THE OHIO STATE UNIVERSITY

College of Arts and Sciences

Department of Mathematics
Thomas Kerler

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March 16th, 2019

TO: College of Arts and Science, Graduate Council, Office of Academic Affairs.

RE: Approval of a sub-plan designation and curriculum for *Applied Mathematics* within the mathematics doctoral program.

Dear Colleagues,

On behalf of the Department of Mathematics I am pleased to submit this request for the approval of a separate track (sup-plan) for *Applied Mathematics* within our existing doctoral program.

Over the past decade or two the research portfolio of our department has expanded in several areas of applied and interdisciplinary mathematics, such as mathematical biology, topological data analysis, and computational mathematics. At the same time the course and qualifying requirements for our beginning graduate students and, by extension, the expected background of applicants has remained focused on the traditional theoretical topics of mathematics.

The attached proposal seeks to better align the initial training of students with interests in applied mathematics with the background required for research in these areas. Moreover, the new track should enable us to significantly expand our applicant pool and, thus, improve our chances to attract highly qualified students.

The possibility of a separate curriculum for applied mathematics has been discussed among our faculty members over the past few years. In the fall of 2017 our Graduate Studies Committee (GSC) constituted an ad-hoc subcommittee composed of colleagues representing the major subfields in our applied mathematics program with the charge of designing an applied mathematics track. On December 16th, 2017 the GSC unanimously approved a respective proposal submitted by this subcommittee.

The proposal was presented and discussed in a faculty meeting in the following month. A subsequent poll among all tenure/tenure-track faculty on January 16th, 2018 resulted in 33 votes in favor of the proposal and 6 votes not in favor. Over the past summer various pending details were further worked out and the documentation organized.

We requested concurrences from the 9 departments offering elective courses and received 7 positive responses. Specific issues with course listings and offerings mentioned in the responses have been incorporated in the attached proposal. We also acknowledged several suggestions to include further electives but decided to reconsider these at a later time after we have gained more experience with this degree track. Two departments did not respond to our requests for concurrence despite several reminders.

This proposal is contingent on the course change requested for the Math 6601-6602 sequence (*Numerical Methods in Scientific Computing*) which we have attached as well as submitted via curriculu.osu.edu. We further include an advising sheet, the already mentioned concurrences as a single PDF file, as well as our current program requirements for our doctoral degree.

We request the new track as a transcript designable. In particular, the current track of a students should be part of their SIS information and applicants need to decide which of our two doctoral tracks they apply to. That is, the full plan of a student would be, for example, either MATH-PH-TH or MATH-PH-AP. We are open to suggestions regarding the technicalities of sub-plan designations and nomenclature.

In summary, this program change request is motivated by clearly identified needs in student training and recruitment. The curriculum has been carefully designed by a representative group of experts, and serious consideration has been given to issues of resources and logistics. The proposal has gained strong support within our GSC as well as our faculty.

Thank you for your consideration.

Sincerely,

Thomas Kerler
Professor & Vice-chair
Department of Mathematics

Attachments:

- Program proposal
- Advising sheet
- Concurrences
- Course change requests with syllabi
- Current PhD requirements

PhD in Mathematics: Proposal for Applied Track

The Department of Mathematics hereby proposes the creation of an Applied Track within the Mathematics PhD. Details for the proposed track are below.

Description of current program

The following paragraph gives the description of the current program:

> *The PhD is the highest degree awarded by the mathematics department. Recipients of the PhD degree have a strong background in core areas of mathematics (analysis, algebra), as well as a broad knowledge of mathematics. They are able to independently acquire advanced mathematical knowledge, through the reading and understanding of original research articles. They can conduct independent mathematical research, and are able to develop their own research program. Finally, they are able to communicate their research to the broader mathematical community, both through the writing of research papers, and the delivery of lectures.*

A PhD student in mathematics has four major milestones marking progress through the program. The milestones, along with their expected completion date, are as follows:

a) **Passing the qualifying requirements**. This is intended to ensure the student has strong competence in core areas of mathematics, and should be completed within the first 3 semesters of the program.

b) **Meeting all breadth requirements**. This requirement ensures the student has an exposure to several areas of mathematics outside of their eventual area of research. It should be completed within the first 2 years of the program.

c) **Completion of the PhD Candidacy Examination**. This evaluates the depth of a student's knowledge in the area of intended specialization. It should be completed by the end of the 3rd year in the program.

d) **Writing the dissertation**. The final stage of the program, this determines that the student can produce new, original research in mathematics, and can communicate it effectively. The dissertation should be completed and defended within 6 years of starting the program.

Rationale for new track

The rationale for creation of an applied track within the mathematics PhD is to recruit strong students with applied interests to OSU. Program requirements are designed to ensure a strong computational foundation, provide flexibility to accommodate different scientific interests, and attract strong students from different backgrounds (for example, engineering) while maintaining rigorous training. This training will prepare graduates from the applied track for jobs in industry as well as in academia.

A large subset of the OSU mathematics faculty has interests in applied mathematics, including in the areas of applied topology, mathematical biology, applications of

partial differential equations, and scientific computing. The department wants to attract students with interests in these scientific areas, but the current structure of the PhD program makes it difficult to recruit strong students with applied interests. The proposed applied track will help with recruitment efforts. The proposed track will also provide rigorous training for students with applied interests to secure sought-after positions in both academia and industry following graduation. For example, in a recent survey a sizeable number of graduate students in the department indicated that they were considering jobs in industry[1]. An applied mathematics track will help meet this demand from students.

Many of Ohio State's peer institutions already have specific training mechanisms in place for applied mathematics, including applied tracks within a mathematics PhD (Minnesota), qualifying examination options in applied mathematics (Wisconsin), and applied mathematics programs (Purdue) or PhD degrees in applied mathematics (Michigan, Michigan State). Creation of an applied track within the mathematics PhD will assist Ohio State in competing for talented students in applied mathematics.

Detailed description of changes to the program
The proposed applied track includes changes to the current qualifying and breadth requirements. Other aspects of the program (Headstart, GTA support, timelines for completing requirements) continue to be the same as in the current program.

Qualifying requirements for the applied track comprise **five courses**, as follows (all must be passed with A- or better by end of Autumn of second year):

- Scientific Computing I (Math 6601)
- One of Analysis I (Math 6211), Analysis II (Math 6212), Algebra I (Math 6111) or Algebra II (Math 6112). This requirement may be satisfied by examination.
- Three additional courses from the following list: Scientific Computing II (Math 6602), ODE (Math 6411), PDE (Math 6451), Analysis I (Math 6211), Analysis II (Math 6212), Algebra I (Math 6111), Algebra II (Math 6112).

For comparison, under the current program all students are required to complete Analysis I, Analysis II, Algebra I, and Algebra II with an A- or better by the end of Autumn of their second year[2].

The **breadth requirement** entails six courses at the 6000-level or above from at least three different areas of mathematics, plus at least one approved graduate-level course of 2 credits or more from outside the department. Approved outside courses include

[1] For example, a survey of graduate students in Spring 2017 drew 56 respondents; only 6 were not considering positions in industry; 30 were considering industry, and 20 were not sure.
[2] Under current program requirements, an approved 6000-level sequence may substitute for one of these core qualifying courses.

options in the life sciences, public health, engineering (including computer science), and statistics. To count towards the breadth requirement the student must complete the course with a grade of B+ or better.

The different mathematical areas and associated sequences within the mathematics department that would count towards the breadth requirement are

- *Algebra:* 6111, 6112 (Abstract Algebra), 7121, 7122 (Number Theory), 7141, 7142 (Algebraic Geometry), 7161, 7162 (Lie groups)
- *Analysis:* 6211, 6212 (Real Analysis), 6221, 6222 (Complex Analysis), 7211, 7212 (Functional Analysis), 7221, 7222 (Ergodic Theory)
- *Differential equations:* 6411, 6451 (ODE / PDE), 7412, 7413 (ODE), 7452, 7453 (PDE)
- *Topology / Geometry:* 6701, 6702 (Differentiable Manifolds and Geometry), 6801, 6802 (Algebraic Topology), 7711, 7721 (Riemannian and Kahler Geometry), 7851, 7852 (Differential Topology)
- *Probability:* 6251, 6252
- *Scientific computing:* 6601, 6602 (Numerical Methods in Scientific Computing), 7611, 7612 (Computational PDE)
- *Combinatorics / graph theory:* 6501, 6502
- *Asymptotics:* 7651, 7652 (Applied Complex Variables and Asymptotics)

There is also interest in developing new PhD-level courses in mathematical biology. Following approval by the Graduate Studies Committee, these mathematical biology courses will also count towards the breadth requirement, in the new area of 'Mathematical Biology'.

An initial list of approved courses from outside the department counting towards the breadth requirement is given in the '*Outside courses*' section.

Contingent course proposals
The PhD level scientific computing course has been revised. The syllabi are attached.

Anticipated enrollment / phase-in
The department currently has about 19 tenured or tenure-track research-active faculty members whose research interests have substantial overlap with applied mathematics. All are interested in advising PhD students. If one expects a faculty member to engage a new student every third year, then an entering class of six applied mathematics track students each year would be an appropriate level. (This is also consistent with the current size of the graduate program in the department, in which the faculty size is about 60, and which admits 22 or 23 new students each year into the PhD program.) The department expects to ramp up to this level over several years, as the existence and reputation of the program become better known. A separate recruiting committee for this program will be created. It is also the case that some students who enter the

theoretical PhD program may decide to change to the applied program. Other entries to the program are the department's current MMS programs in Mathematical Biology and in Scientific Computing. Although those programs were created to offer students a terminal degree, experience has shown that some talented students in these programs decide to seek a PhD in applied mathematics. Since that opportunity did not exist at Ohio State, those students have gone elsewhere, and have succeeded. With a more flexible track, students who enter the MMS program will be able to complete the requirements for PhD qualifying and candidacy here. Assuming that this program is approved by the Graduate School in the 2018-2019 academic year, recruitment will begin for a class entering in Autumn 2020.

