

## Mathematics

Mathematics and related subjects play important dual roles in our culture. On the one hand, mathematics is a study in its own right; on the other hand, it is an indispensable tool for expressing and understanding ideas in the sciences, engineering, and an increasing number of other fields. As a consequence, employment opportunities for mathematicians have been expanding in recent years. The courses offered by the department are designed to develop skills in and an appreciation and understanding of both roles.

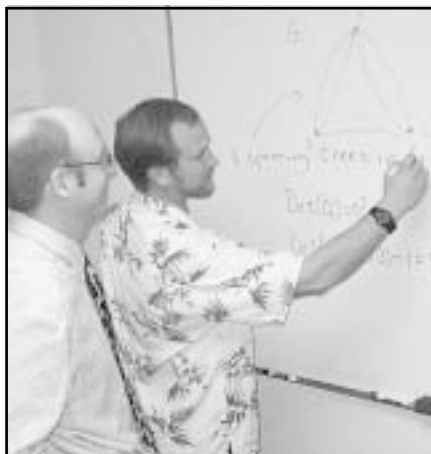
Because there are so many different areas in which a trained mathematician can find employment or continue studies, the department offers a large number of electives within the mathematics major. By selecting appropriate courses, students have considerable flexibility to accommodate their individual interests. Students should consult with a department adviser for specific recommendations as to which electives are suited to their career paths.

Electives in applied mathematics prepare students to assume positions in technical industries or government employment, or to continue advanced studies in the applied area.

Electives in pre-college teaching in mathematics provide students with the necessary background for obtaining a California Single Subject Teaching Credential in mathematics. In order to complete the credential requirements, a fifth year of education courses, classroom observation, and practice teaching is needed. At the present time, there is an increasing demand for well-trained people in this area.

Electives in pure mathematics prepare students for the pursuit of graduate studies leading to advanced degrees and employment at the college or university level, or research in industry.

Electives in statistics and probability provide a foundation for students planning to work as statisticians for industry or government agencies. They also can enhance employment opportunities in the bioscience and health-related fields. Statistics courses (in addition to MATH 75 [or MATH 75A and 75B], 76, and 77) are essential for the first two Actuarial Examinations offered by the Society of Actuaries.



### Faculty

Larry W. Cusick, *Chair*  
 Ernesto Franco, *Graduate Coordinator*  
*Undergraduate Advisers:*  
 All full-time faculty  
*Credential Advisers:* Agnes Tuska,  
 T. Rajee Amarasinghe

Robert F. Arnold  
 Katherine Byler Kelm  
 Stefaan Delcroix  
 Doreen De Leon  
 Della C. Duncan  
 Michael J. Fisher  
 Noal C. Harbertson  
 Merrilee K. Helmers  
 Maria Nogin  
 Hussain Sayid Nur  
 Hugo S. Sun  
 Peter Tannenbaum  
 Ronald L. Wagoner  
 Norman T. Woo  
 Ke Wu

### Bachelor of Arts Degree Requirements Mathematics Major

The requirement for entrance to the major and minor programs is completion of two years of algebra as well as courses in geometry and trigonometry, or a sequence of courses containing their equivalents, such as MATH 4R and 5.

It is strongly recommended that such study be completed before entrance to the university.

**Total Course Requirements for the Bachelor's Degree:** 120 units. See *Baccalaureate Degree Requirements* for complete details on general degree requirements. A minimum of 40 units must be upper division, including those required for the major, General Education, and upper-division writing skills.

College of Science and Mathematics

### Department of Mathematics

Larry W. Cusick, *Chair*  
 Cindy Douglas, *Administrative Analyst/Specialist*  
 Peters Business Building, Room 381  
 559.278.2992  
<http://www.csufresno.edu/math/>

### B.A. in Mathematics

### M.A. in Mathematics

Option: Teaching

### Minor in Mathematics

### Single Subject Teaching Credential

	<i>Units</i>
<b>Major requirements.....</b>	<b>42-48</b>
Core curriculum.....	(30-31)
MATH 75 (or 75A and B), 76, 77 .....	(12)
MATH 111 .....	(3)
MATH 151, 152 .....	(8)
MATH 171 .....	(4)
MATH 128 or 165 or 172 .....	(3-4)
<i>Elective curriculum .....</i>	<i>(12-17)</i>
Four mathematics courses, upper-division or MATH 81, exclud- ing MATH 100, 133, 134, 137, 138	
<b>Additional requirements .....</b>	<b>7</b>
CSCI 40 .....	(4)
PHYS 4A <sup>1</sup> .....	(3)
<b>General Education requirements....</b>	<b>51<sup>2</sup></b>
<b>Electives and remaining degree requirements .....</b>	<b>14-20</b>
<b>Total.....</b>	<b>120</b>

