Mathematics

In the Department of Mathematics and Statistics
In the College of Sciences

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Faculty

Michael E. O'Sullivan, Ph.D., Professor of Mathematics, Chair of Department

Mathematics and Applications

Ricardo Carretero, Ph.D., Professor of Mathematics, Associate Chair of Department (M.S. Dynamical Systems Graduate Adviser)
T. Marc Dunster, Ph.D., Professor of Mathematics, Associate Chair of Department
Peter V. Blomgren, Ph.D., Professor of Mathematics
José E. Castillo, Ph.D., Professor of Mathematics (M.S. Computational Science Graduate Adviser)
Stephen Y. Hui, Ph.D., Professor of Mathematics, Emeritus
J. Carmelo Interlando, Ph.D., Professor of Mathematics (M.S. Communication Systems Graduate Adviser)
Joseph M. Mahaffy, Ph.D., Professor of Mathematics (Applied Mathematics Graduate Adviser)
Antonio Palacios, Ph.D., Professor of Mathematics
Vadím Ponomarenko, Ph.D., Professor of Mathematics (M.A. Mathematics Graduate Adviser)
Peter Salamon, Ph.D., Professor of Mathematics, Emeritus
Samuel S.P. Shen, Ph.D., Albert W. Johnson Distinguished Professor of Mathematics
Stephen J. Kirschvink, Ph.D., Associate Professor of Mathematics
Bo-Wen Shen, Ph.D., Associate Professor of Mathematics
Christopher W. Curtis, Ph.D., Assistant Professor of Mathematics
Jérôme E. Gilles, Ph.D., Assistant Professor of Mathematics
Antoni Luque Santolaria, Ph.D., Assistant Professor of Mathematics

Mathematics Education

Chris L. Rasmussen, Ph.D., Professor of Mathematics, Associate Chair of Department, Mathematics Education
Joanne Lobato, Ph.D., Professor of Mathematics
Janet S. Bowers, Ph.D., Associate Professor of Mathematics
Susan D. Nickerson, Ph.D., Associate Professor of Mathematics (M.A.T.S. Graduate Adviser)
Daniel L. Reinholz, Assistant Professor of Mathematics
William C. Zahner, Ph.D., Assistant Professor of Mathematics

Associateships

Graduate teaching associateships in mathematics are available to a limited number of qualified students. Application blanks and additional information may be secured from the chair of the department.

General Information

The Department of Mathematics and Statistics offers graduate study leading to the Master of Arts degree in mathematics, the Master of Arts degree for teaching service with a concentration in mathematics, the Master of Science degree in applied mathematics, the Master of Science degree in applied mathematics with a concentration in mathematical theory of communications systems, and the Master of Science degree in applied mathematics with a concentration in dynamical systems. The department also offers the Master of Science degree in statistics and the Master of Science degree in statistics with a concentration in biostatistics (see the Statistics section of this bulletin for a description of the statistics program and courses).

Faculty active in research direct theses and research projects in most general areas of the mathematical sciences: in complex analysis, differential equations, number theory, numerical analysis; in cognitive science, computer education and problem solving within mathematics education; in climate mathematics, computational mathematics, control theory, dynamical systems, mathematics of communication, mathematical physics, modeling and optimization within applied mathematics.

Opportunities for research in mathematics education are available through research facilities in the Center for Research in Mathematics and Science Education.

The department hires qualified graduate students as teaching associates. These positions serve as an important stepping stone on the path to a career in the teaching of mathematics at various levels.

Admission to Graduate Study

All students must satisfy the general requirements for admission to the university with classified graduate standing, as described in Part Two of this bulletin.

Students applying for admission should electronically submit the university application available at http://www.calstate.edu/apply along with the $55 application fee.

All applicants must submit admissions materials to SDSU Graduate Admissions.

Graduate Admissions

The following materials should be submitted as a complete package directly to:

Graduate Admissions
Enrollment Services
San Diego State University
San Diego, CA 92182-7416

(1) Official transcripts (in sealed envelopes) from all postsecondary institutions attended;

NOTE:

- Students who attended SDSU need only submit transcripts for work completed since last attendance.
- Students with international coursework must submit both the official transcript and proof of degree. If documents are in a language other than English, they must be accompanied by a certified English translation.

