Graduate Handbook
UC Denver Department of Mathematical & Statistical Sciences

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Degrees

The Department of Mathematical & Statistical Sciences at UC Denver offers the *Master of Science (M.S.) in Applied Mathematics* and the *Doctor of Philosophy (Ph.D.) in Applied Mathematics*. These degrees are designed to give candidates a contemporary, in-depth education in applied mathematics and to provide research opportunities in the special fields of computational mathematics, computational biology, discrete mathematics, mathematics of science and engineering, operations research, optimization, probability, and statistics.

Prerequisites for Graduate Studies in Applied Mathematics

Admission to all mathematics graduate programs requires at least a 2.75 grade point average (GPA) in all undergraduate course work. The Department of Mathematical & Statistical Sciences does not require applicants to submit GRE scores, but strongly recommends that they do so (including Math subject test scores). Applicants to the doctoral program with an overall GPA below 3.0 or a GPA in Math below 3.2 are unlikely to be accepted without strong supporting evidence, such as high GRE scores. Students must also have the following preparation: 30 semester hours of mathematics, at least 24 of which are upper division courses with a grade of B^- or better. These courses must include:

two semesters of advanced calculus or real analysis (or equivalent)
one semester of linear algebra
one semester of one of the following:
abstract algebra
or differential equations
or discrete mathematics
or probability.

Subject to the approval by the Graduate Committee, students with prerequisite deficiencies (such as advanced calculus) may be admitted with the understanding that those deficiencies must be removed after admission. In such cases, credits earned for deficiency course work cannot be applied to a graduate degree. Students who do not have the minimum GPA may be admitted to the M.S. program provisionally. Provisional students are ineligible for financial aid, teaching assistantships, and/or classification as doctoral students.

By University policy, admission of international students requires TOEFL scores above 500, financial documentation, and certified English translation of all records and references not in English. For details and procedures, students should consult the Office of Admissions and Records.

Admission Deadlines

A complete application packet (including two official transcripts, at least three letters of recommendation, application part I and II, and application fee) should be submitted to the Graduate Committee of the Department of Mathematical & Statistical Sciences by the following target dates to be guaranteed full consideration. International students should submit their applications one month prior to these target dates:

Target Dates for M.S. Program

April 1	for the following fall semester
November 1	for the following spring semester
April 1	for the following summer semester

Target Dates for PhD Program

February 15	for the following fall semester
October 1	for the following spring semester
February 15	for the following summer semester

Applications received after the target dates may still be considered for admission, depending on space availability.

To be considered for a ***teaching assistantship*** the application packet must be accompanied by a letter indicating interest in an assistantship and citing prior teaching or tutoring experience. When the Graduate Committee considers requests for teaching assistants, the primary criterion that is used is academic excellence. Other factors that may be considered include ability to teach lower division mathematics courses, quality of faculty recommendations, outside employment (candidate cannot be employed off-campus while holding an assistantship). Only students accepted into the Ph.D. program will be eligible for teaching assistantships.

Advising

Upon acceptance into the graduate program, each student is assigned an academic advisor. A student may request and obtain a change in advisor by informing the Graduate Program Assistant.

A required orientation for all new graduate students is held the week before the fall semester begins. The orientation provides information about the department, the faculty, graduate program requirements, expectations and realities, and an opportunity for students to meet with individual faculty advisors.

During the first semester of graduate study each student is required to set up a tentative plan of study with the advisor's help. The plan of study, which becomes part of the student's file, should include a tentative list of courses to be taken each semester. Both the advisor and the student will sign the plan, which should be reviewed at least once each year with the current advisor. All course substitutions must be approved on the study plan.

Requirements for the M.S. Degree

1. **General Requirements**

   Students must complete at least 30 semester hours, of which at least 24 hours must be in mathematics courses numbered 5000 or above. At most six hours may be in courses outside the Department of Mathematical & Statistical Sciences at the 4000 level or above, if approved by the student's advisor and by the Graduate Committee. The overall grade point average must be 3.0 or higher. Grades below a B- are not accepted (but they do contribute to the overall GPA).

