Mathematics

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Mathematics courses provide an opportunity to study mathematics for its own sake and as a tool for use in the physical, social, and life sciences.

All or part of the calculus sequence is required or recommended by several majors at Whitman and calculus is the most common mathematics course taken by students. However, the department offers other courses (Mathematics 128) that are intended for students who wish to take mathematics but are not interested in or not prepared for calculus.

P-D-F policy: The department places no restrictions on the use of the P-D-F option for mathematics courses for majors or nonmajors, except that students choosing the mathematics major must take Mathematics 260 for a grade. The department strongly recommends that students majoring in mathematics or completing a joint major with mathematics not use the P-D-F option in mathematics courses.

Senior assessment consists of the written exam in mathematics and an oral exam over general and advanced topics.

Distribution: Courses completed in mathematics apply to the quantitative analysis distribution area.

Learning Goals: Upon graduation, a student will be able to:

- **Major-Specific Areas of Knowledge**
  - Solve mathematical problems. Learn new mathematics independently. Evaluate mathematical arguments. Have depth of study in at least one area of mathematics. Have a basic understanding of several branches of mathematics.
- **Communication**
  - Communicate mathematical ideas effectively both orally and in writing.
- **Quantitative Skills**
  - See other goals.

The Mathematics major: A total of 36 credits, to include Mathematics 225, 235, 240, 260; any two of 455, 456, 475, 476; 497 or 498; 12 additional credits in mathematics courses numbered above 200. An average of the grades received in Mathematics 225, Mathematics 240 and Mathematics 260 of 2.5 or better is required. For students with transfer credit from outside of Whitman in one or more of these courses, the grade earned at that institution shall be used. Grades of B (3.0) or better in Mathematics 225, 240, and 260 are strongly recommended for any student considering mathematics as a major, and both courses ought to be completed by the end of the sophomore year. Students planning graduate study should take Mathematics 456 and 486 and should acquire a reading knowledge of either French, German, or Russian.

A student who enters Whitman College without a good working knowledge of the material in Mathematics 125 and 126 will have to complete 42 mathematics credits to fulfill the requirements for the mathematics major (including six credits for Mathematics 125, 126).

Twenty-six mathematics credits are required for the mathematics-physics major, 29 mathematics credits for the economics-mathematics major, and 29 mathematics credits for the 3-2 mathematics-computer science major.

Honors in the major: Students do not apply for admission to candidacy for honors. To be granted honors, a senior Mathematics Major must attain the minimum Cumulative and Major GPAs specified in the faculty code (3.300 and 3.500, respectively), pass the Senior Comprehensive Examination with distinction, register for Mathematics 497, write a thesis graded A or A- by the Mathematics and Computer Science Department faculty, and receive departmental approval. The Chair of the Mathematics and Computer Science Department will notify the Registrar of those students attaining Honors in Major Study no later than the beginning of the third week of April for spring honors thesis candidates. Two copies of the Honors Theses must be submitted to Penrose Library no later than Reading Day.

The Mathematics minor: Fifteen credits or more in mathematics courses numbered 200 or above.

The Economics-Mathematics combined major: Computer Science 167, Mathematics 225, 235, 240, 244, 247, 349, and three additional credits chosen from mathematics courses numbered above 200. Economics 100 or

101, 102, 307, 308, 327, 428, plus one additional course in economics. Students should note that in addition to Economics 307 and 308, the prerequisites for Economics 327 include Economics 227 (or Mathematics 128 or 247). However, neither Economics 227 nor Mathematics 128 applies toward the minimum major requirements. In addition, Economics 100 or 101, 102, and Mathematics 247 are the prerequisites for Economics 327. Economics 227 does not apply toward the minimum major requirements. Economics 493, 494, and other economics courses taken P-D-F may not be used to meet the 27-credit requirement. The senior assessment consists of the written exam in mathematics, the Major Field Test (MFT) in economics, and a combined oral exam scheduled by the economics department.

The Mathematics-Physics combined major: Mathematics 225, 235, 240, 244, and nine additional credits in mathematics courses numbered above 200; Physics 145 or 155 or 165, 156 or 166, 245, 246, 255, 256, 325, 339, and one additional physics course numbered from 300-480, or BBMB 324. Senior assessment consists of the written exam in mathematics, the written exam in physics, and a combined oral exam scheduled by the physics department.

Choosing a Calculus Course Students who wish to take calculus should note the following: Students with a strong background in high school mathematics not including calculus start with Mathematics 125. Students who have taken a high school course in calculus, but who have not taken the BC calculus Advanced Placement Test (see the statement below regarding college credit for the Advanced Placement Test) should take the Advisory Calculus Placement exam offered by the department of mathematics.

