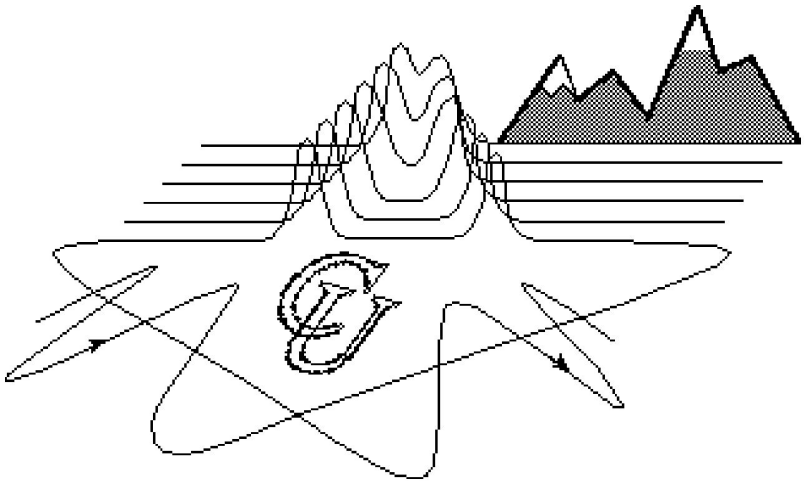
GRADUATE DEGREE PROGRAMS IN

APPLIED MATHEMATICS

UNIVERSITY OF COLORADO AT BOULDER

Academic Year 2020-2021

SUPPLEMENT TO THE CATALOG



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INTRODUCTION

The Department of Applied Mathematics of the University of Colorado at Boulder offers a range of courses and research opportunities in several areas including:

Computational Mathematics
Mathematical Biology
Mathematical Geosciences
Applied Nonlinear PDEs and Dynamics
Statistics and Data Science
Stochastic Processes and Applications

For more information on these areas and research specialties of the department and affiliated faculty, please refer to our website: https://www.colorado.edu/amath.

This document provides information on a variety of topics, ranging from admission procedures to degree requirements. If you have questions that are not answered in this document, please do not hesitate to contact us.

ADMISSION REQUIREMENTS

The admission requirements spelled out below apply equally to the M.S. and Ph.D. programs. Note that the M.S. degree is an inward facing degree, i.e., only current CU Boulder students can apply to enroll in this M.S. program. Applicants external to CU Boulder are directed to the Professional M.S. degree program. For further information, please refer to our website: https://www.colorado.edu/amath. The program that the applicant applies for is *not*, in and of itself, a factor in decisions regarding admission or financial support. Applicants should be aware, however, that both programs are competitive, and meeting the requirements does not guarantee admission. Successful applicants will, in general, have records considerably stronger in breadth and quality than these minimum standards suggest.

Applicants for graduate study in Applied Mathematics must hold at least a bachelor's degree or its equivalent from an institution comparable to the University of Colorado in applied mathematics, engineering, mathematics, or a natural science. Those with significant backgrounds in the physical sciences are encouraged to apply. Applicants should have strong foundations in mathematical course work and the mathematical maturity to understand basic concepts in pure and applied mathematics.

The applicant's academic background should include several semesters of upper division courses of a mathematical nature beyond calculus, including advanced calculus/real analysis and linear algebra. Additional recommended courses include partial differential equations, complex analysis, numerical analysis, and perhaps probability and statistics. These courses need not be taken in a mathematics department; however, they should require the mathematical maturity expected of a strong upper-level mathematics undergraduate.

It is also recommended that applicants have some computing experience. For example, a working knowledge of a scientific programming language such as FORTRAN, C, C++, MATLAB, or Python is recommended, and experience with UNIX can be very helpful.

An exceptional student who has some deficiencies in his/her mathematics background may also be considered for admission. However, such students will likely need to take some upper-division undergraduate mathematics courses during their first year of graduate study. For details, see the **Provisional Admission** section of this supplement.

Application Deadlines

Graduate applications for a given academic year (fall semester admission) should be received from applicants by December 1 of the preceding year. Due to the structure of the graduate courses, spring semester admission to the graduate program generally is discouraged.

Applying for Admission

The online application system is the University's preferred method of receiving application materials including applications, personal statements, supplementary application materials, and letters of recommendation. To submit an online application, create an account and start the application here: https://www.colorado.edu/graduateschool/admissions/apply.

All supporting application materials should arrive prior to the application deadline. Any missing documents will delay application processing and may adversely affect an applicant's chances for admission. Most items sent by mail require 10 to 14 days to reach the Office of Admissions and require additional time to be processed.

Applicants

Transcripts and other supplementary application materials (including official transcripts) should be sent directly to Graduate Admissions.

Transcripts and other supplementary application materials should be submitted electronically. PDFs of all unofficial transcripts should be uploaded to the application. If you are offered admission and accept, then we will request that you have your official transcripts sent to Graduate Admissions.

All academic documents submitted to the Office of Admissions/International become the property of the University and are not returned. For any transcripts or supporting academic documents that are irreplaceable, please contact the International Admissions Team at intlgrad@colorado.edu for alternatives to sending original or expensive documents.

Financial Aid/Teaching Assistantships

Financial aid is available to M.S. and Ph.D. students in the form of teaching assistantships, research assistantships, and fellowships. Requests for financial support should be included in the personal statement submitted with the application for admission. Students receiving financial aid should not expect more than two years of support toward the M.S. or six years toward the Ph.D.

Applicants are encouraged to apply for need-based aid through the Office of Financial Aid, which may be reached at 303-492-5091 or by completing an online email form https://www.colorado.edu/financialaid/ask-us-question.

Teaching assistants must enroll in the Teaching Excellence Seminar, APPM 7400, for one semester.

Graduate Committee

The graduate committee is responsible for interpretation and administration of the policies described in this supplement. By its own initiative or by petition from a student or a student's advisor, the graduate committee may consider exceptions to these policies when warranted by special circumstances. See the **Petition Process** subsection under Ph.D. Degree Requirements for details on the petition process.

Provisional Admission

If accepted, applicants having the listed qualifications will be classified as regular degree students. Applicants with a few deficiencies in the admission requirements listed above will be considered on an individual basis and, if accepted, will be given provisional status.

Standardized Test Scores

Each applicant is required to submit official General Record of Examination (GRE) General Test scores.

Prior to admission, international applicants must demonstrate a minimum level of English proficiency, and this requirement may be met if the applicant:

- Speaks English as the native language
- Has completed at least one year of full-time academic study in the United States or at an institution in a country where English is the native language at the time of application, and within two years of the desired admission term. This may be confirmed by official transcripts.
- Takes the Test of English as a Foreign Language (TOEFL) and attains a score that meets or exceeds the minimum requirements indicated below. TOEFL scores are valid for two years from the test date.

The graduate committee of the Department of Applied Mathematics does not accept International English Language Testing System (IELTS) scores in lieu of TOEFL scores.

GRE Scores

All applicants are required to submit GRE General Test scores. The subject portion of the GRE is not required. GRE scores expire five years after the original test date and are no longer available from ETS.

