



PROGRAM IN
APPLIED MATHEMATICS

Graduate Student Handbook

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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 over 20 different departments in 6 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;
- 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 on the Program’s 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 which 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 Professional Skills and Development Seminar, courses of Independent Study with individual faculty members, various working groups, and ultimately,

supervised dissertation research. New students meet individually with the Program Chair once per year to discuss their academic progress until they connect with a research advisor. Students are then expected to meet regularly with their advisor, but may schedule an appointment with the Program Chair at any given time during their academic career. The Program also schedules an annual Applied Math Student meeting for all students to meet collectively – usually at the end of the spring semester.

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 non-research 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 at <https://appliedmath.arizona.edu/people/faculty>), 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 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 Chair.**

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.

Contact Information

| <i>Name</i> | <i>Title</i> | <i>E-mail</i> | <i>Phone</i> |
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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, Computer Science, Astronomy, Hydrology and Atmospheric Sciences, Bio-Chemistry are in the College of Science and Aerospace and Mechanical Engineering, Materials Science and Engineering, Electrical and Computer Engineering, System and Industrial Engineering are in the College of Engineering). The Chair of the Program in Applied Mathematics reports to **the Dean of the Graduate College as the Chair of the Program.**

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 process (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 Chair 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.

Graduate College and University Policies

The Graduate College is dedicated to promoting and strengthening family relationships. Many resources have been designed to help graduate students balance and manage family, work, and school. Please see the links below for information on child care subsidies and family friendly information:

- **Graduate Assistant/ Associate Parental Leave:**
<https://grad.arizona.edu/funding/ga/benefits-appointment>
- **Temporary Alternative Duty Assignments (TADA) for Teaching Assistants/ Associates:**

<https://grad.arizona.edu/funding/ga/temporary-alternative-duty-assignments-graduate-assistantsassociates>

- **Extension of Time to Degree Policy:**
<https://grad.arizona.edu/policies/academic-policies/extension-time-degree>
- **Life & Work Connections (Child and Elder Care Resources):**
<https://lifework.arizona.edu/>

In addition, graduate students are expected to follow the policies and procedures for both the UA Graduate College and for the Program in Applied Mathematics. Policies are updated frequently and it is the student's responsibility to comply with current policies.

- **Graduate College:**
<https://grad.arizona.edu/new-and-current-students>
- **University General Catalog:**
<https://catalog.arizona.edu/policy-audience/graduate>
- **Summary of Grievance Types:**
<https://grad.arizona.edu/policies/academic-policies/summary-grievance-types-and-responsible-parties>
- **Incomplete Grade (I) Policy:**
<https://registrar.arizona.edu/grades/grading-policy-manual-university-academic-grading-policies-incomplete-i-grade>
- **Academic Integrity:**
<https://deanofstudents.arizona.edu/policies-and-codes/code-academic-integrity>
- **Responsible Conduct of Research:**
<https://rgw.arizona.edu/compliance/home>

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 Chair 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, all 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 approved by the Program's Chair, 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/APPL 581 A/B Methods of Applied Mathematics (3 credit hours per semester)

MATH/APPL 584 A/B Theoretical Foundations of Applied Mathematics (3 credit hours per semester)

MATH/APPL 589 A/B Algorithms of Applied Mathematics (3 credit hours per semester)

MATH 586 a, b Professional Skills and Development Seminar (1 credit hour in the Fall semester; 2 credit hours in the Spring semester); (RTG/599 is taken in the 3rd semester for 3 credit hours – more information is listed below on pages 10-11).

The first three courses, which provide intensive training in applied mathematics, are inter-related. For instance, mathematical techniques, which are introduced in Math 581, will be studied rigorously in Math 584, and numerically in Math 589.

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 journal club projects and the second-semester research project are all factored into the Program's assessment of a student's progress during the first year.

