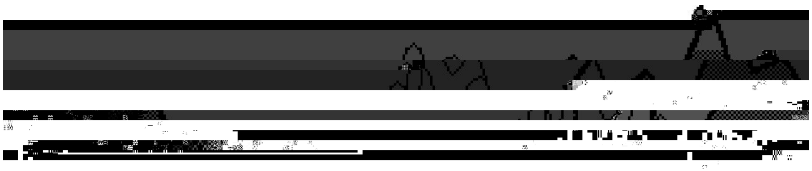
GRADUATE DEGREE PROGRAMS IN

APPLIED MATHEMATICS

UNIVERSITY OF COLORADO AT BOULDER

Academic Year 2018-2019

SUPPLEMENT TO THE CATALOG



Depart[illegible] of Applied Mathematics
U[illegible]ity of Colorado
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ema

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

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

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

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 jA

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

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. A signature page must also be e-mailed to gradinfo@colorado.edu

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.

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

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.

In their third and fourth year of study, each student in the doctoral program is required to take at least one three credit course per year in applied mathematics at the 6000 level, or above. Provided that all other course requirements have been satisfied, this course may be taken on a pass/fail basis. Students who would be unduly burdened by this requirement, for instance in cases where their dissertation research is done off campus, may apply for a

Three printed unbound copies of the thesis should be submitted to the

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

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 [illegible] for approval by the graduate chair.

The thesis committee chair must 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 terminal 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

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's~d

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.

Year 1	Year 2		Year 3	Year 4	Year 5	Year 6	Year 7
P	RP	P	Preliminary exams completed				
Identify advisor, formulate research plan							
Comprehensive exam, first paper submitted							
Defend Ph.D. ~ 5 years							
							TA support not guaranteed

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.

Bachelor's-Að

Combined M.S. and M.A. Program with MCD Biology

Purpose of the Program

This three-year interdisciplinary program offers two masters' degrees, an M.S. in Applied Mathematics and an M.A. in MCD Biology.

The goal of the program is to produce well-trained applied mathematics students who are capable of

This package of 21 credits provides the necessary background in general applied mathematics, computational mathematics, and statistics/probability for students to address challenging problems at the interface of applied mathematics and biology. This preparation is appropriate for either an academic or a commercial setting, especially in the emerging area of bioinformatics.

In MCD Biology, the core curriculum consists of 21 credits as follows. A student takes three 3-credit courses, usually during the second year: Cell Structure and Function (MCDB 5210), Gene Expression (MCDB 5230), and Topics in Developmental Genetics (MCDB 5250). In the third year, a student takes either Molecular Genetics (MCDB 5220) or Cell Signaling and Developmental Regulation (MCDB 5426). In addition, the student takes one 3-credit graduate elective in MCDB and 6 credits of Master's Thesis (MCDB 6950). The graduate elective course can be the other of the two required courses listed above.

MASTER'S PRELIM AND THESIS REQUIREMENTS

Within each department, 21 credits of core courses are required. The proposed MCD Biology courses fulfill the current Applied Mathematics requirement of an outside sequence and election of a third course. Similarly, the APPM courses serve as outside and elective courses to fulfill MCDB requirements.

Requirements for the Applied Mathematics master's degree will be fulfilled by the non-thesis (Plan II) option.

Meanwhile, the requirements for a thesis (Plan I) program will apply to the MCDB master's degree. Thesis hours count only toward the MCDB degree. A student must pass the MCDB preliminary exam (consisting of the exams in MCDB 5210 and MCDB 5230). Further, the student must successfully complete 6 credits of MCDB 6950 by writing a master's thesis on original research in an area at the interface between Applied Mathematics and Molecular, Cellular, and Developmental Biology.

The graduate chairs of both departments must approve successful completion of their departments' respective degree requirements before either degree is conferred.

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APPM 5560 (3 credits) – Markov Processes, Queues and Monte Carlo Simulations, Other approved applied mathematics courses

5. Thesis Option:

APPM 6950 (3 credits) – Master's Thesis

6. Non-thesis option

Graduate electives (6 credits), at least 3 credits in applied mathematics
(A student choosing this option must pass one of the four APPM preliminary exams.)

