#), and take it to the defense/hearing. This form is for departmental records and will not be submitted to the Graduate School.
4. If your M.S. capstone is a thesis, you will need to submit the Thesis & Dissertation Approval and Publishing Options Form along with your thesis to the Graduate School. See [here](#).

Have your advisor complete and sign a Concentration Verification of Completion form. This form must be submitted with the signed Graduation Application. If you do not graduate when anticipated, you must re-apply to graduate in the next semester, but a second graduation fee is not required.

## **12. Ph.D. Milestone Procedures**

**For Graduate School Policies and Procedures, visit**

<http://uwm.edu/graduateschool/doctoral-toolbox/>



## 12.1 Preliminary Exam

When you are sufficiently prepared – normally you have earned 24 credits in specific areas above the 700 level math courses, take these steps to schedule and complete your preliminary exam:

1. Form your exam committee. Choose three faculty members representing three (3) different fields from these five (5) fields: algebra, analysis, applied mathematics, probability and statistics, and topology. The Associate Chair for the Graduate Program must approve both the selected fields and the committee members. Your preliminary exam committee members are usually the faculty members from whom you took the corresponding courses.
2. After your examination areas and committee have been approved, schedule your preliminary exam with your committee members and apply for the preliminary exam online using the [doctoral milestone system](#).
3. Reserve a room for the exam through the [departmental online room request system](#). You should schedule your preliminary exam for two (2) hours and make the room reservation accordingly. Normally, a preliminary exam takes an hour and thirty minutes to two hours to complete.
4. Print the [Departmental Ph.D. Preliminary Exam Form](#) and take it to the exam. The Departmental Ph.D. Preliminary Exam Form is for our department's record and will not be sent to the Graduate School.

## 12.2 Proposal Hearing

When you are ready (to be decided by you and your Ph.D. dissertation advisor), take these steps:

1. Form your proposal hearing committee and schedule your proposal hearing with the committee. Work with your advisor to select your proposal hearing committee members and obtain the approval from the Associate Chair for the Graduate Program. Our Department requires that you form a proposal hearing committee with five (5) graduate faculty members with at least one member outside your dissertation field. Note the difference here with the statement in the graduate school webpage “the committee must have at least three UWM graduate faculty members, including your chosen major professor”. Here, the departmental policy is consistent with the graduate school policy and it supersedes the statement there.
2. Start the online application for your proposal hearing through the doctoral milestone system. Reserve a room (for two hours) for your proposal hearing through the [departmental online room request system](#).
3. Fill in and print the [Departmental Ph.D. Proposal Hearing Form](#) and take it to your proposal hearing.
4. After your proposal hearing, return the Departmental Ph.D. Proposal Hearing Form to the Associate Chair for the Graduate Program.

## 12.3 Apply for Dissertator Status

To become a dissertator, you must have:

1. your Ph.D. candidacy in place (have passed your preliminary exam),
2. satisfied the course requirements for both the primary field and the secondary field – this requires careful planning well ahead of time,
3. satisfied both the foreign language requirement and the computer proficiency requirement, and
4. passed your proposal hearing.

Check these with the Associate Chair for the Graduate Program. Usually you can start your dissertator status application through the [Ph.D. milestone system](#) after your proposal hearing has been approved by your committee.

Note that

- a) If you are a teaching assistant, your pay will increase significantly after you become a dissertator. You can attain dissertator educational status at any point during the semester. However, in order to be paid at the dissertator rate during the semester, you must achieve dissertator status on or before the Registrar's add deadline. There are two cases: 1) You attain dissertator status by the first contractual date as defined by the published academic year calendar of the semester, then you will be paid at the dissertator rate at the beginning of the semester. 2) You attain dissertator status between the contractual date and the Registrar's add deadline, then you will be paid the dissertator rate starting with the first payroll period after the add deadline.
- b) It is a Graduate School policy that after you become a dissertator, you will need to (and can only) register for three (3) credits of reading and research (Math 990). You will not be able to take other classes. For details on the dissertator policy, including the continuous registration requirement, visit <http://uwm.edu/graduateschool/doctoral-toolbox/>.  
Our Department has a partial exemption to the three credit rule: as a dissertator, you may take one three (3) credit 800-level course in your field plus one (1) credit of Math 990.

## 12.4 Apply for Dissertation Defense and Graduation

The procedure for this milestone step is detailed at the Graduate School web page at

<http://uwm.edu/graduateschool/doctoral-toolbox/>.

Note that

- a. The Graduate School sends out emails to remind all UWM graduate students of the deadlines for application for graduation, thesis defense, and thesis submission (to the Graduate School), before each semester starts.
- b. If any of the deadlines are not met, you must apply and graduate in the next semester. You will not be required to register for the next semester if the dissertation has been defended, passed, and accepted by the Graduate School before the first day of classes for the next semester. The date of graduation, however, will be the next semester.

When you and your committee have selected a defense date you must reserve a room for the defense through the [departmental online room request system](#). You must include your advisor's name, defense title, and an abstract (for our departmental announcement) with your room request. You should schedule your dissertation defense for two (2) hours and make the room reservation accordingly.

