MATHEMATICS

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The study of mathematics develops the ability to think carefully – it sharpens analytical and problem-solving skills and trains the mind to reason logically and with precision. The program in Mathematics serves students from many majors, with a variety of academic goals. For the benefit of both majors and non-majors, the course offerings include an array of topics from both pure and applied mathematics. Some courses are theoretical, stressing communication and the development of rigorous, well-written mathematical proofs, while others are computational, using appropriate software as an aid. In preparation for Senior Independent Study, there is an emphasis on clear and precise written and oral communication of mathematical concepts. Most upper-level courses culminate in a final paper, project, or presentation.

First-year and transfer students are given a recommended placement in mathematics based upon their previous records, their scores on the SAT and/or ACT, and their performance on a placement exam offered the summer before enrolling. In some cases, incoming students have multiple options from which to choose their first mathematics course at Wooster.

Major in Mathematics

Consists of thirteen courses:

- One of the following courses: MATH 11100 or 10800
- MATH 11200
- MATH 21100
- MATH 21200
- MATH 21500
- CSCI 10000
- Two of the following courses: MATH 21900-21902, 22100, 22300, 22500, 22700, 22900
- Two of the following courses: MATH 31900-31901, 32700, 32900, 33000, 33200, 33400, 33600
- One elective full-credit Mathematics course numbered above 21500
- Junior Independent Study: See note below
- Senior Independent Study: MATH 45100
- Senior Independent Study: MATH 45200

Minor in Mathematics

Consists of six courses:

- One of the following courses: MATH 11100 or 10800
- MATH 11200
- MATH 21100
- Three elective full-credit Mathematics courses numbered above 21100

Special Notes

- **Junior Independent Study:** In lieu of a MATH 40100 course, the College requirement of a third unit of Independent Study is satisfied through the independent work done as part of the courses numbered above 20000 which are taken to fulfill the requirements of the major.
- **Advanced Placement:** At most two courses of advanced placement may be counted toward a major or minor. Advanced Placement of one or two courses in Mathematics is available to students who have taken the Advanced Placement Examination or an equivalent furnished by the Department of Mathematics and Computer Science. Students are urged to take the AP Examination for this purpose when possible. A minimum score of 3 on the AP Calculus AB examination is required to receive credit for MATH 11100; a minimum score of 4 on the AP Calculus BC examination is required to receive credit for both MATH 11100 and 11200. A student placed in MATH 11200 will receive one course credit; two course credits will be granted if the student is placed in a course above the level of MATH 11200. In cases not involving AP examinations, the decision about granting such placement will be made by the Department of Mathematics and Computer Science. The advanced placement policy of the College is explained in the section on *Admission*.
- Majors are encouraged to pursue a minor and/or second major in related fields. Double majors often write an interdisciplinary Independent Study thesis, typically using mathematics as a tool to better understand a problem in the other field. Students considering a Mathematics major should discuss their plans with a member of the department, ideally during their first year as a student.
- Although MATH 21500 is not a prerequisite for the 300-level courses, majors are strongly encouraged to take this course prior to the 300-level Mathematics courses, to help develop the proof-writing skills necessary in theoretical mathematics.
- Majors must complete the core requirements of the major (Math 11100/10800, 11200, 21100, 21200 and 21500) and at least one additional course in mathematics by the end of their junior year.
- Minors should contact a member of the department to determine which Mathematics electives would be most applicable to their major.
- **Students needing Calculus for their major/minor:** A number of programs require students to complete one or more Calculus courses. If a student does not place into Calculus, it may be necessary for the student to take a College Algebra or a Pre-Calculus course at another institution before enrolling in a Calculus course at Wooster.
- **Mathematics Study Abroad:** The College has direct connections with the overseas program *Budapest Semesters in Mathematics* in Budapest, Hungary. This program is designed for American and Canadian undergraduate mathematics students interested in a one-semester overseas study experience in which they continue their study of mathematics. The program is primarily for junior mathematics students with a strong mathematics background. All courses are taught in English by Hungarian mathematicians, most of whom have spent some time teaching in the U.S. or Canada. Courses taken in Budapest appear on the student's transcript, but grades do not count toward the student's grade point average. Only courses receiving a grade of C or above will receive Wooster credit. Most financial aid is applicable to the program, but students with financial aid should consult directly with the Director of Financial Aid.
- **Teaching Licensure (Early Childhood):** Students who are planning to receive Ohio licensure in early childhood education are required to take EDUC 26000 *Curriculum: Math/Science/Social Studies in the Early Childhood Years*. No mathe-

matics beyond this course is required to fulfill the State requirement; however, MATH 10000 would be an excellent choice to help meet Wooster's Learning Across the Disciplines requirements. Any student wishing to pursue licensure in early childhood education should plan a program carefully with the Department of Education.

