The University of Arizona

Program in Applied Mathematics

Graduate Student Handbook

Updated July 2017

Contents

I Welcome

The Program in Applied Mathematics at the University of Arizona has many strengths, including:

- A diverse and distinguished research faculty who currently come from 20 different departments in 5 colleges at the University of Arizona;
- An international reputation for excellence in interdisciplinary research;
- An outstanding track record of successful Program alumni who have gone on to successful careers in applied mathematics;
- An excellent record of training grants to support its students;
- Two unique experimental laboratories;
- An extensive range of colloquia, workshops, and related activities.

All of these components combine to create a dynamic and intellectually stimulating atmosphere – the heart and soul of the Program. Although this handbook gives only a hint of these strengths, current information is regularly updated and posted on the bulletin boards outside of the Applied Mathematics offices and on the website at http://appliedmath.arizona.edu.

Whether they are in industry or academia, today's research problems are often complex and multi-faceted, requiring highly trained scientists skilled in interdisciplinary approaches. The goal of the Program is to produce active and creative research scientists who can work at the forefronts of their chosen areas of application and contribute to the development of mathematical techniques related to those applications. Such interdisciplinary scientists must possess strong analytical and computational skills in addition to a deep knowledge of the discipline from which their research problems arise. Developing this level of expertise is a difficult goal to achieve and requires real dedication on the part of our students.

Beyond the acquisition of appropriate research skills, students are provided with many opportunities to develop their talents in teaching and communications, which are ever more important in today's job market. Graduate students in the Applied Mathematics Program have the opportunity to work as teaching assistants in the University of Arizona's Mathematics Department that has an outstanding reputation for innovation in undergraduate education. The experiences gained by Program students in both research and teaching result in highly if not uniquely skilled graduates with excellent employment records in both industrial research and academia.

After satisfying basic requirements, which include a first year of "core" courses, each student undertakes an individually designed program of study with the expectation that the PhD degree will be completed, on average, in about five years. Since completion within this time frame depends strongly on a student's motivation and self-discipline, all are

encouraged to explore, from an early stage, a variety of research problems. Opportunities for this are provided through a system of research projects, often referred to as Research Tutorial Groups (RTGs), courses of Independent Study with individual faculty members, various working groups, and ultimately, supervised dissertation research. In addition to the PhD degree, the Program also offers a Masters degree in Applied Mathematics that provides an ideal qualification for those students intending a career in industry or commerce.

Enjoying a lively and professional atmosphere, the Program in Applied Mathematics boasts a strong tradition of collegiality with open and friendly interactions among students and faculty. The Program receives enthusiastic support from all departments and colleges with which it interacts, and our students are highly regarded across campus. In addition, the Program sponsors a variety of seminars, colloquia featuring distinguished invited speakers, special lecture series, workshops and conferences, and a popular weekly graduate student seminar known as the Brown Bag. Faculty in the Program receive grant and contract support from the National Science Foundation (NSF), National Institutes of Health (NIH), Office of Naval Research (ONR), National Aeronautics and Space Administration (NASA), Air Force Office of Scientific Research (AFOSR), Department of Energy (DOE), and several other private foundations and companies. This grant and contract support provides many opportunities for students as research assistants as well as funds for special Program activities.

The University of Arizona is particularly noted for providing an atmosphere in which interdisciplinary research flourishes. As the list of faculty research interests reflects (see the Program website), the Program in Applied Mathematics encompasses a remarkable range of interdisciplinary applications of mathematics from which students can select an advisor.

This handbook describes the Program's current regulations and procedures as well as the various requirements that must be met for the Doctor of Philosophy degree (PhD) or the Master of Science degree (MS). **However, every student has a different experience, and it is very important to discuss any questions about the Program's requirements with the Program Head.**

It is also important to note that while the University's Graduate College lays out a set of basic requirements and regulations for all graduate students these are, in effect, minimal requirements and the **rules and regulations of the Program in Applied Mathematics take precedence over those specified by the Graduate College**. Occasionally a student will not fulfill a Program requirement because they only followed what they found on the Graduate College website. This highlights the importance of always checking with the Program management if any questions arise about Program policies and procedures. In addition, many of the official steps that need to be followed as a graduate student at the University of Arizona are implemented through the use of the online GradPath system so it is important that students familiarize themselves with it as soon as possible.

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II On Being a Student in the Program in Applied Mathematics

Over forty years ago, the University of Arizona recognized the importance of interdisciplinary research and education and the need to develop institutional structures and policies that would eliminate the barriers to collaborations that are all too often thwarted by outmoded disciplinary traditions. To this end, the University introduced the official institutional designation of Graduate Interdisciplinary Programs (GIDPs) and created a series of independent academic units dedicated to interdisciplinary graduate training. The Program in Applied Mathematics is one of the oldest and most successful of these units. Other interdisciplinary programs include American Indian Studies, Cancer Biology, Arid Lands, Statistics, and Neuroscience (more information about the University's network of interdisciplinary programs can be found at http://gidp.arizona.edu). All of the interdisciplinary programs currently operate under the aegis of the Graduate College (while, for example, departments such as Mathematics, Physics, and Chemistry are in the College of Science). The Chair of the Program in Applied Mathematics reports to the Dean of the Graduate College.

The Program in Applied Mathematics has, of course, a long-standing and close-working relationship with the Mathematics Department: we share many training grants, and students in the Program will take many courses offered by the Mathematics Department. Many Program students will have the opportunity to work for the Department as Teaching Assistants and/or carry out research projects with their faculty, while others will work under the supervision of faculty from the many other departments affiliated with the Program. However, whatever trajectory through the Program is chosen and whoever students decide to work with**, their identity will always be that of a student in the Program in Applied Mathematics, and his/her academic performance and professional conduct will always reflect on the Program.** Membership of the Program is also a Program student's official professional identity: when a paper is published, a talk given, or a conference poster presented, Program students must list their affiliation as: Program in Applied Mathematics, University of Arizona, Tucson, Arizona 85721, USA.

Applied Mathematics Graduate Student Representative

The Applied Mathematics Graduate Student Representative plays an important role in the governance of the Program by providing the liaison between the student body and the Program management. The Grad Rep is elected by secret ballot by the students of the Program in Applied Mathematics at the end of every spring semester. The qualifications for candidates for Graduate Student Representative are as follows:

- The candidate must be a full-time doctoral student in the Program in Applied Mathematics.
- The candidate must have passed the qualifying exam (at the PhD level) by the time of candidacy.
- The candidate cannot have been elected Graduate Student Representative of the Program in Applied Mathematics before.

The primary duties of the Graduate Representative are:

- To bring the questions and concerns of the students in the Program to the attention of the Head of the Program, and vice versa; and help the Program management develop Program policy as needed.
- Assist with the organization of the annual recruitment workshop in the Spring semester and other Program activities when appropriate.
- Organize at least 1 "class-to-class meeting" per semester (2 are strongly recommended).

The class-to-class meetings, as organized by the Graduate Representative, are a system of peer-to-peer mentoring in which students at different stages of their academic careers in the Program come together to discuss questions, share experiences, and give each other advice about their academic and professional development.

III Courses of Study

As outlined below, the Program currently offers two courses of study leading to either the Doctor of Philosophy (PhD) degree with a major in Applied Mathematics, or the Masters of Science (MS) degree in Applied Mathematics.

Waivers for coursework completed at other institutions (referred to as "Transfer Coursework" by the Graduate College) must be pre-approved by the Program Head and listed as such on the Doctoral Plan of Study or the Master's Specialist Plan of Study.

PhD in Applied Mathematics Curriculum

In the first year, most students take the following sequence of core courses offered through the Department of Mathematics and taught by faculty in the Applied Mathematics Program. These courses, or their equivalents, are a required part of the PhD program. Beyond the first year (see Section IV), the plan of courses is flexible and individually designed.

