

UNIVERSITY FACULTY SENATE FORMS

Academic Program Approval

This form is a routing document for the approval of new and revised academic programs. Proposing department should complete this form. For more information, call the Faculty Senate Office at 831-2921.

Submitted by: ___Tobin Driscoll_____ phone number ___3383_____

Department: ___Mathematical Sciences_____ email address ___driscoll@udel.edu_____

Date: ___11/8/11_____

Action: ___admission policy change for graduate programs_____

(Example: add major/minor/concentration, delete major/minor/concentration, revise major/minor/concentration, academic unit name change, request for permanent status, policy change, etc.)

Effective term _____12F_____

(use format 04F, 05W)

Current degree ___MS and PhD_____

(Example: BA, BACH, BACJ, HBA, EDD, MA, MBA, etc.)

Proposed change leads to the degree of: ___(no change)_____

(Example: BA, BACH, BACJ, HBA, EDD, MA, MBA, etc.)

Proposed name: _____

Proposed new name for revised or new major / minor / concentration / academic unit (if applicable)

Revising or Deleting:

Undergraduate major / Concentration: _____

(Example: Applied Music – Instrumental degree BMAS)

Undergraduate minor: _____

(Example: African Studies, Business Administration, English, Leadership, etc.)

Graduate Program Policy statement change: ___admission policy _____

(Must attach your Graduate Program Policy Statement)

Graduate Program of Study: _____

(Example: Animal Science: MS Animal Science: PHD Economics: MA Economics: PHD)

Graduate minor / concentration: _____

Note: all graduate studies proposals must include an electronic copy of the Graduate Program Policy Document, highlighting the changes made to the original policy document.

List new courses required for the new or revised curriculum. How do they support the overall program objectives of the major/minor/concentrations)?

Not applicable.

(Be aware that approval of the curriculum is dependent upon these courses successfully passing through the Course Challenge list. If there are no new courses enter "None")

Explain, when appropriate, how this new/revised curriculum supports the 10 goals of undergraduate education: <http://www.ugs.udel.edu/gened/>

Not applicable.

Identify other units affected by the proposed changes:

(Attach permission from the affected units. If no other unit is affected, enter "None")

None.

Describe the rationale for the proposed program change(s):

(Explain your reasons for creating, revising, or deleting the curriculum or program.)

1. The department has long had an English proficiency admission requirement in our own policy document, though not in the catalog. This change makes the policy clearer in the catalog.
2. We have used our existing score requirement (600) for the written TOEFL, and the graduate office's table of equivalent scores, to come up with the minimum values on the other tests.
3. Upon the recommendation of Karen Asenavage at the English Language Institute, we are also requiring a minimum score for each subsection, so that deficiencies in one area (often, speaking) cannot be compensated by extra effort in another.
4. We no longer will accept the graduate office's default exemption of the TOEFL/IELTS requirement for students who receive a higher education degree from the US or another English speaking country. In our experience, standards and practices at other institutions vary widely, and spending time as a student in an English-speaking country does not guarantee proficiency in English.
5. Minor corrections, updates, and cosmetic changes have been made to the program policy statement.

Program Requirements:

(Show the new or revised curriculum as it should appear in the Course Catalog. If this is a revision, be sure to indicate the changes being made to the current curriculum and **include a side-by-side comparison** of the credit distribution before and after the proposed change.)

ROUTING AND AUTHORIZATION: (Please do not remove supporting documentation.)

Department Chairperson _____ Date _____

Dean of College _____ Date _____

Chairperson, College Curriculum Committee _____ Date _____

Chairperson, Senate Com. on UG or GR Studies _____ Date _____

Chairperson, Senate Coordinating Com. _____ Date _____

Secretary, Faculty Senate _____ Date _____

Date of Senate Resolution _____ Date to be Effective _____

Registrar _____ Program Code _____ Date _____

Vice Provost for Academic Affairs & International Programs _____ Date _____

Provost _____ Date _____

Board of Trustee Notification _____ Date _____

Revised 02/09/2009 /khs

Table 1 - Side-by-side course catalog comparison

Current Course Catalog Description	Proposed Course Catalog Description
<p>Mathematical Sciences</p> <p>Telephone: (302) 831-2346 http://www.math.udel.edu Faculty Listing: http://www.math.udel.edu/people/</p> <p>Program Overview</p> <p>The Department of Mathematical Sciences offers programs of study leading to the degrees of Master of Science and Doctor of Philosophy in Applied Mathematics or Mathematics. The department also offers a 4+1 BS/MS program that allows students to complete both the Bachelor of Science degree in any undergraduate major administered by the department and the MS degree in a total of five years of full-time study.</p> <p>Many of the major areas of mathematics are included among the research interests of the faculty of the department. There are numerous active seminars on these and other mathematical topics, as well as a steady stream of visiting scientists from all over the world.</p> <p>The department is committed to providing individualized attention and guidance to every student in the program.</p> <p>Requirements for Admission</p> <p>Admission to the graduate programs in Applied Mathematics and Mathematics is open to students who have completed the equivalent of a baccalaureate degree in mathematics or related fields, and have a sound preparation in linear algebra and advanced calculus. On a 4.0 system, applicants should have a GPA of at least 2.5 and an average of at least 3.0 in mathematics and related areas. Applicants who have</p>	<p>Mathematical Sciences</p> <p>Telephone: (302) 831-2346 http://www.math.udel.edu Faculty Listing: http://www.math.udel.edu/people/</p> <p>Program Overview</p> <p>The Department of Mathematical Sciences offers programs of study leading to the degrees of Master of Science and Doctor of Philosophy in Applied Mathematics or Mathematics. The department also offers a 4+1 BS/MS program that allows students to complete both the Bachelor of Science degree in any undergraduate major administered by the department and the MS degree in a total of five years of full-time study.</p> <p>Many of the major areas of mathematics are included among the research interests of the faculty of the department. There are numerous active seminars on these and other mathematical topics, as well as a steady stream of visiting scientists from all over the world.</p> <p>The department is committed to providing individualized attention and guidance to every student in the program.</p> <p>Requirements for Admission</p> <p>Admission to the graduate programs in Applied Mathematics and Mathematics is open to students who have completed the equivalent of a baccalaureate degree in mathematics or related fields, and have a sound preparation in linear algebra and advanced calculus. On a 4.0 system, applicants should have a GPA of at least 2.5 and an average of at least 3.0 in mathematics and related areas. Applicants who have</p>

completed an advanced degree must have done so with a GPA of at least 3.0. In addition, applicants must take the GRE Aptitude Test.

Students applying to the 4+1 BS/MS program must be in their junior year of study at the University of Delaware enrolled in a Bachelor of Science degree program administered by the Department of Mathematical Sciences, must have a cumulative GPA of at least 3.2, a GPA of at least 3.4 in their major, and must have completed at least two mathematics courses at or above the 400 level. Two letters of recommendation and academic transcripts are required as part of the application process. The letters of recommendation must be from University of Delaware faculty.

Financial Aid

Students holding assistantships are expected to perform satisfactorily in their assigned duties and to make good progress in their academic work. Renewal of financial aid is not automatic. Due to the size of our program, we can only offer financial aid for up to 10 semesters for students entering with a Bachelor's degree; those entering with a Master's degree for up to 8 semesters. The department, however, will make every attempt to provide some form of funding for qualified students. First year teaching assistants are required to attend teaching workshops scheduled by the department.

For continued support beyond the 3rd year, a student entering with a Master's degree must pass the Candidacy Exam by the beginning of his/her 4th semester in order to be offered continued support beyond the 2nd year. For a student who does not pass the Candidacy Examination on the first try, there is no guarantee for support for the following academic year. However, a student may make a second and final attempt to pass the Candidacy Examination, and if the attempt is successful, the department will make every effort to secure funding for such a student.

completed an advanced degree must have done so with a GPA of at least 3.0. In addition, applicants must take the GRE Aptitude Test.

To be eligible for admission, students from a country where English is not a primary language must demonstrate proficiency in English by scoring at least 600 on the paper-based TOEFL exam, at least 100 on the TOEFL iBT, with a minimum score of 20 in each section, or at least 7.5 on the IELTS, with a minimum score of 6.0 in each subsection.

Students applying to the 4+1 BS/MS program must be in their junior year of study at the University of Delaware enrolled in a Bachelor of Science degree program administered by the Department of Mathematical Sciences, must have a cumulative GPA of at least 3.2, a GPA of at least 3.4 in their major, and must have completed at least two mathematics courses at or above the 400 level. Two letters of recommendation and academic transcripts are required as part of the application process. The letters of recommendation must be from University of Delaware faculty.

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For continued support beyond the 3rd year, a student entering with a Master's degree must pass the Candidacy Exam by the beginning of his/her 4th semester in order to be offered continued support beyond

Requirements for the Master's Degree

To be eligible for the degree an M.S. candidate must complete 30 hours of course work beyond the Bachelor's degree. Students must maintain a GPA of 3.0 or better. These thirty hours of course work must be at or above the 600 level excluding [Math 607](#). Students may take 3 credit hours worth of coursework outside of the department. Any additional course work taken for credit outside of the department requires approval of the Graduate Studies Committee.

Of the 30 credit hours required for an MS, at most 3 credits can be from a reading course unless an exception is granted by the Graduate Studies Committee.

The thesis option for the M.S. degree consists of 24 credit hours of course work plus 3 credit hours of research via [Math 868](#) and 3 credit hours of thesis via [Math 869](#), leading to a Master's Thesis. The purpose of this option is to assess the student's ability to conduct and report original research on a particular area within the field of specialization and/or synthesize and critically analyze important issues in the field of specialization. The particular form of the thesis project (e.g., report of original research or critical review of and exposition on the literature) will be determined by the student in consultation with his or her Thesis Advisor and the Thesis Committee. The Thesis Committee shall consist of three faculty; it is not required that a member of the committee be from outside mathematics. After the topic(s) and project format have been determined, the student will have a maximum of one year to complete the written thesis (typically 50 to 60 pages). An oral defense will be scheduled following the Thesis Committee's evaluation of the thesis.

All requirements above must be fulfilled by any student enrolled in the 4+1 BS/MS program. However, a student may count up to six credit

the 2nd year. For a student who does not pass the Candidacy Examination on the first try, there is no guarantee for support for the following academic year. However, a student may make a second and final attempt to pass the Candidacy Examination, and if the attempt is successful, the department will make every effort to secure funding for such a student.

Requirements for the Master's Degree

To be eligible for the degree an M.S. candidate must complete 30 hours of course work beyond the Bachelor's degree. Students must maintain a GPA of 3.0 or better. These thirty hours of course work must be at or above the 600 level excluding [Math 607](#). Students may take 3 credit hours worth of coursework outside of the department. Any additional course work taken for credit outside of the department requires approval of the Graduate Studies Committee.

