Mathematics

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, 76, and 77) are essential for the first two Actuarial Examinations offered by the Society of Actuaries.

Faculty

Ronald L. Wagoner, *Chair*
Larry W. Cusick, *Graduate Coordinator*
Undergraduate Advisers:
All full-time faculty
Credential Advisers: Agnes Tuska, Norman T. Woo
Margretha Bentz, *ILE Coordinator*
Robert F. Arnold
Sean Cleary
Moses E. Cohen
Della C. Duncan
Ernesto Franco
Noal C. Harbertson
Harold B. Haslam
Merrilee K. Helmers
Rudolph M. Najar
Hussain Sayid Nur
Hugo S. Sun
Peter Tannenbaum

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: 124 units. See *Baccalaureate Degree Requirements* for complete details on general degree requirements. A minimum of 40 units, including those required for the major, must be upper division.

College of Science and Mathematics

Department of Mathematics
Ronald L. Wagoner, *Chair*
Diana Carmichael, *Administrative Support Coordinator*
Peters Business Building, Room 381
(559) 278-2992
http://www.csufresno.edu/math/

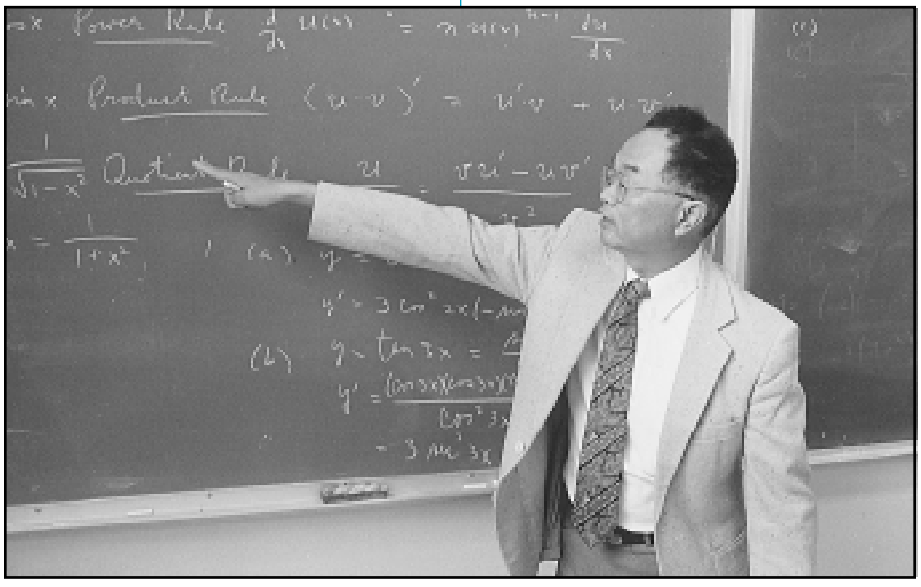
B.A. in Mathematics

M.A. in Mathematics

Minor in Mathematics

Single Subject Teaching Credential

	Units
Major requirements	**43-48**
Core curriculum	(27-28)
MATH 75, 76, 77	(12)
MATH 151, 152	(8)
MATH 171	(4)
MATH 128 or 165 or 172	(3-4)
Elective curriculum	(15-20)
Five mathematics courses, upper-division or MATH 81, excluding MATH 100, 133, 134, 137, 138	



Additional requirements	**7**
C SCI 40	(4)
PHYS 4A[1]	(3)
General Education[2]	**51**
Electives	**18-26**
Total	**124**

Major Advising Note

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. MATH 75 satisfies the Quantitative Reasoning requirement within General Education Foundation courses. It also satisfies the requirement within General Education Core courses, for students under 1998-1999 or earlier catalogs.

Mathematics Minor

The minor requires 20 units in mathematics, MATH 75 or above, including at least two upper-division classes, 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.

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

No credit will be allowed for:	*If taken after completion of:*
MATH 5	MATH 72 or 75
MATH 6	MATH 71 or 75
MATH 70	MATH 72 or 75
MATH 75	MATH 76
MATH 76	MATH 77
MATH 77	MATH 81
MATH 101	MATH 108

Single Subject Credential Program Subject Matter Competency in Mathematics*

MATH 75, 76, 77
MATH 151, 152
MATH 171
MATH 128 or 165 or 172
MATH 101, 114, 116, 143, 145, 161
PHYS 4A
C SCI 40

See the description of the Single Subject Credential Program under *Curriculum, Teaching, and Educational Technology* in this catalog.