PhD Core Courses for First Year – Fall and Spring

MATH 527 a, b Principles of Analysis (3 credit hours per semester)

MATH 575 a, b Numerical Analysis (3 credit hours per semester)

MATH 583 a, b Principles & Methods in Applied Mathematics (3 credit hours per semester)

MATH 586 a, b Professional Skills and Development Seminar (2 credit hours in the Fall semester, 1 credit hour in the Spring semester)

The first three courses, which provide intensive training in applied mathematics, are inter-related. For instance, mathematical techniques, which are introduced in Math 583, will be studied rigorously in Math 527, and numerically in Math 575. In the second semester, students write a **term paper** based on material related to a core course of their choice. The term paper is an opportunity to demonstrate, and develop, intellectual capabilities beyond traditional exams and homework. The term papers are presented at an end-of-term mini-conference and submitted as a formal journal-style document in LaTeX.

The Professional Skills and Development Seminar has two components. In the first semester students are introduced to the scientific methodologies of data analysis, mathematical modeling, and applied mathematics through unique, team-based projects in the Applied Mathematics Laboratory. There are also instructional sessions in the use of LaTeX and PowerPoint, and the projects are presented in both written and oral formats at an end-of-semester mini-conference. The second semester takes the form of a case-studies seminar where Program faculty introduce various research topics that can form the basis of a required three-unit research project (the Research Tutorial Group, or RTG) to be undertaken in the following Fall semester. A number of classes are also devoted to case studies in, and discussion of, professional and scientific ethics.

Experience has shown that involvement in a research project at an early stage is a stimulating and valuable experience that gives students a taste of the realities of independent research, and also an opportunity to demonstrate their capabilities beyond the traditional metrics of exams and homework assignments. Performance in the first-semester lab projects, the second-semester term papers, and third-semester research project are all factored into the Program's assessment of a student's progress.

After the first year, students can choose from a broad range of courses within the Department of Mathematics and in many other departments. For the PhD, at least 65 units of graduate-level courses are required. These include 20 units from the core courses (or equivalents) and 27 units of advanced course in mathematics and other disciplines, plus a minimum of 18 units of dissertation credits (920). See Section V for more details regarding the choices of advanced course work and degree requirements.

The actual choice of courses is made in consultation with faculty mentors and the Program Head. The chosen program of study should achieve a balance between expanding the student's mathematical skills and building on the knowledge base in the application areas of interest to them. Students are also required to pass a written Qualifying Exam (see Section VII) taken at the end of their first year and an Oral Comprehensive Exam (see Section V) at a later stage. They must also fulfill certain other degree requirements as described in Section V.

Students also have the opportunity to complete the requirements of a PhD minor in an area other than Applied Mathematics, e.g., Aerospace and Mechanical Engineering or Biomedical Engineering. This is not a degree requirement but for those of you interested in doing so it is important that you pay attention to the requirements for the minor degree and that you fulfill those requirements by the time you take your Comprehensive exam (see Section V).

Term Paper and RTG as Program Requirements

The term paper and third semester (RTG) project provide an important opportunity for students to demonstrate their abilities outside the usual metrics of course work and exams. In addition to conference-style presentations of both of these projects, properly written scientific papers, approved by the project advisor, are required. The deadlines for submitting these papers and how they are graded are as follows.

The term paper grade is integrated into the second semester Math 586b seminar course (Case Studies in Applied Mathematics). The class ends with the term paper conference and the course grade for this class is an Incomplete until the term paper is handed in. In recognition of the many pressures involved in preparing the presentations, the end of semester exams, and the importance of preparing a good term paper which plays a role in our broader assessment of a student's overall performance, students have up until July 31st to hand in their paper. Papers handed in after that date will not be considered in the Examiners meeting in August. Failure to submit a term paper will result in an F grade for the Math 586b class.

The RTG project is registered for as a 599 course. With these courses, students are assigned one of the following grades: P (pass), S (superior), I (incomplete) or K (course in progress) by the project advisor. However, in order to ensure that the RTG papers themselves are handed in and not left as open ended projects under the vague premise that they will develop in to actual publications the following mechanism will be used. Each student registering for an RTG project will also need to register for the one unit course Math 596g. This will be a Pass/Fail course. The course "instructor" is the Program Head who assigns

the P/F grade. The deadline for submitting the RTG paper, which must be approved by the project advisor, is June 1st (of that academic year). Failure to hand in the paper by that deadline will result in an F grade.

It is important to note that the Term Papers and RTG papers are Program requirements. Failure to fulfill them will prevent a student from holding their comprehensive exam.

MS in Applied Mathematics Curriculum

The MS degree in Applied Mathematics provides a very strong foundation in applied mathematics and is well suited for students wishing to pursue a career in teaching or in industry. A total of at least 30 graduate-level units are required for the MS degree. The first year of study is essentially identical to that of the PhD program as described above and involves taking all the core courses. Students are also required to take six (or more) units of graduate-level courses in departments other than Mathematics. Students must pass a written Qualifying Exam (see Section VII) taken at the end of their first year. An MS thesis is not required although students are encouraged to pursue independent research projects possibly leading to a thesis. The total time to complete an MS degree is normally two years. See Section VI for more information regarding the degree requirements for an MS degree.

IV Programs of Study

Post-Core Course Requirements

During the first year of core studies, the choice of courses is essentially fixed. By contrast, the second year and beyond offer an enormous range of possibilities. However, just taking more courses will not get you a PhD! Making the right choices and developing a plan of course work and independent study is very important and should be done in consultation with faculty advisors and/or the Program Head. Furthermore, each students' mathematics education does not end with the core courses and it is important that each student continues to take advanced mathematics courses in addition to those on interdisciplinary topics.

The Program's post-core course requirements are that students take 27 units of course work according to the following 9+9+9 formula:

- **9 units of advanced graduate mathematics** courses (independent study and special topics classes do not qualify in this category). Students are strongly encouraged to take at least one two-semester sequence (e.g., PDE/numerical PDE; probability/statistics; dynamical systems/methods).
- **9 units of graduate courses outside the Mathematics department**. These should have a strong scientific or technical component in another discipline. (Liberal arts and social science courses do not count in this category.) In case of

doubt, the student should check with the Head of the Program. Laboratory classes offered by the Program qualify.

- **9 units of elective graduate courses** (in mathematics or outside mathematics); only 3 units of independent study will count towards this category.

The 9+9+9 formula gives students considerable flexibility in designing their programs of study while, at the same time, ensuring that they achieve a balance between advanced mathematical training and interdisciplinary exposure.

It is important to note that the post-core requirement of 27 units (essentially 9 courses) is a **minimum requirement**. While you cannot get a PhD or, for that matter, find a dissertation topic by only taking courses it is important to graduate with a well-rounded education and take advantage of appropriate course offerings. The main reason for students running into problems with fulfilling course requirements is when they insist on only taking the minimum number of required courses. This leaves no room for maneuver when it comes to fulfilling the different categories of post-core course requirements.

Courses that Are and Are Not Allowed for Post-Core Requirements

There are some restrictions on the courses that can be counted towards the post- core requirements.

Mathematics courses: all mathematics courses must be true graduate level, i.e. 500 or above, courses. Dual-listed courses, i.e. Math courses offered at both the 400 and 500 level (e.g. Math 524/424 Theory of Complex Variables), even when they are offered as separate sections, do not count towards fulfilling Math course requirements.

Out-of-Math courses: students must be careful when considering cross-listed and dual listed courses for their out-of-Math requirements.

(a) Courses that are cross-listed between the Math department and another department (e.g. Math 541/Phys 541, Introduction to Mathematical Physics) cannot be used towards your out-of-Math requirement, even if you register for them under the other department (e.g. Phys 541 does not count as a non-math course because it is also offered as Math 541).

(b) Dual-listed courses that are strictly out-of-Math, i.e. not cross-listed with Math courses, can count towards your non-Math course requirements.

Independent study (599) and Special Topics (577) courses: Math 599 and Math 577 do not count towards the minimum of 3 post-core mathematics courses. However, up to one of each is allowed towards the total minimum post-core requirement of 9 additional courses, i.e. in the elective course category.