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hours of graduate courses in the mathematical sciences earned while the student was an undergraduate toward the total unit requirement for the MS degree.

Requirements For The PhD Degree

Students with no prior graduate course work must complete 48 credit hours of courses including:

- At least 27 credits of MATH courses at the 600 level or above, excluding [MATH 607](#).
- A maximum of 27 credits of MATH courses at the 600 level.
- A maximum of 6 credits of [MATH868](#) (Research).
- A maximum of 6 credits at the 600 level or above in non-MATH courses, unless special permission is granted in advance by the Graduate Committee.

Candidates for the Ph.D. degree must also:

- Maintain a GPA of 3.0 or better.
- All Applied Mathematics and Mathematics students must complete the requirements for MS and pass the **Preliminary Examination** based on [MATH 600](#), [MATH 602](#), (Advanced Calculus) and [MATH 672](#) (Linear Algebra) or [MATH 612](#) (Numerical Linear Algebra). Students entering with Bachelor's degrees are required to pass the Preliminary Examination by the beginning of their 4th semester. Students entering with a Master's degree must complete this requirement by the end of the second semester of study. Students who do not meet this requirement are recommended for dismissal.

complete the written thesis (typically 50 to 60 pages). An oral defense will be scheduled following the Thesis Committee's evaluation of the thesis.

All requirements above must be fulfilled by any student enrolled in the 4+1 BS/MS program. However, a student may count up to six credit hours of graduate courses in the mathematical sciences earned while the student was an undergraduate toward the total unit requirement for the MS degree.

Requirements For The PhD Degree

Students with no prior graduate course work must complete 48 credit hours of courses including:

- At least 27 credits of MATH courses at the 600 level or above, excluding [MATH 607](#).
- A maximum of 27 credits of MATH courses at the 600 level.
- A maximum of 6 credits of [MATH868](#) (Research).
- A maximum of 6 credits at the 600 level or above in non-MATH courses, unless special permission is granted in advance by the Graduate Committee.

Candidates for the Ph.D. degree must also:

- Maintain a GPA of 3.0 or better.
- All Applied Mathematics and Mathematics students must complete the requirements for MS and pass the **Preliminary Examination** based on [MATH 600](#), [MATH 602](#), (Advanced Calculus) and [MATH 672](#) (Linear Algebra) or [MATH 612](#) (Numerical Linear Algebra). Students entering

- Pass the oral Candidacy Examination.
- Select a Dissertation Committee, subject to the approval of the Graduate Committee.
- Complete two semesters of experience in teaching undergraduate students, or obtain a waiver from the Graduate Committee.
- Complete 9 credits of [MATH 969](#) (Doctoral Dissertation) after admission to candidacy.
- Complete and successfully defend a dissertation.

Candidacy Exam: A student entering with a Bachelor's degree must pass the oral Candidacy Exam by the beginning of their sixth semester of study. Students entering with a Master's degree must pass the Candidacy Examination by the beginning of their fourth semester of study. A second and final attempt is permitted. Dismissal will be recommended for a student who does not pass the Candidacy Exam on the second try.

In this examination a student must choose 2 topics from Algebra, Analysis, Applied Mathematics, Discrete Mathematics, Probability, and Numerical Analysis. The exams are based on [MATH 650](#) and [MATH 845](#) (Algebra), [MATH 616](#), [MATH 617](#) and [MATH 810/MATH 835](#) (Applied Mathematics), [MATH 688](#) and [MATH 888](#) (Discrete Mathematics), [MATH 613](#), [MATH 612](#) and [MATH 813/MATH814](#) (Numerical Analysis), [MATH 806](#) and [MATH 836](#) (Functional Analysis and PDE) and [MATH 630](#), [MATH 631](#) and [MATH 850](#) (Probability). Another subject area may be substituted for one of the above by petition to the graduate committee based on two graduate level courses and supported by a faculty member.

Dissertation: A student must successfully defend his/her dissertation

with Bachelor's degrees are required to pass the Preliminary Examination by the beginning of their 4th semester. Students entering with a Master's degree must complete this requirement by the end of the second semester of study. Students who do not meet this requirement are recommended for dismissal.

- Pass the oral Candidacy Examination.
- Select a Dissertation Committee, subject to the approval of the Graduate Committee.
- Complete two semesters of experience in teaching undergraduate students, or obtain a waiver from the Graduate Committee.
- Complete 9 credits of [MATH 969](#) (Doctoral Dissertation) after admission to candidacy.
- Complete and successfully defend a dissertation.

Candidacy Exam: A student entering with a Bachelor's degree must pass the oral Candidacy Exam by the beginning of their sixth semester of study. Students entering with a Master's degree must pass the Candidacy Examination by the beginning of their fourth semester of study. A second and final attempt is permitted. Dismissal will be recommended for a student who does not pass the Candidacy Exam on the second try.

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in front of a committee consisting of the dissertation advisor and no less than three additional members, one of whom must be from outside the department. The dissertation must contain original publishable results.

[630](#), [MATH 631](#) and [MATH 850](#) (Probability). Another subject area may be substituted for one of the above by petition to the graduate committee based on two graduate level courses and supported by a faculty member.

Dissertation: A student must successfully defend his/her dissertation in front of a committee consisting of the dissertation advisor and no less than three additional members, one of whom must be from outside the department. The dissertation must contain original publishable results.

Graduate Programs in the Department of Mathematical Sciences

November 9, 2011

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1 The Academic Program

1.1 History

Mathematics was present at the University of Delaware right from the start. The founder of the university, Francis Alison, wrote of his new school in 1768 “The Languages are carefully taught, along with arithmetic, geometry, practical branches of mathematics, and logic.” By 1773, the fledgling academy employed two professors - a philosopher and a mathematician. By 1826, the department structure had arrived at U.D., with a separate room set aside for a “Mathematical and English Department.” In 1832, mathematics became part of a new department of “Mathematics and the Natural Sciences.” Over the next century, both the university and the department underwent significant growth but it wasn’t until the late 1950’s that doctoral programs were established at the University of Delaware. In 1965, the Department of Mathematical Sciences created the seventh doctoral program hosted by the university. By 1969, the department had awarded its first Ph.D. degree.

Over the last forty years, well over one hundred students have received doctoral degrees in Mathematics or Applied Mathematics from the University of Delaware. Graduates from our program have gone on to prestigious postdoctoral positions at institutions such as Oxford University, the University of Arizona, and the University of Minnesota. They hold or have held academic positions worldwide and they work in industry, commerce, and government at organizations such as DuPont, Merck, and the National Security Agency. Today, with active research groups in numerous areas of pure and applied mathematics, the department continues to train high-quality mathematics researchers destined to impact the future of mathematics and its applications worldwide.

1.2 Introduction

The Department of Mathematical Sciences offers programs of study leading to Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Applied Mathematics and Mathematics. The department also offers a 4+1 BS/MS program allowing students to complete both a Bachelor of Science and Master of Science degree in five years of full-time study. Requirements for the degrees in the various programs are detailed in Chapter 3.

Many of the major areas of mathematics are included among the research interests of the faculty of the department. There are numerous active seminars on these and other mathematical topics, as well as a steady stream of visiting scientists from all over the world.

1.3 Getting Started

The authority for administering the program rests with the Graduate Studies Committee. The Director of Graduate Studies serves as adviser to all students until such time as a supervisor for the thesis or dissertation is appointed. The Director of Graduate Studies will help you formulate your plan of study through twice yearly scheduled meetings prior to preregistration and through additional meetings as needed.

New students, as part of the usual orientation program, will meet with the Director of Graduate Studies to plan their first year of study in the program. It is recommended that incoming students with an M.S. take the Preliminary Exam prior to beginning courses. Well prepared students with a B.S. may also take the Preliminary Exam in the August prior to beginning course work. Sample exams will be mailed on request. Exams are usually given the week before classes begin ^{Driscoll:} [in fall and spring semesters](#). Please see the website for details.

~~During advisement, help will be given concerning course selection based on students' interests, students' undergraduate background, and the results of the preliminary exam if you choose to take it. Each student will have a progress sheet on which the courses taken,~~
During advisement, help will be given concerning course selection based on a student's interests and undergraduate background, and the results of the Preliminary Exam if taken. Each student has a progress sheet on which the courses taken, grades, and progress toward the degree is noted. Before each semester, students must obtain their advisor's permission to register. Continuing students are required to enroll for courses during the preregistration period, and are required to meet with the Director of Graduate Studies. The department is committed to providing individualized attention and guidance to every student in the program. If at any time you have concerns, questions, or difficulties, you are encouraged to discuss them with any faculty member as well as with your fellow students.

1.4 General Plan of Study

In making your plan of study, you should pay particular attention to the timing of course offerings and your background and interests. It is not unusual that you may want to change your plan as your experience in the department grows. Nevertheless, having even a tentative plan will serve to ensure progress toward your degree.

As you develop your plan of study, you should keep the following points in mind.

- Students holding Graduate Assistantships (**GA**), Research Assistantships (**RA**), or Graduate Teaching Assistantships (**TA**) must register for a minimum of 9 ~~hours~~credits of course work.
- It is expected that the requirements for a Master's degree be completed by the end of the fourth semester^{Driscoll:} for full-time students.
- A student must pass the Preliminary Exam by the beginning of the fourth semester in order to continue his/her studies beyond the Master's degree.

For a student to remain in the Graduate Program a minimum cumulative GPA of 3.0 (B) is required. Students who do not perform to this standard are subject to review and/or dismissal as determined by the Graduate Student Probation Policy.