- **Teaching Licensure (Middle School or Adolescent to Young Adult/ Secondary):** For Ohio licensure in middle school or adolescent to young adult/secondary teaching of mathematics, State requirements call for at least a minor in Mathematics. Because specific courses in Education and Mathematics are required for licensure, Mathematics majors seeking licensure for teaching middle school or adolescent to young adult/secondary mathematics should plan their program early, in consultation with the Department of Education. These students may choose to write a Senior Independent Study Thesis on a topic related to the teaching of middle school or adolescent to young adult/ secondary mathematics.
- Combined programs of liberal arts and engineering are available. (See *Pre-Professional and Dual Degree Programs: Pre-Engineering*.)
- Only grades of C- or better are acceptable in courses for the major or minor.

MATHEMATICS COURSES

MATH 10000. MATHEMATICS IN CONTEMPORARY SOCIETY
This course is designed for students wanting to partially satisfy the Learning Across the Disciplines requirements. This is a survey course that explores a broad spectrum of mathematical topics; examples include the search for good voting systems, the development of efficient routes for providing urban services, and the search for fair procedures to resolve conflict. The emphasis is on observing the many practical uses of mathematics in our modern society and not on mastering advanced mathematical techniques. This course does not satisfy the prerequisites for further Mathematics courses, nor does it count toward a major or minor. *Annually. Fall and Spring. [Q, MNS]*

MATH 10200. BASIC STATISTICS
This course covers an introduction to basic statistical methods and concepts - the basic elements of descriptive and inferential statistics. Topics include exploratory data analysis, experimental design, sampling, inference for means and proportions, regression, and categorical data. This course does not satisfy the prerequisites for further Mathematics courses, nor does it count toward a major or minor. *Annually. Spring. [Q, MNS]*

MATH 10400. CALCULUS FOR SOCIAL SCIENCE
This course is designed primarily for students in the social sciences. The course covers the basic concepts of single variable calculus and, to a lesser extent, multivariable differential calculus. This includes the topics of limits, differentiation, integration, and applications of these topics. The emphasis is on fundamental themes, computational skills, and problem solving, rather than on mathematical theory. This course does not count toward a major or minor. Credit cannot be given for both MATH 10400 and either 10800 or 11100. *Prerequisite: Departmental approval, as determined by performance on placement exam. Annually. Spring. [Q, MNS]*

MATH 10700. CALCULUS WITH ALGEBRA A
This course is the first in a two-course sequence that integrates precalculus and first-semester calculus topics. This course will examine the algebraic, geometric, and analytic properties of polynomial and rational functions. Limits, continuity, differentiation, and integration in connection with these functions will be studied, along with applications. This course does not count toward a major or minor and may not be taken by anyone with credit for MATH 10400 or 11100. *Prerequisite: Departmental approval, as determined by performance on placement exam. Annually. Fall. [Q, MNS]*

MATH 10800. CALCULUS WITH ALGEBRA B
This course is a continuation of MATH 10700 and will further cover topics in differential and integral calculus. It will examine algebraic, geometric, and analytic properties of trigonometric, exponential, and logarithmic functions. Limits, continuity, differentiation, and integration in connection with these functions will be studied, along with applications. This course counts toward a major or minor and may not be taken by anyone with

credit for MATH 10400 or 11100, nor can a student receive credit for both this course and MATH 10400 or 11100. *Prerequisite: MATH 10700 with a C- or better. Annually. Spring. [Q, MNS]*

MATH 11100. CALCULUS AND ANALYTIC GEOMETRY I
This course and MATH 11200 cover the calculus of functions of one variable. Topics include limits, continuity, differentiation and integration, applications of the calculus, elements of analytic geometry, and the Fundamental Theorem of Calculus. *Prerequisite: Departmental approval, as determined by performance on placement exam. Annually. Fall and Spring. [Q, MNS]*