Math 586 a,b and RTG/599: Professional Skills and Development Seminar

The former Term Paper and Research Training Group seminar will now be a sequence of three required activities, each one semester in length. The essence of the sequence is to teach students to do research through extensive interactions and collaborations with the Program's professors. Common elements in the three courses are as follows:

- Selection of the course's adviser and subject for the term should be completed by September 15 in the fall and by February 15 in the spring. Each student should select an advisor from the list of Applied Mathematics faculty listed at the program's website, communicate with the adviser over email or in person, submit the name of the selected professor and brief (1/2 page) description of the selected subject, references, etc., to the Program Chair. At least two different advisers should be selected by the student within the 586 a,b and RTG/599 sequence.
- The student has the rest of the semester/term to complete the project. It is expected that the student will schedule and keep regular meetings with the advisor (a bi-weekly pace is recommended).
- Presentation of the project results for each of three classes of the sequence will take place at a workshop open to the public and typically scheduled in early December (fall) and in late April (spring). All students and advisors are expected to attend. The presentation should be submitted to the Program Chair by 11:59pm on the day preceding the workshop.

- 586 b Research Project and RTG/599 advanced research project each require the submission of a written report.
- All material required from the student towards meeting class requirements should be submitted via D2L.
- Overall participation in each of the three classes of the sequence will be graded as a single score.

Math 586A (one unit):

In the first semester, students are introduced to research in applied mathematics through the individual study of **literature on a selected research topic in applied mathematics**, followed by a presentation at the workshop. In other details, this activity follows generic rules for the Math 586 sequence described above.

Math 586B (two units):

The class has two components: (i) faculty presentations once a week; (ii) students individually study a **research topic in applied mathematics**:

- (i) Each week a program professor, selected by the program chair, will give a presentation (1h 15 min presentation) on his/her research. Students are required to attend, host at least 1 speaker, ask questions during the presentation and then write a short essay (1/2 page) describing in their own words the field of study presented, formulating the main points of research inquiry in the field (potentially of interest for you if you choose to work with this professor in the future). The reports should be submitted electronically via the D2L system by 11:59pm on Sunday of the presentation week. List of professors presenting will be posted at the D2L site of the course in the beginning of the semester/term and on the Program's website.
- (ii) Each student is expected to pick an advisor for **individual study of a research topic in applied mathematics**. Students should 1) present results of the independent study at the Spring workshop; 2) submit a written report (~ 10 page latex-produced, .pdf formatted document) by 11:59pm on May 31. In other details, this activity follows the generic rules of the Math586 sequence described above.

Math RTG/599 (three units):

In their third semester, students conduct **advanced individual study of a research topic in applied mathematics**. Each student is expected to select an advisor for this semester/term-long advanced independent study. Students should 1) present results of the independent study at the fall workshop; 2) submit a written, research paper grade report (~ 20 page latex-produced, .pdf formatted document) by 11:59pm of Jan 15. In other details, this activity follows generic rules of the Math586 sequence described above.

PhD Core Courses after First Year

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 courses 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 coursework and degree requirements.

The actual choice of courses is made in consultation with faculty mentors and the Program Chair. 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 Qualifying Process (see Section VII) and an Oral Comprehensive Exam (see Section V). 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 Oral Comprehensive exam (see Section V).

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 Chair. 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 (586/RTG sequence 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/data science; 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 Chair of the Program.
- **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. Students admitted to the Program in the Fall 2014 and thereafter are *not* allowed to count 400-level courses. This includes co-convened 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 co-convened 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) Co-convened 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, full-time students are required to register for **a minimum of 6 and up to 9 or more units** of course-work per semester (schedules for part-time students will be considered by the Chair on a case-by-case basis). 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). **Students in their 2nd and 3rd years may take an independent study course (599 units) twice. In some semesters course availability and relevance to an individual's program of study is not possible and in this case, a student may petition to register for an additional (third) independent study course.**

A general goal is for students to have completed all their basic course requirements (the nine post-core courses) and pass their Oral Comprehensive exam by the end of their third year. For the semester during which students take their Oral Comprehensive exam they may register for three 900 research units **as 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 Oral 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 no longer acceptable for graduate-level credit for students admitted to the Program starting in Fall 2014 and thereafter).

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 Chair 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 581 core sequence.

Statistics and Data Science Courses

Graduate statistics and data science courses are available through the Department of Mathematics and by the Statistics Graduate Interdisciplinary Program. Most students can benefit from taking a graduate-level statistics course. 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 Oral 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 6 units of credit per semester. This does not necessarily mean always enrolling in 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 must 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 2:00pm on Fridays); the Analysis, Dynamics, and Applications Seminar and the Modeling and Computation Seminar (held at 12:30 on Tuesdays and Thursdays respectively); Graduate Student Brown Bag Seminar (1:00pm on Fridays); 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 students are exempt from this requirement; however, first-year students are still strongly encouraged to attend. For example, students entering the program in Fall 2016 who take the oral comprehensive exam in Spring 2019 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.

