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CALCULUS: MATH 104, the first calculus course, assumes that students have had AB Calculus or the equivalent. Students who have not had AB Calculus or did poorly in AB Calculus should take MATH 103, which provides an introduction to calculus. There are two second-semester calculus courses. Students are advised to check their major department or their program for the specific requirements. In general, Math 114 is taken by students in the natural sciences, engineering and economics. Math 114 prepares students for the more advanced Calculus courses Math 240 and 241. Those who do not plan to take Math 240 may still want to consider taking Math 114. Math 115 is for students who do not plan to take more calculus like Math 240, and want an introduction to probability and matrices. Premed students who do not need Math 114 for their majors could take Math 115. Most Wharton students may take either Calculus II course.

MATH 103, 104, 114, 115, and 170 fulfill the FORMAL REASONING & ANALYSIS General Requirement. Also, MATH 170 satisfies the NATURAL SCIENCE & MATHEMATICS General Requirement.

Students may not receive credit for two courses at the same level where the content is similar. For example, a student may not receive credit for both MATH 114 and MATH 115. The list of FORBIDDEN PAIRS of courses is (114, 115), (312, 370), (312, 412), (360, 508), (361, 509), (370, 502), (371, 503), and several statistics courses. Students are allowed to take a "topics course" such as MATH 480 more than once if the topics are different.

PROSPECTIVE MATH MAJORS should note that the "proof in mathematics" courses, 202 and 203, are recommended for the major. These are courses that are taken concurrently with Calculus. Potential majors who begin Calculus with MATH 114 or 240 usually take at least one of these courses during their freshman year. Potential majors who begin with MATH 104 often postpone their proof courses until the following year.Please see http//www.math.upenn.edu/ugrad/major.html for more information. To find out the requirements for MATH MINORS, please visit our web site http//www.math.upenn.edu/ugrad/minor.html for details. Majors and Minors could also find the most current listing of the cognate courses Majors or Minors may take at http//www.math.upenn.edu/ugrad/cognates.html

103. Introduction to Calculus. (C) Staff. This is a Formal Reasoning course.

Introduction to concepts and methods of calculus for students with little or no previous calculus experience. Polynomial and elementary transcendental functions and their applications, derivatives, extremum problems, curve-sketching, approximations; integrals and the fundamental theorem of calculus.

104. Calculus, Part I. (C) Staff.Prerequisite(s): None. Engineering students are encouraged to register for the 007 lecture and group 7 recitations. This is a Formal Reasoning course.

Brief review of High School calculus, applications of integrals, transcendental functions, methods of integration, infinite series, Taylor's theorem, and first order ordinary differential equations. Use of symbolic manipulation and graphics software in calculus.

114. Calculus, Part II. (C) Staff.Prerequisite(s): Math 104. This is a Formal Reasoning course.

Functions of several variables, vector-valued functions, partial derivatives and applications, double and triple integrals, conic sections, polar coordinates, vectors and vector calculus, first order ordinary differential equations. Applications to physical sciences. Use of symbolic manipulation and graphics software in calculus.

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115. Calculus, Part II with Probability and Matrices. (C) Staff.Prerequisite(s): Math 104. This is a Formal Reasoning course.

Functions of several variables, partial derivatives, multiple integrals, differential equations; introduction to linear algebra and matrices with applications to linear programming and Markov processes. Elements of probability and statistics. Applications to social and biological sciences. Use of symbolic manipulation and graphics software in calculus.

116. Honors Calculus. (C) Staff. This is a Formal Reasoning course.

Students who are interested in math or science might also want to consider a more challenging Honors version of Calculus II and III, Math 116 and Math 260 (the analogues of Math 114 and Math 240, respectively). These courses will cover essentially the same material as 114 and 240, but more in depth and involve discussion of the underlying theory as well as computations.

123. Community Math Teaching Project. (M) Staff.

This course allows Penn students to teach a series of hands-on activities to students in math classes at University City High School. The semester starts with an introduction to successful approaches for teaching math in urban high schools. The rest of the semester will be devoted to a series of weekly hands-on activities designed to teach fundamental aspects of geometry. The first class meeting of each week, Penn faculty teach Penn students the relevant mathematical background and techniques for a hands-on activity. During the second session of each week, Penn students will teach the hands-on activity to a small group of UCHS students. The Penn students will also have an opportunity to develop their own activity and to implement it with the UCHS students.

L/R 170. Ideas in Mathematics. (C) Natural Science & Mathematics Sector. Class of 2010 and beyond. Staff. May also be counted toward the General Requirement in Natural Science & Mathematics

Topics from among the following: logic, sets, calculus, probability, history and philosophy of mathematics, game theory, geometry, and their relevance to contemporary science and society.

180. Analytical Methods in Economics, Law, and Medicine. (M) Staff.

Elementary applications of decision analysis, game theory, probability and statistics to issues in accounting, contracting, finance, law, and medicine, amongst others.

SM 202. Proving Things: Analysis. (C) Staff. Corequisite(s): Math 104, 114 or 240.

This course focuses on the creative side of mathematics, with an emphasis on discovery, reasoning, proofs and effective communication, while at the same time studying real and complex numbers, sequences, series, continuity, differentiability and integrability. Small class sizes permit an informal, discussion-type atmosphere, and often the entire class works together on a given problem. Homework is intended to be thought-provoking, rather than skill-sharpening.

203. Proving things: Algebra. (C) Staff. Corequisite(s): Math 104, 114 or 240.

This course focuses on the creative side of mathematics, with an emphasis on discovery, reasoning, proofs and effective communication, while at the same time studying arithmetic, algebra, linear algebra, groups, rings and fields. Small class sizes permit an informal, discussion-type atmosphere, and often the entire class works together on a given problem. Homework is intended to be thought-provoking, rather than skill-sharpening.

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210. Mathematics in the Age of Information. (C) Staff.Prerequisite(s): Math 114, Math 115 or equivalent.

This course counts as a regular elective for both the Mathematics Major and Minor.
This is a course about mathematical reasoning and the media. Embedded in many stories one finds in the media are mathematical questions as well as implicit mathematical models for how the world behaves. We will discuss ways to recognize such questions and models, and how to think about them from a mathematical perspective. A key part of the course will be about what constitutes a mathematical proof, and what passes for proof in various media contexts. The course will cover a variety of topics in logic, probability and statistics as well as how these subjects can be used and abused.

SM 220. (LAW 520, PHIL220) Proof in Math, Phil, Law. Staff.