### Major Advising Notes

1. PHYS 4AL is not required for the math major. If students wish to include PHYS 4A as a General Education Breadth course, they must also take PHYS 4AL.
2. Three units of MATH 75 (or MATH 75A and B) also will satisfy the G.E. Foundation B4 requirement. It also satisfies the requirement within General Education Core courses, for students under 1998-1999 or earlier catalogs.
3. See Mathematics Road Map at [http://www.csufresno.edu/degreeroadmap/site\\_index.htm](http://www.csufresno.edu/degreeroadmap/site_index.htm).

# Mathematics

## Mathematics Minor

The minor requires 20 units in mathematics, MATH 75 or above, excluding MATH 100, 133, 134, 137, and 138.

### Minor Advising Note

1. Courses in the minor may be taken *CR/NC*, subject to university regulations.
2. The Mathematics Minor also requires a 2.0 GPA and 6 upper-division units in residence.

## Advising Requirements

Mandatory advising at least once a semester is required of all majors in the degree programs. See the department chair for assignment to an adviser.

## Grade Requirements

All courses required as prerequisites for a mathematics course must be completed with a grade of *C* or better before registration will be permitted. All courses taken to fulfill major or minor requirements must be completed with a grade of *C* or better.

## Duplication of Courses

<i>No credit will be allowed for:</i>	<i>If taken after completion of:</i>
MATH 5	MATH 72 or 75 (or 75A and B)
MATH 6	MATH 71 or 75 (or 75A and B)
MATH 70	MATH 72 or 75 (or 75A and B)
MATH 75 (or 75A and B)	MATH 76
MATH 76	MATH 77
MATH 77	MATH 81
MATH 101	MATH 108

## Single Subject Credential Program Subject Matter Competency in Mathematics\*

Units

MATH 75 (or 75A and B), 76, 77; MATH 151, 152; MATH 171; MATH 128 or 165 or 172; MATH 101, 111, 116, 143, 145, 161; PHYS 4A; CSCI 40	<b>55-56</b>
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See the description of the Single Subject Credential Program under *Curriculum, Teaching, and Educational Technology* in this catalog. Completion of this program also fulfills the mathematics major requirement.

\* Approved by the Commission on Teacher Credentialing, State of California.

## Graduate Program

The requirement for entrance to the graduate program is completion of undergradu-

ate preparation equivalent to a California State University, Fresno major in mathematics.

(See also *Admission to Graduate Standing, Advancement to Candidacy, Program Requirements, and Criteria for Thesis and Project.*)

## Master of Arts Degree Program

The Department of Mathematics offers a Master of Arts (M.A.) in Mathematics. Within this degree program, students may choose to complete the traditional track or the teaching option. The admission requirement of all prospective students for this degree program is the completion of undergraduate preparation equivalent to California State University, Fresno majors in mathematics. Candidates are also required to submit current GRE scores. (See *Division of Graduate Studies* admission requirements.)

The M.A. in mathematics is designed for students who wish to study mathematics at an advanced level. The traditional track best satisfies the needs of students who wish to work in industry, teach at community college, or go on to pursue a Ph.D. in mathematics. The teaching option is designed especially for students who wish to enhance their high school mathematics teaching and/or assume a leadership role in high school mathematics education and beyond.

### Course Requirements:

<i>Master's Degree in Mathematics (M.A.) Traditional Track</i>	Units
Core curriculum (MATH 251, 271) <sup>2</sup> ...	<b>6</b>
Elective curriculum .....	<b>21</b>
(A combination of approved courses) <sup>1</sup>	
Project (MATH 298) .....	<b>3</b>
<b>Total</b> .....	<b>30</b>

### *Master's Degree in Mathematics (M.A.) with a Teaching Option*

	Units
Core curriculum (CI 250 <sup>3</sup> , MATH 250, 260, 270 <sup>2</sup> ) .....	<b>12</b>
Mathematics elective curriculum .....	<b>12</b>
(A combination of approved courses) <sup>1</sup>	
Education elective curriculum .....	<b>3</b>
(CI 275 or an approved CI 280T course)	
Project (MATH 298) .....	<b>3</b>
<b>Total</b> .....	<b>30</b>

### Additional Requirements:

- M.A. - Two department qualifying exams: one in analysis and one in algebra. (The exams are offered each semester

and may be retaken once. The exams will also be used to satisfy the *University Graduate Writing Skills* requirement.)

