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Basic commutative algebra and classical algebraic geometry. Introduction to Programming for Data Science. Prerequisite: MATH 233B MATH 234A. MATH 298C. Prerequisite: MATH 205A Concurrent with MATH H140B. Mathematics of Cryptography. Prerequisite: MATH H140B. Mathematical and Computational Biology. Mathematical Modeling in Biology II. Riemannian manifolds, connections, curvature and torsion. Restriction: School of Physical Sciences students have first consideration for enrollment. School of Engineering students have first consideration for enrollment. Includes topics from number theory, probability, and abstract algebra. Provides practical experience to complement the theory developed in Mathematics 105A. Mathematical Modeling. MATH 134B. Satisfactory completion of the Lower-Division Writing requirement. Quantitative Economics Majors have first consideration for enrollment. Prerequisite: (MATH 2B or MATH 5B or MATH 7B or AP Calculus BC) and (MATH 3A or MATH H3A) and (MATH 13 or (ICS 6B and ICS 6D)). Combinatorics . Diophantine equations. Analysis of random processes using computer simulations. Introduction to abstract linear algebra, including bases, linear transformation, eigenvectors, canonical forms, inner products, and symmetric operators. Analytic Function Theory. Introduction to Partial Differential Equations and Applications III. Restriction: School of Physical Sciences students only. MATH 105B. Analytic number theory, character sums, finite fields, discrete logarithm, computational complexity. Number Theory II. Classification of PDEs, separation of variables and series expansions, special functions, eigenvalue problems. Honors Introduction to Linear Algebra. Prerequisite: MATH 121A. Prerequisite: MATH 218A MATH 218C. Algebraic integers, prime ideals, class groups, Dirichlet unit theorem, localization, completion, Cebotarev density theorem, L-functions, Gauss sums, diophantine equations, zeta functions over finite fields. Prerequisite: MATH 218B MATH 220A. MATH 227A Same as CS 285. Introduction to Programming for Numerical Analysis. Riemannian manifolds, connections, curvature, and torsion. General derivatives; call/put options; hedging and investment strategies: spreads and collars; risk management; forwards and futures; bonds. MATH 130A. Prerequisite: MATH 120A and (MATH 3A or MATH H3A) and MATH 13 and (MATH 120A or MATH 121A). consideration for enrollment. Topics include basic logic, set theory, equivalence relations, and various proof techniques such as direct, induction, contradiction, contrapositive, and exhaustion. Polar coordinates. Studies in the Learning and Teaching of Secondary Mathematics. Topics vary from year to year. Line and surface integrals, divergence and curl, theorems of Greens, Gauss, and Stokes. Prerequisite: MATH 280A MATH 280C. (II and Vb). Prerequisite: MATH 210C and MATH 220C MATH 260B. Combinatorial probability, conditional probabilities, independence, discrete and continuous random variables, expectation and variance, common probability distributions. Prerequisite: MATH 2B or MATH 5B or MATH 7B or (AP Calculus BC and (MATH H3A or MATH 3A)). Implicit and inverse function theorems. Provides fundamental materials in algebraic topology: fundamental group and covering space, homology and cohomology theory, and homotopy group. Honors Introduction to Graduate Analysis I. MATH 140B. Partial Differential Equations. Prerequisite: Recommended: MATH 2A and MATH 2B and MATH 3A, or equivalent. Studies in selected areas of mathematical logic, a continuation of MATH 280A-MATH 280B-MATH 280C. Prerequisite: MATH 130A or STAT 120A Overlaps with MATH 133C. Prerequisite: MATH 210C Overlaps with STAT 270. Prerequisite: MATH 140B MATH H140A. Riemann zeta function, Dirichlet L-functions, prime number theorem, zeta functions over finite fields, sieve methods, zeta functions of algebraic curves, algebraic coding theory, L-functions of modular forms, Eisenstein series. Honors Multivariable Calculus I. Construction of the real number system; topology of the real line; concepts of continuity, differential, and integral calculus; sequences and series of functions, equicontinuity, implicit