TOEFL Scores

Foreign applicants must submit official scores from the Test of English as a Foreign Language (TOEFL). This requirement will be waived only if one of the following applies: (1) the applicant's native language is English; (2) the applicant has completed at least one year of academic study in the United States or at an institution in a country where English is the native language at the time of application, and within two years of the desired admission term. Minimum TOEFL scores are: 250 (computer-administered), 600 (paper-based), or 100 (internet-based). The Graduate School will not accept TOEFL scores that are more than two years old. The TSE (Test of Spoken English) is not required.

M.S. Degree Requirements

Academic Advising

Each new student will be assigned a faculty advisor (usually the chair of the graduate committee) for consultation in planning a sound program of study. Advising includes the courses to be taken and the areas in which to take the preliminary exams (if applicable).

The Master's program is an inward facing degree program option for University Ph.D. students. The Professional Master's program is the outward facing program open to applicants from inside or outside the University.

Incoming students will be prevented from registering for courses until they obtain approval from their faculty advisor.

Adequate Progress

M.S. students must demonstrate adequate progress toward the degree by:

- Maintaining a grade point average of the Graduate School minimum of 3.0 or better in all course work attempted

  The Graduate School will not accept any grade below C (2.0) toward the M.S. degree.

- Enrolling in at least 5 credits of qualifying courses every academic term (summer excluded) until the degree is awarded

  Any student not required to maintain full-time status may register part-time. To determine whether a course is considered to be qualifying or to obtain approval for part-time registration, check with a faculty advisor or the graduate chair.

- Attaining either a pass or a research pass on a Ph.D. preliminary exam by the beginning of the fourth semester, for the non-thesis option, or enrolling in a total of 4 to 6 hours of thesis credit by the end of the fourth semester, for the thesis option

Admission to Candidacy

By the posted Graduate School deadline for the term during which the M.S. degree is to be conferred, each master's degree candidate (whether Plan I or Plan II, see below) must formally apply for admission to candidacy for the master's degree by completing the Candidacy Application for an Advanced Degree, available on the Graduate School website.

This application must be submitted to the graduate program assistant with the student's signature and the approval signature of his/her faculty advisor. Once the graduate chair approves the application, the department will forward it to the Graduate School. By this same deadline, the student must apply online for graduation.

Department Course Requirements

The department requires a master's degree candidate to complete an approved program of study consisting of at least 30 semester hours. At least 18 of these 30 hours must be in Applied Mathematics courses at the 5000 level or above. A grade of C (2.0) or higher must be attained in each course. Generally, APPM 4350/5350, 4360/5360, and 4720/5720 do not count toward this requirement.

All master's degree students must complete two yearlong 5000-level course sequences in applied mathematics. See the **Graduate Courses** section of this supplement for a list of acceptable sequences. Other sequences require faculty advisor approval. If APPM 5600/5610 is not taken, the numerical preliminary exam becomes mandatory.

M.S. candidates must take a yearlong 5000-level graduate sequence outside of Applied Mathematics in an area where mathematics has significant application. This sequence must be approved by the chair of the graduate committee.

Upon approval by petition to the graduate committee, up to 6 credit hours may be taken in 4000-level courses in other departments, provided members of the graduate faculty teach those courses.

Foreign Language Requirement

There is no foreign language requirement for the M.S. program.

General M.S. Degree Requirements

The University Catalog provides the general requirements for the degree of Master of Science in all departments of the University of Colorado. The following is a description of the requirements that specifically pertain to students pursuing a course of study leading to the degree of Master of Science in Applied Mathematics. It supplements the requirements outlined in the catalog. In all cases not specifically mentioned below, the general requirements as stated in the catalog apply.

The M.S. degree can serve as a stepping stone for any student considering a Ph.D. program at CU-Boulder or elsewhere. However, the M.S. is unique and an important program in its own right. One of its principal advantages is in preparation for teaching or industry, which is the genesis of the required numerical analysis and out-of-department sequences discussed below. It is also a flexible program in that it supports special interest directions, including the teacher training option listed in the **APPM Teacher Licensure Option** section of this supplement.

Graduation Application

A master's degree student must complete an online application for graduation whether or not he/she plans to attend commencement. To apply for graduation, log on to myCUinfo.colorado.edu. On the Student tab, select the Apply for Graduation link under Academic Resources. Contact the graduate program assistant for additional information on applying online for graduation.

The online application for graduation notifies the department and the Graduate School of a student's intent to graduate and provides necessary information to the Commencement Office for ordering and shipping the diploma.

A student who does not complete the requirements for graduation for the academic term indicated on the online application must apply online to graduate for the new graduation term.

Grievance Policy

If a student feels that he/she has received unfair treatment academically or as a teaching or research assistant, then the student should refer to the Graduate School Grievance Process and Procedures at https://www.colorado.edu/graduateschool/current-students/graduate-school-policies-and-procedures.

Plan Options

The master's degree requirements may be fulfilled by following the requirements for either the thesis (Plan I) option or the non-thesis (Plan II) option as described below. See the University Catalog for further details. Students who choose Plan II must obtain approval from the chair of the graduate committee.

Plan I (Thesis option)

A student electing to do a thesis must enroll in 4-6 hours of thesis credit, which count toward the required 30 hours, and must take an oral comprehensive exam (also referred to as a defense) on his/her thesis work. This exam will be administered by a committee consisting of the faculty advisor, who serves as committee chair, and two other faculty members. Each committee member must hold a current graduate faculty appointment. The chair must have a regular graduate faculty appointment, and the remaining committee members must hold either regular or special membership.

The M.S. student on the thesis option must be registered for a minimum of 1 credit hour during the academic term (including summer session) the defense is passed.

At least three weeks before the defense, the M.S. student on the thesis option must submit for approval, a completed Candidacy Application for Advanced Degree Form, a completed Master's Examination or Project Report form (available on the Graduate School website), and the dissertation title and abstract (in electronic format) to the graduate program assistant.

A student who fails the oral thesis defense may, in a later semester, make one and only one more attempt to satisfy this requirement. In doing so, the student may switch from the thesis to the non-thesis option.

Once the thesis defense is passed, a student must submit their dissertation electronically to the graduate school by the deadline for online submission of the thesis for the semester the master's degree is to be conferred. The dissertation must be submitted electronically to ProQuest/UMI, an external vendor. The Thesis Approval Form (TAF) must be uploaded as a supplemental file with the thesis in order for the submission to be complete. The thesis should be formatted according to Graduate School specifications, available on the Graduate School website www.colorado.edu/graduateschool. Contact amgradco@colorado.edu for questions.

Three printed unbound copies of the thesis should be submitted to the graduate program assistant (one copy must be printed single sided and the other two copies can be printed double sided). They must be printed on 8.5 x 11 watermarked bond paper of at least 25 percent cotton content and 20-pound weight.

All copies are due by the posted Graduate School deadline for online submission of the thesis for the semester the master's degree is to be conferred.

Plan II (Non-thesis option)

A student choosing the non-thesis option must pass (Pass or Ph.D. Research Pass) any one of four Ph.D. preliminary exams. Details are provided in the **Ph.D. DEGREE REQUIREMENTS** section of this supplement.

Each M.S. student electing the non-thesis option must submit a completed Candidacy Application for an Advanced Degree and Masters Exam form to the graduate program assistant. The Masters Exam form will designate which prelim is going to be used to fulfill this requirement and the prelim committee for that exam will need to sign off on the Masters Exam form.

A student who fails a written preliminary exam may, in a later semester, make one and only one more attempt to satisfy this requirement. In doing so, the student may switch between the thesis and the non-thesis option of the program, or between one preliminary exam area and another. Students who fail two preliminary exams are subject to dismissal from the program.

