

# MATHEMATICS

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[www.math.calpoly.edu](http://www.math.calpoly.edu)

Department Chair: Joseph E. Borzellino

## Academic Programs

Program name	Program type
Mathematics	BS, MS, Minor

The Mathematics Department offers a comprehensive undergraduate program of courses leading to a Bachelor of Science degree in mathematics. It also offers a program of courses for students who wish to minor in mathematics, as well as graduate courses for programs of study leading to a Master of Science degree. The mix of pure and applied mathematics in these courses increases both the usefulness of and the demand for graduates with a degree in mathematics. In addition, the Mathematics Department offers courses that serve all departments in the university.

The rich variety of courses in the Mathematics department provides students with the opportunity to experience those fields and the techniques of mathematics that are most useful in the physical sciences, engineering, statistics and business. Examples include mathematical modeling, mathematical biology, data analysis, operations research, fluid dynamics, numerical analysis, financial mathematics and sustainability.

Satisfactory completion of the Entry Level Mathematics (ELM) requirement is a prerequisite for enrollment in all mathematics courses except MATH 92 and MATH 96. For additional mathematics placement (MAPE) information visit the Academic Standards and Policies (<http://catalog.calpoly.edu/academicstandardsandpolicies/academicplacement>) section.

## Undergraduate Programs

### BS Mathematics

The undergraduate program for math majors contains a central core of courses. These courses give a solid basis for advanced work that is tailored to fit the needs and objectives of each individual student. Advanced coursework is chosen in close consultation with faculty advisors.

### Concentrations

The General Curriculum in Mathematics is not a concentration, and is the default curriculum required for students who do not declare a concentration. The general curriculum and all of the concentrations provide a strong mathematical foundation for the student contemplating the pursuit of a graduate degree in mathematics.

### Applied Mathematics

Provides a curriculum with an emphasis on applications to the physical sciences and engineering. This concentration benefits students who are interested in the use of mathematics in areas such as engineering, data analytics, physics, aeronautics, finance, actuarial science, biology, medicine, and the geosciences. Potential career paths include pursuit of advanced degrees in any of the above fields or in applied mathematics,

as well as industry jobs in a broad range of areas in which physical processes are modeled or analyzed using the tools of mathematics.

### Mathematics Teaching

Students wishing to prepare for a career teaching mathematics in middle or senior high school should choose the concentration in teaching. The courses in the concentration, coupled with the other required courses in the major, fulfill the prerequisites for the California Commission on Teacher Credentialing.

### Pure Mathematics

A broad and rigorous curriculum designed both for students who will pursue an advanced degree in mathematics as well as those who choose careers requiring significant mathematical training. Graduates of the program are well prepared to enter graduate programs in mathematics and capable of bringing a broad range of mathematical skills and expertise to a wide range of professional careers.

## Mathematics Minor

Students may earn a minor in mathematics by completing a coordinated program of study. The program consists of a core of required courses, followed by four advanced courses coordinated with a student's career objectives. Interested students should contact the Mathematics Department for individual advisement.

## Graduate Program

### Master of Science Degree in Mathematics

#### General Characteristics

The master of science program in mathematics prepares students to enter careers in industry, teaching at the community college level, or to prepare for entering a PhD program in pure or applied mathematics.

#### Prerequisites

General CSU minimum qualifications for students entering a Master's degree program include a bachelor's degree from an accredited institution with a minimum grade point average of 2.5 in the last 90 quarter units attempted.

Generally the Mathematics department at Cal Poly expects incoming Master's degree students to have a grade point average of 3.0 or higher, and preferably a major in mathematics. Applicants without a major in mathematics are still welcome to apply, but must have substantial exposure to upper level mathematics courses. Such applicants may be subject to acceptance conditional upon completion of remaining standard undergraduate mathematics curricula.

#### Program of Study

The Master's program requires 45 units of coursework and a culminating oral exam. There are nine 500 level courses that are required of all graduating Master's students in mathematics. Two of these courses have prerequisites qualifying exams, each offered twice a year.

## Blended BS+MS Mathematics

The blended program provides motivated students with an efficient way to complete a BS and MS in mathematics with both degrees being conferred simultaneously. Students are provided with ample advising to ensure a seamless transition from undergraduate to graduate status.

## Eligibility

Cal Poly students interested in applying for the blended program are expected to have a 3.3 grade point average or higher, to have completed some upper division coursework, and should be on or ahead of track to finish their undergraduate degree. Students normally apply during their senior year. Interested students should arrange to meet with the Graduate Coordinator to discuss when and how to apply.

## Program of Study

Students must complete the requirements of both the undergraduate and master's program of study for a total of 225 units. They are advised to take undergraduate courses suitable for preparation for graduate studies in mathematics, including several 400 level courses in linear and abstract algebra and real analysis.

## MATH Courses

### **MATH 92. Beginning Algebra Review. 3 units**

CR/NC

Term Typically Offered: F, W

Review of basic algebra skills at the beginning algebra level intended primarily to prepare students for MATH 96 (formerly MATH 104). Course open only to students who have taken the ELM examination and are not qualified for MATH 96 (formerly MATH 104). Not for baccalaureate credit. Credit/No Credit grading only. 3 lectures. Formerly MATH 100.

### **MATH 94. Beginning Algebra Workshop. 1 unit**

CR/NC

Term Typically Offered: TBD

Concurrent: Enrollment in the associated section of MATH 92 (formerly MATH 100).

Facilitated study and discussion of the theory, problems, and applications of beginning algebra. Not for baccalaureate credit. Credit/No Credit grading only. 1 laboratory. Formerly MATH 110.

### **MATH 96. Intermediate Algebra. 3 units**

CR/NC

Term Typically Offered: F, W, SP

Prerequisite: Appropriate score on the ELM examination, or credit in MATH 92 (formerly MATH 100).

Review of basic algebra skills at the intermediate algebra level intended primarily to prepare students for MATH 116. Not for baccalaureate credit. Credit/No Credit grading only. 3 lectures. Formerly MATH 104.