(2) GRE scores (http://www.ets.org SDSU institution code 4682);

(3) English language score, if medium of instruction was in a language other than English (http://www.ets.org SDSU institution code 4682).

Advancement to Candidacy

All students must satisfy the general requirements for advancement to candidacy as described in Part Four of this bulletin. In addition, the student must have passed a qualifying examination in some programs.

Specific Requirements for the Master of Arts Degree in Mathematics

(Major Code: 17011) (SIMS Code: 776301)

In addition to meeting the requirements for classified graduate standing and the basic requirements for the master's degree as described in Part Four of this bulletin, the student must meet the following requirements:

1. Complete 30 units of approved 500-, 600-, and 700- level courses, of which at least 24 units must be in mathematics. At least 21 units must be at the 600-level or above. Mathematics 600, 601, and 602 may not be part of this degree. No more than six units of Mathematics 797 and 798 will be accepted toward the degree.
2. Before entering the program, students should have completed the following courses or their equivalents: Mathematics 521A, 524, 532, and 534B. If a student has not completed these courses before entering the program, he or she may be admitted conditionally.
3. Among the 30 units of coursework, students must include Mathematics 620; one course in analysis selected from 630A or 631A, and one course selected from Mathematics 621, 630B, or 631B.
4. Students must select Plan A and complete Mathematics 799A. Students are advised that a thesis normally takes a year to complete.

Specific Requirements for the Master of Science Degree in Applied Mathematics

(Major Code: 17031) (SIMS Code: 776314)

In addition to meeting the requirements for classified graduate standing and the basic requirements for the master's degree described in Part Four of this bulletin, the student must meet the following requirements:

1. Have completed before entering the program, the following courses or their equivalents: Mathematics 524, 534A, 534B, 537, 541; Statistics 551A. At most one of these courses can be counted towards the degree course requirements. Programming proficiency in a computer language is also a prerequisite. Admission to the program as conditionally classified may be granted without some of the coursework above, contingent on the student removing any deficiencies by the end of the first year in the program.
2. Complete a minimum of 30 units of approved 500-, 600-, and 700-numbered courses. All programs must include at least 21 units in mathematical science (with the possible exception of a student whose main interest is mathematical modeling) and at least 18 units selected from 600- and 700-numbered courses. No more than six units in Mathematics 797 and 798 will be accepted for credit toward the degree. A program of study must be approved by the graduate adviser.
3. The student must select Plan A and complete Mathematics 799A, Thesis. The student must also have an oral defense of their thesis or research, open to the public.

Concentration in Dynamical Systems
(Major Code: 17031) (SIMS Code: 776316)

This concentration focuses on interdisciplinary applications of dynamical systems and nonlinear modeling in biology, chemistry, engineering, and physics. Students with interests in modeling and analyzing real life problems through mathematics will benefit from this concentration. To enter the program, students must possess a bachelor's degree with a strong mathematical background. In addition to completing the specific requirements for the Master of Science degree in applied mathematics, students pursuing this concentration will complete the following 15 units of core courses: Mathematics 531, 537, 538, 636, and 638; 12 units of electives and three units of Mathematics 799A (Thesis/Project). Possible electives include Mathematics 635 and 639 to be offered depending on demand and resources. Other recommended electives include Mathematics 542, 623, 668, 693A, 693B, 797; Computer Science 553; Physics 580. Depending on the student's interests and background, electives from other departments may be approved by the adviser. For additional information, visit http://nlds.sdsu.edu/masters/.

Concentration in Mathematical Theory of Communication Systems
(Major Code: 17031) (SIMS Code: 776317)

This concentration focuses on the area of mathematics relevant to the transmitting and processing of information by digital or analog methods. In addition to meeting the requirements for classified standing in the Master of Science program in applied mathematics, students pursuing this concentration should also have completed Mathematics 521A or its equivalent before entering the program. Students must complete Mathematics 525, 626, 668; one course selected from Mathematics 625 or 667, and three courses selected from Mathematics 623, 627A, 627B, 630A-630B, 631A-631B. Two additional courses in mathematics or in a related area may be selected with the approval of the program adviser. Either Mathematics 797 (Research) or 799A (Thesis) are required of students in this degree program.