   Exception: Note that the Computational Biology option has a special provision that students may take up to 9 hours outside the Department of Mathematical & Statistical Sciences.

   At most 9 hours of total transfer credit or 9 hours earned as a nondegree student, with grade B- or better, may be applied towards the M.S. degree upon approval of the Graduate Committee. Courses already used for another degree cannot be used for the M.S. degree. The following courses will **not** count toward a graduate degree in applied mathematics:

   MATH 5000-5010, MATH 5017, MATH 5198, and MATH 5250.

2. **Math Clinic**

   All students are encouraged to participate in at least one Math Clinic. With the approval of the student's advisor, a clinic may be used in lieu of a stated area requirement. Details about current and upcoming projects are available from the Clinic Director.

3. **Advisory Committee**

   By the end of the first year of graduate study, each student must choose an advisor to chair the advisory committee. With this advisor's help, the student will choose two additional members of the advisory committee. All three members must be on the UC Denver Graduate Faculty, and at least two must be members of the Department of Mathematical & Statistical Sciences.

4. Thesis Option

Each student is encouraged to write a thesis to which 4-6 of the 30 hours of course work may be devoted. Although original work is encouraged, the thesis may be expository in nature. The topic should be within a relevant area of applied mathematics and should be chosen with the approval of the advisor. The thesis should be prepared in TeX, LaTeX, or AMSTeX (thesis templates available), and it must comply in format with the specifications of the Graduate School. A typed copy of the thesis must be given to all members of the advisory committee at least three weeks before the defense. Eighteen days before the date of graduation, three complete copies of the thesis must be filed with the Graduate School. The student must provide a single .pdf file of the thesis with an attached statement giving the Department the right to distribute the thesis as it wishes.

5. Final Examination

All students must take and pass a final oral exam. The exam is given by the student's advisory committee. For students choosing the thesis option, the exam consists of a one-hour thesis defense. The advisory committee may declare the thesis defense successful, but request further changes in the thesis and specify a deadline and the manner in which the revised thesis will be reviewed. In that case, the student does not need to register for further thesis credit hours, but the requirements for the Master's degree are not satisfied until the final version of the thesis is approved by the student's advisory committee and the Graduate School. If no member of the advisory committee raises further questions or objections within 30 days after the revised thesis has been received by the advisor, the thesis is considered approved by the advisory committee.

Students choosing the non-thesis option will give a one-hour presentation and answer questions on a relatively specific topic that has been selected in consultation with the advisor. Students completing a Master's degree while pursuing a Ph.D. degree are encouraged to choose a topic that will advance their Ph.D. research. A student who does not pass the exam on the first attempt may take it again after three months. Guidelines for oral presentations and thesis defenses are available in the Department of Mathematical & Statistical Sciences.

6. Time Limits for Completion of Degree

Master's degree students have seven years from the date of admission to complete all degree requirements.

7. Leave of Absence

A student may request up to a one-year leave of absence from the M.S. program. The student must be in good standing, indicate the return date, give justification for the leave of absence, and agree to contact his/her advisor and the Graduate Committee at least once per semester. Each petition must be approved by the Graduate Committee.

A leave of absence pauses the clock, but does not extend deadlines automatically; extension of deadlines requires a separate petition to the Graduate Committee. Students who leave a graduate program for more than three consecutive semesters must reapply for admission.

8. Course Requirements by Area

The core courses MATH 5070 (Applied Analysis) or MATH 6131 (Real Analysis), and MATH 5718 (Applied Linear Algebra) are required of all M.S. students. In addition, the requirements in one of the following areas must be satisfied. Substitutions may be made with the advisor's written approval. One course cannot be used to fulfill two requirements.

a. Applied Statistics

MATH 5387 Regression Analysis, Modeling and Time Series
MATH 6381 Mathematical Statistics I
MATH 6382 Mathematical Statistics II
MATH 6388 Advanced Statistical Methods for Research
MATH 5330 Workshop in Statistics Consulting (This course can be taken more than once.)