- M.A. with a Teaching Option - Passing score in the two Praxis Exams: 63 and 64. (The exams will also be used to satisfy the *University Graduate Writing Skills* requirement.)

### Graduate Advising Notes

1. Under the direction of the department graduate adviser, each candidate should prepare and submit for approval a program of courses as early as possible.
2. All graduate students should obtain a copy of the *Mathematics Graduate Advising Booklet* for more detailed information on the program requirements.
3. CI 250 has a prerequisite of CI 150 or 159.

## COURSES

### Mathematics (MATH)

#### MATH 1RA. Developmental Mathematics I (3)

The first semester in a two semester sequence preparing students for college level mathematics. See the online *Class Schedule* for restrictions on enrollment based on the Entry Level Math test. Properties of ordinary arithmetic, integers, rational numbers and linear equations. *CR/NC* grading only; not applicable towards baccalaureate degree requirements.

#### MATH 1RB. Developmental Mathematics II (3)

Prerequisite: MATH 1RA. The second semester in a two semester sequence preparing students for college level mathematics. Systems of linear equations, exponents, rational expressions, polynomials and quadratic equations. *CR/NC* grading only; not applicable toward baccalaureate degree requirements.

#### MATH 4R. Intermediate Algebra (3)

Prerequisite: see the online *Class Schedule* for restrictions on enrollment based on the Entry Level Math test. Covers radicals, rational exponents, quadratic equations, simultaneous linear equations, graphing, inequalities, and complex numbers. *CR/NC* grading only; not applicable toward baccalaureate degree requirements.

#### MATH 4RA. Intermediate Algebra (3)

Focuses on arithmetic review, linear equalities, inequalities, and graphing. *Note:* MATH 4RA together with MATH 4RB is equivalent to MATH 4R. Enrollment is limited to first-time freshmen who score 30 and below on the ELM exam. *CR/NC* grading only; not applicable toward baccalaureate degree requirements. (Formerly MATH ILR)

**MATH 4RB. Intermediate Algebra (3)**  
Prerequisite: MATH 4RA. Focuses on radicals, rational exponents, and quadratic equations. *Note* MATH 4RB together with MATH 4RA is equivalent to MATH 4R. Enrollment is limited to first-time freshmen who score 30 and below on the ELM exam. *CR/NC* grading only; not applicable toward baccalaureate degree requirements. (Formerly MATH ILR)

**MATH 4RL. Intermediate Algebra Laboratory (1)**

Prerequisites: concurrently enrolled in MATH 4RA, 4RB, or MATH 4R and assigned to laboratory after taking placement examination. Laboratory does not count toward baccalaureate degree. Extra review and practice with skills essential to success in intermediate algebra. *CR/NC* grading only; not applicable toward baccalaureate degree requirements.

**MATH 5. Trigonometry (3)**

Prerequisite: students must meet the ELM requirement. Concept of a function, sine and cosine functions, tables and graphs, other trigonometric functions, identities and equations. Trigonometric functions of angles, solution of triangles. (See *Duplication of Courses*.) (CAN MATH 8)

**MATH 6. Precalculus (4)**

Prerequisite: students must meet the ELM requirement. Basic algebraic properties of real numbers; linear and quadratic equations and inequalities; functions and graphs; polynomials; exponential and logarithmic functions; analytic trigonometry and functions; conics; sequences, and series. (CAN MATH 16)

**MATH 10A. Structure and Concepts in Mathematics I (3)**

Prerequisite: students must meet the ELM requirement. No credit for MATH 10A if taken after MATH 41. Designed for prospective elementary school teachers. Development of real numbers including integers, rational and irrational numbers, computation, prime numbers and factorizations, and problem-solving strategies. Meets B4 G.E. requirement only for liberal studies majors.

