

APPLIED MATHEMATICS

Director of undergraduate studies: John Wettlaufer (john.wettlaufer@yale.edu);
associate director of undergraduate studies: Ian Adelstein (ian.adelstein@yale.edu)

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; 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 in satisfying the requirements of the two majors.

Frequently Asked Questions Students are encouraged to consult the Applied Mathematics FAQ for more detail 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 120 or ENAS 151, and MATH 222 or 225 or 226. It may also be satisfied by MATH 230, 231 for the Class of 2024 and 2025 (see below). Computer programming skills are also required and may be acquired by taking ENAS 130, CPSC 100, or 112. 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

Students in the Class of 2024 and Class of 2025 may count MATH 230, 231 (linear algebra), MATH 250 (vector analysis), and MATH 300 and 301 (analysis) toward their analysis requirements.

Students in the Class of 2026 and subsequent classes follow the requirements as listed.

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 194 or MATH 246)
2. A course in probability (S&DS 241 or S&DS 238)
3. A course in data analysis (S&DS 361 or S&DS 230)
4. A course in discrete mathematics (AMTH 244 or CPSC 202)
5. Courses in at least three of the following areas* including, but not limited to:
 - (a) optimization: AMTH 437, EENG 400, CPSC 485
 - (b) probability and statistics: S&DS 242, 312, 351, 364, 400, 410, 411, 425, ECON 136, APHY 470
 - (c) partial differential equations and analysis: MATH 247, 250, 255, 256, 260, 300, 301, 302, 305, 310, 447, AMTH 428
 - (d) algorithms and numerical methods: CPSC 365, 366, 424, 440, 465, 467, 468, 469, ENAS 440, 441
 - (e) graph theory: AMTH 562, ENAS 962
 - (f) mathematical economics: ECON 125, 126, 350, 351, 417, 433, 460, 471
 - (g) electrical engineering: EENG 397, 436, 455, AMTH 342, S&DS 364
 - (h) data mining and machine learning: S&DS 262, 365, 669, 671, CPSC 445, 453, 470, 474, 477, 486, 745, AMTH 552
 - (i) biological modeling and computation: CPSC 453, 475, 476, BENG 352, 445, 458, ENAS 559
 - (j) physical sciences: ASTR 320, 420, CHEM 333^{* *}, EPS 322, 323, 421, 428, 456, PHYS 342, 343, 344, 401, 402, 410, 420, 430, 440, 442, 460, APHY 439, 448
 - (k) engineering: MENG 280, 285, 361, 365, 383, 463, 469, CENG 301, 315
 - (l) mathematical linguistics: LING 224, 227, 380
 - (m) mathematical philosophy: PHIL 267, PHIL 427, MATH 270

* 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. Programs in science, engineering, computer science, statistics, and economics are natural sources of concentration. 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 course an additional choice relevant to the Applied Mathematics major such as those listed in point 5 above or for the B.S. 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 including the senior requirement, must also include the three items listed below.

1. A vector analysis course, (MATH 302 or MATH 305). MATH 310, 320, 325, and 447 and those courses listed under "(c) partial differential equations and analysis" can act as replacements for MATH 250, 300, 301 and/or act as concentration or breadth courses.

The course selected may not be counted toward the requirements for the major under item 5 above. (MATH 350 and MATH 440 can in specific cases be considered in consultation with the DUS.)

2. An additional course selected from item 5 above.

3. Another course numbered 300 or higher selected from item 5 above, or a course numbered 300 or higher in mathematics, applied mathematics, statistics, or quantitative computer science or engineering, subject to the approval of 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 A maximum of one course credit taken Credit/D/Fail may be counted toward the requirements of the major.

SENIOR REQUIREMENT

Both the B.A. and B.S. degree programs require a senior thesis research project (AMTH 491).

SUMMARY OF MAJOR REQUIREMENTS

Prerequisites MATH 120 or ENAS 151, and MATH 222 or 225 or 226, or equivalents; ENAS 130, CPSC 100, or 112

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 194 or MATH 246; S&DS 241 or S&DS 238; S&DS 361 or S&DS 230; AMTH 244 or CPSC 202; *B.S.* – same as *B.A. degree*

Distribution of courses *B.A.* – at least 3 advanced courses in a field of concentration concerning the application of math to that field; 3 addtl courses, as specified; *B.S.* – same as *B.A. degree*, plus MATH 302 or 305 (or MATH 350 and 440 with DUS approval), with 2 addtl courses, as specified

Senior requirement Senior thesis research project (AMTH 491)