functions, curves and surfaces. MATH 399. MATH H120B. Multiple scales and WKB. Weekly colloquia on topics of current interest in mathematics. MATH 274. Basic properties of rings; ideals, quotient rings; polynomial and matrix rings. Prerequisite: MATH 230C MATH 232B. Repeatability: May be repeated for credit unlimited times. (Vb) MATH 3D. MATH 140A with a grade of A or better Concurrent with MATH 205A. MATH 297. Prerequisite: MATH 295B MATH 296. Numerical Analysis II. Topics in Analysis . Intro to algorithms in data science using Python and R. Corequisite: MATH 105A MATH 105LB. Topics in Partial Differential Equations. Mathematics of Financial Derivatives. MATH 5B with a grade of A or better. Prerequisite: (MATH 3A or MATH H3A) and MATH 13 and (MATH 120A or MATH 121A). MATH 290A. MATH 121A with a grade of C or better. Students taking the course in fall will prepare for and take the Putnam examination in December. (Vb) MATH 2D. Honors Introduction to Graduate Algebra III. MATH 184L. Introduction to formal definition and rigorous proof writing in mathematics. MATH 2B with a grade of A or better. MATH 5A. Introduction to Abstract Algebra: Groups. Special emphasis on students doing proofs. MATH 162A with a grade of C- or better MATH 173A. Mathematics Majors have first consideration for enrollment. MATH 110A. Theory and techniques for linear and nonlinear partial differential equations. Corequisite: MATH 105LB Prerequisite: MATH 105A MATH 105LA. Single-Variable Calculus II. Supervised reading and research with Mathematics faculty. Mathematics of public key cryptography: encryption and signature schemes; RSA; factoring; primality testing; discrete log based cryptosystems, elliptic and hyperelliptic curve cryptography and additional topics as determined by the instructor. Theory of determinants. AP Calculus BC with a minimum score of 3 MATH 9. Explorations of applications and connections in topics in algebra, geometry, calculus, and statistics for future secondary math educators. The mathematics which is covered includes topics from number theory, probability, and abstract algebra. Studies in selected areas of differential geometry, a continuation of MATH 240A-MATH 240B-MATH 240C. Mathematical Logic. MATH 121A with a grade of C or better Restriction: Mathematics Majors have first consideration for enrollment. Prerequisite: MATH 220C and MATH 230C MATH 239B. MATH 13. Prerequisite: Recommended: MATH 150. Prerequisite: MATH 239B MATH 240A. Prerequisite: Recommended: MATH 270C. Prerequisite or corequisite: (MATH 2D or MATH H2D) and (MATH 3A or MATH H3A) and MATH 9 Restriction: Mathematics Majors have first consideration for enrollment. Green functions and integral representations, method of characteristics. MATH H2E with a grade of A or better. Canonical forms; inner products; similarity of matrices. School of Info & Computer Sci students have first consideration for enrollment. 1-4 Units. Galois theory. Prerequisite: MATH 180A Restriction: Mathematics Majors have first consideration for enrollment. Exponential, logarithmic, and trigonometric functions. Analytic Methods in Arithmetic Geometry. MATH 227B. Supervised reading. Prerequisite: (MATH 2B or MATH 5B or MATH 7B or AP Calculus BC) and (MATH 3A or MATH H3A) and MATH 13. Introduction to Topology. MATH 280B. MATH 270B. Repeatability: May be taken for credit 2 times. Prerequisite: (MATH 3A or MATH H3A) and (MATH 2D or MATH H2D) Restriction: School of Physical Sciences students have first consideration for enrollment. Special emphasis on doing proofs. Prerequisite: MATH 3D and MATH 140A MATH 118. Mathematical Modeling in Biology I. Prerequisite: MATH 230A MATH 230C. Seminar . Restriction: Business Economics Majors have first consideration for enrollment. Introduction to the theory and practice of numerical computation with an emphasis on solving equations. Prerequisite: MATH 282A MATH 282C. Calculus for Life Sciences II. MATH 2E with a grade of A or better. Prerequisite or corequisite: MATH 2A or MATH 5A or MATH 7A or AP Calculus AB or AP Calculus BC. MATH 195W. O-minimality. Prerequisite: Recommended: MATH 120B and MATH 141, or equivalent. Honors Multivariable Calculus II. Differential and