Students should note that several programs require the calculus lab, Mathematics 235, in addition to Mathematics 225. Because the lab course teaches skills that are useful in other mathematics and science courses, it is strongly recommended that students take Mathematics 235 as early as possible in their programs. Programs that require the calculus labs are the mathematics major, the economics-mathematics major, the mathematics-physics major, the physics major, the 3-2 engineering program, and the 3-2 mathematics-computer science major.

Advanced Placement The policy for advanced standing and credit for the College Board Advanced Placement program is as follows:

I. Students with a 4 or 5 on the BC calculus test are considered to have completed the equivalent of Mathematics 125 and 126 and receive six credits in mathematics.

II. Students with a 4 or 5 on the AB calculus test (or on the AB subtest of the BC test) are considered to have completed the equivalent of Mathematics 125 and receive three credits in mathematics. These students should take the placement test offered by the department of mathematics to determine whether they should enroll in Mathematics 126 or Mathematics 225.

III. Students with a 4 or 5 on the computer science (A) test are considered to have completed the equivalent of Computer Science 167 and receive three credits in computer science.

IV. Students with a 4 or 5 on the statistics test are considered to have completed the equivalent of Mathematics 128 and receive three credits in mathematics. Students should consider taking Mathematics 247 if they have also completed the equivalent of Mathematics 125.

A student has the option of repeating a course for which AP credit has been granted, but with a commensurate reduction in advanced placement credit.

125 Calculus I

Fall, Spring Fall: Keef, L. Schueller; Spring: L. Schueller 3 credits

A brief review of some precalculus topics followed by limits, continuity, a discussion of derivatives, and applications of the derivative. *Prerequisites:* two years of high school algebra; one year of plane geometry; and knowledge of trigonometry and exponential/logarithmic functions or consent of instructor.

126 Calculus II

Fall, Spring Fall: Guichard, L. Schueller; Spring: R. Gordon, L. Schueller 3 credits

A continuation of Mathematics 125, covering integration, techniques for computing antiderivatives, the fundamental theorem of calculus, applications of the definite integral, and infinite series.

128 Elementary Statistics

Fall, Spring Ptukhina 3 credits

Probability and statistics including methods for exploring data and relationships in data, methods for producing data, an introduction to probability and distributions, confidence intervals, and hypothesis testing. *Prerequisite:* two years of high school mathematics.

203, 204 Special Topics in Introductory Level Mathematics
1-3 credits

On occasion, the mathematics department will offer courses on introductory topics in mathematics that are not generally covered in other introductory courses. Possible topics include Introduction to Number Theory, Chaos and Applied Discrete Probability. Any current offerings follow.

220 Discrete Mathematics & Functional Programming
Fall **J. Davis** **3 credits**

Students will practice formal reasoning over discrete structures through two parallel modes: mathematical proofs and computer programs. We will introduce sets and lists, Boolean logic, and proof techniques. We will explore recursive algorithms and data types alongside mathematical and structural induction. We consider relations and functions as mathematical objects built on set theory and develop idioms of higher-order programming. If time permits, additional topics may include graphs, lattices, or groups, and their applications to computer science. May be elected as Computer Science 220. *Prerequisite:* Computer Science 167 or any course in mathematics.

225 Calculus III
Fall, Spring **Fall: Balof; Spring: Hundley** **4 credits**

Topics include partial derivatives, gradients, extreme value theory for functions of more than one variable, multiple integration, line integrals, and various topics in vector analysis.

235 Calculus Laboratory
Not offered 2017-18 **1 credit**

A laboratory to investigate ways in which the computer can help in understanding the calculus and in dealing with problems whose solutions involve calculus. No programming required; a variety of existing programs will be used. *Pre-* or *corequisite:* Mathematics 225.

240 Linear Algebra
Fall, Spring **Fall: Edmondson; Spring: Keef** **3 credits**

This course first considers the solution set of a system of linear equations. The ideas generated from systems of equations are then generalized and studied in a more abstract setting, which considers topics such as matrices, determinants, vector spaces, inner products, linear transformations, and eigenvalues. *Prerequisite:* Mathematics 225.

244 Differential Equations
Fall, Spring **Hundley** **3 credits**

This course includes first and second order linear differential equations and applications. Other topics may include systems of differential equations and series solutions of differential equations. *Prerequisite:* Mathematics 225.

247 Statistics with Applications
Fall, Spring **Fall: Edmondson, Ptukhina; Spring: Edmondson** **3 credits**

An introduction to statistics for students who have taken at least one course in calculus. Focuses on learning statistical concepts and inference through investigations. Topics include, but are not limited to, exploratory graphics, sampling methods, randomization, hypothesis tests, confidence intervals, and probability distributions. A statistical software package will be used. *Prerequisite:* Mathematics 125 or equivalent.