## **13. Graduate Program Forms**

[M.S. Project of Thesis Form](#)

[Ph.D. Preliminary Exam Form](#)

[Ph.D. Proposal Hearing Form](#)

[Verification - Actuarial Science](#)

[Verification - Atmospheric Science](#)

[Verification - Industrial Mathematics](#)

[Verification - Statistics](#)

## **14. Courses**

*Courses numbered 300-699 are Undergraduate/Graduate. Courses numbered 700 and above are Graduate only.*

### **14.1 Atmospheric Sciences**

330 Air-Pollution Meteorology. 3 cr. U/G.

Pollutant sources and sinks, fundamental pollutant chemistry, monitoring techniques, averaging boundary layers and turbulence, diffusion theories, diffusion models, regional and global-scale pollution problems. Prereq: Atm Sci 240(P); Chem 102(P); stats course recom.

350 Atmospheric Thermodynamics. 3 cr. U/G.

Radiant energy, sensible heat, and atmospheric thermodynamics; the gas laws; hydrostatic and psychrometric equations; dry and moist convection; clouds and their physical and energy relations. Optional field exercise. Prereq: jr st; Physics 210(P); Math 232(P); Atm Sci 240(P).

351 Dynamic Meteorology I. 3 cr. U/G.

The role of dynamics in atmospheric physics; equations of motion; symmetric circulation models; gravity waves; Rossby waves, quasi-geostrophy; introduction to instability of atmospheric flows. Prereq: jr st; Atm Sci 240(P); Math 233(P).

352 Dynamic Meteorology II. 3 cr. U/G.

Circulation, vorticity, potential vorticity; shallow water equations: Poincare, Kelvin, and Rossby waves, energy and enstrophy; quasi-geostrophy for a stratified atmosphere; barotropic and baroclinic instability. Prereq: jr st; Atm Sci 351(P); Math 234(P).

360 Synoptic Meteorology I. 4 cr. U/G.

Fundamental principles; synoptic-scale structure and dynamics; equivalent barotropic model; vertical motions; introduction to and application of quasi-geostrophic theory. Prereq: jr st; Math 232(P); Physics 210(P); Atm Sci 240(P).

361 Synoptic Meteorology II. 4 cr. U/G.

Extension of quasi-geostrophic theory to Q-vectors; isentropic potential vorticity applied to mid-latitude weather systems; fronts and jets. Prereq: jr st; Atm Sci 360(P).

460 Mesoscale Circulations. 3 cr. U/G.

Theory, analysis and forecasting of mesoscale flows, including convective systems, polar lows, terrain and surface-forced flows, jet streams and hurricanes. Prereq: jr st; Atm Sci 360(R) or cons instr.

464 Cloud Physics. 3 cr. U/G.

Formation of cloud droplets, droplet growth by condensation, formation of ice crystals, precipitation processes, weather radars, cloud models. Prereq: jr st; Physics 210(P); Math 232(P); Atm Sci 350(P).

470 Tropical Meteorology. 3 cr. U/G.

Dynamics and energetics of tropical circulations. Origins and evolution of equatorial disturbances and easterly waves. Structure and dynamics of tropical cyclones. Hurricane modeling and prediction. Prereq: Atm Sci 351(P) or 360(P).

480 The General Circulation and Climate Dynamics. 3 cr. U/G.

Historical overview, the zonally symmetric circulation, momentum, heat and water budgets, stationary waves, the El Nino Southern oscillation, global warming, interpentadal variability in the North Atlantic. Prereq: jr st; Atm Sci 351(P).

497 Study Abroad: (Subtitled). 1-12 cr. U/G.

Designed to enroll students in UWM sponsored program before course work level, content, and credits are determined and/or in specially prepared course work. Retakable w/chg in topic. Prereq: jr st; acceptance for Study Abroad Prog.

500 Statistical Methods in Atmospheric Sciences. 3 cr. U/G.

Mathematical and statistical tools applicable to the investigation of atmospheric problems; the nature and treatment of atmospheric data. Prereq: jr st; Atm Sci 240(P) or 350(P), & Math 231(P), 232(P) or cons instr.

505 Micrometeorology. 3 cr. U/G.

Surface energy budget; radiation balance and heat transfer; boundary-layer profiles of wind, temperature and moisture; turbulence and boundary-layer fluxes; evapotranspiration; special topics. Prereq: jr st; Atm Sci 351(P) & 330(P).

511 Seminar in Atmospheric Radiation and Remote Sensing. 3 cr. U/G.

Basic laws of radiation, absorption and scattering, weather radar, retrieval of soundings, remote sensing and climate, weather satellites. Prereq: jr st; Math 232(P); Atm Sci 350(P) & Physics 210(P).

690 Seminar in Atmospheric Sciences: (Subtitled). 1-3 cr. U/G.

Intensive topical studies of currently active problem areas. Retakable w/chg in topic to 9 cr max. Satisfies L&S Seminar req. Prereq: jr st; cons instr.

705 Air Pollution Modeling. 3 cr. G.

Computational techniques for determining surface fluxes of heat and momentum. Numerical methods for solving advection and diffusion problems; statistical diffusion modeling. Prereq: grad st; cons instr.

711 Cloud Dynamics. 3 cr. G.

Atmospheric applications of turbulent flow theory. Nonprecipitating clouds: structure of individual cumulus clouds, stratocumulus and cumulus boundary layers. Precipitating clouds: thunderstorms, squall lines, hurricanes. Prereq: grad st; cons instr.