Permission to continue study toward a Ph.D. degree is given on the basis of ^{Driscoll:} a complete ongoing review of your academic performance^{Driscoll:} ~~The Graduate Studies Committee permits students to enter the Ph.D. program on the basis of,~~ as measured by performance on the Preliminary Exam, course grades, and instructor assessments. By the time you ^{Driscoll:} are admitted to become a candidate in the Ph.D. program, you ^{Driscoll:} should will have identified an area in which you wish to ^{Driscoll:} work write your dissertation.^{Driscoll:} ~~The Department may waive course requirements and certify that requirements have been met after a review of your record. The department will work with the Graduate Office at that time to certify that all requirements have been met after a review of your record. Waivers of requirements will be at the discretion of the Graduate Studies Committee.~~

^{Driscoll:} ~~Waiver of hour requirements will be made on the basis of transcripts and information supplied by you. You should make an appointment with the Director of Graduate Studies as early as possible to ensure that all the information the Committee will need is available. It is important that your course waivers be approved as early as possible so that you know what requirements you will have to satisfy for your degree. Transfer of credit from other U.S. institutions is available only for courses at the graduate level that have not counted towards the requirements of any other academic degree. Permission is required from the student's advisor and the Chair of the department. A form and instructions are available from the website of the university's Office of Graduate Studies. Transfers of credit should be requested in a timely manner so that the student's plan of study is clear. Transfer of credit from non-U.S. institutions is generally not possible.~~

2 Regulations for the Master's and Ph.D. Programs

1. In order to graduate with a Master's Degree in Mathematics, a student must satisfy the general academic requirements of the Office of Graduate Studies and must have a "B" or better average in all courses.
2. Under normal circumstances a student with a "C" or lower in 3 courses will be advised to leave the graduate program.
3. A student who has not passed the Candidacy Exam for the Ph.D. is not allowed to register for Ph.D. dissertation or noncontractual research.
4. Two semesters experience in the teaching of undergraduates is required of all candidates for a Master's Degree and Ph.D. candidates. This is a Departmental requirement; students may petition the Graduate Studies Committee for a waiver of this requirement.
5. The Graduate Office requires that those graduate students holding GAs, RAs and TAs register for a *minimum* of 6 hours. However, it is the policy of the department that all such students register for 9 hours each semester. Under special circumstances, and when approved by the Graduate Studies Committee, 3 hours may be taken as a listener. The Graduate Studies Committee *strongly* discourages students in their first three years of study from registering as a listener. Students may carry more than the 9 credits which are covered by the tuition. A student wishing to carry 13 credits or more must first get permission from the Department Director of Graduate Studies and the Office of Graduate Studies.
6. ^{Driscoll:} ~~Students who expect to continue beyond the Master's level toward a Ph.D. degree~~ Students enrolled in the M.S. program who wish to continue on to the Ph.D. program must file a Change of Classification Form no later than the start of their fourth semester.
7. Students enrolled in the 4+1 BS/MS program must satisfy regulations number one and number two from this list. ^{Driscoll:} In particular, students in the 4+1 BS/MS program are not required to obtain teaching experience.

3 Program Descriptions

3.1 Admission Requirements

Admission to the graduate programs in Applied Mathematics and Mathematics is open to students who have completed the equivalent of a baccalaureate degree in mathematics or related fields, and have a sound preparation in linear algebra and advanced calculus. On a 4.0 system, applicants should have a GPA of at least 2.5 and an average of at least 3.0 in mathematics and related areas. Applicants who have completed an advanced degree must have done so with a GPA of at least 3.0. In addition, applicants must take the GRE ^{Driscoll:} ~~Aptitude Test. The applicant is required to take a GRE subject test.~~ General Test and one GRE Subject Test. It is not required that ^{Driscoll:} ~~this subject test be in mathematics, i.e., a student may submit results of a GRE subject test in any field as part of their application.~~ the GRE Subject Test be in mathematics.

^{Driscoll:} ~~For foreign students, the TOEFL exam is also required, with a minimum grade of 600 for the written exam or 250 for the electronic exam. The IELTS exam will be accepted in place of the TOEFL. The minimum score for the IELTS is 6.5 with no subsection below 6.0.~~

^{Driscoll:} [This paragraph was approved by the department faculty on 11/1/2011.] To be eligible for admission, students from a country where English is not a primary language must demonstrate proficiency in English by meeting at least one of the following criteria:

- Score at least 600 on the paper-based TOEFL exam.
- Score at least 100 on the TOEFL IBT, with a minimum score of 20 in each section.
- Score at least 7.5 on the IELTS with a minimum score of 6.0 in each subsection.

Admission to the graduate program is selective and competitive based on the number of well-qualified applicants and the limits of available faculty and facilities. Those who meet stated minimum academic requirements are not guaranteed admission, nor are those who fail to meet those requirements necessarily precluded from admission if they offer other appropriate strengths.

Students who wish to be admitted to the 4 + 1 BS/MS program should submit an application during their junior year of academic study toward an undergraduate degree at the University of Delaware. Such students must be enrolled in a Bachelor of Science degree program administered by the

Department of Mathematical Sciences. At a minimum, the applicant must have a cumulative GPA of 3.2 and a GPA of 3.4 in their undergraduate major. The applicant must have completed at least two mathematics courses at or above the 400 level. Two letters of recommendation from University of Delaware faculty and academic transcripts must be submitted. Neither the GRE nor the TOEFL exam is required. However, note that meeting minimum requirements is not a guarantee of admission. Similarly, those who fail to meet minimum requirements are not precluded admission if they offer other appropriate strengths.

3.2 Requirements for the M.S. in Mathematics and Applied Mathematics

Driscoll: ~~To be eligible for the degree an M.S. candidate must complete 30 hours of course work beyond the Bachelor's degree. Students must maintain a GPA of 3.0 or better. Note, all requirements in this section apply to students enrolled in the 4 + 1 BS/MS program. However, such students may count up to six hours of course work in the mathematical sciences, at or above the 600 level, excluding Math 607, toward both their BS and MS degrees.~~ To be eligible for the degree, an M.S. candidate must complete 30 credits of course work beyond the Bachelor's degree, subject to all of the following conditions:

1. *Driscoll:* ~~Complete thirty hours of course work at or above the 600 level excluding Math 607. Students may take 3 credit hours worth of course work outside of the department. Any additional course work taken for credit outside of the department requires approval of the Graduate Studies Committee.~~ The student must maintain a GPA of 3.0 or better.
2. *Driscoll:* Coursework must be at or above the 600 level, exclusive of courses that the catalog designates as not counting towards mathematics graduate degrees.
3. *Driscoll:* Students in the 4 + 1 program may count up to six credits of course work in the mathematical sciences, at or above the 600 level and exclusive of courses that the catalog designates as not counting towards mathematics graduate degrees, toward both their B.S. and M.S. degrees.
4. *Driscoll:* A maximum of 3 credits of course work taken outside of the mathematical sciences may be applied. The use of any additional course work taken for credit outside of the department requires approval of the Graduate Studies Committee.

5. ~~*Driscoll:* Of the 30 credit hours required for an MS, at most 3 credits can be from a reading course unless an exception is granted by the Graduate Studies Committee. A maximum of 3 credits may be from a reading course (MATH 870). The use of additional reading credits requires approval of the Graduate Studies Committee.~~
6. ~~*Driscoll:* The thesis option for the M.S. degree consists of 24 credit hours of course work plus 3 credit hours of research via Math 868 and 3 credit hours of thesis via Math 869, leading to a Master's Thesis. For students who select the thesis option for the M.S., the 30 credit total must include 3 credit hours of research (MATH 868) and 3 credit hours of thesis (MATH 869), leading to a Master's Thesis.~~ The purpose of this option is to assess the student's ability to conduct and report original research on a particular area within the field of specialization and/or synthesize and critically analyze important issues in the field of specialization. The particular form of the thesis project (e.g., report of original research or critical review of and exposition on the literature) will be determined by the student in consultation with his or her Thesis Advisor and the Thesis Committee. The Thesis Committee shall consist of three faculty; it is not required that a member of the committee be from outside mathematics. After the topic(s) and project format have been determined, the student will have a maximum of one year to complete the written thesis (typically 50 to 60 pages). An oral defense will be scheduled following the Thesis Committee's evaluation of the thesis.

3.3 Requirements for the Ph.D. in Mathematics and Applied Mathematics

1. Complete 48 credits of coursework, including:
 - (a) At least 27 credits of MATH courses at the 600 level or above, ~~*Driscoll:* excluding MATH 607~~exclusive of courses designated in the catalog as not counting towards graduate degrees in mathematics.
 - (b) A maximum of 27 credits of MATH courses at the 600 level.
 - (c) A maximum of 6 credits of MATH 868 (Research).
 - (d) A maximum of 6 credits at the 600 level or above in non-MATH courses, unless special permission is granted in advance by the Graduate Committee.

2. Maintain a GPA of 3.0 or better.
3. Fulfill the Preliminary Examination requirement (see Chapter 4). Students entering with only a Bachelor's degree must complete this requirement by the beginning of the fourth semester of study. Students entering with a Master's degree must complete this requirement by the end of the second semester of study.
4. Pass the oral Candidacy Examination (see Chapter 5).
5. Select a Dissertation Committee, subject to the approval of the Graduate Committee.
6. Complete two semesters of experience in teaching undergraduate students, or obtain a waiver from the Graduate Committee.
7. Complete 9 credits of MATH 969 (Doctoral Dissertation) after admission to candidacy.
8. Complete and successfully defend a dissertation.

The course work requirements are a superset of those for the Master's degree. An M.S. degree is awarded once the requirements for it have been met.

Special notes about the Requirements for the Doctor of Philosophy in the University's Graduate Catalog: *If a student completes his or her course requirements before admission to candidacy, the student is expected to enroll for MATH 964 until admitted to candidacy. Once a student has been admitted to candidacy and has taken 9 credits of MATH 969, he or she must maintain matriculation in the graduate program via MATH 999 (Doctoral Sustaining).*

3.4 Seminar Attendance

~~*Driscoll:* The department offers a wide range of regularly scheduled seminars and colloquia. This includes the weekly Graduate Student Seminar series, the Applied Mathematics Seminar series, the Analysis and PDE Seminar series, the Discrete Mathematics Seminar series, the Probability Seminar series, the Scattering Theory Seminar series, and the Topology Seminar series. The department offers a wide range of regularly scheduled seminars and colloquia, including the Graduate Student Seminar series, Rees Distinguished Lecturers, and numerous seminar series organized by the faculty around research interests in the department.~~ *Driscoll:* Students should attend

~~the Graduate Student Seminar each week, should attend all colloquia, and should sample other available seminars during their first year.~~ Students should attend the Graduate Student Seminar each week and all departmental colloquia, in addition to sampling other available seminars during their first year. By the second year of study, students should have become a regular attendee at one or more regular department seminars in addition to the Graduate Student Seminar.

3.5 Dissertation

The typical student will select a thesis adviser by the end of the fifth semester of study. The thesis adviser will guide the student's research and preparation of the dissertation. The dissertation is expected to reflect the results of original, significant research written in a literate and scholarly manner worthy of publication. The student must defend their dissertation before a thesis committee consisting of the student's thesis adviser and no less than three and no more than five additional members. One member of the thesis committee must be from a different academic unit, or from outside of the University of Delaware. The student's dissertation must be ^{Driscoll:} ~~deposited~~ submitted to the department's main office at least two weeks prior to the oral defense. The time, date, and place of the oral defense will be announced to the faculty and the oral defense will be open to the academic community.

3.6 Sustaining Status

Once a student has completed all the course requirements, passed the Preliminary and the Candidacy Examinations, and registered for 9 credits of dissertation (MATH 969), the student is required to maintain his/her matriculation in the degree program by registering for Doctoral Sustaining (UNIV 999). A student must be registered in the semester in which the degree is awarded.