Advising sheet
A sample advising sheet for preparation for the Candidacy Examination is attached.

Outside courses
This list of outside courses for the breadth requirement builds off existing approved lists that have been deemed appropriate for graduate students in applied mathematics. Graduate students in the department have successfully been taking courses from this list for several years. Courses from the Translational Data Analytics Program and the graduate minor in statistical data analytics are also included, to reflect demand from students wishing to pursue careers in data science. Additional courses may be approved by petition. Consistent with Graduate School policy, concurrences have been obtained from the relevant departments.

Biochemistry:
- BIOCHEM 5613 (3 cr): Biochemistry and Molecular Biology I
- BIOCHEM 5614 (3 cr): Biochemistry and Molecular Biology II
- BIOCHEM 5615 (3 cr): Biochemistry and Molecular Biology III

Ecology, Evolution, and Organismal Biology
- EEOB 7720 (4 cr): Theoretical Ecology

Molecular Genetics
- MOLGEN 5607 (3 cr): Cell Biology
- MOLGEN 5608 (3 cr): Genes and Development
- MOLGEN 5623 (3 cr): Genetics and Genomics
- MOLGEN 5630 (3 cr): Plant Physiology
- MOLGEN 5700 (3 cr): Systems of Genetic Analysis
- MOLGEN 5701 (3 cr): DNA Transactions and Gene Regulation

Public Health -- Epidemiology
- PUBH-EPI 6410 (3 cr): Principles of Epidemiology
- PUBH-EPI 6411 (3 cr): Biological Basis of Public Health
- PUBH-EPI 6436 (3 cr): Infectious Disease Epidemiology

Statistics

- STAT 5301 (4 cr): Intermediate Data Analysis I
- STAT 5302 (3 cr): Intermediate Data Analysis II
- STAT 6194 (2-5 cr): Topics in Mathematical Statistics
- STAT 6510 (3 cr): Survey Sampling Methods
- STAT 6520 (3 cr): Applied Statistical Analysis with Missing Data
- STAT 6530 (2 cr): Introduction to Spatial Statistics
- STAT 6540 (3 cr): Applied stochastic processes I
- STAT 6550 (2 cr): Statistical Analysis of Time Series
- STAT 6560 (3 cr): Applied Multivariate Analysis
- STAT 6570 (2 cr): Applied Bayesian Analysis
- STAT 6605 (3 cr): Applied Survival Analysis
- STAT 6610 (3 cr): Applied Nonparametric Statistics
- STAT 6615 (2 cr): Design and Analysis of Clinical Trials
- STAT 6620 (2 cr): Environmental Statistics
- STAT 6640 (3 cr): Principles of Statistical Quality Control
- STAT 6650 (2 cr): Discrete Data Analysis
- STAT 6625 (3 cr): Statistical Analysis in Genetic Epidemiology
- STAT 6690 (1-5 cr): Graduate Topics in Statistics

Computer Science

- CSE 5243 (3 cr): Introduction to Data Mining
- CSE 5331 (2 cr): Foundations II: Data Structures and Algorithms
- CSE 5339 (2 cr): Intermediate Studies in Algorithms
- CSE 5441 (3 cr): Introduction to Parallel Computing
- CSE 5449 (2 cr): Intermediate Studies in Parallel Computing
- CSE 5523 (3 cr): Machine Learning and Statistical Pattern Recognition
- CSE 5541 (3 cr): Computer Animation
- CSE 5543 (3 cr): Geometric Modeling
- CSE 5544 (3 cr): Introduction to Scientific Visualization
- CSE 5545 (3 cr): Advanced Computer Graphics
- CSE 5526 (3 cr): Introduction to Neural Networks
- CSE 6331 (3 cr): Algorithms
- CSE 6332 (3 cr): Advanced Algorithms
- CSE 6333 (3 cr): Distributed Algorithms

Computational Electromagnetics

- ECE 5510 (3 cr): Introduction to Numerical Methods for Electromagnetics
- ECE 6010 (3 cr): Electromagnetic Field Theory I
- ECE 7010 (3 cr): Electromagnetic Field Theory II
- ECE 7011 (3 cr): Computational Electromagnetics

Computational Fluid Dynamics and Aerodynamics

- AAE 5615 (3 cr): Introduction to Computational Aerodynamics
- AAE 5771 (3 cr): Viscous Fluid Flow: Laminar and Transitional

- AAE 8802 (3 cr): Advanced Mathematical Methods in Engineering
- AAE 8873 (3 cr): Computational Fluid Dynamics

Signal Processing
- ECE 5200 (3 cr): Introduction to Digital Signal Processing
- ECE 5460 (3 cr): Digital Image Processing
- ECE 5602 (3 cr): Medical Imaging
- ECE 6200 (3 cr): Digital Signal Processing
- ECE 6202 (3 cr): Stochastic Digital Signal Processing

Computational Mechanics
- MECHENG 6505 (3 cr): Intermediate Fluid Dynamics
- MECHENG 6507 (3 cr): Intermediate Numerical Methods
- MECHENG 7511 (3 cr): Computational Fluid Dynamics
- MECHENG 7518 (3 cr): Advanced Mathematical Methods in Mechanical Engineering

Assessment plan (similar to the Mathematics Department's plan)
PhD Assessment Outcomes

1. **Proficiency** Students should achieve working proficiency in selected core mathematical subjects and in an application area (chosen by student and advisor). (Active)

Direct - Other classroom assessment methods Students need to complete basic proficiency requirements in Scientific Computing and at least two of Differential Equations, Analysis or Algebra by classwork within the first two years in the program. For each cohort, we track the number of requirements completed by students after each semester. Students also complete an approved course in another discipline. (Active)

Criteria: Minimum criterion: 50% of students complete all requirements within two semesters, 60% within three semesters, and 70% within four semesters. Aspirational criterion: 60% of students complete all requirements within two semesters, 70% within three semesters, and 80% within four semesters.

2. **Synthesis and Presentation** Students should be able to synthesize results from the literature and present these in a clear and coherent manner. (Active)

Direct - Graduate - Candidacy/Qualifying Examination - Oral presentation/defense Committee members on the candidacy examination will evaluate both the mathematical content and the communication skills exhibited by the student. They will evaluate these for the written portion of the examination, as well as for the oral presentation. (Active)

Criteria: Minimum criterion: 60% of students meet expectations in all categories. Aspirational criterion: 80% of students meet expectations in all four categories.

3. **Scholarship and Research Skills** Graduates should attain scholarship and research skills in a specialized field of applied or interdisciplinary mathematics, and should be able to communicate this new research to the broader mathematical community. (Active)

Direct - Graduate - Dissertation - Oral presentation/defense Committee members on the doctoral committee will evaluate the quality of the mathematical sciences research, and the expository skills demonstrated by the student. They will evaluate these for the written dissertation, as well as for the oral defense. (Active)

Criteria: Minimum criterion: 60% of students meet expectations in all categories. Aspirational criterion: 80% of students meet expectations in all four categories.

Attachments:
Math 6601 Syllabus
Math 6602 Syllabus
Advising Form-appl

Advising Sheet & Candidacy Exam Checklist for Applied Mathematics Track

On this form, students must confirm that they have fulfilled all departmental requirements before scheduling their candidacy exam. The completed form should be signed by the Vice Chair for Graduate Studies and returned to the Math Graduate Office.

Student Name: _____

1. Passed Qualifying Requirement

1. **Sci Comp (6601)**_____ semester year

2. _____ semester year

3. _____ semester year

4. _____ semester year

5. _____ semester year

One of Analysis I and II (6211, 6212) and Algebra I and II (6111, 6112) (which may be passed by examination) and three additional courses to be chosen from ODE (Math 6411), PDE (Math 6451), Sci Comp II (Math 6602), Analysis I and II (6211, 6212) and Algebra I and II (6111, 6112).

2. Elected Thesis Advisor

Thesis Advisor _____ name **Change Form Submitted** _____ semester year

3. Invitation to Mathematics

Between passing qualifying requirements and electing a thesis advisor a student signs up for the lecture series every semester. Enter semester and year for each enrollment into Invitation to Mathematics.

1 _____ semester year **3** _____ semester year

2 _____ semester year **4** _____ semester Year

4. Fulfilled Breadth Requirements

Complete the attached breadth requirement page.
Breadth requirements cannot be fulfilled by examination.

5. Language Requirement

☐ German ☐ By Course ☐ Course_____ Grade___

☐ French

☐ Russian ☐ By Exam ☐ Date Passed_____

Questions about the language requirements should be directed to the language coordinator.

6. CANDIDACY EXAMINATION COMMITTEE MEMBERS (BESIDES ADVISOR)

1_____

2_____ **3** _____

All committee members must be P-status faculty and at least two subject areas must be represented in the exam.

7. EARNED CREDIT HOURS

EH _____

*It is strongly recommended to accumulate at least **62 EH** before candidacy as 80 EH are required for graduation.*

8. POST-CANDIDACY REGISTRATION & TUITION

Post-candidacy tuition is covered up to the minimum of 3 hours. Students enroll themselves for exactly 3 credit hours of Math 8999 with their advisor with the OSU Registrar. Tuition beyond 3 hours requires special permission or is the responsibility of the student.