TIME LIMIT

All requirements for the M.S. degree must be completed within four years of the start of graduate studies. See the University Catalog for details.

Students may enroll in the Time Off Program through the Registrar's Office with faculty advisor approval. Through this planned leave program, graduate students may take three to four semesters off (including summer) without reapplying to return to the University. This program guarantees students a place in the graduate program when they return and allows access to certain benefits while they are away. However, there is no guarantee of financial support upon return.

Otherwise, the graduate committee may remove an inactive student from the degree program.

TRANSFER CREDIT

Master's degree students may request a maximum of 9 semester hours to be transferred from another institution. All transfer requests *must* have approval of the graduate committee and the Graduate School.

Work already applied toward a graduate degree received from CU-Boulder or another institution cannot be accepted for transfer toward another graduate degree of the same level at CU-Boulder. For example, work already applied to meet requirements for a master's degree earned by a student cannot be used toward a second master's degree from CU. In addition, work completed for a doctoral degree may not be applied toward a subsequent master's degree.

Credit may not be transferred until the student has completed 6 credits of graduate-level course work as a regular, degree-seeking student on the CU-Boulder campus with a GPA of 3.0 or above.

Ph.D. Degree Requirements

Academic Advising

Each new student will be assigned a faculty advisor (usually a member of the graduate committee) for consultation in planning a sound program of study. This includes advising on the courses to be taken and the preliminary exams. Incoming students will not be able to register for classes and preliminary exams until they obtain approval from their faculty advisor. For Ph.D. students, the chair of the student's thesis committee will assume the duties of the faculty advisor when the committee is formed.

Adequate Progress

Doctoral students must demonstrate adequate progress toward the degree by:

- Maintaining a grade point average of the Graduate School minimum of 3.0 or better in all course work.

  The Graduate School will not accept any grade below B- (2.7) toward the Ph.D. degree.

- Meeting the following targets for passing preliminary exams: (1) At least one Pass before starting the third semester. (2) At least one Pass and one Research Pass before starting the fourth semester. The Research Pass must be attained in either the Numerical Analysis or the Applied Analysis exam. (3) At least two Passes and one Research Pass before starting the fifth semester.

  (See the **Preliminary Examinations** section for details.)

- Identifying a dissertation advisor and a separate faculty mentor by the end of the spring semester of the third year. In collaboration with his/her dissertation advisor, a research plan is formulated.

  (See the **Dissertation Advisor and Research Plan** section for details.)

- Passing the comprehensive examination by the end of the spring semester of the fourth year.

- Registering for at least five dissertation credit hours every fall and spring semester, beginning with the semester following the passing of the comprehensive exam and extending through the academic term (including summer session) when the dissertation is successfully defended.

Department Course Requirements

A minimum of 60 credits is required for the degree, including 30 credits in courses numbered 5000 or above and 30 hours of Applied Mathematics dissertation credit. A grade of B- (2.7) or higher must be attained in each course. Generally, APPM 4350/5350, 4360/5360, and 4720/5720 do not count toward this requirement. Ph.D. students must maintain a grade point average of 3.0 or better each semester.

Students are required to take the sequences in applied analysis (5440/5450) and numerical analysis (5600/5610). A student can opt out of either one of these two sequences only if they have demonstrated proficiency in the subject by passing the corresponding preliminary exam. A third sequence in applied

mathematics is also required. Refer to the **BASIC COURSES** section of this supplement for a list of acceptable APPM 5000-level sequences. Other sequences require approval from the chair of the graduate committee.

Doctoral candidates must take at least two semesters of seminar courses (8000, 8100, 8300, 8400, 8500 or 8600). These courses are to be taken no earlier than the second year of graduate study in the department. First-year graduate students are not permitted to enroll in these seminar courses except by special petition to the graduate committee. Note: Transcripts might include the phrase "repeat—not for credit" when seminar courses are taken more than once. This statement is an artifact of the system and should be ignored. Repeated seminars will be credited toward the M.S. or Ph.D.

Finally, each student must take a yearlong graduate sequence outside of applied mathematics in an area where mathematics has significant application. Approval of this sequence by the graduate chair is required.

DISSERTATION ADVISOR AND RESEARCH PLAN

Doctoral students are required to identify a doctoral dissertation advisor and a faculty mentor no later than the end of the spring semester of the third year. In collaboration with their doctoral advisor, the doctoral student is also required to formulate a research plan that is submitted to the graduate chair no later than the end of the spring semester of the third year. Those students initiating research at an earlier stage are encouraged to submit this information as soon as it is available.

The faculty mentor must be an APPM faculty member holding a graduate faculty appointment. This mentor could potentially serve as a Comprehensive Exam committee member. The faculty mentor's role is to serve as a secondary "sounding board" for the doctoral student regarding concerns and issues that may arise.

Doctoral students are advised to begin "rotations" to identify a dissertation advisor no later than the start of the Fall semester of the third year, earlier if possible. The dissertation advisor is expected to be the chair of the doctoral student's Comprehensive Exam committee.

A doctoral student's research plan, formulated in collaboration with their dissertation advisor, provides the official designation of the student's dissertation advisor and faculty mentor. The plan includes a title, a brief description of the proposed scientific problem with relevant references, and a brief description of the proposed methods to be utilized in the course of the research. The plan addresses commitments by the two advisors and student, plans for disseminating research (e.g., journal venue and date, talk venue and date, extended research visits, etc), the anticipated thesis defense date, and the anticipated research level for each semester. For example, if coursework is complete, an RA appointment would have a 100% research allocation whereas a TA appointment would be 50%. Student, advisor, and mentor signatures designate approval and acceptance of the research plan that is to be filed with the graduate program administrator.

If a doctoral student changes their dissertation advisor after the spring term of the third year, a new research plan is required.

Dissertation Credit-Hour Requirement

Doctoral students are required to enroll in a minimum of 30 dissertation credit hours to complete the requirements for the Ph.D.

No more than 10 dissertation credit hours taken in the semesters prior to the academic term during which the comprehensive exam is passed will count toward the dissertation hours required for the Ph.D. degree.

Ph.D. candidates may enroll in a maximum of 10 dissertation credit hours per semester and must be enrolled in a minimum of 5 dissertation credit hours per semester (summer excluded) starting the semester following the passing of the comprehensive exam and extending through the academic term during which the dissertation is successfully defended.

A Ph.D. student must be enrolled full time for a minimum of 5 dissertation credit hours during the academic term (including summer session) the dissertation defense is passed.

Students electing to be part-time after passing the comprehensive exam may enroll in 3+ dissertation hours but must be full-time the semester they defend. See the University Catalog for details.

Dissertation Defense/Final Exam

Upon dissertation completion, the student's committee administers an oral final exam (defense) on the thesis and related topics. This exam is open to the public.

More than one dissenting vote will disqualify the candidate. A student who fails the examination may attempt the exam once more after a period of time as determined by the examining committee.

At least two weeks prior to the exam, the Ph.D. student must submit a completed Doctoral Examination Report form, available on the Graduate School website, to the graduate program assistant for approval by both the graduate chair and the Graduate School. Also, the student must submit his/her abstract and title, which should be forwarded to the graduate program assistant in electronic format.