Post-Core Unit Requirements

After the first year, all students are required to register for at least 9 units of course-work per semester. These units are made up of specific classes that are part of the student's program of study and/or some independent study units (599 units). In some semesters course availability and relevance to an individual's program of study is such that registering for 9 units of classes is not possible, and in this case the student should register for an independent study course. Sometimes a student will register for a class and then drop it and in the process drop from being registered for 9 units to 6 units. Until passing the comprehensive exam (see below) it is not acceptable to be registered for less than the required nine units, and students will need to find an alternative (but useful) class or register for an independent study. The reason why we require registration for 9 units is to ensure that students stay on track with course work and exploration of research topics (through the use of independent study units) until they pass their comprehensive exam.

A general goal is for students to have completed all their basic course requirements (the nine post-core courses) and pass their comprehensive exam by the end of their third year. For the semester that students take their comprehensive exam they may register for three 900 research units as part of the 9 units per semester requirement – this is a mechanism to provide some time to prepare for the exam. Sometimes, it is not possible to accurately predict in which semester the exam will take place and it may be that a student will end up needing to register for second semester's worth of 900 units. In that case, students will be required to fill out the Program's 900-Research Units Enrollment Request form (see Appendix 2.)

The Program does not allow its students to be registered for more than two semesters worth of 900 units and the use of these units is closely monitored.

After completing the comprehensive exam students may register for a minimum of 6 units. These will primarily consist of 920 dissertation units and units corresponding to additional course work. Obviously a student may register for more than 6 units if it is consistent with their program of study and dissertation work.

General Principles of Course Selection

As a student narrows his or her research interests, taking the right courses can help lay the groundwork for the Oral Comprehensive Exam and for beginning the dissertation research. Getting off on the right foot in the second year is especially important. A common mistake is to choose, in a semi-random way, a variety of mathematics courses from the catalogue in the vague hope that they might prepare one for some future, but as yet unknown, research topic. For example, the student believes that topology might be useful one day, so takes an introductory course in it now. At the other extreme, a student will dutifully follow the advice of a professor with whom he or she is thinking about working (but is not certain) and take a whole set of specialized courses only to find, at the end of it all, that his or her interests have changed! It is not uncommon for faculty to recommend a series of courses as prerequisites for working with them, but before embarking on such a course of action, it is often a good idea to "test the waters" with an Independent Study course.

Despite the range of courses from which to choose and the variety of dissertation topics, some guidelines can be given. A useful way to think about course choices is as those that might be considered "general education" courses and those that might be thought of as "research-specific" choices. Another factor is that certain courses that may be important to the student may be offered only on an alternate-year basis. Also, different instructors can impart different flavors to a course and may cover somewhat different material. Students should always talk to an instructor about their plans and goals before registering for a course. Students who have been in the Program for a couple of years are also valuable sources of information about particular courses and the instructors.

The University currently has a minimum enrollment requirement of five students for a 500-level graduate course. This sometimes means, unfortunately, that an offered course can be canceled at the beginning of the semester that it is being offered. Checking with the instructor about potential enrollment shortages and having a back-up plan is also advised. Sometimes graduate students coordinate their enrollments to ensure that a given course can run.

For courses in mathematics, students are expected to take fully-fledged 500-level graduate courses (the 400/500-level course offerings are not acceptable for graduate-level courses in mathematics). For courses outside of mathematics, some 400- and/or 400/500-level courses are permitted. The taking of such courses must be discussed with the Program Head.

Students should also pay attention to whether a course is cross-listed with another department. Registering for the appropriate version can sometimes help fulfill the "math" and "non-math" course requirements in the most efficient way.

Guidelines to Advanced Mathematics Courses

Below are listed some advanced graduate-level courses offered by the Mathematics Department which, for the most part, can be thought of as being in the general education category and are often taken by Applied Mathematics students. (This discussion is by no means comprehensive and if students have questions about the appropriateness of the many other Mathematics courses being offered, they should check with the Program Head or their advisor).

MATH 528 – Hilbert and Banach Spaces: This is an advanced functional analysis course and can be thought of as a sequel to the Math 527 core sequence. Students with research directions involving analysis should consider taking this course, which is currently offered on an alternate-year basis.

MATH 557 – Dynamical Systems & Chaos: This is currently offered every year but alternates yearly between a more "theoretical" and a more "applied" presentation. Both forms are appropriate for Applied Mathematics students, and many of the same topics are covered. The second semester of the sequence, when offered, tends to cover more specialized aspects of the field.

MATH 563 – Probability Theory: If the student has not done a course in probability theory, this is well worth considering. It can also consolidate some of the ideas learned in Math 527 and can be helpful to students needing to retake the Qualifying Exam. This one-semester course is currently offered every year.

MATH 565 – Stochastic Processes: Students with a strong interest in discrete mathematics may want to consider taking this course – especially after having taken Math 563. However, students intending to pursue research in operations research may want to consider alternatives offered by the Systems and Industrial Engineering (SIE) department – such as SIE 520 (Stochastic Modeling) followed by SIE 525 (Queuing Theory).

MATH 576 and MATH 553: One of the great strengths of the Applied Mathematics Program is its record of research in partial differential equations. The courses, Math 576 – Numerical Methods in Partial Differential Equations, and Math 553 – Partial Differential Equations (which covers theoretical aspects of the topic), are run in alternating years as two-semester sequences. Not all students are necessarily interested in partial differential equations, but those who are should take advantage of one or both of these offerings. Aspects of 553 can help consolidate material learned in both 527 and 583. Students needing to retake the Qualifying Exam can usually benefit from taking 553.

MATH 587 – Perturbation Methods in Applied Mathematics: This is a one-semester offering of advanced mathematical methods and is not always available every year. The material covered can vary quite a lot depending on the instructor but typically covers (as indicated by the course title) advanced perturbation and asymptotic methods. To some extent, it can be thought of as an advanced methods course to be taken after the Math 583 core sequence.

MATH 697B – Applied Mathematics Laboratory: This is an advanced mathematical modeling course combining theory with sophisticated experiments. It also aims to provide a flavor of what applied mathematics research might be like after graduate school. This unique one-semester course can count as either a "math" or "non-math" course. This course is currently being offered on an alternate-year basis.

Statistics Courses

Graduate statistics courses are available through the Department of Mathematics and by the Graduate Interdisciplinary Program in Statistics. Most students can benefit from taking a graduate-level statistics course. The nature and frequency of these offerings is still being developed. However STAT 566 (also crossed listed as MATH 566) is a basic graduate statistics course and is highly recommended.

The Graduate Interdisciplinary Program in Statistics was established in 2007, and more information about statistics courses and opportunities for further training in statistics can be found at http://stat.arizona.edu.

Non-Mathematics Courses

As described above, under "Post-Core Course Requirements," a Program requirement is to take a minimum of 9 units of coursework outside mathematics. This is an important part of the educational experience and is intended to give some of the scientific "breadth" necessary for interdisciplinary researchers. In most cases, these courses will be in the "research-specific" category related to a student's dissertation topic. Nonetheless, a course on quantum mechanics, electromagnetism, signal processing, etc., can be a valuable part of a student's general education and is well worth considering at some point. As students assemble their program of courses outside Mathematics, he/she should determine if these courses qualify towards a PhD minor in that area.

Sometimes students will postpone taking non-mathematics courses until later in their graduate careers. This is not a good idea for several reasons! Firstly, the requirements for the Masters Degree in Applied Mathematics (see Section VI for more details) include taking 2 non-mathematics courses. Even if the intention is to complete the PhD, we strongly encourage all students to complete the requirements of the MS degree as soon as possible – which in most cases is easily done by the end of the second year. Another good reason for starting to take non-mathematics courses in the second year is that this provides an additional way of learning about interdisciplinary research opportunities and meeting potential research advisors. For those students interested in obtaining a PhD minor in another area (see Section V for more details) it is sometimes necessary to start taking the courses required for that minor in the second year to ensure that all the requirements are complete by the time the student takes the Comprehensive exam.

Independent Study (599) and Special Topics Courses

As students target a particular research topic, the relevant faculty member(s) will be able to provide more specific course recommendations. Comments from other students who have taken these courses should also be sought. Two additional types of courses, Independent Study (599) and Special Topics (577), can form a valuable part of a program of study.