Communication Systems Certificate

(SIMS Code: 776347)

The Communication Systems Certificate provides mathematicians and engineers with the specialized training in the areas of coding, cryptography, and signal processing relevant for the understanding of modern communication systems. This certificate is designed for individuals who need the knowledge this certificate program provides to participate in projects in the area of communication systems and signal processing.

This is an advanced academic certificate at the postbaccalaureate level. The admission requirement is a bachelor's degree in mathematics, engineering, or a closely related field. Individuals with knowledge of the background materials through work or self-study may also be accepted into this program at the discretion of the program director.

Course requirements for the certificate program are the following courses completed with a grade point average of 3.0 or above: Mathematics 522, 525, 626, 667, and 668.

For information on the application process, contact the Department of Mathematics and Statistics or call 619-594-6191.

Courses Acceptable for Master's Degree Programs in Applied Mathematics, Mathematics, and Statistics (MATH)

Refer to Courses and Curricula and Regulations of the Division of Graduate Affairs sections of this bulletin for explanation of the course numbering system, unit or credit hour, prerequisites, and related information.

UPPER DIVISION COURSES

MATH 509. Computers in Teaching Mathematics (3)
Two lectures and three hours of laboratory.
Prerequisite: Mathematics 252 with a grade of C (2.0) or better. **Proof of completion of prerequisite required:** Copy of transcript.
Solving mathematical tasks using an appropriate computer interface, and problem-based curricula. Intended for those interested in mathematics teaching.

MATH 510. Introduction to the Foundations of Geometry (3)
Prerequisite: Mathematics 151 with a grade of C (2.0) or better. **Proof of completion of prerequisite required:** Copy of transcript.
The foundations of Euclidean and hyperbolic geometries. Highly recommended for all prospective teachers of high school geometry.

MATH 521A. Abstract Algebra (3)
Prerequisites: Mathematics 245 and 254 with a grade of C (2.0) or better in each course. **Proof of completion of prerequisites required:** Copy of transcript.
Elementary number theory and rings to include ideals, polynomial rings, quotient rings, ring homomorphisms and isomorphisms. Introduction to basic aspects of group theory.

MATH 521B. Abstract Algebra (3)
Prerequisite: Mathematics 521A with a grade of C (2.0) or better. **Proof of completion of prerequisite required:** Copy of transcript.
Continuation of Mathematics 521A. Group theory to include finite Abelian groups, group homomorphisms and isomorphisms, normal subgroups, quotient groups, and Sylow theorems. Selected advanced topics to include field extensions or integral domains.

MATH 522. Number Theory (3)
Prerequisite: Mathematics 245 with a grade of C (2.0) or better. **Proof of completion of prerequisite required:** Copy of transcript.
Theory of numbers to include congruences, Diophantine equations, and a study of prime numbers; cryptography.

MATH 523. Mathematical Logic (3)
Prerequisite: Mathematics 245 with a grade of C (2.0) or better. **Proof of completion of prerequisite required:** Copy of transcript.
Propositional logic and predicate calculus. Rules of proof and models. Completeness and the undecidability of arithmetic. Not open to students with credit in Philosophy 521.

MATH 524. Linear Algebra (3)
Prerequisites: Mathematics 245 and either 254 or 342A with a grade of C (2.0) or better in each course. **Proof of completion of prerequisites required:** Copy of transcript.
Vector spaces, linear transformations, orthogonality, eigenvalues and eigenvectors, normal forms for complex matrices, positive definite matrices and congruence.

MATH 525. Algebraic Coding Theory (3)
Prerequisite: Mathematics 254 with a grade of C (2.0) or better. **Proof of completion of prerequisite required:** Copy of transcript.
Linear codes, perfect and related codes, cyclic linear codes, BCH codes, burst error-correcting codes.

MATH 531. Partial Differential Equations (3)
Prerequisites: Mathematics 252 and 337 with a grade of C (2.0) or better in each course. **Proof of completion of prerequisites required:** Copy of transcript.
Boundary value problems for heat and wave equations: eigenfunction expansions, Sturm-Liouville theory and Fourier series. D'Alembert's solution to wave equation; characteristics. Laplace's equation, maximum principles, Bessel functions.