b. Applied Probability

MATH 5310 Probability
MATH 5792 Probabilistic Modeling
MATH 5780 Stochastic Processes
One of the following two courses:
MATH 6131 Real Analysis
MATH 6381 Mathematical Statistics I

c. Computer Science

i) Two foundations courses from the following list:
MATH 5446 Theory of Automata (same as C SC 5464)
MATH 5576 Mathematical Foundations of Artificial Intelligence I
C SC 5451 Algorithms

ii) One discrete computer-related course from the following list:
MATH 5405 Applied Graph Theory
MATH 5410 Modern Cryptology
MATH 5793 Discrete MATH Modeling
MATH 6221 Projective Geometry
MATH 6409 Applied Combinatorics

iii) A continuous computer-related MATH course from the following list:
MATH 5595 Comput Methods/Nonlinear Programming,was MATH 5665
MATH 5660 Numerical Analysis I
MATH 5663 Intro to Finite Element Methods, formerly MATH 7172
MATH 6663 Numerical Solution of PDE
MATH 6664 Numerical Linear Algebra

iv) One additional computer-related course from the following:
One course from i, ii, iii (above), or a sequel to it
MATH 5674 Parallel Computing & Architectures (same as C SC 6551)
MATH 5779 MATH Clinic, subject to approval
MATH 5780 Stochastic Processes

d. Discrete Mathematics

Four of the following nine courses:
MATH 5113 Modern Algebra I
MATH 5405 Applied Graph Theory
MATH 5410 Modern Cryptology
MATH 5432 Computational Graph Theory
MATH 5490 Network Flows
MATH 5793 Discrete MATH Modeling
MATH 6023 Topics in Discrete Math
MATH 6221 Projective Geometry

MATH 6222 Topics in Projective Geometry
MATH 6406 Combinatorial Structures
MATH 6409 Applied Combinatorics

Other suggested courses:

MATH 5110 Number Theory
MATH 5593 Linear Programming
MATH 6114 Modern Algebra II
MATH 7594 Integer Programming

e. Mathematics of Engineering and Science

Three of the following seven courses:

MATH 5387 Regression Analysis, Modeling and Times Series
MATH 5779 MATH Clinic
MATH 5791 Continuous Modeling
MATH 5792 Probabilistic Modeling
MATH 5793 Discrete MATH Modeling
MATH 5794 Optimization Modeling
MATH 6735 Continuum Mechanics

Two of the following seven courses:

MATH 5660 Numerical Analysis I
MATH 5661 Numerical Analysis II
MATH 5663 Intro to Finite Element Methods
MATH 5733 Partial Differential Equations
MATH 5743 Ordinary Differential Equations
MATH 6663 Numerical Solution of PDEs
MATH 6664 Numerical Linear Algebra

f. Numerical Analysis

MATH 5660 Numerical Analysis I
MATH 5661 Numerical Analysis II

Three of the following ten courses:

MATH 5593 Linear Programming
MATH 5595 Computational Methods in Nonlinear Programming
MATH 5663 Intro to Finite Element Methods, formerly MATH 7172
MATH 5667 Intro to Approximation Theory
MATH 5733 Partial Differential Equations, formerly MATH 6733
MATH 6663 Numerical Solution of PDEs
MATH 6664 Numerical Linear Algebra
MATH 6735 Continuum Mechanics
MATH 7664 Iterative Methods in Numerical Linear Algebra
MATH 7760 MATH Foundations of Finite Element Methods

Students in this area are also encouraged to take graduate-level computer science and/or parallel computing courses.

g. Operations Research

MATH 5593 Linear Programming
MATH 5792 Probabilistic Modeling or MATH 5780 Stochastic Processes

Two of the following courses:

MATH 5390 Game Theory
MATH 5490 Network Flows
MATH 5595 Computational Methods in Nonlinear Programming
MATH 5779 MATH Clinic, with approval
MATH 5794 Optimization Modeling
MATH 7594 Integer Programming

h. Computational Biology

MATH 5396 Bayesian Statistics
MATH 5610 Computational Biology
C SC 5451 Algorithms
BIOL 5099 Biology for Computer Scientists, Engineers and Mathematicians
MATH 5840 Independent Study - Complex Programming Project (subject to approval)