integral calculus of real-valued functions of several real variables, including applications. Hodge theory applications to geometry and topology. Limit distributions for sums of independent random variables. Overview of interest theory, time value of money, annuities/cash flows with payments that are not contingent, loans, sinking funds, bonds, general cash flow and portfolios, immunization, duration and convexity, swaps. Numerical Analysis Laboratory. Honors Introduction to Graduate Algebra II. Error analysis, approximation of functions, nonlinear equations. History of Mathematics Lesson Lab. Prerequisite: MATH 230C Repeatability: Unlimited as topics vary. Group theory, homological algebra, and other selected topics. Preparation for calculus and other mathematics courses. Elliptic, parabolic, hyperbolic cases in 226A-B-C, respectively. Introduction to Cryptology II. Prerequisite: MATH 295C Repeatability: Unlimited as topics vary. Stochastic processes. Strong limit theorems. Number Theory I. Introduction to partial differential equations and their applications in engineering and science. Introduction to real analysis, including convergence of sequence, infinite series, differentiation and integration, and sequences of functions. Introduction to topological properties. Prerequisite: MATH H120B Restriction: Mathematics Honors students only. Local and global theory of partial differential equations: analytic, geometric, and functional analytic methods. Prerequisite: MATH 270B MATH 271A. 1 Unit. Overlaps with MATH 5A, MATH 7A. Undeclared Majors have first consideration for enrollment. Prerequisite: MATH 173A MATH 175. Integral calculus and multivariable calculus with applications to life sciences. Linear Algebra II. Overlaps with MATH 2A, MATH 7A. Prerequisite: MATH 260A MATH 260C. Prerequisite: MATH H120A Restriction: Mathematics Honors students only. MATH 3A. Optimization II. Prerequisite: MATH 281A MATH 281C. Prerequisite: MATH 245A Repeatability: Unlimited as topics vary. Theory of schemes, sheaves, divisors, cohomology. MATH 245C. After reviewing tools from probability, statistics, and elementary differential and partial differential equations, concepts such as hedging, arbitrage, Puts, Calls, the design of portfolios, the derivation and solution of the Blac-Scholes, and other equations are discussed. 5 Units. MATH 227A. Dynamical Systems. Exponentials, logarithms, trigonometry, polynomials, and rational functions. Techniques of mathematical writing and communication. MATH 218B. Prerequisite: (MATH 2E or MATH H2E) and MATH 3D MATH 131. AP Calculus BC with a minimum score of 4. Multivariable Calculus I. Model completeness. Standard theorems about analytic functions. Concurrent with MATH 206C. MATH 225B. MATH H140B with a grade of C- or better Concurrent with MATH 205C. Linear Algebra I. Optimization I. Concurrent with MATH H140A. Prerequisite: MATH 130B MATH 134A. MATH 120C. Corequisite: MATH 184 Prerequisite: PS 5 MATH 192. MATH 10. Introduction to Numerical Analysis and Scientific Computing. MATH 162A. Ordinals, cardinals, cardinal arithmetic, combinatorial set theory, models of set theory, Gödel's constructible universe, forcing, large cardinals, iterate forcing, inner model theory, fine structure. Prerequisite: MATH 299B. Basic set theory: models, compactness, and completeness; basic model theory; Incompleteness and Gödel's Theorems; basic recursion theory; constructible sets. Restriction: School of Biological Sciences students have first consideration for enrollment. 4 Units. Introduction to Graduate Analysis. Prerequisite: MATH 2B or MATH 5B or MATH 7B or AP Calculus B. MATH 205C. (Vb) MATH 7B. Prerequisite: MATH 120A or MATH 121A or MATH 140A. Prerequisite: (MATH 2D or MATH H2D) and MATH 3D MATH 162B. MATH 1A. Emphasis on nonstandard modeling problems. MATH 234B. Comparison theorems and their geometric applications. Basic equations and inequalities, linear and quadratic functions, and systems of simultaneous equations. Students are expected to do proofs. Measure theory, Lebesgue integral, signed measures, Radon-Nikodym theorem, functions of bounded variation and absolutely continuous functions, classical Banach spaces, Lp