MATH 532. Functions of a Complex Variable (3)
Prerequisite: Mathematics 252 with a grade of C (2.0) or better. **Proof of completion of prerequisite required:** Copy of transcript.
Analytic functions, Cauchy-Riemann equations, theorem of Cauchy, Laurent series, calculus of residues, and applications.

MATH 533. Vector Calculus (3)
Prerequisite: Mathematics 254 or 342A with a grade of C (2.0) or better. **Proof of completion of prerequisite required:** Copy of transcript.
Scalar and vector fields; gradient, divergence, curl, line and surface integrals: Green's, Stokes' and divergence theorems. Green's identities. Applications to potential theory or fluid mechanics or electromagnetism.

MATH 534A. Advanced Calculus I (3)
Prerequisites: Mathematics 245 and either 254 or 342A with a grade of C (2.0) or better in each course. **Proof of completion of prerequisites required:** Copy of transcript.
Completeness of the real numbers and its consequences, sequences of real numbers, continuity, differentiability and integrability of functions of one real variable.

MATH 534B. Advanced Calculus II (3)
Prerequisite: Mathematics 534A with a grade of C (2.0) or better. **Proof of completion of prerequisite required:** Copy of transcript.
Series and sequences of functions and their applications, functions of several variables and their continuity, differentiability and integrability properties.

MATH 537. Ordinary Differential Equations (3)
Prerequisite: Mathematics 337 with a grade of C (2.0) or better. **Proof of completion of prerequisite required:** Copy of transcript.
Theory of ordinary differential equations: existence and uniqueness, dependence on initial conditions and parameters, linear systems, stability and asymptotic behavior, plane autonomous systems, series solutions at regular singular points.

MATH 538. Discrete Dynamical Systems and Chaos (3)
Prerequisites: Mathematics 151 and either 254 or 342B with a grade of C (2.0) or better in each course. **Proof of completion of prerequisites required:** Copy of transcript.
One- and two-dimensional iterated maps, equilibria and their stability, sensitive dependence on initial conditions, Lyapunov exponents, horseshoe maps, period doubling, chaotic attractors, Poincare maps, stable/unstable manifolds, bifurcations. Applications in biology, chemistry, physics, engineering, and other sciences.

MATH 541. Introduction to Numerical Analysis and Computing (3)
Prerequisites: Mathematics 254 or 342A; and either Mathematics 242 or Aerospace Engineering 280 or Computer Science 107 with a grade of C (2.0) or better in each course. **Proof of completion of prerequisites required:** Copy of transcript.
Solution of equations of one variable, polynomial interpolation and approximation, numerical differentiation and quadrature, linear least squares approximation, the fast Fourier transformation.

MATH 542. Introduction to Computational Ordinary of Differential Equations (3)
Prerequisites: Mathematics 337 and 541 with a grade of C (2.0) or better in each course. **Proof of completion of prerequisites required:** Copy of transcript.
Initial and boundary value problems for ordinary differential equations. Runge-Kutta, linear multi-step, predictor-corrector, adaptive, hybrid, shooting, and general linear methods. System, stiffness, and non-linear problems. Iterative methods.

MATH 543. Numerical Matrix Analysis (3)
Prerequisite: Mathematics 541 with a grade of C (2.0) or better. **Proof of completion of prerequisite required:** Copy of transcript.
Singular value decomposition. Projections, QR-factorization, orthogonalization, conditioning and stability, Gaussian Elimination, LU-Factorization, pivoting strategies, Cholesky Factorization. Iterative methods for diagonalization and eigensystem computation. Tridiagonal, Hessenberg, and Household matrices. The QR algorithm.

MATH 562. Mathematical Methods of Operations Research (3)
Prerequisites: Mathematics 252 and 254 with a grade of C (2.0) or better in each course. **Proof of completion of prerequisites required:** Copy of transcript.
Theory and applications concerned with optimization of linear and non-linear functions of several variables subject to constraints, including simplex algorithms, duality, applications to game theory, and descent algorithms.

MATH 579. Combinatorics (3)
Prerequisite: Mathematics 245 with a grade of C (2.0) or better. **Proof of completion of prerequisite required:** Copy of transcript.
Permutations, combinations, generating functions, recurrence relations, inclusion-exclusion counting. Polya's theory of counting, other topics and applications.