4 Preliminary Examinations

All students who wish to obtain a Ph.D. degree must take a written examination called the Preliminary Examination. The Preliminary Examination contains two subject areas: Real and Complex Analysis, which covers material from MATH 600 and MATH 602, and either Linear Algebra, which covers material from MATH 672, or Numerical Linear Algebra, which covers material from MATH 614. Note that material outside the course syllabi may be on the syllabus for the exams as given below.

The Preliminary Exam will be given twice each year, once before the start of the Fall Semester, and once before the start of the Spring Semester. For students entering with a Bachelor's degree, it is required that the Preliminary Exam be passed by the beginning of the fourth semester of study. Providing it is before the beginning of the 4th semester, a student may take each part of this exam up to two times. Only the part not passed needs to be repeated. Students who fail to pass both subject areas of the Preliminary Exam by the beginning of the fourth semester will be asked to leave the graduate program. Student's entering with a Master's degree must pass the Preliminary Exam by the start of the third semester of study. Providing it is by the start of the third semester of study, a student with a Master's degree may take each part of this exam up to two times. Only the part not passed needs to be repeated. Students entering with a Master's degree who fail to pass both subject areas of the Preliminary Exam by the end of the second semester will be asked to leave the graduate program. Notification of the results of the Preliminary Exams will be sent to the Office of Graduate and Professional Studies.

The syllabus to be covered by each examination is included in the following subsections. Please obtain copies of past examinations and the syllabus from the Graduate Program Secretary in 301 Ewing Hall. Note also that the references cited on the following pages are intended to indicate the material to be covered. It is not necessarily intended that the student study all the references.

4.1 Real and Complex Analysis

Topics covered on the exam include the following. Many of these topics are discussed in Math 600 and Math 602. References are given for each topic.

1. Metric Spaces: open and closed sets, compactness, connected sets, complete sets, continuous functions on metric spaces ([1], Chapters 3 and 4).
2. Continuity and Differentiation: mean value theorem, Rolle's theorem, Taylor's formula, derivatives of vector valued functions, uniform continuity, monotonic functions, functions of bounded variation ([1], Chapters 5 and 6).
3. Integration: Sets of measure zero. Lebesgue's criterion for the existence of Riemann integrals. The Lebesgue integral in R^1 . Convergence

theorems. Measurable functions. Fubini's theorem. Measurable sets. The space $L^2(I)$. The Riesz-Fischer theorem. ([1], Chapter 10)

4. Infinite Sequences and Series: Limit superior and limit inferior, monotonic sequences, alternating series, absolute and conditional convergence, power series, tests for convergence of series, rearrangement of series ([1], Chapter 8).
5. Sequences of Functions: Pointwise convergence, uniform convergence, uniform convergence and continuity, differentiability and integration ([1], Chapter 9).
6. Functions of Several Variables: Directional derivatives, the total derivative, Jacobians, inverse function theorem, implicit function theorem, extrema problems ([1], Chapters 12 and 13).
7. Vector Calculus: Line integrals, Green's theorem, surface integrals, Stokes theorem, the divergence theorem ([2], Chapters 10, 11 and 12).
8. Analytic Function Theory: Analytic functions, Cauchy's theorem, Cauchy's integral theorem, the maximum principle, the identity theorem, Taylor and Laurent series, the residue theorem, elementary conformal mappings ([1], Chapter 16).

References:

1. Tom Apostol, *Mathematical Analysis*, 2nd edition, Addison Wesley, 1974.
2. Tom Apostol, *Calculus, Vol. 2*, 2nd edition, John Wiley, 1969.

4.2 Linear Algebra

Topics covered on the exam include the following. Most of these topics are discussed in Math 672. References are given for each topic.

1. Subspaces, bases and dimension (Chapters 1 - 2, [SA]).
2. Linear transformations and matrix representations (Chapter 2, [SA]; Chapters III - IV, [SL]).
3. Determinants and rank (Chapter VI, Section V.3, [SL]).
4. Inner products and inner product spaces (Chapter 6, [SA]).

5. Linear functionals, adjoints, and dual spaces (Chapter 6, [SA]).
6. Bilinear forms, Hermitian forms, and quadratic forms (Chapter V, [SL]; Sections IV.A - IV.C, [MLC]).
7. Eigenvalues, eigenvectors, and characteristic polynomials (Sections VIII.1 - VIII.2, [SL]).
8. Cayley-Hamilton Theorem (Sections X.1 - X.2, [SL]; Sections III.A - III.C, [MLC]).
9. Operators on inner product spaces and Spectral Theorems (Chapter 7, [SA]; Section VIII.3 - VIII.6, [SL]; Section III.D, [MLC]).
10. Jordan Canonical Form (Chapter XI, [SL]; Section III.E, [MLC]; Chapter 8, [SA]).

References:

- SA** Sheldon Axler, *Linear Algebra Done Right, Second Edition*, Springer-Verlag, 1997.
- MLC** Morton L. Curtis, *Abstract Linear Algebra*, Springer-Verlag, 1990.
- SL** Serge Lang, *Linear Algebra, Third Edition*, Springer-Verlag, 1987.

4.3 Numerical Linear Algebra

Direct and iterative methods for the solution of linear systems, LU factorization, row pivoting, stable QR factorization, solution of linear least squares problems by normal equations and QR, stability and conditioning issues, power and inverse iterations, QR iteration, singular value decomposition, simple iterations for sparse matrices, conjugate gradients and other Krylov subspace iterations.

Suggested References:

1. L.N. Trefethen and D. Bau, III, *Numerical Linear Algebra*, SIAM (see e.g., I, II, III).
2. J.W. Demmel, *Applied Numerical Linear Algebra*, SIAM (Sections 2.1-2.4, 3.1-3.3, 4.4, 6.5, 6.6.)
3. A. Quarteroni, R. Sacco and F. Saleri, *Numerical Mathematics*, Springer-Verlag (Sections 3.1, 3.3, 4.1-4.3, 5.2-5.5, 5.8.)

5 Candidacy Examination

This oral examination can take place at any time mutually agreed upon by the Examining Committee and student. Students entering with a Bachelor's degree must pass the Candidacy Examination by the beginning of their sixth semester of study. Students entering with a Master's degree must pass the Candidacy Examination by the end of their fourth semester of study. A second and final attempt is permitted following a failed attempt. Dismissal will be recommended for a student who does not pass the Candidacy Examination on the second try. Students who fail the Candidacy Examination are eligible for the M.S. degree.

The student should take the following steps to organize their Candidacy Examination and are advised to allow ample time for the process:

1. Contact four faculty to act as an Examining Committee. Since the student must be examined on two topics, normally two faculty will be expert in each area. The thesis adviser should be a member of the committee if the student has already chosen one. Students are strongly encouraged to choose a thesis adviser prior to forming an examining committee for the Candidacy Examination.
2. After the faculty agree to serve as examiners the student should contact the Director of Graduate Studies at least six weeks in advance of the proposed examination date and supply the following information:
 - (a) Date of the exam.
 - (b) Names of the examiners making up the Examining Committee.
 - (c) Choice of topics. Note that the topics must contain material from at least one 8xx level course.
3. Final approval of the Examining Committee and topics rests with the Graduate Studies Committee. Only after the Graduate Studies Committee has approved the Examining Committee and topics may the exam take place.

The scheduling, topics and composition of the Examining Committee will be announced to the faculty.

It is the responsibility of the examining committee to decide the duration of the exam (typically 2-3 hours). They should report the results of the exam and a recommendation of Pass or Fail with written justification to the Director of Graduate Studies within two days of the exam. A final decision

on the outcome of the exam is the responsibility of the Graduate Studies Committee.

In this examination a student must choose 2 topics from the following table:

Topic	Relevant Courses
Algebra	M650 and ^{Driscoll:} M846 M845
Applied Mathematics	M616, M617 and M810/M835
Discrete Mathematics	M688 and M888
Numerical Analysis	^{Driscoll:} M613, M614 and M813/M814 M611, M612, and M817 or M838
Probability	M630, M631 and M850
Functional Analysis and PDE	M806 and M836

Another subject area may be substituted for one in the table above by petition to the Graduate Studies Committee. The substituted subject area must be based on at least two graduate level courses, and this petition must be supported by at least one faculty member who is also a member of the student's examining committee.

Should a candidate fail a part of the Candidacy Exam, the candidate need only retake the failed topic. In no case will a candidate be allowed to take the candidacy exam more than twice.

6 Assessment

All graduate programs in the Department of Mathematical Sciences are designed to take high-quality students, with a strong background in mathematics, and transform them into full-fledged practitioners of the discipline of mathematics. For students seeking the M.S. we seek to broaden and deepen their knowledge of mathematics and properly train them for a mathematics related career. For students seeking the Ph.D. we again seek to broaden and deepen their knowledge of mathematics and also to train them as practitioners so that they may impact the discipline in a deep and meaningful way.

6.1 Learning Outcomes

Our program focuses on five key learning objectives, or outcomes. These are:

- Graduates should be able to conduct original, quality research in particular area of specialization.
- Graduates should be able to synthesize and critically analyze important issues in their field and understand and appreciate how their work fits into the larger body of science.
- Graduates should be able to communicate mathematical proofs, ideas, and concepts orally.
- Graduates should be able to communicate mathematical proofs, ideas, and concepts in writing.
- Graduates should be able to demonstrate both breadth and depth of mathematical knowledge.

6.2 Assessment Plan

In order to ensure that our graduate programs are meeting the objectives stated above, our learning outcomes are continually monitored. Changes resulting from this assessment are implemented periodically. For each of the five learning objectives, we rely upon a variety of direct and indirect measurement tools. A sample is listed below for each objective.

- Are graduates conducting original, high quality research within their field of specialization?
 - Our sources of information include student thesis or dissertation, student publications, and conference presentations. Our measuring instruments are rubrics that quantify student research work for a thesis, dissertation, or conference presentation. Results are used to compare and contrast student work.
- Are students able to synthesize and critically analyze important issues in their field and understand and appreciate how their work fits into the larger body of science?
 - Our sources of information include student thesis, oral candidacy examinations, and oral theses defenses. Our measuring instrument is a rubric used by faculty serving on thesis committees.
- Are students able to communicate mathematical proofs, ideas, and concepts orally?

- Our sources of information include student evaluations of their performance as teaching assistants, oral candidacy examinations, oral theses defenses, talks in the Graduate Student Seminar, and talks at conferences. Our measurement instruments are rubrics for oral communication used by faculty for student presentations and a teaching observation form.
- Are students able to communicate mathematical proofs, ideas, and concepts in writing?
 - Our sources of information include our preliminary examinations, publications by students and a written thesis. Our measurement instruments include a common rubric for evaluating student writing.
- Are students able to demonstrate both breadth and depth of mathematical knowledge.
 - Our sources of information include results of preliminary examinations, results of oral candidacy examinations, and theses defenses. Our measurement instruments include a rubric to evaluate preliminary examinations, candidacy examinations, and faculty feedback on these examinations.

