MATH6001
Advanced Calculus I

MATH6002
Advanced Calculus II
This is a direct continuation of Math 6001 with the emphasis on the calculus of mappings between general Euclidean spaces. Material covered includes: linear maps, differentiability, partial derivatives, differentiability of functions whose partial derivatives are continuous, chain rule, Jacobian, inverse and implicit function theorems. Uniform convergence of sequences of functions, Arzela-Ascoli theorem. Basics of Fourier series. Students will be expected to have completed MATH 6001 or the equivalent. Credit Level:U,G Credit Hrs:4 Pre-req: See your college advisor for details. Baccalaureate Competency: Critical Thinking, Effective Communication, Information Literacy, Knowledge Integration.

MATH6003
Abstract Linear Algebra
The course will study topics in linear algebra in the abstract setting, including abstract vector spaces, subspaces, isomorphisms, quotient spaces, linear independence, basis, dimension. Additional topics include linear functionals, duals, codimension, linear mappings, null space, range, Rank-Nullity theorem, transpositions, similarity, projections, matrices, Gaussian elimination, determinants, eigenvalues, eigenvectors, Spectral Mapping and Cayley-Hamilton theorems, minimal and characteristic polynomials, similarity of matrices, canonical forms. Credit Level:U,G Credit Hrs:3 Pre-req: See your college advisor for details. Baccalaureate Competency: Critical Thinking, Effective Communication, Information Literacy, Knowledge Integration.

MATH6004
Group Theory

MATH6005
Introduction to Complex Analysis
Complex numbers considered algebraically and geometrically, polar form, powers and roots, derivative of complex-valued functions, analyticity, Cauchy-Riemann equations, harmonic functions, elementary functions, and their derivatives, visualization of complex-valued functions, conformal mapping, elementary functions as conformal mappings, integration of complex-valued functions, Cauchy's Integral Theorem, Cauchy's Integral Formula, residue theory and applications, basics of Mobius transformations. Students will be expected to have a strong background in multivariable calculus (MATH 2063). Credit Level:U,G Credit Hrs:3 Baccalaureate Competency: Critical Thinking, Effective Communication, Knowledge Integration.
MATH6006
Numerical Analysis
Topics will include floating point arithmetic, rootfinding for nonlinear equations, fixed point analysis, stability, interpolation theory, least squares methods for function approximation and numerical methods for integration. A primary focus is on the use of Taylor's theorem to analyze the methods. The analysis will be emphasized here instead of computation. Carefully chosen model or prototype problems will be examined in order to furnish theorems and insight into the behavior of the approximation methods. Credit Level: U,G Credit Hrs: 3 Baccalaureate Competency: Critical Thinking, Effective Communication, Information Literacy, Knowledge Integration.

MATH6007
Partial Differential Equations and Fourier Analysis

MATH6008
Applied Probability and Stochastic Processes
A review of random variables and probability theory with an emphasis on conditioning as a technique for computing probabilities and expectations. Detailed study of discrete and continuous time Markov chains and Poisson processes, with introduction to one or more of the following: martingales, Brownian motion, random walks, renewal theory. Students will be expected to have a working knowledge of multivariable calculus (MATH 2063), linear algebra (MATH 2076) and an introduction to probability (STAT 2037 or MATH 4008). Credit Level: U,G Credit Hrs: 3 Baccalaureate Competency: Critical Thinking, Effective Communication, Information Literacy, Knowledge Integration, Social Responsibility.

MATH6010
Probabilistic Aspects of Financial Modeling
This course begins with models for finite financial markets in discrete time, covering derivatives, arbitrage pricing, market completeness, trading strategies, replicating portfolios, and risk neutral measures in this context, and constructing single and multiple period binomial tree models for modeling stock prices and pricing options. Then the analogous continuous time theory is developed. Concepts and techniques from probability and stochastic processes are introduced, including Brownian motion, martingales and stochastic calculus, in order to derive the martingale (risk-neutral) approach to solving the Black-Scholes p.d.e. and pricing a variety of financial contracts and derivatives. This course will be useful for students preparing for the Financial Economics segment of Actuarial Exam M. Credit Level: U,G Credit Hrs: 3 Pre-req: See your college advisor for details. Baccalaureate Competency: Critical Thinking, Effective Communication, Information Literacy, Knowledge Integration, Social Responsibility.