### **MATH 98. Intermediate Algebra Workshop. 1 unit**

CR/NC

Term Typically Offered: TBD

Concurrent: Enrollment in the associated section of MATH 96 (formerly MATH 104).

Facilitated study and discussion of the theory, problems, and applications of intermediate algebra. Not for baccalaureate credit. Credit/No Credit grading only. 1 laboratory. Formerly MATH 114.

### **MATH 112. Nature of Modern Math. 4 units**

GE Area B1

Term Typically Offered: W, SP

Prerequisite: Passing score on ELM examination, or an ELM exemption, or credit in MATH 96 (formerly MATH 104).

Topics from contemporary mathematics, their development, applications, and role in society. Some typical topics, to be chosen by the instructor: graph theory, critical path analysis, statistical inference, coding, game theory, and symmetry. 4 lectures. Fulfills GE B1; for students admitted Fall 2016 or later, a grade of C- or better in one GE B1 course is required to fulfill GE Area B.

### **MATH 116. Precalculus Algebra I. 3 units**

GE Area B1

Term Typically Offered: F, W, SP

Prerequisite: Passing score on ELM examination, or an ELM exemption, or credit in MATH 96 (formerly MATH 104).

Pre-calculus college algebra without trigonometry. Special products and factoring, exponents and radicals. Fractional and polynomial equations. Matrices, determinants, and systems of equations. Polynomial, rational, exponential, and logarithmic functions. Graphing, inequalities, absolute value, and complex numbers. MATH 116 and MATH 117 are equivalent to MATH 118, but are taught at a slower pace. Upon completion of MATH 116 and MATH 117, a student will receive 4 units of GE credit for Area B1. Students admitted Fall 2016 or later need a grade of C- or better in one of their GE B1 requirements in order to fulfill GE Area B. Not open to students with credit in MATH 118, MATH 141, MATH 161, or MATH 221. Credit will be granted in only one of the following courses: MATH 116, MATH 118. 3 lectures.

### **MATH 117. Precalculus Algebra II. 3 units**

GE Area B1

Term Typically Offered: F, W, SP

Prerequisite: MATH 116 with a grade of C- or better or consent of instructor.

Pre-calculus college algebra without trigonometry. Special products and factoring, exponents and radicals. Fractional and polynomial equations. Matrices, determinants, and systems of equations. Polynomial, rational, exponential, and logarithmic functions. Graphing, inequalities, absolute value, and complex numbers. MATH 116 and MATH 117 are equivalent to MATH 118, but are taught at a slower pace. Upon completion of MATH 116 and MATH 117, a student will receive 4 units of GE credit for Area B1. Students admitted Fall 2016 or later need a grade of C- or better in one of their GE B1 requirements in order to fulfill GE Area B. Not open to students with credit in MATH 118. 3 lectures.

**MATH 118. Precalculus Algebra. 4 units**

GE Area B1

Term Typically Offered: F,W,SP,SU

Prerequisite: Completion of ELM requirement and passing score on appropriate Mathematics Placement Examination.

Pre-calculus algebra without trigonometry. Special products and factoring, exponents and radicals. Fractional and polynomial equations. Matrices, determinants, and systems of equations. Polynomial, rational, exponential, and logarithmic functions. Graphing, inequalities, absolute value, and complex numbers. MATH 118 is equivalent to MATH 116 and MATH 117. Not open to students with credit in MATH 117, MATH 141, MATH 161, or MATH 221. Credit will be granted in only one of the following courses: MATH 116, MATH 118. 4 lectures. Fulfills GE B1; for students admitted Fall 2016 or later, a grade of C- or better in one GE B1 course is required to fulfill GE Area B.

**MATH 119. Precalculus Trigonometry. 4 units**

GE Area B1

Term Typically Offered: F, W, SP

Prerequisite: Completion of ELM requirement and passing score on appropriate Mathematics Placement Examination, or MATH 117, or MATH 118.

Rectangular and polar coordinates. Trigonometric functions, fundamental identities. Inverse trigonometric functions and relations. Vectors, complex numbers, conic sections, and analytic geometry. Not open to students with credit in MATH 141, MATH 161, or MATH 221. 4 lectures. Fulfills GE B1; for students admitted Fall 2016 or later, a grade of C- or better in one GE B1 course is required to fulfill GE Area B.

**MATH 126. Pre-Calculus Algebra Workshop I. 1 unit**

CR/NC

Term Typically Offered: TBD

Concurrent: Enrollment in the associated section of MATH 116.

Facilitated study and discussion of the theory, problems, and applications of precalculus algebra. Credit/No Credit grading only. 1 laboratory.

**MATH 127. Pre-Calculus Algebra Workshop II. 1 unit**

CR/NC

Term Typically Offered: TBD

Concurrent: Enrollment in the associated section of MATH 117.

Facilitated study and discussion of the theory, problems, and applications of pre-calculus algebra. Credit/No Credit grading only. 1 laboratory.

**MATH 128. Pre-Calculus Algebra Workshop. 1 unit**

CR/NC

Term Typically Offered: TBD

Concurrent: Enrollment in the associated section of MATH 118.

Facilitated study and discussion of the theory, problems, and applications of pre-calculus algebra. Credit/No Credit grading only. 1 laboratory.

**MATH 129. Precalculus Trigonometry Workshop. 1 unit**

CR/NC

Term Typically Offered: TBD

Corequisite: Concurrent enrollment in the associated section of MATH 119.

Facilitated study and discussion of the theory, problems, and applications of pre-calculus trigonometry. Credit/No Credit grading only. 1 laboratory.

**MATH 141. Calculus I. 4 units**

GE Area B1

Term Typically Offered: F,W,SP,SU

Prerequisite: Completion of ELM requirement and passing score on appropriate Mathematics Placement Examination, or MATH 118 and high school trigonometry, or MATH 119.