7 Financial Aid

Financial aid for study at Delaware takes several forms including Research Assistantships, Departmental Fellowships, Teaching Assistantships and Tuition Scholarships. These forms of financial aid are awarded by the Department on a yearly basis. Continuation of support is dependent upon your academic progress and on your performance of any duties assigned to you. All students receiving support of any kind are expected to discharge assigned tasks including certain jobs such as proctoring of departmental examinations and assisting with undergraduate registration.

The Department encourages students to compete for nationally advertised graduate fellowships. Information on what fellowships are currently available can be obtained from the graduate studies secretary.

The stipend for Teaching and Research Assistants for the 2009-2010 academic year is determined by the following schedule. Check the Departmental websites for updates.

1. Initial appointments of first year graduate students will be made at a rate no lower than the University minimum level; this is level 1.
2. TA qualified second year graduate students or initial appointment of TA qualified graduate students who have passed the Preliminary Exam will be paid at least \$250 more than level 1; this is level 2.
3. Graduate students who have passed their Candidacy Exam will be paid at least \$250 more than level 2; this is level 3.

Students will remain at level 2 until the requirements for level 3 are met.

As most students are supported as Teaching Assistants, at least for some period of their studies, it is expected that all graduate students prepare themselves for classroom teaching. All new students are required to participate in the Department's orientation and TA training program which takes place before the start of classes. The program includes both departmental and University presentations. In addition, new teaching assistants are required to attend teaching workshops scheduled by the department.

For foreign students, preparation for classroom duties includes work with the English Language Institute (ELI) both in the month preceding the Fall or Spring term as appropriate. Students also must attend departmental training sessions. ELI must certify that a foreign student has a sufficient command of English before the Department can make a classroom assignment. It is Departmental policy that no foreign student be supported more than two semesters without being certified for classroom assignments by ELI. Foreign students are expected to meet the following schedule with respect to test scores reported by ELI:

- (1) achieve a score of at least 600 on the TOEFL examination (or an equivalent score on another examination approved by ELI) before the beginning of the first semester of study;
- (2) attend the workshop for foreign Teaching Assistants given by ELI and CTE before the *beginning of the Fall or Spring term* of residence;
- (3) must meet the minimum requirements set forth by the University's policy for SPEAK and UDIA scores for ITA instructional assignments (level II).

7.1 Support for Student Travel

The department encourages graduate students to attend national meetings and supports this by providing funding for student travel. Students should note that additional funds are often available from the Office of Graduate

Studies, their thesis advisers, and other travel fellowship opportunities. The department follows the following guidelines in providing student travel funds.

1. Supported graduate students who pass both the preliminary and candidacy exams will be awarded an amount of travel money at the current rate determined by the department for use during the remainder of their studies at the University of Delaware. This money may be spent on a combination of approved travel at the choice of the student.
2. The student may apply to use this travel money to pay the costs of attending scientific meetings or other educational/academic events. To apply for travel funds the student must fill out a travel approval form obtained from the Graduate Administrative Assistant. The form must be completed and approved before travel commences. In no case will students be reimbursed for travel without prior approval of this form.
3. Except as noted below, in no case will any funds beyond the amount approved for the student at the time of passing the candidacy exams be made available. Exceptions to the funding cap are as follows:
 - (a) Students who wish to return to their undergraduate school to help recruit new graduate students may petition the department for extra support.
 - (b) Students may also petition the Graduate Studies Committee to receive travel funding for special opportunities related to their studies. Such requests must be clearly documented and students are asked to exhaust other sources of funding prior to making such a request.

7.2 Support during the Summer

Graduate student contracts are usually for nine months. Opportunities for further employment during the summer months include Research Assistantships and Teaching positions. In addition the department offers summer support as follows:

- Continuing students, with financial support, who are in their first summer at Delaware are eligible for summer support at the rate specified in their offer letter.
 - Students are expected to be at Delaware during this time and available for classes and workshops as determined by the Graduate Studies Committee.

- At the request of the student this support may be carried over to the second summer.
- Students who have passed the candidacy exam are eligible for an additional summer of support at the current rate for summer support determined by the department.
- The duration of support is for the first summer session.
- By university policy, all students supported during the summer must register as full-time students (minimum 3 credit hours) for M868, M964, or M969.
- Students who are being supported may not teach, or receive other University of Delaware support in the first summer session.

7.3 Continuation of Financial Aid

Students holding assistantships are expected to perform satisfactorily in their assigned duties and to make good progress in their academic work. Renewal of financial aid is not automatic.

For continued support beyond the 3rd year, a student entering with a Bachelor's degree must pass the Candidacy Exam by the beginning of his/her 6th semester. A student entering with a Master's degree must pass the Candidacy Exam by the beginning of his/her 4th semester in order to be guaranteed continued support beyond the 2nd year. For a student who does not pass the Candidacy Examination on the first try, there is no guarantee for support for the following academic year. However, a student may make a second and final attempt to pass the Candidacy Examination, and if the attempt is successful, the department will make every effort to secure funding for such a student.

8 Guidelines for the Teaching Assistant

1. Teaching Assistants are expected to attend lectures in the course in which they are assisting if so asked by the instructor. They are expected to know the content of the course, methods of teaching used by the professor, and the relative importance of the subject matter.
2. Teaching Assistants are responsible for assisting the professor in charge of the course in the formulation, administration and grading of quizzes

and examinations given in the course. Specific responsibilities will be discussed with the professor in charge.

3. Quiz sections should be conducted along guidelines specified by the professor in charge of the course. The quiz sections are an integral part of each course and are expected to meet for the full 50 minutes in the assigned classroom. Teaching Assistants may not dismiss class early unless directed to do so by the professor in charge of the course.
4. The Teaching Assistant will be informed what part he or she will play in the final exam process. The assignment of final course grades is the responsibility of the professor in charge of the course. No Teaching Assistant may leave campus until final exam grades for their course have been turned in to the Registrar's Office.
5. At the beginning of the semester, professors and Teaching Assistants together should plan office hours and then announce office hours to their classes.
6. Teaching Assistants are expected to spend an average of 20 hours per week working in the course in which they are assisting. This average includes time in class, in preparation for class, and in grading of quizzes and exams.
7. The TA cannot give out information on student performance (including grades) over the telephone. The TA cannot give out final exams. If students wish to see them, the TA will need to make an appointment to meet them after classes have ended, or leave the exams with a secretary in 501 Ewing and have students check with the secretaries. Final exams must remain in the department for one year after students take them.
8. Renewal of assistantships is not automatic. Continued support is contingent upon appropriate progress toward a degree and satisfactory performance of assigned duties as a graduate assistant.
9. Teaching Assistants may not be absent during any semester without permission of the Associate Chair.

9 Miscellaneous Information

Change of Address or Telephone Number Please notify the Math Office (301 Ewing) of your current address and telephone number and notify us immediately of any changes.

Class Enrollment Limits Limits for all classes are established by the Department.

Class Supplies TA classroom supplies (as opposed to personal supplies) may be secured from the workroom supply cabinet (obtain key from 501 Ewing). Available supplies: grade books, chalk, pencils, pens, writing pads. *These supplies are for the classes you are teaching, not the classes you are taking.*

Computer Accounts As students you are automatically ^{*Driscoll:*} ~~given accounts for e-mail on the university's Unix machines. Please go to Smith Hall, Room 2A, to obtain your user number and password.~~ given a university email account (udel.edu). For instructions on activating the account, see www.udel.edu/help. ^{*Driscoll:*} ~~For your mathematical sciences workstation account all students need to fill out a "System Security and Access" form available from the staff office in Ewing. This form must be completed and handed in to the Graduate Secretary. For additional computing resources, please see the Assistant to the Chair. You will also get a departmental network account and email address (math.udel.edu). See the computing staff in Ewing to sign up for your account, and to ask questions about other available computing resources.~~

Keys The keys issued to you will be for your office in Ewing Hall and outside entrances to Ewing Hall. Your office key opens Ewing public areas: work room, computer terminal room, and the conference room.

Proctoring of Exams As part of their obligation to the department, all students are required to assist in the proctoring of the hour exams and finals in courses with common exams (e.g. M010, M115, M221, etc.). Failure to do so will affect your winter/summer teaching assignments and will jeopardize future support from the department.

Pay You are paid twice monthly, on the 15th and the last day of the month. In order to receive your first check, you will need to fill out a W-4 form and an I-9 for tax purposes. ^{*Driscoll:*} ~~All graduate students must use direct deposit.~~

Foreign students who receive temporary Social Security Numbers will need to fill out a second W-4 form when they receive their permanent Social Security Numbers, or their paychecks will be halted. These students must also change their UD ID cards.

^{*Driscoll:*} ~~Checks are automatically deposited after a form that can be obtained in 501 Ewing is sent to Payroll. Your pay stub can be viewed online. Your stipend continues straight through all nine months of the academic year and, therefore, you can expect your paycheck as usual between semesters.~~ All graduate students must use direct deposit, which requires filing a form that you can obtain from the staff in Ewing 501. Your pay stub can be viewed online. Your stipend is automatically paid continuously through all nine months of the academic year, including between semesters.

Winter session is a separate contract, and this stipend is added into your paycheck over the Winter session period. Your stipend does not include summer session, but there is a possibility of teaching. For winter and summer sessions, if you don't have 10 people in your class after the first day of class, contact someone in the Math Office, 501 Ewing Hall. Your pay could be substantially reduced if this happens.

Telephone Any call beyond the Newark local calling area is to be paid by the student making the call.

Textbooks Desk copies may be obtained in 501 Ewing by TA's for courses in which they are assisting.

Copying Free photocopying is available for use in any course in which you are assisting. Students are responsible for reimbursing the department for the cost of any photocopying for personal use. The photocopy machine should not be used for large copy jobs. Please see the office staff for any copy job exceeding 100 copies.

Graduate Programs in the Department of Mathematical Sciences

November 15, 2011

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1 The Academic Program

1.1 History

Mathematics was present at the University of Delaware right from the start. The founder of the university, Francis Alison, wrote of his new school in 1768 “The Languages are carefully taught, along with arithmetic, geometry, practical branches of mathematics, and logic.” By 1773, the fledgling academy employed two professors - a philosopher and a mathematician. By 1826, the department structure had arrived at U.D., with a separate room set aside for a “Mathematical and English Department.” In 1832, mathematics became part of a new department of “Mathematics and the Natural Sciences.” Over the next century, both the university and the department underwent significant growth but it wasn’t until the late 1950’s that doctoral programs were established at the University of Delaware. In 1965, the Department of Mathematical Sciences created the seventh doctoral program hosted by the university. By 1969, the department had awarded its first Ph.D. degree.