750 Nonlinear Time Series Analysis. 3 cr. G.

Phase space reconstruction; singular spectrum analysis; prediction; dimension estimation; application of nonlinear time series analysis techniques to selected data sets. Prereq: grad st; cons instr.

761 Advanced Synoptic/Mesoscale Meteorology. 3 cr. G.

Advanced analysis techniques for synoptic/mesoscale diagnoses, case studies of relevant circulation systems; role of planetary, synoptic, and mesoscale flows in system development. Prereq: grad st; cons instr.

888 Candidate for Degree. 0 cr. G.

Available for graduate students who must meet minimum credit load requirement. Fee for 1 cr assessed. Prereq: grad st.

950 Seminar on Topics in Atmospheric Sciences. 1-3 cr. G.

Selected topics in atmospheric dynamics, satellite meteorology, atmospheric &

oceanic convection, air & water pollution, numerical prediction, remote sensing, & others. Prereq: grad st in physical sciences or engineering.

990 Master's Thesis. 1-8 cr. G.

Prereq: grad st; cons instr & completed thesis proposal.

997 Doctoral Externship. 1-12 cr. G.

Prereq: grad st; admis to candidacy for the Ph.D..

998 Doctoral Dissertation. 1-12 cr. G.

Prereq: grad st; admis to candidacy for Ph.D..

999 Advanced Independent Reading. 1-4 cr. G.

Independent meteorological study. Retakable to 4 cr max. Prereq: grad st & cons instr.

## **14.2 Mathematical Sciences**

305 Introduction to Mathematical and Computational Modeling. 3 cr. U/G.

Construction and analysis of discrete and continuous mathematical models in applied, natural, and social sciences. Elements of programming, simulations, case studies from scientific literature. Counts as repeat of Math 690(675) w/topic "Adv Math Models with Apps." Prereq: jr st; grade of C or better in Math 211(P) & one addl 200-level or higher Math or MthStat course, or grade of C or better in Math 231(P), or cons instr.

313 Linear Programming and Optimization. 3 cr. U/G.

Primal and dual formulations of linear programming problems; simplex and related methods of solution; algorithms for transportation; optimization. Prereq: jr st; grade of C or better in Math/ElecEng 234(P) or Math 240(P); or grad st.

315 (314) Mathematical Programming and Optimization. 3 cr. U/G.

Introduction to operations research. Network analysis; integer programming; game theory; nonlinear programming; dynamic programming. Prereq: jr st, grade of C or better in either Math 234(P) or 240(P), & grade of C or better in either Math 211(P) or 233(P); or cons instr; or grad st.

320 Introduction to Differential Equations. 3 cr. U/G.

Elementary types and systems of differential equations, series solutions, numerical methods, Laplace transforms, selected applications. No grad cr in Math Sci. Prereq: jr st, grade of C or better in both Math 232(P) & 240(P), or grade of C or better in Math/ElecEng 234(P); or grad st.

321 Vector Analysis. 3 cr. U/G.

Topics selected from vector algebra; scalar and vector fields; line, surface, and

volume integrals; theorems of Green, Gauss, and Stokes; vector differential calculus. Prereq: jr st, grade of C or better in Math 233(P); or grad st.

322 Introduction to Partial Differential Equations. 3 cr. U/G.

Partial differential equations of mathematical physics, boundary value problems in heat flow, vibrations, potentials, etc. Solved by Fourier series; Bessel functions and Legendre polynomials. Prereq: jr st, Math 320(P), & grade of C or better in Math 233(P); or grad st.

371 Introduction to Stochastic Models in Finance. 3 cr. U/G.

Elementary modeling of financial instruments for students in mathematics, economics, business, etc. Statistical and stochastic tools leading to the Black-Scholes model. Real data parameter fitting. Prereq: jr st & one of the following pairs; Econ 413(431)(P) & 506(P), Bus Adm 210(P) & 350(P), Bus Adm 701(P) & 702(P), or Math 234(P) & MthStat 361(P), or cons instr; or grad st.

405 Mathematical Models and Applications. 3 cr. U/G.

Modeling techniques for analysis and decision-making in social and life sciences and industry. Deterministic and stochastic modeling. Topics may vary with instructors. Prereq: jr st, grade of C or better in either Math 211(P) or Math 231(P), & grade of C or better in either Math/ElecEng 234(P) or Math 240(P); or grad st.

413 Introduction to Numerical Analysis. 3 cr. U/G.

Root finding and solution of nonlinear systems; direct solution of linear systems; interpolation & approximation of functions; least squares; fast Fourier transform; quadrature. Prereq: jr st, grade of C or better in Math 233(C), & grade of C or better in Math/ElecEng 234(C); or grad st.

415 Introduction to Scientific Computing. 3 cr. U/G.

Nonlinear systems; iterative solution of linear systems; initial value problems in ordinary differential equations; boundary value problems in ordinary and partial differential equations. Prereq: jr st, grade of C or better in Math 233(C), & grade of C or better in Math/ElecEng 234(C); or grad st.

417 (416) Computational Linear Algebra. 3 cr. U/G.