II. CSCI courses – minimum of 3 credits:

CSCI 5576 (4 credits) – High-Performance Scientific Computing 1
(or other approved CSCI course)

III. Credits in second department - 12 credits approved by outside advisor

Thesis option: must include 3 credits of MS thesis in outside department

IV. Students working as TAs in APPM also must take:

APPM 7400 (1 credit) – Teaching Excellence Seminar

V. The Graduate School requires at least 30 graduate credits.

VI. To waive any of the course requirements:

a) A student can waive the requirement for APPM 5600 and APPM 5610 by passing the APPM preliminary exam in Numerical Analysis.

b) A student can waive the requirement for APPM 5440 by passing the APPM preliminary exam in Applied Analysis, or by passing the final exam in APPM 5440 given that year.

c) A student can waive the requirement for APPM 5470 by passing the APPM preliminary exam in PDEs.

VII. Other recommended courses:

APPM 5430 (3 credits) – Methods in Applied Mathematics: Applications of Complex Variables
APPM 5480 (3 credits) – Methods of Applied Mathematics: Approximation Methods
APPM 6610 (3 credits) – Introduction to Numerical Partial Differential Equations
APPM 7400 (3 credits) – Topics in Applied Mathematics: Stochastic Simulations

SOME SAMPLE PROGRAMS

A. Computational Physics, non-thesis option

Any four of the following six courses, along with the required courses in APPM and CSCI:

PHYS 5250 (3 credits) – Introduction to Quantum Mechanics 1
PHYS 5260 (3 credits) – Introduction to Quantum Mechanics 2
PHYS 7310 (3 credits) – Electromagnetic Theory 1
PHYS 7320 (3 credits) – Electromagnetic Theory 2
PHYS 5210 (3 credits) – Theoretical Mechanics
PHYS 7230 (3 credits) – Statistical Mechanics

B. Computational Astrophysics, non-thesis option

Any four of the following eight courses, along with the required courses in APPM and CSCI:

ASTR 5110 (4 credits) – Atomic and Molecular Processes
ASTR 5120 (4 credits) – Radiative and Dynamical Processes
ASTR 5140 (3 credits) – Astrophysical and Space Plasmas
ASTR 5150 (3 credits) – Introductory Plasma Physics
ASTR 5400 (3 credits) – Introduction to Fluid Dynamics
ASTR 5540 (3 credits) – Mathematical Methods
ASTR 5560 (3 credits) – Radiative Processes in Planetary Atmospheres
ASTR 5820 (3 credits) – Origin and Evolution of Planetary Systems

C. Computational Aerospace Mechanics, non-thesis option

Fall semester, first year
ASEN 5012 (3 credits) – Mechanics of Aerospace Structures
APPM 5470 (3 credits) – Methods of Applied Mathematics: Partial Differential and Integral Equations
APPM 5600 (3 credits) – Numerical Analysis 1

Spring semester, first year
ASEN 5022 (3 credits) – Dynamics of Aerospace Structures
APPM 5610 (3 credits) – Numerical Analysis 2
CSCI 5576 (4 credits) – High-Performance Scientific Computing

Fall semester, second year
ASEN 5007 (3 credits) – Introduction to Finite Elements
APPM 5440 (3 credits) – Applied Analysis 1
APPM Elective (3 credits)

Spring semester, second year
ASEN Core (3 credits)
ASEN @PM Elective (3 credits)

Admitted students are nominally enrolled in one of the home departments that pre-approved them. By

Dissertation:
Thesis research needs to be carried out with a faculty advisor in Applied Mathematics, and the Ph.D.

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:

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 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

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.:

STAT 5250 (3). Data Assimilation in High Dimensional Dynamical Systems. Develops and analyzes approximate

processes,

APPM 8300 (1). Nonlinear Waves Seminar. Introduces the core methods in the analysis of nonlinear partial differential and