Student Initial____

Approval: _____ Date _____
(Vice Chair for Grad Studies)

Area	Sequence Name	Course	AY	Grade	Course	AY	Grade
☐ Analysis							
☐ Diff Equat							
☐ Topology							
☐ Algebra							
☐ Probability							
☐ Sci Comp							
☐ Comb/Graph							
☐ External							

Subject: RE: Applied Math PhD Track Concurrence Letter Request
Date: Thursday, December 6, 2018 at 3:06:58 PM Eastern Standard Time
From: Critchlow, Douglas
To: Math Graduate Office, Keyfitz, Barbara
CC: Davis, Greg, Critchlow, Douglas

Hi Barbara,

I have discussed this with the Executive Committee of our department, and we are happy to concur with your request for the Applied Math PhD Track.

As a side comment, many of our courses fill up pretty quickly, and so while we make every effort to enroll appropriate students, we cannot guarantee that spaces will always be available. Each semester, it would be to your advantage to inform our Graduate Program Coordinator, Greg Davis (davis.1671@osu.edu) , of your specific needs for that semester, as much in advance as possible.

Best regards,
Doug Critchlow
Vice Chair for Graduate Studies
Department of Statistics

From: Math Graduate Office
Sent: Tuesday, November 27, 2018 4:35 PM
To: Magliery, Thomas <magliery.1@osu.edu>; Wolfe, Andrea <wolfe.205@osu.edu>; Wharton, Robin <wharton.88@osu.edu>; Schweikhart, Sharon <schweikhart.1@osu.edu>; Critchlow, Douglas <dec@stat.osu.edu>; Qin, Feng <qin.34@osu.edu>; Serrani, Andrea <serrani.1@osu.edu>; Bons, Jeffrey <bons.2@osu.edu>
Cc: Math Graduate Office <grad-office@math.osu.edu>; Keyfitz, Barbara <bkeyfitz@math.ohio-state.edu>
Subject: Applied Math PhD Track Concurrence Letter Request

Dear Colleague,

The Mathematics Department is proposing a new track towards the PhD in Mathematics.

The purpose of this letter to you is to request your statement of concurrence for our planned submission of the degree track proposal to the Graduate School. The statement can be a simple note that your department concurs with our request for the program; if you wish to attach stipulations, then you should include them in your concurrence.

Here is some information. The Applied Math Track differs from the current path in having a more flexible set of qualifying requirements that will allow students to attain more quickly the course background needed to begin research on an applied topic.

One aspect of this is a requirement that every student in this program take a graduate-level course in a department outside mathematics. Courses in your department are suggested as one way of satisfying this requirement. The attached document (pp 4-6) lists the courses in question (these are the same as the courses, approved some time ago, for the department's professional Master's program, MMS).

Because we are requiring courses in your department, we need to obtain concurrence from you that this is acceptable and will not impose a strain on your resources. We do not anticipate a large uptake in this track. Our goal is that when the program has ramped up to full strength, we will admit six students per year. Based on the research expertise of our faculty, we have identified the most likely departments from which students will choose their "outside" course, and we expect that, on average, student interest will span most of the departments we list, suggesting that no more than one student every couple of years will select a course in any one department.

In short, we expect the burden on your department's resources will not be great. Furthermore, we hope that you will see, as we do, the advantage to stimulating greater interaction between our departments at the level where students are beginning to engage in research.

We hope you will concur with this request.

Barbara Keyfitz

%%%%%%%%%%%%%%%%%%%%%%%%%%
Barbara Lee Keyfitz
Dr Charles Saltzer Professor of Mathematics

Department of Mathematics
The Ohio State University
100 Math Tower
231 West 18th Avenue
Columbus, OH 43210-1174

Telephone: 614-292-5583
Fax: 614-292-1479
email: bkeyfitz@math.ohio-state.edu
Website: https://people.math.osu.edu/keyfitz.2

Subject: FW: Applied Math PhD Track Concurrence Letter Request
Date: Thursday, December 13, 2018 at 8:55:13 AM Eastern Standard Time
From: Bisesi, Michael
To: Keyfitz, Barbara
CC: Schweikhart, Sharon, Archer, Kellie J., Rempala, Grzegorz A., Hyder, Ayaz, Miller, William C., Kenah, Eben E., Song, Chi, Pomeroy, Laura, Martin, William J., Math Graduate Office, Anthony, Erin M.
Attachments: Applied Math Track Program Proposal.pdf, image001.png

Dear Dr. Keyfitz,

Regarding below and the attached, thank you for sharing the proposal for an applied math track for the PhD mathematics degree program. We agree that there is value, and, support your proposal. However, you listed some examples of public health courses with emphasis on epidemiology. This is fine, however, you may want to consider additional quantitative courses from the College of Public Health such as biostatistics, public health data analytics, mathematical modeling of exposures and diseases, quantitative environmental/human health risk assessment. WW ear in the process of developing minors in these areas for graduate students, especially PhD students. If you want to meet and discuss optimizing complementary, collaborative and cooperative efforts please let me know and I will convene a meeting that will include applicable chairs and faculty from here.

Best wishes,

Michael Bisesi

THE OHIO STATE UNIVERSITY

***Michael S. Bisesi*, PhD, REHS, CIH**
Senior Associate Dean and Director Academic Affairs
Professor & Chair (Interim), Environmental Health Sciences
College of Public Health
Fellow AIHA
Phone: (614) 247-8290 Email: bisesi.12@osu.edu
(Executive Administrative Assistant Mindy Freed (614) 292-4475 freed.28@osu.edu)
(EHS Division Coordinator Christy Mcleod 614-688-4388 mcleod.53@osu.edu)

From: "Anthony, Erin M." <anthony.69@osu.edu> on behalf of Math Graduate Office <grad-office@math.osu.edu>
Date: Tuesday, November 27, 2018 at 4:34 PM
To: "Magliery, Thomas" <magliery.1@osu.edu>, "Wolfe, Andrea" <wolfe.205@osu.edu>, "Wharton, Robin" <wharton.88@osu.edu>, "Schweikhart, Sharon"

<schweikhart.1@osu.edu>, "Critchlow, Douglas" <dec@stat.osu.edu>, "Qin, Feng" <qin.34@osu.edu>, "Serrani, Andrea" <serrani.1@osu.edu>, "Bons, Jeffrey" <bons.2@osu.edu>
Cc: Math Graduate Office <grad-office@math.osu.edu>, "Keyfitz, Barbara" <bkeyfitz@math.ohio-state.edu>
Subject: Applied Math PhD Track Concurrence Letter Request

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Because we are requiring courses in your department, we need to obtain concurrence from you that this is acceptable and will not impose a strain on your resources. We do not anticipate a large uptake in this track. Our goal is that when the program has ramped up to full strength, we will admit six students per year. Based on the research expertise of our faculty, we have identified the most likely departments from which students will choose their "outside" course, and we expect that, on average, student interest will span

most of the departments we list, suggesting that no more than one student every couple of years will select a course in any one department.

In short, we expect the burden on your department's resources will not be great. Furthermore, we hope that you will see, as we do, the advantage to stimulating greater interaction between our departments at the level where students are beginning to engage in research.

We hope you will concur with this request.

Barbara Keyfitz

%%%%%%%%%%%%%%%%%%%%%%%%%%
Barbara Lee Keyfitz
Dr Charles Saltzer Professor of Mathematics

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Website: https://people.math.osu.edu/keyfitz.2

THE OHIO STATE UNIVERSITY

Department of Molecular Genetics

Susan E. Cole
209 Biological Sciences Building
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Columbus, OH 43210

614-292-3276 Phone
614-292-4466 Fax

cole.354@osu.edu

December 13th, 2018

To whom it may concern,

The Math department has requested concurrence from Molecular Genetics for a proposal for an applied track in the Math PhD program. This track requires students to take a class outside of the Math department as a breadth requirement, and lists several courses in Molecular Genetics as options. We have no concerns with this request but would make the following notes:

1) The listed class MOLGEN 5640 (3 cr): The Genetic Basis of Evolution is not currently being offered, and will not be offered in the future

2) The course numbers listed in the proposal are taken from our initial semester conversion document before the course numbering system was updated, and some of them are incorrect. Corrected course listings are listed below:

• MOLGEN **5**700 (3 cr): Systems of Genetic Analysis
• MOLGEN **5**701 (3 cr): DNA Transactions and Gene Regulation

3) Students in this program should carefully note the prerequisites for each course prior to enrolling. A strong undergraduate background in (at least) genetics is likely required for success in any of the listed courses.

Please feel free to contact me with any questions.

Signed:

Susan E Cole

Susan Cole, Ph.D.
Professor and Vice Chair
Director of Undergraduate Studies, co-chair curriculum committee
Department of Molecular Genetics, Ohio State University
282 Biological Sciences Building
484 W 12th Ave
Columbus, OH 43210
phone: 614-292-3276
cole.354@osu.edu

Subject: RE: Applied Math PhD Track Concurrence Letter Request
Date: Thursday, January 24, 2019 at 4:43:14 PM Eastern Standard Time
From: Bons, Jeffrey
To: Math Graduate Office
Attachments: image001.png

Erin,

I apologize for my tardiness in replying. We are supportive of this new applied math PhD track. As you might guess, math plays a critical role in our department. In fact, we just recently made it a requirement that the Math QE must be taken by ALL PhD hopefuls.
Our grad students are required to take at least 1 graduate math/stat course. We have 2 applied courses that we offer in our department:
MECHENG 6507 and MECHENG 8518 (crosslisted with AAE 8802)

Students can satisfy their math requirement with either of these courses, or a course from Math or Stat.