Direct solution of linear systems; iterative solution of linear systems; least squares; eigenvalue problems. Prereq: jr st & grade of C or better in Math/ElecEng 234(P) or Math 240(P); or grad st.

423 (623) Complex Analysis. 3 cr. U/G.

Complex numbers; definition and properties of analytic functions of a complex variable; conformal mapping; calculus of residues; applications to mathematics and physics. See also Math 713. Prereq: jr st; grade of C or better in Math 233(P); or grad st.

431 Modern Algebra with Applications. 3 cr. U/G.

Groups, rings, fields, Boolean algebras with emphasis on their applications to computer science and other areas. Does not carry grad cr in math sci. Prereq: jr st & grade of C or better in Math 232(P); or grad st.

451 Axiomatic Geometry. 3 cr. U/G.

An axiomatic approach to Euclidean and non-Euclidean geometry (historic role of the parallel postulate and models). Dept cons req'd for grad cr in math sci. Prereq: jr st, grade of C or better in both Math 341(P) & Math 232(C); or grad st.

453 Transformations in Geometry. 3 cr. U/G.

Selected topics from vector geometry and geometric transformations such as the study of invariants and conics. Recom for secondary school teachers. Dept cons req'd for grad cr in math sci. Prereq: jr st, grade of C or better in both Math 341(P) & Math 232(C); or grad st.

490 Topics in Mathematics: (Subtitled). 3 cr. U/G.

Specific topics and any additional prerequisites announced in Schedule of Classes each time course is offered. Retakable w/chg in topic to 9 cr max. Prereq: jr st; grade of C or better in a Math or MthStat course at the 200 level or above; or grad st.

497 Study Abroad: (Subtitled). 1-12 cr. U/G.

Designed to enroll students in UWM sponsored programs before course work level, content and credits are determined and/or in specially prepared program course work. Retakable w/chg in topic. Prereq: jr st; acceptance for Study Abroad Prog.

511 Symbolic Logic. 3 cr. U/G.

First-order predicate calculus; formal properties of theoretical systems; chief results of modern mathematical logic; advanced topics such as completeness and computability. CompSci 511, Math 511 & Philos 511 are jointly offered; they count as repeats of one another. Prereq: jr st & either Philos 212(P) or 6 cr in math at the 300-level or above.

521 Advanced Calculus I. 3 cr. U/G.

Fundamental notions of sets and functions; limits, continuity; Riemann integral, improper integral; infinite series; uniform convergence; power series; improper integrals with a parameter. Prereq: jr st; grades of C or better in Math 232(P) & 341(P); or grad st.

522 Advanced Calculus II. 3 cr. U/G.

Linear functions; differentiation of functions of several variables (implicit functions, Jacobians); change of variable in multiple integrals; integrals over curves, surfaces; Green, Gauss, Stokes theorems. Prereq: jr st, Math 521(P), grade of C or better in Math 233(P), & grade of C or better in either Math 234(P) or 240(P); or grad st.

531 Modern Algebra. 3 cr. U/G.

Integers; groups; rings; fields; emphasis on proofs. Prereq: jr st; grade of C or better



in Math 341(P).

535 Linear Algebra. 3 cr. U/G.

Vector spaces; linear transformations and matrices; characteristic values and vectors; canonical forms; bilinear, quadratic, and Hermitian forms; selected applications. Prereq: jr st, grade of C or better in either Math 234(P) or 240(P), & grade of C or better in Math 341(P); or grad st.

537 Number Theory. 3 cr. U/G.

Number theoretic functions; distribution of primes; Diophantine approximation; partitions; additive number theory; quadratic reciprocity. Prereq: jr st, grade of C or better in both Math 232(P) & 341(P); or grad st.

551 Elementary Topology. 3 cr. U/G.

General theory of point sets in Euclidean spaces, with emphasis on topology of two-dimensional and three-dimensional spaces; elementary notions of metric spaces; applications. Prereq: jr st; grades of C or better in Math 233(P) & 341(P); or grad st.

553 Differential Geometry. 3 cr. U/G.

The theory of curves and surfaces by differential methods. Prereq: jr st, grade of C or better in all of Math 233(P), 234(P) & 341(P); or grad st.

571 Introduction to Probability Models. 3 cr. U/G.

Probability review, Markov chains in discrete and continuous time. Random walks, branching processes, birth and death processes. Queuing theory. Applications to physical sciences, engineering, mathematics. Prereq: jr st; grade of C or better in Math 233(P); grade of C or better in Math/ElecEng 234(P) or in both Math 240(P) & 320(P); & one calculus-based course in statistics or probability at the 300 level or above; or grad st.

575 High School Mathematics from an Advanced Viewpoint. 3 cr. U/G.

Number systems; algebra of polynomials; theory of equations; functions; modeling; geometric measurement; geometric transformations; connections between advanced mathematics and high school topics. Counts as repeat of Math 690(675) w/similar topic. Prereq: jr st, either Math 451(P) or 453(P), & either Math 431(P) or 531(P); or cons instr; or grad st.

581 Introduction to the Theory of Chaotic Dynamical Systems. 3 cr. U/G.

Iterated mappings, one parameter families, attracting and repelling periodic orbits, topological transitivity, Sarkovski's theorem, chaos, bifurcation theory, period doubling route to chaos, horseshoe maps, attractors. Prereq: jr st & Math 521(P), 529(P) or 621(P), or cons instr; or grad st.