MATH6011
Computational Financial Mathematics
The course covers financial mathematics from the basics to advanced techniques and concepts. Financial mathematics and corresponding mathematical concepts are explained and derived mathematically while being implemented through programming in Mathematica at the same time. No knowledge of Mathematica is required, but will be gained quickly, as it is used extensively. Topics include: Elementary stochastic differential equation (SDE); Monte-Carlo simulations; Ito chain rule; Log-Normal market model; derivation of the Black-Scholes partial differential equation (PDE) - pricing and hedging in complete markets; statistics of SDEs; statistical and implied volatility; local volatility pricing models and numerical PDEs; American options and free boundary problems; optimal portfolio theory; introduction to pricing and hedging in incomplete markets. Students will be expected to have a strong background in multivariable calculus (MATH 2063), differential equations (MATH 2073), linear algebra (MATH 2076), and an introduction to probability theory (STAT 2037). Credit Level: U,G Credit Hrs: 3 Baccalaureate Competency: Critical Thinking, Effective Communication, Information Literacy, Knowledge Integration, Social Responsibility.
MATH6012
Applied Linear Algebra
Gaussian elimination, matrix operations, LDU factorization, inverses. Vector spaces, basis and dimension, the fundamental subspaces of a matrix. Linear transformations, matrix representations, change of bases. Orthogonality, Gram-Schmidt method, QR factorization, projections, least squares. Determinants, properties and applications. Eigenvalues and eigenvectors, diagonalization of a matrix, similarity transformations, symmetric matrices, applications to difference equations and differential equations. The Jordan form. Credit Level:U,G Credit Hrs:3 Baccalaureate
Competency: Critical Thinking, Effective Communication, Information Literacy, Knowledge Integration, Social Responsibility.

MATH6015
Mathematical Programming
Applications of mathematical programming using packages such as MATLAB and Mathematica. Projects will encompass calculus, linear algebra, and differential equations. Students will be expected to have a working knowledge of multivariable calculus (MATH 2063), linear algebra (MATH 2076), and differential equations (MATH 2073). Credit Level:U,G Credit Hrs:3 Baccalaureate Competency: Critical Thinking, Effective Communication, Information Literacy, Knowledge Integration, Social Responsibility.

MATH6048
Advanced Topics in Math/Stat I
The course will vary according to the topic. Credit Level:U,G Credit Hrs:2 - 4 Pre-req: See your college advisor for details. Baccalaureate Competency: Critical Thinking.

MATH6049
Advanced Topics in Math/Stat II
The course will vary according to the topic. Credit Level:U,G Credit Hrs:2 - 4 Baccalaureate Competency: Critical Thinking.

MATH6051
Applied Ordinary Differential Equations
This course is intended for undergraduates and for graduate students in other departments; it is not intended for graduate students in the mathematical sciences. It covers the theory of ordinary differential equations, with an emphasis on applications. Basic concepts, special types of differential equations of the first order, and problems that lead to them. Linear differential equations of order greater than one and problems that lead to them. Linear vector spaces. Systems of differential equations, linearization of first order systems, problems giving rise to systems. Existence and uniqueness theorem for first order differential equations. Existence and uniqueness theorem for a system of first order differential equations and for linear and nonlinear differential equations of order greater than one. Wronskians. Other supplementary topics: state variable description of systems, fundamental matrix, state transition matrix, matrix exponential, stability of linear systems. Time permitting: Operators and Laplace transforms, series methods. Credit Level:U,G Credit Hrs:3 Baccalaureate Competency: Critical Thinking, Information Literacy, Knowledge Integration, Social Responsibility.