I see that you have other applied match courses listed as well: 6505, 7511, 7518.
There are two AAE courses that might be considered applied math as well: 8820, 8873
That is from a cursory review. If you'd like a more comprehensive list, I could solicit feedback from the MAE faculty more generally. Let me know.

I hope this is helpful.

Jeffrey

From: Math Graduate Office <grad-office@math.osu.edu>
Sent: Thursday, January 24, 2019 3:44 PM
To: Magliery, Thomas <magliery.1@osu.edu>; Wolfe, Andrea <wolfe.205@osu.edu>; Bons, Jeffrey <bons.2@osu.edu>; Serrani, Andrea <serrani.1@osu.edu>
Cc: Keyfitz, Barbara <bkeyfitz@math.ohio-state.edu>
Subject: Applied Math PhD Track Concurrence Letter Request

Good afternoon,

I am writing to follow up one more time on the Math Department's request for a statement of concurrence from you regarding the inclusion of some of your department's courses in our new applied math PhD track (original message from Barbara Keyfitz below). We will need to move forward with our proposal very soon.

Thank you,
Erin

Erin Anthony, M.A.
Graduate Program Coordinator
Department of Mathematics
102 Math Bldg, 231 W. 18th Ave, Columbus, OH 43210

614-292-6274 Office
anthony.69@osu.edu http://math.osu.edu/graduate

From: Math Graduate Office <grad-office@math.osu.edu>
Date: Tuesday, November 27, 2018 at 4:34 PM
To: "Magliery, Thomas" <magliery.1@osu.edu>, "Wolfe, Andrea" <wolfe.205@osu.edu>, "Wharton, Robin" <wharton.88@osu.edu>, "Schweikhart, Sharon" <schweikhart.1@osu.edu>, "Critchlow, Douglas" <dec@stat.osu.edu>, "Qin, Feng" <qin.34@osu.edu>, "Serrani, Andrea" <serrani.1@osu.edu>, "Bons, Jeffrey" <bons.2@osu.edu>
Cc: Math Graduate Office <grad-office@math.osu.edu>, "Keyfitz, Barbara" <bkeyfitz@math.ohio-state.edu>
Subject: Applied Math PhD Track Concurrence Letter Request

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We hope you will concur with this request.

Barbara Keyfitz

%%%%%%%%%%%%%%%%%%%%%%%%%%

Barbara Lee Keyfitz
Dr Charles Saltzer Professor of Mathematics

Department of Mathematics
The Ohio State University
100 Math Tower
231 West 18th Avenue
Columbus, OH 43210-1174

Telephone: 614-292-5583
Fax: 614-292-1479
email: bkeyfitz@math.ohio-state.edu
Website: https://people.math.osu.edu/keyfitz.2

Subject: Re: Applied Math PhD Track Concurrence Letter Request
Date: Friday, January 25, 2019 at 10:10:45 AM Eastern Standard Time
From: Wolfe, Andrea
To: Math Graduate Office, Magliery, Thomas, Bons, Jeffrey, Serrani, Andrea
CC: Keyfitz, Barbara
Attachments: image001.png

EEOB is fine with this proposed track.

Andi Wolfe
--

Andrea D. Wolfe
Professor
Chair, EEOB Graduate Studies Committee
Department of Evolution, Ecology and Organismal Biology
The Ohio State University
318 W. 12th Ave
Columbus, Ohio 43210
USA
President, Botanical Society of America

ph: 614-292-0267
Fax: 614-292-2030

From: Math Graduate Office <grad-office@math.osu.edu>
Date: Thursday, January 24, 2019 at 3:44 PM
To: "Magliery, Thomas" <magliery.1@osu.edu>, Andrea Wolfe <wolfe.205@osu.edu>, "Bons, Jeffrey" <bons.2@osu.edu>, "Serrani, Andrea" <serrani.1@osu.edu>
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Telephone: 614-292-5583
Fax: 614-292-1479
email: bkeyfitz@math.ohio-state.edu
Website: https://people.math.osu.edu/keyfitz.2

Subject: Re: Applied Math PhD Track Concurrence Letter Request
Date: Thursday, December 13, 2018 at 3:01:33 PM Eastern Standard Time
From: Qin, Feng
To: Serrani, Andrea, Math Graduate Office
CC: Reeves, Kathryn

Dear Andrea,

We concur your request for the Applied Math PhD Track.

One suggestion from Mrs. Kathryn Reeves, our Assistant Director of Academic Programs & Student Services, is assigning the new track with a plan destination. For example, the plan destination for an MS in Mathematical Sciences with a Computational Sciences track is MATHSC-MMS-CPS. This way, she can put the plan on the reserve cap so that a certain number of students in the new track can be automatically enrolled in the class. We believe this will significantly reduce the administrative load for all the Departments.

thanks,
-feng

From: Serrani, Andrea
Sent: Tuesday, December 11, 2018 7:28 PM
To: Math Graduate Office
Cc: Magliery, Thomas; Wolfe, Andrea; Wharton, Robin; Schweikhart, Sharon; Qin, Feng; Bons, Jeffrey; Keyfitz, Barbara
Subject: Re: Applied Math PhD Track Concurrence Letter Request

The attachment is missing

Andrea Serrani
Professor
Dept. of Electrical & Computer Engineering
The Ohio State University
412 Dreese Labs
2015 Neil Ave.
Columbus, OH
phone: (614) 292 4976

On Dec 11, 2018, at 5:04 PM, Math Graduate Office <grad-office@math.osu.edu> wrote:

> Good afternoon,
>
> In order to adhere to our timeline, we would greatly appreciate a response to this request as

soon as possible, and by January 15 at latest.

Thank you for your timely attention to this matter. Wishing you the best during this busy holiday season.

From: "Anthony, Erin M." <anthony.69@osu.edu> on behalf of Math Graduate Office <grad-office@math.osu.edu>
Date: Tuesday, November 27, 2018 at 4:34 PM
To: "Magliery, Thomas" <magliery.1@osu.edu>, "Wolfe, Andrea" <wolfe.205@osu.edu>, "Wharton, Robin" <wharton.88@osu.edu>, "Schweikhart, Sharon" <schweikhart.1@osu.edu>, "Critchlow, Douglas" <dec@stat.osu.edu>, "Qin, Feng" <qin.34@osu.edu>, "Serrani, Andrea" <serrani.1@osu.edu>, "Bons, Jeffrey" <bons.2@osu.edu>
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Subject: RE: Applied Math PhD Track Concurrence Letter Request
Date: Thursday, January 24, 2019 at 4:20:16 PM Eastern Standard Time
From: Magliery, Thomas
To: Math Graduate Office
Attachments: image001.png

Hi Erin, it's no problem to include the Biochem 56xx courses. There is no capacity issues. I'm sorry this slipped off my radar. I'll take care of it today or tomorrow. Tom

---

From: Math Graduate Office
Sent: Thursday, January 24, 2019 3:44 PM
To: Magliery, Thomas <magliery.1@osu.edu>; Wolfe, Andrea <wolfe.205@osu.edu>; Bons, Jeffrey <bons.2@osu.edu>; Serrani, Andrea <serrani.1@osu.edu>
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THE OHIO STATE UNIVERSITY

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Term Information

Effective Term	Autumn 2020
Previous Value	*Summer 2012*

Course Change Information

What change is being proposed? (If more than one, what changes are being proposed?)

Revision of the 6601-6602 syllabi:

Topics have been rearranged and more advanced topics added.

The catalog description and prerequisites have been updated accordingly.

References to quarter courses have been removed.

One of the four credits has been identified as am individually scheduled lab requirement.

What is the rationale for the proposed change(s)?

The course sequence is intended serve as a required (also elective) for a newly proposed applied mathematics track in the mathematics PhD program. The rigor and sophistication of the content, the level of training, as well as the required preparations of the sequence thus needed to be adjusted to match that of our traditional track as well as the expected strength of incoming students.

What are the programmatic implications of the proposed change(s)?

(e.g. program requirements to be added or removed, changes to be made in available resources, effect on other programs that use the course)?

As noted above, Math 6601 will constitute a core gateway course requirement for the applied mathematics track. The 6601-2 sequence also serves as an elective in the traditional track but has historically very rarely been used by students as an elective. The impact on the traditional track is thus expected to be minimal.

Is approval of the requrest contingent upon the approval of other course or curricular program request? Yes

Please identify the pending request and explain its relationship to the proposed changes(s) for this course (e.g. cross listed courses, new or revised program)

This course approval request is submitted in conjunction with the change request for Math 6602 as well as the approval of the proposal for an applied math track/subplan.