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 Chair 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 comprehensive 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 Chair. 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-four (24) units from the core courses: MATH/APPL 581 A/B; MATH/APPL 584 A/B; MATH/APPL 589 A/B; MATH 586 A/B (1-2 units) and RTG Independent Study 599 (3 units).
- 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. Students admitted to the Program in the Fall 2014 and thereafter may not use any 400-level coursework. 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 6 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 Oral 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 Oral 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 Process 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 Process

This important process is described in detail in Section VII.

The PhD Oral Comprehensive Examination

The Oral 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 Oral 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 Oral 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 submit a Special Member request to the Graduate College for approval. 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) Oral Comprehensive Exam Committee Appointment Form; 3) Announcement of Doctoral Oral 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 Oral 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 Oral 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.** Assistance with creating a website can be found at <https://bit.ly/3tbALy8> If the committee does not find these requirements satisfactory, the Oral Comprehensive Exam will not take place.
- A “road map” describing (i) the student's plan of study after the Oral 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 Comprehensive Exam following the standard rules of the Graduate College.

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

The Oral 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 Oral 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 Oral Comprehensive Exam is conducted as a closed exam and no portion of it is open to the public.**

Oral Comprehensive Examination Committee and Exam Logistics

To reiterate: the Oral 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 Oral Comprehensive exam committee students should bear in mind that the dissertation committee is formed (see below) soon after passing the Oral 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 Oral 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 Oral Comprehensive Examination

Occasionally, a student fails the Oral 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 Chair. 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 Chair, one faculty member chosen by the student, and a third faculty member at the discretion of the Chair. 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 Comprehensive Exam has been scheduled.

If the student has already scheduled (or completed) his or her Oral Comprehensive Exam by the end of the third year, the review will take the form of a brief meeting with the Program Chair and the student advisor where she/he will present a plan of study (including a description of the Oral 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 Oral Comprehensive Exam is scheduled (as noted above). After successful completion of the Oral 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 available to the public online at <https://search.proquest.com/advanced?selectids=pqdtft>. 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 Oral 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 should 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 Oral 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 Oral 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 Oral 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 Oral 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 Chair. This proposal will be reviewed by Final Defense committee members. Other types of proposals may also be permitted subject to approval by the Program Chair. 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 Oral 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 Chair.

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-four (24) units from the core courses: MATH/APPL 581 A/B; MATH/APPL 584 A/B; MATH/APPL 589 A/B; MATH 586 A/B (1-2 units) and RTG Independent Study 599 (3 units).

- 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. Students should be careful that courses counted towards the Minor are not 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 6 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 Chair must approve the Doctoral Plan of Study form in GradPath prior to the Oral Comprehensive Exam date.

PhD Recommended Timeline

| | |
|-------------|--|
| Year 1 | <ul style="list-style-type: none"> ● Complete core courses ● Identify research areas of interest ● Complete Qualifying Process ● Apply for a summer internship in the field of interest |
| Year 2 | <ul style="list-style-type: none"> ● Using GradPath, submit the <u>Master’s Specialist Plan of Study</u> and <u>Master’s Completion of Degree Requirements</u> forms to receive MS degree in the spring semester. ● Investigate research opportunities in one or more areas ● Identify possible research advisors ● Apply for a second summer internship in a different (than first) field of interest |
| Year 3 | <ul style="list-style-type: none"> ● Select an advisor ● Using GradPath, submit <u>Doctoral Plan of Study</u>, <u>Oral Comp Exam Committee Appointment Form</u> ● Schedule Oral Comprehensive Exam and, using GradPath, submit the <u>Announcement of Doctoral Oral Comprehensive Exam</u> ● Using GradPath, your advisor will submit the <u>Results of Oral Comprehensive Examination</u> after your exam ● Begin doctoral research and select your Dissertation Committee. |
| Years 4 & 5 | <ul style="list-style-type: none"> ● 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 <u>Doctoral Dissertation Committee Appointment</u> form ● Select outside dissertation reviewer ● Using GradPath, submit the <u>Announcement of Final Oral Defense</u> ● Pass Dissertation Defense Examination ● Using GradPath, your advisor will submit the <u>Results of Final Oral Defense</u> ● Electronically submit final copy of dissertation to the Graduate Student Academic Services (GSAS) 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 24 units from the core courses (see Section III, "PhD in Applied Mathematics Curriculum")
- 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 courses must be at the 500-level for students admitted to the Program starting in the Fall 2014 and thereafter.

