

## Department of Mathematics

**Professors** M. Aguiar, G. D. Allen, G. A. Battle, G. R. Blakley, H. P. Boas, A. Boggess (Head), I. Borosh, J. H. Bramble, G. Chen, R. A. DeVore, R. G. Douglas, K. J. Dykema, Y. Efendiev, T. Erdelyi, C. Foias, S. A. Fulling, S. C. Geller, R. Grigorchuk, J. Guermond, D. A. Hensley, W. B. Johnson, P. Kuchment, J. Landsberg, D. R. Larson, R. Lazarov, D. R. Lewis, P. Lima-Filho, F. J. Narcowich, V. V. Nekrashevych, R. L. Panetta, M. Papanikolas, J. E. Pasciak, C. Pearcy, M. S. Pilant, G. Pisier, J. T. Pitts, A. Poltoratski, K. R. Rajagopal, J. N. Reddy, J. M. Rojas, W. Rundell, J. F. Schielack, T. Schlumprecht, J. C. Slattery, R. R. Smith, F. Sortile, P. F. Stiller, E. Straube, P. Tretkoff, J. R. Walton, J. D. Ward, S. Witherspoon, C. H. Yan, J. Zhou, J. Zinn; **Associate Professors** M. V. Anshelevich, W. Bangerth, G. Berkolaiko, A. Comech, P. Daripa, R. D. DeBlassie, R. A. Gustafson, P. Howard, G. Kanschat, D. Kerr, T. R. Kiffe, B. D. Lowe, L. F. Matusevich, D. A. Panchenko, G. Petrova, B. Popov, M. H. Rahe, V. P. Schielack, Jr., N. Sivakumar, M. J. Stecher, Z. Sunik, S. D. Taliaferro, T. I. Vogel, Y. Vorobets, P. B. Yasskin; **Assistant Professors** A. Bonito, L. Bowen, R. Masri, G. Paouris, C. Robles, E. C. Rowell, M. P. Young, I. Zelenko; **Senior Lecturers** A. Allen, A. L. Austin, A. Belmonte, M. Boggess, K. L. Bollinger, M. Drost, J. Epstein, Y. C. Hester, J. E. Kahlig, K. Kilmer, G. S. Klein, D. Manuel, H. Moghbelli, M. Mogilevsky, S. Nite, H. L. Ramsey, S. Scarborough, M. Vorobets, J. Whitfield; **Lecturers** B. Aurispa, C. Chen, L. Cox, D. J. Lackey, D. Lazarov, J. Lewis, P. Poage, M. Roque-Sol, N. Simpson, J. Zarestky

## Mathematics

### (MATH)

102. (MATH 1314) **Algebra**. (3-0). **Credit 3. I, II, S** Sets, structure of number system; absolute values, solution sets of linear and nonlinear equations, of systems of equations, and of inequalities; relations and functions, graphical representations, progressions, mathematical induction, determinants.
103. (MATH 1316) **Plane Trigonometry**. (3-0). **Credit 3.** Angular measure; definitions of trigonometric functions, evaluation of functions of special angles, fundamental relations, solution of triangles, trigonometric reductions, angular measure, functions of composite angle, logarithms, inverse trigonometric functions, trigonometric equations.
131. **Mathematical Concepts—Calculus**. (3-0). **Credit 3. I, II, S** Limits and continuity; rates of change, slope; differentiation: the derivative, maxima and minima; integration: the definite and indefinite integral techniques; curve fitting. Prerequisites: High school algebra I and II and geometry. Credit will not be given for more than one of MATH 131, 142, 147, 151 and 171.
141. (MATH 1324) **Business Mathematics I**. (3-0). **Credit 3. I, II, S** Linear equations and applications, systems of linear equations, matrix algebra and applications, linear programming (graphical method), probability and applications, statistics. Prerequisites: High school algebra I and II and geometry. Credit will not be given for more than one of MATH 141 and 166.
142. (MATH 1325) **Business Mathematics II**. (3-0). **Credit 3. I, II, S** Derivatives, curve sketching and optimization, techniques of derivatives, logarithms and exponential functions with applications, integrals, techniques and applications of integrals, multivariate calculus. Prerequisites: High school algebra I and II and geometry or satisfactory performance on a qualifying examination. Credit will not be given for more than one of MATH 131, 142, 147, 151 and 171.
147. **Calculus I for Biological Sciences**. (3-2). **Credit 4.** Introduction to differential calculus in a context that emphasizes applications in the biological sciences. Prerequisite: MATH 150 or equivalent. Credit will not be given for more than one of MATH 131, 142, 147, 151 and 171.
148. **Calculus II for Biological Sciences**. (3-2). **Credit 4.** Introduction to integral calculus in a context that emphasizes applications in the biological sciences; ordinary differential equations and analytical geometry. Prerequisite: MATH 147 or approval of instructor. Credit will not be given for more than one of MATH 148, 152 and 172.
150. (MATH 2412) **Functions, Trigonometry and Linear Systems**. (3-2). **Credit 4. I, II, S** Graphs, functions, college algebra and trigonometry, linear systems and vectors.
151. (MATH 2413) **Engineering Mathematics I**. (3-2). **Credit 4. I, II, S** Rectangular coordinates, vectors, analytic geometry, functions, limits, derivatives of functions, applications, integration, computer algebra (Maple). Prerequisite: MATH 150 or equivalent. Credit will not be given for more than one of MATH 131, 142, 147, 151 and 171.