MATH 596. Advanced Topics in Mathematics (1-4)
Prerequisite: Consent of instructor.
Selected topics in classical and modern mathematical sciences. May be repeated with the approval of the instructor. See *Class Schedule* for specific content. Limit of nine units of any combination of 296, 496, 596 courses applicable to a bachelor's degree. Maximum credit of six units of 596 applicable to a bachelor's degree. Credit for 596 and 696 applicable to a master's degree with approval of the graduate adviser.

GRADUATE COURSES

MATH 620. Groups, Rings, and Fields (3)
Prerequisite: Mathematics 521A, 522, 524, or 525 with a grade of C (2.0) or better.
Group theory to include finite Abelian groups, isomorphism theorems, matrix groups, and permutation groups. Ring theory to include ideals, principal ideal domains, and unique factorization. Field theory to include field extensions and finite fields.

MATH 621. Topics in Advanced Algebra (3)
Prerequisite: Mathematics 620 with a grade of C (2.0) or better.
Topics in advanced algebra. Typical courses to include algebra-geometry dictionary, commutative algebra, groups, fields, and Galois theory. May be repeated with new content. See *Class Schedule* for specific content. Maximum credit six units.

MATH 623. Linear Algebra and Matrix Theory (3)
Prerequisite: Mathematics 524 with a grade of C (2.0) or better.
Characteristic and minimal polynomials, Cayley-Hamilton theorem, canonical forms, hermitian matrices, Sylvester's law, norms, singular values, stability, non-negative matrices.

MATH 625. Algebraic Coding Theory (3)
Prerequisites: Mathematics 525 and Mathematics 521B or 522 with a grade of C (2.0) or better in each course.
Algebraic theory of error correction codes and decoding algorithms used in modern communications systems. Reed-Solomon codes and algebraic decoding algorithms. Code duality, MacWilliam's identities and the linear programming bound. Probabilistic decoding of convolutional codes, low-density parity-check codes and turbo codes.

MATH 626. Cryptography (3)
Prerequisites: Mathematics 521A and 522 with a grade of C (2.0) or better in each course.
Design of secure cryptosystems with applications. Classical and public key cryptosystems. Primality testing, factoring, discrete log problem, and knapsack problem.

MATH 627A. Modern Algebra I (3)
Prerequisite: Mathematics 521B with a grade of C (2.0) or better.
Group theory, including isomorphism theorems, permutation groups, and simplicity of An, finite abelian groups, and Sylow theorems. Rings, ideals, principal ideal domains, and unique factorization.

MATH 627B. Modern Algebra II (3)
Prerequisite: Mathematics 627A with a grade of C (2.0) or better.
Modules and the Wedderburn-Artin theorem, field extensions, splitting fields, Galois theory, finite fields, the fundamental theorem of algebra.

MATH 630A-630B. Functions of a Real Variable (3-3)
Prerequisites: Mathematics 524 and 534B with a grade of C (2.0) or better in each course. Mathematics 630A is prerequisite to Mathematics 630B.
Lebesgue measure and integration, metric spaces, Banach spaces, Hilbert spaces, spectral theory.

MATH 631A-631B. Functions of a Complex Variable (3-3)
Prerequisites: Mathematics 532 and 534B. Mathematics 631A is prerequisite to 631B.
Theory of analytic functions. Elementary functions and power series, Cauchy's theorem and its consequences. Entire functions, conformal mappings, Riemann mapping theorem. Harmonic functions.

MATH 635. Pattern Formation (3)
Prerequisites: Mathematics 337 or 531 and Mathematics 254 or 342A, 342B.
Linear stability, marginal stability curves, classification. One dimensional patterns, bifurcations. Two dimensional patterns, square and hexagonal patterns, spirals, defects. Diffusion driven instability, Turing patterns. Spatio-temporal chaos. Applications in biology, chemistry, and physics.

MATH 636. Mathematical Modeling (3)
Prerequisites: Mathematics 254 and 337 or Mathematics 342A and 342B or Aerospace Engineering 280 with a grade of C (2.0) or better in each course.
Advanced models from the physical, natural, and social sciences. Emphasis on classes of models and corresponding mathematical structures.