In order for graduate students to be considered full-time, they are required to register for at least nine units of credit per semester. This does not necessarily mean always enrolling in three full-blown courses. The Independent Study course, through either Mathematics (MATH 599) or another department, can be a useful part of the study plan. It is often a good way of "trying out" a match with a faculty member (for them as well!). Such a course usually consists of some combination of reading and research assignments. When embarking on such a venture, it is very important that the expectations of both the student and professor are thoroughly discussed.

The 599 course number is generic. Students who undertake an independent study course with a professor outside of Mathematics will typically enroll for it as a 599 course in that professor's department, e.g. PHYS 599 when working with a Physics professor. Such courses may, subject to approval, count towards fulfillment of the "out-of-math" course

requirements [see (2) under "Post-Core Course Requirements"]. The Program's "Independent Study Form" (see Appendix 1.) must be completed and submitted to the Applied Mathematics office before taking the 599-level course.

As useful as the 599 courses can be to a student's study plan, it is important to remember the limited role they play in fulfilling the actual Program requirements as described above, in "Post-Core Course Requirements."

Note: 599 courses should not be confused with 920 PhD dissertation units. The University requires students to have registered for at least 18 units of 920 by the time they graduate. Students should wait until they have passed their Oral Comprehensive Exam and their dissertation research is underway before using 920 units.

Colloquia and Seminar Attendance Requirements

The Program sponsors a variety of colloquia and seminars including the Applied Mathematics Colloquium (held at 3:00pm on Fridays); the Analysis, Dynamics, and Applications Seminar and the Modeling and Computation Seminar (held at 12:30 on Tuesdays and Thursdays respectively); and the Quantitative Biology Seminar (Tuesday afternoons). There are also weekly seminars run by the Mathematics Department on Mathematical Physics, and many other topics.

Attendance at the colloquium and seminars is a very important part of a student's professional development: it provides an introduction to a broad variety of research topics and, especially in the case of the colloquium, the chance to hear and meet a leading figure in a given research field. *Students must meet a minimum colloquium and seminar attendance requirement in order to be allowed to take the oral comprehensive exam.* Specifically, students must attend 5 colloquia each semester up to (but not including) the semester the oral exam is taken. Similarly, students must attend 4 Tuesday/Thursday seminars a semester prior to the semester the oral exam takes place. Since the Tuesday/Thursday seminars are usually on more specialized topics, the first year is exempt from this requirement; however, first-year students are still strongly encouraged to attend. For example, students entering the program in Fall 2011 who take the oral exam in Spring 2014 must have attended at least 25 colloquia and 12 Tuesday/Thursday seminars. Note that only the Applied Mathematics Colloquium and the Tuesday/Thursday seminars count towards the attendance requirement, and that attendance will be recorded via sign-in sheets at the start of each colloquium or seminar. Additionally, students who entered the program prior to Fall 2011 do not need to make up attendance for semesters already completed; nevertheless, attendance at 5 colloquia and 4 Tuesday/Thursday seminars a semester is required for all future semesters prior to the semester the oral exam is taken, beginning with Fall 2011.

If a student has a legitimate reason for not being able to fulfill the attendance requirement in a given semester (e.g., taking or teaching a class at the same time as the colloquium or seminars, spending a semester at a different university) they should inform the Program Head and discuss possible alternatives. It is important to plan ahead in case of unforeseen circumstances by attending additional colloquia and seminars beyond the minimum

requirement. In any case, all students, including those who have passed the oral exam, are strongly encouraged to attend as many colloquia and seminars as possible and to consider this as an important part of their education (as opposed to a chore). Overall, as a student progresses through the Program, his or her attendance at the colloquium and seminars should increase rather than decrease.

V PhD Degree in Applied Mathematics

The following outline of requirements constitutes the basic structure of the PhD program but, depending on the student's background, etc., variations may be worked out with the Program Head. Refer to the PhD Timeline (below) as a general guideline.

Overall Requirements for the PhD

Completion of forty-eight (48) units of graduate-level courses, exclusive of dissertation, approved by the Program and including:

- Twenty-one (21) units from the core courses: MATH 527 a, b; MATH 575 a, b; MATH 583 a, b; MATH 586 a, b.
- Nine (9) or more units of advanced 500-level Mathematics courses
- Nine (9) or more units from departments other than Mathematics.
- Nine (9) or more units of elective course work either in mathematics or interdisciplinary topics.

Note: If the student has taken courses equivalent to some of the core courses, the core requirements may be revised. The total requirement of 48 units will not, however, be reduced. The Graduate College requires that 50% of the units must be in courses for which ABC grades are given. It is also a Graduate College requirement that all courses must be at the 500 level or above, with the exception that up to six units of 400-level courses may be taken outside the major area (i.e., mathematics) with prior approval from the Program. The Program's requirement of a minimum of 9 units of course work in an area other than mathematics is strictly adhered to.

Eighteen (18) dissertation units (920) are required for graduation. Students may register for more, but the maximum number of 920 units allowed per semester is nine (9).

Registration of Units: Every student will be required to register for a minimum of 9 units until all course requirements are met. After all course requirements are met, students are required to register for 6 or more units (unless other restrictions apply). A student should register for dissertation units after passing the Comprehensive Examination and when he/she is ready to start (or has started) his or her dissertation research. The semester during which preparation for the Comprehensive Examination takes place would be an appropriate time to register for 900-level research units. Students should always discuss registration for 900 and 920 units with their advisors.

- Successful completion of the Qualifying Examination at the PhD level.
- Successful completion of the Oral Comprehensive Examination (see below).
- Satisfactory completion of the Research Proposal Writing requirement (see below).
- There is no foreign language requirement.

The Qualifying Exam

This important exam is described in detail in Section VII.

The PhD Comprehensive Examination

The Comprehensive Exam should be scheduled within two years of passing the written Qualifying Exam. At an appropriate point during the course of the student's second or third year, he/she should be involved in serious research (through, for example, an independent study project) with a faculty member who in all likelihood will become his/her dissertation advisor. When it becomes clear that the student is ready to take the PhD Comprehensive Examination, a research paper (or an appropriate article, or articles) is identified for the student to study and discuss with his/her advisor. The student, in consultation with the advisor, will then select his/her Comprehensive Examination committee. The committee must be made up of a minimum of four tenured or tenure-track UA faculty affiliated with the Program. The committee chair is the student's advisor. In some cases it may be appropriate to have a committee member (with tenure, tenure- track, or equivalent status) who is not affiliated with the Program on the committee. At the request of the committee chair, the Program can ask for a waiver to enable this to happen. This is usually straightforward but should not be assumed to be automatic and must be formally approved by the Dean of the Graduate College.

Approximately 4 weeks before the intended exam date, students should work with the Applied Mathematics Program Coordinator to process the required Graduate College paperwork in order to schedule the exam. Using GradPath, students must submit the following forms in order: 1) Doctoral Plan of Study; 2) Comprehensive Exam Committee Appointment Form; 3) Announcement of Doctoral Comprehensive Exam. After the exam has taken place, the student's advisor will receive GradPath instructions to submit the Results of Oral Comprehensive Examination form.

The Comprehensive Exam must be conducted on the UA campus. Students who wish to schedule their exam in the Math building or ENR2 building must reserve a room in advance for a minimum of 3 hours (see http://resources.math.arizona.edu/support/home and click on Room Reservation Request).

The committee will administer the exam that consists of the following components:

- A written research report on the topics chosen for the Oral Examination (described in more detail below). The report is to be written following the standard journal article format used for the second-semester term paper and the third-semester project. **A copy of the report will be given to each member of the student's Comprehensive Exam committee *at least two weeks before* the Oral Exam. If the committee does not find the report satisfactory, the Oral Exam will not take place.**
- A professional résumé and a link to the student's web page **will be given to the committee members at the same time as the written report.** If the committee does not find these requirements satisfactory, the Oral Exam will not take place.
- A "road map" describing (i) the student's plan of study after the comprehensive exam, i.e., a timetable for the proposed research and graduation, future course work, etc.; and (ii) plans for professional development, e.g., meetings and workshops to be attended, teaching and outreach projects, internships, etc.
- An Oral Exam following the standard rules of the Graduate College.

