DEPARTMENT OF MATHEMATICS AND APPLIED MATHEMATICS

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Professor and chair

math.vcu.edu (http://www.math.vcu.edu)

The Department of Mathematics and Applied Mathematics offers an undergraduate program leading to a Bachelor of Science in Mathematical Sciences with concentrations in applied mathematics, biomathematics, mathematics and secondary mathematics teacher preparation. The department administers the Master of Science in Mathematical Sciences concentrations in applied mathematics or mathematics and is involved in administering the Doctor of Philosophy in Systems Modeling and Analysis. The curricula of these programs are run jointly with additional concentrations offered by the Department of Statistical Sciences and Operations Research.

- Mathematical Sciences, Master of Science (M.S.) with a concentration in applied mathematics (http://bulletin.vcu.edu/graduate/college-humanities-sciences/mathematics-applied-mathematics/mathematical-sciences-ms-concentration-applied-mathematics)
- Mathematical Sciences, Master of Science (M.S.) with a concentration in mathematics (http://bulletin.vcu.edu/graduate/college-humanities-sciences/mathematics-applied-mathematics/mathematical-sciences-ms-concentration-mathematics)
- Systems Modeling and Analysis, Doctor of Philosophy (Ph.D.) (http://bulletin.vcu.edu/graduate/college-humanities-sciences/mathematics-applied-mathematics/systems-modeling-analysis-phd)

Mathematics and applied mathematics

MATH 502. Abstract Algebra I. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 401 with a minimum grade of a C, or permission of instructor. A study of groups, subgroups, quotient groups and homomorphisms, group actions, sylow theorems, direct and semi-direct products, rings, integrals domains, and polynomial rings.

MATH 505. Modern Geometry. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 300, and MATH 307 or MATH 310, or permission of instructor. Topics in Euclidean, projective and non-Euclidean geometries from a modern viewpoint.

MATH 507. Bridge to Modern Analysis. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Enrollment restricted to student with graduate standing. Metric spaces, normed vector spaces, inner-product spaces and orthogonality, sequences and series of functions, convergence, compactness, completeness, continuity, contraction mapping theorem, and inverse and implicit function theorems.

MATH 511. Applied Linear Algebra. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 310 or permission of instructor. The algebra of matrices, the theory of finite dimensional vector spaces and the basic results concerning eigenvectors and eigenvalues, with particular attention to applications.

MATH 515. Numerical Analysis. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Enrollment restricted to student with graduate standing. Knowledge of a programming language or mathematical software package recommended. Theoretical derivation and implementation of numerical methods. Topics to include direct methods, data fitting, differentiation, integration and solutions to ordinary differential equations.

MATH 535. Introduction to Dynamical Systems. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Enrollment restricted to students with graduate standing. Theoretical and computational introduction to continuous and discrete dynamical systems with applications. Topics include existence and uniqueness of solutions, stability and bifurcations.

MATH 550. Combinatorics. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 211 or MATH 300; and MATH 350, both with a minimum grade of C; or permission of instructor. Topics include basic counting, binomial theorems, combinations and permutations, recurrence relations, generating functions, and basic graph theory with emphasis to applications.

MATH 555. Dynamics and Multivariable Control I. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 301 and 310 or the equivalent. Systems of differential equations with controls, linear control systems, controllability, observability, introduction to feedback control and stabilization. Crosslisted as: EGRE 555.

MATH 556. Graph Theory. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 211 or MATH 300; MATH 310; and MATH 356, each with a minimum grade of C; or permission of instructor. Introduction to graph classes, graph invariants, graph algorithms, graph theoretic proof techniques and applications.

MATH 585. Biomathematics Seminar:____. 1 Hour.
Semester course; 2 lecture hours. 1 credit. Prerequisite: MATH 301 or permission of instructor. May be repeated with different thematic content. Opportunity for students to develop their understanding of the connection between mathematics and the areas of biology and medicine. Activities include reading of classical and contemporary research literature, attending seminar talks and class discussions.

MATH 591. Topics in Mathematics. 1-3 Hours.
Semester course; 1-3 credits. May be repeated for credit with different topics. Prerequisite: permission of the instructor. Open to qualified undergraduates. A study of selected topics in mathematical sciences. See the Schedule of Classes for specific topics to be offered each semester and prerequisites.

MATH 593. Internship in Mathematical Sciences. 3,6 Hours.
Semester course; variable hours. 1-6 credits. May be repeated for credit. Student participation in a planned educational experience under the supervision of a mathematical sciences faculty member. The internship may include supervised teaching, statistical consulting or participation in theoretical or applied research projects. A grade of P may be assigned students in this course. May be applied toward the degree in mathematical sciences only with the permission of the graduate affairs committee.

MATH 602. Abstract Algebra II. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 502. A study of modules, vector spaces, field extensions and Galois theory.

MATH 607. Measure and Integration Theory. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: Math 507. Measurable sets and functions, sets of measure zero, Borel sets, Lebesgue measure and integral, fundamental convergence theorems, Lp spaces, and foundations of probability theory.