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

Graduate Program

The requirement for entrance to the graduate program is completion of undergraduate 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.)*

Prior to advancement to candidacy, the candidate must pass the department's Graduate Qualifying Exam. This exam is given in two parts: analysis and algebra.

Master of Arts Degree Requirements

The Master of Arts degree program in Mathematics is designed to provide preparation for work in industry, for high school and community college teaching, and for advanced graduate study in mathematics.

Language Requirement. There is no foreign language requirement for the master's degree. However, any student preparing for graduate work in mathematics is advised to meet the foreign language requirements of the university in which the graduate work will be taken, since most graduate programs do not leave time for language study. Such preparation normally involves at least two of the languages: French, German, Russian.

Under the direction of the graduate adviser, each candidate prepares and submits for approval a coherent program individually designed within the following framework:

	Units
At least 21 units of mathematics in the 200 series	**21**
Approved electives (no more than 6 units in a related field)	**9**
Total	**30**

Specific requirements: MATH 228, 251, 271, 298.

The MATH 298 research project culminates in a written and oral report to the Department of Mathematics.

COURSES

Mathematics (MATH)

4R. Entry Level Mathematics (4)
Covers all topics in the ELM exam. (I) *Data Interpretation, Counting, Probability and Statistics* (reading, interpreting, and manipulating data, the Multiplication Principle, permutations and combinations, basic probability laws, means, medians, and expected values); (II) *Geometry* (basic Euclidean geometry, congruence and similarity, coordinate geometry, basic right angle trigonometry); and (III) *Algebra* (manipulating algebraic expressions, solving equations and inequalities, investigating functions and their graphs). *CR/NC* grading only; not applicable towards baccalaureate degree requirements.

4RA. Entry Level Mathematics (3)
Arithmetic review; *Algebra* — manipulating algebraic expressions (polynomial), solving equations and inequalities (linear), and investigating functions and their graphs (linear); *Geometry* — basic Euclidean geometry, congruence and similarity, coordinate geometry, and basic right angle trigonometry. *Note*: MATH 4RA together with MATH 4RB is equivalent to MATH 4R. Enrollment is limited to first-time freshmen who score 370 and below on the ELM exam. *CR/NC* grading only; not applicable toward baccalaureate degree requirements. (Formerly MATH ILR)

4RB. Entry Level Mathematics (3)
Prerequisite: MATH 4RA. Arithmetic review; *Algebra* — manipulating algebraic expressions (rational and radical), solving equations and inequalities (quadratic), and investigating functions and their graphs (quadratic); *Data Interpretation, Probability, and Statistics* — reading, interpreting, and manipulating data, the Multiplication Principle, permutations and combinations, basic probability laws, means, medians, and expected values. *Note*: MATH 4RB together with MATH 4RA is equivalent to MATH 4R. Enrollment is limited to first-time freshmen who score 370 and below on the ELM exam. *CR/NC* grading only; not applicable toward baccalaureate degree requirements. (Formerly MATH ILR)

4RL. Entry Level Mathematics Laboratory (1)
Prerequisites: concurrently enrolled in 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.

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)

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)

10A. Structure and Concepts in Mathematics I (3)
Prerequisite: students must meet the ELM requirement. 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 Area B4 G.E. requirement for liberal studies majors.

10B. Structure and Concepts in Mathematics II (3)
Prerequisite: MATH 10A. 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.

11. Elementary Statistics (3)
Prerequisite: students must meet the ELM requirement. Illustration of statistical concepts: elementary probability models, sampling, descriptive measures, confidence intervals, testing hypotheses, chi-square, nonparametric methods, regression. It is recommended that students with credit in MATH 72 or 75 take MATH 101. (CAN STAT 2)

14. Introduction to Discrete Mathematics (3)
No credit if taken after MATH 75. Prerequisite: students must meet the ELM requirement. Set theory, relations and functions, logic, proof techniques, number systems.

25. Mathematica (1)
Prerequisites: MATH 70, 71, 75 (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.

41. Number Systems (3)
Not open to mathematics majors. Prerequisite: students must meet the ELM requirement. Designed for elementary credential students. Development of the rational number system and its subsystems from the informal point of view; sets, relations and operations, equivalence classes; definitions of number systems and operations; algorithms for operations; prime numbers, divisibility tests; ratios. (CAN MATH 4)

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.

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.

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.