Proofs are vital to many parts of life. They arise typically in formal logic, mathematics, the testing of medication, and convincing a jury. How do you prove that the earth is essentially a sphere (in particular, not flat)? In reality, proofs arise anywhere one attempts to convince others. However, the nature of what constitutes a proof varies wildly depending on the situation -- and on whom you are attempting to convince. Convincing your math teacher or a judge is entirely different from convincing your mother or a jury. The course will present diverse views of Proof. On occasion there may be guest lecturers.

240. Calculus, Part III. (C) Staff.Prerequisite(s): Calculus II.

Linear algebra: vectors, matrices, systems of linear equations, vector spaces, subspaces, spans, bases, and dimension, eigenvalues, and eigenvectors, maxtrix exponentials. Ordinary differential equations: higher-order homogeneous and inhomogeneous ODEs and linear systems of ODEs, phase plane analysis, non-linear systems.

241. Calculus, Part IV. (C) Staff.Prerequisite(s): MATH 240.

Partial differential equations and their solutions, including solutions of the wave, heat and Laplace equations, and Sturm-Liouville problems. Introduction to Fourier series and Fourier transforms. Computation of solutions, modeling using PDE's, geometric intuition, and qualitative understanding of the evolution of systems according to the type of partial differential operator.

260. Honors Calculus, Part II. (M) Staff.Prerequisite(s): Calculus II.

This is an honors version of Math 240 which explores the same topics but with greater mathematical rigor.

312. (MATH412) Linear Algebra. (M) Staff.Prerequisite(s): MATH 240. Students who have already received credit for either Math 370, 371, 502 or 503 cannot receive further credit for Math 312 or Math 313/513. Students can receive credit for at most one of Math 312 and Math 313/513.

Linear transformations, Gauss Jordan elimination, eigenvalues and eigenvectors, theory and applications. Mathematics majors are advised that MATH 312 cannot be taken to satisfy the major requirements.

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313. (MATH513) Computational Linear Algebra. Staff.Prerequisite(s): Math 240, and some programming experience. Students who have already received credit for either Math 370, 371, 502 or 503 cannot receive further credit for Math 312 or Math 313. Students can receive credit for at most one of Math 312 and Math 313.

Many important problems in a wide range of disciplines within computer science and throughout science are solved using techniques from linear algebra. This course will introduce students to some of the most widely used algorithms and illustrate how they are actually used.

Some specific topics: the solution of systems of linear equations by Gaussian elimination, dimension of a linear space, inner product, cross product, change of basis, affine and rigid motions, eigenvalues and eigenvectors, diagonalization of both symmetric and non-symmetric matrices, quadratic polynomials, and least squares optimazation.

Applications will include the use of matrix computations to computer graphics, use of the discrete Fourier transform and related techniques in digital signal processing, the analysis of systems of linear differential equations, and singular value deompositions with application to a principal component analysis.

The ideas and tools provided by this course will be useful to students who intend to tackle higher level courses in digital signal processing, computer vision, robotics, and computer graphics.

314. (AMCS514, MATH514) Advanced Linear Algebra. Staff..Prerequisite(s): Math 114 or 115. Math 314/514 covers Linear Algebra at the advanced level with a theoretical approach. Students can receive credit for at most one of Math 312 or Math 314.

Topics will include: Vector spaces, Basis and dimension, quotients; Linear maps and matrices; Determinants, Dual spaces and maps; Invariant subspaces, Cononical forms; Scalar products: Euclidean, unitary and symplectic spaces; Orthogonal and Unitary operators; Tensor products and polylinear maps; Symmetric and skew-symmetric tensors and exterior algebra.

320. Computer Methods in Mathematical Science I. (A) Staff.Prerequisite(s): MATH 240 or concurrent and ability to program a computer, or permission of instructor.

Students will use symbolic manipulation software and write programs to solve problems in numerical quadrature, equation-solving, linear algebra and differential equations. Theoretical and computational aspects of the methods will be discussed along with error analysis and a critical comparison of methods.

321. Computer Methods in Mathematical Sciences II. (M) Staff.Prerequisite(s): MATH 320.

Continuation of MATH 320.

340. (LGIC210) Discrete Mathematics I. (M) Staff.Prerequisite(s): MATH 114 or Math 115 or permission of the instructor.

Topics will be drawn from some subjects in combinatorial analysis with applications to many other branches of math and science: graphs and networks, generating functions, permutations, posets, asymptotics.

341. (LGIC220) Discrete Mathematics II. Staff.Prerequisite(s): Math 340/Logic 210 or permission of the instructor.

Topics will be drawn from some subjects useful in the analysis of information and computation: logic, set theory, theory of computation, number theory, probability, and basic cryptography.

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350. Number Theory. (M) Staff.

Congruences, Diophantine equations, continued fractions, nonlinear congruences, and quadratic residues.

360. Advanced Calculus. (C) Staff.Prerequisite(s): MATH 240.

Syllabus for MATH 360-361: a study of the foundations of the differential and integral calculus, including the real numbers and elementary topology, continuous and differentiable functions, uniform convergence of series of functions, and inverse and implicit function theorems. MATH 508-509 is a masters level version of this course.

361. Advanced Calculus. (C) Staff.Prerequisite(s): MATH 360.

Continuation of MATH 360.

370. Algebra. (C) Staff.Prerequisite(s): MATH 240. Students who have already received credit for either Math 370, 371, 502 or 503 cannot receive further credit for Math 312 or Math 313/513. Students can receive credit for at most one of Math 312 and Math 313/513.

Syllabus for MATH 370-371: an introduction to the basic concepts of modern algebra. Linear algebra, eigenvalues and eigenvectors of matrices, groups, rings and fields. MATH 502-503 is a masters level version of this course.

371. Algebra. (C) Staff.Prerequisite(s): MATH 370. Students who have already received credit for either Math 370, 371, 502 or 503 cannot receive further credit for Math 312 or Math 313/513. Students can receive credit for at most one of Math 312 and Math 313/513.

Continuation of MATH 370.

410. (AMCS510, MATH299) Complex Analysis. (C) Staff.Prerequisite(s): MATH 240 or permission of instructor.

Complex numbers, DeMoivre's theorem, complex valued functions of a complex variable, the derivative, analytic functions, the Cauchy-Riemann equations, complex integration, Cauchy's integral theorem, residues, computation of definite integrals by residues, and elementary conformal mapping.

420. (AMCS520) Ordinary Differential Equations. (C) Staff.Prerequisite(s): MATH 240 permission of instructor.

After a rapid review of the basic techniques for solving equations, the course will discuss one or more of the following topics: stability of linear and nonlinear systems, boundary value problems and orthogonal functions, numerical techniques, Laplace transform methods.

425. (AMCS525) Partial Differential Equations. (A) Staff.Prerequisite(s): MATH 240 or permission of instructor. Knowledge of PHYS 150-151 will be helpful.