MATH 11200. CALCULUS AND ANALYTIC GEOMETRY II
This course is a continuation of MATH 11100. Topics include calculus of transcendental functions, integration techniques, infinite series, polar and parametric representations and/or first-order differential equations. *Prerequisite: MATH 11100 or 10800 with a C- or better, or AP/equivalent credit. Annually. Fall and Spring. [Q, MNS]*

MATH 12300. DISCRETE MATHEMATICS
This course covers logic, proofs, sets, relations, functions, algorithms, counting methods, recurrence relations, graph theory, trees, Boolean Algebras, automata and grammars. *[Q, MNS]*

MATH 21100. LINEAR ALGEBRA
This course covers systems of linear equations, matrix theory, vector spaces and linear transformations, determinants, eigenvalues and eigenvectors, and inner product spaces. *Prerequisite: MATH 11200 with a C- or better, AP/equivalent credit, or permission of the instructor. Annually. Fall. [Q, MNS]*

MATH 21200. MULTIVARIATE CALCULUS
This course covers analytic geometry of functions of several variables, limits and partial derivatives, multiple and iterated integrals, non-rectangular coordinates, change of variables, line and surface integrals and the theorems of Green and Stokes. *Prerequisite: MATH 11200 with a C- or better, or AP/equivalent credit. Annually. Fall and Spring. [Q, MNS]*

MATH 21500. TRANSITION TO ADVANCED MATHEMATICS
This is a transition course from the primarily computational and algorithmic mathematics found in calculus to the more theoretical and abstract mathematics in the 300-level mathematics courses. The emphasis is on developing the skills and tools needed to read and write proofs, and to understand their importance in mathematics. The course examines topics such as set theory and logic, mathematical induction, and a number of other proof techniques. *Prerequisite: MATH 11200 with a C- or better or AP/equivalent credit. Annually. Fall and Spring. [W, MNS]*

MATH 21900-21902. SPECIAL TOPICS
The content and prerequisites of this course will vary according to the needs of students. It will be given at irregular intervals when there is need for some special topic.

MATH 22100. DIFFERENTIAL EQUATIONS
This course covers the classification of equations, forms of solution (algebraic, numeric, qualitative, geometric), solution and application of first-order and constant-coefficient second-order equations, systems of linear differential equations, phase plane analysis, applications to modeling, and computational methods (including the use of appropriate software). *Prerequisite: MATH 11200 or AP/equivalent credit. Every third semester. [Q, MNS]*

MATH 22300. COMBINATORICS AND GRAPH THEORY
This course introduces the basic techniques and modes of reasoning of combinatorial problem-solving in the same spirit that calculus introduces continuous problem-solving. It will include fundamental topics in graph theory, counting, the inclusion/exclusion principle, recurrence relations, and generating functions. *Prerequisite: MATH 12300 or 21100. Alternate years. [Q, MNS]*

MATH 22500. MATHEMATICAL MODELING
This course considers a variety of mathematical models in the physical, life, and social sciences. In addition to analyzing models, a major component of the course is using computational tools to construct mathematical models and test their validity against empirical data. *Prerequisite: MATH 11200 and CSCI 10000 or permission of the instructor. Every third semester. [Q, MNS]*

MATH 22700. OPERATIONS RESEARCH
This course begins with an introduction to the general methodology of operations research supported by examples and a brief history. A fairly extensive coverage of the theory and applications of linear programming leads

to both discrete and continuous models used in economics and the management sciences. Among those models are nonlinear programming, continuous and discrete probability models, dynamic programming, and transportation and network flow models. *Prerequisite: MATH 21100 and 21200 (may be taken concurrently) or permission of the instructor. Every third semester. [Q, MNS]*

MATH 22900. PROBABILITY AND STATISTICS I
This course is an introduction to probability and statistics. Topics include permutations and combinations, sample spaces, probability, random variables, discrete probability distributions, continuous probability distributions, multivariate distributions, transformations of random variables, and moment generating function techniques. *Prerequisite: MATH 11200. Annually. Fall. [Q, MNS]*

MATH 27900. PROBLEM SEMINAR
This course is a seminar in problem solving. In the Fall semester, the seminar focuses on analysis and solution of advanced contest-type problems, concluding with the taking of the Putnam Examination. In the Spring semester, the seminar may include the International Mathematical Contest in Modeling, in addition to introduction to problem solving. *(.25 course credit) S/NC course. May be repeated for credit. Annually. Fall and Spring.*

MATH 31900-31901. SPECIAL TOPICS
The content and prerequisites of this course will vary according to the needs of students. It will be given at irregular intervals when there is need for some special topic.

