MATHEMATICS (MATH)

MATH 96 – PREPARATORY ALGEBRA
3 credits.

Covers the necessary mathematical tools needed to succeed in our algebra course and provides fundamental mathematical skills. Topics include real numbers, linear equations and inequalities, integral and fractional exponents, polynomials and their arithmetic, polynomial equations and equations with fractional exponents, the quadratic formula and completing the square, systems of two linear equations, graphing, and problem solving using algebra and graphs. All students must pass an assessment on basic mathematical skills to complete the course. The course does not count for degree credit.
Requisites: Placement into MATH 96
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Perform arithmetic operations, such as addition, multiplication, exponentiation, and their inverses using various sets of numbers (including integers, fractions, decimals, and radicals).
Audience: Undergraduate

2. Algebraically manipulate polynomial, rational, and radical expressions.
Audience: Undergraduate

3. Solve various types of one-variable equations and inequalities.
Audience: Undergraduate

4. Identify functions and determine their domain, range, and other properties.
Audience: Undergraduate

5. Recognize the coordinate plane and relate two-variable equations to their graphs.
Audience: Undergraduate

6. Solve linear systems of two-variable equations.
Audience: Undergraduate

7. Evaluate real-world problems by applying linear and other equations.
Audience: Undergraduate

8. Support solutions by using algebraic concepts in justifications.
Audience: Undergraduate

MATH 112 – ALGEBRA
3 credits.

Properties of elementary functions, such as polynomial, absolute value, radical, rational, exponential, and logarithmic functions. Topics include equations, inequalities, functions, and their graphs. Students will formulate, analyze, solve, and interpret mathematical and real-world problems. Intended to provide the algebra skills required for calculus.
Requisites: MATH 96 or placement into MATH 112. MATH 118 does not fulfill the requisite
Course Designation: Gen Ed - Quantitative Reasoning Part A
Level - Elementary
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Solve equations and inequalities using algebraic techniques.
Audience: Undergraduate

2. Interpret the properties of functions, including their domains and ranges.
Audience: Undergraduate

3. Graph, transform, combine, compose, and solve for the inverse of functions.
Audience: Undergraduate

4. Interpret and graph polynomial, rational, exponential, logarithmic functions, and their combinations.
Audience: Undergraduate

5. Solve linear and nonlinear systems of equations.
Audience: Undergraduate

6. Model and analyze real-world problems using functions and their properties.
Audience: Undergraduate

7. Support solutions by applying mathematical concepts and reason to justifications.
Audience: Undergraduate

MATH 113 – TRIGONOMETRY
3 credits.

Covers the graphs, properties and geometric significance of trigonometric functions of a real variable. Other topics include trigonometric equations and identities, application, trigonometric form of complex numbers, DeMoivre's theorem, and polar and parametric equations. The course also has a significant number of applications, especially related to other disciplines.
Requisites: MATH 112 or placement into MATH 113
Course Designation: Level - Elementary
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Define the sine, cosine, and tangent functions with respect to the unit circle and other geometric objects.
Audience: Undergraduate

2. Identify the properties of trigonometric functions, including their domains and ranges.
Audience: Undergraduate

3. Graph trigonometric functions using the concepts of amplitude, period, and phase shift.
Audience: Undergraduate

4. Interpret and graph inverse trigonometric functions using restricted domains.
Audience: Undergraduate

5. Solve equations using factoring, trigonometric identities, and other algebraic techniques.
Audience: Undergraduate

6. Model and analyze real-world problems using trigonometric functions and their properties.
Audience: Undergraduate

7. Support solutions and arguments by applying mathematical concepts and reason to justifications.
Audience: Undergraduate

MATH 114 – ALGEBRA AND TRIGONOMETRY
5 credits.

The two semester sequence MATH 112-MATH 113 covers similar material as MATH 114, but in a slower pace. Not recommended for students with less than an AB in MATH 96.
Requisites: MATH 96 or placement into MATH 114. MATH 118 does not fulfill the requisite
Course Designation: Gen Ed - Quantitative Reasoning Part A
Level - Elementary
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Solve equations and inequalities using algebraic and trigonometric techniques.
Audience: Undergraduate

2. Interpret the properties of functions, including their domains and ranges.
Audience: Undergraduate

3. Graph, transform, combine, compose, and solve for the inverse of functions.
Audience: Undergraduate

4. Interpret and graph polynomial, rational, exponential, and trigonometric functions.
Audience: Undergraduate

5. Define the sine, cosine, and tangent functions with respect to the unit circle and other geometric objects.
Audience: Undergraduate

6. Interpret and graph radical, logarithmic, and inverse trigonometric functions using restricted domains.
Audience: Undergraduate

7. Model and analyze real-world problems using functions and their properties.
Audience: Undergraduate

8. Support solutions and arguments by applying mathematical concepts and reason to justifications.
Audience: Undergraduate

MATH 118 — SUMMER COLLEGIATE EXPERIENCE MATHEMATICS COURSE
2 credits.