Is this a request to withdraw the course? No

General Information

Course Bulletin Listing/Subject Area	Mathematics
Fiscal Unit/Academic Org	Mathematics - D0671
College/Academic Group	Arts and Sciences
Level/Career	Graduate
Course Number/Catalog	6601
Course Title	Numerical Methods in Scientific Computing I
Transcript Abbreviation	Num Meth Sc Comp 1
Course Description	Numerical linear algebra: matrix operations, direct and iterative methods for systems of linear equations, eigenvalue problems; Nonlinear equations and systems; Numerical Integration.
Previous Value	*What is scientific computing; the evaluation of functions; solving linear systems using Gaussian elimination; finding zeroes and minima of nonlinear equations; bifurcation studies.*
Semester Credit Hours/Units	Fixed: 4

Offering Information

Length Of Course	14 Week, 12 Week
Flexibly Scheduled Course	Never
Does any section of this course have a distance education component?	No
Grading Basis	Letter Grade
Repeatable	No
Course Components	Laboratory, Lecture
Previous Value	*Lecture*
Grade Roster Component	Lecture
Credit Available by Exam	No
Admission Condition Course	No
Off Campus	Never
Campus of Offering	Columbus

Prerequisites and Exclusions

Prerequisites/Corequisites	Graduate standing or Math 5603
Previous Value	*Prereq: 2415.xx and 2568; or 255 or 415, and 568 or 572.*
Exclusions	
Previous Value	Not open to students with credit for 707
Electronically Enforced	No

Cross-Listings

Cross-Listings

Subject/CIP Code

Subject/CIP Code	27.0301
Subsidy Level	Doctoral Course
Intended Rank	Doctoral

Requirement/Elective Designation

Required for this unit's degrees, majors, and/or minors
The course is an elective (for this or other units) or is a service course for other units

Previous Value

The course is an elective (for this or other units) or is a service course for other units

Course Details

Course goals or learning objectives/outcomes

- Acquire a strong knowledge and skill set in doctoral level numerical methods in scientific computing.

Previous Value

Content Topic List

- Matrix operations, Singular value decomposition.

  Projection, QR factorization, Gram-Schmidt orthogonalization.
- Householder triangularization, least squares.

  Conditioning, stability, back substitution.
- Direct methods: Gauss elimination, LU factorization, Cholesky decomposition.

  Banded linear systems. Block systems.
- Iterative methods: Gauss-Siedel, Jacobi, SOR, Convergence.

  Gradient method, conjugate gradient, Krylov, GMRES.
- Eigenvalues. Power method, Rayleigh quotient, QR with shift
- Nonlinear equations: root finding, fixed point, bisection, convergence.
- Nonlinear systems: Newton, quasi-Newton, Secant, fixed-point.
- Numerical integration: mid-point, trapezoidal, Newton-Cotes, composite rules, Richardson extrapolation.

Previous Value

- *What is scientific computing*
- *The evaluation of functions*
- *Solving linear systems using Gaussian elimination*
- *Finding zeroes and minima of nonlinear equations*
- *Bifurcation studies*

Sought Concurrence

No

Attachments

- MATH6601_Syllabus_ed_2019_03_04.pdf: Math 6601 Syllabus

  (Syllabus. Owner: Kerler,Thomas)

Comments

Workflow Information

Status	User(s)	Date/Time	Step
Submitted	Kerler,Thomas	03/19/2019 08:47 PM	Submitted for Approval
Pending Approval	Husen,William J	03/19/2019 08:47 PM	Unit Approval

Math 6601 Syllabus **Autumn 2018**

Numerical Methods in Scientific Computing I

Instructor and Class Information

Lecturer:	**Course Num.:**
Office:	**Lecture Room:**
Phone:	**Lecture Times:**
Email:	**Office Hours:**

About Course Goals

FORMAT

The course includes three 55-minute meetings a week and a one-hour, individually scheduled lab. Instruction will be mainly lectures delivered by the instructor. It may also include occasional in-class discussion as well as short student presentations, particularly by post-candidacy students.

DESCRIPTION & GOALS

This course covers the core numerical methods for scientific computing. Major topics include: numerical linear algebra, direct and iterative methods for linear system of equations, nonlinear equation and systems, and numerical integration.

PREREQUISITES

Math 5603 or graduate standing or permission of instructor.

Textbook

MAIN REFERENCE

L.N. Trefethen and D. Bau, III*: "Numerical Linear Algebra",* SIAM, 1997. ISBN: 978-0-898713-61-9.

A. Quarteroni, R. Sacco, and F. Saleri: *"Numerical Mathematics",* Springer, 2000. ISBN: 0-387-98959-5.

Assessments

HOMEWORK ASSIGNMENTS

There will be approximately 10 homework assignment sheets, which will typically contain several fully described problems as well as a list of numbers of textbook problems. Due dates of assignments will be announced and set typically a week after the assignments are published

FINAL PROJECT

The final project is a more extensive written assignment that will draw on techniques acquired throughout the semester through lectures and the weekly lab. It will be published about two weeks before the end of classes and will be due at the beginning of finals week.

CLASS PARTICIPATION AND ATTENDANCE

Although attendance is not regularly monitored frequent absences are likely to be noted and may factor into the grade in borderline cases.

Grading

COURSE SCORE

A course score will be computed from the above assessments. Homework assignments will count 70% towards the grade and the final project 30%.

LETTER GRADES

Letter grades will be determined based on the course score. The major topics include: numerical linear algebra, direct and iterative methods for linear system of equations, methods for nonlinear equation and systems, numerical integration.

Weekly Schedule

Week 1	Matrix operations, Singular value decomposition
Week 2	Projection, QR factorization, Gram-Schmidt orthogonalization
Week 3	Householder triangularization, least squares
Week 4	Conditioning, stability, back substitution
Week 5	Direct methods: Gauss elimination, LU factorization, Cholesky decomposition
Week 6	Banded linear systems. Block systems
Week 7	Iterative methods: Gauss-Siedel, Jacobi, SOR, Convergence
Week 8	Iterative methods: gradient method, conjugate gradient, Krylov, GMRES
Week 9	Eigenvalues. Power method, Rayleigh quotient, QR with shift
Week 10	Nonlinear equations: root finding, fixed point, bisection, convergence.
Week 11	Nonlinear systems: Newton, quasi-Newton
Week 12	Nonlinear systems: Secant, fixed-point
Week 13	Numerical integration: mid-point, trapezoidal
Week 14	Numerical integration: Newton-Cotes, composite rules, Richardson extrapolation

General Policies

ACADEMIC MISCONDUCT

It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term “academic misconduct” includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to

the committee (Faculty Rule 3335-5-487). For additional information, see the Code of Student Conduct (https://trustees.osu.edu/index.php?q=rules/code-of-student-conduct/)."

DISABILITY SERVICES

Students with disabilities that have been certified by Student Life Disability Services will be appropriately accommodated and should inform the instructor as soon as possible of their needs. Student Life Disability Services is located in 098 Baker Hall, 113 W. 12th Ave; telephone 614-292-3307, VRS 614-500-4445; https://slds.osu.edu/.

Term Information

Effective Term	Spring 2020
Previous Value	*Summer 2012*

Course Change Information

What change is being proposed? (If more than one, what changes are being proposed?)

Revision of the 6601-6602 syllabi:

Topics have been rearranged and more advanced topics added.

The catalog description and prerequisites have been updated accordingly.

References to quarter courses have been removed.

One of the four credits has been identified as am individually scheduled lab requirement.

What is the rationale for the proposed change(s)?

The course sequence is intended serve as a required (also elective) for a newly proposed applied mathematics track in the mathematics PhD program. The rigor and sophistication of the content, the level of training, as well as the required preparations of the sequence thus needed to be adjusted to match that of our traditional track as well as the expected strength of incoming students.

What are the programmatic implications of the proposed change(s)?

(e.g. program requirements to be added or removed, changes to be made in available resources, effect on other programs that use the course)?

As noted above, Math 6602 will constitute a core gateway course requirement for the applied mathematics track. The 6601-2 sequence also serves as an elective in the traditional track but has historically very rarely been used by students as an elective. The impact on the traditional track is thus expected to be minimal.

Is approval of the requrest contingent upon the approval of other course or curricular program request? Yes

Please identify the pending request and explain its relationship to the proposed changes(s) for this course (e.g. cross listed courses, new or revised program)

This course approval request is submitted in conjunction with the change request for Math 6601 as well as the approval of the proposal for an applied math track/subplan.

Is this a request to withdraw the course? No

General Information

Course Bulletin Listing/Subject Area	Mathematics
Fiscal Unit/Academic Org	Mathematics - D0671
College/Academic Group	Arts and Sciences
Level/Career	Graduate
Course Number/Catalog	6602
Course Title	Numerical Methods in Scientific Computing II
Transcript Abbreviation	Num Meth Sc Comp 2
Course Description	Approximation theory: interpolation, projection, integration; Initial value problems: one- and multi-step methods, Runge-Kutta methods, stability analysis; PDEs: advection equation, diffusion equation, stability analysis.
Previous Value	*Interpolation and approximation theory; numerical differentiation and integration; time evolution ODEs; boundary value ODEs; eigenvalues, including Krylov subspace methods; solving linear systems using iterative methods.*
Semester Credit Hours/Units	Fixed: 4

Offering Information

Length Of Course	14 Week, 12 Week
Flexibly Scheduled Course	Never
Does any section of this course have a distance education component?	No
Grading Basis	Letter Grade
Repeatable	No
Course Components	Laboratory, Lecture
Previous Value	*Lecture*
Grade Roster Component	Lecture
Credit Available by Exam	No
Admission Condition Course	No
Off Campus	Never
Campus of Offering	Columbus

Prerequisites and Exclusions

Prerequisites/Corequisites	Math 6601
Previous Value	*Prereq: 6601 (708)*
Exclusions	
Previous Value	Not open to students with credit for 709
Electronically Enforced	No

Cross-Listings

Cross-Listings

Subject/CIP Code

Subject/CIP Code	27.0301
Subsidy Level	Doctoral Course
Intended Rank	Doctoral

Requirement/Elective Designation

Required for this unit's degrees, majors, and/or minors
The course is an elective (for this or other units) or is a service course for other units

Previous Value

The course is an elective (for this or other units) or is a service course for other units

Course Details

Course goals or learning objectives/outcomes

- Acquire a strong knowledge and skill set in doctoral level numerical methods in scientific computing.