Two graduate mathematics courses

One elective pre-approved courses listed below

MATH 5060 Exploratory Data Analysis
MATH 5405 Applied Graph Theory
MATH 5593 Linear Programming
MATH 5595 Computational Methods in Nonlinear Programming
MATH 5791 Continuous Modeling
MATH 5576 Mathematical Foundations of Artificial Intelligence
C SC 5582 Artificial Intelligence
C SC 5559 Database Systems
BIOL 5124 Molecular Biology
BIOL 5550 Cell Signaling
CHEM 5810 General Biochemistry I

Requirements for the Ph.D. Degree

Admission to the Ph.D. Program

The requirements for admission to the Ph.D. program are the same as for the M.S. program, although a Master's degree in mathematics is sufficient for admission to the Ph.D. program. Applicants to the Ph.D. program who have course deficiencies may be admitted to the M.S. until the deficiencies have been remedied.

Graduation Requirements

There are five phases to the Ph.D. program. A candidate must fulfill course requirements, pass the preliminary examinations, meet the academic residency and participation requirements, pass the comprehensive examination, and write and defend a thesis.

1. Course requirements

Students in the Ph.D. program must complete:

At least 42 credit hours of non-thesis graduate courses if admitted without a Master's degree
At least 12 credit hours of non-thesis graduate courses beyond the Master's degree if admitted with a mathematics Master's degree
A number of credit hours to be determined by the Graduate Committee if admitted with a Master's degree in a field other than mathematics.

The following courses are required as a part of the formal course work:

4 courses (3 hours each) at 6000 level or above
Math Clinic (MATH 5779) (3 hours)
3 Readings Courses (MATH 7921-7926) (1 credit hour each)

Selected 5000 level courses may be used in place of 6000 and above level courses with the consent of the student's advisor. The Readings Courses are one-hour seminar courses that are announced prior to the start of each semester. All courses should be chosen in consultation with an advisor. Course replacements and equivalencies should be approved by the Graduate Committee.

A maximum of 9 hours earned as nondegree student, with grade B- or better, may be transferred to the Ph.D. program. All Ph.D. course work must be completed with at least a 3.25 grade point average. Grades below a B- are not acceptable for the Ph.D. A student who receives a grade of C+ or lower, or whose overall GPA as a doctoral student falls below 3.25 will be reviewed by the Graduate Committee and may be put on probation or suspended.

Within the coursework requirement, students must satisfy a breadth requirement by completing six graduate MATH courses from the following categories. No more than three of these courses can come from any one category:

Computational Mathematics
Discrete Mathematics
Operations Research (including Probability)
Statistics
General

A list of which courses are included in each of the areas is available on the Department web page. (See Graduate Courses by Area). The breadth courses must be formal courses excluding MATH 5070 (Applied Analysis), MATH 5718 (Applied Linear Algebra), MATH 5779 (MATH Clinic), readings courses, and independent studies. Courses used for a Master's degree may be used to satisfy this requirement. The breadth courses will be recorded on the student's study plan as a separate Ph.D. requirement.

2. Preliminary examinations

Each student must pass two preliminary exams: one in Applied Analysis and one in Applied Linear Algebra. These are four-hour written exams that cover material roughly at the level of first-year graduate study. The exams are offered twice a year, from 10:00 am to 2:00 pm. The first set of exams are offered in January. The Applied Analysis preliminary exam will be held the Monday prior to the start of classes, and the Applied Linear Algebra exam is offered the Friday before the start of classes. The second exam offerings follow the spring semester. The Applied Linear Algebra exam is held the Friday before the start of the summer semester, and the Applied Analysis exam is offered the first Friday of the summer semester.

A student wishing to take a preliminary exam must sign up with the graduate program assistant at least one month prior to the administration of the exam. Students who cannot take the exam as planned must give notice of withdrawal at least one week prior to the exam.