MATH7001
Complex Analysis
MATH7002
Real Analysis

MATH7003
Rings, Fields and Galois Theory
Rings, homomorphisms and ideals, quotient rings, integral domains and fraction fields, prime and irreducible elements. Unique factorization domains, principal ideal domains and Euclidean domains, Gauss’ lemma.Fields and field extensions, algebraic and transcendental elements, adjunction of roots, finite fields.Galois theory: splitting fields, normal and separable extensions, the Main Theorem of Galois theory. Cyclic and cyclotomic extensions, solvable and radical extensions, insolvability of the quintic equation. Credit Level:G Credit Hrs:3. Pre-req: See your college advisor for details.

MATH7004
Topology
Pointset topology (approximately 10 weeks): Topological spaces, closed sets, subspaces, closure, boundary, interior, connectedness, path-connectedness, compactness, normal topology, Hausdorff property, continuity at a point (topological continuity and sequential continuity), continuous maps, Urysohn metrization theorem, Tietze extension theorem, quotient topology, weak topology, Baire category theorem, nets, convergence with respect to nets.Fundamental groups (approximately 4 weeks): Homotopy of paths, homotopy of maps, fundamental groups, fundamental groups of (i) circles, (ii) spheres, (iii) torii, (iv) Möbius strip and (v) Klein bottle, free groups, simply connected spaces, covering spaces, homotopy lifting theorem. Credit Level:G Credit Hrs:3. Pre-req: See your college advisor for details.

MATH7005
Ordinary Differential Equations
Linear systems: linear systems with constant coefficients, phase portraits and dynamical classification, linear systems and exponentials of operators, linear systems and canonical forms of operators.Fundamental theory: existence and uniqueness, continuity and differentiability of solutions in initial conditions, extending solutions, global solutions.Nonlinear systems: nonlinear sinks and sources, hyperbolicity, stability, limit sets, gradient and Hamiltonian systems, other topics at instructor's discretion. Credit Level:G Credit Hrs:3. Pre-req: See your college advisor for details.

MATH7006
Partial Differential Equations

MATH7011
Advanced Mathematical Modeling
Mathematical modeling with ordinary and partial differential equations is used to simulate and understand physical systems in a broad range of applications in fields including engineering, physics, chemistry, biology and sociology. This course, which is intended for graduate students in Mathematics, Engineering, Physics, and Chemistry, will introduce techniques used to derive these types of models as well as a wide range of methods to solve them including non-dimensionalization, qualitative analysis, regular and singular perturbations, traveling waves, and scientific computing. Possible example problems involving solidification, phase separation, physiological flow, enzyme kinetics, population growth, neuronal networks, calcium dynamics, glycolysis, climate change, and tumor growth will be given to illustrate the modeling and solution techniques. Students will be expected to have a strong background in single- and multivariable calculus (MATH 1062, 2063), differential equations (MATH 2073), linear algebra (MATH 2076), and basic computer programming skills. Credit Level:G Credit Hrs:3.
MATH7047
Individual Work in Graduate Mathematical Sciences
Individual Work in Graduate Mathematical Sciences allows students to focus on topics outside the standard curriculum in Mathematics and
Statistics. Students work closely with faculty to develop reading lists and assignments. Permission of the Graduate Program Director and Graduate
Advisor is required. Credit Level: G Credit Hrs: 1 - 8

MATH7071
Algebra & Number Theory 1
Properties of the Integers, Rationals, Reals, Complexes and Integers mod m. Solutions of linear and quadratic equations. Division and Euclidean
algorithm. Prime factorization. Number theoretic functions, representations of numbers. Credit Level: G Credit Hrs: 3

MATH7072
Algebra & Number Theory 2
Theory of primes and factorization in Euclidean domains especially the Gaussian Integers and polynomial rings over subfields of Complexes.
Rational and irrational numbers, constructable numbers. Credit Level: G Credit Hrs: 3

MATH7073
Probability and Statistical Inference
Probability axioms and finite probability spaces. Combinatorics. Binomial and Normal distributions. Historical topics. Design of statistical studies and
methods of statistical inference. Credit Level: G Credit Hrs: 2

MATH7074
Technology for Statistics
Spreadsheets and statistical packages for handling and exploring data, doing simulations, and illustrating concepts of statistics. Project-oriented
with cooperative learning component. Credit Level: G Credit Hrs: 1