Previous Value

Content Topic List

- Approximation theory: Polynomial interpolation, orthogonal polynomials, orthogonal projection, best approximation.
- Numerical integration, Gauss quadrature, bounded and unbounded domains
- Initial value problem (IVP): basic methods, Euler forward, mid-point rule, truncation errors.
  Analysis of one-step methods: consistency, convergence, stability.
  Multi-step methods. Adams methods, BDF methods.
- Runge-Kutta methods
- Zero-stability for IVP, absolute stability for ODEs.
- PDE: boundary value problems, steady-state diffusion equation. Parabolic problems. Von Neuman analysis. Method of lines.
- Linear advection equations: Euler forward, Leapfrog, Lax-Friedrichs, Lax-Wendroff.
- Stability analysis. Upwinding methods, CFL condition. Multi-dimensions. Boundary conditions.

Previous Value

- *Interpolation and approximation theory*
- *Numerical differentiation and integration*
- *Time evolution ODEs*
- *Boundary value ODEs*
- *Eigenvalues, including Krylov subspace methods*
- *Solving linear systems using iterative methods*

Sought Concurrence

No

Attachments

- MATH6602_Syllabus_ed_2019_03_04.pdf: Math 6602 Syllabus

(Syllabus. Owner: Kerler,Thomas)

Comments

Workflow Information

Status	User(s)	Date/Time	Step
Submitted	Kerler,Thomas	03/19/2019 08:48 PM	Submitted for Approval
Pending Approval	Husen,William J	03/19/2019 08:48 PM	Unit Approval

Math 6602 Syllabus **Spring 2019**

Numerical Methods for Scientific Computing II

Instructor and Class Information

Lecturer:	**Course Num.:**
Office:	**Lecture Room:**
Phone:	**Lecture Times:**
Email:	**Office Hours:**

About Course Goals

FORMAT

The course includes three 55-minute meetings a week and a one-hour, individually scheduled lab. Instruction will be mainly lectures delivered by the instructor. It may also include occasional in-class discussion as well as short student presentations, particularly by post-candidacy students.

DESCRIPTION & GOALS

This course covers the core numerical methods for scientific computing. The major topics include: basic approximation theory, methods for initial value problems and ordinary differential equations, and finite difference methods for partial differential equations.

PREREQUISITES

Math 6601, or instructor's permission

Textbook

MAIN REFERENCES

A. Quarteroni, R. Sacco, F. Saleri: *"Numerical Mathematics",* Springer, 2000. ISBN: 0-387-98959-5.

R. LeVeque: *"Finite Difference Methods for Ordinary and Partial Differential Equations: Steady-State and Time-Dependent Problems"*, SIAM 2007. ISBN: 0-898-71629-2.

Assessments

HOMEWORK ASSIGNMENTS

There will be approximately 10 homework assignment sheets, which will typically contain several fully described problems as well as a list of numbers of textbook problems. Due dates of assignments will be announced and set typically a week after the assignments are published

FINAL PROJECT

The final project is a more extensive written assignment that will draw on techniques acquired throughout the semester and via the weekly lab. It will be published about two weeks before the end of classes and will be due at the beginning of finals week.

CLASS PARTICIPATION AND ATTENDANCE

Although attendance is not regularly monitored frequent absences are likely to be noted and may factor into the grade in borderline cases.

Grading

COURSE SCORE

A course score will be computed from the above assessments. Homework assignments will count 70% towards the grade and the final project 30%.

LETTER GRADES

Letter grades will be determined based on the course score.

Weekly Schedule

Week 1	Approximation theory: Polynomial interpolation, orthogonal polynomials.
Week 2	Approximation theory: Orthogonal projection, best approximation
Week 3	Gaussian integration, Gauss quadrature, bounded and unbounded domains
Week 4	Initial value problem (IVP): basic methods, Euler forward, mid-point rule, truncation errors
Week 5	IVP: analysis of one-step methods: consistency, convergence, stability
Week 6	IVP: multi-step methods. Adams methods, BDF methods.
Week 7	Runge-Kutta methods
Week 8	Zero-stability for IVP
Week 9	Absolute stability for ODEs
Week 10	PDE: boundary value problems, steady-state diffusion equation.
Week 11	PDE: Parabolic problems. Von Neuman analysis. Method of lines
Week 12	Linear advection equations: Euler forward, Leapfrog, Lax-Friedrichs, Lax-Wendroff
Week 13	Stability analysis. Upwinding methods, CFL condition
Week 14	Multi-dimensions. Boundary conditions.

General Policies

ACADEMIC MISCONDUCT

It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term "academic misconduct" includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-487). For additional information, see the Code of Student Conduct (https://trustees.osu.edu/index.php?q=rules/code-of-student-conduct/)."

DISABILITY SERVICES

Students with disabilities that have been certified by Student Life Disability Services will be appropriately accommodated and should inform the instructor as soon as possible of their needs. Student Life Disability Services is located in 098 Baker Hall, 113 W. 12th Ave; telephone 614-292-3307, VRS 614-500-4445; https://slds.osu.edu/.

6. DOCTOR OF PHILOSOPHY (PHD)

The PhD is the flagship degree of our program with the largest enrollment and the highest standards. Graduates have a sophisticated background over a broad range of areas in mathematics and they are able to conduct independent and original research in their chosen discipline.

6.1 ADMISSION POLICIES AND REQUIREMENTS

The PhD program considers only admissions for autumn semesters and by application only. All applications need to be received by the advertised deadlines for full consideration. Admissions are granted only upon positive review by the GRC during the annual admission process in the spring semester.

Students who are not already graduate students at OSU need to submit a full application through the OGPA system as outlined in Section 5.1.1. Students who have already been admitted to a graduate program at OSU need to apply for a program transfer as noted in Section 5.1.2 and should submit all materials to the OGPA system. This includes master's students in our program and students who have already graduated from a graduate program at OSU.

Expectations for consideration to the PhD program include the following:

- Strong preparations in Real Analysis and Abstract Algebra, at the level comparable to our Math 5201-5202 and Math 5111-5112 course sequences.
- Substantial upper division of higher coursework in other mathematical subjects.
- Three letters of recommendations from faculty that evaluate mathematical ability and research potential.
- Submission of a recent score on the GRE Subject Test in Mathematics that is within our typical range of admissions.
- Acceptable English skills that predict OPA certification within one year.

6.2 TIME EXPECTATIONS AND REINSTATEMENT

6.2.1 General Time Expectations

Doctoral students are expected to complete all of their dissertation requirements by the end of their sixth year of study in the program.

The *effective start date* for this time limit is normally identical with the with the date of matriculation in our mathematics PhD program and independent of prior enrollments in undergraduate or graduate programs or degrees earned in these.

For special admissions that do not occur through the regular application process other effective start dates may be determined by the department. This typically pertains to students who are also given significant credit towards their pre-candidacy requirements at the time of matriculation and are, thus, expected to be at the level of a second year student when they enter the program.

6.2.2 Leaves and Reinstatement

On occasion a student who left the PhD program before candidacy while maintaining good standing and adequate progress may seek to reenter the program. In order to be readmitted the student should submit a petition the GSC that includes the prior academic record in our program, justifications for having previously completed pre-candidacy requirements counted, as well as a proposal for an effective start date for the six-year time limit.

Typically, students in good standing are reinstated in the year of study that they would have entered at the time when they started their leave and all pre-candidacy requirements are counted. The GSC may, however, deviate from this default if, for example, the leave period was unusually long, the pre-candidacy requirements have changed during the leave, or there are concerns about the student's academic performance.

Students who left the program without degree after passing candidacy (ABD) and seek to be reinstated are required to also find a dissertation advisor to support their petition to the GSC and need to retake the candidacy examination following all rules and procedures required by the Graduate School. The GSC will also determine time expectations for a returning ABD student which would typically be three years after retaking the candidacy examination.

6.2.3 Continued Enrollment beyond Time Expectations

Students may request to be allowed enrollment beyond time expectation with special permission by the GSC. This requires a student to submit a petition to the GSC for *every* autumn and spring semester of additional enrollment. The petition needs to include a letter of support by the advisor detailing recent progress and a plan towards completion of the dissertation.

The GSC decision may include special time expectations, stipulations for reporting, as well as recommendations for a Graduate School performance letter. If a student makes no credible progress towards the completion of a dissertation and a performance letter was already sent the student may be barred from reenrollment.

Financial support as a Graduate Associate may be extended on a semester-by-semester basis and upon petitions to the GSC throughout the seventh year with stipends at the probationary O-level. The petition for extended financial support must provide credible evidence and testimony by the advisor that the dissertation can be completed during the time of support.

Students beyond their seventh year of study are not eligible for departmental financial support at Graduate Associates, regardless of academic progress, advisor support, or stipend level. Thus, even students who have been granted continued enrollment by the GSC are responsible for their own subsistence, tuition fees, health insurance, and benefits normally covered by a Graduate Associateship.

6.3 Overview and Timeline of Pre-Candidacy Requirements

The career of a PhD student is divided into two portions separated by the candidacy examination. During the pre-candidacy period student will need to complete a fixed set of program requirements, while post-candidacy students are expected to focus entirely on their dissertation research.