Over the last forty years, well over one hundred students have received doctoral degrees in Mathematics or Applied Mathematics from the University of Delaware. Graduates from our program have gone on to prestigious postdoctoral positions at institutions such as Oxford University, the University of Arizona, and the University of Minnesota. They hold or have held academic positions worldwide and they work in industry, commerce, and government at organizations such as DuPont, Merck, and the National Security Agency. Today, with active research groups in numerous areas of pure and applied mathematics, the department continues to train high-quality mathematics researchers destined to impact the future of mathematics and its applications worldwide.

1.2 Introduction

The Department of Mathematical Sciences offers programs of study leading to Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) degrees in Applied Mathematics and Mathematics. The department also offers a 4+1 BS/MS program allowing students to complete both a Bachelor of Science and Master of Science degree in five years of full-time study. Requirements for the degrees in the various programs are detailed in Chapter 3.

Many of the major areas of mathematics are included among the research interests of the faculty of the department. There are numerous active seminars on these and other mathematical topics, as well as a steady stream of visiting scientists from all over the world.

1.3 Getting Started

The authority for administering the program rests with the Graduate Studies Committee. The Director of Graduate Studies serves as adviser to all students until such time as a supervisor for the thesis or dissertation is appointed. The Director of Graduate Studies will help you formulate your plan of study through twice yearly scheduled meetings prior to preregistration and through additional meetings as needed.

New students, as part of the usual orientation program, will meet with the Director of Graduate Studies to plan their first year of study in the program. It is recommended that incoming students with an M.S. take the Preliminary Exam prior to beginning courses. Well prepared students with a B.S. may also take the Preliminary Exam in the August prior to beginning course work. Sample exams will be mailed on request. Exams are usually given the week before classes begin in fall and spring semesters. Please see the website for details.

During advisement, help will be given concerning course selection based on a student's interests and undergraduate background, and the results of the Preliminary Exam if taken. Each student has a progress sheet on which the courses taken, grades, and progress toward the degree is noted. Before each semester, students must obtain their advisor's permission to register. Continuing students are required to enroll for courses during the preregistration period, and are required to meet with the Director of Graduate Studies. The department is committed to providing individualized attention and guidance to every student in the program. If at any time you have concerns, questions, or difficulties, you are encouraged to discuss them with any faculty member as well as with your fellow students.

1.4 General Plan of Study

In making your plan of study, you should pay particular attention to the timing of course offerings and your background and interests. It is not unusual that you may want to change your plan as your experience in the department grows. Nevertheless, having even a tentative plan will serve to ensure progress toward your degree.

As you develop your plan of study, you should keep the following points in mind.

- Students holding Graduate Assistantships (**GA**), Research Assistantships (**RA**), or Graduate Teaching Assistantships (**TA**) must register for a minimum of 9 credits of course work.

- It is expected that the requirements for a Master's degree be completed by the end of the fourth semester for full-time students.
- A student must pass the Preliminary Exam by the beginning of the fourth semester in order to continue his/her studies beyond the Master's degree.

For a student to remain in the Graduate Program a minimum cumulative GPA of 3.0 (B) is required. Students who do not perform to this standard are subject to review and/or dismissal as determined by the Graduate Student Probation Policy.

Permission to continue study toward a Ph.D. degree is given on the basis of ongoing review of your academic performance, as measured by performance on the Preliminary Exam, course grades, and instructor assessments. By the time you become a candidate in the Ph.D. program, you will have identified an area in which you wish to write your dissertation. The department will work with the Graduate Office at that time to certify that all requirements have been met after a review of your record. Waivers of requirements will be at the discretion of the Graduate Studies Committee.

Transfer of credit from other U.S. institutions is available only for courses at the graduate level that have not counted towards the requirements of any other academic degree. Permission is required from the student's advisor and the Chair of the department. A form and instructions are available from the website of the university's Office of Graduate Studies. Transfers of credit should be requested in a timely manner so that the student's plan of study is clear. Transfer of credit from non-U.S. institutions is generally not possible.

2 Regulations for the Master's and Ph.D. Programs

1. In order to graduate with a Master's Degree in Mathematics, a student must satisfy the general academic requirements of the Office of Graduate Studies and must have a "B" or better average in all courses.
2. Under normal circumstances a student with a "C" or lower in 3 courses will be advised to leave the graduate program.
3. A student who has not passed the Candidacy Exam for the Ph.D. is not allowed to register for Ph.D. dissertation or noncontractual research.
4. Two semesters experience in the teaching of undergraduates is required of all candidates for a Master's Degree and Ph.D. candidates. This

is a Departmental requirement; students may petition the Graduate Studies Committee for a waiver of this requirement.

5. The Graduate Office requires that those graduate students holding GAs, RAs and TAs register for a *minimum* of 6 hours. However, it is the policy of the department that all such students register for 9 hours each semester. Under special circumstances, and when approved by the Graduate Studies Committee, 3 hours may be taken as a listener. The Graduate Studies Committee *strongly* discourages students in their first three years of study from registering as a listener. Students may carry more than the 9 credits which are covered by the tuition. A student wishing to carry 13 credits or more must first get permission from the Department Director of Graduate Studies and the Office of Graduate Studies.
6. Students enrolled in the M.S. program who wish to continue on to the Ph.D. program must file a Change of Classification Form no later than the start of their fourth semester.
7. Students enrolled in the 4+1 BS/MS program must satisfy regulations number one and number two from this list. In particular, students in the 4+1 BS/MS program are not required to obtain teaching experience.

3 Program Descriptions

3.1 Admission Requirements

Admission to the graduate programs in Applied Mathematics and Mathematics is open to students who have completed the equivalent of a baccalaureate degree in mathematics or related fields, and have a sound preparation in linear algebra and advanced calculus. On a 4.0 system, applicants should have a GPA of at least 2.5 and an average of at least 3.0 in mathematics and related areas. Applicants who have completed an advanced degree must have done so with a GPA of at least 3.0. In addition, applicants must take the GRE General Test and one GRE Subject Test. It is not required that the GRE Subject Test be in mathematics.

To be eligible for admission, students from a country where English is not a primary language must demonstrate proficiency in English by meeting at least one of the following criteria:

- Score at least 600 on the paper-based TOEFL exam.

- Score at least 100 on the TOEFL IBT, with a minimum score of 20 in each section.
- Score at least 7.5 on the IELTS with a minimum score of 6.0 in each subsection.

Admission to the graduate program is selective and competitive based on the number of well-qualified applicants and the limits of available faculty and facilities. Those who meet stated minimum academic requirements are not guaranteed admission, nor are those who fail to meet those requirements necessarily precluded from admission if they offer other appropriate strengths.

Students who wish to be admitted to the 4 + 1 BS/MS program should submit an application during their junior year of academic study toward an undergraduate degree at the University of Delaware. Such students must be enrolled in a Bachelor of Science degree program administered by the Department of Mathematical Sciences. At a minimum, the applicant must have a cumulative GPA of 3.2 and a GPA of 3.4 in their undergraduate major. The applicant must have completed at least two mathematics courses at or above the 400 level. Two letters of recommendation from University of Delaware faculty and academic transcripts must be submitted. Neither the GRE nor the TOEFL exam is required. However, note that meeting minimum requirements is not a guarantee of admission. Similarly, those who fail to meet minimum requirements are not precluded admission if they offer other appropriate strengths.

3.2 Requirements for the M.S. in Mathematics and Applied Mathematics

To be eligible for the degree, an M.S. candidate must complete 30 credits of course work beyond the Bachelor's degree, subject to all of the following conditions:

1. The student must maintain a GPA of 3.0 or better.
2. Coursework must be at or above the 600 level, exclusive of courses that the catalog designates as not counting towards mathematics graduate degrees.
3. Students in the 4 + 1 program may count up to six credits of course work in the mathematical sciences, at or above the 600 level and exclusive of courses that the catalog designates as not counting towards

mathematics graduate degrees, toward both their B.S. and M.S. degrees.

4. A maximum of 3 credits of course work taken outside of the mathematical sciences may be applied. The use of any additional course work taken for credit outside of the department requires approval of the Graduate Studies Committee.
5. A maximum of 3 credits may be from a reading course (MATH 870). The use of additional reading credits requires approval of the Graduate Studies Committee.
6. For students who select the thesis option for the M.S., the 30 credit total must include 3 credit hours of research (MATH 868) and 3 credit hours of thesis (MATH 869), leading to a Master's Thesis. The purpose of this option is to assess the student's ability to conduct and report original research on a particular area within the field of specialization and/or synthesize and critically analyze important issues in the field of specialization. The particular form of the thesis project (e.g., report of original research or critical review of and exposition on the literature) will be determined by the student in consultation with his or her Thesis Advisor and the Thesis Committee. The Thesis Committee shall consist of three faculty; it is not required that a member of the committee be from outside mathematics. After the topic(s) and project format have been determined, the student will have a maximum of one year to complete the written thesis (typically 50 to 60 pages). An oral defense will be scheduled following the Thesis Committee's evaluation of the thesis.

3.3 Requirements for the Ph.D. in Mathematics and Applied Mathematics

1. Complete 48 credits of coursework, including:
 - (a) At least 27 credits of MATH courses at the 600 level or above, exclusive of courses designated in the catalog as not counting towards graduate degrees in mathematics.
 - (b) A maximum of 27 credits of MATH courses at the 600 level.
 - (c) A maximum of 6 credits of MATH 868 (Research).

- (d) A maximum of 6 credits at the 600 level or above in non-MATH courses, unless special permission is granted in advance by the Graduate Committee.
- 2. Maintain a GPA of 3.0 or better.
- 3. Fulfill the Preliminary Examination requirement (see Chapter 4). Students entering with only a Bachelor's degree must complete this requirement by the beginning of the fourth semester of study. Students entering with a Master's degree must complete this requirement by the end of the second semester of study.
- 4. Pass the oral Candidacy Examination (see Chapter 5).
- 5. Select a Dissertation Committee, subject to the approval of the Graduate Committee.
- 6. Complete two semesters of experience in teaching undergraduate students, or obtain a waiver from the Graduate Committee.
- 7. Complete 9 credits of MATH 969 (Doctoral Dissertation) after admission to candidacy.
- 8. Complete and successfully defend a dissertation.

The course work requirements are a superset of those for the Master's degree. An M.S. degree is awarded once the requirements for it have been met.