248 Statistical Modeling
Spring **Ptukhina** **3 credits**

This course follows introductory statistics by investigating more complex statistical models and their application to real data. The topics may include simple linear regression, multiple regression, non-parametric methods, and logistic regression. A statistical software package will be used. *Prerequisite:* Mathematics 128, Mathematics 247, Biology 228, Economics 227, or Environmental Studies 207.

260 An Introduction to Higher Mathematics
Fall, Spring **Fall: Balof; Spring: R. Gordon** **3 credits**
An introduction to some of the concepts and methodology of advanced mathematics. Emphasis is on the notions of rigor and proof. This course is intended for students interested in majoring in mathematics; students should plan to complete it not later than the spring semester of the sophomore year. *Prerequisite:* Mathematics 225.

281, 282 Independent Study
Fall, Spring **Staff** **1-3 credits**
A reading project in an area of mathematics not covered in regular courses or that is a proper subset of an existing course. The topic, selected by the student in consultation with the staff, is deemed to be introductory in nature with a level of difficulty comparable to other mathematics courses at the 200-level. May be repeated for a maximum of six credits. *Prerequisite:* consent of supervising instructor.

287 Independent Study in Geometry
Fall, Spring **Staff** **3 credits**
This independent study in geometry will include a review of high school geometry, a few topics in advanced Euclidean geometry, a reading of Books I and II of Euclid's Elements, and an introduction to hyperbolic geometry. The grading for the course will be based on a journal (20%), a two-hour written midterm exam (40%), and a one-hour oral final exam (40%). Since the student will be working independently on the material, a disciplined work ethic is required. *Prerequisite:* Mathematics 225.

299 Problem-Solving in Mathematics
Fall **Balof** **1 credit**
Students will meet weekly to discuss problem-solving techniques. Each week a different type of problem will be discussed. Topics covered will include polynomials, combinatorics, geometry, probability, proofs involving induction, parity arguments, and divisibility arguments. The main focus of the course will be to prepare students for the William Lowell Putnam Mathematics Competition, a national examination held the first Saturday in December. Students who place in the top 500 on this exam nationwide have their names listed for consideration to mathematics graduate programs. Graded credit/no credit. May be repeated for a maximum of four credits. *Prerequisite:* Mathematics 260 or consent of instructor.

320 Theory of Computation
Spring **Exley** **3 credits**
Which problems can be solved computationally? Which cannot? Why? We can prove that computers can perform certain computations and not others. This course will investigate which ones, and why. Topics will include formal models of computation such as finite state automata, push-down automata, and Turing machines, as well as formal languages such as context-free grammars and regular expressions. May be elected as Computer Science 320. *Prerequisite*: Computer Science/Mathematics 220 or Mathematics 260.

327 Algorithm Design & Analysis
Spring **Stratton** **3 credits**
How can we be confident that an algorithm is correct before we implement it? How can we compare the efficiency of different algorithms? We present rigorous techniques for design and analysis of efficient algorithms. We consider problems such as sorting, searching, graph algorithms, and string processing. Students will learn design techniques such as linear programming, dynamic programming, and the greedy method, as well as asymptotic, worst-case, average-case and amortized runtime analyses. Data structures will be further developed and analyzed. We consider the limits of what can be efficiently computed. May be elected as Computer Science 327. *Prerequisites:* Computer Science 270; Mathematics 126; Computer Science/Mathematics 220 or Mathematics 260.

337 Geometry
Not offered 2017-18 **3 credits**
Essential for prospective high school mathematics teachers, this course includes a study of Euclidean geometry, a discussion of the flaws in Euclidean geometry as seen from the point of view of modern axiomatics, a consideration of the parallel postulate and attempts to prove it, and a discussion of the discovery of non-Euclidean geometry and its philosophical implications. *Prerequisite:* Mathematics 126.

339 Operations Research
Fall **Hundley** **3 credits**
Operations research is a scientific approach to determining how best to operate a system, usually under conditions requiring the allocation of scarce resources. This course will consider deterministic models, including those in linear programming (optimization) and related subfields of operations research. May be elected as Computer Science 339. *Prerequisites:* Mathematics 240; Computer Science 167 or Mathematics 235.

349 Probability Theory
Spring **Edmondson** **3 credits**
A formal introduction to probability and randomness. The topics of the course include but are not limited to conditional probability, Bayes' Theorem, random variables, the Central Limit Theorem, expectation and variance. Both discrete and continuous probability distribution functions and cumulative distribution functions are studied. *Prerequisite:* Mathematics 225.

350 Mathematical Modeling and Numerical Methods
Not offered 2017-18 **3 credits**
This course explores the process of building, analyzing and interpreting mathematical descriptions of physical processes. This may include theoretical models using statistics and differential equations, simulation modeling, and empirical modeling (meaning model building from data). The course will involve some computer programming, so previous programming experience is helpful. May be elected as Computer Science 350. *Prerequisites:* Mathematics 240 and 244.