All requirements must be completed *before* applying for the candidacy examination. Any applications for candidacy of students with pending requirements will be denied by the department. The deadline for passing the candidacy requirement is the summer at the end of the third year of study.

a) The **Qualifying Requirement** tests and ensures that students have strong working knowledge and competence in core areas of mathematics. The general deadline for completion is the end of the autumn semester of the second year of study. See Section 6.3 for more details.

b) The **Breadth Requirement** serves to expose students to a range of areas of mathematics that may not be within of their narrow area of research. Students are expected to complete this within the first 2 years of study. See Section 6.4.

c) For the **Foreign Language Requirement** students need to prove their ability to read and understand a scientific text in one of three foreign languages with the help of a dictionary. This requirement should be completed as early as possible to allow time for failed exams or courses. Details about the process are given in Section 6.5.

d) The **Invitations Requirement** states that all students need to be enrolled in the Invitations to Mathematics/Problem Solving activities each semester until they have officially declared a dissertation advisor.

e) **Advisor and Committee:** Doctoral students should have officially declared a dissertation advisor by the beginning of their third year. The advisor will serve as chair of the candidacy examination committee. Before applying for the candidacy examination the remaining members of the committee also need to have consented to serve upon the request by the student.

f) All **ESL and Oral Proficiency Requirements** must be completed before candidacy by all students whose native language is not English.

In addition, students are strongly recommended to have accrued at least 63 graduate credits before entering candidacy, either by taking courses in our program or from transfer graduate credits, in order to be able complete the university requirement mentioned in Section 5.3.1.

6.4 QUALIFYING REQUIREMENT

6.4.1 Overview

In order to fulfill the Qualifying Requirement a student needs to receive a Pass in *each* one of four subject requirements. The four subject requirements correspond to the courses

Math 6111, Math 6112, Math 6211, and Math 6212

in Real Analysis and Abstract Algebra, with the option of one sequence substitution.

A Pass can be earned in each subject *either* by taking the respective course *or* by passing a respective qualifying examination.

In addition to a Pass in one of these courses and examinations a student may also earn a (lesser) Master-Pass which does not count towards the Qualifying Requirement but may count towards a master's requirements.

The content and syllabi of these courses can be found on the university course bulletin as well as the departmental web pages.

6.4.2 Subject Passes via Regular Course Completion

A student can earn a Pass in a given subject of the four above by completing the respective semester course with a grade of A or A-. Completion of a course with a grade of B+ counts as a Master-Pass in the subject.

Note that Math 6111 and Math 6211 are offered every autumn semester, thus providing two opportunities for a student to earn a Pass in these subject by course grades within the regular deadline. Since Math 6112 and Math 6212 are offered in spring semesters there is only one such opportunity within the stated deadline.

6.4.3 Subject Passes via Examination

The department offer a qualifying examinations for each of the four subject once a year in mid-to-late August on separate days. The possible outcomes of each examination are “Pass”, “Master-Pass”, and “Fail”.

Each examination is approximately two hours long and closed-book. It is in scope and content similar to a final examination of the respective course. Detailed syllabi can be found on the department web pages.

The examinations are designed, administered, and graded by respective departmental committees. The chairs of these committees are appointed by the GSC chair and the committees are overseen by the GSC. The examinations are open to PhD students who have not yet completed the autumn semester of their second year. It is not open to students past their second year or students in other degree programs, including our master’s students.

6.4.4 Subject Pass via Sequence Substitution

One of the four subject requirements can be substituted and fulfilled by completing a year-long sequence chosen from the following list:

- Math 6221-6222 (Complex Analysis)
- Math 6251-6252 (Theory of Probability)
- Math 6411-6412 (Differential Equations)
- Math 6501-6502 (Combinatorics and Graph Theory)
- Math 6601-6602 (Num. Methods in Scientific Comp.)
- Math 6701-6702 (Diff. Manifolds/Diff. Geometry)
- Math 6801-6802 (Algebraic Topology)

A sequence will count as a Pass for the substituted subject if a student has earned at least a grade of A- in both courses of the sequence. The sequence is counted as a Master-Pass if at least a B+ is earned in *both* courses of a sequence.

Only one such sequence substitution is allowed, so at least three subject requirements need to be fulfilled by course completion or examination as in Sections 6.4.2 and 6.4.3 above. The two courses used to substitute for one subject must be from the same sequence. However, these two courses need to be taken consecutively or during the same academic year.

6.4.5 Timeline and Evaluation of Requirements

All students need to complete their qualifying requirement by the end of the autumn semester of their second year.

This provides each student with four attempts at passing the Math 6111 and Math 6211 subject requirements (2 by course, 2 by examination) and three attempts at the Math 6112 and Math 6212 requirements (1 by course, 2 by examination). Students using the substitution option may (re)take the first course of a sequence for a passing grade in the autumn semester of their second year if they received a passing grade for the second course of the sequence during the previous spring semester.

Unsuccessful attempts on a subject requirement are not counted against a student, but, for the purpose of the qualifying requirement, are considered equivalent to not taking a course or examination.

Students who have not passed the qualifying requirements at the beginning of their second year and who are not certain that they will complete missing requirements during the autumn semester need to submit a petition to the GSC well before November 15th if they seek to be granted a one-semester extension of the qualifying requirement deadline. The petition will need to include a convincing plan for the fulfillment of the requirement during the spring semester as well as a justification from the advisor. Extensions beyond the spring semester second year are not granted.

6.5 Breadth Requirement

6.5.1 Purpose and Selection Rules

The breadth requirement seeks to ensure that graduates master not only their eventual field of specialization but also develop the breadth, versatility, and maturity expected from mathematicians working in academic professions that traditionally require a PhD-degree.

The selection rules, referring to the course list in Section 6.5.3 below, are as follows:

a) Choose *three* of the five breadth areas.

b) Within each of the three chosen breadths areas choose *one* course sequence.

c) In each of the three chosen course sequences pass two distinct courses in the sequence with a grade of B+ of better.

Note that the last condition is equivalent to passing all of the courses of a sequence with a B+ or better with the exception of the logic course sequence. Courses within a sequence do not have to be taken consecutively and may also be taken in different academic years. A course with insufficient grade for the breadth requirement may be repeated with the permission of the instructor.

6.5.2 Relation to Qualifying Requirement

A course or course sequence used to fulfill a qualifying subject requirement either via the course completion option (Section 6.4.2) or the sequence substitution option (Section 6.4.4) may, simultaneously, be used to fulfill the breadth requirement.

However, passing a qualifying examination in a given subject cannot be counted as the equivalent of taking a respective course towards the breadth requirement.

6.5.3 Breadth Area Course List

Besides the selection rules in Section 6.5.1 students should also keep the offering patters from Section **Error! Reference source not found.** in mind. Students with advanced preparation at the 6000-level have the option to take courses at the 7000-level.

Area 1 Sequences [ALGEBRA]

- Math 6111-6112 (Abstract Algebra)
- Math 7121-7122 (Number Theory)
- Math 7141-7142 (Algebraic Geometry)
- Math 7161-7162 (Lie Groups)

Area 2 Sequences [ANALYSIS]

- Math 6211-6212 (Real Analysis
- Math 7211-7212 (Functional Analysis)
- Math 7221-7222 (Ergodic Theory)

Area 3 Sequences [DIFFERENTIAL EQUATIONS]

- Math 6411, 6451 (Differential Equations)
- Math 7412-7413 (Ordinary Differential Equations)
- Math 7452-7453 (Partial Differential Equations)

Area 4 Sequences [TOPOLOGY/GEOMETRY]

- Math 6801-6802 (Algebraic Topology)
- Math 6701-6702 (Differential Manifolds & Geometry)
- Math 7851-7852 (Differential Topology)
- Math 7711, 7721 (Riemannian & Kähler Geometry)

Area 5 Sequences [ALTERNATE TOPICS]

- Math 6001-6004 (Advanced Mathematical Logic)
- Math 6501-6502 (Combinatorics and Graph Theory)
- Math 6251-6252 (Theory of Probability)
- Math 6221-6222 (Complex Analysis)
- Math 7651-7652 (Appl. Complex Variables & Asymptotics)
- Math 6601-6602 (Num. Methods in Scientific Computing)

6.5.4 Time Expectations and Evaluation

Students are expected to have their breadth requirements completed by the end of the spring semester of their second year of study.

Progress on and status of completion of the breadth requirement is reviewed by the GSC during the annual evaluation of graduate students, see Section 2.3.4. Students and advisor should address the likelihood of passing the requirement. In case there is a chance the student will not be able to complete the requirement by the deadline a petition should be submitted to the GSC sufficiently early during the spring semester.

6.6 Foreign Language Requirement

6.6.1 Purpose and Options

The foreign language requirement tests the ability to read (with the aid of a dictionary) a scientific text in *one* of three available foreign languages. The requirement can be fulfilled in the chosen language either by course completion or by examination. The selection process thus involves the following two steps:

a) Choose *one* of the available languages, namely, French, German, or Russian.

b) Decide whether to complete the requirement in the chosen language by course completion *or* examination and follow the instructions in the respective section below.

6.6.2 Language Courses Completion

Students with little to no prior knowledge of the chosen language can fulfill their language requirement by passing German 6101, German 6102, Russian 6171, Russian 6172, French 6571 or French 6572 with a grade of B or better. Students should plan early enrolling in these courses as they are often offered only during the summer term.

6.6.3 Language Examination

Students who have sufficient familiarity with their chosen languages can fulfill their requirement by passing an examination instead. It involves the translation of a passage from a mathematical text submitted by the department's Language Coordinator and graded by the appropriate language department.

Students who want to pursue this option should contact the department’s Language Coordinator for procedural details and scheduling. Students may also request textbooks or articles from the Language Coordinator. Contact information of language examination coordinators in the three departments are available either in the Graduate Office or on respective web pages.

6.6.4 Timeline and Reporting

The requirement should be completed before the start of the third year of study. Students with Graduate School fellowships following the course completion option are urged to enroll in language courses during their first summer while still on fellowship support.

Students who take the language examination need to confirm with the Graduate Office to make sure test results have been properly communicated and recorded.