A preparation and introductory math course for students enrolled in the Summer Collegiate Experience program. Includes material from precalculus and calculus and related topics depending on students' results on the math placement exam.
Requisites: Enrolled in the Summer Collegiate experience program
Course Designation: Level - Elementary
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Summer 2023

MATH 141 — QUANTITATIVE REASONING AND PROBLEM SOLVING
3 credits.

Develops a habit of mind, competency, and comfort in working with numerical data. Learn to reason and solve quantitative problems from a wide array of authentic contexts and everyday life situations, develop the ability to reason mathematically, and make and evaluate logical arguments supported by quantitative evidence. This course is for students who need to satisfy part A of the Quantitative Reasoning requirement and prepare for QR-B courses, but do not want to continue in the calculus sequence.
Requisites: MATH 96 or placement into MATH 141. MATH 118 does not fulfill the requisite
Course Designation: Gen Ed - Quantitative Reasoning Part A
Level - Elementary
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Identify appropriate models to fit scenarios described with numerical data and/or verbal descriptions (e.g. related to basic financial, probabilistic, and statistical models).
Audience: Undergraduate

2. Make predictions and draw conclusions in real world contexts using a model, and recognize the limitations of mathematical models in those contexts.
Audience: Undergraduate

3. Understand and be able to create and evaluate arguments supported by quantitative evidence and clearly communicate those arguments using words, tables, graphs, mathematical equations, etc., as appropriate in various contexts (e.g. with problems related to financial planning, basic probability).
Audience: Undergraduate

4. Construct and interpret graphical displays of data and understand how they can be used and misused.
Audience: Undergraduate

MATH 171 — CALCULUS WITH ALGEBRA AND TRIGONOMETRY I
5 credits.

Topics in algebra, trigonometry and precalculus are integrated with elementary differential calculus. Part of a 2-semester sequence with MATH 217; these two courses together are equivalent to MATH 114 and 221.
Requisites: MATH 96 or placement into MATH 171. MATH 118 does not fulfill the requisite
Course Designation: Gen Ed - Quantitative Reasoning Part A
Level - Elementary
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Recall the algebraic and geometric properties of polynomial and power functions, use such functions to model practical situations, and use such properties to resolve practical problems.
Audience: Undergraduate

2. Recall formal and informal definitions and theory related to limits and use such statements to perform relevant computations, analyze the behavior of functions, and resolve practical problems (e.g., determine if a function is continuous, find horizontal asymptotes, determine long term behavior of a model, etc.).
Audience: Undergraduate

3. Recall formal and informal definitions and theory related to differential calculus and use such statements to perform relevant computations, analyze the behavior of functions, and resolve practical problems (e.g., determine where a function is increasing or decreasing, compute a linear approximation, predict future behavior, etc.).
Audience: Undergraduate

4. Recall formal and informal definitions and theory related to integrability and use such statements to perform relevant computations, analyze the behavior of functions, and resolve practical problems (e.g., compute antiderivatives, determine areas and volumes, compute average value, etc.).
Audience: Undergraduate

5. Convey informal mathematical arguments and formal computations using appropriate mathematical terminology, notation, and grammar.
Audience: Undergraduate

MATH 198 — DIRECTED STUDY
1-3 credits.

Directed study projects as arranged with a faculty member.
Requisites: Consent of instructor
Course Designation: Level - Elementary
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Summer 2012

MATH 207 – TOPICS IN MATHEMATICS STUDY ABROAD
1-5 credits.

Credit is awarded to students who have completed an appropriate math course abroad at the intermediate level having no direct equivalence within the math department offerings. The study abroad course must be pre-approved by the math department.
Requisites: None
Course Designation: Breadth - Natural Science
Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: Yes, unlimited number of completions

MATH 211 – SURVEY OF CALCULUS
4 credits.

