Applied Mathematics

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Mathematical models are widely used throughout natural science, social science, and engineering in fields as diverse as physics, bioinformatics, robotics, image processing, and economics. Despite the broad range of mathematical settings and applications, there exists a core of essential concepts and techniques used in addressing most problems. The Applied Mathematics major provides a foundation in these mathematical techniques and prepares the student to use them in a substantive field of application.

The interdisciplinary major permits a great deal of flexibility in design. It is intended to appeal to students who wish to study the more mathematical aspects of science or engineering, as well as those whose primary interest is in mathematics and statistics and who wish to become acquainted with applications. Core courses are drawn from Computer Science, Mathematics, Statistics and Data Science, and Engineering and Applied Science. Courses applying mathematics may be drawn from participating programs in Applied Physics; Astronomy & Astrophysics; the biological sciences, including Ecology and Evolutionary Biology, Molecular Biophysics and Biochemistry, and Molecular, Cellular, and Developmental Biology; Chemistry; Economics; the various programs in engineering, including Biomedical Engineering, Chemical Engineering, Electrical Engineering, Environmental Engineering, and Mechanical Engineering; Earth and Planetary Sciences; Physics; and even Linguistics and Political Science. The Applied Mathematics degree program requires a three-course concentration in a field in which mathematics is used.

Students in the major are often sought after by graduate programs in either Applied Mathematics or in the disciplines in which they choose their concentration, as well as by industries and startup companies in which their breadth of quantitative skills are essential and often unique.

Students may pursue a major in Applied Mathematics as one of two majors and can thereby equip themselves with mathematical modeling skills while being fully engaged in a field of application. In this case, the concentration requirement of the Applied Mathematics program is flexible in order to recognize the contribution of the other major. A two-course overlap is permitted to satisfy the requirements of the two majors.

Frequently Asked Questions Students are encouraged to consult the Applied Mathematics FAQ for more details about courses and policies in the major.

PREREQUISITE AND INTRODUCTORY COURSES

Multivariable calculus and linear algebra are required and should be taken before or during the sophomore year. This requirement may be satisfied by MATH 1200 or ENAS 1510, and MATH 2220 or 2250 or 2260. Computer programming skills are also required and may be acquired by taking ENAS 1300 or CPSC 1001 . Details of individual programs must be worked out in consultation with the director of undergraduate studies (DUS), whose signed permission is required.

REQUIREMENTS OF THE MAJOR

The B.A. degree program The program requires eleven term courses beyond the prerequisites, including the senior project, comprising a coherent program:

1. A course in differential equations (ENAS 1940 or MATH 2460)

2. A course in probability (S&DS 2410 or S&DS 2380)

3. A course in data analysis (S&DS 3610 or S&DS 2300)

4. A course in discrete mathematics (AMTH 2440 or CPSC 2020)

5. Courses in at least three of the following areas* (with DUS approval) including, but not limited to:

(a) optimization: AMTH 4310, 4370, EENG 433, 4000, CPSC 4850, S&DS 4320

(b) probability and statistics: S&DS 2420, 3120, 3510, 3640, 4000, 4100, 4110, 4250, ECON 2136, APHY 4700

(c) partial differential equations and analysis: MATH 2470, 2550, 2560, 2600, 3020, 3050, 3100, 3200, 3250, 4470, AMTH 4280

(d) algorithms and numerical methods: CPSC 3650, 3660, 4240, 4371, 4410, 4650, 4660, 4670, 4680, 4690, 6400, ENAS 4400, ENAS 4410

(e) graph theory: AMTH 3620, AMTH 4200, 5620, MATH 7990, CPSC 4620

(f) mathematical economics: ECON 2125, 2126, 3350, 3351, 4417, 4428, 4433, 2251, 4471, CPSC 4550

(g) electrical engineering: ECE 4390, AMTH 3420, S&DS 3640

(h) data mining and machine learning: S&DS 2620, 2660, 3650, 6690, 6710, 6850, CPSC 4391, 4520, 4530, 4700, 4740, 4770, 3810, 4830, 4860, 4880, 7450, AMTH 5520, AMTH 2320

(i) biological modeling and computation: CPSC 4530, 4750, 4760, BENG 3400, 4450, BENG 4580, PSYC 2658

(j) physical sciences: ASTR 3200, 4200, CHEM 3330**, EPS 3220, 3230, 4210, 4280, 4560, 5290, 6590, 3430, 3440, 4010, 4020, 4100, 4120, 4500, 4300, 4400, 4410, 4420, APHY 4390, 4480

(k) engineering: MENG 2311, 2615, 3422, 3465, 3323, 4463, 4469, CENG 3010, 3150, BIS 555

(l) mathematical linguistics: LING 2249, LING 2270, LING 3800

(m) mathematical philosophy: PHIL 2267, 4427, MATH 2700

* Because departmental curricula from which the program draws regularly change, the DUS maintains a more exhaustive list of courses and areas satisfying this particular requirement. Additionally, due to rapid advances in many areas, these categories are often fluid, and their union can evolve. In order to accommodate this fluidity, students are strongly encouraged to revisit their program of study each term and share their checklist with the DUS. Students can independently and systematically plan multiple

routes toward completion of the major by using the checklist and the master list of courses.

** Chemistry courses numbered 410 and above may count as a breadth requirement (either 1 full-term 1 credit course or 2 half-credit courses) with permission of the DUS.

6. At least *three advanced courses* in a field of concentration involving the application of mathematics to that field. The standard way to form a concentration is to take three courses all from the same breadth (a)-(m) category from item 5 above, at least two of which are level 3000+. Any concentration that deviates from this standard formula must be worked out in consultation with, and approved by, the DUS.