Very Important: **Copies of the Comprehensive Exam research report, the résumé, the road map, and the web page address must also be submitted to the Applied Mathematics *office* *at least 2 weeks before the date of the exam*. If this is not done, the exam will not be allowed to proceed.**

The Comprehensive Examination is intended to test the student's fundamental knowledge in the fields of his or her major and minor subjects of study and to determine readiness to undertake a PhD-quality research project. This assessment is based upon the student's ability to describe and discuss the chosen research paper and the affiliated areas of science and mathematics. However, at the time of the exam, a specific dissertation topic does not need to have been identified.

The spirit of the Comprehensive Exam is well characterized by the following quote from the Graduate College website:

This is the occasion when faculty committee members have both the opportunity and obligation to require the student to display a broad knowledge of the chosen field of study and sufficient depth of understanding in areas of specialization. Discussion of proposed dissertation research may be included. The examining committee must attest that the student has demonstrated the professional level of knowledge expected of a junior academic colleague.

The exam itself usually begins with a short presentation (ideally about 45 minutes but no more than one hour) in which the student presents a summary of the chosen research paper(s) with appropriate background material as needed. The student is then questioned about the paper, its scientific setting (background, importance, future work), and other related mathematical and scientific material. Students are encouraged to discuss the

research paper (and the research area in general) with members of their committee before the exam. **The Comprehensive Exam is conducted as a closed exam and no portion of it is open to the public.**

Comprehensive Examination Committee and Exam Logistics

To reiterate: the Comprehensive exam committee must be made up of a minimum of four tenured or tenure-track UA faculty affiliated with the Program with the chair being the student's advisor. If the student is minoring in another field (e.g. a PhD minor in BME, AME) one of the committee members must be from that department. However, "double counting" is permitted, i.e. if one of the committee members is affiliated with the Applied Mathematics Program and is also a member of the minor department (this is quite common) he/she can also count as that department's minor representative.

When selecting the comprehensive exam committee students should bear in mind that the dissertation committee is formed (see below) soon after passing the comprehensive exam, and students will be required to meet with that committee at least once a year until graduating. Therefore, it makes good sense to choose the comprehensive exam committee members with the intention of at least some of them also serving on the dissertation committee.

Please note that the Graduate College does not set any time limits on the duration of the oral comp exam, however, it typically lasts two to three hours. The exam should not be rushed and when finding a room for the exam (which is the student's responsibility) **it is important to make sure that the *room is available for no less than three hours.***

It is traditional for the student to provide light refreshments for the examiners. The Program staff will provide tea and coffee but anything else is the student's responsibility.

Retake of the Comprehensive Examination

Occasionally, a student fails the Comprehensive Examination. This indicates that the committee has serious reservations about the student's ability to perform quality research. In this eventuality, the student may be allowed to retake the exam within a reasonable time frame, but the decision to do so must be made in consultation with the student's advisor and the Program Head. In the rare event of the student failing the exam on the second attempt, he or she will not be allowed to continue in the Program.

Third-Year Oral Review

If a student has not passed his or her Oral Exam by the end of their third year, he/she will be subject to a constructive review to help identify a dissertation topic and make any necessary adjustments to his or her program of study. This review will be undertaken at the end of the sixth semester by an ad hoc committee consisting of the Program Head, one faculty member chosen by the student, and a third faculty member at the discretion of the Head. The student will present some of her/his previous research, an extensive study plan

(clearly showing how he or she intends to complete the doctoral requirements), a résumé, a web page, and a plan of study that, in addition to plans for future coursework, explains how the student intends to find a dissertation topic and advisor.

This review will take place every semester until the Oral Exam has been scheduled.

If the student has already scheduled (or completed) his or her Oral Exam by the end of the third year, the review will take the form of a brief meeting with the Program Head and the student advisor where she/he will present a plan of study (including a description of the Comprehensive Exam), a résumé, and a web page.

PhD Plan of Study and Doctoral Dissertation Committee Appointment (Advancement to Candidacy)

Students in the Program in Applied Mathematics are required to file the Doctoral Plan of Study at the same time the Comprehensive Exam is scheduled (as noted above). After successful completion of the Comprehensive Exam, the Doctoral Dissertation Committee Appointment form (formerly known as the Advancement to Candidacy form) must be filed using GradPath. Please contact the Program Coordinator with any questions.

The Dissertation

The most important requirement for the PhD degree is the completion of a dissertation that contains original contributions by the candidate to the solution of a mathematical problem in a scientific discipline or to the development of mathematical methods for classes of such problems. The quality and scope of such contributions should be of a sufficiently high standard as to warrant publication in a reputable journal. Dissertations are housed indefinitely in the University Library and are available to the public. Requirements for style and format are set forth by the Graduate College and the guidelines are stated on the Graduate College website. **A draft of the dissertation must be given to each committee member *at least three weeks* prior to the Final Oral Defense Examination.**

The Dissertation Committee

The student should, in consultation with their advisor, form their dissertation committee as soon as possible after passing their comprehensive exam. The Graduate College requires a minimum of three members, all of whom must be current University of Arizona faculty members that are tenured, tenure-track, or approved as equivalent. The committee members must be affiliated with the Applied Mathematics Program. In some cases it may be appropriate to have a committee member who is not Program affiliated and in these cases, as with the Comprehensive Exam Committee, Program permission is required.

Students are required to meet with their dissertation committee *as a group* no less than once a year after the comprehensive exam and no later than May 1st of each academic year. Although these meetings are relatively informal the student must give the committee an update on their progress and be willing and able to discuss what they have done up to that time. It is also an opportunity for the student to seek suggestions from the committee.

If the student's comprehensive exam is held in the Fall semester of a given academic year, the first meeting with the dissertation committee would be in the following Spring semester. If the student's comprehensive exam is held in the Spring semester of a given academic year, then the first meeting would be no later than the Spring semester of the following academic year.

Outside Review of Dissertation

The Program in Applied Mathematics requires an evaluation of the dissertation by a reviewer *outside* of the University of Arizona who is an expert in the field of the research. The choice of the external reviewer is made by the student's advisor. A draft of the dissertation must be sent to the external reviewer *at least three weeks* prior to the Final Oral Defense Examination with the request that the reviewer submits a report to the Committee chair (with a copy to the Program Coordinator) at least two days before the exam. (The reviewer may send his/her report via email and need not be more than 1 or 2 pages).

Research Proposal Writing Requirement

To complete their doctoral work, students are required to write a research proposal following the guidelines of a National Science Foundation post-doctoral fellowship, or according to the format of some other agency (such as DOE or NIH) with prior agreement from the Program Head. This proposal will be reviewed by Final Defense committee members. Other types of proposals may also be permitted subject to approval by the Program Head. The proposal must be submitted to the student's committee, and the Applied Mathematics office, *at least one week* prior to the Final Oral Defense Examination. If the committee does not find the proposal satisfactory, the student will not be allowed to present his or her Final Dissertation Defense.

Although many students leave this requirement to the last minute, the best time to write this proposal is at the time they are seeking post-graduation jobs, i.e., many months before the final defense! Writing the proposal at this stage is a valuable exercise in developing a compelling personal statement and it thus becomes a valuable professional instrument rather than a last- minute chore.

PhD Final Dissertation Defense Examination Logistics

The Final Dissertation Defense Examination begins with a presentation (up to an hour in length) by the candidate of some significant aspects of their research. The presentation portion of the exam is open to the public. Members of the student's committee then question the candidate in depth in order to satisfy themselves as to its originality and significance.

There is no minimum time limit for the Final Oral Examination, but the entire proceedings may not exceed three hours (however, the exam room should be booked for three hours). Members of the committee must be present for the entire exam. Should special

circumstances require a member to attend remotely, prior permission from the Graduate College is necessary.

It is traditional for the student to provide light refreshments for the examiners. The Program staff can provide tea and coffee but anything else is the student's responsibility.