Method of separation of variables will be applied to solve the wave, heat, and Laplace equations. In addition, one or more of the following topics will be covered: qualitative properties of solutions of various equations (characteristics, maximum principles, uniqueness theorems), Laplace and Fourier transform methods, and approximation techniques.

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430. (AMCS530) Introduction to Probability. (M) Staff.Prerequisite(s): MATH 240.

Random variables, events, special distributions, expectations, independence, law of large numbers, introduction to the central limit theorem, and applications.

432. (AMCS532) Game Theory.. (C) Staff.

A mathematical approach to game theory, with an emphasis on examples of actual games. Topics will include mathematical models of games, combinatorial games, two person (zero sum and general sum) games, non-cooperating games and equilibria.

460. (MATH500) Topology. (M) Staff.Prerequisite(s): MATH 240/241.

Point set topology: metric spaces and topological spaces, compactness, connectedness, continuity, extension theorems, separation axioms, quotient spaces, topologies on function spaces, Tychonoff theorem. Fundamental groups and covering spaces, and related topics.

465. (MATH501) Differential Geometry. (M) Staff.Prerequisite(s): MATH 361 or Permission of the instructor.

Differential geometry of curves in the plane and in 3-space;n gauge theories Surfaces in 3-space; The geometry of the Gauss map;ons. The language of Intrinsic geometry of surfaces; Geodesics; Moving frames; of vector bundles, The Gauss-Bonnet Theorem; Assorted additional topics.

501. (MATH465) Geometry-Topology, Differential Geometry. (M) Staff.Prerequisite(s): Math 240, Math 312 (or 370), and Math 361 (or 508); or Math 500; or with the permission of the instructor.

The course moves from a study of extrinsic geometry (curves and surfaces in n-space) to the intrinsic geometry of manifolds. After a review of vector calculus and a section on tensor algebra, we study manifolds and their intrinsic geometry, including metrics, connections, geodesics, and the Riemann curvature tensor. Topics include Eulerian curvature and Euler's theorems, the Gauss map and first/second fundamental forms, the Theorema Egregium, minimal surfaces in n-space; other topics as time permits.

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480. Topics in Modern Math. (M) Staff.Prerequisite(s): A year of analysis at the 300 level or above (for example, Mathematics 360-361,508-509); a semester of linear algebra at the 300 level or above (for example, Mathematics 370).

Mathematics 480 will open with a review of the basics of real analysis (brief or extended background requires). The review will include: introduction of the real numbers through Dedekind cuts, continuity of real-valued functions on the real line; Cantor nested-interval principle, basic results for continuous functions, Maximum and Intermediate Value theorems, Heine-Borel Theorem, Uniform Continuity on closed intervals; metric spaces, convergence of sequences, Cauchy sequences, completeness, more general uniform continuity and intermediate value theorems; general topology, separation, compactness, product spaces, Tychonoff's Theorem.

Special topics in analysis: Weierstrass Polynomial Approximation Theorem, Bernstein polynomials and simultaneous approxfunctions and derivatives, topics from divergent series, summation methods; r measure theory, the Lebesgue integral, Lp spaces, Holder, Minkowski, and and Cauchy-Schwarz inequalities; basics of Functional Analysis, normed spaces, Banach spaces and Hilbert space, with examples (Lp spaces, continuous-functions spaces), Banach spaces and spectral theory, groups and Fourier transforms, Tauberian theorems; approximation theory, again, through the prism of functional analysis; extension of the polynomial approximation theorem (Stone-Weierstrass theorem), Muntz approximation theorem (by polynomials with preassigned powers), compact operators, the Spectral theorem, Stone's theorem (resprsentations of the additive group of real numbers); Peter-Weyl theory (represenations of compact groups). A selection from these topics as time and class preparation allow.

499. Supervised Study. (C) Staff.Prerequisite(s): Permission of major adviser. Hours and credit to be arranged

Study under the direction of a faculty member. Intended for a limited number of mathematics majors.

500. (MATH460) Geometry-Topology, Differential Geometry. (M) Staff.Prerequisite(s): Math 240/241.

Point set topology: metric spaces and topological spaces, compactness, connectedness, continuity, extension theorems, separation axioms, quotient spaces, topologies on function spaces, Tychonoff theorem. Fundamental groups and covering spaces, and related topics.

502. Abstract Algebra. (A) Staff.Prerequisite(s): Math 240. Students who have already received credit for either Math 370, 371, 502 or 503 cannot receive further credit for Math 312 or Math 313/513. Students can receive credit for at most one of Math 312 and Math 313/513.

An introduction to groups, rings, fields and other abstract algebraic systems, elementary Galois Theory, and linear algebra -- a more theoretical course than Math 370.

503. Abstract Algebra. (B) Staff.Prerequisite(s): Math 502 or with the permission of the instructor. Students who have already received credit for either Math 370, 371, 502 or 503 cannot receive further credit for Math 312 or Math 313/513. Students can receive credit for at most one of Math 312 and Math 313/513.

Continuation of Math 502.

504. Graduate Proseminar in Mathematics. (A) Staff.

This course focuses on problems from Algebra (especially linear algebra and multilinear algebra) and Analysis (especially multivariable calculus through vector fields, multiple integrals and Stokes theorem). The material is presented through student solving of problems. In addition there will be a selection of advanced topics which will be accessible via this material.

MATHEMATICS
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505. Graduate Proseminar in Mathematics. (B) Staff.

This course focuses on problems from Algebra (especially linear algebra and multilinear algebra) and Analysis (especially multivariable calculus through vector fields, multiple integrals and Stokes theorem). The material is presented through student solving of problems. In addition there will be a selection of advanced topics which will be accessible via this material.

508. Advanced Analysis. (A) Staff.Prerequisite(s): Math 240/241. Math 200/201 also recommended.

Construction of real numbers, the topology of the real line and the foundations of single variable calculus. Notions of convergence for sequences of functions. Basic approximation theorems for continuous functions and rigorous treatment of elementary transcendental functions. The course is intended to teach students how to read and construct rigorous formal proofs. A more theoretical course than Math 360.

509. Advanced Analysis. (B) Staff.Prerequisite(s): Math 508 or with the permission of the instructor. Linear algebra is also helpful.

Continuation of Math 508. The Arzela-Ascoli theorem. Introduction to the topology of metric spaces with an emphasis on higher dimensional Euclidean spaces. The contraction mapping principle. Inverse and implicit function theorems. Rigorous treatment of higher dimensional differential calculus. Introduction to Fourier analysis and asymptotic methods.

520. (MATH702) Selections from Algebra. (M) Staff. Corequisite(s): Math 502 or permission of the instructor.