6.7 Candidacy Examination

6.7.1 Overview, Purpose, and Scope of Examination

The Candidacy Examination aims to assess a student's preparedness to engage in independent research for the purpose of writing a doctoral thesis in mathematics. This includes vetting of a dissertation research proposal and testing of adequate mathematical skills and knowledge to carry out the proposed research.

If deemed appropriate by the committee, the examination may also extend to the mastery of topics generally expected from any doctoral candidate in mathematics or a respective subarea, even if these lie outside of a narrow set of dissertation research questions.

The examination must include a written portion and an oral portion. It has to comply with, both, university rules and procedures detailed in in Sections VII.4-7 of the GSH as well as the formats and rules prescribed by the mathematics program in the following sections.

Passing the candidacy examination is a necessary condition for achieving candidacy status in the following semester. In addition, students need to be in good standing and fulfill university residency end enrollment requirements. The examination needs to be retaken after five years on candidacy status by students who have been permitted by the GCS to remain enrolled beyond the program time expectations.

6.7.2 Application and Scheduling

The examination may be scheduled at any time deemed appropriate by the advisor, during the same times and days allowed for master's and doctoral oral examinations as explained in Section 5.3.4.

The applications for the candidacy examination need to be submitted *three weeks* before the oral portion of the examination via gradforms.osu.edu. At the time of application *all* pre-candidacy requirements listed in the previous sections need to have been fulfilled without exception. Applications submitted with missing requirements or less than three weeks before the oral portion will be denied by the mathematics department.

The written portion of the examination may be started before the application but should be limited in length and scope by the advisor. Advisors and students who plan to extend the written portion to a period of more than one semester should consult with the GSC.

6.7.3 Advisor as Committee Chair

The examination committee is chaired by the candidate's dissertation advisor, who has Category P status in the mathematics department. As chair the advisor is responsible for the coordination of both portions of the examination. Particularly, the advisor approves dates for issuing, submitting, and evaluation of the written part, as well as the times and format of the oral part. The advisor also chairs the oral portion and approves its scheduling.

6.7.4 Other Committee Members

Besides the advisor, the examination committee has to include three additional authorized members of the Graduate Faculty, who are approved on the Application for Doctoral Candidacy form and who vote on the outcome of the examination. The additional members may also hold Category M status and may also be from other departments with the permission of the GSC chair or vice-chair for graduate students.

In addition to the four authorized members the committee can include further members who help in the oral examination, but who do not vote on the outcome of the examination. Subject to petition to the

Graduate School and permission of the GSC, nonvoting members do not have to be Graduate Faculty and may, for example, be post-docs who have previously taught or directed the student.

6.7.5 Written Portion

The written portion of the examination has the form of a dissertation research proposal, including a substantive mathematical exposition of background materials, a set of research questions, a realistic strategy to pursue them, as well as results of preliminary investigations if available.

The write-up should contain an abstract and a list of references, including original research articles that are considered standard preparations in the respective area of research. The proposal document should be at least 10 pages in length in standard article format and should normally not exceed 15 pages (excluding bibliography and appendices). It should also be prepared using professional mathematical typesetting tools such as LaTeX or TeX.

The written proposal has to be submitted to the committee members in its final form at least *one week* before the oral examination is scheduled to allow adequate time for review. After submission the student should remain available in order to respond to questions, concerns, and suggestions for revisions.

More extensive revisions should be reported to the GSC and may be cause to halt the examination. If, based on the evaluation of the written portion, the advisor or another member of the committee see no possibility for a satisfactory overall performance the student and committee should inform the GSC chair and follow university procedures outlined in Section VII.5 of the GSH.

6.7.6 Oral Portion

The oral portion is further divided into two parts. The first part is a presentation mandated by the mathematics program and the second part is the official examination satisfying the rules of the university for the oral portion. All members of the candidacy examination committee need to be in attendance for both parts.

The first part is a prepared presentation of the candidate of the submitted dissertation research proposal, which should be at least 20 minutes and no more than 40 minutes long. Additional attendance is determined by the advisor in agreement with the student and committee.

The first part should, generally, be scheduled right before the second part during regular university business hours. It may be followed by a brief period of questioning, particularly by attending non-committee members who will not participate in the second part. Significant deviations from this format should be discussed with the GSC chair and approved by the GSC before the examination.

The second part needs to fulfill all requirements stipulated in Section VII.6 of the GSH. In particular, this part needs be between one and two hours in duration. Attendance is restricted to examination committee members. Moreover, the entire time needs to be devoted the questioning of the candidate and all members are expected to fully participate in the questioning.

There are no restrictions set, either by our program or the university, on the scope or type of questioning. It may make references to or request further clarifications of the preceding presentation or written portion, but it may also test mathematical background not directly related to the research proposal.

Video conferencing rules for either part should follow guidelines in the GSH. Approvals of petitions in regard to video conferencing given by the Graduate School extend to both parts and do not require an additional petition to the GSC.

6.7.7 Result of Examination

Immediately following the second part authorized committee members decide, in absence of the student, the outcome of the examination. The student should be informed as soon as the decision is reached.

The Candidacy Examination Report is to be completed via gradforms.osu.edu by all voting committee members on the same or the following business day. If a student does not pass the examination, the advisor should submit copies of the written examination to the Mathematics Graduate Office and inform the GSC Chair and the VC of the details of the examination.

Assuming the student is permitted a second attempt at the examination, Graduate School rules require a Graduate Faculty Representative (GFR). All procedures provided in the GSH for including the GFR and conducting a second attempt at the examination should be carefully followed. A second failure of the candidacy examination results in the automatic dismissal of the students from the Graduate School, which bars the student also from enrollment in other graduate programs on campus.

6.8 CANDIDACY

6.8.1 Definition and Time Expectations

In order to be on candidacy status a student must have completed the candidacy examination during the previous term, be in good standing with the Graduate School and the mathematics program, and fulfill all other requirements defined in Section 7.7 of the GSH. A student on candidacy status is also referred as a "post-candidacy student" or a "doctoral candidate".

During candidacy, a doctoral candidate is generally expected to focus entirely on the original research and writing required for the completion of a dissertation. Students need to be on candidacy status in order to defend their dissertation and graduate.

Although there is no program specific time-limit for the candidacy period it should be within the overall time expectations of our doctoral program, which typically constrains the candidacy time period to three to four years. The Graduate School limit for the candidacy period is five years, after which a supplemental candidacy examination must be passed.

The following university and mathematics program level requirements apply to all doctoral candidates:

6.8.2 Three-Hour Enrollment

Post-candidacy students are required to enroll themselves for *exactly* 3 credit hours of courses every autumn and spring semester with the university registrar. Enrollment in the summer is not required.

Normally, students enroll in 3 hours of Math 8999 with their dissertation advisor. Students who require additional coursework towards their research preparations may *instead* enroll in three hours of mathematics courses at the 7000 or 8000-level with permission of the dissertation advisor.

Enrollment in other types of courses as well as enrollments beyond three hours requires special permission by the department. Students on departmental support may petition the GSC for tuition fee waivers of such course if they are academically justified. They may also ask the department to enroll in such courses with advisor permission provided they reimburse tuition fees to the department.

Students on external grant support need to negotiate with the respective P.I. about additional enrollments.

6.8.3 Continuous Enrollment

Post-candidacy students are required to be enrolled for three hours during every autumn and spring semester. Leave semesters are not allowed only under special circumstances, such as medical issues, and only with permission of the Graduate School. For detailed rules on leaves, see Section VII.8 of the GSH.

6.9 Dissertation and Final Examination

6.9.1 Summary of General Graduation Procedures

Students and advisors should carefully read and follow instructions given in Section 5.3 as well as references to other rules given therein for general university and departmental procedures required for graduations and final examinations.

The final doctoral examination should be completed within the time expectations laid out in Section 6.2 and students need to submit an application on gradforms.osu.edu at the beginning of the intended term of graduation.

Before applying to graduate students need to be in good standing with both the university and our program, maintained or reinstated their candidacy status, and fulfilled all residency and credit hour requirements detailed in the GSH. Moreover, students should have found an examination committee, completed a dissertation document meeting all standards and requirements, and submitted the document to committee members and GFR at least two weeks before the oral examination.

6.9.2 Summary of Final Examination Rules and Guidelines

All rules and procedures of the GSH regarding the final document and final oral examination for doctoral students need to be observed. As noted already in Section 5.3.5 the dissertation document need to be at an acceptable state of completion and has to be submitted to all committee members (including the GFR) at least two weeks before the oral examination.

Graduate School rules require that he examination takes place during regular university hours. It is limited in time to two hours of which at least one hour needs to be devoted to questioning of the candidate. The time for a prepared presentation by the student is limited to 30 minutes and questions by visitors not on the committee are restricted to this portion of the examination.

Committee members may ask the candidate to present material in additional depth, or to extrapolate on aspects of the public presentation or any other aspect of the work completed toward the degree. The Graduate School has no restrictions on attendance during any portion of the examination.

The customary format in our program is that the first hour of the examination is open to the public and the second hour is restricted to committee members only. Moreover, the public portion usually consists of a presentation as well as further elaborations on parts of the presentation as directed by committee members. The second portion, closed to the public, is dedicated to questioning by the committee mainly about the dissertation research. The discussion may also probe conceptual background, investigate relevance of results and their connections with other lines of mathematical research, as well as expand on possible future research questions.

Advisors who would like to significantly deviate from this format should discuss this with the GSC Chair. The decision on passing the final oral examination should be reached immediately after the examination by the Final Oral Examination Committee.