MAH 4005 Exploratory Data Analysis with R: 3 semester hours
Prerequisites: MATH 1320, MATH 2000 and MATH 2450. This course covers data analysis methods with R. It introduces the basic goals and techniques of the data science process, methods of characterizing and visualizing data and building predictive and inferential models. R will be introduced at the beginning of the class and then used throughout the rest of the class.

MAH 4010 Financial Mathematics I: 3 semester hours
Prerequisites: MATH 1900 or MATH 1100, and MATH 1320 or LOG OM 3300 (or equivalents). An introduction to the theory of interest, annuities (certain), annuities with differing pay periods, amortization schedules and sinking funds.

MAH 4030 Applied Mathematics I: 3 semester hours
Prerequisite: MATH 2020 and MATH 2450. Topics chosen from Fourier series, special functions, partial differential equations, and boundary value problems.

MAH 4060 Applied Differential Equations: 3 semester hours
Prerequisites: MATH 2020 and MATH 2450. The study of ordinary differential equations and partial differential equations is continued with applications in such areas as physics, engineering and biology.

MAH 4070 Introduction to Nonlinear Optimization: 3 semester hours
Prerequisites: MATH 1320, MATH 2000, MATH 2450 and (MATH 3000 or MATH 3250). This course will introduce the theory, methods, and applications of nonlinear optimization. It will cover convex functions, convex analysis, linear and quadratic programs, semidefinite programming and other optimization problems. Topics may include duality theory, algorithms of descent method, Newton’s method and interior-point methods, and applications to signal processing, statistics and other fields will be covered. Credit cannot be earned for both MAH 4070 and MAH 5070.

MAH 4080 Introduction to Scientific Computation: 3 semester hours
Prerequisites: MATH 2000 and MATH 2450. This course will introduce fundamental algorithms in numerical linear algebra, matrix factorizations including SVD and QR, direct and iterative methods for solving linear systems, least squares problems and eigenvalue problems. Other topics covered will be chosen from numerical integration and differentiation, iterative methods for ODEs and PDEs, Discrete Fourier transform and FFT, spline smoothing and kernel smoothing. Credit cannot be earned for both MAH 4080 and MAH 5080.

MAH 4090 Introduction to High-dimensional Data Analysis: 3 semester hours
Prerequisites: MATH 1320, MATH 2000 and MATH 2450. This course introduces several advanced classical and modern techniques for modeling and analysis of high-dimensional datasets with low-dimensional structures. The topics covered in this course include principal component analysis, factor analysis, clustering-based methods, and sparse and low-rank recovery theory and algorithms. Credit cannot be earned for both MAH 4090 and MAH 5090.
**MATH 4100 Real Analysis I: 3 semester hours**
Prerequisites: MATH 3250 or consent of the instructor. Introduction to real analysis in one variable. Topics include the real number system, limits, continuity, differentiability, and sequences and series of functions.

**MATH 4160 Complex Analysis I: 3 semester hours**
Prerequisites: MATH 2000 or consent of the instructor. This course introduces complex numbers and their geometrical representation, point sets, analytic functions of a complex variable, complex integration, Taylor and Laurent series, residue theorem, and conformal mapping.

**MATH 4200 Mathematical Statistics I: 3 semester hours**
Prerequisites: MATH 1320 and MATH 2000. Introduction to the theory of probability and statistics using concepts and methods of calculus.

**MATH 4210 Mathematical Statistics II: 3 semester hours**
Prerequisites: MATH 4200. Continuation of MATH 4200. Sampling distributions, estimation theory, properties of estimators, hypothesis testing, Neyman-Pearson Theorem, likelihood ratio tests, introduction of analysis of variance and linear models. Basics of some non-parametric procedures.

**MATH 4220 Bayesian Statistical Methods: 3 semester hours**
Prerequisites: MATH 1320, MATH 2000 or MATH 1100; or consent of the instructor. This course introduces Bayesian methods in data analysis and the use of the R language and BUGS. The first half of the course covers inferential theorems and computation methods on fundamental Bayesian statistics, such as estimation, hypothesis testing, MCMC methods, model selection and hierarchical modeling. The second half of the course concentrates on particular models used in practice, such as Bayesian generalized linear models, Bayesian two-factor ANOVA, Bayesian logistic and probit models.

**MATH 4225 Introduction to Statistical Computing: 3 semester hours**
Prerequisites: MATH 1320, MATH 2000 and MATH 2450. This course will introduce fundamental algorithms in Monte Carlo methods: random variable generation, Monte Carlo integration, Monte Carlo optimization, Markov chain Monte Carlo, Metropolis-Hastings algorithm, Gibbs sampler, Langevin algorithms and Hamilton Monte Carlo, perfect, iterated and sequential importance sampling. Other topics covered may include particle systems, hidden Markov models, parallel and cloud computing. Credit cannot be earned for both MATH 4225 and MATH 5225.