601 (effective 09/06/2016) Advanced Engineering Mathematics I. 3 cr. U/G.

Sequences and series, elementary complex analysis; Fourier series; linear and nonlinear ordinary differential equations; matrix theory, elementary functional

analysis; elementary solution of partial differential equations. Prereq: jr st; grade of C or better in both of Math 233(P) and Math/ElecEng 234(P); 3 cr Math at 300-level or above; or cons instr; or grad st.

601 Advanced Engineering Mathematics I. 3 cr. U/G.

Sequences and series, elementary complex analysis; Fourier series; linear and nonlinear ordinary differential equations; matrix theory, elementary functional analysis; elementary solution of partial differential equations. Prereq: jr st; grade of C or better in Math/ElecEng 234(P); 3 cr Math at 300-level or above; or cons instr; or grad st.

602 Advanced Engineering Mathematics II. 3 cr. U/G.

Continuation of Math 601. Partial differential equations, Fourier and Laplace transforms, convolutions, special functions, mathematical modeling. Prereq: jr st; Math 601(P).

615 Numerical Solution of Partial Differential Equations. 3 cr. U/G.

Finite difference solution of elliptic boundary value problems and of evolution problems; solution of hyperbolic conservation laws; finite volume methods; finite element methods. Prereq: jr st; Math 413(P), 415(414)(P), or 417(416)(P); Math 322(P) or 602(P); or cons instr.

617 Optimization. 3 cr. U/G.

Unconstrained and constrained optimization: linear, nonlinear, and dynamic programming; barrier, penalty, and Lagrangian methods; Karush-Kuhn-Tucker theory, quadratic, and sequential quadratic programming; evolutionary algorithms. Prereq: jr st; Math 321(P) or 602(P); or grad st or cons instr.

621 Introduction to Analysis I. 3 cr. U/G.

Topology of Euclidean space; continuity; differentiation of real and vector-valued functions; Riemann-Stieltjes integration. Prereq: jr st: grades of C or better in Math 233(P), 341(P), & either 234(P) or 240(P); cons dept advisor; or grad st.

622 Introduction to Analysis II. 3 cr. U/G.

Continues Math 621. Sequences and series of functions; uniform convergence; power series; functions of several variables; inverse and implicit function theorems; differential forms; Stokes' theorem. Prereq: jr st; Math 621(P) or cons instr; or grad st.

631 Modern Algebra I. 3 cr. U/G.

Group theory, including normal subgroups, quotients, permutation groups, Sylow's theorems, Abelian groups; field theory; linear algebra over general fields. Prereq: jr st; grade of C or better in Math 341(P) & either Math 234(P) or 240(P); cons dept advisor; or grad st.

632 Modern Algebra II. 3 cr. U/G.

Continuation of Math 631. Ring theory, including ideals, quotient rings, Euclidean rings, polynomial rings, unique factorization; modules, including vector spaces, linear transformations, canonical forms; bilinear forms. Prereq: jr st; Math 631(P) or cons instr; or grad st.

690 (675) Topics in Mathematics: (Subtitled). 3 cr. U/G.

Specific topics and any additional prerequisites announced in Schedule of Classes each time course is offered. Retakable w/chg in topic to 9 cr max. Prereq: jr st, at least one U/G Math or MthStat course; cons instr; or grad st.

701 Industrial Mathematics I. 3 cr. G.

Elementary functional analysis, wavelets, control theory. Use of mathematical software emphasized throughout. Prereq: grad st in nat sci discipline; Math 522(P) or 602(P) or 622(P).

702 Industrial Mathematics II. 3 cr. G.

Optimal control theory, digital signal processing, image processing, linear programming, nonlinear optimization, artificial neural networks. Use of mathematical software emphasized throughout. Prereq: grad st in nat sci discipline; Math 701(P).

703 Boundary Value Problems. 3 cr. G.

Analytic methods for PDE's in mathematical physics, emphasis on green's functions. Theory of distributions, fundamental solutions, generalized eigenfunction expansions, generalized fourier and laplace transforms. Prereq: grad st; Math 322(P) & 623(P).

709 Differential Geometry. 3 cr. G.

The theory of curves, surfaces, and manifolds in modern terminology. Global results on closed surfaces, geodesics, differential forms and tensor calculus. introduction to riemannian geometry. Prereq: grad st; Math 522(P) or 622(P).

711 Theory of Functions of a Real Variable I. 3 cr. G.

Equivalence relations; cardinal and ordinal numbers; topology of real line; cantor and borel sets; lebesgue measure on real line; baire and measurable functions; lebesgue integral. Prereq: grad st; Math 522(P) & 551(P); or Math 622(P).

712 Theory of Functions of a Real Variable II. 3 cr. G.

Lebesgue integration; modes of convergence; lp spaces; vitali covering and lebesgue density theorems; dini derivates; differentiation; fundamental theorem of the lebesgue integral calculus; fubini's theorem. Prereq: grad st; Math 711(P).