MATH 638. Continuous Dynamical Systems and Chaos (3)
Prerequisites: Mathematics 337 or 537 and Mathematics 254 or 342A, 342B with a grade of C (2.0) or better in each course.
Nonlinear systems of differential equations, potential fields, periodic solutions, Lyapunov functions. Chaos in differential equations, Lyapunov exponents, chaotic attractors, Poincare maps. Lorenz and Rossler attractors, forced oscillators, Chua's circuit, stable manifolds. Bifurcations. Applications in science and engineering.

MATH 639. Nonlinear Waves (3)
Prerequisite: Mathematics 531 or 537 with a grade of C (2.0) or better.
Linear waves, dissipation, dispersion. Conservation laws. Water waves. KdV equation, solitary waves, cnoidal waves. Scattering and inverse scattering. Perturbation theory. Nonlinear Schroedinger equation, dark and bright solitons, vortex solutions. Variational techniques, modulational instability, stability.

MATH 667. Mathematical Aspects of Systems Theory (3)
Prerequisites: Mathematics 524 and 537 with a grade of C (2.0) or better in each course.
Linear and nonlinear systems, nonlinear differential equations, equilibrium equations. Linearization, state transition matrix, stability theory, feedback control systems.

MATH 668. Applied Fourier Analysis (3)
Prerequisites: Mathematics 524, 534A; 532 or 534B with a grade of C (2.0) or better in each course.
Discrete and continuous Fourier transform methods with applications to statistics and communication systems.

MATH 693A. Advanced Numerical Methods: Computational Optimization (3)
Prerequisites: Mathematics 524 and 541 with a grade of C (2.0) or better in each course.
Numerical optimization: Newton, Truncated-Newton, and Quasi-Newton methods for unconstrained optimization; with applications to nonlinear least squares, orthogonal distance regression, and nonlinear equations.

MATH 693B. Advanced Numerical Methods: Computational Partial Differential Equations (3)
Prerequisites: Mathematics 531 and 541 with a grade of C (2.0) or better in each course.
Methods for hyperbolic, parabolic, and elliptic partial differential equations: consistency, stability, convergence.

MATH 696. Selected Topics in Mathematical Sciences (3)
Prerequisite: Graduate standing.
Intensive study in specific areas of mathematical sciences. May be repeated with new content. See *Class Schedule* for specific content. Credit for 596 and 696 applicable to a master's degree with approval of the graduate adviser.

MATH 720. Seminar (1-3)
Prerequisite: Consent of instructor.
An intensive study in advanced mathematics. May be repeated with new content. See *Class Schedule* for specific content. Maximum credit six units applicable to a master's degree.

MATH 790. Practicum in Teaching of Mathematics (1) Cr/NC
Prerequisite: Award of graduate teaching associateship in mathematics.
Supervision in teaching mathematics. Lecture writing, style of lecture presentation and alternatives, test and syllabus construction, and grading system. Not applicable to an advanced degree. Required for first semester GTA's.

MATH 797. Research (1-3) Cr/NC/RP
Prerequisite: Six units of graduate level mathematics.
Research in one of the fields of mathematics. Maximum credit six units applicable to a master's degree.

MATH 798. Special Study (1-3) Cr/NC/RP
Prerequisite: Consent of staff; to be arranged with department chair and instructor.
Individual study. Maximum credit six units applicable to a master's degree.

MATH 799A. Thesis or Project (3) Cr/NC/RP
Prerequisites: An officially appointed thesis committee and advancement to candidacy.
Preparation of a project or thesis for the master's degree.

MATH 799B. Thesis or Project Extension (0) Cr/NC
Prerequisite: Prior registration in Thesis or Project 799A with an assigned grade symbol of RP.
Registration required in any semester or term following assignment of RP in Course 799A in which the student expects to use the facilities and resources of the university; also student must be registered in the course when the completed thesis or project is granted final approval.

MATH 799C. Comprehensive Examination Extension (0) Cr/NC
Prerequisite: Completion or concurrent enrollment in degree program courses.
Registration required of students whose only requirement is completion of the comprehensive examination for the master's degree. Registration in 799C limited to two semesters.

For additional courses useful to mathematicians see the sections under:
Computer Science
Mathematics and Science Education
Statistics