Students have a maximum of three attempts to pass each exam. The time limit clock starts the first semester a student is admitted into the program.

Students entering the Ph.D. program without a master's degree in mathematics have three years to pass both preliminary exams.
Students entering the Ph.D. program with a master's degree in mathematics have two years to pass both preliminary exams.

No appeals will be considered if a student fails the respective exam a third time.

3. Ph.D. Advisory Committee

Each student must choose an advisor and, with the advisor's help, select other members of the Ph.D. advisory committee. This committee assumes the dual responsibility for advising and testing the student. In particular, under the direction of the advisor, each member of this committee will:

Design and evaluate the Comprehensive Exam;

Advise on research and serve as the examining committee for the student's dissertation defense.

The Graduate Committee must approve the composition of this committee at least 30 days before the student takes the comprehensive exam. If the committee membership changes after the comprehensive examination, the advisor must again request approval by the Graduate Committee at least 30 days before the date of the thesis defense.

The Ph.D. advisory committee consists of five graduate faculty members from the CU system, one of whom is the student's advisor. At least one committee member must be from outside the Department of Mathematical & Statistical Sciences, and at least one must be a regular faculty member of the Department of Mathematical & Statistical Sciences. Committee members may be from outside the CU system, but must be granted special membership on the graduate faculty for this purpose. The chair of the Ph.D. advisory committee must be a regular member of UC Denver mathematics faculty. The main role of the chair is to assure compliance with the rules of the program and direct the design and administration of the comprehensive exam. Normally the chair and the thesis advisor are the same person, but the thesis advisor may be affiliated with another university department, a government lab, or industry, subject to approval by the Graduate Committee. (Include vitae of proposed members who are not known to the Graduate Committee.)

4. Residency and Participation

By Graduate School rules, all Ph.D. candidates must accumulate six semesters of resident credit at the University of Colorado beyond the bachelor's degree (two of these six semesters may be replaced by a master's degree in mathematics from another institution). For this purpose a full course load is defined to be five semester hours of course work. The manner in which resident credits may be accumulated is described in the Graduate School Rules.

In order to foster participation in the life of the department and immersion in research, each student is expected to spend at least two consecutive semesters as a full time student without employment outside the university. When this is not feasible, it is the responsibility of the student's advisory committee to consider the special situation of the student and to devise and document the way in which the student will uphold the spirit of this requirement as fully as possible. At a minimum, students are expected to participate in department functions such as colloquia, seminars, and orientations during this two-semester period.

5. Comprehensive Examination

Application for candidacy to the Ph.D. program must be made at least two weeks before the comprehensive examination is taken. Candidacy will be granted after at least three semesters of residence have been earned, an advisory committee has been selected, all preliminary and comprehensive examinations have been passed, and essentially all course requirements (including the breadth requirement) have been satisfied.

The comprehensive exam has the following objectives: to determine mastery of graduate level mathematics, capacity to synthesize mathematical concepts, and ability to embark upon doctoral thesis research. The comprehensive exam has three parts:

1. The first part consists of a written exam of roughly (but not limited to) six hours. The written exam covers material from the student's intended area of research. The choice of area and the extent of coverage within that area will be determined by the student's advisory committee. The advisory committee will prepare and conduct the exam and determine the outcome. The written exam has three possible outcomes: pass, conditional pass, and failure. In the event of failure, the advisory committee and the Graduate Committee will decide if a retake of the written exam is warranted.
2. Given a conditional pass on the written exam, the second part of the exam consists of an oral follow-up, not to exceed two hours in length. The student will be given a copy of the graded written exam, no later than seven days after that exam, and a list of topics in which the committee found the student deficient. The oral follow-up will cover questions on the written exam and topics on the list provided to the student. The oral must be given within four weeks of returning the graded exam to the student, and it has two possible outcomes: pass and failure. In the event of failure, the student's advisory committee and the Graduate Committee will determine the next step (dismissal from the program, retake of the oral follow-up and/or a retake of the written exam are possible outcomes). The Graduate Committee will hear grievances and appeals of the outcome of the comprehensive exam.
3. Within six months of successful completion of the written exam and/or oral follow-up, the student must give an **oral research proposal** before the advisory committee. The purpose of this presentation is to determine the feasibility of the student's proposed thesis topic. The research proposal is open to the public and must be advertised at least two weeks prior to the presentation. The student will be provided a detailed summary of the committee's assessment and recommendations. At the discretion of the advisory committee, a student may be asked to give a subsequent oral proposal at a later date.