Special notes about the Requirements for the Doctor of Philosophy in the University's Graduate Catalog: *If a student completes his or her course requirements before admission to candidacy, the student is expected to enroll for MATH 964 until admitted to candidacy. Once a student has been admitted to candidacy and has taken 9 credits of MATH 969, he or she must maintain matriculation in the graduate program via MATH 999 (Doctoral Sustaining).*

3.4 Seminar Attendance

The department offers a wide range of regularly scheduled seminars and colloquia, including the Graduate Student Seminar series, Rees Distinguished Lecturers, and numerous seminar series organized by the faculty around research interests in the department. Students should attend the Graduate

Student Seminar each week and all departmental colloquia, in addition to sampling other available seminars during their first year. By the second year of study, students should have become a regular attendee at one or more regular department seminars in addition to the Graduate Student Seminar.

3.5 Dissertation

The typical student will select a thesis adviser by the end of the fifth semester of study. The thesis adviser will guide the student's research and preparation of the dissertation. The dissertation is expected to reflect the results of original, significant research written in a literate and scholarly manner worthy of publication. The student must defend their dissertation before a thesis committee consisting of the student's thesis adviser and no less than three and no more than five additional members. One member of the thesis committee must be from a different academic unit, or from outside of the University of Delaware. The student's dissertation must be submitted to the department's main office at least two weeks prior to the oral defense. The time, date, and place of the oral defense will be announced to the faculty and the oral defense will be open to the academic community.

3.6 Sustaining Status

Once a student has completed all the course requirements, passed the Preliminary and the Candidacy Examinations, and registered for 9 credits of dissertation (MATH 969), the student is required to maintain his/her matriculation in the degree program by registering for Doctoral Sustaining (UNIV 999). A student must be registered in the semester in which the degree is awarded.

4 Preliminary Examinations

All students who wish to obtain a Ph.D. degree must take a written examination called the Preliminary Examination. The Preliminary Examination contains two subject areas: Real and Complex Analysis, which covers material from MATH 600 and MATH 602, and either Linear Algebra, which covers material from MATH 672, or Numerical Linear Algebra, which covers material from MATH 614. Note that material outside the course syllabi may be on the syllabus for the exams as given below.

The Preliminary Exam will be given twice each year, once before the start of the Fall Semester, and once before the start of the Spring Semester.

For students entering with a Bachelor's degree, it is required that the Preliminary Exam be passed by the beginning of the fourth semester of study. Providing it is before the beginning of the 4th semester, a student may take each part of this exam up to two times. Only the part not passed needs to be repeated. Students who fail to pass both subject areas of the Preliminary Exam by the beginning of the fourth semester will be asked to leave the graduate program. Student's entering with a Master's degree must pass the Preliminary Exam by the start of the third semester of study. Providing it is by the start of the third semester of study, a student with a Master's degree may take each part of this exam up to two times. Only the part not passed needs to be repeated. Students entering with a Master's degree who fail to pass both subject areas of the Preliminary Exam by the end of the second semester will be asked to leave the graduate program. Notification of the results of the Preliminary Exams will be sent to the Office of Graduate and Professional Studies.

The syllabus to be covered by each examination is included in the following subsections. Please obtain copies of past examinations and the syllabus from the Graduate Program Secretary in 301 Ewing Hall. Note also that the references cited on the following pages are intended to indicate the material to be covered. It is not necessarily intended that the student study all the references.

4.1 Real and Complex Analysis

Topics covered on the exam include the following. Many of these topics are discussed in Math 600 and Math 602. References are given for each topic.

1. Metric Spaces: open and closed sets, compactness, connected sets, complete sets, continuous functions on metric spaces ([1], Chapters 3 and 4).
2. Continuity and Differentiation: mean value theorem, Rolle's theorem, Taylor's formula, derivatives of vector valued functions, uniform continuity, monotonic functions, functions of bounded variation ([1], Chapters 5 and 6).
3. Integration: Sets of measure zero. Lebesgue's criterion for the existence of Riemann integrals. The Lebesgue integral in R^1 . Convergence theorems. Measurable functions. Fubini's theorem. Measurable sets. The space $L^2(I)$. The Riesz-Fischer theorem. ([1], Chapter 10)

4. Infinite Sequences and Series: Limit superior and limit inferior, monotonic sequences, alternating series, absolute and conditional convergence, power series, tests for convergence of series, rearrangement of series ([1], Chapter 8).
5. Sequences of Functions: Pointwise convergence, uniform convergence, uniform convergence and continuity, differentiability and integration ([1], Chapter 9).
6. Functions of Several Variables: Directional derivatives, the total derivative, Jacobians, inverse function theorem, implicit function theorem, extrema problems ([1], Chapters 12 and 13).
7. Vector Calculus: Line integrals, Green's theorem, surface integrals, Stokes theorem, the divergence theorem ([2], Chapters 10, 11 and 12).
8. Analytic Function Theory: Analytic functions, Cauchy's theorem, Cauchy's integral theorem, the maximum principle, the identity theorem, Taylor and Laurent series, the residue theorem, elementary conformal mappings ([1], Chapter 16).

References:

1. Tom Apostol, *Mathematical Analysis*, 2nd edition, Addison Wesley, 1974.
2. Tom Apostol, *Calculus, Vol. 2*, 2nd edition, John Wiley, 1969.

4.2 Linear Algebra

Topics covered on the exam include the following. Most of these topics are discussed in Math 672. References are given for each topic.

1. Subspaces, bases and dimension (Chapters 1 - 2, [SA]).
2. Linear transformations and matrix representations (Chapter 2, [SA]; Chapters III - IV, [SL]).
3. Determinants and rank (Chapter VI, Section V.3, [SL]).
4. Inner products and inner product spaces (Chapter 6, [SA]).
5. Linear functionals, adjoints, and dual spaces (Chapter 6, [SA]).

6. Bilinear forms, Hermitian forms, and quadratic forms (Chapter V, [SL]; Sections IV.A - IV.C, [MLC]).
7. Eigenvalues, eigenvectors, and characteristic polynomials (Sections VIII.1 - VIII.2, [SL]).
8. Cayley-Hamilton Theorem (Sections X.1 - X.2, [SL]; Sections III.A - III.C, [MLC]).
9. Operators on inner product spaces and Spectral Theorems (Chapter 7, [SA]; Section VIII.3 - VIII.6, [SL]; Section III.D, [MLC]).
10. Jordan Canonical Form (Chapter XI, [SL]; Section III.E, [MLC]; Chapter 8, [SA]).

References:

SA Sheldon Axler, *Linear Algebra Done Right, Second Edition*, Springer-Verlag, 1997.

MLC Morton L. Curtis, *Abstract Linear Algebra*, Springer-Verlag, 1990.

SL Serge Lang, *Linear Algebra, Third Edition*, Springer-Verlag, 1987.

4.3 Numerical Linear Algebra

Direct and iterative methods for the solution of linear systems, LU factorization, row pivoting, stable QR factorization, solution of linear least squares problems by normal equations and QR, stability and conditioning issues, power and inverse iterations, QR iteration, singular value decomposition, simple iterations for sparse matrices, conjugate gradients and other Krylov subspace iterations.

Suggested References:

1. L.N. Trefethen and D. Bau, III, *Numerical Linear Algebra*, SIAM (see e.g., I, II, III).
2. J.W. Demmel, *Applied Numerical Linear Algebra*, SIAM (Sections 2.1-2.4, 3.1-3.3, 4.4, 6.5, 6.6.)
3. A. Quarteroni, R. Sacco and F. Saleri, *Numerical Mathematics*, Springer-Verlag (Sections 3.1, 3.3, 4.1-4.3, 5.2-5.5, 5.8.)

5 Candidacy Examination

This oral examination can take place at any time mutually agreed upon by the Examining Committee and student. Students entering with a Bachelor's degree must pass the Candidacy Examination by the beginning of their sixth semester of study. Students entering with a Master's degree must pass the Candidacy Examination by the end of their fourth semester of study. A second and final attempt is permitted following a failed attempt. Dismissal will be recommended for a student who does not pass the Candidacy Examination on the second try. Students who fail the Candidacy Examination are eligible for the M.S. degree.

The student should take the following steps to organize their Candidacy Examination and are advised to allow ample time for the process:

1. Contact four faculty to act as an Examining Committee. Since the student must be examined on two topics, normally two faculty will be expert in each area. The thesis adviser should be a member of the committee if the student has already chosen one. Students are strongly encouraged to choose a thesis adviser prior to forming an examining committee for the Candidacy Examination.
2. After the faculty agree to serve as examiners the student should contact the Director of Graduate Studies at least six weeks in advance of the proposed examination date and supply the following information:
 - (a) Date of the exam.
 - (b) Names of the examiners making up the Examining Committee.
 - (c) Choice of topics. Note that the topics must contain material from at least one 8xx level course.
3. Final approval of the Examining Committee and topics rests with the Graduate Studies Committee. Only after the Graduate Studies Committee has approved the Examining Committee and topics may the exam take place.

The scheduling, topics and composition of the Examining Committee will be announced to the faculty.

It is the responsibility of the examining committee to decide the duration of the exam (typically 2-3 hours). They should report the results of the exam and a recommendation of Pass or Fail with written justification to the Director of Graduate Studies within two days of the exam. A final decision

on the outcome of the exam is the responsibility of the Graduate Studies Committee.

In this examination a student must choose 2 topics from the following table:

Topic	Relevant Courses
Algebra	M650 and M845
Applied Mathematics	M616, M617 and M810/M835
Discrete Mathematics	M688 and M888
Numerical Analysis	M611, M612, and M817 or M838
Probability	M630, M631 and M850
Functional Analysis and PDE	M806 and M836

Another subject area may be substituted for one in the table above by petition to the Graduate Studies Committee. The substituted subject area must be based on at least two graduate level courses, and this petition must be supported by at least one faculty member who is also a member of the student's examining committee.

Should a candidate fail a part of the Candidacy Exam, the candidate need only retake the failed topic. In no case will a candidate be allowed to take the candidacy exam more than twice.

6 Assessment

All graduate programs in the Department of Mathematical Sciences are designed to take high-quality students, with a strong background in mathematics, and transform them into full-fledged practitioners of the discipline of mathematics. For students seeking the M.S. we seek to broaden and deepen their knowledge of mathematics and properly train them for a mathematics related career. For students seeking the Ph.D. we again seek to broaden and deepen their knowledge of mathematics and also to train them as practitioners so that they may impact the discipline in a deep and meaningful way.

6.1 Learning Outcomes

Our program focuses on five key learning objectives, or outcomes. These are:

- Graduates should be able to conduct original, quality research in particular area of specialization.

- Graduates should be able to synthesize and critically analyze important issues in their field and understand and appreciate how their work fits into the larger body of science.
- Graduates should be able to communicate mathematical proofs, ideas, and concepts orally.
- Graduates should be able to communicate mathematical proofs, ideas, and concepts in writing.
- Graduates should be able to demonstrate both breadth and depth of mathematical knowledge.