MATH 610. Advanced Linear Algebra. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Vector spaces, bases and dimension, change of basis. Linear transformations, linear functionals. Simultaneous triangularization and diagonalization. Rational and Jordan canonical forms.

MATH 615. Iterative Numerical Methods. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 515. Theoretical development of solutions to large linear and nonlinear systems by iterative methods with consideration given to optimal implementation.

MATH 632. Ordinary Differential Equations I. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 507 and MATH 535. Linear systems theory; existence, uniqueness and continuous dependence for nonlinear systems; invariant manifolds; stable manifold theorem; Hartman-Grobman theorem; Lyapunov stability theory; Hamiltonian and gradient systems.

MATH 633. Partial Differential Equations. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 507. Classification of partial differential equations, initial and boundary value problems, well-posedness; first-order equations and methods of characteristics; wave equation; heat equation, transform methods, maximum principle, energy methods; Laplace's equation. Other topics may vary depending on the interest of the students and the instructor.

MATH 640. Mathematical Biology I. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 535. Mathematical modeling in the biological and medical sciences. Topics will include continuous and discrete dynamical systems describing interacting and structured populations, resource management, biological control, reaction kinetics, biological oscillators and switches, and the dynamics of infectious diseases.

MATH 650. Advanced Combinatorics. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 550. Topics include advanced applications of the pigeonhole principle and inclusion-exclusion principle, recurrence relations, generating functions, special counting sequences, Ramsey theory, and combinatorial designs and codes.

MATH 656. Advanced Graph Theory. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 556. This course lays a rigorous theoretical foundation for further advanced study in graph theory. Topics may include connectivity, matching, planarity, coloring, Hamiltonian cycles and topological graph theory, as well as further advanced material.

MATH 661. Number and Operations. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Ways of representing numbers, relationships between numbers, number systems, the meanings of operations and how they relate to one another, and computation within the number system as a foundation for algebra; episodes in history and development of the number system; and examination of the developmental sequence and learning trajectory as children learn number concepts. A core course for preparation as a K-8 mathematics specialist. Not applicable to M.S. in Mathematical Sciences.

MATH 662. Geometry and Measurement. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Explorations of the foundations of informal measurement and geometry in one, two and three dimensions. The van Hiele model for geometric learning is used as a framework for how children build their understanding of length, area, volume, angles and geometric relationships. Visualization, spatial reasoning and geometric modeling are stressed. As appropriate, transformational geometry, congruence, similarity and geometric constructions will be discussed. A core course of preparation as a K-8 mathematics specialist. Not applicable to M.S. in Mathematical Sciences.

MATH 663. Functions and Algebra. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Examination of representation and analysis of mathematical situations and structures using generalization and algebraic symbols and reasoning. Attention will be given to the transition from arithmetic to algebra, working with quantitative change, and the description of and prediction of change. A core course for preparation as a K-8 mathematics specialist. Not applicable to M.S. in Mathematical Sciences.

MATH 664. Statistics and Probability. 3 Hours.
Semester course; 3 lecture hours. 3 credits. An introduction to probability, descriptive statistics and data analysis; exploration of randomness, data representation and modeling. Descriptive statistics will include measures of central tendency, dispersion, distributions and regression. Analysis of experiments requiring hypothesizing, experimental design and data gathering. A core course for preparation as a K-8 mathematics specialist. Not applicable to M.S. in Mathematical Sciences.

MATH 665. Rational Numbers and Proportional Reasoning. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Basic number strands in fractions and rational numbers, decimals and percents; ratios and proportions in the school curriculum. Interpretations, computations and estimation with a corrdinated program of activities that develop both rational number concepts and skills and proportional reasoning. A core course for preparation as a K-8 mathematics specialist. Not applicable to M.S. in Mathematical Sciences.

MATH 667. Functions and Algebra II. 3 Hours.
Semester course; 3 lecture hours, 3 credits. Prerequisite: Math 663 or equivalent. Examination of the K-8 strands related to algebra. A study of linear, exponential and quadratic functions. Use of number lines, coordinate axes, tables, graphing calculators and manipulatives to understand core algebraic ideas and real-world contexts. Course provides preparation for K-8 mathematics specialists. Not applicable to M.S. in Mathematical Sciences.

MATH 690. Research Seminar. 2 Hours.
Semester course; 2 lecture hours; 2 credits. Enrollment is restricted to students with graduate standing. Discussion of topics in the mathematical sciences stimulated by independent reading in selected area. Each student will give at least one oral presentation and complete an expository writing assignment.

MATH 691. Special Topics in Mathematics. 1-3 Hours.
Semester course; 1-3 lecture hours. 1-3 credits. May be repeated for credit. Prerequisite: permission of instructor. A detailed study of selected topics in mathematics. Possible topics include commutative rings and algebras, topological groups, special functions, Fourier analysis, abstract harmonic analysis, operator theory, functional analysis, differential geometry, Banach algebras and control theory.