358 Combinatorics and Graph Theory
Spring **Guichard** **3 credits**
Topics in elementary combinatorics, including: permutations, combinations, generating functions, the inclusion-exclusion principle, and other counting techniques; graph theory; and recurrence relations. *Prerequisite:* Mathematics 260 or consent of instructor.

367 Engineering Mathematics
Not offered 2017-18 **3 credits**
An introduction to mathematics commonly used in engineering and physics applications. Topics may include: vector analysis and applications; matrices, eigenvalues, and eigenfunctions; boundary value problems and spectral representations; Fourier series and Fourier integrals; solution of partial differential equations of mathematical physics; differentiation and integration of complex functions, residue calculus, conformal mapping. *Prerequisite:* Mathematics 244.

368 Complex Variables
Spring **Schueller** **3 credits**
Complex analysis is the study of functions defined on the set of complex numbers. This introductory course covers limits and continuity, analytic functions, the Cauchy-Riemann equations, Taylor and Laurent series, contour integration and integration theorems, and residue theory. *Prerequisite:* Mathematics 225.

371, 372 Special Topics
1-3 credits
Any current offerings follow.

371 ST: Introduction to Set Theory
Fall Keef 3 credits
An introduction to the theory of infinite sets and their applications in other mathematical subjects. Topics include the Axiom of Choice, Zorn's Lemma, the Well-Ordering Principle, cardinal and ordinal numbers and their arithmetics. *Prerequisite:* Mathematics 260. Distribution area: quantitative analysis.

372 ST: Design and Analysis of Research Studies
Spring Ptukhina 3 credits
Statistical concepts and statistical methodology useful in descriptive, experimental, and analytical study of biological and other natural phenomena. Course covers major design structures, including blocking, nesting and repeated measures (longitudinal data), and statistical analysis associated with these structures. *Prerequisite:* Mathematics 247 or consent of instructor. Distribution area: quantitative analysis.

438 Statistical Theory
Fall Edmondson 4 credits
This course studies the mathematical theory of statistics with a focus on the theory of estimation and hypothesis tests. Topics may include properties of estimators, maximum likelihood estimation, convergence in probability, the central limit theorem, order statistics, moment generating functions, and likelihood ratio tests. A statistical software package will be used. *Prerequisites:* Mathematics 349 and one of Mathematics 128, Mathematics 247, Biology 228, Economics 227, or Environmental Studies 207.

455, 456 Real Analysis
Fall, Spring Schueller 4 credits
First semester: a rigorous study of the basic concepts of real analysis, with emphasis on real-valued functions defined on intervals of real numbers. Topics include sequences, continuity, differentiation, integration, infinite series, and series of functions. Second semester: content varies from instructor to instructor but includes topics from metric spaces, the calculus of vector-valued functions, and more advanced integration theory. *Prerequisite:* Mathematics 260.

467 Numerical Analysis
Not offered 2017-18 3 credits
An introduction to numerical approximation of algebraic and analytic processes. Topics include numerical methods of solution of equations, systems of equations and differential equations, and error analysis of approximations. May be elected as Computer Science 467. *Prerequisite:* Computer Science 167. *Pre-* or *corequisite:* Mathematics 240.

471, 472 Special Topics
1-3 credits
On occasion, the mathematics department will offer courses on advanced topics in mathematics that are not found in other course offerings. Possible topics include topology, number theory, and problem-solving. Any current offerings follow.

475, 476 Abstract Algebra
Fall, Spring Guichard 4 credits
The first semester is an introduction to groups and rings, including subgroups and quotient groups, homomorphisms and isomorphisms, subrings and ideals. Topics for the second semester may include fields, simple groups, Sylow theorems, Galois theory, and modules. *Prerequisite:* Mathematics 260.

481, 482 Independent Study
Fall, Spring Staff 1-3 credits
A reading or research project in an area of mathematics not covered in regular courses. The topic is to be selected by the student in consultation with the staff. Maximum of six credits. *Prerequisite*: consent of supervising instructor.

497 Senior Project

Spring **Keef** **4 credits**

Preparation of the senior project required of all graduating mathematics majors. Each student will be matched with a faculty member from the mathematics department who will help supervise the project. Course objectives include developing students' abilities to independently read, develop, organize, and communicate mathematical ideas, both orally and in writing. A final written and oral report on the project is completed.

498 Honors Thesis

Fall, Spring **Staff** **4 credits**

Preparation of an honors thesis. Required of and limited to senior honors candidates in mathematics. Students will be a part of the Mathematics 497 *Senior Project* class (described above), but their work will be held to a higher standard. P*rerequisite:* admission to honors candidacy.