Informal introduction to such subjects as homological algebra, number theory, and algebraic geometry.

512. Advanced Linear Algebra. Staff.Prerequisite(s): Math 114 or 115. Math 512 covers Linear Algebra at the advanced level with a theoretical approach. Students can receive credit for at most one of Math 312 and Math 512.

Topics will include: Vector spaces, Basis and dimension, quotients; Linear maps and matrices; Determinants, Dual spaces and maps; Invariant subspaces, Cononical forms; Scalar products: Euclidean, unitary and symplectic spaces; Orthogonal and unitary operators; Tensor products and polylinear maps; Symmetric and skew-symmetric tensors and exterior algebra.

513. (MATH313) Computational Linear Algebra. Staff.

A number of important and interesting problems in a wide range of disciplines within computer science are solved by recourse to techniques from linear algebra. The goal of this course will be to introduce students to some of the most important and widely used algorithms in matrix computation and to illustrate how they are actually used in various settings. Motivating applications will include: the solution of systems of linear equations, applications matrix computations to modeling geometric transformations in graphics, applications of the Discrete Fourier Transform and related techniques in digital signal processing, the solution of linear least squares optimization problems and the analysis of systems of linear differential equations. The course will cover the theoretical underpinnings of these problems and the numerical algorithms that are used to perform important matrixcomputations such as Gaussian Elimination, LU Decomposition and Singular Value Decomposition.

514. (AMCS514, MATH314) ADVANCED LINEAR ALGEBRA.

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521. Selections from Algebra. (M) Staff. Corequisite(s): Math 502 or permission of the instructor.

Informal introduction to such subjects as homological algebra, number theory, and algebraic geometry.

524. Topics in Modern Applied Algebra. (M) Staff.Prerequisite(s): Math 371 or Math 503.

Topics such as automata, finite state languages, Boolean algebra, computers and logical design will be discussed.

525. Topics in Modern Applied Algebra. (M) Staff.Prerequisite(s): Math 371 or Math 503.

Topics such as automata, finite state languages, Boolean algebra, computers and logical design will be discussed.

530. Mathematics of Finance. (M) Staff.Prerequisite(s): Math 240, Stat 430.

This course presents the basic mathematical tools to model financial markets and to make calculations about financial products, especially financial derivatives. Mathematical topics covered: stochastic processes, partial differential equations and their relationship. No background in finance is assumed.

540. (MATH730) Selections from Classical and Functional Analysis. (M) Staff. Corequisite(s): Math 508 or permission of the instructor.

Informal introduction to such subjects as compact operators and Fredholm theory, Banach algebras, harmonic analysis, differential equations, nonlinear functional analysis, and Riemann surfaces.

546. (STAT930) Probability Theory. (A) Staff.

The required background is (1) enough math background to understand proof techniques in real analysis (closed sets, uniform covergence, fourier series, etc.) and (2) some exposure to probability theory at an intuitive level (a course at the level of Ross's probability text or some exposure to probability in a statistics class).

After a summary of the necessary results from measure theory, we will learn the probabist's lexicon (random variables, independence, etc.). We will then develop the necessary techniques (Borel Cantelli lemmas, estimates on sums of independent random variables and truncation techniques) to prove the classical laws of large numbers. Next come Fourier techniques and the Central Limit Theorem, followed by combinatorial techniques and the study of random walks.

547. (STAT531) Stochastic Processes. (M) Staff.Prerequisite(s): Math 546/Stat 530 or the equivalent.

Markov chains, Markov processes, and their limit theory. Renewal theory. Martingales and optimal stopping. Stable laws and processes with independent increments. Brownian motion and the theory of weak convergence. Point processes.

548. Topics in Analysis. (M) Staff.Prerequisite(s): Math 360/361 and Math 370; or Math 508/509 and Math 502.

Topics may vary but typically will include an introduction to topological linear spaces and Banach spaces, and to Hilbert space and the spectral theorem. More advanced topics may include Banach algebras, Fourier analysis, differential equations and nonlinear functional analysis.

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549. Topics in Analysis. (M) Staff.Prerequisite(s): Math 548 or with the permission of the instructor.

Continuation of Math 548.

560. (MATH760) Selections from Geometry and Topology. (M) Staff. Corequisite(s): Math 500 or permission of the instructor.

Informal introduction to such subjects as homology and homotopy theory, classical differential geometry, dynamical systems, and knot theory.

561. Selections from Geometry and Topology. (M) Staff. Corequisite(s): Math 500 or permission of the instructor.

Informal introduction to such subjects as homology and homotopy theory, classical differential geometry, dynamical systems, and knot theory.

580. Combinatorial Analysis and Graph Theory. (M) Staff.Prerequisite(s): Permission of the instructor.

Generating functions, enumeration methods, Polya's theorem, combinatorial designs, discrete probability, extremal graphs, graph algorithms and spectral graph theory, combinatorial and computational geometry.

570. (LGIC310, PHIL410) Introduction to Logic and Computability. (M) Staff.Prerequisite(s): Math 371 or Math 503.

Propositional logic: semantics, formal deductions, resolution method. First order logic: validity, models, formal deductions; Godel's completeness theorem, Lowenheim-Skolem theorem: cut-elimination, Herbrand's theorem, resolution method.Computability: finite automata, Turing machines, Godel's incompleteness theorems. Algorithmically unsolvable problems in mathematics.

SM 571. (CIS 518, LGIC320, MATH671, PHIL412) Topics in Logic. (M) Staff.Prerequisite(s): Math 570 or with the permission of the instructor.

Continuation of Math 570.

575. Mathematical Theory of Computation. (M) Staff.Prerequisite(s): Math 574 or with the permission of the instructor.

Continuation of Math 574.

581. Combinatorial Analysis and Graph Theory. (M) Staff.Prerequisite(s): Math 580 or with the permission of the instructor.

Continuation of Math 580.

582. (AMCS701) Applied Mathematics and Computation. (M) Staff.Prerequisite(s): Math 240-241. Math 312, Math 360. Knowledge of Math 412 and Math 508 is recommended.

This course offers first-hand experience of coupling mathematics with computing and applications. Topics include: Random walks, randomized algorithms, information theory, coding theory, cryptography, combinatorial optimization, linear programming, permutation networks and parallel computing. Lectures will be supplemented by informal talks by guest speakers from industry about examples and their experience of using mathematics in the real world.

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583. Applied Mathematics and Computation. (M) Staff.Prerequisite(s): Math 582 or with the permission of the instructor.

Continuation of Math 582.

584. (BE 584) The Mathematics of Medical Imaging and Measurement. (M) Staff..Prerequisite(s): Math 241, knowledge of linear algebra and basic physics.