Essential concepts of differential and integral calculus; exponential and logarithmic functions; functions of several variables. Primarily for students in prebusiness and some social sciences. Students preparing for advanced study in mathematics, physics, engineering and other sciences (including most biological sciences) should take MATH 221
Requisites: MATH 112, 114, 171, or placement into MATH 211 or 221
Course Designation: Gen Ed - Quantitative Reasoning Part B
Breadth - Natural Science
Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Apply differential calculus to analyze rates of change, and in particular to model physical and economic phenomena (e.g., derivatives of exponential and logarithmic functions, modeling with linear differential equations, first and second derivative tests for extrema, applied optimization, etc.).
Audience: Undergraduate

2. Analyze the behavior of functions of one variable, including their asymptotic behavior, local behavior and existence of extrema (e.g., limits, continuity, tangent lines, finding extrema, etc.).
Audience: Undergraduate

3. Apply integral calculus to analyze the cumulative effects of continuous processes (e.g., difference between indefinite and definite integral, integration by parts, the Fundamental Theorem of Calculus, etc.).
Audience: Undergraduate

4. Analyze functions of two variables (e.g., partial derivatives, tangent lines to curves, maximization and minimization in two variables, etc.).
Audience: Undergraduate

5. Successfully perform computations related to limits, differentiation, and integration.
Audience: Undergraduate

6. Articulate mathematical knowledge and understanding of differential and integral calculus in a written context.
Audience: Undergraduate

MATH 213 – CALCULUS AND INTRODUCTION TO DIFFERENTIAL EQUATIONS
3 credits.

Techniques of integration, multiple integrals, infinite sequences and series, first order differential equations, two-dimensional systems of differential equations, difference equations, with models from and applications in business and the social and biological sciences.
Requisites: MATH 211, 217, 221, or 275
Course Designation: Gen Ed - Quantitative Reasoning Part B
Breadth - Natural Science
Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall the algebraic and geometric properties of polynomial and power functions and use these properties to resolve practical problems.
Audience: Undergraduate

2. Use definitions, properties, and theory related to the concept of the derivative to perform standard computations and analyze functions (e.g., use Lagrange multipliers to optimize multivariate functions, etc.).
Audience: Undergraduate

3. Use definitions, properties and theory related to limits, sequences, and series to determine convergence, divergence, and limit values as possible (e.g., geometric sums, use limit values as approximations to long term behavior, etc.).
Audience: Undergraduate

4. Use definitions, properties, and theory related to integrals to perform standard computations and analyze functions (e.g., numerical integration, multiple integrals, etc.).
Audience: Undergraduate

5. Use definitions, properties, and theory related to differential equations to produce families of solutions and resolve initial value problems (e.g., first-order linear and separable ordinary differential equations, etc.).
Audience: Undergraduate

6. Use functions to model practical behavior, analyze those functions using calculus concepts, and interpret that analysis in a practical context (e.g., identify concavity and use it to make investment decisions, model an annuity through a geometric series and determine its total present value, determine total change from a marginal rate, etc.).
Audience: Undergraduate

7. Produce informal arguments and formal computations in English using proper mathematical terminology, notation, and logic.
Audience: Undergraduate

MATH 217 – CALCULUS WITH ALGEBRA AND TRIGONOMETRY II
5 credits.

Continuation of MATH 171. Topics in algebra, trigonometry and precalculus are integrated with elementary differential calculus. Completion of MATH 217 implies completion of MATH 221 and 114.
Requisites: MATH 171
Course Designation: Gen Ed - Quantitative Reasoning Part B
Breadth - Natural Science
Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall the algebraic and geometric properties of exponential and trigonometric functions, their inverses, and their algebraic combinations and compositions, and use these properties to resolve practical problems.
Audience: Undergraduate

2. Recall formal and informal definitions and theory related to limits (e.g., limit properties, continuity, the intermediate value theorem, etc.) and use such statements to perform relevant computations, analyze the behavior of functions, and resolve practical problems (e.g., determine if a function is continuous, find horizontal asymptotes, determine long term behavior of a model, etc.).
Audience: Undergraduate

3. Recall formal and informal definitions and theory related to the derivative (e.g., definition, chain rule, interpretation as rate of change, critical point theory, l'Hopital's rule, etc.) and use such statements to perform relevant computations, analyze the behavior of functions, and resolve practical problems (e.g., determine where a function is increasing, compute a linear approximation, etc.).
Audience: Undergraduate

4. Recall formal and informal definitions and theory related to integrability (e.g., definition as the limit of a Riemann sum, the fundamental theorem of calculus, definite integral as total change, etc.) and use such statements to perform relevant computations, analyze the behavior of functions, and resolve practical problems (e.g., compute antiderivatives, determine areas/volumes, etc.).
Audience: Undergraduate

5. Offer informal mathematical arguments and formal computations in English using appropriate mathematical terminology, notation, and grammar.
Audience: Undergraduate

MATH 221 – CALCULUS AND ANALYTIC GEOMETRY 1
5 credits.