Examination Requirements

Successfully complete the Qualifying Process (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

Please note: When filling 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.'

(i) If you are filing for a **terminal MS degree** you do **not** need to identify a committee and you may check "no" in reference to above

(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 Chair as your advisor.

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

VII The Qualifying Process

Purpose

The purpose of the qualifying process is two-fold:

- To test core material considered important for advanced work in applied mathematics.
- To provide feedback to the students to help identify areas which need improvement

Diagnostic Exam

New incoming students will take a diagnostic exam in August before their first semester, to evaluate if they are ready for the core classes so that the Program Chair can suggest any remedial classes/independent study as necessary.

Core Courses - Finals 1

Finals for the six core course exams are equated to the written qualifier. The exam will be prepared by the core course instructors in collaboration with the qualification committee whose membership will be largely stable across years. Each question on the exam will be graded by the core instructor, and separately by the member of the qualification committee. Overall results are "pass" or "no pass" in each of the three areas of theory, methods and algorithms (taught in Math 584, Math 581 and Math 589 respectively) will be decided by the qualification committee. Three "pass" grades will indicate completion of the qualification requirement for the PhD.

No pass resolution - oral exam

A student with "no pass" in one or more areas will then be called for an oral examination at the end of the third semester after starting the core. The committee of AM faculty will convene for the oral exam and to discuss the results of the written and oral exams as part of a broad-based assessment including (but not limited to) the 586a,b, 599 Independent study RTG projects presentations and papers and the evaluation of the mentor for the projects, to decide if the student has demonstrated sufficient mastery of the required core materials. The decision of the committee

to determine if the student is qualified for PhD (with or without conditions) or qualified for M.S. (with or without conditions) and leave the program with a terminal M.S. (when conditions are completed) will be communicated in the form of written feedback.

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

Comments

Although most students who pass the written Qualifying Process at the PhD level go on successfully to complete a PhD, completion of the process 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 completion of the Qualifying Process and provides the Program and student with the opportunity to assess the student's readiness and ability to write an original, high-quality dissertation.

It is also important to note that while the Qualifying Process 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 taking the oral examination can play a significant role in determining the final outcome of the qualifying exam.

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 4 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

Chair. 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 with a 10-hour work week.

The University's Graduate Assistantship Hiring Manual states that to maintain student employee status, graduate students are limited to no more than 26.4 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 26.4-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 26.4 hours per week 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 Policies for GAs

When a 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:

- Must enroll for a minimum of 6 graduate-level units, or the minimum required by your department.
- 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.
- The Graduate College offers many benefits for the student hired on a Notice of Appointment contract such as tuition remission, parental leave, health insurance, family and medical leave, temporary alternative duty assignments, bookstore discount, deferment plan, and qualified tuition reduction. Details about these benefits and more can be found in the GA Manual at <https://grad.arizona.edu/funding/ga/>

Additional University and Mathematics Department Information for GAs

- New TAs in the Math Department are **required** to complete a 3-day, pre-semester training, course meetings, and attend a year-long course about teaching

mathematics. GTAs are also mandated to complete the University's Teaching Assistant/Associate Training Online (TATO).

- Math 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.

Student Appeals

All students in the Program in Applied Mathematics GIDP have the right to an internal appeal process regarding decisions which impact their academic standing. Appeals should be made in writing to the Program Chair and will be considered at the next Steering Committee meeting.

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

Instructor's name: _____

Brief statement of why you were not able to take your Oral 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 Oral Comprehensive exam: _____

Planned Date of Oral Comprehensive Exam: _____

Student's signature: _____

Date: _____

Instructor's signature: _____

Date: _____

Program Chair signature: _____

Date: _____

*(Required for 2rd and 3rd semester of registration of 900 units)