In the last 25 years there has been a revolution in image reconstruction techniques in fields from astrophysics to electron microscopy and most notably in medical imaging. In each of these fields one would like to have a precise picture of a 2 or 3 dimensional object which cannot be obtained directly.The data which is accesible is typically some collection of averages. The problem of image reconstruction is to build an object out of the averaged data and then estimate how close the reconstruction is to the actual object. In this course we introduce the mathematical techniques used to model measurements and reconstruct images. As a simple representative case we study transmission X-ray tomography (CT).In this context we cover the basic principles of mathematical analysis, the Fourier transform, interpolation and approximation of functions, sampling theory, digital filtering and noise analysis.

585. The Mathematics of Medical Imaging and Measurement. (M) Staff.Prerequisite(s): Math 584 or with the permission of the instructor.

Continuation of Math 584.

586. (BIOL586) Topics in Mathematical Biology. Staff.Prerequisite(s): Math 430 or equivalent is required. Math 241 and 340 are recommended.

This course will cover various mathematical models and tools that are used to study modern biological problems. The specific emphasis will vary from year to year, but typically will include an introduction to stochastic processes and computational methods that arise in evolutionary biology and population genetics. No prior knowledge of biology is needed to take this course, but a strong background in probability and familiarity with algorithms and combinatorics will be assumed.

594. (PHYS500) Advanced Methods in Applied Mathematics. (M) Staff.Prerequisite(s): Math 241 or Permission of Instructor. Physics 151 would be helpful for undergraduates.

Introduction to mathematics used in physics and engineering, with the goal of developing facility in classical techniques. Vector spaces, linear algebra, computation of eigenvalues and eigenvectors, boundary value problems, spectral theory of second order equations, asymptotic expansions, partial differential equations, differential operators and Green's functions, orthogonal functions, generating functions, contour integration, Fourier and Laplace transforms and an introduction to representation theory of SU(2) and SO(3). The course will draw on examples in continuum mechanics, electrostatics and transport problems.

599. Independent Study. (C)

600. Topology and Geometric Analysis. (A) Staff.Prerequisite(s): Math 500/501 or with the permission of the instructor.

Differentiable functions, inverse and implicit function theorems. Theory of manifolds: differentiable manifolds, charts, tangent bundles, transversality, Sard's theorem, vector and tensor fields and differential forms: Frobenius' theorem, integration on manifolds, Stokes' theorem in n dimensions, de Rham cohomology. Introduction to Lie groups and Lie group actions.

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601. Topology and Geometric Analysis. (B) Staff.Prerequisite(s): Math 600 or with the permission of the instructor.

Covering spaces and fundamental groups, van Kampen's theorem and classification of surfaces. Basics of homology and cohomology, singular and cellular; isomorphism with de Rham cohomology. Brouwer fixed point theorem, CW complexes, cup and cap products, Poincare duality, Kunneth and universal coefficient theorems, Alexander duality, Lefschetz fixed point theorem.

605. First Year Seminar in Mathematics. (B) Staff..Prerequisite(s): Open to first year Mathematics graduate students. Others need permission of the instructor.

Continuation of Math 604.

602. Algebra. (A) Staff.Prerequisite(s): Math 370/371 or Math 502/503.

Group theory: permutation groups, symmetry groups, linear algebraic groups, Jordan-Holder and Sylow theorems, finite abelian groups, solvable and nilpotent groups, p-groups, group extensions. Ring theory: Prime and maximal ideals, localization, Hilbert basis theorem, integral extensions, Dedekind domains, primary decomposition, rings associated to affine varieties, semisimple rings, Wedderburn's theorem, elementary representation theory. Linear algebra: Diagonalization and canonical form of matrices, elementary representation theory, bilinear forms, quotient spaces, dual spaces, tensor products, exact sequences, exterior and symmetric algebras. Module theory: Tensor products, flat and projective modules, introduction to homological algebra, Nakayama's Lemma. Field theory: separable and normal extensions, cyclic extensions, fundamental theorem of Galois theory, solvability of equations.

603. Algebra. (B) Staff.Prerequisite(s): Math 602 or with the permission of the instructor.

Continuation of Math 602.

604. First Year Seminar in Mathematics. (A) Staff.Prerequisite(s): Open to first year Mathematics graduate students. Others need permission of the instructor.

This is a seminar for first year Mathematics graduate student, supervised by faculty. Students give talks on topics from all areas of mathematics at a level appropriate for first year graduate students. Attendance and preparation will be expected by all participants, and learning how to present mathematics effectively is an important part of the seminar.

608. (AMCS608) Analysis. (C) Staff.Prerequisite(s): Math 508-509.

Complex analysis: analyticity, Cauchy theory, meromorphic functions, isolated singularities, analytic continuation, Runge's theorem, d-bar equation, Mittlag-Leffler theorem, harmonic and sub-harmonic functions, Riemann mapping theorem, Fourier transform from the analytic perspective. Introduction to real analysis: Weierstrass approximation, Lebesgue measure in Euclidean spaces, Borel measures and convergence theorems, C0 and the Riesz-Markov theorem, Lp-spaces, Fubini Theorem.

609. (AMCS609) Analysis. (C) Staff.Prerequisite(s): Math 608 or permission of the instructor.

Real analysis: general measure theory, outer measures and Cartheodory construction, Hausdorff measures, Radon-Nikodym theorem, Fubini's theorem, Hilbert space and L2-theory of the Fourier transform. Functional analysis: normed linear spaces, convexity, the Hahn-Banach theorem, duality for Banach spaces, weak convergence, bounded linear operators, Baire category theorem, uniform boundedness principle, open mapping theorem, closed graph theorem, compact operators, Fredholm theory, interpolation theorems, Lp-theory for the Fourier transform.

MATHEMATICS
(AS) {MATH}

618. Algebraic Topology, Part I. (A) Staff.Prerequisite(s): Math 600/601 or with the permission of the instructor.

Homotopy groups, Hurewicz theorem, Whitehead theorem, spectral sequences. Classification of vector bundles and fiber bundles. Characteristic classes and obstruction theory.

619. Algebraic Topology, Part I. (B) Staff.Prerequisite(s): Math 618 or with the permission of the instructor.

Rational homotopy theory, cobordism, K-theory, Morse theory and the h-corbodism theorem. Surgery theory.

634. ARITHMETIC GEOMETRY.

642. Topics in Partial Differential Equations. Staff.Prerequisite(s): Math 608, 609. This course will not presume courses in Partial Differential Equations or Differential Geometry. Background will be covered in the course.

Problems in differential geometry, as well as those in physics and engineering, inevitable involve partial derivatives. This course will be an introduction to these problems and techniques. We will use P.D.E. as a tool. Some of the applications will be small, some large. The proof of the Hodge Theorem will be a small application. Discussion of the Yamabe problem and ricci flow (used to prove the Poincare Conjecture) will be larger.