**MATH 10B. Structure and Concepts in Mathematics II (3)**

Prerequisite: MATH 10A or 41. Designed for prospective elementary school teachers. Counting methods, elementary probability and statistics. Topics in geometry to include polygons, congruence and similarity, measurement, geometric transformations, coordinate geometry, and connections between numbers and geometry with selected applications.

**MATH 11. Elementary Statistics (3)**

Prerequisite: students must meet the ELM requirement. Illustration of statistical concepts: elementary probability models, sam-

pling, descriptive measures, confidence intervals, testing hypotheses, chi-square, non-parametric methods, regression. It is recommended that students with credit in MATH 72 or 75 (or 75A and B) take MATH 101. (CAN STAT 2)

**MATH 25. Mathematica (1)**

Prerequisites: MATH 70, 71, 75 or 75A and B (may be taken concurrently) or permission of instructor. In addition, students must meet the ELM requirement. Use of Mathematica™ software as an exploratory tool in Mathematics. Examples drawn from a broad range of Mathematics. *CR/NC* grading only.

**MATH 43. Elementary Problem Solving (3)**

Prerequisite: students must meet the ELM requirement. The purpose of this course is to develop problem-solving skills using elementary mathematics.

**MATH 45. What Is Mathematics? (3)**

Prerequisite: students must meet the ELM requirement. Covers topics from the following areas: (I) The Mathematics of Social Choice; (II) Management Science and Optimization; (III) The Mathematics of Growth and Symmetry; and (IV) Statistics and Probability. G.E. Foundation B4.

**MATH 61. Geometry and the Imagination (3)**

Prerequisite: students must meet the ELM requirement. Topics in Geometry. May include, but is not restricted to, tilings and tessellations, regular polyhedra in 3 and 4 dimensions, ruler and compass constructions, map coloring.

**MATH 70. Mathematical Analysis for Life Sciences (4)**

No credit if taken after MATH 72 or 75 or 75A and B. Prerequisite: students must meet the ELM requirement. Functions and graphs, limits, derivatives, antiderivatives, differential equations, and partial derivatives with applications in the Life Sciences.

**MATH 71. Elementary Mathematical Analysis I (3)**

No credit if taken after MATH 70, 72, or 75 or 75A and B. Prerequisite: students must meet the ELM requirement. Review of algebra, real numbers, inequalities, functions, graphs, finite induction, limits, differentiation of algebraic functions and applications to extrema, mean value theorem, l'Hôpital's rule.

**MATH 72. Elementary Mathematical Analysis II (3)**

No credit if taken after MATH 75 or 75A and B. Prerequisites: MATH 71 and trigonometry. Analytic geometry and calculus of polynomials, rational functions, transcendental functions; polar coordinates, conic sections, integration and applications.

**MATH 75. Mathematical Analysis I (4)**

Prerequisite: elementary geometry, intermediate algebra, trigonometry, or MATH 6. In addition, students must meet the ELM requirement. Inequalities, functions, graphs, limits, continuity, derivatives, antiderivatives, the definite integral, and applications. Using Mathematica™ software as an exploratory tool. G.E. Foundation B4. (CAN MATH 18)

**MATH 75A. Math Analysis with Review IA (4)**

Prerequisite: elementary geometry, intermediate algebra, trigonometry, ELM requirement. Inequalities, functions, graphs, limits, continuity, derivatives, and applications, with extensive review of algebra and elementary functions. Use of computer software as an exploratory tool. With MATH 75B, equivalent to MATH 75.

**MATH 75B. Math Analysis with Review IB (4)**

Prerequisite: MATH 75A. Applications of differentiation, antidifferentiation, the definite integral, and applications, with extensive review of algebra. Use of computer software as an exploratory tool. With MATH 75A, equivalent to MATH 75.

**MATH 76. Mathematical Analysis II (4)**

Prerequisite: MATH 75 or 75A and B. Transcendental functions, techniques of integration, improper integrals, conic sections, polar coordinates, infinite series. Using Mathematica™ software as an exploratory tool. (CAN MATH 20)

**MATH 77. Mathematical Analysis III (4)**

Prerequisite: MATH 76. Vectors, three dimensional calculus, partial derivatives, multiple integrals, Green's Theorem, Stokes' Theorem. Using Mathematica™ software as an exploratory tool. (CAN MATH 22)

**MATH 81. Applied Analysis (3)**

Prerequisite: MATH 77. Introduction to ordinary linear differential equations; solutions by power series and Laplace transforms. Solution of systems of equations. Introduction to Fourier series. Using computer software as an exploratory tool.