MATH 32700. NUMERICAL ANALYSIS
This course covers error analysis, interpolation theory, solution of nonlinear equations and systems of linear and nonlinear equations, numerical differentiation and integration, and solution of ordinary differential equations. While theoretical results are discussed, there is also an emphasis on implementing algorithms and analyzing computed results. *Prerequisite: CSCI 10000, MATH 11200 and 21100, or permission of the instructor. Alternate years.*

MATH 32900. PROBABILITY AND STATISTICS II
This course is a continuation of MATH 22900. Topics include random vectors and random sampling, estimation and hypothesis testing, analysis of variance, regression, and nonparametric statistics. *Prerequisite: MATH 21100 and 22900. Alternate years. Spring.*

MATH 33000. TOPOLOGY
This course covers sets and functions, metric spaces, topological spaces, compactness, separation, and connectedness. Strongly recommended previous course: MATH 21500. *Prerequisite: MATH 21100 and 21200 or permission of the instructor. Alternate years. Fall.*

MATH 33200. REAL ANALYSIS I
This course develops the theoretical background for many Calculus concepts. The course begins with a study of sets, mathematical induction, and proof techniques. We then focus on the properties of the real numbers, sequences, convergence, and the Bolzano-Weierstrass Theorem. The course finishes with a study of functions defined on the real numbers, limits, continuity, and differentiation. *Strongly recommended previous course: MATH 21500. Prerequisite: MATH 21100 or permission of the instructor. Annually. Spring.*

MATH 33300. REAL ANALYSIS II
This course is a continuation of MATH 33200, covering uniform continuity, uniform convergence, and further topics in differentiation and integration. Some discussion of metric spaces, introductory measure theory, and the Lebesgue integral will be included. *Prerequisite: MATH 33200. Offered as needed.*

MATH 33400. ABSTRACT ALGEBRA I
This course is an introduction to abstract algebraic structures. This course and MATH 33500 include an axiomatic approach to familiar number systems, equivalence, groups, rings, isomorphism, and fields. Emphasis is on understanding and writing mathematical proofs. *Strongly recommended previous course: MATH 21500. Prerequisite: MATH 21100. Annually. Fall.*

MATH 33500. ABSTRACT ALGEBRA II
This course is a continuation of MATH 33400. Topics include groups, subgroups, symmetric groups, congruence, Lagrange's Theorem, and further topics in ring and field theory. *Prerequisite: MATH 33400. Offered as needed.*

MATH 33600. FUNCTIONS OF A COMPLEX VARIABLE
This course covers complex numbers, elementary functions, Cauchy's theorem and formula, infinite series, elements of conformal mapping, and residues. *Strongly recommended previous course: MATH 21500. Prerequisite: MATH 21100 and 21200 or permission of the instructor. Alternate years.*

MATH 40000. TUTORIAL
This course will be given for topics not normally covered in regular courses. *Prerequisite: The approval of both the supervising faculty member and the chairperson are required prior to registration.*

MATH 45100. SENIOR INDEPENDENT STUDY – SEMESTER ONE
Senior Independent Study is a two-semester project culminating in the I.S. Thesis and an oral presentation. In the first semester, the student will produce a project abstract, an annotated bibliography, and a substantial written portion of the thesis. The semester concludes with a short oral presentation on the project and progress in the first semester. *Prerequisites: C- or better in MATH 21100, 21200, 21500 and one additional course numbered above 21500, or approval of the Department.*

MATH 45200. SENIOR INDEPENDENT STUDY – SEMESTER TWO
In the second semester of Senior Independent Study the student completes the I.S. Thesis and an oral presentation. *Prerequisite: MATH 45100.*