SM 878. Probability and Algorithm Seminar. Staff..

Seminar on current and recent literature in probability and algorithm.

SM 879. Seminar on additive combinatorics.. Staff..

Advanced Graduate Courses

612. Selections from Algebra. (M) Staff. Corequisite(s): MATH 600 and 602.

Informal introduction to such subjects as homological algebra, number theory, and algebraic geometry.

Algebra

620. Algebraic Number Theory. (M) Staff.Prerequisite(s): Math 602/603.

Dedekind domains, local fields, basic ramification theory, product formula, Dirichlet unit theory, finiteness of class numbers, Hensel's Lemma, quadratic and cyclotomic fields, quadratic reciprocity, abelian extensions, zeta and L-functions, functional equations, introduction to local and global class field theory. Other topics may include: Diophantine equations, continued fractions, approximation of irrational numbers by rationals, Poisson summation, Hasse principle for binary quadratic forms, modular functions and forms, theta functions.

621. Algebraic Number Theory. (M) Staff.Prerequisite(s): Math 620 or with the permission of the instructor.

Continuation of Math 620.

MATHEMATICS
(AS) {MATH}

622. Complex Algebraic Geometry. (M) Staff.Prerequisite(s): Math 602/603 and Math 609.

Algebraic geometry over the complex numbers, using ideas from topology, complex variable theory, and differential geometry. Topics include: Complex algebraic varieties, cohomology theories, line bundles, vanishing theorems, Riemann surfaces, Abel's theorem, linear systems, complex tori and abelian varieties, Jacobian varieties, currents, algebraic surfaces, adjunction formula, rational surfaces, residues.

623. Complex Algebraic Geometry. (M) Staff.Prerequisite(s): Math 622 or with the permission of the instructor.

Continuation of Math 622.

624. Algebraic Geometry. (M) Staff.Prerequisite(s): Math 602/603.

Algebraic geometry over algebraically closed fields, using ideas from commutative algebra. Topics include: Affine and projective algebraic varieties, morphisms and rational maps, singularities and blowing up, rings of functions, algebraic curves, Riemann Roch theorem, elliptic curves, Jacobian varieties, sheaves, schemes, divisors, line bundles, cohomology of varieties, classification of surfaces.

625. Algebraic Geometry. (M) Staff.Prerequisite(s): Math 624 or with the permission of the instructor.

Continuation of Math 624.

626. Commutative Algebra. (M) Staff.Prerequisite(s): Math 602/603.

Topics in commutative algebra taken from the literature. Material will vary from year to year depending upon the instructor's interests.

627. Commutative Algebra. (M) Staff.Prerequisite(s): Math 602/603.

Topics in commutative algebra taken from the literature. Material will vary from year to year depending upon the instructor's interests.

628. Homological Algebra. (M) Staff.Prerequisite(s): Math 602/603.

Complexes and exact sequences, homology, categories, derived functors (especially Ext and Tor). Homology and cohomology arising from complexes in algebra and geometry, e.g. simplicial and singular theories, Cech cohomology, de Rham cohomology, group cohomology, Hochschild cohomology. Projective resolutions, cohomological dimension, derived categories, spectral sequences. Other topics may include: Lie algebra cohomology, Galois and etale cohomology, cyclic cohomology, l-adic cohomology. Algebraic deformation theory, quantum groups, Brauer groups, descent theory.

629. Homological Algebra. (M) Staff.Prerequisite(s): Math 628 or with the permission of the instructor.

Continuation of Math 628.

Algebraic and Differential Topology

MATHEMATICS
(AS) {MATH}

630. Differential Topology. (M) Staff.Prerequisite(s): Math 600/601.

Fundamentals of smooth manifolds, Sard's theorem, Whitney's embedding theorem, transversality theorem, piecewise linear and topological manifolds, knot theory. The instructor may elect to cover other topics such as Morse Theory, h-cobordism theorem, characteristic classes, cobordism theories.

631. Differential Topology. (M) Staff.Prerequisite(s): Math 630 or with the permission of the instructor.

Continuation of Math 630.

632. Topological Groups. (M) Staff.Prerequisite(s): Math 600/601 and Math 602/603.

Fundamentals of topological groups. Haar measure. Representations of compact groups. Peter-Weyl theorem. Pontrjagin duality and structure theory of locally compact abelian groups.

633. Topological Groups. (M) Staff.Prerequisite(s): Math 632 or with the permission of the instructor.

Continuation of Math 632.

638. Algebraic Topology, Part II. (C) Staff.Prerequisite(s): Math 618/619.

Theory of fibre bundles and classifying spaces, fibrations, spectral sequences, obstruction theory, Postnikov towers, transversality, cobordism, index theorems, embedding and immersion theories, homotopy spheres and possibly an introduction to surgery theory and the general classification of manifolds.

639. Algebraic Topology, Part II. (C) Staff.Prerequisite(s): Math 638 or with the permission of the instructor.

Continuation of Math 638.

Classical Analysis

640. Ordinary Differential Equations. (M) Staff.Prerequisite(s): Math 508/509.

The general existence and uniqueness theorems for systems of ordinary differential equations and the dependence of solutions on initial conditions and parameters appearing in the equation. The proofs of existence and uniqueness are related to numerical algorithms for finding approximate solutions for systems of ODE's. We consider special properties of constant coefficient and linear systems. We then present the theory of linear equations with analytic coefficients, the theories of singular points, indicial roots and asymptotic solutions. We then turn to boundary value problems for second order equations with an emphasis on the eigenfunction expansions associated with self adjoint boundary conditions and the Sturm comparison theory. The remaining time is devoted to topics; for example: Hamiltonian systems and symplectic geometry, singular boundary value problems, perturbation theory, the Lyapounov-Schmidt theory and the Poincare-Bendixson theorem, the equations of mathematical physics, the calculus of variations, symmetries of ODE's and transformation groups.

641. Ordinary Differential Equations. (M) Staff.Prerequisite(s): Math 640 or with the permission of the instructor.

Continuation of Math 640

MATHEMATICS
(AS) {MATH}

644. Partial Differential Equations. (M) Staff.Prerequisite(s): Math 600/601, Math 608/609.

Subject matter varies from year to year. Some topics are: the classical theory of the wave and Laplace equations, general hyperbolic and elliptic equations, theory of equations with constant coefficients, pseudo-differential operators, and non-linear problems. Sobolev spaces and the theory of distributions will b developed as needed.