152. (MATH 2414) **Engineering Mathematics II.** (3-2). **Credit 4. I, II, S** Differentiation and integration techniques and their applications (area, volumes, work), improper integrals, approximate integration, analytic geometry, vectors, infinite series, power series, Taylor series, computer algebra (Maple). Prerequisite: MATH 151 or equivalent. Credit will not be given for more than one of MATH 148, 152 and 172.
166. **Topics in Contemporary Mathematics II.** (3-0). **Credit 3. I, II, S** Finite mathematics, matrices, probability and applications. Prerequisites: High school algebra I and II and geometry. Credit will not be given for more than one of MATH 141 and 166.
167. **For All Practical Purposes.** (3-0). **Credit 3.** Application of mathematics to real world situations using quantitative methods; includes urban services and elements of management science (optimal routes, planning and scheduling), elements of statistics (sampling/polling methods, analyzing data to make decisions), codes used by stores, credit cards, internet security, cryptography. Prerequisite: High school Algebra I and II.
170. **Freshman Mathematics Laboratory.** (0-2). **Credit 1.** Computing and problem solving laboratory; introduction to the various mathematical disciplines; development of skills in mathematical problem solving and skills in teamwork. May be taken two times for credit. Prerequisites: Concurrent enrollment in MATH 171 or 172; admission to College of Science.
171. **Analytic Geometry and Calculus.** (4-0). **Credit 4. I, II** Vectors, functions, limits, derivatives, Mean Value Theorem, applications of derivatives, integrals, Fundamental Theorem of Calculus. Prerequisite: MATH 150 or equivalent. Credit will not be given for more than one of MATH 131, 142, 147, 151 and 171.
172. **Calculus.** (4-0). **Credit 4. I, II** Techniques of integration, applications of integrals, improper integrals, sequences, infinite series, vector algebra and solid analytic geometry. Prerequisite: MATH 151 or 171. Credit will not be given for more than one of MATH 148, 152 and 172.
202. **Discrete Mathematics for Computer Science.** (3-0). **Credit 3.** Logic, methods of proof, set theory, functions and sequences, growth of functions, mathematical induction, divide-and-conquer recursions, relations, equivalence relations, and finite-state machines. Prerequisite: MATH 151 or equivalent.
220. **Foundations of Mathematics.** (3-0). **Credit 3.** Foundations of mathematics including logic, set theory, combinatorics, and number theory. Prerequisite: MATH 172.
221. **Several Variable Calculus.** (4-0). **Credit 4. I, II** Vector algebra and solid analytic geometry; calculus of functions of several variables; Lagrange multipliers; multiple integration, theory, methods and application; line and surface integrals, Green's and Stokes' theorems; Jacobians. Prerequisite: MATH 172 or approval of instructor. Credit will not be given for more than one of MATH 221, 251 and 253.
251. **Engineering Mathematics III.** (3-0). **Credit 3. I, II, S** Vector algebra, calculus of functions of several variables, partial derivatives, directional derivatives, gradient, multiple integration, line and surface integrals, Green's and Stokes' theorems. Prerequisite: MATH 152 or equivalent. Credit will not be given for more than one of MATH 221, 251 and 253.
253. (MATH 2415) **Engineering Mathematics III.** (3-2). **Credit 4. I, II, S** Vector algebra; calculus of functions of several variables, partial derivatives, directional derivatives, gradient, multiple integration, line and surface integrals, Green's and Stokes' theorems, computer algebra. Prerequisite: MATH 152 or equivalent. Credit will not be given for more than one of MATH 221, 251 and 253.
281. **Seminar in Mathematics.** (1-0). **Credit 1.** Designed to familiarize students with mathematics pertaining to real world applications in such areas as biology, signal processing, quantum computation and robotics. May be taken four times for credit.
285. **Directed Studies.** **Credit 1 to 4.** Special problems not covered by any other lower-division course in the curriculum; intended for freshman and sophomore students. Prerequisite: Approval of department head.
289. **Special Topics in...** **Credit 1 to 4.** Selected topics in an identified area of mathematics. May be repeated for credit. Prerequisite: Approval of instructor.
291. **Research.** **Credit 1 to 4.** Research conducted under the direction of faculty member in mathematics. May be repeated 2 times for credit. Prerequisites: Freshman or sophomore classification and approval of instructor.
302. **Discrete Mathematics.** (3-0). **Credit 3. I, II, S** Formal structures for describing data, algorithms and computing devices; theory and applications of sets, graphs and algebraic structures. Prerequisite: MATH 152 or equivalent.