Limits, continuity, differentiation. Introduction to integration. 4 lectures. Crosslisted as HNRS/MATH 141. Fulfills GE B1; for students admitted Fall 2016 or later, a grade of C- or better in one GE B1 course is required to fulfill GE Area B.

**MATH 142. Calculus II. 4 units**

GE Area B1

Term Typically Offered: F,W,SP,SU

Prerequisite: MATH 141 with a grade of C- or better or consent of instructor.

Techniques of integration, applications to physics, transcendental functions. 4 lectures. Crosslisted as HNRS/MATH 142. Fulfills GE B1; for students admitted Fall 2016 or later, a grade of C- or better in one GE B1 course is required to fulfill GE Area B.

**MATH 143. Calculus III. 4 units**

GE Area B1

Term Typically Offered: F,W,SP,SU

Prerequisite: MATH 142 with a grade of C- or better or consent of instructor.

Infinite sequences and series, vector algebra, curves. 4 lectures. Crosslisted as HNRS/MATH 143. Fulfills GE B1; for students admitted Fall 2016 or later, a grade of C- or better in one GE B1 course is required to fulfill GE Area B.

**MATH 151. Calculus Workshop I. 1 unit**

CR/NC

Term Typically Offered: TBD

Concurrent: Enrollment in the associated section of MATH 141.

Facilitated study and discussion of the theory, problems, and applications of calculus. Credit/No Credit grading only. 1 laboratory.

**MATH 152. Calculus Workshop II. 1 unit**

CR/NC

Term Typically Offered: TBD

Concurrent: Enrollment in the associated section of MATH 142.

Facilitated study and discussion of the theory, problems, and applications of calculus. Credit/No Credit grading only. 1 laboratory.

**MATH 153. Calculus Workshop III. 1 unit**

CR/NC

Term Typically Offered: TBD

Concurrent: Enrollment in the associated section of MATH 143.

Facilitated study and discussion of the theory, problems, and applications of calculus. Credit/No Credit grading only. 1 laboratory.

**MATH 161. Calculus for the Life Sciences I. 4 units**

GE Area B1

Term Typically Offered: W, SP, SU

Prerequisite: Completion of ELM requirement and passing score on appropriate Mathematics Placement Examination, or MATH 118.

Review of exponential, logarithmic, and trigonometric functions. Differential and integral calculus with applications to the biological sciences. Introduction to differential equations and mathematical modeling. Examples, exercises and applications to emphasize problems in life sciences. Not open to students with credit in MATH 141. 4 lectures. Fulfills GE B1; for students admitted Fall 2016 or later, a grade of C- or better in one GE B1 course is required to fulfill GE Area B.

**MATH 162. Calculus for the Life Sciences II. 4 units**

GE Area B1

Term Typically Offered: F, SP, SU

Prerequisite: MATH 161.

Review of exponential, logarithmic, and trigonometric functions. Differential and integral calculus with applications to the biological sciences. Introduction to differential equations and mathematical modeling. Examples, exercises and applications to emphasize problems in life sciences. Not open to students with credit in MATH 142. 4 lectures. Fulfills GE B1; for students admitted Fall 2016 or later, a grade of C- or better in one GE B1 course is required to fulfill GE Area B.

**MATH 171. Calculus for the Life Sciences Workshop I. 1 unit**

CR/NC

Term Typically Offered: TBD

Concurrent: Enrollment in the associated section of MATH 161.

Facilitated study and discussion of the theory, problems, and applications of calculus for the life sciences. Credit/No Credit grading only. 1 laboratory.

**MATH 172. Calculus for the Life Sciences Workshop II. 1 unit**

CR/NC

Term Typically Offered: TBD

Concurrent: Enrollment in the associated section of MATH 162.

Facilitated study and discussion of the theory, problems, and applications of calculus for the life sciences. Credit/No Credit grading only. 1 laboratory.

**MATH 182. Calculus for Architecture and Construction Management. 4 units**

GE Area B1

Term Typically Offered: W, SP

Prerequisite: MATH 141.

Integral calculus with applications to architecture and construction management. The algebra of vectors. Polar, cylindrical, and spherical coordinate systems. Not open to students with credit in MATH 142. 4 lectures. Fulfills GE B1; for students admitted Fall 2016 or later, a grade of C- or better in one GE B1 course is required to fulfill GE Area B.

**MATH 192. Calculus for Architecture and Construction Management Workshop. 1 unit**

CR/NC

Term Typically Offered: TBD

Concurrent: Enrollment in the associated section of MATH 182.

Facilitated study and discussion of the theory, problems, and applications of calculus to architecture and construction management. Credit/No Credit grading only. 1 laboratory.

**MATH 202. Orientation to Mathematics Major. 1 unit**

CR/NC

Term Typically Offered: F, SP

Prerequisite: MATH 143.

Career opportunities in the field of mathematics, preparing a field of study, and a survey of departmental facilities and procedures related to research, study and graduation. Credit/No Credit grading only. 1 lecture.

**MATH 206. Linear Algebra I. 4 units**

Term Typically Offered: F,W,SP,SU

Prerequisite: MATH 143.

Systems of linear equations. Matrix algebra, including inverses and determinants. Vectors, vector spaces, bases and linear transformations in real coordinate space of  $n$  dimensions. Eigenvalues, eigenvectors and diagonalization. Applications of linear algebra. Introduction to inner products and orthogonality. 4 lectures.

**MATH 221. Calculus for Business and Economics. 4 units**

GE Area B1

Term Typically Offered: W, SP

Prerequisite: Completion of ELM requirement and passing score on appropriate Mathematics Placement Examination, or MATH 118.

Polynomial calculus for optimization and marginal analysis, and elementary integration. Not open to students with credit in MATH 142. 4 lectures. Fulfills GE B1; for students admitted Fall 2016 or later, a grade of C- or better in one GE B1 course is required to fulfill GE Area B.

**MATH 227. Mathematics for Elementary Teaching I. 4 units**

GE Area B1

Term Typically Offered: F, W

Prerequisite: Passing score on ELM examination, or an ELM exemption, or credit in MATH 96 (formerly MATH 104).