PhD Minor in Applied Mathematics and PhD Minor in Other Fields

The PhD degree at the University of Arizona is structured to have both a major and a minor. However, by completing the degree requirements for the PhD in Applied Mathematics, students simultaneously fulfill the requirements of the PhD minor in Applied Mathematics. Most students are not concerned with the minor. However, students working on an interdisciplinary research topic and who want to highlight their knowledge in some area outside of mathematics may wish to investigate the possibilities of completing the minor requirements in that field. Not all departments offer a minor and requirements may vary. If the student has declared a minor outside of Applied Mathematics, the Comprehensive Exam committee must include one faculty member representing the minor department. The representative of the minor department does not have to be a member of the Applied Mathematics Program but must be a tenure-track professor at the UA.

Deciding whether to take a minor in another field and planning the timetable to complete its requirements is not always obvious and students are strongly encouraged to discuss the matter with their advisor and/or the Program Head.

PhD Major and Minor Requirements and How to File the Doctoral Plan of Study in GradPath

Students must submit their Doctoral Plan of Study through the online GradPath system. It is important to understand how to enter the information regarding the Major and Minor requirements, and how the requirements for a PhD in Applied Mathematics relate to the University's basic requirements for a PhD in any discipline.

The PhD degree at the University of Arizona is structured to have both a major and a minor. However, by completing the degree requirements, as required by the Program in Applied Mathematics, for the PhD in Applied Mathematics students simultaneously fulfill the requirements of the PhD minor in Applied Mathematics, and may list it as such on the form.

When submitting the Doctoral Plan of Study form in GradPath, students who are claiming Applied Math as their Minor should list a minimum of forty-eight (48) units of graduate-level courses on the Major section of the form (exclusive of dissertation 920 units) including:

- Twenty-one (21) units from the core courses: MATH 527 a, b; MATH 575 a, b; MATH 583 a, b; MATH 586 a, b
- Nine (9) or more units of advanced 500-level Mathematics courses;
- Nine (9) or more units from departments other than Mathematics*****

- Nine (9) or more units of elective course work either in Mathematics or interdisciplinary topics.

A minimum of nine (9) units of any electives or out-of-math courses should then be listed on the Minor section of the form.

*****Students who claim a Minor that is ***not*** Applied Mathematics must submit the Doctoral Plan of Study form in GradPath as described above for the Major section of the form, but must list the required courses to fulfill the Minor in the Minor section of the form. **Courses counted towards the Minor may not be double-counted for the Major (**this does not commonly occur unless there is an overlap of Mathematics courses taken – such as for the Statistics minor).

PhD Minor in Applied Mathematics for Students in Other Degree Programs

Students in other graduate programs can earn a PhD minor in Applied Mathematics. The requirements are as follows:

- Students must complete 12 units of approved coursework in Applied Mathematics. Students should make sure that their proposed programs of coursework for the PhD minor are approved *before* they begin taking the courses.
- At least 3 of these units must be from the Applied Mathematics core sequence (see Section III, "PhD in Applied Mathematics Curriculum").
- Students must maintain *better* than a 3.0 GPA.
- There is no exam requirement for the minor.

One Applied Mathematics faculty Member or Affiliate Member is required to serve on the minor student's oral comprehensive exam. Program faculty who are also on the student's committee as representatives of the major department are eligible to play the role of minor representative as well.

The Applied Mathematics Program Head must approve the Doctoral Plan of Study form in GradPath prior to the Comprehensive Exam date.

PhD Recommended Timeline

Year 1

- Complete core courses
- Prepare for Qualifying Exam
- Identify research areas of interest

Year 2

- Pass Qualifying Exam
- Using GradPath, submit the Master's Specialist Plan of Study and Master's Completion of Degree Requirements forms to receive MS degree in the spring semester.
- Investigate research opportunities in one or more areas
- Identify possible research advisors

Year 3

- Select an advisor
- Using GradPath, submit Doctoral Plan of Study , Comp Exam Committee Appointment Form
- Schedule Comprehensive Exam and, using GradPath, submit the Announcement of Doctoral Comprehensive Exam
- Using GradPath, your advisor will submit the Results of Oral Comprehensive Examination after your exam
- Begin doctoral research and select your Dissertation Committee.

Years 4 & 5

- Identify employment opportunities (ongoing)
- Meet with your Dissertation Committee at least once a year.
- Complete doctoral research
- Choose committee members for Dissertation Defense Examination and, using GradPath, submit the Doctoral Dissertation Committee Appointment form
- Select outside dissertation reviewer
- Using GradPath, submit the Announcement of Final Oral Defense
- Pass Dissertation Defense Examination
- Using GradPath, your advisor will submit the Results of Final Oral Defense
- Electronically submit final copy of dissertation to Graduate Degree Certification Office according to the specified deadline for the semester in which the defense takes place.

VI Master's Degree in Applied Mathematics

MS Requirements

The Master's degree in Applied Mathematics consists of the following requirements:

- Completion of 21 units from the core courses (see Section III, "PhD in Applied Mathematics Curriculum") with 3 of these being the Professional Skills and Development seminar.

- Completion of 6 or more units at the 500 level from departments other than Mathematics.

Note: If a student has taken courses equivalent to some of the core courses, the requirements may be revised. The requirement of 30 total units will not, however, be reduced. The Graduate College requires that 50% of the units must be in courses for which ABC grades are given. All units must be at the 500 level or above, with the exception that up to six units of 400-level courses may be taken outside the Department of Mathematics, with prior approval from the Program Head.

Examination Requirements

Successfully complete the written Qualifying Examination (see Section VII) at the MS level.

MS Degree for Students Pursuing a PhD

Since the MS and PhD tracks in Applied Mathematics are initially the same, students complete (normally within two years) the requirements of the MS degree along the way to completing a PhD. Once students are eligible to obtain the MS degree, they will be notified by the Program Coordinator with instructions regarding activation of the MS forms in GradPath (see below). Obtaining the MS degree is not only helpful to the Program administratively but can also have an impact on your later career, e.g., your stipend for a summer internship may be higher if you have an MS degree, and in some companies the lack of an MS degree, even if you have a PhD, can adversely affect your pay grade!

How to file for the MS Degree

There are 2 forms in GradPath that must be filled out to obtain the MS degree. They are:

1) Master's Plan of Study
2) Master's/Specialist Committee Appointment Form

When students fill out the Master's/Specialist Committee Appointment form, there is a statement in GradPath that says:

'Not all programs require a faculty committee. If your program does not require a committee, check "no" below. If you are required to have a committee, enter the names below.'

To date, the Program policy has been that all students need to identify an MS committee – a process that we were able to monitor directly since the paperwork went directly through the Program's administrative office. Now that the online GradPath system is in place the Program will adopt the following policy:

(i) If you are filing for a ***terminal*** **MS degree you do *not* need to identify a committee** and you may check the "no" referred to above. (If you are a terminal MS student and you have already filed for your degree and identified a committee that is not a problem and you do not need to
change anything.)

(ii) If you **are continuing on to PhD you must identify a committee in accordance with past policy: advisor + 2 committee members who must be tenured or tenure-track professors**. If you do not yet have an advisor, you may list the Program Head as your advisor.

In either case you *not* need to register for thesis units or write a Masters thesis.

VII The Qualifying Examination

Preparing for the Exam

Upon completion of the core courses, students pursuing the MS and PhD degrees in Applied Mathematics are required to take a written Qualifying Exam. Traditionally, most students receive a stipend from the Program to spend the summer after their first year in Tucson studying for the Qualifying Exam. It is **strongly prohibited** for a student to take on internships, part-time teaching, research or other activities during that summer. Any desire to do so **must be discussed with the Program Chair before the end of the spring semester**. In the unlikelihood that the extra activity is approved by the Chair, the summer stipend from the Program will be forfeited.

Copies of previous exams are available from the Graduate Coordinator (Room 410) to use for studying.

Scheduling

The Qualifying Exam is given in early August and in early January of each year. Students can take the exam for the first time in August just before the beginning of their second Fall semester or they may postpone taking the examination until January – just before the beginning of their second Spring semester in the Program. Students who wish to consider taking the examination for the first time in January must discuss their plans with the Program Head at the end of their first spring semester or during the early summer. Students intending to take the exam in August are required to sign up at the end of the Spring semester. It will be counted as a failure of exam if a student does not take the examination

at the designated time without prior authorization of change of plans from the Program Head.