650. Lie Algebras. (M) Staff.Prerequisite(s): Math 602/603.

Connections with Lie groups, universal enveloping algebras, Poincare-Birkhoff-Witt Theorem, Lie and Engels theorems, free Lie algebras, Killing form, semisimple algebras, root systems, Dynkin diagrams, classification of complex simple Lie algebras, representation theory of Lie algebras, cohomology of Lie algebras.

645. Partial Differential Equations. (M) Staff.Prerequisite(s): Math 600/601, Math 608/609.

Subject matter varies from year to year. Some topics are: the classical theory of the wave and Laplace equations, general hyperbolic and elliptic equations, theory of equations with constant coefficients, pseudo-differential operators, and nonlinear problems. Sobolev spaces and the theory of distributions will be developed as needed.

646. Several Complex Variables. (M) Staff.Prerequisite(s): Math 600/601, Math 608/609.

Analytic spaces, Stein spaces, approximation theorems, embedding theorems, coherent analytic sheaves, Theorems A and B of Cartan, applications to the Cousin problems, and the theory of Banach algebras, pseudoconvexity and the Levi problems.

647. Several Complex Variables. (M) Staff.Prerequisite(s): Math 646 or with the permission of the instructor.

Continuation of Math 646.

Functional Analysis

651. Lie Algebras. (M) Staff.Prerequisite(s): Math 650 or with the permission of the instructor.

Continuation of Math 650.

652. Operator Theory. (M) Staff.

Subject matter may include spectral theory of operators in Hilbert space, C*-algebras, von Neumann algebras.

653. Operator Theory. (M) Staff.

Subject matter may include spectral theory of operators in Hilbert space, C*-algebras, von Neumann algebras.

654. Lie Groups. (M) Staff.Prerequisite(s): Math 600/601, Math 602/603.

Connection of Lie groups with Lie algebras, Lie subgroups, exponential map. Algebraic Lie groups, compact and complex Lie groups, solvable and nilpotent groups. Other topics may include relations with symplectic geometry, the orbit method, moment map, symplectic reduction, geometric quantization, Poisson-Lie and quantum groups.

MATHEMATICS
(AS) {MATH}

655. Lie Groups. (M) Staff.Prerequisite(s): Math 654 or with the permission of the instructor.

Continuation of Math 654.

656. Representation of Continuous Groups. (M) Staff.

Possible topics: harmonic analysis on locally compact abelian groups; almost periodic functions; direct integral decomposition theory, Types I, II and III: induced representations, representation theory of semisimple groups.

657. (PHYS657) Representation of Continuous Groups. (M) Staff.

Possible topics: harmonic analysis on locally compact abelian groups; almost periodic functions; direct integral decomposition theory, Types I, II and III: induced representations, representation theory of semisimple groups.

Differential Geometry

660. Differential Geometry. (M) Staff.Prerequisite(s): Math 600/601, Math 602/603.

Riemannian metrics and connections, geodesics, completeness, Hopf-Rinow theorem, sectional curvature, Ricci curvature, scalar curvature, Jacobi fields, second fundamental form and Gauss equations, manifolds of constant curvature, first and second variation formulas, Bonnet-Myers theorem, comparison theorems, Morse index theorem, Hadamard theorem, Preissmann theorem, and further topics such as sphere theorems, critical points of distance functions, the soul theorem, Gromov-Hausdorff convergence.

661. Differential Geometry. (M) Staff.Prerequisite(s): Math 660 or with the permission of the instructor.

Continuation of Math 660.

Other Subjects

SM 670. (LGIC320, PHIL412, PHIL416, PHIL516) Topics in Logic. (M) Staff.Prerequisite(s): Math 570/571.

Discusses advanced topics in logic.

SM 671. (CIS 518, LGIC320, MATH571, PHIL412) Topics in Logic. (M) Staff.Prerequisite(s): Math 570/571.

Discusses advanced topics in logic.

676. (CIS 610) Advanced Geometric Methods in Computer Science. (M) Staff.Prerequisite(s): Math 312 or Math 412, or with the permission of the instructor.

Advanced geometric methods used in geometric modeling,computer graphics, computer vision, and robotics.

MATHEMATICS
(AS) {MATH}

680. Applied Linear Analysis. (M) Staff.Prerequisite(s): Math 241 and one semester of: Math 360/361 or Math 508/509.

Application of techniques from linear algebra to real problems in economics, engineering, physics, etc. and the difficulties involved in their implementation. Particular emphasis is placed on solving equations, the eigenvalue problem for symmetric matrices and the metric geometry of spaces of matrices. Applications to problems such as options pricing, image reconstruction, airplane and ship design, oil prospecting, etc. (these topics will vary from year to year). Analysis of the numerical algorithms available to solve such problems, rates of convergence, accuracy and stability.

681. Applied Linear Analysis. (M) Staff.Prerequisite(s): Math 680 or with the permission of the instructor.

Continuation of Math 680.

693. Numerical Analysis. (M) Staff.Prerequisite(s): Math 692 or with the permission of the instructor.

Continuation of Math 692.

690. Topics in Mathematical Foundations of Program Semantics. (M) Staff.

This course discusses advanced topics in mathematical foundations of semantics of programming languages and programming structures.

"What is to distinguish a digital dollar when it is as easily reproducible as the spoken word? How do we converse privately when every syllable is bounced off a satellite and smeared over an entire continent? How should a bank know that it really is Bill Gates requesting from his laptop in Fiji a transfer of $100,000,.....,000 to another bank? Fortunately, the mathematics of cryptography can help. Cryptography provides techniques for keeping information secret, for determining that information has not been tampered with, and for determing who authored pieces of information." (From the Foreword by R. Rivest to the "Handbook of Applied Cryptography" by Menezes, van Oorschot, and Vanstone.)

Textbook: Douglas R. Stinson. "Cryptography: Theory and Practice". Publisher: Chapman & Hall/ CRC; 3 edition (November 1, 2005) ISBN: 1584885084.

691. Topics in Mathematical Foundations of Program Semantics. (M) Staff.

The course discusses advanced topics in mathematical foundations of semantics of programming languages and programming structures.

692. Numerical Analysis. (M) Staff.Prerequisite(s): Math 320/321.

A study of numerical methods for matrix problems, ordinary and partial differential equations, quadrature and the solution of algebraic or transcendental equations. Emphasis will be on the analysis of those methods which are particularly suited to automatic high-speed computation.

694. (PHYS654) Mathematical Foundations of Theoretical Physics. (M) Staff.

Selected topics in mathematical physics, such as mathematical methods of classical mechanics, electrodynamics, relativity, quantum mechanics and quantum field theory.

695. (PHYS655) Mathematical Foundations of Theoretical Physics. (M) Staff.