Introduction to problem solving, set theory, number systems, arithmetic operations, models, and number theory. This class is designed for Liberal Studies majors. Other students will be admitted only by consent of instructor. 4 lectures. Fulfills GE B1; for students admitted Fall 2016 or later, a grade of C- or better in one GE B1 course is required to fulfill GE Area B.

**MATH 231. Calculus for Business and Economics Workshop. 1 unit**

CR/NC

Term Typically Offered: TBD

Concurrent: Enrollment in the associated section of MATH 221.

Facilitated study and discussion of the theory, problems, and applications of business calculus. Credit/No Credit grading only. 1 laboratory.

**MATH 241. Calculus IV. 4 units**

Term Typically Offered: F,W,SP,SU

Prerequisite: MATH 143.

Partial derivatives, multiple integrals, introduction to vector analysis. 4 lectures. Crosslisted as HNRS/MATH 241.

**MATH 242. Differential Equations I. 4 units**

Term Typically Offered: W, SP

Prerequisite: MATH 206 and MATH 241.

Ordinary differential equations: first-order linear equations, separable equations, exact equations, second-order linear equations, nonhomogeneous equations, systems of first-order linear equations, systems of nonlinear equations, modeling and applications. Not open to students with credit in MATH 244. 4 lectures.

**MATH 244. Linear Analysis I. 4 units**

Term Typically Offered: F,W,SP,SU

Prerequisite: MATH 143.

Separable and linear ordinary differential equations with selected applications; numerical and analytical solutions. Linear algebra: vectors in  $n$ -space, matrices, linear transformations, eigenvalues, eigenvectors, diagonalization; applications to the study of systems of linear differential equations. 4 lectures. Crosslisted as HNRS/MATH 244.

**MATH 248. Methods of Proof in Mathematics. 4 units**

Term Typically Offered: F,W,SP,SU

Prerequisite: MATH 143.

Methods of proof (direct, contradiction, conditional, contraposition); valid and invalid arguments. Examples from set theory. Quantified statements and their negations. Functions, indexed sets, set functions. Proofs in number theory, algebra, geometry and analysis. Proof by induction. Equivalence and well-defined operations and functions. The axiomatic method. 4 lectures.

**MATH 251. Calculus Workshop IV. 1 unit**

CR/NC

Term Typically Offered: TBD

Concurrent: Enrollment in the associated section of MATH 241.

Facilitated study and discussion of the theory, problems, and applications of calculus. Credit/No Credit grading only. 1 laboratory.

**MATH 254. Linear Analysis Workshop I. 1 unit**

CR/NC

Term Typically Offered: TBD

Concurrent: Enrollment in the associated section of MATH 244.

Facilitated study and discussion of the theory, problems, and applications of linear analysis. Credit/No Credit grading only. 1 laboratory.

**MATH 258. Methods of Proof in Mathematics Workshop. 1 unit**

CR/NC

Term Typically Offered: TBD

Concurrent: Enrollment in the associated section of MATH 248.

Facilitated study and discussion of the methods and techniques of proof in mathematics. Credit/No Credit grading only. 1 laboratory.

**MATH 270. Selected Topics. 1-4 units**

Term Typically Offered: TBD

Prerequisite: Consent of instructor.

Directed group study of selected topics. The Schedule of Classes will list title selected. Total credit limited to 8 units. 1 to 4 lectures.

**MATH 300. Technology in Mathematics Education. 4 units**

Term Typically Offered: F

Prerequisite: MATH 248.

Examination of existing hardware and software designed for educational uses. Discussion of mathematical topics appropriate for computer enhancement. Special methods and techniques for educational uses of computers. Emphasis on activity learning and applications. Computer as a classroom management device. 4 lectures.

**MATH 304. Vector Analysis. 4 units**

GE Area B6

Term Typically Offered: W, SP

Prerequisite: MATH 206 or MATH 244, and MATH 241.

Differential and integral calculus of vector-valued functions. Green's Theorem, Stokes' Theorem, and the Divergence Theorem. Applications and generalizations. 4 lectures. Fulfills GE B6.

**MATH 306. Linear Algebra II. 4 units**

Term Typically Offered: F, W, SP

Prerequisite: MATH 206 or MATH 244; MATH 241; and a C- or better in MATH 248, or consent of instructor.

Rigorous development of real and complex vector spaces, including infinite dimensional spaces. Subspaces, bases, products and direct sums. Examples and properties of linear transformations. Similarity, eigenvalues, eigenvectors and diagonalization. Characteristic and minimal polynomials, Cayley-Hamilton Theorem. 4 lectures.

**MATH 316. Introduction to Linear Algebra Workshop II. 1 unit**

CR/NC

Term Typically Offered: TBD

Concurrent: Enrollment in the associated section of MATH 306.

Facilitated study and discussion of the methods and techniques of proof in linear algebra. Credit/No Credit grading only. 1 laboratory.

**MATH 328. Mathematics for Elementary Teaching II. 4 units**

Term Typically Offered: W, SP

Prerequisite: MATH 227 with a grade of C- or better or consent of instructor.

Introduction to rational and real numbers, probability and counting techniques, statistics, and geometry. Computer applications. 4 lectures.

**MATH 329. Mathematics for Elementary Teaching III. 4 units**

Term Typically Offered: F, SP

Prerequisite: MATH 328.

Introduction to rational and real numbers, probability and counting techniques, statistics, and geometry. Computer applications. 4 lectures.



**MATH 330. Algebraic Thinking with Technology. 4 units**

Term Typically Offered: F, W

Prerequisite: MATH 329.

Algebraic concepts for elementary teachers. Mathematical patterns, equations and inequalities, linear and quadratic functions, exponential and logarithmic functions, systems of equations, roots of polynomials, factoring of polynomials, and right-triangle trigonometry. Computer applications. 4 lectures.

**MATH 335. Graph Theory. 4 units**

Term Typically Offered: F

Prerequisite: MATH 248 or junior standing.