MATH 697. Directed Research. 1-3 Hours.
Semester course; variable hours. 1-3 credits per semester. May be repeated for credit. Prerequisite: graduate standing. Supervised individual research and study in an area not covered in the present curriculum or in one which significantly extends present coverage. Research culminates with an oral presentation and submission of a written version of this presentation to the supervising faculty member.

MATH 698. Thesis. 1-3 Hours.
Hours to be arranged. 1-3 credits. A total of 3 or 6 credits may be applied to the M.S. in Mathematical Sciences/Applied Mathematics or to the M.S. in Mathematical Sciences/Mathematics. May be repeated for credit. Prerequisite: graduate standing. Independent research culminating in the writing of the required thesis as described in this bulletin. Grade of S/U/F may be assigned in this course.

MATH 707. Functional Analysis I. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 507. Banach and Hilbert spaces, bounded linear maps, Hahn-Banach theorem, open mapping theorem, dual spaces, weak topologies, Banach-Alaoglu theorem, reflexive spaces, compact operators, spectral theory in Hilbert spaces.

MATH 715. Numerical Solutions for Differential Equations. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 515 or MATH 615. Students will use the finite difference method and the finite element method to solve ordinary and partial differential equations. Course will explore the theoretical underpinnings of the techniques and implement the methods to solve a variety of equations.

MATH 727. Topics in Analysis: ____. 3 Hours.
Semester course; 3 lecture hours. 3 credits. May be repeated for credit with different topics. A detailed study of selected topics, which may include complex analysis, geometric analysis, harmonic analysis, mathematical logic, nonlinear functional analysis, nonstandard analysis and variational analysis.

MATH 732. Ordinary Differential Equations II. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 632. Center manifold theory; normal form theory; oscillations in nonlinear systems; local bifurcation theory of equilibria and periodic orbits.

MATH 750. Topics in Combinatorics: ____. 3 Hours.
Semester course; 3 lecture hours. 3 credits. May be repeated with different topics for credit. Prerequisite: MATH 650. A detailed study of selected topics, which may include probabilistic methods, linear algebra methods, extremal problems, partially ordered sets and symmetric functions.

MATH 756. Topics in Graph Theory: ____. 3 Hours.
Semester course; 3 lecture hours. 3 credits. May be repeated with different topics for credit. Prerequisite: MATH 656. A detailed study of selected topics, which may include extremal graph theory, spectral graph theory, infinite graphs, random graphs and graph minors.

MATH 769. Topics in Applied Mathematics: ____. 3 Hours.
Semester course; 3 lecture hours. 3 credits. May be repeated with different topics for credit. A detailed study of selected topics, which may include advanced partial differential equations, discrete dynamical systems, fluid dynamics, computational physiology, disease dynamics, kinetic theory, optimal transportation, numerical optimization and population dynamics.

Systems modeling and analysis

SYSM 681. Systems Seminar I. 1 Hour.
Semester course; 1 lecture hour. 1 credit. Prerequisite: graduate standing in mathematical sciences or systems modeling and analysis. Designed to help students attain proficiency in academic communication and research in the context of mathematics, operations research and statistics. Focuses on the discipline-specific communication and research skills necessary to excel in graduate studies in these disciplines.

SYSM 682. Systems Seminar II. 1 Hour.
Semester course; 1 lecture hour. 1 credit. Prerequisite: graduate standing in mathematical sciences or systems modeling and analysis. Designed to help students attain proficiency in professional communication and research in the context of mathematics, operations research and statistics. Focuses on the discipline-specific communication and research skills necessary to excel in professional careers in these disciplines.

SYSM 683. Systems Seminar III. 1 Hour.
Semester course; 1 lecture hour. 1 credit. Prerequisite: graduate standing in mathematical sciences or systems modeling and analysis. Designed to help students attain proficiency in literature review and research in the context of mathematics, operations research and statistics. Focuses on the discipline-specific literature review and research skills necessary to write an applied project, thesis or dissertation.

SYSM 697. Systems Research. 3 Hours.
Semester course; 3 credits. May be repeated for credit. Prerequisite: graduate standing in systems modeling and analysis. Supervised individual research and study. Research culminates with an oral presentation and submission of a written report to the supervising faculty member.

SYSM 780. Stochastic Methods in Mathematical Biology. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: STAT 513 or STAT 613, and MATH 535. Covers commonly used stochastic methods in mathematical biology, including cellular physiology and related areas. Topics covered include stochastic differential equation models, applications of first passage time (escape time) and applications of density or master equations, diffusion in cells, stochastic ion channel dynamics, and cellular communication. Students will be expected to learn how to program in appropriate software packages.

SYSM 798. Dissertation Research. 1-12 Hours.
Semester course; variable hours. 1-12 credits. May be repeated for credit. Research and work leading to the completion of the Ph.D. dissertation in systems modeling and analysis. Graded S/U/F.