spaces, integration on locally compact spaces and the Riesz-Markov theorem, measure and outer measure, product measure spaces. Economics Majors have first consideration for enrollment. Applications to algebra. Applications of advanced calculus and linear algebra to the geometry of curves and surfaces in space. Honors Introduction to Graduate Analysis III. MATH 13 with a grade of C or better MATH 176. Concurrent with MATH 206A. MATH 140A. (Vb) MATH 5B. Differential Geometry. Provides practical experience to complement the theory developed in Mathematics 105B. Existence and uniqueness of solutions, continuous dependence of solutions on initial conditions and parameters, Lyapunov and asymptotic stability, Floquet theory, nonlinear systems, and bifurcations. MATH 234C. Nonhomogeneous problems and Green's functions, Sturm-Liouville theory, special Fourier expansions, applications of partial differential equations in different areas of science. Prerequisite: MATH 271B Overlaps with STAT 270. (Ib) MATH 199A. Prerequisite: MATH 210A MATH 210C. Elementary Differential Equations. AP Calculus BC with a minimum score of 3 Overlaps with MATH 7B. (Vb) MATH 2B. Prerequisite: MATH 1A. MATH 161. Introduction to Partial Differential Equations and Applications I. Rigorous treatment of basic complex analysis: analytic functions, Cauchy integral theory and its consequences, power series, residue calculus, harmonic functions, conformal mapping. Introduction to ordinary and partial differential equations and their applications in engineering and science. Algebraic Number Theory. AP Calculus AB with a minimum score of 4. MATH 299A. Prerequisite: (MATH 3A or MATH H3A) and MATH 13. MATH 220C MATH 225A. Prerequisite: MATH 282B MATH 285. Restriction: Graduate students only. MATH 225C. AP Calculus BC with a minimum score of 3 Overlaps with ICS 6N, MATH H3A. Elements of the theories of groups, rings, fields, modules. Prerequisite: MATH 2A or MATH 5A or MATH 7A or ICS 6D Restriction: Mathematics Majors have first consideration for enrollment. Prerequisite: (MATH 2E or MATH H2E) and (MATH 3A or MATH H3A) and 13 and MATH 121A and MATH 140A. Infinite sequences and series. MATH 112A. Prerequisite: MATH 1B or AP Calculus AB or SAT Mathematics or ACT Mathematics. Real Analysis. Probability. Prerequisite: MATH 280B MATH 281A. Prerequisite: MATH 250B MATH 260A. Prerequisite: MATH 5A or MATH 2A or MATH 7A or AP Calculus AB or AP Calculus BC. Harmonic functions. MATH H3A with a grade of B- or better. AP Calculus BC with a minimum score of 3 Restriction: Mathematics Majors have first consideration for enrollment. MATH 199B. Omitting types theorems. Geodesics, minimal submanifolds, first and second fundamental forms, variational formulas. Undeclared Majors only. Elementary Analysis I. Approximation theory. Introduction to number theory and applications. Mathematics Colloquium. Linear transformations and their matrix representations. MATH H2D. Other topics as time permits. Introduction to Differential Geometry II. MATH 194. Mathematics of Finance. AP Calculus AB with a minimum score of 3. Set Theory. Corequisite: MATH 107 MATH 110A. Differential calculus with applications to life sciences. Numerical Differential Equations Laboratory. Topics in Mathematical Logic. Second variation and Legendre condition. Quick treatment of functional and nonlinear analysis background: weak solution, Lp spaces, Sobolev spaces. MATH H2D with a grade of B- or better Overlaps with MATH 2E. MATH 140A with a grade of C or better. Mathematical and Computational Biology . Introduction to Cryptology I. Probability II. Overlaps with MATH 2A, MATH 5A. Linear algebra; differential equations models; dynamical systems; stability; hysteresis; phase plane analysis; applications to cell biology, viral dynamics, and infectious diseases. Numerical Differential Equations. Grading Option: Workload Credit Letter Grade with P/NP. Prerequisite: MATH 220A MATH 220C. Introduction to computers and programming using Matlab and Mathematica. Basic concepts of Python, store, access, and manipulate data in lists; functions, methods, and packages; NumPy, Numerical stability, and accuracy. Morley's theorem. Joint distributions, sums of independent