**MATH 90. Directed Study (1-3; max total 3)**

Independently arranged course of study in some limited area of mathematics either to remove a deficiency or to investigate a topic in more depth. (1-3 hours, to be arranged)

**MATH 100. Exploring Mathematics (3)**

Prerequisite: MATH 10B. A problem-solving approach to topics from game theory, combinatorics, mathematical modeling, and finite geometries.

**MATH 101. Statistical Methods (4)**

Prerequisite: MATH 70, 71, or 75 or 75A and B; no credit if taken after MATH 108.

Application of statistical procedures to examples from biology, engineering, and social science; one- and two-sample normal theory methods; chi-square, analysis of variance, and regression; nonparametric methods. Computerized statistical packages are used.

### **MATH 107. Introduction to Probability and Statistics (3)**

Prerequisite: MATH 77 (may be taken concurrently). Basic concepts required for applications of probability theory; standard discrete and continuous models; random variables; conditional distributions; limit theorems.

### **MATH 108. Statistics (3)**

Prerequisite: MATH 107. Criteria used for selecting particular procedures of data analysis; derivation of commonly used procedures; topics from sampling, normal theory, nonparametrics, elementary decision theory.

### **MATH 109. Applied Probability (3)**

Prerequisite: MATH 107. Introduction to stochastic processes and their applications in science and industry. Markov chains, queues, stationary time series.

### **MATH 110. Symbolic Logic (3)**

(Similar to PHIL 145; consult department.) Prerequisite: MATH 75 or 75A and B. An informal treatment of the theory of logical inference, statement calculus, truth-tables, predicate calculus, interpretations applications.

### **MATH 111. Transition to Advanced Mathematics (3)**

Prerequisite: MATH 76. Introduction to the language and problems of mathematics. Topics include set theory, symbolic logic, types of proofs, and mathematical induction. Special emphasis is given to improving the student's ability to construct, explain, and justify mathematical arguments.

### **MATH 114. Discrete Structures (3)**

Prerequisite: MATH 111. Counting techniques, matrix algebra, graphs, trees and networks, recurrence relations and generating functions, applied modern algebra.

### **MATH 116. Theory of Numbers (4)**

Prerequisite: MATH 111. Divisibility theory in the integers, primes and their distribution, congruence theory, Diophantine equations, number theoretic functions, primitive roots, indices, the quadratic reciprocity law.

### **MATH 118. Graph Theory (3)**

Prerequisite: MATH 111. Trees, connectivity, Euler and Hamilton paths, matchings, chromatic problems, planar

graphs, independence, directed graphs, networks.

### **MATH 121. Numerical Analysis I (3)**

Prerequisites: MATH 77 and CSCI 40. Zeros of nonlinear equations, interpolation, quadrature, systems of equations, numerical ordinary differential equations, and eigenvalues. Use of numerical software libraries.

### **MATH 123. Topics in Applied Mathematics (3)**

Prerequisite: MATH 77. Vector spaces and linear transformations, eigenvalues and eigen functions. Special types of linear and nonlinear differential equations; solution by series. Fourier transforms. Special functions, including gamma, hypergeometric, Legendre, Bessel, Laguerre, and Hermite functions. Introduction to partial differential equations.

### **MATH 128. Applied Complex Analysis (3)**

Prerequisite: MATH 77. Analytic functions of a complex variable, contour integration, series, singularities of analytic functions, the residue theorems, conformal mappings; emphasis on engineering and physics applications.

### **MATH 133. Number Theory for Liberal Studies (3)**

Prerequisite: MATH 10B or permission of instructor. The historical development of the concept of number and arithmetic algorithms. The magnitude of numbers. Basic number theory. Special numbers and sequences. Number patterns. Modular arithmetic

### **MATH 134. Geometry for Liberal Studies (3)**

Prerequisite: MATH 10B or permission of instructor. The use of computer technology to study and explore concepts in Euclidean geometry. Topics include, but are not restricted to, properties of polygons, tilings, and polyhedra.