Admission to candidacy follows successful completion of the three parts of the comprehensive exam.

6. Thesis

Each student must complete at least 30 hours of thesis credit. Not more than 10 of these hours may be taken in any one semester. Not more than 10 thesis hours taken prior to the semester of the comprehensive examination may be applied to this requirement.

Candidates for the Ph.D. degree are required to write a dissertation containing original contributions and evidence of significant scholarship. The thesis is written under the guidance of an advisor who is a member of the graduate faculty of the University of Colorado. The thesis must comply in format with the specifications of the Graduate School and must be prepared in TeX, LaTeX, or AMSTeX (thesis templates available). Six weeks before the date of graduation, the Graduate School must be notified by the candidate of the dissertation title. Thirty days before the final thesis defense, the thesis must be available in written form. Eighteen days before the date of graduation, three complete copies of the thesis must be filed with the Graduate School. The student must provide the Department with a pdf file of the thesis with an attached statement giving the Department the right to distribute the thesis.

At least thirty days before the date of graduation, the candidate must present and defend the dissertation before the student's advisory committee. The defense is open to the public and must be announced at least two weeks in advance. The committee may declare the thesis defense successful, but request further changes in the thesis, and specify a deadline and the manner in which the revised thesis will be reviewed. In that case, the student does not need to register for additional thesis hours, but the requirements for the Ph.D. are not satisfied until the final version of the thesis is approved by the advisory committee and the Graduate School. If no member of the committee raises further questions or objections within 30 days after the revised thesis has been received by the advisor, the thesis will be considered approved by the advisory committee.

7. Language Requirement

The University of Colorado permits each department to decide whether or not to implement a foreign language requirement. The Department of Mathematical & Statistical Sciences has approved the following policy:

Recognizing that the need of a foreign language to do research varies from no languages in many areas to one or two languages in a few areas, the department has no formal language requirement. Instead, the necessity for some level of proficiency in a foreign language is left to the discretion of each student's advisor, as is the case for other matters related to a student's preparation for research.

8. Time Limits

Preliminary Exams:

Students entering the Ph.D. program without a master's degree in mathematics have three years to pass both preliminary exams.

Students entering the Ph.D. program with a master's degree in mathematics have two years to pass both preliminary exams.

Students must select an advisor and a Ph.D. advisory committee by the end of the semester in which all preliminary exams have been passed. Students must pass the comprehensive examination by the end of the seventh semester in the program (sixth semester for students entering the program with a Master's degree in any area), or by the time set by the student's advisory committee. All requirements for the Ph.D. degree must be completed within four years of passing the comprehensive examination and within eight years of entering the Ph.D. program.

It is recognized that flexibility is necessary, especially for transfer and part-time students; hence petitions for exceptions will be considered by the Graduate Committee. The eight-year deadline for completing the Ph.D. is imposed by the Graduate School and exceptions require approval of the Dean of the Graduate School.

Transitional Rules

All current M.S. and Ph.D. students have the option of graduating under the current rules or under the rules in effect when they were admitted.

Leave of Absence

A student may request up to a one-year leave of absence from the Ph.D. program. The student must be in good standing, indicate the return date, give justification for the leave of absence, and agree to contact his/her advisor and the Graduate Committee at least once per semester. Each petition must be approved by the Graduate Committee.

A leave of absence pauses the clock, but does not extend deadlines automatically; extension of deadlines requires a separate petition to the Graduate Committee. A leave of absence does allow the student to interrupt registration for thesis hours following the comprehensive exam. Students who leave a graduate program for more than three consecutive semesters must reapply for admission.