Introduction to graph theory and its applications: isomorphism, paths and searching, connectedness, trees, tournaments, planarity, graph colorings, matching theory, network flow, adjacency and incidence matrices.

Further topics to be selected from the theory of finite state machines, Ramsey theory, extremal theory, and graphical enumeration. 4 lectures.

**MATH 336. Combinatorial Math. 4 units**

Term Typically Offered: F, W

Prerequisite: MATH 248 or junior standing.

Methods of enumerative combinatorics: sum, product, and division rules, bijective and recursive techniques, inclusion and exclusion, generating functions, and the finite difference calculus. Advanced topics to be selected from the theory of partitions, Polya theory, designs, and codes. 4 lectures.

**MATH 341. Theory of Numbers. 4 units**

Term Typically Offered: F, SP

Prerequisite: MATH 248 with a grade of C- or better or consent of instructor.

Properties of numbers. Euclid's Algorithm, greatest common divisors, diophantine equations, prime numbers, congruences, number theoretic functions, the quadratic reciprocity laws, primitive roots and indices. 4 lectures.

**MATH 344. Linear Analysis II. 4 units**

GE Area B6

Term Typically Offered: F, W, SP

Prerequisite: MATH 206 and MATH 242, or MATH 241 and MATH 244.

Linear methods applied to the solution of differential equations. Laplace transforms. Series solutions to ordinary differential equations. Orthogonality in  $n$ -space, Gram-Schmidt orthogonalization and least squares methods. Orthogonal bases in function spaces, Sturm-Liouville theory. Fourier series and transforms. Special functions of applied mathematics. 4 lectures. Fulfills GE B6.

**MATH 350. Mathematical Software. 4 units**

Term Typically Offered: SP

Prerequisite: MATH 206 or MATH 244, and MATH 241, and an introductory college-level programming course, or consent of instructor.

Problem-solving using mathematical software. 4 lectures.

**MATH 351. Typesetting with LaTeX. 1 unit**

CR/NC

Term Typically Offered: W

Prerequisite: Junior standing.

Preparing documents, especially mathematical ones, using LaTeX and AMS-LaTeX. Credit/No Credit grading only. 1 lecture.

**MATH 370. Putnam Exam Seminar. 2 units**

Term Typically Offered: F

Prerequisite: Consent of instructor.

Directed group study of mathematical problem solving techniques. Open to undergraduate students only. Class members are expected to participate in the annual William Lowell Putnam Mathematical Competition. Course may be repeated up to eight units. 2 seminars.

**MATH 371. Math Modeling Seminar. 2 units**

Term Typically Offered: W

Prerequisite: Consent of instructor.

Directed group study of mathematical modeling techniques. Open to undergraduate students only. Class members are expected to participate in the annual Mathematical Competition in Modeling. Total credit limited to 8 units. 2 seminars.

**MATH 400. Special Problems for Advanced Undergraduates. 1-4 units**

Term Typically Offered: F,W,SP,SU

Prerequisite: Junior standing and consent of department chair.

Individual investigation, research, studies, or surveys of selected problems. Total credit limited to 8 units.

**MATH 404. Introduction to Differential Geometry. 4 units**

Term Typically Offered: F

Prerequisite: MATH 304.

Theory of curves and surfaces in space. Topics such as Frenet formulas, curvature, geodesics, Cartan structural equations, Gauss-Bonnet Theorem. 4 lectures.

**MATH 406. Linear Algebra III. 4 units**

Term Typically Offered: SP

Prerequisite: MATH 306.

Rigorous development of real and complex inner product spaces. Orthogonal bases and direct sums of subspaces. Linear transformations on inner product spaces. Properties of self-adjoint and normal operators. Additional topics such as the Jordan Decomposition Theorem and the Spectral Theorem. 4 lectures.

**MATH 408. Complex Analysis I. 4 units**

GE Area B6

Term Typically Offered: F

Prerequisite: MATH 242, or MATH 241 and MATH 244.

Elementary analytic functions and mappings. Cauchy's Integral Theorem; Poisson's Integral Formula. Taylor and Laurent series, theory of residues, and the evaluation of integrals. Harmonic functions, conformal mappings. 4 lectures. Fulfills GE B6.

**MATH 409. Complex Analysis II. 4 units**

Term Typically Offered: W

Prerequisite: MATH 408.

Elementary analytic functions and mappings. Cauchy's Integral Theorem; Poisson's Integral Formula. Taylor and Laurent series, theory of residues, and the evaluation of integrals. Harmonic functions, conformal mappings. 4 lectures.

**MATH 412. Introduction to Analysis I. 4 units**

Term Typically Offered: F, W

Prerequisite: MATH 306.

Introduction to concepts and methods basic to real analysis. Topics such as the real number system, sequences, continuity, uniform continuity and differentiation. 4 lectures.

**MATH 413. Introduction to Analysis II. 4 units**

Term Typically Offered: W

Prerequisite: MATH 412.

A continuation of Introduction to Analysis I covering such topics as integration, infinite series, uniform convergence and functions of several variables. 4 lectures.

**MATH 414. Introduction to Analysis III. 4 units**

Term Typically Offered: SP

Prerequisite: MATH 413.

Continuation of Introduction to Analysis II covering such topics as differentiation and integration of functions of several variables and other advanced topics. 4 lectures.

**MATH 416. Differential Equations II. 4 units**

Term Typically Offered: F, W

Prerequisite: MATH 206 and MATH 242, or MATH 241 and MATH 244.

Qualitative theory of ordinary differential equations: Existence and Uniqueness Theorem, phase portraits, limit sets, stability of fixed points and periodic orbits, energy functions, Poincare-Bendixson Theorem, Poincare maps, bifurcations, attractors, chaos. 4 lectures.

**MATH 418. Partial Differential Equations. 4 units**

Term Typically Offered: F, SP

Prerequisite: MATH 344. Recommended: MATH 304.