Alternatively, when two majors are undertaken, if the second major is in a participating program, then, recognizing that there can be an overlap of two courses, the student may take for the remaining concentration course an additional choice relevant to the Applied Mathematics major such as those listed in point 5 above or for the B.S. degree below. Details of a student's program to satisfy the concentration requirement must be worked out in consultation with, and approved by, the DUS.

The B.S. degree program In addition to the courses indicated for the B.A. degree, the B.S. degree, which totals fourteen term courses beyond the prerequisites and includes the senior requirement, must also include the three items listed below.

1. A vector analysis course (MATH 3020 or MATH 3050). MATH 3100, 3200, 3250, and 4470 and those 3000+ level courses listed under "(c) partial differential equations and analysis" can act as replacements.

The course selected may not be counted toward the requirements for the major under item 5 above. (MATH 3500 and MATH 4400 can in specific cases be considered in consultation with the DUS.)

2. An additional course selected from item 5 above.

3. Another course numbered 3000 or higher selected from item 5 above, or a course numbered 3000 or higher in mathematics, applied mathematics, statistics, or quantitative computer science or engineering, or as approved by the DUS.

Alternatively, students may petition to receive a B.S. in Applied Mathematics by fulfilling the B.A. requirements in Applied Mathematics and the B.S. requirements in another program.

Credit/D/Fail No more than one course taken Credit/D/Fail may be applied toward the requirements of the major.

Distinction in the major Earn a grade of A or A– in at least 9/11 of the non-prerequisite courses in the Applied Math B.A., or at least 11/14 of the non-prerequisite courses in the B.S. One of those A's or A–'s must come from AMTH 4900 or AMTH 4910, with the rest coming from core, concentration, and/or breadth courses. Grades of Cr in classes taken Cr/D/F count as non-A grades. Grades earned in prerequisite courses (multivariable calculus, linear algebra, and programming), and grades of P or W, do not count in the calculation.

Outside credit Courses taken at another institution or during an approved summer or term-time study abroad program may count toward the major requirements with DUS approval.

SENIOR REQUIREMENT

Both the B.A. and B.S. degree programs require a senior thesis research project (AMTH 4910).

SUMMARY OF MAJOR REQUIREMENTS

Prerequisites MATH 1200 or ENAS 1510, and MATH 2220 or 2250 or 2260, or equivalents; ENAS 1300, or CPSC 1001

Number of courses *B.A.*—11 term courses beyond prereqs (incl senior req); *B.S.*—14 term courses beyond prereqs (incl senior req)

Specific courses required *B.A.*—ENAS 1940 or MATH 2460; S&DS 2410 or S&DS 2380; S&DS 3610 or S&DS 2300; AMTH 2440 or CPSC 2020; *B.S.*—same as *B.A. degree*

Distribution of courses *B.A.*—at least 3 advanced courses in a concentration concerning the application of math to that field; 3 addtl courses, as specified; *B.S.*—same as *B.A. degree*, plus MATH 3020 or 3050 (or MATH 3500 and 4400 with DUS approval), with 2 addtl courses, as specified

Senior requirement Senior thesis research project (AMTH 4910)

FACULTY ASSOCIATED WITH THE PROGRAM OF APPLIED MATHEMATICS

Professors Andrew Barron (*Statistics & Data Science*), David Bercovici (*Earth & Planetary Sciences*), Donald Brown (*Emeritus*) (*Economics, Mathematics*), Joseph Chang (*Statistics & Data Science*), Ronald Coifman (*Mathematics*), Michael Fischer (*Computer Science*), Igor Frenkel (*Mathematics*), Anna Gilbert (*Mathematics, Statistics & Data Science*), Roger Howe (*Emeritus*) (*Mathematics*), Peter Jones (*Mathematics*), John Lafferty (*Statistics & Data Science*), A. Stephen Morse (*Electrical Engineering*), Corey O'Hern (*Mechanical Engineering & Materials Science*), David Pollard (*Statistics & Data Science*), Nicholas Read (*Physics, Applied Physics*), Vladimir Rokhlin (*Computer Science, Mathematics*), John Schotland (*Mathematics*), Peter Schultheiss (*Emeritus*) (*Electrical Engineering*), Martin Schultz (*Emeritus*) (*Computer Science*), Mitchell Smooke *(Mechanical Engineering & Materials Science, Applied Physics*), Daniel Spielman (*Computer Science, Statistics & Data Science*), Mary-Louise Timmermans *(Earth & Planetary Sciences),* Van Vu *(Mathematics),* Günter Wagner *(Ecology & Evolutionary Biology),* John Wettlaufer *(Earth & Planetary Sciences, Mathematics, Physics),* Huibin Zhou (*Statistics & Data Science*), Steven Zucker (*Computer Science, Biomedical Engineering*)

Associate Professors John Emerson (*Statistics & Data Science*), Thierry Emonet (*Molecular, Cellular, & Developmental Biology, Physics*), Josephine Hoh (*Epidemiology & Public Health*), Yuval Kluger (*Pathology*), Michael Krauthammer *(Pathology*), Smita Krishnaswamy (*Genetics, Computer Science*), Sekhar Tatikonda (*Electrical Engineering, Statistics & Data Science*), Madhusudhan Venkadesan (*Mechanical Engineering & Materials Science*)

J. W. Gibbs Assistant Professors Yariv Aizenbud, Abinand Gopal, Erik Hiltunen, Boris Landa, Kevin O'Neill