Selected topics in mathematical physics, such as mathematical methods of classical mechanics, electrodynamics, relativity, quantum mechanics and quantum field theory.

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696. (PHYS656) Topics in Mathematical Physics and String Theory. (M) Staff.Prerequisite(s): Math 694 or permission of the instructor.

This interdisciplinary course discusses advanced topics in mathematical physics. Topics may include elliptic operators, heat kernels, complexes and the Atiyah-Singer index theorem, Feynman graphs and anomalies, computing Abelian and non-Abelian anomalies, and the relation of anomalies to the index theorem.

697. (PHYS657) Topics in Mathematical Physics and String Theory. (M) Staff.Prerequisite(s): Math 696 or permission of the instructor.

Continuation of Math 696. Topics may include the family index theorem, equivariant cohomology and loop spaces, the homological algebra of BRST invariance and the Wess-Zumino consistency condition, the descent equations, and worldsheet anomalies in string theory.

Advanced Topics Courses

702. (MATH520) Topics in Algebra. (M) Staff.

Topics from the literature. The specific subjects will vary from year to year.

703. Topics in Algebra. (M) Staff.

Topics from the literature. The specific subjects will vary from year to year.

720. Advanced Number Theory. (M) Staff.Prerequisite(s): Math 620/621.

Ramification theory, adeles and ideles, Tate's thesis, group cohomology and Galois cohomology, class field theory in terms of ideles and cohomology, Lubin-Tate formal groups, Artin and Swan conductors, central simple algebras over local and global fields, general Hasse principles. Other topics may include the following: zero-dimensional Arakelov theory, Tate duality, introduction to arithmetic of elliptic curves, local and global epsilon factors in functional equations, p-adic L-functions and Iwasawa theory, modular forms and functions and modular curves.

721. Advanced Number Theory. (M) Staff.Prerequisite(s): Math 720 or with the permission of the instructor.

Continuation of Math 720.

724. Topics in Algebraic Geometry. (M) Staff.Prerequisite(s): Either Math 622/623 or Math 624/625.

Topics from the literature. The specific subjects will vary from year to year.

725. Topics in Algebraic Geometry. (M) Staff.Prerequisite(s): Either Math 622/623 or Math 624/625.

Topics from the literature. The specific subject will vary from year to year.

730. (MATH560) Topics in Algebraic and Differential Topology. (M) Staff.Prerequisite(s): Math 618/619.

Topics from the literature. The specific subjects will vary from year to year.

MATHEMATICS
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731. Topics in Algebraic and Differential Topology. (M) Staff.Prerequisite(s): Math 618/619.

Topics from the literature. The specific subjects will vary from year to year.

748. Topics in Classical Analysis. (M) Staff.Prerequisite(s): Math 608 and Math 609 and permission from the instructor.

Harmonic analysis in Euclidean space, Riemann surfaces, Discontinuous groups and harmonic analysis in hyperbolic space, Pseudodifferential operators and index theorems, Variational methods in non-linear PDE, Hyperbolic equations and conservation laws, Probability and stochastic processes, Geometric measure theory, Applications of analysis to problems in differential geometry. The specific subjects will vary from year to year.

749. Topics in Classical Analysis. (M) Staff.Prerequisite(s): Math 748 or with the permission of the instructor.

Continuation of Math 748.

753. Topics in Operator Theory. (M) Staff.

Topics from the literature. The specific subjects will vary from year to year.

750. Topics in Functional Analysis. (M) Staff.

Topics from the literature. The specific subjects will vary from year to year.

751. Topics in Functional Analysis. (M) Staff.

Topics from the literature. The specific subjects will vary from year to year.

752. Topics in Operator theory. (M) Staff.

Topics from the literature. The specific subjects will vary from year to year.

760. (MATH560) Topics in Differential Geometry. (M) Staff.Prerequisite(s): Math 660/661.

Topics from the literature. The specific subjects will vary from year to year.

761. Topics in Differential Geometry. (M) Staff.Prerequisite(s): Math 660/661.

Topics from the literature. The specific subjects will vary from year to year.

794. Physics for Mathematicians. (M) Staff.Prerequisite(s): Math 694. Corequisite(s): Math 695.

This course is designed to bring mathematicians with no physics background up to speed on the basic theories of physics: mechanics,relativity,quantum mechanics,classical fields,quantum filed theory, the standard model,strings,superstrings,and M-theory.

Graduate Seminars

SM 820. Algebra Seminar. (M) Staff.

Seminar on current and recent literature in algebra.

MATHEMATICS
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SM 821. Algebra seminar. (M) Staff.

Seminar on current and recent literature in algebra.

SM 824. Seminar in Algebra, Algebraic Geometry, Number Theory. (M) Staff.

Seminar on current and recent literature in algebra, algebraic geometry, and number theory.

SM 825. Seminar in Algebra, Algebraic Geometry, Number Theory. (M) Staff.

Seminar on current and recent literature in algebra, algebraic geometry, and number theory.

SM 830. Geometry-Topology Seminar. (M) Staff.

Seminar on current and recent literature in geometry-topology

SM 831. Geometry-Topology Seminar. (M) Staff.

Seminar on current and recent literature in geometry-topology

SM 840. Analysis Seminar. (M) Staff.

Seminar on current and recent literature in analysis.

SM 841. Analysis Seminar. (M) Staff.

Seminar on current and recent literature in analysis.

SM 844. Seminar in Partial Differential Equations. (M) Staff.

Seminar on current and recent literature in partial differential equations.

SM 845. Seminar in Partial Differential Equations. (M) Staff.

Seminar on current and recent literature in partial differential equations.

SM 850. Seminar in Functional Analysis. (M) Staff.

Seminar on current and recent literature in functional analysis.

SM 851. Seminar in Functional Analysis.. (M) Staff.

Seminar on current and recent literature in functional analysis.

SM 860. Seminar in Riemannian Geometry. (M) Staff.

Seminar on current and recent literature in Riemannian geometry.

SM 861. Seminar in Riemannian Geometry. (M) Staff.

Seminar on current and recent literature in Riemannian geometry.

MATHEMATICS (AS) {MATH}

SM 870. Logic Seminar. (M) Staff.

Seminar on current and recent literature in logic.

SM 871. Logic Seminar. (M) Staff.

Seminar on current and recent literature in logic.

SM 872. Seminar in Logic and Computation. (M) Staff.

Seminar on current and recent literature in logic and computation.

SM 873. Seminar in Logic and Computation. (M) Staff.

Seminar on current and recent literature in logic and computation.

SM 880. Combinatorics Seminar. (M) Staff.

Seminar on current and recent literature in combinatorics.

SM 881. Combinatorics Seminar. (M) Staff.

Seminar on current and recent literature in combinatorics.