Mathematical formulation of physical laws. Separation of variables. Orthogonal functions and generalized Fourier series. Bessel functions, Legendre polynomials. Sturm-Liouville problem. Boundary value problems; nonhomogeneous techniques. Applications to heat flow, potential theory, vibrating strings and membranes. 4 lectures.

**MATH 419. Introduction to the History of Mathematics. 4 units**

Term Typically Offered: W

Prerequisite: MATH 248 with a grade of C- or better and at least one upper division course in mathematics, or consent of instructor.

Evolution of mathematics from earliest to modern times. Major trends in mathematical thought, the interplay of mathematical and technological innovations, and the contributions of great mathematicians. Appropriate for prospective and in-service teachers. 4 lectures.

**MATH 422. Introduction to Analysis I Workshop. 1 unit**

CR/NC

Term Typically Offered: TBD

Concurrent: Enrollment in the associated section of MATH 412.

Facilitated study and discussion of the methods and techniques of proof in introductory analysis. Credit/No Credit grading only. 1 laboratory.

**MATH 423. Advanced Mathematics for Teaching. 4 units**

Term Typically Offered: SP

Prerequisite: MATH 442 and MATH 481.

Introduction to mathematics education research and advanced exploration of the mathematics taught in California's public high schools and middle schools through problem analysis, concept analysis, and problem connections. 4 lectures.

**MATH 424. Organizing and Teaching Mathematics. 4 units**

CR/NC

Term Typically Offered: F

Prerequisite: Acceptance into the Mathematics Single Subject Credential Program.

Organization, selection, presentation, application and interpretation of subject matter in mathematics. Introduction to current issues in mathematics education. For students who will be teaching in secondary schools. Credit/No Credit grading only. 4 lectures.

**MATH 425. Mathematics Student Teaching Seminar. 2 units**

CR/NC

Term Typically Offered: W, SP

Prerequisite: Acceptance into Step II of the Single Subject Credential Program in Mathematics. Concurrent: EDUC 469 or EDUC 479.

Principles and practice in effective teaching of mathematics at the middle and high school level, learning theories, curriculum content and structure, classroom issues, and the teaching profession. Credit/No Credit grading only. Total credit limited to 4 units. 2 seminars.

**MATH 435. Discrete Mathematics with Applications I. 4 units**

Term Typically Offered: F

Prerequisite: MATH 248 with a grade of C- or better and MATH 336, or consent of instructor.

Methods of discrete mathematics with applications. Generating functions and Lagrange inversion, partition theory, permutation statistics and q-analogues, posets and Moebius inversion. Additional topics including lattice paths and basic hypergeometric series. 4 lectures. Not open to students with credit in MATH 530.

**MATH 436. Discrete Math with Applications II. 4 units**

Term Typically Offered: TBD

Prerequisite: MATH 435. Corequisite: MATH 482.

Methods of discrete mathematics with applications. Polya theory, codes, designs, matroids, the combinatorics of symmetric functions, and tableaux combinatorics. Additional topics including transversals and Latin squares, asymptotics, and discrete probability theory. 4 lectures. Not open to students with credit in MATH 531.

**MATH 437. Game Theory. 4 units**

Term Typically Offered: SP

Prerequisite: MATH 206 or MATH 244, and MATH 248 with a grade of C- or better, or consent of instructor.

Development of the mathematical concepts, techniques, and models used to investigate optimal strategies in competitive situations; games in extensive, normal, and characteristic form, Nash equilibrium points and Nash Bargaining Model. 4 lectures.

**MATH 440. Topology I. 4 units**

Term Typically Offered: W

Prerequisite: MATH 412. Corequisite: MATH 481.

Introduction to general topological spaces with emphasis on surfaces and manifolds. Open and closed sets, continuity, compactness, connectedness. Quotient spaces. 4 lectures. Not open to students with credit in MATH 540.

**MATH 441. Topology II. 4 units**

Term Typically Offered: TBD

Prerequisite: MATH 440.

Introduction to general topological spaces with emphasis on surfaces and manifolds. Fundamental group. Triangulations of spaces, classification of surfaces. Other topics may include covering spaces, simplicial homology, homotopy theory and topics from differential topology. 4 lectures. Not open to students with credit in MATH 541.

**MATH 442. Euclidean Geometry. 4 units**

Term Typically Offered: W

Prerequisite: MATH 248 with a grade of C- or better or consent of instructor. Recommended: MATH 300 or familiarity with dynamic geometry software.

Foundations of Euclidean geometry, finite geometries, congruence, similarities, polygonal regions, circles and spheres. Constructions, mensuration, the parallel postulate. Appropriate for prospective and in-service mathematics teachers. 4 lectures.

**MATH 443. Modern Geometries. 4 units**

Term Typically Offered: SP

Prerequisite: MATH 442.

Non-Euclidean and projective geometries. Properties of parallels, biangles, Saccheri and Lambert quadrilaterals, angle-sum and area. Limiting curves: hyperbolic trigonometry, duality, perspectivity, quadrangles, fundamental theorems of projective geometry, conics. 4 lectures.

**MATH 451. Numerical Analysis I. 4 units**

Term Typically Offered: W

Prerequisite: MATH 206 and MATH 242, or MATH 241 and MATH 244, and an introductory college-level programming course.

Topics in interpolation and approximation methods, initial value problems, and boundary value problems of ordinary differential equations. 4 lectures.

**MATH 452. Numerical Analysis II. 4 units**

Term Typically Offered: SP

Prerequisite: MATH 451.

Numerical techniques for solving partial differential equations of the parabolic, hyperbolic and elliptic type. Further topics in approximation theory. 4 lectures.

**MATH 453. Numerical Optimization. 4 units**

Term Typically Offered: SP

Prerequisite: MATH 306 and MATH 451.

Algorithms for solving optimization problems that cannot be solved analytically. Descent algorithms including exact and practical line-searches, steepest descent method, and Newton and quasi-Newton methods for unconstrained minimization. Optimality conditions for constrained optimization, linear programming. Projection and Lagrangian methods, and interior point methods for constrained minimization. 4 lectures.