713 Theory of Functions of a Complex Variable I. 3 cr. G.

Complex numbers; linear transformations; elementary functions; conformal mapping; complex integration; infinite sequences; dirichlet problem; multivalued functions. Prereq: grad st; Math 522(P) or 621(P).

714 Theory of Functions of a Complex Variable II. 3 cr. G.  
Continuation of Math 713. Prereq: grad st; Math 713(P).

715 Numerical Analysis. 3 cr. G.  
Interpolation and approximation; differentiation and quadrature; numerical solution of ordinary differential equations; solution of linear and nonlinear algebraic equations. Prereq: grad st; Math 413(P); Math 521(P) or 621(P).

716 Ordinary Differential Equations. 3 cr. G.  
Existence and uniqueness theorems for systems of ode; qualitative properties of solutions, including stability and asymptotic behavior; general theory of linear systems; sturm-liouville problems. Prereq: grad st; Math 522(P) or 622(P).

719 Partial Differential Equations. 3 cr. G.  
First and second order equations; characteristics, cauchy problem; classical solutions of linear elliptic, parabolic and hyperbolic equations. Prereq: grad st; Math 522(P) or 622(P); math 320(P).

721 Abstract Measure and Integration. 3 cr. G.  
General theory of measures and integration; differentiation of set functions; relation to stochastic variables; atomic measures; haar measure and integral applications to probability theory. Prereq: grad st; Math 712(P).

726 Introduction to Functional Analysis. 3 cr. G.  
Basic notions of functional analysis in hilbert space will be introduced. The concepts will be illustrated by applications to elementary differential and integral equation problems. Prereq: grad st; Math 522(P) or 622(P).

731 Abstract Algebra I. 3 cr. G.  
Basic course which is prerequisite for all other 700-799 level courses in algebra; groups, rings, fields, galois theory, modules, and categories. Prereq: grad st; Math 632(P); cons instr.

732 Abstract Algebra II. 3 cr. G.  
Continuation of Math 731. Prereq: grad st; Math 731(P).

735 Theory of Groups. 3 cr. G.  
Topics selected from permutation groups; representations of groups and algebras; group algebras; group characters; extension problems; simple groups; solvable and nilpotent groups. Prereq: grad st; Math 732(P).

736 Theory of Rings and Modules I. 3 cr. G.  
Noetherian and artinian rings and modules; primitive, prime and simple rings and ideals; radicals; localization; morita theory; construction and study of special classes of rings. Prereq: grad st; Math 732(P).

737 Theory of Rings and Modules II. 3 cr. G.  
Continuation of Math 736. Prereq: grad st; Math 736(P) or cons instr.

751 Introductory Topology I. 3 cr. G.  
Fundamental properties and examples of topological spaces and continuous functions, including compactness, connectedness, metrizable, completeness, product and quotient spaces, homeomorphisms, embedding, extension, and euclidean spaces. Prereq: grad st; Math 522(P) or 621(P).

752 Introductory Topology II. 3 cr. G.  
Continuation of Math 751. Prereq: grad st; Math 751(P).

753 Introduction to Algebraic Topology I. 3 cr. G.  
Homology theory; complexes and simplicial homology theory; general homology theories; cohomology rings; applications to manifolds, fixed point theorems, etc. Prereq: grad st; Math 632(P); Math 551(P) or 751(P) or cons instr.

754 Introduction to Algebraic Topology II. 3 cr. G.  
Continuation of Math 753. Prereq: grad st; Math 753(P).

767 Statistical Methods for Engineers and Scientists. 3 cr. G.  
Elementary bayesian decision theory; prior posterior and predictive distributions; posterior and pre-posterior analysis of two action decision problems; concept of likelihood functions for binomial, poisson, exponential and normal distributions; simple and multiple regression analysis; introduction to autoregressive models. Not open to students who have cr in ElecEng 767, which is identical to Math 767. Prereq: grad st; Math 362(P) or math 467(P).

768 Applied Stochastic Processes. 3 cr. G.  
Concepts in queueing theory; exponential channels; applications of markov chains to queueing problems; queue disciplines with priorities. Not open to students who have cr in ElecEng 768, which is identical to Math 768. Prereq: grad st; Math 361(P) or math 467(P).

771 Theory of Probability. 3 cr. G.  
Measure-theoretic foundations; limit-law theorems; weak and strong laws of large numbers; central limit problem; conditional expectations, martingales; stochastic processes. Prereq: grad st; Math 471(C) or 712(C).

781 Iterated Maps as Dynamical Systems. 3 cr. G.  
Periodic, recurrent and non-wandering points, kneading theory, unstable manifolds, unimodal mappings, turbulent and chaotic maps, symbolic dynamics, structural stability, topological conjugacy, topological dynamics. Prereq: grad st; Math 711(P) or cons instr.

790 Master's Thesis. 1-3 cr. G.

Cr count toward masters degree only if student completes thesis option. Prereq: grad st; cons instr.

791 Master's Seminar. 1-3 cr. G.

May not be taken for cr more than once. Prereq: grad st; cons instr.

792 Industrial Internship. 1-3 cr. G.

Students earn credits for serving in an industrial internship that involves work of an advanced mathematical nature. They must prepare a report based on the internship. Retakable w/chg in topic to 6 cr max. Prereq: grad st; cons instr.