A doctoral candidate will submit a copy of the dissertation to the committee at least two weeks in advance of the defense date, allowing ample time for the reader to review the doctoral thesis. The reader is a committee member, often a co-advisor, who is assigned the task of reading the thesis.

Once the dissertation defense is passed, a student must submit their dissertation electronically to the graduate school by the deadline for online submission of the thesis for the semester the Doctoral degree is to be conferred. The dissertation must be submitted electronically to ProQuest/UMI. The thesis should be formatted according to Graduate School specifications, available on the Graduate School website (www.colorado.edu/graduateschool).

Three printed unbound copies of the thesis should be submitted to the graduate program assistant (one copy must be printed single sided and the other two copies can be printed double sided). They must be printed on 8.5 x 11 watermarked bond paper of at least 25 percent cotton content and 20-pound weight.

All copies are due by the posted Graduate School deadline for online submission of the thesis for the semester the Doctoral degree is to be conferred.

Foreign Language Requirement

There is no foreign language requirement.

General Ph.D. Degree Requirements

Studies leading to the Doctor of Philosophy degree must be chosen so as to contribute to a high level of scholarship in a broad field of study. Since applied mathematics is by nature interdisciplinary, these studies will include courses in one or more application areas, in addition to those within the department.

The University Catalog provides the general requirements for the degree of Doctor of Philosophy. In all cases not specifically mentioned in this supplement, the general requirements as stated in the catalog apply. The faculty advisor must approve the program of study.

Graduation Application

A Ph.D. candidate must complete an online application for graduation whether or not he/she plans to attend commencement. To apply for graduation, log on to myCUinfo.colorado.edu. On the Student tab, select the Apply for Graduation link under Academic Resources. Contact the graduate program assistant for additional information on applying online for graduation.

The online application for graduation notifies the department and the Graduate School of a student's intent to graduate and provides necessary information to the Commencement Office for ordering and shipping the diploma.

A student who does not complete the requirements for graduation for the academic term indicated on the online application must apply online to graduate for the new graduation term.

Grievance Policy

If a student feels that he/she has received unfair treatment academically or as a teaching or research assistant, then the student should refer to the Graduate School Grievance Process and Procedures at https://www.colorado.edu/graduateschool/current-students/graduate-school-policies-and-procedures.

M.S. Degree for Ph.D. Students

Courses taken at the University to satisfy the requirements for the M.S. degree in Applied Mathematics will be counted toward the minimum requirements for the Ph.D. degree in Applied Mathematics.

A student pursuing a Ph.D. degree need not also obtain the M.S. degree in Applied Mathematics. However, any Ph.D. student also intending to receive the master's degree must satisfy the requirements for that degree. A doctoral candidate may complete the M.S. non-thesis option by passing one of the preliminary exams. Interested students should contact the graduate program assistant for details.

Preliminary Examinations

Preliminary exams are offered in four areas: (1) Applied Analysis, (2) Numerical Analysis, (3) Partial Differential Equations, and (4) Probability/Statistics. The preliminary exams serve as a bridge to research. The purpose of the exams is to both test a student's content knowledge as covered in preparatory coursework, as well as a student's ability to think creatively and critically about material in the greater context of the field. Each is a three-hour written exam. Previous preliminary exams and syllabi with version history are available on the Applied Mathematics Website.

The preparatory courses for the preliminary exams are:

- Applied Analysis: APPM 5440 and APPM 5450
- Numerical Analysis: APPM 5600 and APPM 5610
- Partial Differential Equations: APPM 5470 (not MATH 5470)
- Probability/Statistics: STAT 5100 and STAT 5530

The exam syllabi contain the expected content knowledge that may be covered on the exam; the preparatory coursework may or may not cover all topics on the syllabi. Please note that STAT 5100 and STAT 5530 may be taken in any order, and that STAT 5000/5010 is not a preparatory course sequence for the Probability/Statistics preliminary exam.

Preliminary exams are given the week prior to the first week of classes in the fall and spring semesters. Notification of results for a given preliminary exam will be sent to students by e-mail within two weeks of the exam date. The exams are prepared, anonymized, and graded by a committee of at least two faculty members.

Each preliminary exam has three possible grades: Research Pass, Pass, and Fail. To fulfill the preliminary exam requirement, a doctoral student must pass three exams. Both the Applied Analysis and the Numerical Analysis preliminary exams must be included in the three passes, and a Research Pass must be earned in at least one of these two exams. No exam may be attempted more than twice.

Ph.D. students are expected to meet the following targets: (1) To obtain at least one Pass by August following the end of their first year. (2) To obtain at least one Research Pass and one Pass by January in their second year. The Research Pass must be in either Applied Analysis or Numerical Analysis. (3) To complete all preliminary exam requirements before starting their third year. Continuation of financial support is contingent upon meeting this requirement. If at any point a student fails to meet these targets, they are out of compliance. Extenuating circumstances will be considered by petition to the graduate committee, see the **Petition Process** section for details.

A student must complete all Preliminary Examination requirements before attempting their Comprehensive Examination. Students who fail the same preliminary exam twice are subject to dismissal from the program.

Petition Process

If a student is out of compliance with any requirements, a petition must be submitted to the graduate chair via email within two weeks of notification. The purpose of the petition is to explain extenuating circumstances that may have led to the student's status as out of compliance, to clarify the student's

academic status within the department (e.g., historical class performance, research agenda) and to propose a course of action that will lead to future success. It is advisable to supplement petitions with supporting letters from faculty members as appropriate.

Within one month, the graduate committee will respond to the petition by either adopting the proposed course of action or with a counterproposal. A student who fails to submit a petition is subject to dismissal from the program.

THESIS COMMITTEE

After choosing a field of specialization, the Ph.D. student will present a list of no fewer than five faculty members to serve on her/his thesis committee, for approval by the graduate chair.

The thesis committee chair will serve as the student's thesis advisor and will supervise his/her research. The chair must be a member of the department faculty or affiliate faculty and must have a current regular or tenured graduate faculty appointment. If an affiliate is selected to serve as chair, the student must first receive approval from the graduate chair, and a member of the department faculty must serve as co-chair.

The other four thesis committee members must hold current regular or special memberships on the graduate faculty. At least three of the committee members must be on the department faculty; any others may be affiliated faculty members, faculty members outside the department, or Ph.D.-holding scientists outside the university holding regular or special graduate faculty appointments. At least one member must be outside the department.

The graduate committee and the dean of the Graduate School must approve the composition of the thesis committee. Modifications to the committee membership may be made, provided the graduate committee and the dean of the Graduate School approve all changes.

THESIS PROPOSAL/COMPREHENSIVE EXAMINATION

Prior to admission to candidacy, and no later than the end of the spring semester of the fourth year in the department, each doctoral student must pass the comprehensive examination. The exam must take place at least one year prior to the dissertation defense.

Note: Ph.D. students must satisfy the preliminary exam requirement before attempting the comprehensive exam. (See the **PRELIMINARY EXAMINATIONS** section for details.)

The purpose of the comprehensive exam is to ensure that the student has a sufficient grasp of the fundamentals of the chosen thesis area to begin research, the ability to exchange ideas and information with the members of the examining board (thesis committee), and a broad base of knowledge in applied mathematics. Typical benchmarks achieved by the time of the comprehensive exam include a research paper submitted or about to be submitted to a peer-reviewed journal or conference proceeding and a conference presentation.