MATH7075
Geometry 1
Axiomatic geometry, both neutral and Euclidean. Credit Level: G Credit Hrs: 3

MATH7076
Geometry 2
Transformational geometry, topics in analytical geometry Credit Level: G Credit Hrs: 3

MATH7077
Linear Algebra For Geometry
Study of vectors and linear transformations from a geometric viewpoint; the algebra of matrices. Focus is on dimensions 2 and 3; isometries and
symmetry groups. Credit Level: G Credit Hrs: 2

MATH7078
Technology for Geometry
Technology for teaching geometry including: dynamic geometry programs such as GeoGebra; computer graphics; technical word processing.
Design of lessons that use technology. Project-oriented with cooperative learning component. Credit Level: G Credit Hrs: 1

MATH7079
Analysis 1
Theory of calculus of one variable. Continuity and differentiability. Credit Level: G Credit Hrs: 3

MATH7080
Analysis 2
Theory of calculus of one variable. Riemann integral and infinite series. Credit Level: G Credit Hrs: 3
MATH7081
Mathematical Models
Development and analysis of mathematical models of continuous phenomena with special attention to topics from high school physics an chemistry. Illustrates and uses concepts from Analysis 1 and 2 Credit Level:G Credit Hrs:2

MATH7082
Technology for Calculus
Introduction to the use of technology for teaching analysis (pre-calculus and calculus). Graphing calculators, symbolic algebra programs, dynamic geometry programs. Design and delivery of lessons that use technology. Project-oriented with cooperative learning component. Credit Level:G Credit Hrs:1

MATH7083
MAT Project
This is a directed study that allows the student to pursue personal interests related to mathematics and the teaching of mathematics. Credit Level:G Credit Hrs:3

MATH8001
Geometric Function Theory
This course will cover selected topics from the following list: normal families, Arzela-Ascoli Theorem, Riemann Mapping Theorem, boundary behavior of conformal mappings, measures of distortion, conformal maps and Liouville's Theorem in higher dimensions, quasiconformal and quasiregular mappings, mappings of finite distortion, hyperbolic and other conformal metrics. Credit Level:G Credit Hrs:3

MATH8002
Geometric Analysis
This course will cover selected topics from the following list: Quasiconformal mappings between metric spaces, Uniform metric spaces and Gromov hyperbolicity, Metric space analysis, Potential theory in metric measure spaces, Geometric measure theory (Euclidean or metric space). Credit Level:G Credit Hrs:3

MATH8003
Functional Analysis

MATH8004
Operator Theory
Hilbert spaces, orthonormal bases, examples, including wavelets, Fourier series. Bounded linear operators, selfadjoints operators, projections, spectra, resolvents. Compact operators and Fredholm operators and examples from integral equations and other applications. The spectral theorem for selfadjoint operators. Unbounded operators. Examples from differential equations. Time permitting, an introduction to operator algebras. Credit Level:G Credit Hrs:3

MATH8005
Introduction to Algebraic Geometry
MATH8006
Algebra and Cryptography
This course is an introduction to Algebra and Cryptography, where we show how algebra plays the role of foundation of modern cryptography. We will first cover the basic structures of finite fields including all the basic concepts and theorems. Then we will introduce the theory of multivariate public key cryptosystems including the basics of MPKCs and constructions of MPKCs, the fundamental problems behind the security of MPKCs, and different attack and defense methods. We will next cover the basics of symmetric ciphers, their explicit constructions, the fundamental problems behind the security of symmetric ciphers and different attack and defense methods, in particular, algebraic attacks. The last topic we will cover is about the new Mutant XL family of polynomial solving algorithms and implementations. This course should enable students to develop a solid foundation in applying modern algebraic theory to cryptography. Optional topics: RSA, Diffie-hellman, Elliptic curve cryptography, factoring problem, discrete logarithm problem. Credit Level:G Credit Hrs:3

MATH8007
Advanced Stochastic Processes
Martingales, Kolmogorov's Existence Theorem, Kolmogorov's continuity criterion, Wiener process, point processes. Other examples and methods from the area of stochastic processes, depending on student interest and instructor choice. Students will be expected to have prior knowledge of either real analysis (MATH 7002) or measure-theoretic probability (STAT 7032). Credit Level:G Credit Hrs:3