793 Scientific Computational Laboratory: (Subtitled). 1-2 cr. G.

Retakable w/chg in topic to 6 cr max. Prereq: grad st; Math 715(C).

799 Seminar in Mathematics: (Subtitled). 1-3 cr. G.

Specific topics and any additional prerequisites announced in Timetable each time course is offered. Retakable w/chg in topic to 9 cr max. Prereq: grad st & cons instr.

801 Topics in Applied Mathematics: (Subtitled). 3 cr. G.

Specific topics and any additional prerequisites will be announced in the Timetable each time the course is offered. Retakable w/chg in topic to 9 cr max. Prereq: grad st; cons instr.

807 Group Theory and Its Applications to Physics. 3 cr. G.

Representations of discrete and continuous groups, including rotation groups, unitary groups and crystal point and space groups. Symmetries of elementary particles. Molecular orbitals, energy bands. Counts as a repeat of Physics 807. Prereq: grad st; Physics 532(P).

809 Topics in Differential Geometry: (Subtitled). 1-3 cr. G.

Specific topics and any additional prerequisites will be announced in the Timetable each time the course is offered. Topics may be selected from Riemannian geometry, minimal surfaces and surfaces of prescribed mean curvature, geometric partial differential equations, or related areas of geometry. Retakable w/chg in topic to 9 cr max. Prereq: grad st; cons instr.

813 Numerical Solution of Ordinary Differential Equations. 3 cr. G.

Methods for initial value and boundary value problems; stiff equations, singular points and bifurcation. Prereq: grad st; Math 715(P).

814 Numerical Solution of Partial Differential Equations. 3 cr. G.

Finite difference and finite element methods for linear elliptic, parabolic and hyperbolic equations; nonlinear equations. Prereq: grad st; Math 715(P).

815 Topics in Numerical Analysis: (Subtitled). 3 cr. G.

Retakable w/chg in topic to 9 cr max. Prereq: grad st; Math 715(P).

816 Advanced Ordinary Differential Equations I. 3 cr. G.  
Existence and uniqueness theorems; singularity of solutions; oscillation and comparison theorems; poincare-bendixon theory. Prereq: grad st; Math 716(P).

817 Advanced Ordinary Differential Equations II. 3 cr. G.  
Continuation of Math 816; dynamical systems, bifurcation theory, topological methods. Prereq: grad st; Math 816(P).

821 Advanced Topics in Real Analysis: (Subtitled). 3 cr. G.  
Specific topics and any additional prerequisites will be announced in the Timetable each time the course is offered. Retakable w/chg in topic to 9 cr max. Prereq: grad st; Math 712(P).

825 Functional Analysis. 3 cr. G.  
Basic theorems of b-spaces and f-spaces including the closed graph; Hahn-Banach and Banach-Steinhaus theorems; Banach algebras; generalized functions; spectral theory. Prereq: grad st; Math 712(P).

841 Advanced Topics in Algebra: (Subtitled). 3 cr. G.  
Specific topics and any additional prerequisites will be announced in the Timetable each time the course is offered. Retakable w/chg in topic to 9 cr max. Prereq: grad st; Math 732(P); cons instr.

843 Homological Algebra I. 3 cr. G.  
Modules; diagrams; categories; functors; complexes; cohomology; extensions; resolutions; injective and projective systems; graded modules; homological dimension; spectral sequences; derived functors. Prereq: grad st; Math 731(P).

844 Homological Algebra II. 3 cr. G.  
Continuation of Math 843. Prereq: grad st; Math 843(P).

851 Advanced Topics in Topology: (Subtitled). 3 cr. G.  
Specific topics and any additional prerequisites will be announced in the Timetable each time the course is offered. Retakable w/chg in topic to 9 cr max. Prereq: grad st; Math 752(P); cons instr.

873 Advanced Topics in Probability: (Subtitled). 3 cr. G.  
Specific topics and any additional prerequisites will be announced in the Timetable each time the course is offered. Retakable w/chg in topic to 9 cr max. Prereq: grad st; cons instr.

881 Topics in Nonlinear Dynamics: (Subtitled). 3 cr. G.  
Specific topics and any additional prerequisites will be announced in the Timetable each time the course is offered. Retakable w/chg in topic to 9 cr max. Prereq: grad st; Math 711(P); cons instr.

888 Candidate for Degree. 0 cr. G.

Available for graduate students who must meet minimum credit load requirement. Fee for 1 cr assessed. Prereq: grad st.

990 Reading and Research. 1-6 cr. G.

To be arranged with your instructor and department chair. Retakable. Prereq: grad st.

### **14.3 Mathematical Statistics**

361 Introduction to Mathematical Statistics I. 3 cr. U/G.

Probability spaces; discrete and continuous, univariate and multivariate distributions; moments; independence, random sampling, sampling distributions; normal and related distributions; point and interval estimation. Not recom for grad students in math, or students not planning to take MthStat 362. Prereq: jr st; Math 233(P).

362 Introduction to Mathematical Statistics II. 3 cr. U/G.

Testing statistical hypothesis; linear hypothesis; regression; analysis of variance and experimental designs; distribution-free methods; sequential methods. Not recom for grad students in math. Prereq: jr st; MthStat 361(P).