304. **Linear Algebra.** (3-0). **Credit 3. I, II, S** Introductory course in linear algebra covering abstract ideas of vector space and linear transformation as well as models and applications of these concepts, such as systems of linear equations, matrices and determinants. Prerequisite: MATH 152 or equivalent.
308. **Differential Equations.** (3-0). **Credit 3. I, II, S** Ordinary differential equations, solutions in series, solutions using Laplace transforms, systems of differential equations. Prerequisites: MATH 251 or equivalent; knowledge of computer algebra system.
311. **Topics in Applied Mathematics I.** (3-0). **Credit 3. I, II, S** Matrices, determinants, systems of linear equations, eigenvalues, eigenvectors, diagonalization of symmetric matrices, special functions; vector analysis, including normal derivative, gradient, divergence, curl, line and surface integrals, Gauss', Green's and Stokes' theorems. Prerequisites: MATH 221, 251 or 253; MATH 308 or concurrent enrollment therein.
323. **Linear Algebra.** (3-0). **Credit 3. I, II** Linear equations and matrices; real vector spaces, linear transformations, change of bases, determinants, eigenvalues and eigenvectors, diagonalization, inner products. Prerequisites: MATH 148, 152 or 172; MATH 220 or approval of instructor.
325. **The Mathematics of Interest.** (3-0). **Credit 3.** The mathematical theory associated with interest; annuities; internal rate of return; coupon bonds; valuation of noncallable bonds; yield of maturity; interest rate sensitivity; duration and convexity; reinvestment risk; total return; compound return; STRIPS; yield curve; short selling; hedge ratio; bond swaps. Prerequisites: MATH 142, 147, 151 or 171; junior classification.
365. **Structure of Mathematics I.** (3-0). **Credit 3. I, II, S** Informal logic, sets, relations, functions, whole numbers, numeration systems, binary operations, integers, elementary number theory, modular systems, rational numbers and the system of real numbers. Designed primarily for elementary teacher certification. Others must have consent of instructor. Prerequisites: Must have completed University Core Curriculum mathematics requirements with a grade of C or better.
366. **Structure of Mathematics II.** (3-0). **Credit 3. I, II, S** Geometry, measurement and coordinate geometry. Designed primarily for elementary teacher certification. Others must have consent of instructor. Prerequisite: MATH 365 or equivalent with a grade of C or better.
367. **Basic Concepts of Geometry.** (3-0). **Credit 3. I, II, S** Formal development of geometry: finite [Euclidean and non-Euclidean]. Designed primarily for elementary mathematics teacher certification. Others must have consent of instructor. Prerequisite: MATH 366 or equivalent with a grade of C or better.
368. **Introduction to Abstract Mathematical Structures.** (3-0). **Credit 3.** Mathematical proofs, sets, relations, functions, infinite cardinal numbers, algebraic structures, structure of the real line; designed primarily for elementary teacher certification. Prerequisite: MATH 366 or equivalent with a grade of C or better.
375. **Intermediate Real Analysis.** (3-0). **Credit 3.** Development of the real numbers, limits, foundations and major theorems of calculus. Designed primarily for mathematics teacher certification. Others must have consent of instructor. Prerequisite: MATH 220 or equivalent.
376. **Intermediate Abstract Algebra.** (3-0). **Credit 3. II** Relations, functions, binary operators, rings, homomorphisms, integral domains and fields. Designed primarily for mathematics teacher certification. Others must have consent of instructor. Prerequisites: MATH 220 or 302; MATH 304 or equivalent.
401. **Advanced Engineering Mathematics.** (3-0). **Credit 3. II** Engineering mathematics including Perturbation Theory, Fourier series and partial differential equations. Designed primarily for engineering majors. Others must have consent of instructor. Prerequisite: MATH 308.
403. **Mathematics and Technology.** (3-0). **Credit 3.** Mathematical problem-solving and communication through the use of various technologies (both hardware and software). Intended primarily, but not limited to, students working toward teacher certification. Prerequisite: MATH 367 or 467 with a grade of C or better.
407. **Complex Variables.** (3-0). **Credit 3.** Fundamental theory of analytic functions, including residues and their applications. Prerequisite: MATH 221 or equivalent.
409. **Advanced Calculus I.** (3-0). **Credit 3. I, II** Axioms of the real number system; point set theory of  $\mathbb{R}^1$ ; compactness, completeness and connectedness; continuity and uniform continuity; sequences, series; theory of Riemann integration. Prerequisites: MATH 220 and 221.
410. **Advanced Calculus II.** (3-0). **Credit 3. I, II** Differential and integral calculus of functions defined on  $\mathbb{R}^m$  including inverse and implicit function theorems and change of variable formulas for integration; uniform convergence. Prerequisites: MATH 323 and 409.