MATH8008
Stochastic Differential Equations
Wiener process; Itô's integral; Itô’s chain rule and the martingale representation theorem; stochastic differential equations - existence and uniqueness; the filtering problem; Itô diffusions - generator, Kolmogorov's backward equation; Girsanov's theorem; optimal stopping problem - connection with variational inequality; stochastic control; applications drawn from finance, statistics, or second-order partial differential equations. Credit Level:G Credit Hrs:3

MATH8009
Advanced Partial Differential Equations

MATH8010
Advanced Numerical Analysis
Partial differential equations (PDEs) model a wide range of physical phenomena including heat conduction, wave propagation, and fluid flow. Computer approximations to the solutions of the PDE problems that arise in these applications are usually required. This course will focus on the finite element method (FEM) and will use energy (Hilbert space) techniques. The first part of the course will cover error analysis for ordinary differential equations from the Atkinson text (Chapter 6) and also iterative methods for matrices (Sections 8.6-8.8). The second part of this course will discuss the mathematical foundations of the FEM in Sobolev spaces and develop a basic approximation theory. Once this background is established, we will survey error estimates developed in various applications which may include first order hyperbolic equations, nonlinear time-dependent parabolic problems including the Cahn-Hilliard (phase transitions) or the Navier-Stokes (fluid flow) equations. We may also look at discontinuous Galerkin discretizations in time and space. Nonconforming methods are also of interest as well as the development of a posteriori error estimates and how they are used to design adaptive schemes. Credit Level:G Credit Hrs:3
MATH8011
Scientific Computation
Fluid-structure interaction (FSI) problems are one of the popular topics in scientific computing that can be found in nature and many engineering systems. Examples include aircrafts, bridges, aneurysms in large arteries, biofilms, and artificial heart valves. FSI problems are often very complex and hard to solve analytically so they have to be analyzed by numerical simulation. The department has expertise in a wide range of modern computational techniques including the Immersed Boundary Method, the X-FEM scheme for problems with singularities and Moving Least Squares Meshless Methods. The first two are popular in applications in the biosciences and are used for FSI problems. Leading up to the special topics above will be consideration of finite difference (FD) schemes for stationary and time-dependent partial differential equation problems, iteration techniques such as preconditioned conjugate gradients and the use of FFT’s for the FD approximation of solutions to the Poisson problem, fluid and elastodynamics problems and computational solutions, and the use of FEM packages such as PDE Tool in MATLAB. Credit Level:G Credit Hrs:3

MATH8012
Applied Mathematics Methods
While intended for Mathematics graduate students, those in Engineering, Physics, and Chemistry will also find this course useful. Techniques covered are valuable for solving, approximating, or simplifying a wide class of ordinary and partial differential equation problems modeling physical systems. These include: nondimensionalization, qualitative analysis, regular and singular perturbation techniques, multiscale analysis including two-timing, traveling waves, and modeling. Techniques are developed within applications which will vary depending on the instructor. Possible examples arise from solidification, climate change, cancer tumor growth, phase separation, kidney function, calcium dynamics, neurons and neuronal networks, enzyme kinetics, and osmotic flow. Others might focus on fluid dynamics. Here we would study theories of continuous fields including the continuum model, kinematics of deformable media, the material derivatives, field equations of continuum mechanics, and inviscid fluid flow. Students will be expected to have a working knowledge of Advanced Calculus (MATH 6002), Linear Algebra (MATH 6012), and PDEs (MATH 6007). Some knowledge of Complex Analysis (MATH 6005), ODEs (MATH 7005), and programming would be helpful. Credit Level:G Credit Hrs:3

MATH8048
Graduate Topics in Math/Stat I
The course will vary according to the topic. Credit Level:G Credit Hrs:2 - 4

MATH8049
Graduate Topics in Math/Stat II
The course will vary according to the topic. Credit Level:G Credit Hrs:2 - 4

MATH8098
Practicum in Applied Mathematics
This course is intended for graduate students who obtain internships in applied mathematics. Credit Level:G Credit Hrs:1 Pre-req: See your college advisor for details.