**MATH 4230 Numerical Analysis I: 3 semester hours**
Prerequisites: MATH 2020, MATH 2450, and the ability to program in an upper-level language. Solutions of equations, interpolation and approximation, numerical differentiation and integration, and numerical solutions of initial value problems in ordinary differential equations. Selected algorithms will be programmed for solution on computers.

**MATH 4250 Introduction to Statistical Methods in Learning and Modeling: 3 semester hours**
Prerequisites: MATH 1320, MATH 2000 and MATH 2450. This course will introduce basic statistical principles and methods for modeling, inference, prediction and classification. The topics will be chosen from linear regression, basis expansion methods, kernel smoothing methods, model regularization, model selection and assessment, and other non-parametric methods. Credit cannot be earned for both MATH 4250 and MATH 5250.
MATH 4260 Introduction to Stochastic Processes: 3 semester hours
Prerequisites: MATH 4200. Basic theory and applications of stochastic processes. Markov chains, recurrent and transient states, stationary distributions, ergodic theorem, renewal processes, discrete martigales and stationary processes.

MATH 4350 Theory of Numbers: 3 semester hours
Prerequisites: MATH 2450 and either MATH 3000 or MATH 3250; or consent of instructor. This course examines the properties of integers, multiplicative functions, congruences, primitive roots, and quadratic residues.

MATH 4390 Topics in Probability and Statistics: 3 semester hours
Prerequisites: Consent of Instructor. A seminar on special topics in probability and statistics to be determined by the interests of the instructor. May be repeated for credit provided different topics are studied.

MATH 4400 Introduction to Abstract Algebra I: 3 semester hours
Prerequisites: MATH 2450 and MATH 3250; or consent of instructor. This course introduces groups, rings, and fields, with an emphasis on groups and rings.

MATH 4450 Linear Algebra: 3 semester hours
Prerequisites: MATH 2450 and MATH 3250; or consent of instructor. This course focuses on topics selected from vector spaces, bases, linear transformations, matrices, canonical forms, eigenvalues, hermitian and unitary matrices, inner product spaces, and quadratic forms.

MATH 4460 Introduction to Coding Theory: 3 semester hours
Prerequisites: MATH 2450 and either MATH 3000 or MATH 3250. This course is an introductory course in coding theory. Topics may include linear codes, generator and parity check matrices, dual codes, weight and distance, encoding and decoding, and the Sphere Packing Bound; various examples of codes like the Hamming codes, Golay codes, binary Reed–Muller codes, and the hexacode; Shannon’s theorem for the binary symmetric channel, upper and lower bounds on the size of linear and nonlinear codes; constructions and properties of finite fields, basic theory of cyclic codes; concepts of idempotent generator, generator polynomial, zeros of a code, and defining sets, special families of BCH and Reed-Solomon cyclic codes as well as generalized Reed-Solomon codes. Credit cannot be granted for both MATH 4460 and MATH 5460.

MATH 4500 Special Readings: 1-10 semester hours
Prerequisites: 6 credit hours at the Math 4000 level and consent of the instructor. Advanced topics in Mathematics. May be repeated for credit if the topic differs.

MATH 4550 Combinatorics: 3 semester hours
Prerequisites: MATH 2450 and either MATH 3000 or MATH 3250; or consent of instructor. This course introduces advanced counting methods including the use of generating functions for the solution of recurrences and difference equations. Additional topics may include: graphs and trees, combinatorial designs, combinatorial games, error-correcting codes, and finite-state machines.

MATH 4580 Mathematical Logic: 3 semester hours
Prerequisites: Either MATH 2450 and MATH 3250, or PHIL 4460; or consent of instructor. This course focuses on a study of the logic of mathematics by the axiomatic method, with a development of the propositional calculus and restricted predicate calculus emphasizing its application to the foundations of mathematics.
MATH 4620 Projective Geometry: 3 semester hours
Prerequisites: MATH 2000, MATH 2450, and MATH 3250; or consent of instructor. This course provides an analytic approach to the study of projective spaces. Theorems of Desargues, Pascal, and Brianchon and projective properties of conics are studied.

MATH 4660 Foundations of Geometry: 3 semester hours
Prerequisites: MATH 2450 and MATH 3250; or consent of instructor. This course focuses on a development of portions of Euclidean geometry from a selected set of axioms, including a discussion of consistency, independence, categoricity, and completeness of the axioms.