### **MATH 137. Exploring Statistics (3)**

Prerequisite: MATH 10B or permission of instructor. Descriptive and inferential statistics with a focus on applications to mathematics education. Use of technology and activities for student discovery and understanding of data organization, collection, analysis, and inference.

### **MATH 138. Exploring Algebra (3)**

Prerequisite: MATH 10B or permission of instructor. Designed for prospective school teachers who wish to develop a deeper conceptual understanding of algebraic themes and ideas needed to become competent and effective mathematics teachers.

### **MATH 143. History of Mathematics (4)**

Prerequisite: MATH 72 or 75 or 75A and B. History of the development of mathematical concepts in algebra, geometry, number theory, analytical geometry, and calculus from ancient times through modern times. Theorems with historical significance will be studied as they relate to the development of modern mathematics.

### **MATH 145. Problem Solving (3)**

Prerequisite: MATH 111; EHD 50 (may be enrolled concurrently). A study of formulation of problems into mathematical form; analysis of methods of attack such as specialization, generalization, analogy, induction, recursion, etc. applied to a variety of non-routine problems. Topics will be handled through student presentation.

### **MATH 151. Principles of Algebra (4)**

Prerequisite: MATH 111. Equivalence relations; groups, cyclic groups, normal subgroups, and factor groups; rings, ideals, and factor rings; integral domains and polynomial rings; fields and field extensions.

### **MATH 152. Linear Algebra (4)**

Prerequisite: MATH 77. Vector spaces, linear transformations, matrices, determinants, eigenvalues and eigenvectors, linear functions, inner-product spaces, bilinear forms, quadratic forms, orthogonal and unitary transformations, selected applications.

### **MATH 161. Principles of Geometry (3)**

Prerequisite: MATH 111. The classical elliptic, parabolic, and hyperbolic geometries developed on a framework of incidence, order and separation, congruence; coordinatization. Theory of parallels for parabolic and hyperbolic geometries. Selected topics of modern Euclidean geometry.

### **MATH 165. Differential Geometry (3)**

Prerequisite: MATH 111 or permission of instructor. Study of geometry in Euclidean space by means of calculus, including theory of curves and surfaces, curvature, theory of surfaces, and intrinsic geometry on a surface.

### **MATH 171. Intermediate Mathematical Analysis I (4)**

Prerequisite: MATH 111. Sets, real numbers as a complete ordered field, its usual topology, functions of a real variable, limits, continuity, uniform continuity, differentiability, generalized mean value theorem, Riemann integrals, series of functions, uniform convergence, and Fourier series of integrable functions. (Formerly MATH 171A)

### **MATH 172. Intermediate Mathematical Analysis II (4)**

Prerequisite: MATH 77 and 171. Differentiation of functions of several variables,

applications of partial differentiation, functions of bounded variation, rectifiable curves, theory of Riemann-Stieltjes integration, multiple integrals and line integrals, improper Riemann-Stieltjes integrals. Inverse and implicit function theorems.

**MATH 181. Differential Equations (3)**  
Prerequisite: MATH 81 or 123. Definition and classification of differential equations; general, particular, and singular solutions; existence theorems; theory and technique of solving certain differential equations: phase plane analysis, elementary stability theory; applications.

**MATH 182. Partial Differential Equations (3)**  
Prerequisites: MATH 81 or 123. Classical methods for solving partial differential equations including separation of variables, Green's functions, the Riemann-Volterra method and Cauchy's problem for elliptic, parabolic, and hyperbolic equations; applications to theoretical physics.

**MATH 190. Independent Study (1-3; max total 6)**  
See *Academic Placement — Independent Study*. Approved for *RP* grading.

**MATH 191T. Proseminar (1-3; max total 9)**  
Prerequisite: permission of instructor. Presentation of advanced topics in mathematics in the field of the student's interest.

**MATH 198. Senior Project (3)**  
Prerequisites: senior standing or permission of instructor; MATH 151, 171, and 152. Independent investigation and presentation of an advanced topic in mathematics. Satisfies the senior major requirement for the B.A. in Mathematics.

**GRADUATE COURSES**  
(See *Catalog Numbering System*.)

**Mathematics (MATH)**

**MATH 202. Fundamental Concepts of Mathematics (3)**  
Prerequisites: MATH 151, 161, and 171. Fundamental notions regarding number theory, number systems, algebra of number fields; functions.