Format of Exam

The Qualifying Exam has two parts taken on two consecutive days. The student has four hours on each day to complete the exam questions given on that day.

The student identifies him- or herself by a nickname and his or her identity is not revealed to the examination committee until after the exam has been graded.

If a student is present for only one of the two days, he/she will be counted as having attempted the entire exam.

Material Covered

The exam is prepared by a team of faculty members including those who have taught the core courses. It is intended to test basic material considered important for advanced work in applied mathematics. This includes topics covered in the core courses, plus other material as listed in Appendix 3. In order to pass the examination, the student must have mastered material covered in the core courses and have a strong background in basic applied mathematics (see Appendix 3).

Grading of Exam Questions

Questions are graded by the committee members who wrote the examination. Two examiners grade every question independently.

Broad-Based Assessment

After all grading has been completed, the exam results and all aspects of the student's academic performance are discussed by the entire examining committee and the Program Head. The student's overall result is determined by the following criteria:

- Performance in the written qualifying exam
- Performance in the first-semester Professional Skills and Development seminar
- Performance in the second-semester term paper
- Performance in the third-semester research project (if the student is retaking the exam, on a two-year core, or postponed the first attempt at the exam to his or her third semester)

There are three possible outcomes to the exam:

- **PhD Pass**: Students may continue in the Program towards a PhD subject to continued satisfactory performance and their passing the PhD Comprehensive Exam.
- **MS Pass**: Students interested in pursuing a PhD will be required to retake the exam the next time it is offered and improve to a grade of PhD pass. Students who wish to complete an MS degree only will not be required to retake the exam. In either case, students must continue to work towards completing all the requirements for the MS degree.
- **Fail**: Students must retake the exam the next time it is offered in order to remain in the Program and be eligible (subject to second-attempt exam results) to pursue an MS or PhD degree.

After receiving written notice of the Qualifying Exam results, each student will meet individually with the Program Head to discuss his/her performance and options for the coming year. Students may request a consultation with a designated instructor (or instructors) to review their exams.

Retakes

Students who pass at the MS level and hope to improve their exam results, as well as those who received a fail on their first attempt, must retake the entire examination the next time it is offered. The result of the second attempt (retake) is final. If the result is a second failure, the student will not be allowed to continue in the Program. Likewise, if the second result is at the MS level, the student will only be allowed to complete an MS degree in the Program and will not be allowed to continue in pursuit of a PhD.

Comments

Although most students who pass the written Qualifying Examination at the PhD level go on successfully to complete a PhD, the exam result alone does not guarantee this! Successful PhD research requires a high level of commitment, hard work, and the ability to work and think independently. The PhD Oral Comprehensive Exam (see Section V), is generally scheduled within two years of the Qualifying Exam and provides the Program and student with the opportunity to assess the student's readiness and ability to write an original, high-quality dissertation.

Passing the Qualifying Exam at the MS level on the first attempt indicates that the student has made good progress but also identifies areas of weakness that need to be worked on in order to pursue more advanced studies. Although students are often initially disappointed at not having achieved a PhD-level pass at the first attempt, they should recognize that an MS pass demonstrates real progress in their studies. It is not uncommon for many students who retake the exam, after the benefit of further study, to go on to produce excellent PhD dissertations.

It is also important to note that while the Qualifying Exam is often a good indicator of technical skills it does not necessarily tell the entire story concerning a student's abilities. ***That is why we take a broad-based assessment approach***. Thus an excellent term paper, or an outstanding third-semester research project by students retaking the exam on a two-year core, can play a significant role in determining the final outcome of the qualifying exam.

Failing the Qualifying Exam on the first attempt indicates serious deficiencies in mathematical skills. Those students are encouraged to retake the exam and to discuss their long-term goals with the Program Head.

VIII Financial Support Options

Eligibility

Most students in the Program receive financial assistance in the form of fellowships, teaching assistantships, and/or research assistantships. In order to receive financial aid, it is necessary to be considered a full-time graduate student, which means a student must register for a minimum of 9 units each semester.

Teaching assistantships (TAs) carry teaching assignments in the Department of Mathematics. Research assistantships (RAs) usually come from grants and contracts of faculty members and generally require the recipient to perform research related to the grant or contract. There are a variety of sources for fellowships: training grants, Program Fellowships, the Graduate College, etc. The duties associated with these fellowships depend on their source. However, all support is contingent upon meeting various Graduate College requirements: these include maintaining, at a minimum, a 3.0 grade point average. Students must also satisfy, at all times, the Program requirement of being in good standing academically and maintaining a high standard of professional conduct.

Most students entering the PhD program with financial support receive a commitment of support – usually in the form of teaching assistantships – for up to four years subject to satisfactory progress. The nature of the support may vary from year to year. If additional time is required to complete the PhD, a fifth year of support may be made available. This policy applies to all sources of support controlled by the Program in Applied Mathematics including teaching assistantships, fellowships, and research assistantships funded by grants administered by Applied Mathematics. Continuation of research assistantships from other sources is always at the discretion of the Principal Investigator of the grant, regardless of the number of years of prior funding.

Students should recognize that financial support from the Program is a privilege and not a right. Students are strongly encouraged to apply for research assistantship support through faculty and fellowship awards from local and national agencies.

Fellowships and Research Grants

There are opportunities for students to obtain external fellowships of various kinds from funding agencies such as the NSF, NIH, DOE, and private foundations. These fellowships are prestigious, financially advantageous, and, by relieving a student of the need to teach for support, can speed up the time to graduation. Students are strongly encouraged to apply for these awards. The Office of Fellowships and Community Engagement at the Graduate College, will be pleased to assist you. Information about Grad student funding and Fellowship opportunities can be found on their website at: https://grad.arizona.edu/ofce .

IX Assistantships and Professional Conduct

Satisfactory Academic Progress

The Graduate College Statement of Academic Policies refers to "Satisfactory Academic Progress." This important phrase is defined as follows, "In addition to maintaining a minimum 3.00 grade-point average, students enrolled in a graduate degree program are required to demonstrate satisfactory academic progress toward degree completion. Failure to meet satisfactory academic progress requirements is grounds for disqualification by the Dean of the Graduate College. Each department has its own criteria for evaluation of a student's academic progress. The Graduate College will apply the appropriate department's criteria if the department requests a student's disqualification for failure to meet satisfactory academic progress guidelines."

It is important to remember that maintaining satisfactory academic progress at any one time is more than just maintaining a good GPA. Students must satisfy all Program requirements as described in this Handbook, including some that might sometimes appear irksome, such as handing in the second-semester term-papers and third- semester research project papers, as well as being registered for the requisite number of units each semester. Passage through the various transition points and milestones in students' graduate careers requires GradPath approval from the Program Head. This approval will be withheld if not all of the Program's requirements have been fulfilled up to that point.

Status as a Teaching Assistant

Students in the Applied Math Program are sometimes confused about their "status" when they are teaching assistants in the Mathematics Department. The way to think about it is that the students are being "contracted out" by the Applied Mathematics Program to the Mathematics Department (this type of arrangement often happens with employees of consulting companies in the commercial sector). While a student has a TA contract with the Mathematics Department, the student must follow their (and the University's) rules and procedures with regard to teaching (see below). However, the student is always a "citizen" of, and the responsibility of, the Applied Mathematics Program and as such, governed by all Program academic policies and requirements.

The relationship between the Program and the Mathematics Department has been very successful and cordial for many years and we expect all Program students, especially when they are performing TA duties for the Mathematics Department, to conduct themselves in this spirit. Exhibiting professional conduct is a very important part of being a TA (or RA) and what this means in practice is discussed in detail below.

Multiple Means of Support

The University has strict rules about academic year employment limits. These are described in the University's Graduate Assistantship Hiring Manual (available at http://grad.arizona.edu/funding/ga). A "full-time" TA or RA position is designated as a "0.50 FTE." What does this mysterious terminology mean? FTE means "full-time equivalency" and, in effect, corresponds to a 40-hour work week. So why is a full-time TA or RA a 0.50 FTE, which corresponds to a 20-hour work week? The idea is that students should spend the "other" half of their time on coursework and other scholarly pursuits. Students who are "half-time" TAs with reduced teaching duties are usually designated as being a 0.25 FTE.