411. **Mathematical Probability.** (3-0). **Credit 3. I, II** Probability spaces, discrete and continuous random variables, special distributions, joint distributions, expectations, law of large numbers, the central limit theorem. Prerequisite: MATH 221 or equivalent.
412. **Theory of Partial Differential Equations.** (3-0). **Credit 3. I** Formulation and solution of partial differential equations of mathematical physics; Fourier series and transform methods, complex variable methods, methods of characteristics and first order equations. Prerequisite: MATH 308 or 451 or approval of instructor.
414. **Fourier Series and Wavelets.** (3-0). **Credit 3.** Fourier series and wavelets with applications to data compression and signal processing. Prerequisite: MATH 304, 311 or 323.
415. **Modern Algebra I.** (3-0). **Credit 3. I** Groups, rings, fields. Prerequisite: MATH 323.
416. **Modern Algebra II.** (3-0) **Credit 3. II** Continuation of topics introduced in MATH 415. Prerequisite: MATH 415.
417. **Numerical Analysis I.** (3-3). **Credit 4. I, II, S** Linear systems, matrix decomposition and eigensystems, numerical integration, interpolation and numerical solution of ordinary differential equations. Prerequisites: MATH 304, 311 or 323; MATH 308 or equivalent; ability to program.
419. **Applications of Actuarial Science.** (2-0). **Credit 2.** Applications of actuarial science using mathematical and statistical methods to assess risk in the insurance and finance industries; emphasis on probability, statistics, finance, and economics; focus on using probabilistic models in the estimation of insurance premiums. May be taken 2 times for credit. Prerequisite: MATH 411 or STAT 414.
423. **Linear Algebra II.** (3-0). **Credit 3. I, II, S** Eigenvalues, similarity and canonical forms, applications to differential equations and quadratic forms. Prerequisite: MATH 304 or 323, or approval of instructor.
425. **The Mathematics of Contingent Claims.** (3-0). **Credit 3.** The mathematical theory associated with asset price dynamics; binomial pricing models; Black-Scholes analysis; hedging; volatility smile; implied volatility trees; implied binomial trees. Prerequisites: MATH 172 or equivalent; MATH 308 or equivalent; basic probability.
427. **Introduction to Number Theory.** (3-0). **Credit 3.** Prime and composite integers; Euclidean algorithm; modular arithmetic; Chinese remainder theorem; unique factorization; quadratic reciprocity; Riemann zeta function; representation of numbers as a sum of squares. Prerequisites: MATH 220 and 323; junior or senior classification or approval of instructor.
431. **Structures and Methods of Combinatorics.** (3-0). **Credit 3.** Enumerative techniques generating functions, partially ordered sets, elementary graph theory, elementary Ramsey theory. Prerequisite: MATH 220 or 302 or approval of instructor.
433. **Applied Algebra.** (3-0). **Credit 3.** An introduction to groups, rings, fields with emphasis on modular arithmetic; applications to number theory, coding theory, and other areas. Prerequisites: MATH 220 or 302; MATH 304 or 323.
436. **Introduction to Topology.** (3-0). **Credit 3.** Metric spaces; continuity of metric spaces; topological spaces; basic notions; separation axioms; compactness; local compactness; connectedness; basic notions in homotopy theory; quotient spaces, paracompactness and topological manifolds. Prerequisites: MATH 220 and 221 or approval of instructor.
439. **Differential Geometry of Curves and Surfaces.** (3-0). **Credit 3.** Local and global theory of parameterized curves; regular surfaces, local coordinates, first fundamental form, orientation, area; Gauss map, second fundamental form; Gauss Bonnet theorem; additional topics to be selected by the instructor. Prerequisites: MATH 308 and 323 or approval of instructor.
442. **Mathematical Modeling.** (3-0). **Credit 3.** The construction of mathematical models from areas such as economics, game theory, integer programming, mathematical biology and mathematical physics. Prerequisites: MATH 304 and 308 or equivalents.