462 Data Analysis and Graphing Using SAS-II. 2 cr. U/G.

Continuation of MthStat 461. Procedures GLM, LIFEREG, LIFETEST, LOGISTIC, PROBIT and advanced GRAPHING. Offered second half of sem. U cr does not count toward math sci major. Prereq: jr st; MthStat 461(P) or cons instr.

465 Introductory Mathematical Statistics for Social Sciences and Education. 3 cr. U/G.

Probability distributions; parameter estimation and confidence intervals; hypothesis testing; applications. Not open for cr to students w/cr in MthStat 467, 362, or for grad cr in math. Not open for cr toward major in math except in School of Education. Prereq: jr st; Math 211(P) or 232(P).

467 Introductory Statistics for Physical Sciences and Engineering Students. 3 cr. U/G.

Concepts of probability and statistics; probability distributions of engineering applications; sampling distributions; hypothesis testing, parameter estimation; experimental design; regression analysis. Not open for cr for Math majors or students with cr in MthStat 362 or 465. Ind Eng 467 & MthStat 467 are jointly offered & count as repeats of one another. Prereq: jr st; Math 233(P).

469 Biostatistics. 3 cr. U/G.

Simple distributions, estimation and hypothesis testing, simple regression, analysis



of variance, nonparametric methods in biology. Demography and vital statistics and bioassay and clinical trials. Not allowed as part of core curric for Math majors. Not open for cr to students with cr in MthStat 569 & not open for grad cr in Math. Prereq: jr st; an elementary stats course.

562 Design of Experiments. 3 cr. U/G.

Latin squares; incomplete block designs; factorial experiments; confounding; partial confounding; split-plot experiments; fractional replication. Prereq: jr st; MthStat 362(P); Math 234(P) or 240(P).

563 Regression Analysis. 3 cr. U/G.

Straight line, polynomial and multiple regression; multiple and partial correlation; testing hypotheses in regression; residual analysis. Prereq: jr st; MthStat 467(P) or 362(P).

564 Time Series Analysis. 3 cr. U/G.

Autocorrelation; spectral density; linear models; forecasting; model identification and estimation. Prereq: jr st; MthStat 362(P).

565 Nonparametric Statistics. 3 cr. U/G.

Sign, rank and permutation tests; tests of randomness and independence; methods for discrete data and zeroes and ties; power and efficiency of nonparametric tests. Prereq: jr st; MthStat 362(P).

566 Computational Statistics. 3 cr. U/G.

Basics of programming and optimization techniques; resampling, bootstrap, and Monte Carlo methods; design and analysis of simulation studies. Prereq: jr st; MthStat 362(P) or cons instr.

568 Multivariate Statistical Analysis. 3 cr. U/G.

Multivariate normal distribution; Wishart distribution; Hotelling's  $T^2$ ; multivariate normal distribution; multivariate analysis of variance; classification problems. Prereq: jr st; MthStat 362(P); Math 234(P) or 240(P).

596 Actuarial Statistics I: Fitting of Loss Models. 3 cr. U/G.

Statistical modeling of insurance data. Model specification, fitting and validation. Measures of confidence for model-based decisions. Prereq: jr st; B- or better in each Math 234(P) and MthStat 362(P); CompSci 151(P) or 201(P); or cons instr.

597 Actuarial Statistics II: Credibility, Risk Measures and Related Topics. 3 cr. U/G.

Statistical techniques for insurance data. Credibility and ratemaking. Risk measures. Dependent risks and copulas. Simulations. Prereq: jr st; B- or better in each Math 234(P) and MthStat 362(P); CompSci 151(P) or 201(P); or cons instr.

691 Actuarial Models I: Life Contingencies. 3 cr. U/G.

Modeling and valuation of cash flows dependent on death, survival and other

random events. Survival models for single and multiple risks. Life insurances and annuities. Prereq: jr st; B- or better in each Math 571(P) and Math 311(P); or cons instr.

692 Actuarial Models II: Financial Economics. 3 cr. U/G.

Modeling and managing of financial risks. Interest rate models. Valuation of derivatives securities. Risk management. Prereq: jr st; B- or better in each Math 571(P) and Math 311(P); or cons instr.

761 Mathematical Statistics I. 3 cr. G.

Probability and distribution theory; point and interval estimation; testing hypotheses; large sample inference; nonparametric inference; sequential analysis. Prereq: grad st; Math 522(C) or 622(C).

762 Mathematical Statistics II. 3 cr. G.

Continuation of MthStat 761. Prereq: grad st; MthStat 761(P).

795 Actuarial Risk Theory. 3 cr. G.

Risk models; premium principles; reinsurance contracts; ruin theory; ordering of risks; bonus-malus systems; IBNR techniques. Prereq: grad st; Math 571(P) & MthStat 596(P), or cons instr

863 Hypothesis Testing. 3 cr. G.

Exponential families; uniformly most--powerful tests; least favorable priors; unbiased tests; invariant tests; applications to exponential families and the general linear hypothesis. Prereq: grad st; MthStat 762(P).

869 Advanced Topics in Mathematical Statistics: (Subtitled). 3 cr. G.

Specific topics and any additional prerequisites will be announced in the Timetable each time the course is offered. Retakable w/chg in topic to 9 cr max. Prereq: grad st; MthStat 762(P).