No fewer than two weeks before attempting the comprehensive exam, the Ph.D. student must formally apply for admission to candidacy for the doctoral degree by completing a Candidacy Application for an Advanced Degree, available on the Graduate School website. The application for admission to candidacy

for the Ph.D. must be submitted to the graduate program assistant with the student's signature and the approval signature of his/her faculty advisor.

At the same time, the Ph.D. student must forward a completed Doctoral Examination Report form, available on the Graduate School website, to the graduate program assistant for approval by both the graduate chair and the Graduate School. Upon filing the exam form, the student must forward his/her abstract and title to the graduate program assistant.

Also, at least two weeks before attempting the comprehensive exam, the student must submit a completed Candidacy Application for Advanced Degree form to his/her faculty advisor for approval. Once signed by the student and the faculty advisor, the form should be submitted to the graduate program assistant.

One week before the comprehensive exam, the Ph.D. student must submit a 5-10 page thesis proposal, complete with motivation for the topic and references to key papers, to each member of the thesis committee. This proposal should be written in consultation with the chair of the thesis committee and the student's original research plan (see the section **DISSERTATION ADVISOR AND RESEARCH PLAN**) must be appended to the thesis proposal.

The exam will consist of a presentation by the student on his/her research proposal for a maximum of one hour in length, followed by a questioning period of up to one additional hour. The presentation portion is open to all faculty and students in the program.

The thesis committee will constitute the examining board. A passing grade is given if at least four of the five members (including the chair) of the examining committee vote satisfactory performance.

THESIS REQUIREMENT

A thesis must be based on original investigation and reflect a mature understanding and critical judgment of the subject matter, as well as familiarity with tools and methods of research. The thesis subject must be approved by the thesis committee and must be submitted to the committee at least two weeks before the defense. The thesis should contain material that is publishable in a peer-reviewed journal in, or related to, applied mathematics, and its format must comply with the specifications outlined on the Graduate School website, www.colorado.edu/graduateschool.

There is an expectation that students submit for publication in peer-reviewed journals prior to graduation.

The Ph.D. candidate is required to submit both an electronic copy (in PostScript or PDF format) and an unbound copy, printed single-sided on 8.5 x 11 watermarked bond paper of at least 25 percent cotton content and 20-pound weight, of his/her dissertation to the department, by the posted Graduate School deadline for online submission of the dissertation for the semester the Ph.D. degree is to be conferred. The dissertation should be formatted according to Graduate School specifications, available on the Graduate School website, www.colorado.edu/graduateschool.

TIME LIMIT

Doctoral candidates are expected to complete all degree requirements within six years of beginning graduate studies. See the University Catalog for details.

<table>
<tr><td>Year 1</td><td colspan="2">Year 2</td><td>Year 3</td><td>Year 4</td><td>Year 5</td><td>Year 6</td><td>Year 7</td></tr>
<tr><td>P</td><td>RP</td><td>P</td><td colspan="5">Preliminary exams completed</td></tr>
<tr><td colspan="4">Identify advisor, formulate research plan</td><td colspan="4"></td></tr>
<tr><td colspan="5">Comprehensive exam, first paper submitted</td><td colspan="3"></td></tr>
<tr><td colspan="6">Defend Ph.D. ~ 5 years</td><td colspan="2"></td></tr>
<tr><td colspan="7"></td><td>TA support not guaranteed</td></tr>
</table>

Timeline for Ph.D. milestones.

Students may enroll in the Time Off Program through the Registrar's Office with faculty advisor approval. Through this leave program, graduate students may take three to four semesters off (including summer) without reapplying to return to the University. This program guarantees students a place in the graduate program when they return and allows access to certain benefits while they are away. However, there is no guarantee of financial support upon return.

Otherwise, the graduate committee may remove an inactive student from the degree program.

TRANSFER CREDIT

The Graduate School will allow Ph.D. students to transfer up to 21 semester hours of course work from another institution toward the doctoral degree. All transfer requests must have the approval of the graduate committee in Applied Mathematics.

Course work already applied toward a graduate degree received from CU-Boulder or another institution cannot be accepted for transfer toward another graduate degree of the same level at CU-Boulder. For example, work already applied to meet requirements for a master's degree earned by a student cannot be used toward a second master's degree from CU. In addition, work completed for a doctoral degree may not be applied toward a subsequent master's degree.

Credit may not be transferred until the student has completed 6 credits of graduate-level course work as a regular, degree-seeking student on the CU-Boulder campus with a GPA of 3.0 or above.

Bachelor's-Accelerated Master's Degree Program: Bachelor's Degree in Applied Mathematics, Master's degree in Applied Mathematics

Purpose of the Program

This is a five-year degree program leading to both a Bachelor of Science and a Master of Science degree in Applied Mathematics at the conclusion of the fifth year. It enables well-qualified and motivated students to experience graduate-level course work earlier in their education and to obtain an M.S. degree in a reduced time period.

The Bachelor's-Accelerated Master's (BAM) degree program offers currently enrolled CU Boulder undergraduate students the opportunity to receive a bachelor's and master's degree in a shorter period of time. Students receive the bachelor's degree first, but begin taking graduate coursework as undergraduates, typically in their senior year. Because some courses are allowed to double count for both the bachelor's and the master's degrees, students receive a master's degree in less time and at a lower cost than if they were to enroll in a stand-alone master's degree program after completion of their baccalaureate degree. In addition, staying at CU Boulder to pursue a Bachelor's-Accelerated Master's program enables students to continue working with their established faculty mentors.

Admissions Requirements

In order to gain admission to the BAM program named above, a student must meet the following criteria:

- Have a cumulative GPA of 3.4 or higher
- Have a minimum GPA of 3.4 in APPM, STAT and MATH courses
- Have completed a minimum of 60 credit hours of coursework
- Transfer students must have completed a minimum of 24 credit hours at CU Boulder
- Students must have completed a minimum of two APPM/STAT courses numbered 3000 or higher with grades of 3.4 GPA or higher

Program Requirements

Students may take up to and including 12 hours while in the undergraduate program which can later be used toward the master's degree. However, only 6 credit hours may be double counted toward the bachelor's degree and the master's degree. Students must apply to graduate with the bachelor's degree, and apply to continue with the master's degree, early in the semester in which the undergraduate requirements will be completed.[1]

If you are interested in the BAM degree program, please meet with your advisor regarding the BAM program and then contact the graduate coordinator at amgradco@colorado.edu for more information.

[1]Students who were admitted prior to July 2019 follow a concurrent Bachelor's/Master's structure, and the two degrees are awarded simultaneously when requirements for both degrees are met.

For more information about the B.S./M.S program, consult the Department of Applied Mathematics Undergraduate Curriculum Guide.

Ph.D. with Certificate in Interdisciplinary Quantitative Biology

Purpose of the Program

The IQ Biology program is designed to prepare graduate students for interdisciplinary and collaborative research at the intersection of mathematics, computational biology, bioengineering, biophysics, and image analysis, fostering an interdisciplinary culture in the early years of training. The Ph.D. in Applied Mathematics with a certificate in IQ Biology will strengthen this training with foundations in numerical and mathematical analysis, probability and statistics, mathematical biology, and network analysis.

Admission to the Program

IQ Biology is currently accepting applications from existing CU Ph.D. students. For more information, visit https://www.colorado.edu/certificate/iqbiology.