**MATH 210. Foundations of Mathematics (3)**  
Prerequisite: MATH 110 or 151. Formal introduction to theories of inference, first order theories, completeness metatheorems, consistency metatheorems, decision problems.

**MATH 216T. Topics in Number Theory (3; max total 6)**  
Prerequisite: MATH 116. An investigation of topics having either historical or

current research interest in the field of number theory. (Formerly MATH 216)

**MATH 221. Advanced Numerical Analysis (3)**  
Prerequisite: MATH 121. Linear equations and matrices; parabolic, hyperbolic, and elliptic differential equations; constructive function theory.

**MATH 223. Principles and Techniques of Applied Mathematics (3)**  
Prerequisite: graduate standing or permission of instructor. Linear spaces and spectral theory of operators.

**MATH 224. Optimization Methods (3)**  
Prerequisite: graduate standing or permission of instructor. Techniques for optimizing static and dynamic systems, calculus of variations, Hamiltonian canonical form, maximum principle, with applications.

**MATH 228. Functions of a Complex Variable (3)**  
Prerequisite: MATH 128. Representation theorems of Weierstrass and Mittag-Leffler, normal families, conformal mapping and Riemann mapping theorem, analytic continuation, Dirichlet problem.

**MATH 232. Mathematical Models with Technology (3)**  
Prerequisite: graduate standing in mathematics or permission of instructor. A technology-assisted study of the mathematics used to model phenomena in statistics, natural science, and engineering.

**MATH 250. Perspectives in Algebra (3)**  
Prerequisite: graduate standing in mathematics or permission of instructor. Study of advanced topics in algebra, providing a higher perspective to concepts in the high school curriculum. Topics selected from, but not limited to, groups, rings, fields, and vector spaces.

**MATH 251. Abstract Algebra I (3)**  
Prerequisite: undergraduate abstract algebra. Groups, rings, integral domains, and fields.

**MATH 252. Abstract Algebra II (3)**  
Prerequisite: MATH 251. Rings and ideals, modules, linear and multilinear algebras, representations.

**MATH 260. Perspectives in Geometry (3)**  
Prerequisite: graduate standing in mathematics or permission of instructor. Geometry from a transformations point of view. Euclidean and noneuclidean geometries in two and three dimensions. Problem solving and proofs using transformations. Topics chosen to be relevant to geometrical concepts in the high school curriculum.

**MATH 263. Point Set Topology (3)**  
Prerequisite: MATH 172. Basic concepts of point set topology, set theory, topological spaces, continuous functions; connectivity, compactness and separation properties of spaces. Topics selected from function spaces, metrization, dimension theory.

**MATH 265. Differential Geometry (3)**  
Prerequisites: MATH 165, 172. Study of geometry of curves and surfaces in Euclidean space; including an introduction to Riemannian geometry and theory of manifolds.

**MATH 270. Perspectives in Analysis (3)**  
Prerequisite: graduate standing in mathematics or permission of instructor. An overview of the development of mathematical analysis, both real and complex. Emphasizes interrelation of the various areas of study, the use of technology, and relevance to the high school mathematics curriculum.

**MATH 271. Real Variables (3)**  
Prerequisite: MATH 172. Theory of sets; cardinals; ordinals; function spaces, linear spaces; measure theory; modern theory of integration and differentiation.

**MATH 272. Functional Analysis (3)**  
Prerequisite: MATH 271. The Lebesgue-Stieltjes integral and its generalizations, integral equations, Hilbert and Banach spaces, linear transformations (bounded and unbounded).

**MATH 290. Independent Study (1-3; max total 6)**  
See *Academic Placement — Independent Study*. Approved for *RP* grading.

**MATH 291. Seminar (3)**  
Prerequisite: graduate standing. Presentation of current mathematical research in field of student's interest.

**MATH 298. Research Project in Mathematics (3)**  
Prerequisite: graduate standing. Independent investigation of advanced character as the culminating requirement for the master's degree. Approved for *RP* grading.

**IN-SERVICE COURSE**  
(See *Catalog Numbering System*.)

**Mathematics (MATH)**

**MATH 302. Topics in Mathematics for Teachers (1-3; max total 6 if topic not repeated)**  
Prerequisite: permission of instructor. Topics in modern mathematics with special emphasis for teachers.