**MATH 459. Senior Project Seminar. 4 units**

Term Typically Offered: F, SP

Prerequisite: MATH 306, and completion of at least two additional upper-division courses in the math major.

Written and oral analyses and presentations by students on topics from advanced mathematics and mathematical modeling. Not open to students with credit in MATH 460. 4 seminars.

**MATH 460. Senior Project Applied Seminar. 4 units**

Term Typically Offered: F

Prerequisite: CSC/CPE 101 or MATH 350; MATH 306; and MATH 344.

Written and oral analyses and presentations by students on topics in applied mathematics, including applications to sustainability. Construction of mathematical models for physical and biological problems, with analysis and interpretation of the solutions of these models using both analytical and numerical techniques. Not open to students with credit in MATH 459. 4 seminars.

**MATH 461. Senior Project I. 2 units**

Term Typically Offered: F,W,SP,SU

Prerequisite: Senior Standing.

Selection and development of a mathematics project under faculty supervision. Minimum 60 hours total time.

**MATH 462. Senior Project II. 2 units**

Term Typically Offered: F,W,SP,SU

Prerequisite: MATH 461.

Completion of a mathematics project under faculty supervision. Project results are presented in a formal report. Minimum 60 hours total time.

**MATH 470. Selected Advanced Topics. 1-4 units**

Term Typically Offered: TBD

Prerequisite: Consent of instructor.

Directed group study of selected topics for advanced students. Open to undergraduate and graduate students. The Schedule of Classes will list title selected. Total credit limited to 8 units. 1 to 4 lectures.



**MATH 474. Advanced Topics in Geometry and Topology. 1 unit**

Term Typically Offered: TBD

Prerequisite: MATH 248 and consent of instructor. Recommended: MATH 404 and MATH 440.

Exploration of advanced topics and problems in geometry and topology through reading, writing and oral presentations. The Schedule of Classes will list the specific topic as a subtitle. Total credit limited to 6 units. 1 seminar.

**MATH 475. Advanced Topics in Mathematics. 4 units**

Term Typically Offered: TBD

Prerequisite: MATH 306 and consent of instructor.

Exploration of advanced topics and problems in mathematics. The Schedule of Classes will list topic selected. Total credit limited to 8 units. 4 lectures.

**MATH 476. Advanced Topics in Applied Mathematics. 4 units**

Term Typically Offered: TBD

Prerequisite: MATH 306 and consent of instructor.

Exploration of advanced topics and problems in applied mathematics. The Schedule of Classes will list topic selected. Total credit limited to 8 units. 4 lectures.

**MATH 481. Abstract Algebra I. 4 units**

Term Typically Offered: F, W

Prerequisite: MATH 306 or MATH 341.

Introduction to the study of groups. Topics include groups of permutations, cyclic groups, normal subgroups and quotient groups. Homomorphisms, Lagrange's Theorem, Cayley's Theorem, the Isomorphism Theorems and the Fundamental Theorem of Finite Abelian Groups. 4 lectures.

**MATH 482. Abstract Algebra II. 4 units**

Term Typically Offered: W, SP

Prerequisite: MATH 481.

Introduction to rings and fields. Reducible and irreducible polynomials, ideals, prime and maximal ideals, quotient rings, ring homomorphisms, the Isomorphism Theorems, integral domains, unique factorization domains, principal ideal domains, Euclidean domains, fields of fractions, field extensions and finite fields. 4 lectures.

**MATH 483. Abstract Algebra III. 4 units**

Term Typically Offered: SP

Prerequisite: MATH 482.

Algebraic field extensions, the tower law, ruler-and-compass constructions, the primitive element theorem, algebraic and transcendental numbers, algebraic closure, the fundamental theorem of algebra, finite fields, Galois extensions and the fundamental theorem of Galois theory. Not open to students with credit in MATH 560. 4 lectures.

**MATH 485. Cooperative Education Experience. 6 units**

CR/NC

Term Typically Offered: TBD

Prerequisite: Consent of instructor.

Part-time work experience in business, industry, government, and other areas of student career interest. Positions are paid and usually require relocation and registration in course for two consecutive quarters. Formal report and evaluation by work supervisor required. No major credit allowed; total credit limited to 12 units. Credit/No Credit grading only.

**MATH 491. Abstract Algebra I Workshop. 1 unit**

CR/NC

Term Typically Offered: TBD

Concurrent: Enrollment in the associated section of MATH 481.

Facilitated study and discussion of the methods and techniques of proof in abstract algebra. Credit/No Credit grading only. 1 laboratory.

**MATH 495. Cooperative Education Experience. 12 units**

CR/NC

Term Typically Offered: TBD

Prerequisite: Consent of instructor.

Full-time work experience in business, industry, government, and other areas of student career interest. Positions are paid and usually require relocation and registration in course for two consecutive quarters. Formal report and evaluation by work supervisor required. No major credit allowed; total credit limited to 12 units. Credit/No Credit grading only.

**MATH 500. Individual Study. 1-4 units**

Term Typically Offered: F,W,SP,SU

Prerequisite: Graduate standing and consent of department chair.

Individual research or advanced study planned and completed under the direction of a departmental faculty member. Open only to graduate students demonstrating ability to do independent work. Total credit limited to 12 units.

**MATH 501. Analytic Methods in Applied Mathematics. 4 units**

Term Typically Offered: F

Prerequisite: MATH 344 or AERO 300, and graduate standing.

Introduction to advanced methods of mathematics useful in the analysis of engineering problems. Selected topics in perturbation theory, optimization and Fourier analysis. Not open to students in math major or master's degree program in mathematics. 4 lectures.

**MATH 502. Numerical Methods in Applied Mathematics. 4 units**

Term Typically Offered: W

Prerequisite: MATH 344 or AERO 300, an introductory college-level programming course, and graduate standing.