New students apply directly to the IQ Biology program (https://www.colorado.edu/certificate/iqbiology/apply), and are first evaluated by the IQ Biology Admissions Committee. An applicant with an interest in Applied Mathematics should indicate this in the application.

Admitted students are nominally enrolled in one of the home departments that pre-approved them. By May of the first year, however, each student must choose a home department among the departments that pre-approved him or her.

IQ Bio Curriculum in Applied Mathematics

IQ Biology students pre-approved by Applied Mathematics may count the IQ Biology Core courses as 12 of the 30 credits required outside Applied Mathematics for the successful completion of the Ph.D.

In addition to Applied Mathematics Ph.D. requirements, the following courses and requirements are mandatory for the Applied Mathematics Ph.D. with a Certificate in IQ Biology:

Year 1:
Quantitative Biology Foundations (IQ Biology Core course, 6 credits)
Statistics and Computations for Genomes and Meta-Genomes (IQ Biology Core course, 3 credits)
Forces in Biology (IQ Biology Core course, 3 credits)
One or two other graduate courses to fill gaps in background related to quantitative biology and pre-approved by the IQ Biology Mentoring Committee
Three 10-week lab rotations with IQ Biology faculty

Years 1-5:
Attend the IQ Biology Seminar and Workshop Series

Year 2:
Start thesis research with IQ Biology faculty in Applied Mathematics (co-advising with mentors outside Applied Mathematics is encouraged), and present at the IQ Biology Symposium. For information about IQ Biology faculty, visit http://iqbiology.colorado.edu/faculty.

Years 2-3:
Applied Analysis series (APPM 5440, APPM 5450; 6 credits)
Numerical Analysis series (APPM 5600, APPM 5610; 6 credits)
Probability and Statistics series (STAT 5530, STAT 5100; 6 credits)
One Science Ethics Course (e.g., CHEM 5776; 1 credit)

Years 2-5:
Attend Applied Mathematics colloquia.

Years 3-5:
Participate on the IQ Biology Symposium Organization Committee.

Preliminary Exams:
Pass at least three of the following preliminary exams in Applied Math, with a Ph.D. Research Pass in at least two of them: Applied Analysis, Numerical Analysis, and Probability & Statistics

Comprehensive Exam:
The comprehensive examination must be completed by the end of Year 3.

Dissertation:
Thesis research needs to be carried out with a faculty advisor in Applied Mathematics, and the Ph.D. thesis committee must include at least one other IQ Biology faculty member.

For details on IQ Biology curriculum, visit: http://iqbiology.colorado.edu/programs/curriculum-overview.

APPM Teacher Licensure Option

Every graduate student in the Department of Applied Mathematics takes a yearlong sequence of courses in some area of application of mathematics. One option is to take this sequence in the School of Education, and ultimately, to both obtain a master's degree in Applied Mathematics and pursue a license to teach mathematics in a secondary school (i.e., middle through high school). This option is not simple, and pursuing it will delay graduation from the department.

Nevertheless, for graduate students in Applied Mathematics who also seek a teaching license, here are some guidelines.

The Teacher Education Program (TEP) in the School of Education for Secondary Mathematics Teacher Licensure consists of seven courses: (EDUC 3013, EDUC 4023, EDUC 4050, EDUC 4060, EDUC 4232, EDUC 5317, and EDUC 5375), plus one semester of student teaching (which includes EDUC 4513 and EDUC 4712, and is a full-time, full-semester, in-school commitment), and a passing score on the PRAXIS II or PLACE licensure exam in mathematics. Students not yet admitted to TEP are eligible to enroll in EDUC 3013 and EDUC 4050 but must be admitted to take any of the other courses listed above.

Before being admitted to TEP, a student must have met requirements that include a minimum of 56 hours of college work, grade point average minimums (2.75 in several areas, including mathematics courses), 25 hours of youth experience, and a passing score on the PRAXIS II or PLACE licensure exam in mathematics. Prior to student teaching, the student must have completed all but the student teaching semester courses, a series of mathematics requirements, and the PRAXIS II or PLACE Basic Skill Assessment. How much preliminary work will be required depends on details of the student's college background. Interested students should consult with an advisor in the School of Education to learn precise details.

A student interested in pursuing this dual-objective program should plan to complete all of the necessary courses within Applied Mathematics in the first two years. Some of the courses required by the School of Education also may be taken during this time.

With *very* careful planning from the beginning of the Applied Mathematics program, it is possible to complete this dual program within three to three and one-half years. A student following this plan will not necessarily receive financial assistance (a teaching assistantship) from Applied Mathematics after the second year.

Interested students should consult with an advisor in the School of Education for more information.

The Applied Mathematics requirement of a yearlong sequence outside the department may be satisfied by taking EDUC 5317 and EDUC 5375. The other requirements for a Master of Science in Applied Mathematics are found in previous sections of this supplement.

GRADUATE COURSES

Numerous graduate courses in other departments at the University, in essence, are courses in applied mathematics and may be taken for credit toward graduate coursework in Applied Mathematics. In fact, each graduate student must take a yearlong sequence outside the department. Consult a faculty advisor for more information and approval.

BASIC COURSES

Acceptable 5000-level APPM sequences include the following (others require faculty advisor approval): APPM 5380-5390, APPM 5430-5470, APPM 5440-5450, STAT 5530-5100, APPM 5460-5470, APPM 5470-5480, STAT 5530-5540, APPM 5600-5610, APPM 5380-STAT 5400, STAT 5530-5400, STAT 5400-5540, STAT 5400-5100, and STAT 5400-5610.

The following courses, which are cross-listed as graduate/undergraduate courses, generally **do not** count toward the 30-credit-hour M.S. or Ph.D. requirement:

APPM 5350 (3) Methods in Applied Mathematics: Fourier Series and Boundary Value Problems
APPM 5360 (3) Methods in Applied Mathematics: Complex Variables and Applications
STAT 5000 (3) Statistical Methods and Application I
APPM 5720 (3) Open Topics in Applied Mathematics

All of the remaining courses listed below **do** count toward the 30-credit-hour M.S. or Ph.D. requirement with the exception of STAT 5520 which only counts toward the B.S./M.S. track:

*APPM 5120 (3). Introduction to Operations Research***.** Studies linear and nonlinear programming, the simplex method, duality, sensitivity, transportation and network flow problems, some constrained and unconstrained optimization theory, and the Kuhn-Tucker conditions, as time permits. Prereqs.: APPM 3310 or MATH 3130. Same as APPM 4120 and MATH 4120/5120. (Normally offered spring semester)

APPM 5380 (3). Modeling in Applied Mathematics. An exposition of a variety of mathematical models arising in the physical and biological sciences. Students' modeling projects are presented in class. Topics may include GPS navigation, medical imaging, ocean waves, and computerized facial recognition. Prereq.: graduate standing. Recommended: APPM 3310, 4350, and 4650. Same as APPM 4380. (Normally offered fall semester)

APPM 5370 (3). Computational Neuroscience. Applies mathematical and computational methods to neuroscience. Techniques from linear algebra, differential equations, introductory dynamical systems, probability, stochastic processes, model validation, and machine learning will be learned and used. Neuroscience topics include neural spiking, network dynamics, probabilistic inference, learning, and plasticity. Will learn how the brain uses computational principles to enact decision making, vision, and memory. Recommended background includes linear algebra, differential equations, probability, and programming. Students will hone programming skills in MATLAB/Python and TensorFlow. Same as APPM 4370.