random variables, conditional distributions and conditional expectation, covariances, moment generating functions, limit theorems. Prerequisite: MATH 140A MATH 147. MATH 140C. Prerequisite: MATH 117. MATH 271B. Topics addressed vary each quarter. MATH 298A. MATH 239A. MATH 110B. Selected topics, such as theory of stochastic processes, martingale theory, stochastic integrals, stochastic differential equations. Representation of numbers and precision, input/output, functions, custom data types, testing/debugging, reading exceptions, plotting data, numerical differentiation, basics of algorithms. Numerical linear algebra, numerical solutions of differential equations; stability. Prerequisite: MATH 232A MATH 232C. MATH 226A. Introduction to Manifolds and Geometry. Prerequisite: (MATH 2D or MATH H2D) and (MATH 3A or MATH H3A) and MATH 13. Placement into MATH 1B via the Calculus Placement exam, or a score of 450 or higher on the Mathematics section of the SAT Reasoning Test. Computational Differential Equations. Lagrange interpolation; Gaussian quadrature; Fourier series and transforms; Methods from data science including least squares and L1 regression. MATH 226B. Functional Analysis. Introduction to the theory and practice of numerical computation with an emphasis on topics from calculus and approximation theory. Mathematical Models for Finance. The simplex method, interior point method, penalty barrier method, primal dual method, augmented Lagrangian method, and stochastic gradient method. Advanced topics as time permits. Systems of linear equations, matrix operations, determinants, eigenvalues, eigenvectors, vector spaces, subspaces, and dimension. MATH H140C. Definite integrals; the fundamental theorem of calculus. Topics in Differential Geometry. MATH 110A with a grade of C or better Restriction: Mathematics Majors have first consideration for enrollment. Analytical methods. University Teaching. Vector spaces, linear independence, bases, dimension. Applications of integration including finding areas and volumes. Introduction to modern abstract linear algebra. Topics in Algebra Prerequisite: MATH 140A. Equilibria and periodic solutions. Introduction to combinatorics including basic counting principles, permutations, combinations, binomial coefficients, inclusion-exclusion, derangements, ordinary and exponential generating functions, recurrence relations, Catalan numbers, Stirling numbers, and partition numbers. Corequisite: MATH 105B MATH 107. The differential and integral calculus of vector-valued functions. Prerequisite: MATH 233A MATH 233C. MATH 134C. Prerequisite: MATH 2A or MATH 5A or MATH 7A or AP Calculus AB or AP Calculus BC. Prerequisite: MATH 220B MATH 222A. Perturbation methods: approximate solution of differential equations. MATH 121A. Introduction to coding theory. Congruences. School of Engineering students only. (Vb) MATH H2E. Repeatability: May be taken for credit for 4 units as topics vary. Several Complex Variables and Complex Geometry. Model-theoretic constructions. Jacobians, Inverse and Implicit Function theorems. Prerequisite: MATH 245B Repeatability: Unlimited as topics vary. Numerical Analysis I. Probability I. Modern Geometry. MATH 140A with a grade of C- or better Restriction: Mathematics Majors have first consideration for enrollment. Covers the same material as MATH 2D-E, but with a greater emphasis on the theoretical structure of the subject matter. Prerequisite: MATH 218A Repeatability: Unlimited as topics vary. Covers effectively writing mathematical papers, creating effective presentations, and communicating mathematics in a variety of media. Introduction to ODEs and dynamical systems: existence and uniqueness. Fixed Income. Satisfies no requirements other than contribution to the 180 units required for graduation. Artinian, Noetherian, and semisimple rings and modules. Prerequisite: MATH 230B MATH 232A. Prerequisite: MATH 130A or STAT 120A MATH 130C. Finite difference and finite element methods. MATH 3A with a grade of A or better Overlaps with MATH 2D. Probability spaces, distribution and characteristic functions. Prerequisite: Recommended: MATH 140C or equivalent. Arithmetic functions. Concurrent with MATH 206B. 4 Workload Units. Application to life sciences: genetics, tissue growth and patterning, cancers, ion channels gating, signaling networks, morphogen gradients. MATH H3A. Probability spaces, distribution, and characteristic functions. MATH 230B. Languages, structures, compactness, and completeness. Quadratic residue. Prerequisite: MATH 120A. MATH 120A with a grade of A or better. 