MATH 4670 Introduction to Non-Euclidean Geometry: 3 semester hours
Prerequisites: MATH 2000, MATH 2450, and MATH 3250; or consent of instructor. This course focuses on a summary of the history of the non-Euclidean geometries and a study of hyperbolic plane geometry.

MATH 4800 Introduction to Topology: 3 semester hours
Prerequisites: MATH 2000 and MATH 3250; or consent of instructor. This course focuses on the study of topological spaces, including the concepts of limit, continuity, connectedness, compactness, etc. Special emphasis is placed on, and examples taken from, the space of real numbers.

MATH 4890 Topics in Mathematics: 3 semester hours
Prerequisite: Consent of Instructor.

MATH 4995 Internship in Actuarial Science: 1-3 semester hours
Same as ECON 4995. Prerequisites: Junior standing and consent of program director. Supervised off-campus training in a private or public sector position in which the student applies the knowledge and skills learned in their actuarial science coursework. The internship is monitored by a faculty member and the student must provide a written report at the end of the project. This course may be repeated for a maximum of 6 credit hours.

MATH 5060 Computational Harmonic Analysis: 3 semester hours
Prerequisites: MATH 4030, MATH 4100 and MATH 4450. The course covers the basics of Fourier analysis and wavelet analysis. Topics include Fourier transforms and series, discrete Fourier transform, discrete cosine transform and their fast computational schemes, fast wavelet transform, and the lifting scheme. Additional topics include industrial standards for image compression and several aspects of signal processing.

MATH 5070 Nonlinear Optimization: 3 semester hours
Prerequisites: Graduate Standing. This course will introduce the theory, methods, and applications of nonlinear optimization. It will cover convex functions, convex analysis, linear and quadratic programs, semidefinite programming and other optimization problems. Topics chosen from duality theory, algorithms of descent method, Newton’s method and interior-point methods, and applications to signal processing, statistics and other fields will be covered. Topics are the same as Math 4070 but material is covered at a greater depth and additional projects/assignments are required. Credit cannot be earned for both Math 4070 and Math 5070.
MATH 5080 Scientific Computation: 3 semester hours
Prerequisites: Graduate Standing. This course will introduce fundamental algorithms in numerical linear algebra, matrix factorizations including SVD and QR, direct and iterative methods for solving linear systems, least squares problems and eigenvalue problems. Other topics covered will be chosen from numerical integration and differentiation, iterative methods for ODE’s and PDE’s, Discrete Fourier transform and FFT, spline smoothing and kernel smoothing. Topics are the same as Math 4080 but material is covered at a greater depth and additional projects/assignments are required. Credit cannot be earned for both Math 4080 and Math 5080.

MATH 5090 High-dimensional Data Analysis: 3 semester hours
Prerequisites: Graduate Standing. This course introduces several advanced classical and modern techniques for modeling and analysis of high-dimensional datasets with low-dimensional structures. The methods covered in this course include principal component analysis, factor analysis, clustering-based methods, and sparse and low-rank recovery theory and algorithms. Topics are the same as Math 4090 but material is covered at a greater depth and additional projects/assignments are required. Credit cannot be earned for both Math 4090 and Math 5090.

MATH 5100 Real Analysis II: 3 semester hours
Prerequisites: MATH 4100. Introduction to measure and integration. Topics include the Riemann-Stieltjes integral, Lebesgue measure, measurable functions, the Lebesgue integral, Radon-Nikodym and Fubini theorems and the basics of Lp-spaces.

MATH 5110 Differentiable Manifolds: 3 semester hours
Prerequisites: MATH 4100, MATH 4450, and MATH 4800. An introduction to smooth manifolds and maps. Topics will include the Implicit Function Theorem, Sard's Theorem, transversality, intersection and degree theory, differential forms and integration on manifolds.

MATH 5140 Set Theory and Metric Spaces: 3 semester hours
Prerequisites: MATH 4100 or consent of instructor. Naive set theory, cardinal arithmetic, ordinal numbers, the axiom of choice and equivalents, metric spaces, convergence, continuity, compactness, contraction principals and applications. Construction of completions and examples like real numbers and p-adic numbers. Other topics could include the Stone-Weierstrass theorem and metrizability theorems.

MATH 5160 Complex Analysis II: 3 semester hours
Prerequisites: MATH 4160 and either MATH 4100 or MATH 4800. A second course in complex analysis, emphasizing the theory of analytic functions, and including various topics like the Riemann mapping theorem, normal families, analytic continuation, representations of analytic functions, and elliptic functions.