APPM 5380 (3). Modeling in Applied Mathematics. An exposition of a variety of mathematical models arising in the physical and biological sciences. Students' modeling projects are presented in class. Topics may include: GPS navigation, medical imaging, ocean waves, and computerized facial recognition. Prereqs.: APPM 3310, 4350, and 4650.

APPM 5390 (3). Modeling in Mathematical Biology. Investigates how complex systems in biology can be studied using applied mathematics. Examines several case studies which include topics from microbiology, enzyme kinetics, neuroscience, ecology, epidemiology, physiology, and bioengineering. Prereqs.: APPM 2360, 3310.

APPM 5430 (3). Methods in Applied Mathematics: Applications of Complex Variables. Reviews basic ideas of complex analysis, including solutions of ODEs and PDEs of physical interest via complex analysis; conformal mapping including Schwarz-Christoffel transformations and generalizations; computational methods; Riemann-Hilbert problems; and topics in asymptotic methods. Prereq.: APPM 4360 or 5360, or instructor consent. (Offered on a variable schedule)

APPM 5440 (3). Applied Analysis 1. Discusses the elements of basic real and complex analysis, Banach spaces, LP spaces, and many relevant inequalities. Includes applications of existence and uniqueness of solutions to various types of ordinary differential equations, partial differential equations, and integral equations. Prereqs.: APPM 4440 and 4450, or equivalent; or instructor consent. (Normally offered fall semester)

APPM 5450 (3). Applied Analysis 2. Continuation of APPM 5440. Prereq.: APPM 5440 or instructor consent. (Normally offered spring semester)

APPM 5460 (3). Methods in Applied Mathematics: Dynamical Systems and Differential Equations. Introduces the theory and applications of dynamical systems through solutions to differential equations. Covers existence and uniqueness theory, local stability properties, qualitative analysis, global phase portraits, perturbation theory, and bifurcation theory. Special topics may include Melnikov methods, averaging methods, bifurcations to chaos, and Hamiltonian systems. Prereqs.: undergraduate courses equivalent to APPM 2360, 3310, and MATH 3001 and MATH 4001. (Normally offered fall semester)

APPM 5470 (3). Methods of Applied Mathematics: Partial Differential and Integral Equations. Studies properties and solutions of partial differential equations. Covers methods of characteristics, well-posedness, wave, heat, and Laplace equations, Green's functions, and related integral equations. Prereqs.: APPM 4350 and 4360 or equivalent. (Normally offered fall semester)

APPM 5480 (3). Methods of Applied Mathematics: Approximation Methods. Covers asymptotic evaluation of integrals (stationary phase and steepest descent), perturbation methods (regular and singular methods, and inner and outer expansions), multiple scale methods, and applications to differential and integral equations. Prereq.: APPM 5470 or instructor consent. (Normally offered spring semester)

APPM 5600 (3). Numerical Analysis 1. Solution of nonlinear algebraic equations, interpolation, integration, approximation, and numerical linear algebra. Prereq.: APPM 3310 or MATH 3130, and experience with a scientific programming language. Same as MATH 5600. (Normally offered fall semester)

APPM 5610 (3). Numerical Analysis 2. Numerical linear algebra, eigenvalue problems, optimization problems, and ordinary and partial differential equations. Prereq.: APPM 5600 or MATH 5600. Same as MATH 5610. (Normally offered spring semester)

APPM 5630 (3). Advanced Convex Optimization. Investigates landmark convex optimization algorithms and their complexity results. Studies theoretical foundations while also surveying current practical state-of-the-art methods. Topics may include Fenchel-Rockafellar duality, KKT conditions, proximal methods, and Nesterov acceleration. Recommended prerequisites: APPM 4440 or equivalent, and familiarity with linear programming.

APPM 5565 (3). Random Graphs. Introduces mathematical techniques, including generating functions, the first- and second-moment method and Chernoff bounds to study the most fundamental properties of the Erdos-Renyl model and other celebrated random graph models such as preferential attachment, fixed degree distribution, and stochastic block models. Same as APPM 4565.

STAT 5100 (3). Markov Processes, Queues and Monte Carlo Simulations. Brief review of conditional probability and expectation followed by a study of Markov chains, both discrete and continuous time. Queuing theory, terminology, and single queue systems are studied with some introduction to networks of queues. Uses Monte Carlo simulation of random variables throughout the semester to gain insight into the processes under study. Prereq.: APPM 3570 or equivalent. Same as APPM 4560/5560. (Normally offered fall semester)

STAT 5230 (3). Stochastic Analysis for Finance. Studies mathematical theories and techniques for modeling financial markets. Specific topics include the binomial model, risk neutral pricing, stochastic

calculus, connection to partial differential equations and stochastic control theory. Same as APPM 4530, APPM 5530 and STAT 4230.

STAT 5250 (3). Data Assimilation in High Dimensional Dynamical Systems. Develops and analyzes approximate methods of solving the Bayesian inverse problem for high-dimensional dynamical systems. After briefly reviewing mathematical foundations in probability and statistics, the course covers the Kalman filter, particle filters, variational methods and ensemble Kalman filters. The emphasis is on mathematical formulation and analysis of methods. Same as APPM 4510, 5510, and STAT 4250.

STAT 5400 (3). Advanced Statistical Modeling. Introduces methods, theory and applications of modern statistical models, from linear to hierarchical linear models, to generalized hierarchical linear models, including hierarchical logistic and hierarchical count regression models. Topics such as estimation, residual diagnostics, goodness of fit, transformations, and various strategies for variable selection and model comparison will be discussed in depth. Examples will be demonstrated using statistical programming language R.

STAT 5430 (3). Spatial Statistics. Introduces the theory of spatial statistics with applications. Topics include basic theory for continuous stochastic processes, spatial prediction and kriging, simulation, geostatistical methods, likelihood and Bayesian approaches, spectral methods and an overview of modern topics such as nonstationary models, hierarchical modeling, multivariate processes, methods for large datasets and connections to splines. Same as STAT 4430.

STAT 5520 (3). Introduction to Mathematical Statistics. Examines point and confidence interval estimation. Principles of maximum likelihood, sufficiency, and completeness: tests of simple and composite hypotheses, linear models, and multiple regression analysis if time permits. Analyzes various distribution-free methods. Department enforced prerequisite: one semester calculus-based probability course, such as MATH 4510 or APPM 3570.. Same as STAT 4520 and MATH 4520/5520. (Normally offered spring and fall semesters). Only counts toward credit for the B.S./M.S. track.

STAT 5530 (3). Mathematical Statistics. Covers the theory of estimation, confidence intervals, hypothesis testing, and decision theory. In particular, it covers the material of APPM 5520 in greater depth, especially the topics of optimality and asymptotic approximation. Additional topics include M-estimation, minimax tests, the EM algorithm, and an introduction to Bayesian estimation and empirical likelihood techniques. Recommended Prerequisite is a one-semester calculus-based probability course such as MATH 4510 or APPM 3570. Credit not granted for STAT 5530 and STAT 5520 or MATH 5520.