446. **Principles of Analysis I.** (3-0). **Credit 3.** Construction of the real and complex numbers; topology of metric spaces, compactness and connectedness; Cauchy sequences, completeness and the Baire Category Theorem; Continuous Mappings; introduction to Point-Set Topology. Prerequisites: MATH 409; junior or senior classification.
447. **Principles of Analysis II.** (3-0). **Credit 3.** II Riemann-Stieltjes integration; sequences and series of functions; the Stone-Weierstrass and Arzela-Ascoli Theorems; introduction to Lebesgue measure theory and integration. Prerequisites: MATH 446 or approval of instructor; junior or senior classification.
451. **Theory of Ordinary Differential Equations.** (3-0). **Credit 3.** Existence and uniqueness of solutions to differential equations, linear systems, nonlinear equations, stability analysis, qualitative behavior of solutions, and modeling with differential equations. Prerequisites: MATH 323 or equivalent; MATH 308 or equivalent.
460. **Tensors and General Relativity.** (3-0). **Credit 3.** Vectors and tensors in special relativity, curvature, manifolds, covariant differentiation, Einstein field equations, Schwarzschild geometry and black holes, cosmology, gauge field theories. Prerequisites: MATH 308; PHYS 311 or MATH 323 or MATH 311; junior or senior classification.
467. **Modern Geometry.** (3-0). **Credit 3.** Rigorous development of Euclidean Geometry; Classic non-Euclidean models; Matrix representations of transformations in  $\mathbb{R}^3$ ; Isometries; Transformation and symmetric groups; Similarity and Affine transformations. Prerequisite: MATH 304 or 323.
469. **Introduction to Mathematical Biology.** (3-0). **Credit 3.** Introduction to mathematical modeling techniques in the biological sciences; continuous versus discrete models; deterministic versus stochastic models; includes population dynamics and ecology, spread of infectious diseases, population genetics and evolution, spatial pattern formation. Prerequisites: MATH 304, 308 or equivalent.
470. **Communications and Cryptography.** (3-0). **Credit 3.** Introduction to coded communications, digital signatures, secret sharing, one-way functions, authentication, error control and data compression. Prerequisites: MATH 304 or 323 and CSCE 110 and approval of instructor.
471. **Communications and Cryptography II.** (3-0). **Credit 3.** Additional topics in coded communications; information and entropy, elliptical curves, error corrections, quantum methods. Prerequisites: MATH 470 or consent of instructor.
482. **Research Seminar.** (3-0). **Credit 3.** Problems, methods and recent developments in mathematics, with emphasis on student projects, and written and oral presentations. May be repeated for credit. Prerequisites: MATH 409 or 415 (may be taken concurrently); junior or senior classification; approval of instructor.
485. **Directed Studies.** **Credit 1 to 8.** I, II, S Special problems in mathematics not covered by any other course in the curriculum. Work may be in either theory or laboratory. Prerequisite: Approval of department head.
489. **Special Topics in...** **Credit 1 to 4.** I, II, S Selected topics in an identified area of mathematics. May be repeated for credit. Prerequisite: Approval of instructor.
490. **The Putnam Challenge.** (1-0). **Credit 1.** Intensive individualized training for preparation for the Putnam Exam, a national contest for mathematics majors. May be taken four times for credit. Prerequisites: Approval of instructor; junior or senior classification.
491. **Research.** **Credit 1 to 3.** Active research of basic nature under supervision of Department of Mathematics or affiliated department graduate faculty member. Students can earn a maximum of 4 hours of credit to use in their degree plans. Registration in multiple sections of this course is possible within a given semester provided that the per semester credit hour limit is not exceeded. Prerequisites: Mathematics or Applied Mathematical Sciences major; junior classification or approval of mathematics advisor.