Introduction to advanced numerical analysis. Numerical techniques for solving ordinary and partial differential equations, error analysis, stability, methods for linear systems. Not open to students in math major or master's degree program in mathematics. 4 lectures.

**MATH 504. Mathematical Topics for Teachers. 1-4 units**

CR/NC

Term Typically Offered: SU

Prerequisite: Multiple Subject or Single Subject teaching credential.

Mathematical topics for practicing credentialed teachers. Professional growth through improvement of teachers' mathematical content knowledge and pedagogical approaches using technology, discussion, reflection, and hands-on activities. Content will vary according to teaching level. The Schedule of Classes will list topic selected. Total credit limited to 12 units. Not open to students in math major or master's degree program in mathematics. Credit/No Credit grading only. 1-4 activities.

**MATH 505. Graduate Teaching Seminar. 1 unit**

CR/NC

Term Typically Offered: F

Prerequisite: Graduate standing.

Principles and practice in effective teaching of college-level mathematics. Issues related to present and future teaching experiences, including time management, professionalism, student assessment, grading, classroom management, and qualities of good mathematics teachers. Reflection on individual teaching, and consideration of improvements in instruction. Credit/No Credit grading only. Total credit limited to 2 units. 1 seminar.

**MATH 520. Applied Analysis I. 4 units**

Term Typically Offered: W

Prerequisite: MATH 408, MATH 412 and graduate standing.

Recommended: MATH 418.

Advanced mathematical methods of analysis in science and engineering, integrated with modeling of physical phenomena. Topics include applications of complex analysis, Fourier analysis, ordinary and partial differential equations. Additional topics to be drawn from perturbation methods, asymptotic analysis, dynamical systems, numerical methods, optimization, and the calculus of variations. 4 lectures.

**MATH 521. Applied Analysis II. 4 units**

Term Typically Offered: SP

Prerequisite: MATH 520.

Advanced mathematical methods of analysis in science and engineering, integrated with modeling of physical phenomena. Topics include applications of complex analysis, Fourier analysis, ordinary and partial differential equations. Additional topics to be drawn from perturbation methods, asymptotic analysis, dynamical systems, numerical methods, optimization, and the calculus of variations. 4 lectures.

**MATH 530. Discrete Mathematics with Applications I. 4 units**

Term Typically Offered: F

Prerequisite: MATH 248 with a grade of C- or better and MATH 336 and graduate standing, or consent of instructor.

Methods of discrete mathematics with applications. Generating functions and Lagrange inversion, partition theory, permutation statistics and  $q$ -analogues, posets and Möbius inversion. Additional topics including lattice paths and basic hypergeometric series. 4 lectures. Not open to students with credit in MATH 435.

**MATH 531. Discrete Mathematics with Applications II. 4 units**

Term Typically Offered: W

Prerequisite: MATH 435 or MATH 530. Corequisite: MATH 482 or graduate standing in Mathematics.

Methods of discrete mathematics with applications. Polya theory, codes, designs, matroids, the combinatorics of symmetric functions, and tableaux combinatorics. Additional topics including transversals and Latin squares, asymptotics, and discrete probability theory. 4 lectures. Not open to students with credit in MATH 436.

**MATH 540. Topology I. 4 units**

Term Typically Offered: W

Prerequisite: MATH 412 or graduate standing in Mathematics.

Corequisite: MATH 481 or graduate standing in Mathematics.

Introduction to general topological spaces with emphasis on surfaces and manifolds. Open and closed sets, continuity, compactness, connectedness. Quotient spaces. 4 lectures. Not open to students with credit in MATH 440.

**MATH 541. Topology II. 4 units**

Term Typically Offered: SP

Prerequisite: MATH 440 or MATH 540.

Introduction to general topological spaces with emphasis on surfaces and manifolds. Fundamental group. Triangulations of spaces, classification of surfaces. Other topics may include covering spaces, simplicial homology, homotopy theory and topics from differential topology. 4 lectures. Not open to students with credit in MATH 441.

**MATH 550. Real Analysis. 4 units**

Term Typically Offered: F

Prerequisite: Satisfactory completion of the Graduate Written Examination in Analysis or consent of the Graduate Committee.

Introduction to Lebesgue measure and integration, convergence theorems,  $L_p$  spaces, Radon-Nikodym Theorem and Fubini's Theorem. 4 lectures.

**MATH 560. Field Theory. 4 units**

Term Typically Offered: SP

Prerequisite: MATH 482 or graduate standing.

Polynomial rings, field extensions, normal and separable extensions, automorphisms of fields, fundamental theorem of Galois theory, and further topics such as solvable groups, solution by radicals, insolvability of the quintic. Not open to students with credit in MATH 483. 4 lectures.

**MATH 561. Graduate Algebra. 4 units**

Term Typically Offered: F

Prerequisite: MATH 483 or MATH 560, and completion of the Graduate Written Exam in Algebra or consent of the Graduate Committee.

An introduction to advanced topics from modern algebra, including group actions, the Sylow theorems, semi-direct products and modules over a principal ideal domain. Other topics may include commutative algebra, advanced Galois theory, homological algebra, and topics from advanced linear algebra. 4 lectures.

**MATH 570. Selected Advanced Topics. 1-4 units**

Term Typically Offered: TBD

Prerequisite: Graduate standing and consent of instructor.

Directed group study of selected topics for graduate students. Open to undergraduate and graduate students. The Schedule of Classes will list title selected. Total credit limited to 8 units. 1-4 lectures.

**MATH 580. Seminar. 1-4 units**

Term Typically Offered: TBD

Prerequisite: Graduate standing and consent of instructor.

Built around topics in advanced mathematics chosen according to the common interests and needs of the students enrolled. Each seminar will have a subtitle according to the nature of the content. Total credit limited to 12 units. 1-4 seminars.

**MATH 599. Thesis. 3 units**

Term Typically Offered: F,W,SP,SU

Prerequisite: Graduate standing and consent of instructor.

Serious research endeavor devoted to the development, pedagogy or learning of mathematics. Course to be taken twice for a total of 6 units.