6.2 Assessment Plan

In order to ensure that our graduate programs are meeting the objectives stated above, our learning outcomes are continually monitored. Changes resulting from this assessment are implemented periodically. For each of the five learning objectives, we rely upon a variety of direct and indirect measurement tools. A sample is listed below for each objective.

- Are graduates conducting original, high quality research within their field of specialization?
 - Our sources of information include student thesis or dissertation, student publications, and conference presentations. Our measuring instruments are rubrics that quantify student research work for a thesis, dissertation, or conference presentation. Results are used to compare and contrast student work.
- Are students able to synthesize and critically analyze important issues in their field and understand and appreciate how their work fits into the larger body of science?
 - Our sources of information include student thesis, oral candidacy examinations, and oral theses defenses. Our measuring instrument is a rubric used by faculty serving on thesis committees.
- Are students able to communicate mathematical proofs, ideas, and concepts orally?

- Our sources of information include student evaluations of their performance as teaching assistants, oral candidacy examinations, oral theses defenses, talks in the Graduate Student Seminar, and talks at conferences. Our measurement instruments are rubrics for oral communication used by faculty for student presentations and a teaching observation form.
- Are students able to communicate mathematical proofs, ideas, and concepts in writing?
 - Our sources of information include our preliminary examinations, publications by students and a written thesis. Our measurement instruments include a common rubric for evaluating student writing.
- Are students able to demonstrate both breadth and depth of mathematical knowledge.
 - Our sources of information include results of preliminary examinations, results of oral candidacy examinations, and theses defenses. Our measurement instruments include a rubric to evaluate preliminary examinations, candidacy examinations, and faculty feedback on these examinations.

7 Financial Aid

Financial aid for study at Delaware takes several forms including Research Assistantships, Departmental Fellowships, Teaching Assistantships and Tuition Scholarships. These forms of financial aid are awarded by the Department on a yearly basis. Continuation of support is dependent upon your academic progress and on your performance of any duties assigned to you. All students receiving support of any kind are expected to discharge assigned tasks including certain jobs such as proctoring of departmental examinations and assisting with undergraduate registration.

The Department encourages students to compete for nationally advertised graduate fellowships. Information on what fellowships are currently available can be obtained from the graduate studies secretary.

The stipend for Teaching and Research Assistants for the 2009-2010 academic year is determined by the following schedule. Check the Departmental websites for updates.

1. Initial appointments of first year graduate students will be made at a rate no lower than the University minimum level; this is level 1.
2. TA qualified second year graduate students or initial appointment of TA qualified graduate students who have passed the Preliminary Exam will be paid at least \$250 more than level 1; this is level 2.
3. Graduate students who have passed their Candidacy Exam will be paid at least \$250 more than level 2; this is level 3.

Students will remain at level 2 until the requirements for level 3 are met.

As most students are supported as Teaching Assistants, at least for some period of their studies, it is expected that all graduate students prepare themselves for classroom teaching. All new students are required to participate in the Department's orientation and TA training program which takes place before the start of classes. The program includes both departmental and University presentations. In addition, new teaching assistants are required to attend teaching workshops scheduled by the department.

For foreign students, preparation for classroom duties includes work with the English Language Institute (ELI) both in the month preceding the Fall or Spring term as appropriate. Students also must attend departmental training sessions. ELI must certify that a foreign student has a sufficient command of English before the Department can make a classroom assignment. It is Departmental policy that no foreign student be supported more than two semesters without being certified for classroom assignments by ELI. Foreign students are expected to meet the following schedule with respect to test scores reported by ELI:

- (1) achieve a score of at least 600 on the TOEFL examination (or an equivalent score on another examination approved by ELI) before the beginning of the first semester of study;
- (2) attend the workshop for foreign Teaching Assistants given by ELI and CTE before the *beginning of the Fall or Spring term* of residence;
- (3) must meet the minimum requirements set forth by the University's policy for SPEAK and UDIA scores for ITA instructional assignments (level II).

7.1 Support for Student Travel

The department encourages graduate students to attend national meetings and supports this by providing funding for student travel. Students should note that additional funds are often available from the Office of Graduate

Studies, their thesis advisers, and other travel fellowship opportunities. The department follows the following guidelines in providing student travel funds.

1. Supported graduate students who pass both the preliminary and candidacy exams will be awarded an amount of travel money at the current rate determined by the department for use during the remainder of their studies at the University of Delaware. This money may be spent on a combination of approved travel at the choice of the student.
2. The student may apply to use this travel money to pay the costs of attending scientific meetings or other educational/academic events. To apply for travel funds the student must fill out a travel approval form obtained from the Graduate Administrative Assistant. The form must be completed and approved before travel commences. In no case will students be reimbursed for travel without prior approval of this form.
3. Except as noted below, in no case will any funds beyond the amount approved for the student at the time of passing the candidacy exams be made available. Exceptions to the funding cap are as follows:
 - (a) Students who wish to return to their undergraduate school to help recruit new graduate students may petition the department for extra support.
 - (b) Students may also petition the Graduate Studies Committee to receive travel funding for special opportunities related to their studies. Such requests must be clearly documented and students are asked to exhaust other sources of funding prior to making such a request.

7.2 Support during the Summer

Graduate student contracts are usually for nine months. Opportunities for further employment during the summer months include Research Assistantships and Teaching positions. In addition the department offers summer support as follows:

- Continuing students, with financial support, who are in their first summer at Delaware are eligible for summer support at the rate specified in their offer letter.
 - Students are expected to be at Delaware during this time and available for classes and workshops as determined by the Graduate Studies Committee.

- At the request of the student this support may be carried over to the second summer.
- Students who have passed the candidacy exam are eligible for an additional summer of support at the current rate for summer support determined by the department.
- The duration of support is for the first summer session.
- By university policy, all students supported during the summer must register as full-time students (minimum 3 credit hours) for M868, M964, or M969.
- Students who are being supported may not teach, or receive other University of Delaware support in the first summer session.

7.3 Continuation of Financial Aid

Students holding assistantships are expected to perform satisfactorily in their assigned duties and to make good progress in their academic work. Renewal of financial aid is not automatic.

For continued support beyond the 3rd year, a student entering with a Bachelor's degree must pass the Candidacy Exam by the beginning of his/her 6th semester. A student entering with a Master's degree must pass the Candidacy Exam by the beginning of his/her 4th semester in order to be guaranteed continued support beyond the 2nd year. For a student who does not pass the Candidacy Examination on the first try, there is no guarantee for support for the following academic year. However, a student may make a second and final attempt to pass the Candidacy Examination, and if the attempt is successful, the department will make every effort to secure funding for such a student.

8 Guidelines for the Teaching Assistant

1. Teaching Assistants are expected to attend lectures in the course in which they are assisting if so asked by the instructor. They are expected to know the content of the course, methods of teaching used by the professor, and the relative importance of the subject matter.
2. Teaching Assistants are responsible for assisting the professor in charge of the course in the formulation, administration and grading of quizzes

and examinations given in the course. Specific responsibilities will be discussed with the professor in charge.

3. Quiz sections should be conducted along guidelines specified by the professor in charge of the course. The quiz sections are an integral part of each course and are expected to meet for the full 50 minutes in the assigned classroom. Teaching Assistants may not dismiss class early unless directed to do so by the professor in charge of the course.
4. The Teaching Assistant will be informed what part he or she will play in the final exam process. The assignment of final course grades is the responsibility of the professor in charge of the course. No Teaching Assistant may leave campus until final exam grades for their course have been turned in to the Registrar's Office.
5. At the beginning of the semester, professors and Teaching Assistants together should plan office hours and then announce office hours to their classes.
6. Teaching Assistants are expected to spend an average of 20 hours per week working in the course in which they are assisting. This average includes time in class, in preparation for class, and in grading of quizzes and exams.
7. The TA cannot give out information on student performance (including grades) over the telephone. The TA cannot give out final exams. If students wish to see them, the TA will need to make an appointment to meet them after classes have ended, or leave the exams with a secretary in 501 Ewing and have students check with the secretaries. Final exams must remain in the department for one year after students take them.
8. Renewal of assistantships is not automatic. Continued support is contingent upon appropriate progress toward a degree and satisfactory performance of assigned duties as a graduate assistant.
9. Teaching Assistants may not be absent during any semester without permission of the Associate Chair.

9 Miscellaneous Information

Change of Address or Telephone Number Please notify the Math Office (301 Ewing) of your current address and telephone number and notify us immediately of any changes.

Class Enrollment Limits Limits for all classes are established by the Department.

Class Supplies TA classroom supplies (as opposed to personal supplies) may be secured from the workroom supply cabinet (obtain key from 501 Ewing). Available supplies: grade books, chalk, pencils, pens, writing pads. *These supplies are for the classes you are teaching, not the classes you are taking.*

Computer Accounts As students you are automatically given a university email account (udel.edu). For instructions on activating the account, see www.udel.edu/help. You will also get a departmental network account and email address (math.udel.edu). See the computing staff in Ewing to sign up for your account, and to ask questions about other available computing resources.

Keys The keys issued to you will be for your office in Ewing Hall and outside entrances to Ewing Hall. Your office key opens Ewing public areas: work room, computer terminal room, and the conference room.

Proctoring of Exams As part of their obligation to the department, all students are required to assist in the proctoring of the hour exams and finals in courses with common exams (e.g. M010, M115, M221, etc.). Failure to do so will affect your winter/summer teaching assignments and will jeopardize future support from the department.

Pay You are paid twice monthly, on the 15th and the last day of the month. In order to receive your first check, you will need to fill out a W-4 form and an I-9 for tax purposes.

Foreign students who receive temporary Social Security Numbers will need to fill out a second W-4 form when they receive their permanent Social Security Numbers, or their paychecks will be halted. These students must also change their UD ID cards.

All graduate students must use direct deposit, which requires filing a form that you can obtain from the staff in Ewing 501. Your pay stub can be viewed online. Your stipend is automatically paid continuously through all nine months of the academic year, including between semesters.

Winter session is a separate contract, and this stipend is added into your paycheck over the Winter session period. Your stipend does not include summer session, but there is a possibility of teaching. For winter and summer sessions, if you don't have 10 people in your class after the first day of class, contact someone in the Math Office, 501 Ewing Hall. Your pay could be substantially reduced if this happens.

Telephone Any call beyond the Newark local calling area is to be paid by the student making the call.

Textbooks Desk copies may be obtained in 501 Ewing by TA's for courses in which they are assisting.

Copying Free photocopying is available for use in any course in which you are assisting. Students are responsible for reimbursing the department for the cost of any photocopying for personal use. The photocopy machine should not be used for large copy jobs. Please see the office staff for any copy job exceeding 100 copies.