STAT 5540 (3). Introduction to Time Series. Studies basic properties, trend-based models, seasonal models modeling and forecasting with ARIMA models, spectral analysis and frequency filtration. Department enforced prerequisite: APPM 5520 or MATH 5520. Prereqs.: APPM 3570 or MATH 4510, and STAT 5520/MATH 5520. Same as STAT 4540 and MATH 4540/5540. (Normally offered spring semester)

STAT 5610 (3). Statistical Learning. Consists of applications and methods of statistical learning. Reviews multiple linear regression and then covers classification, regularization, splines, tree-based methods, support vector machines, unsupervised learning and Gaussian process regression. Same as STAT 4610.

STAT 5630 (3). Computational Bayesian Statistics. Introduces Bayesian statistics, normal and non-normal approximation to likelihood and posteriors, the EM algorithm, data augmentation, and Markov Chain Monte Carlo (MCMC) methods. Additionally, introduces more advanced MCMC algorithms and requires significant statistical computing. Examples from a variety of areas, including biostatistics, environmental sciences, and engineering, will be given throughout the course. Prereqs.: STAT 5520 or 5530 and STAT 5100 or APPM 6550. Same as STAT 4630.

STAT 5650 (3). Randomized Algorithms. Investigates modern randomized methods that are used in scientific and numerical computing, in particular randomized matrix approximation methods. Other topics may include stochastic gradient methods and variance reduced versions, compressed sensing, and locality sensitive hashing. Prereq.: APPM 4440.

STAT 5680 (3). Statistical Collaboration. Educates and trains students to become effective interdisciplinary collaborators by developing the communication and collaboration skills necessary to apply technical statistics and data science skills to help domain experts answer research questions. Topics include structuring effective meetings and projects; communicating statistics to non-statisticians; using peer feedback, self-reflection and video analysis to improve collaboration skills; creating reproducible statistical workflows; working ethically. Prereq.: STAT 5520. Same as STAT 4680.

STAT 5690 (2). Advanced Statistical Collaboration. Educates and trains students to become advanced interdisciplinary collaborators by developing and refining the communication, collaboration and technical statistics and data science skills necessary to collaborate with domain experts to answer research questions. Students work on multiple projects. Discussions center on technical skills necessary to solve research problems and video analysis to improve communication and collaboration skills. Prereq.: STAT 4680 or 5680. Same as STAT 4690.

STAT 5700 (3). Philosophical and Ethical Issues in Statistics. Introduces students to philosophical issues that arise in statistical theory and practice. Topics include interpretations of probability, philosophical paradigms in statistics, inductive inference, causality, reproducible, and ethical issues arising in statistics and data analysis. Same as STAT 4700.

ADVANCED COURSES

APPM 6470 (3). Advanced Partial Differential Equations. Continuation of APPM 5470. Advanced study of the properties and solutions of elliptic, parabolic, and hyperbolic partial differential equations. Topics include the study of Sobolev spaces and variational methods as they relate to PDEs, and other topics as time permits. Prereq.: APPM 5470. (Normally offered spring semester)

APPM 6520 (3). Mathematical Statistics. Emphasizes mathematical theory of statistics. Topics include distribution theory, estimation and testing of hypotheses, multivariate analysis, and nonparametric inference, all with emphasis on theory. Prereq.: APPM 5520 or MATH 5520. Same as MATH 6520. (Offered on a variable schedule)

APPM 6550 (3). Introduction to Stochastic Processes. Systematic study of Markov chains and some of the simpler Markov processes including renewal theory, limit theorems for Markov chains, branching processes, queuing theory, birth and death processes, and Brownian motion. Applications to physical and biological sciences. Prereqs.: MATH 4001, MATH 4510 or APPM 3570, or APPM 4560, or instructor

consent. Same as MATH 6550. (Normally offered by MATH in spring semesters of even-numbered years)

APPM 6610 (3). Introduction to Numerical Partial Differential Equations. Covers finite difference, finite element, finite volume, pseudo-spectral, and spectral methods for elliptic, parabolic, and hyperbolic partial differential equations. Prereq.: APPM 5600. Recommended prereq.: APPM 5610 or graduate numerical linear algebra. (Normally offered fall semesters of odd-numbered years)

APPM 6640 (3). Multigrid Methods. Develops a fundamental understanding of the principles and techniques of the multigrid methodology, which is a widely used numerical approach for solving many problems in such diverse areas as aerodynamics, astrophysics, chemistry, electromagnetics, hydrology, medical imaging, meteorology/oceanography, quantum mechanics, and statistical physics. (Normally offered spring semesters of odd-numbered years)

APPM 6900 (1-6). Independent Study. Introduces graduate students to research foci of the Department of Applied Mathematics. Prereq.: instructor consent.

APPM 6940 (1-3). Master's Degree Candidate.

APPM 6950 (1-6). Master's Thesis. May be repeated up to 6 total credit hours.

APPM 7100 (3). Mathematical Methods in Dynamical Systems. Covers dynamical systems defined by mappings and differential equations. Hamiltonian mechanics, action-angle variables, results from KAM and bifurcation theory, phase plane analysis, Melnikov theory, strange attractors, chaos, etc. Prereq.: APPM 5460. (Offered on a variable schedule)

APPM 7300 (3). Nonlinear Waves and Integrable Equations. Includes basic results associated with linear dispersive wave systems, first-order nonlinear wave equations, nonlinear dispersive wave equations, solitons, and the method of the inverse scattering transform. Prereqs.: APPM 5470-5480, PHYS 5210, or instructor consent. (Offered on a variable schedule)

APPM 7400 (1-3). Topics in Applied Mathematics. Provides a vehicle for the development and presentation of new topics with the potential of being incorporated into the core courses in applied mathematics. May be repeated up to 6 total credit hours. Prereq.: instructor consent.

APPM 7900 (1-3). Independent Study. Introduces graduate students to research foci of the Department of Applied Mathematics. Prereq.: instructor consent.

APPM 8000 (1). Colloquium in Applied Mathematics. Introduces graduate students to the major research foci of the Department of Applied Mathematics. Prereq.: instructor consent. (Normally offered fall and spring semesters)

APPM 8100 (1). Seminar in Dynamical Systems. Introduces advanced topics and research in dynamical systems. Prereq.: Instructor consent. (Normally offered fall and spring semesters)

APPM 8300 (1). Nonlinear Waves Seminar. Introduces the core methods in the analysis of nonlinear partial differential and integral equations or systems to graduate students. Provides a vehicle for the development, presentation, and corporative research of new topics in PDE analysis. Prereq.: APPM 5440.

APPM 8400 (1). Mathematical Biology Seminar. Introduces advanced topics and research in mathematical and computational biology. Instructor consent required.

APPM 8500 (1). Statistics, Optimization and Machine Learning Seminar. Research-level seminar that explores the mathematical foundations of machine learning, in particular how statistics and optimization give rise to well-founded and efficient algorithms.

APPM 8600 (1). Seminar in Computational Mathematics. Introduces advanced topics and research in computational mathematics. Prereq.: Instructor consent. (Normally offered fall and spring semesters)

APPM 8990 (1-10). Doctoral Dissertation. All doctoral students must register for no fewer than 30 hours of dissertation credit as part of the requirements for the degree. No more than 10 credit hours may be taken in any one semester.

Note: Transcripts might state "repeat - not for credit" when seminar courses are taken more than once. This statement is an artifact of the system and should be ignored. Repeated seminars will be credited toward the M.S. or Ph.D.

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