2-4 Units. Prerequisite: MATH 120B MATH H120A. Prerequisite: MATH 227A MATH 227C. Analytical and numerical methods for dynamical systems, temporal-spatial dynamics, steady state, stability, stochasticity. Mathematical modeling and analysis of phenomena that arise in engineering physical sciences, biology, economics, or social sciences. Explorations in Functions and Modeling. Prerequisite: MATH 134B or MATH 133A Overlaps with MATH 133B. Introduction to Mathematical Logic. The Theory of Differential Equations. Grading Option: Pass/no pass only. Prerequisite: MATH 3A or MATH H3A Same as ECON 135. Prerequisite: Recommended: MATH 3D and MATH 112A and (MATH 140B or MATH 105B), or equivalent. Axioms for group theory; permutation groups, matrix groups. Placement via the Calculus Placement exam (fee required) is also accepted. Prerequisite: Recommended: MATH 2E and MATH 3A and MATH 13, or equivalent. MATH 299C. Basic methods for classical PDEs (potential, heat, and wave equations). Prerequisite: MATH 210C. Algebraic curves and surfaces, Riemann-Roch theorem, Jacobians, classification of curves and surfaces. Restriction: MATH 1B may not be taken for credit if taken after MATH 2A. Aspiring math teachers research, design, present, and peer review middle school or high school math lessons that draw from history of mathematics topics. Prerequisite: MATH 2A or MATH 5A or AP Calculus AB or AP Calculus BC or MATH 7A. SAT Mathematics with a minimum score of 650. Several Complex variables, d-bar problems, Kaehler geometry, de Rham and Dolbeault Theorems, Chern Classes, Hodge Theorems, Calabi conjecture, Kahler-Einstein geometry. Monge-Ampere. Algebraic Geometry. MATH 121A with a grade of A or better. Prerequisite: MATH 230C MATH 233B. Prerequisite: MATH 210B MATH 211A. Provides practical experience to complement the theory developed in Mathematics 107. Rigorous treatment of multivariable differential calculus. Introduction to Abstract Algebra: Galois Theory. Model Theory. Prerequisite: MATH 2D or MATH H2D Restriction: School of Physical Sciences students have first consideration for enrollment. AP Calculus BC with a minimum score of 3 Restriction: School of Biological Sciences students have first consideration for enrollment. Theory and applications of numerical methods to initial and boundary value problems. MATH 299A Repeatability: May be repeated for credit unlimited times. MATH 299A Repeatability: May be repeated for credit unlimited times. 1 Units. differentiation techniques, optimization and difference equations. Calculus of variations: direct methods, Euler-Lagrange equation. Prerequisite: Recommended: MATH 120A and MATH 121A and MATH 121B, or equivalent. Prerequisite: MATH 299B Repeatability: May be repeated for credit unlimited times. AP Calculus BC with a minimum score of 3 Overlaps with MATH 2B, MATH 5B. AP Calculus BC with a minimum score of 5. Prerequisite: MATH 134A or MATH 133C Overlaps with MATH 133A. MATH 250A. Introduction to cryptography. Pre-Calculus II. Normed linear spaces, Hilbert spaces, Banach spaces, Stone-Weierstrass Theorem, locally convex spaces, bounded operators on Banach and Hilbert spaces, the Gelfand-Neumark Theorem for commutative C*-algebras, the spectral theorem for bounded self-adjoint operators, unbounded operators on Hilbert spaces. MATH 7B with a grade of A or better. The elements of naive set theory and the basic properties of metric spaces. Corequisite: MATH 105LA Prerequisite: MATH 3A or MATH H3A Overlaps with MAE 185. Discrete mathematical and statistical models; difference equations, population dynamics, Markov chains, and statistical models in biology. Probabilistic methods. MATH 2A. MATH 13 with a grade of C- or better Restriction: Mathematics Majors have first consideration for enrollment. Elementary Analysis II. MATH 218A.