70. Mathematical Analysis for Life Sciences (4)
No credit if taken after MATH 72 or 75; one unit of credit if taken after MATH 71. Prerequisite: students must meet the ELM requirement. Functions and graphs, limits, derivatives, antiderivatives, differential equations, and partial derivatives with applications in the Life Sciences.

71. Elementary Mathematical Analysis I (3)
No credit if taken after MATH 70, 72, or 75. 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.

72. Elementary Mathematical Analysis II (3)
No credit if taken after MATH 75; 2 units of credit if taken after MATH 70. Prerequisites: MATH 71 and trigonometry. Analytic geometry and calculus of polynomials, rational functions, transcendental functions; polar coordinates, conic sections, integration and applications.

75. Mathematical Analysis I (4)
Two units of credit if taken after MATH 70; 3 units of credit if taken after MATH 71; 2 units of credit if taken after MATH 72. 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)

76. Mathematical Analysis II (4)
Prerequisite: MATH 75. Transcendental functions, techniques of integration, improper integrals, conic sections, polar coordinates, infinite series. Using Mathematica™ software as an exploratory tool. (CAN MATH 20)

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)

81. Applied Analysis (4)
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 Mathematica™ software as an exploratory tool.

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)

100. Exploring Mathematics (3)
Prerequisite: MATH 10B. A problem-solving approach to topics from game theory, combinatorics, mathematical modeling, and finite geometries.

101. Statistical Methods (4)
Prerequisite: MATH 70, 71, or equivalent; 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.

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.

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.

109. Applied Probability (3)
Prerequisite: MATH 107. Introduction to stochastic processes and their applications in science and industry. Markov chains, queues, stationary time series.

110. Symbolic Logic (3)
(Similar to PHIL 145; consult department.)
Prerequisite: MATH 75. An informal treatment of the theory of logical inference, statement calculus, truth-tables, predicate calculus, interpretations applications.

114. Discrete Structures (3)
Prerequisite: MATH 76. Counting techniques, matrix algebra, graphs, trees and networks, recurrence relations and generating functions, applied modern algebra.

116. Theory of Numbers (4)
Prerequisite: MATH 75. Divisibility theory in the integers, primes and their distribution, congruence theory, Diophantine equations, number theoretic functions, primitive roots, indices, the quadratic reciprocity law.

118. Graph Theory (3)
Prerequisite: MATH 77. Trees, connectivity, Euler and Hamilton paths, matchings, chromatic problems, planar graphs, independence, directed graphs, networks.

121. Numerical Analysis I (3)
Prerequisites: MATH 77 and working knowledge of *C*, Fortran, or Pascal. Zeros of nonlinear equations, interpolation, quadrature, systems of equations, numerical ordinary differential equations, and eigenvalues. Use of numerical software libraries.

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.

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.

133. Number Theory for Liberal Studies (3)
Prerequisite: completion of at least one university-level mathematics course (MATH 5 or above). 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. (Formerly N SCI 140T section)

134. Geometry for Liberal Studies (3)
Prerequisite: completion of at least one university-level mathematics course (MATH 5 or above). 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.

137. Exploring Statistics (3)
Prerequisite: at least one university-level mathematics course (MATH 5 or above). 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.

138. Exploring Algebra (3)
Prerequisite: at least one university-level mathematics course (MATH 5 or above). 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.

143. History of Mathematics (4)
Prerequisite: MATH 72 or 75. 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.

145. Problem Solving (3)
Prerequisite: MATH 76. 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.

151. Principles of Algebra (4)
Prerequisite: MATH 76. Equivalence relations; groups, cyclic groups, normal subgroups, and factor groups; rings, ideals, and factor rings; integral domains and polynomial rings; fields and field extensions.

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.

161. Principles of Geometry (3)
Prerequisite: MATH 77. 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.

165. Differential Geometry (3)
Prerequisite: MATH 77. 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.

171. Intermediate Mathematical Analysis I (4)
Prerequisite: MATH 77. 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)

172. Intermediate Mathematical Analysis II (4)
Prerequisite: MATH 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.

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.

182. Partial Differential Equations (3)
Prerequisites: MATH 81 or 123, and 171. 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.

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

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.

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 *Course Numbering System.*)

Mathematics (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.

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.

216. 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.

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

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

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.

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.

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

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

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.

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.

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

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).

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

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

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 *SP* grading.

IN-SERVICE COURSE

(See *Course Numbering System.*)

Mathematics (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.