MATHEMATICS

See also Applied Mathematics

Directors of undergraduate studies: Richard Kenyon and Miki Havlickova; contact email: math.dus@yale.edu; Math DUS website; Math department website

Mathematics has many aspects: it is the language and tool of the sciences, a cultural phenomenon with a rich historical tradition, and a model of abstract reasoning. The course offerings and the major in Mathematics reflect these multiple facets. The Mathematics major provides a broad education in various areas of mathematics in a program flexible enough to accommodate many ranges of interest. Incoming students are encouraged to visit the Math first-year student resources website for advice about choosing their mathematics courses.

PREREQUISITE

The prerequisite for both the B.A and B.S. degree programs is single variable calculus, through the level of MATH 115 or equivalent (score of 4 or 5 on the AP Calculus BC exam).

CALCULUS PLACEMENT PROCEDURES

The department offers a three-term sequence in calculus, MATH 112, 115, and 120. Students who have not taken calculus at Yale and who wish to enroll in calculus must take the mathematics online placement examination. Detailed information is available on the Math first-year student resources website. A calculus advising session will be held prior to registration, to answer student questions about placement.

MATH 112 covers differential calculus, and assumes mastery of high school algebra, geometry, and trigonometry. Enrolling students are expected to know the basic definitions of the trigonometric functions, inverse functions, factoring quadratic polynomials, and elementary area and volume formulas of plane and solid geometry. Students who could benefit from a review of precalculus are encouraged to consider MATH 110 and 111 in place of MATH 112.

The next course in the calculus sequence is MATH 115, which covers integral calculus, including sequences and series. It assumes mastery of the content of MATH 112 or equivalent (AP Calculus AB exam).

MATH 120 covers multivariable calculus, and assumes mastery of the material in MATH 115 or equivalent (AP Calculus BC exam).

REQUIREMENTS OF THE MAJOR

Students are held to the requirements that were in place when they declared their major. However, with approval from the director of undergraduate studies (DUS), the following requirements, updated for the academic year 2024-2025, may be fulfilled by students who declared the major in a prior term.

Introductory sequence requirement Each student is expected to complete Linear algebra with proofs (MATH 225 or 226), Real analysis (MATH 255 or MATH 256), and Vector analysis or Multivariable calculus (MATH 302 or 120).

B.A. degree program The B.A. degree program consists of ten term courses in Mathematics numbered 200 or higher, including the senior requirement, but excluding MATH 470. To acquire both depth and breadth in the field, students are required to take at least three courses that carry the "math distribution" attribute (YC MATH: Distribution), searchable in Yale Course Search (YCS). Students are also required to complete MATH 350 (algebra), and at least one of MATH 305 (real analysis) or MATH 310 (complex analysis). Taking all three is recommended. With prior and written permission from the DUS, students familiar with the material may substitute a higher level course in the same area (typically MATH 370, 320, 315 respectively.)

B.S. degree program The B.S. degree program consists of twelve term courses and follows the same requirements as for the B.A. degree, with the addition of at least two advanced term courses in the physical sciences, such as ASTR 418, 430, CHEM 333, 470, PHYS 401 or 410, 402 or 430, 420, 440, 441. Other such courses require the approval of the director of undergraduate studies (DUS); written approval is advised.

Searchable attribute YC Math: Distribution

Distinction in the major To be eligible for Distinction in the Major, a student must have completed MATH 305 (real analysis), MATH 310 (complex analysis), and MATH 350 (algebra).

The intensive major Candidates for a degree with an intensive major in Mathematics must take MATH 305, 310, and 350. Intensive majors are also expected to include at least two graduate courses in the Mathematics department, or equivalent independent study, among their required ten mathematics courses. Familiarity with the material of the following courses is prerequisite to graduate courses in each category: *algebra:* MATH 350 and MATH 370; *analysis:* MATH 305, 310; *algebraic topology:* MATH 350, 430.

Substitutions With permission of the Math DUS, up to two courses from other departments may be counted towards the required courses. For a list of courses that are typically approved, visit the FAQ page on the Math department website.

Credit/D/Fail Courses taken Credit/D/Fail may not be counted toward the requirements of the major.

SENIOR REQUIREMENT

During the senior year, students majoring in Mathematics fulfill the senior requirement by taking any Math course numbered MATH 480 through MATH 489. Alternatively, with the consent of the DUS, students may write a senior essay in MATH 475 under the guidance of a faculty member, which includes both a written and an oral report. Students wishing to write a senior essay should consult the DUS at least six weeks before enrolling in MATH 475, and are encouraged to pursue independent study opportunities prior to their senior year, for example through the Mathematics directed reading program or through summer research programs.

ADVISING

Students interested in pursuing further study in pure mathematics should include MATH 302, 305, 310, 350, 370, and 430 in their programs, and should consider taking one or more graduate-level courses. Students interested in applications of

mathematics should include MATH 302, 310, 350, and a selection of courses from MATH 241, 242, 244, 246, 247, 251, 260.

Courses related to mathematics Each Mathematics major is urged to acquire additional familiarity with the uses of mathematics by taking courses in Applied Mathematics, Computer Science, Engineering and Applied Science, Economics, Philosophy, Physics, Statistics & Data Science, or other departments. In some instances, a limited number of such courses may be counted among the ten courses required for the major in Mathematics, with the approval of the DUS.

Graduate work Each year the Mathematics department offers a large number of graduate courses, some of which are accessible to undergraduates with advanced preparation in mathematics.

Combined B.S./M.S. degree program Students who, by the end of their senior year, complete the requirements of the department for the M.S. in Mathematics are eligible to receive this degree at their Senior Commencement. Required are: (1) eight additional term courses numbered 500 or higher, most of which must be completed with grades of B or better; (2) passing a written qualifying examination of the student's choice from analysis, algebra, or topology.

The master's program is in no sense a substitute for the B.S. program; rather, it is designed to accommodate exceptional students who, by means of accelerated or independent study, can satisfy the department as to their command of the content of the normal undergraduate program by the end of the junior year. Candidates must contact the Mathematics DUS at least two weeks prior to the last day of classes of their fifth term at Yale College. Minimum eligibility criteria include at least seventy-five percent of A/A– grades within mathematics as well as seventy-five percent of A/A– grades overall. For more information on mathematics requirements, please see the B.S./M.S. section of the Math major FAQ. For more information on Yale College requirements for the program, see Academic Regulations, Section L, Special Academic Arrangements, “Simultaneous Award of the Bachelor's and Master's Degrees.”

SUMMARY OF MAJOR REQUIREMENTS

Prerequisite Single-variable calculus through MATH 115 or equivalent

Introductory sequence Linear algebra with proofs (MATH 225 or MATH 226), Real analysis (MATH 255 or MATH 256), and Vector analysis or Multivariable calculus (MATH 302 or MATH 120).

Number of courses *B.A.*—10 term courses numbered 200 or higher (incl senior req), excludes MATH 470; *B.S.*—12 term courses numbered 200 or higher (incl senior req), excludes MATH 470

Specific courses required *B.A. and B.S.*—MATH 350; MATH 305 or MATH 310

Distribution of courses *B.A. and B.S.*— 3 courses in the Math distribution category; *B.S.*—at least two adv term courses in the physical sciences as approved by DUS

Substitution permitted With DUS permission, up to 2 courses from other depts, as specified

Intensive major All three of MATH 305, 310, 350; 2 math grad courses or equivalent independent study counted among the required courses

Senior requirement Senior seminar numbered MATH 480 through MATH 489 or, MATH 475 with DUS permission