MATH9001
Advanced Financial Mathematics
General SDE framework for financial mathematics; complete and incomplete markets; optimal portfolio theory; non-linear PDE of portfolio optimization; neutral pricing PDE systems - linear and non-linear; indifference pricing non-linear PDE systems; general portfolio hedging formula; applications in interest rate models, equity valuation models, equity derivatives, foreign exchange models and derivatives. Credit Level:G Credit Hrs:3

MATH9040
Proseminar in the Teaching of College Mathematics
This course is meant for first year graduate students, as an introduction to teaching in a college environment. This course cannot be used to satisfy the breadth requirement for the PhD program or the credit requirement for the MS program in Math or Stat. Credit Level:G Credit Hrs:1 - 3
MATH9051
Seminar in Functional Analysis
Participants will present recent results in their area of research interest, mainly in operator theory and operator algebras. This course can be repeated. Credit Level: G Credit Hrs: 3

MATH9052
Seminar in Functional Analysis
Participants will present recent results in their area of research interest, mainly in operator theory and operator algebras. This course can be repeated. Credit Level: G Credit Hrs: 3

MATH9053
Seminar in Geometric Analysis
Participants will present recent results in their area of research interest, mainly in geometric analysis. This course can be repeated. Credit Level: G Credit Hrs: 3

MATH9054
Seminar in Geometric Analysis
Participants will present recent results in their area of research interest, mainly in geometric analysis. This course can be repeated. Credit Level: G Credit Hrs: 3

MATH9055
Seminar in Algebra
Participants will present recent results in their area of research interest in various areas of algebra and its applications to cryptography. Credit Level: G Credit Hrs: 3

MATH9056
Seminar in Algebra
Participants will present recent results in their area of research interest in various areas of algebra and its applications to cryptography. Credit Level: G Credit Hrs: 3

MATH9057
Seminar in Partial Differential Equations
Participants will present recent results in their area of research interest in various areas of partial differential equations. This course can be repeated. Credit Level: G Credit Hrs: 3

MATH9058
Seminar in Partial Differential Equations
Participants will present recent results in their area of research interest in various areas of partial differential equations. This course can be repeated. Credit Level: G Credit Hrs: 3

MATH9059
Seminar in Probability
Participants will present recent results in their area of research interest in various areas of probability. This course can be repeated. Credit Level: G Credit Hrs: 3

MATH9060
Seminar in Probability
Participants will present recent results in their area of research interest in various areas of probability. This course can be repeated. Credit Level: G Credit Hrs: 3
MATH9061
Seminar in Applied Mathematics
Participants will present recent results in their area of research interest in various areas of applied mathematics. This course can be repeated. Credit Level:G Credit Hrs:3

MATH9062
Seminar in Applied Mathematics
Participants will present recent results in their area of research interest in various areas of applied mathematics. This course can be repeated. Credit Level:G Credit Hrs:3

MATH9063
Seminar in Financial Mathematics
Participants will present recent results in their area of research interest in financial mathematics. This course can be repeated. Credit Level:G Credit Hrs:3

MATH9064
Seminar in Financial Mathematics
Participants will present recent results in their area of research interest in financial mathematics. This course can be repeated. Credit Level:G Credit Hrs:3

MATH9071
Thesis Research
Writing a doctoral dissertation. This course can be repeated. Credit Level:G Credit Hrs:1 - 12

MATH9072
Dissertation Research
Writing a doctoral dissertation. This course can be repeated. Credit Level:G Credit Hrs:1 - 12

MATH9073
Research
Research in mathematics. This course can be repeated. Credit Level:G Credit Hrs:1 - 12

MATH9074
Research
Research in mathematics. This course can be repeated. Credit Level:G Credit Hrs:1 - 12

MATH9075
Readings
Independent work on advanced mathematics texts and papers. This course can be repeated. Credit Level:G Credit Hrs:1 - 12

MATH9076
Readings
Independent work on advanced mathematics texts and papers. This course can be repeated. Credit Level:G Credit Hrs:1 - 12