The University's Graduate Assistantship Hiring Manual states that to maintain student employee status, graduate students are limited to no more than 30 hours per week total employment: this includes their Graduate Assistantship (either TA or RA) position, and any additional on-campus employment during periods of enrollment. Does this mean that students with "full-time," i.e., 0.50 FTE, TA or RA support can rush out and find an additional 0.25 FTE position as a TA or RA to make up a 30-hour work week? Basically, the answer is no. A 0.50 FTE position is considered to be working full-time. If a student already has a full-time TA, no responsible professor will hire them as a part-time RA; or, equivalently, if a student has a full-time RA, no sensible department will hire them as a part-time TA. Essentially a student cannot be hired under more than one full-time contract at a time.

However, if a student has partial support from one source, say a half-time TA position (0.25 FTE), and is endeavoring to acquire further support from another source, the situation becomes a little more complex and the student must work closely with the Program's Coordinator to make sure that everything is above board.

So where could the 30 hours stated in the Hiring Manual come from? One situation where the Program might approve extra hours, usually termed "supplementary compensation," is for performing special tutoring assignments. For example, the Program sometimes asks selected advanced students to provide, in return for some supplementary compensation, additional coaching/review sessions for students preparing for the qualifying exam.

Graduate College Polices

When as student is awarded a teaching or research assistantship, the student essentially becomes a student employee of the University and must electronically sign an employment contract – the Notice of Appointment (NOA). The contract is sent to students electronically

and each student should take a few minutes to read it carefully. Some of the key points mentioned in the NOA are listed below. Students must:

- Be enrolled for a minimum of 6 graduate-level units, or the minimum required by your department. (Applied Math requires you to be registered for a minimum of 9 units.)
- Maintain a cumulative GPA of 3.0 or higher.
- Limit hours per pay period to the required guidelines of your FTE (.50 or .25).*
- Perform duties, whether teaching or research, to the best of your abilities. Students may be subject to termination before the end of the appointment if performance does not meet acceptable levels.
- Understand that assistantship appointments are not automatically renewable and may be subject to funding availability. There should be no expectation of employment beyond the dates listed on the current NOA.
- Adhere to any conditions of employment in addition to those mentioned in the NOA that your hiring department (the Mathematics Department) may establish (see "Additional University and Mathematics Department Policies for Teaching Assistants," below).

Additional University and Mathematics Department Policies for Teaching Assistants

In addition to the key points listed above that were established by the Graduate College, the Mathematics Department also has a standard set of guidelines which must be followed when you are working for them as a teaching assistant. These guidelines are summarized below:

- Students working as teaching assistants are classified by the University as student workers; therefore there is no provision for sick or medical leave time. If one becomes sick and cannot teach their class, the course supervisor and the TA coordinator must be contacted immediately, and necessary arrangements for coverage of the class must be put in place.**
- There is no vacation time for Teaching Assistants. Time off during the semester is only allowed for the most exceptional family situations (e.g. death, serious illness) and must be kept to a minimum number of days. Obviously students must inform the course supervisor and the TA coordinator if such a situation arises.

Students will not be paid for time taken off during the semester and must report time away to the Mathematics business office for payroll purposes.

TA contracts for teaching in the Fall semester become binding after June 30th.

Professional Conduct

Professional conduct means not only following the letter of given requirements but also conforming to their spirit. Being a TA or RA is a privilege, not a right. Just because one may be able to find somebody to cover their class, it doesn't mean that one can disappear for a vacation in the middle of the term! Irresponsible actions of this sort not only damage the TA's own reputation but ultimately damage the reputation of the Program. TA and RA positions are terrific opportunities for professional development. Enjoy them and benefit from them – on no account abuse them.

Professional conduct also means adhering to Program policies and requirements in a timely manner. When Program staff ask for information, or for students to sign forms, etc., it is expected that students in the Program will do so promptly and courteously. Disrespectful treatment of Program staff will not be tolerated. Similarly, when students are working as TA's in the Mathematics Department, the staff and the TA supervisors must be treated with respect at all times. Although most contact is with the staff in the Program or the Mathematics Department, the same principles of good conduct apply when in contact with staff from any other unit in the University.

* A pay period consists of two weeks. If you are on a .50 assistantship the maximum number of hours worked per pay period is 40; if on a .25 assistantship the maximum number of hours worked per pay period is 20. Students on F-1 or J-1 visas are limited to a maximum total of 40 hours per pay period.

**In the extreme circumstance of your being incapacitated to the extent that you cannot teach for an indefinite or extended period of time, the University will require you to resign from your teaching position.

Appendix 1. 599 Independent Study Enrollment Form *(contact Program Coordinator for electronic version)*

Complete and sign this form and submit it to the Program in Applied Mathematics office. Upon completion of the semester, fill in page 2 of the form, sign it, and give it to the Program in Applied Mathematics office for your permanent file.

Student's name:

_____

Term registered:

_____

Instructor's name:

_____

Brief statement of study plan:

_____
_____
_____
_____
_____
_____
_____
_____

Expected results:

_____
_____
_____
_____
_____
_____
_____
_____

Student's signature:

_____

Instructor's signature:

_____

Date:

_____

Independent Study Form (page 2)

Statement of results obtained:

_____
_____
_____
_____
_____
_____
_____
_____

Grade: S P

Student's signature:_____

Instructor's signature:_____

Date: _____

Appendix 2. Program in Applied Mathematics 900-Research Units Enrollment Request Form

(contact Program Coordinator for electronic version)

Upon requesting registration for 900-Research Units, please complete, print and obtain signatures on this form. Return it to the Program in Applied Mathematics to process your registration.

Student's name: _____

Term of registration request: _____

*Is this your 2nd semester to request registration for 900-Research Units? Yes No
*Is this your 3rd semester to request registration for 900-Research Units? Yes No

Instructor's name: _____

Brief statement of why you were not able to take your Comprehensive Exam during the semester you originally planned to take it: _____

Brief statement of what you and your advisor will be doing this (coming) semester to ensure that you take the Comprehensive exam: _____

Planned Date of Oral Comprehensive Exam: _____

Student's signature: _____ Date: _____

Instructor's signature: _____ Date: _____

Program Head signature: _____ Date: _____
*(Required for 2rd and 3rd semester of registration of 900 units)

Appendix 3. Material Covered in the Qualifying Exam

Core courses (527 a, b; 575 a, b; and 583 a, b):

527 Principles of Analysis

Topology, metric spaces, normed linear spaces; elements of distribution theory and measure theory. Emphasis on the needs of applied mathematics.

575 Numerical Analysis

Error analysis, solution of linear systems and nonlinear equations, eigenvalues interpolation and approximation, numerical integration, initial and boundary value problems for ordinary differential equations, optimization.

583 Principles and Methods of Applied Mathematics

Phase plane analysis and traveling waves, Fourier series and transforms, contour integration, Spectral theory, distributions and delta functions, Greens functions, integral equations, calculus of variation, elementary perturbation theory, asymptotic expansions of integrals, assorted topics in linear and nonlinear waves.

Assumed background material, as follows:

Ref: Linear Algebra (G. Strang)
Topics: Vector spaces
Linear dependence ñ independence.
Bases.
Matrices representing linear transformations.
Kernel, cokernel, range.
Theory of Ax = b ñ when can it be solved, when can't it (all cases).
Diagonalizing symmetric matrices.
Spectral theory of orthogonal, unitary, symmetric, hermitian matrices.
How to take exponentials of matrices.
Least squares solutions of Ax = b.
Gaussian elimination; lower-diagonal-upper factorization.

Ref: Complex Variables and Applications (R. Churchill and J. Brown). McGraw-Hill (1984)
Chapter 6, Residues and Poles; Chapter 7, Mapping by Elementary Functions; Chapter 11, Integral Formulas of Poisson Type; Chapter 12, Further Theory (Analytic Continuation, Singular Points and Zeros, Riemann Surfaces)

Ref: Differential Equations with Applications and Historical Notes (G. Simmons). McGraw-Hill (1972)
Chapter 7, Systems of First Order Equations ; Chapter 8, Nonlinear Equations