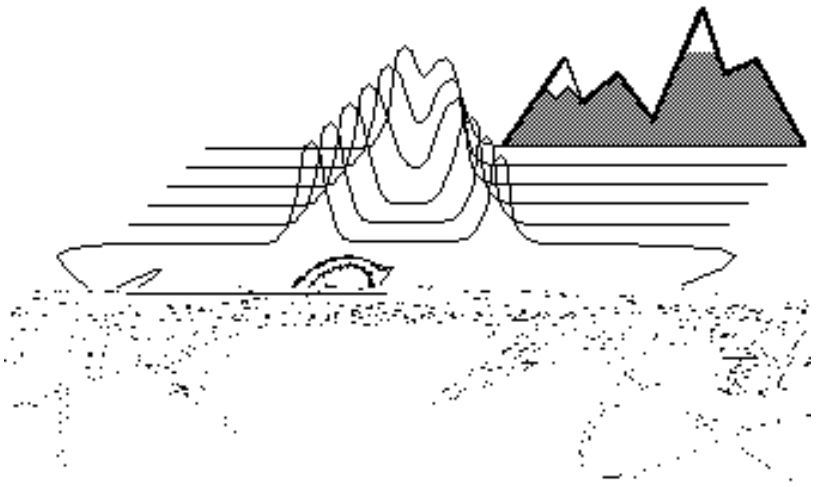
GRADUATE DEGREE PROGRAMS IN

APPLIED MATHEMATICS

UNIVERSITY OF COLORADO AT BOULDER

Academic Year 2016-2017

SUPPLEMENT TO THE CATALOG



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All academic documents submitted to Graduate Admissions become the property of the University. Thus, any original documents or official transcripts received by the University cannot be returned to the applicant.

INTERNATIONAL APPLICANTS

Transcripts and other supplementary application materials should be sent directly to the Office of Admissions/International:

Standard International Mail or Mail Sent within the U.S.
(including USPS Priority and Express)

GRADUATE COMMITTEE

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 exam (if applicable).

Incoming students will be prevented from registering 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 avera

chair of the graduate committee. The restriction that one of the sequences must be 5600/5610 can be waived for a student who obtains a pass on the numerical analysis preliminary exam.

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

PLAN OPTIONS
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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

PH.D. 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. Incoming students will be prevented from registering 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.)

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

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

any order, and that APPM 5570-5580 is not a preparatory course sequence for the Probability/Statistics preliminary exam.

Preliminary exams are given at the beginning of 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.

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

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, preferably in electronic format.

Also, at least two weeks before attempting the comprehensive exam, the student must submit a completed Ph.D. degree audit 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.

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

B.S./M.S. (Concurrent) Degree Program

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.

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

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

Purpose of the Program

This three-year interdisciplinary program offers two

Applications: Software and Methods (APPM 5580), Numerical Methods for Unconstrained Optimization (CSCI 6676), and two semesters of Independent Study in Applied Mathematics (APPM 6900).

One semester of APPM 6900 (2 credits) for this program will focus on a basic study of the principles of genetics. The second semester of APPM 6900 (1 credit) will focus on oral student presentations on thesis research, including fielding questions, responding to critiques, and presenting background information. Both sections of APPM 6900 will be arranged in consultation with the student's faculty advisor, who will nominally serve as the course instructor.

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.

MASTERÕS 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.

LEAVING THE PROGRAM

A student will be terminated from the dual degree program if he/she is terminated from either individual program. The student may petition the Applied Mathematics graduate committee to remain in the Applied Mathematics master's degree program if he/she was terminated from the MCDB program.

Students who are not making adequate progress (See **M.S. DEGREE REQUIREMENTS** section) may be terminated from the Applied Mathematics program.

COMPUTATIONAL SCIENCE AND ENGINEERING TRACK

PURPOSE OF THE PROGRAM

The purpose of this program is to meet the needs of students who want to learn the basic concepts and skills of Computational Science and Engineering and then continue toward a Ph.D. in a discipline outside Applied Mathematics. A student who completes this program successfully will obtain a master's degree in Applied Mathematics, in the Computational Science and Engineering Track.

The program is designed to provide interested students with a foundation in computational mathematics and, at the same time, to allow sufficient latitude for students to become proficient in an outside discipline. Approximately half of the credits for the master's degree will be taken from a department other than Applied Mathematics.

ADMISSION TO THE PROGRAM

A student in the Computational Science and Engineering Track will be enrolled simultaneously in two graduate programs, one in Applied Mathematics and one in the department from which the student wishes to receive a Ph.D.
ROPh.D.
An interested student may apply for admission to this track either when applying for graduate study at CU or at any time during the first two years of graduate study. First-year and second-year graduate students in any of the participating departments may apply for admission to this program.

CURRICULUM

The proposed curriculum is flexible in that a student may choose from a set of courses most useful to the discipline in which the Ph.D. is sought. Each participating department

APPM 5460 (3 credits) – Methods in Applied Mathematics: Dynamical Systems, Differential Equations, and Chaos

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

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 &

Note: A student may replace APPM 5470 (PDEs) with either APPM 5460 (Dynamical Systems), or APPM 5560 (Markov Processes).

D. Atmospheric and Oceanic Sciences, non-thesis option

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)

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 PRAX3(th2((meste

work 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):
5380-

equivalent to APPM 2360, 3310, and MATH 3001 and MATH 4001. (Normally offered spring semesters of even-numbered years)

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 MATH 4430, 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 semesters of odd-numbered years)

APPM 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. Analyzes variance distribution-free methods. Prereq.: one semester calculus-based probability such as MATH 4510 or APPM 3570. Same as APPM 4520 and MATH 4520/5520. (Normally offered spring and fall semesters)

APPM 5540 (3). Introduction to Time Series. Single and multivariable regression, forecasting using regression models, time series models, and modeling with MA, AR, ARMA, and ARIMA models, forecasting with time series models, and spectral analysis. Prereqs.: APPM 3570 or MATH 4510, and APPM 5520/MATH 5520. Same as APPM 4540 and MATH 4540/5540. (Normally offered spring semester)

APPM 5560 (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. (Normally offered fall semester)

APPM 5570 (3). Statistical Methods. Covers discrete and continuous probability laws, random variables; expectations; laws of large numbers and central limit theorem; estimation, testing hypotheses, analysis of variance, regression analysis, and nonparametric methods. Emphasizes applications with an introduction to packaged computer programs. Prereq.: APPM 1360 or equivalent Calculus 2 course. Same as APPM 4570. (Normally offered fall and spring semesters)

APPM 5580 (3). Statistical Applications: Software and Methods. Continuation of APPM 5570. Combines statistical methods with practical applications and computer software. Develops commonly used statistical models such as analysis of variance as well as linear and logistic regression. The statistical models are implemented and interpreted in the context of actual data sets using available statistical software. Prereq.: one semester of statistics. Same as APPM 4580. (Normally offered spring semester)

APPM 5590 (3), Statistical Modeling. Introduces methods, theory and applications of statistical models,

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

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). PDE and Analysis 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 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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