MATH 5225 Statistical Computing: 3 semester hours
Prerequisites: Graduate Standing. This course will introduce fundamental algorithms in Monte Carlo methods: random variable generation, Monte Carlo integration, Monte Carlo optimization, Markov chain Monte Carlo, Metropolis-Hastings algorithm, Gibbs sampler, Langevin algorithms and Hamilton Monte Carlo, perfect, iterated and sequential importance sampling. Other topics covered may include particle systems, hidden Markov models, parallel and cloud computing. Topics are the same as Math 4085 but material is covered at a greater depth and additional projects/assignments are required. Credit cannot be earned for both MATH 4225 and MATH 5225.
MATH 5250 Statistical Methods in Learning and Modeling: 3 semester hours
Prerequisites: Graduate Standing. This course will introduce basic statistical principles and methods for modeling, inference, prediction and classification. The topics will be chosen from linear regression, basis expansion methods, kernel smoothing methods, model regularization, other nonparametric methods, and model selection and assessment. Topics are the same as MATH 4250 but material is covered at a greater depth and additional projects/assignments are required. Credit cannot be earned for both MATH 4250 and MATH 5250.

MATH 5320 Topics in Statistics and its Applications: 3 semester hours
Prerequisites: MATH 4210 or consent of instructor. The course studies classical and recently developed statistical procedures selected from areas including multivariate analysis, linear and non-linear models, nonparametric methods, and statistical learning. Emphasis is on applications of the procedures.

MATH 5460 Coding Theory: 3 semester hours
Prerequisites: Graduate Standing. This course is an introductory course in coding theory. Topics may include linear codes, generator and parity check matrices, dual codes, weight and distance, encoding and decoding, and the Sphere Packing Bound; various examples of codes like the Hamming codes, Golay codes, binary Reed–Muller codes, and the hexacode; Shannon’s theorem for the binary symmetric channel, upper and lower bounds on the size of linear and nonlinear codes; constructions and properties of finite fields, basic theory of cyclic codes; concepts of idempotent generator, generator polynomial, zeros of a code, and defining sets, special families of BCH and Reed–Solomon cyclic codes as well as generalized Reed–Solomon codes. Topics are the same as MATH 4460 but material is covered at a greater depth and additional projects/assignments are required. Credit cannot be granted for both MATH 4460 and MATH 5460.

MATH 5500 Directed Readings: 1-6 semester hours
Prerequisite: Consent of instructor. Independent readings at an advanced level.

MATH 5550 Topics in Advanced Math for the Teacher: 3 semester hours
Prerequisite: Consent of Instructor. This course will look at various topics in Algebra, Analysis, and Geometry that will deepen a teacher's understanding of the Mathematics of the precollegiate curriculum. It can be taken more than once for credit.

MATH 5600 Topics in Computation: 3 semester hours
Prerequisite: consent of instructor. The course will cover various advanced topics in computation, and can be taken more than once for credit. Examples of such topics are: computer graphics, computer architecture, theories of language, analysis of operating systems, numerical geometry and computer aided design, etc.

MATH 5700 Topics in Applied Mathematics: 3 semester hours
Prerequisite: consent of instructor. The course will cover various advanced topics on applied mathematics, and can be taken more than once for credit. Examples of such topics are: fast transforms, digital filters, etc.

MATH 5710 Topics in Analysis: 3 semester hours
Prerequisites: MATH 5100 or consent of instructor. Topics selected from the areas of Fourier analysis, harmonic analysis, functional analysis, special functions, generalized functions, and partial differential equations. May be taken more than once for credit with consent of department.
**MATH 5770 Advanced Topics in Nonlinear Optimization: 3 semester hours**
Prerequisites: MATH 4070 or MATH 5070; or consent of the instructor. Topics chosen from theory and algorithms of Lagrange multipliers, algorithms for solving variational inequalities, forward-backward splitting algorithms and proximal alternating minimization algorithm for non-convex optimization problems.

**MATH 5820 Topics in Algebra: 3 semester hours**
Prerequisite: Consent of instructor. Topics selected from the theory of groups, rings, fields, algebras and other algebraic systems. May be taken more than once for credit with consent of department.

**MATH 6900 Masters Thesis: 1-6 semester hours**
Prerequisite: Consent of instructor. Thesis work under the supervision of a faculty member. The course is designed for those students intending to present a thesis as part of their M.A. program. Students who do not write a thesis cannot apply MATH 6900 to a degree.

**MATH 7990 Ph.D. Dissertation Research: 1-9 semester hours**
Prerequisites: Completion of Comprehensive. May be taken for no more than nine hours.