Introduction to differential and integral calculus and plane analytic geometry; applications; transcendental functions.
Requisites: MATH 114 or (MATH 112 and 113) or placement into MATH 221. MATH 211 or MATH 213 does not fulfill the requisite.
Course Designation: Gen Ed - Quantitative Reasoning Part B
Breadth - Natural Science
Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Apply differential calculus to analyze rates of change, and in particular to model real world phenomena (e.g., derivatives of exponential, logarithmic and trigonometric functions, first and second derivative tests for extrema, applied optimization, etc.).
Audience: Undergraduate

2. Analyze the behavior of functions of one variable, including their asymptotic behavior, local behavior and existence of extrema (e.g., limits, continuity, tangent lines, finding extrema, etc.).
Audience: Undergraduate

3. Apply integral calculus to model the cumulative effects of continuous processes (e.g., difference between indefinite and definite integral, the Fundamental Theorem of Calculus, computing areas, volumes, and surface areas, etc.).
Audience: Undergraduate

4. Successfully perform computations related to limits, differentiation, and integration.
Audience: Undergraduate

MATH 222 – CALCULUS AND ANALYTIC GEOMETRY 2
4 credits.

Techniques of integration, improper integrals, first order ordinary differential equations, sequences and series, Taylor series, vector geometry in two and three dimensions.
Requisites: MATH 217 or 221. MATH 211 or 213 does not fulfill the requisite.
Course Designation: Gen Ed - Quantitative Reasoning Part B
Breadth - Natural Science
Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Apply a variety of integration techniques to compute proper and improper integrals (e.g., integration by parts, substitution including trigonometric substitution, partial fractions, etc.).
Audience: Undergraduate

2. Find and analyze the solutions to first order differential equations and initial value problems (e.g., separable equations, equilibrium solutions, linear equations and integrating factors, etc.).
Audience: Undergraduate

3. Recall the main definitions and results related to limits, continuity, sequences, and series (e.g., convergence, divergence, convergence of geometric sequences, convergence of geometric series, different tests for convergence and divergence, the Integral test, etc.).
Audience: Undergraduate

4. Derive and manipulate asymptotic expansions of functions, and use these expansions to understand the properties of the functions they approximate (e.g., Taylor series, etc.).
Audience: Undergraduate

5. Describe objects in three dimensional space and how they interact with each other (the coordinate system, vector addition and scalar multiplication, the dot product and cross product, etc.).
Audience: Undergraduate

6. Describe physical and biological phenomena using mathematical models (e.g. linear growth models, logistic growth models, pressure and force, moments and center of mass, etc.).
Audience: Undergraduate

7. Offer informal mathematical arguments and formal computations in English using appropriate mathematical terminology, notation, and grammar.
Audience: Undergraduate

MATH 228 – WES CALCULUS SUPPLEMENT
2 credits.

Topics in algebra, trigonometry, differential, integral and multi-variable calculus and analytic geometry will be covered depending on which calculus course MATH 228 is attached to. MATH 228 must be taken in conjunction with the appropriate WES section of MATH 171, 217, 221, 222, or 234.
Requisites: Member of Wisconsin Emerging Scholars--MATH Program
Course Designation: Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024

MATH 234 – CALCULUS--FUNCTIONS OF SEVERAL VARIABLES
4 credits.

Introduction to calculus of functions of several variables; calculus on parameterized curves, derivatives of functions of several variables, multiple integrals, vector calculus.
Requisites: MATH 222
Course Designation: Breadth - Natural Science
Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Analyze the behavior of functions of several variables, including their asymptotic behavior, local behavior, and existence of extrema with the tools of calculus (e.g., limits and continuity of multidimensional functions, derivatives and integrals of vector valued functions, arc length and curvature, partial derivatives, tangent planes, etc.).
Audience: Undergraduate

2. Describe and analyze motion in space with the tools of calculus (velocity vector and acceleration, directional derivatives and the gradient vector, etc.).
Audience: Undergraduate

3. Represent and compute areas and volumes by means of multiple integrals (e.g., integration over rectangles and more general spaces, average values, integration with polar, cylindrical, and spherical coordinates, general changes of variables, etc.).
Audience: Undergraduate

4. Derive relations between different physical phenomena and their integral representations (e.g., using Green's theorem, the Divergence theorem, and Stokes' theorem).
Audience: Undergraduate

5. Describe physical, biological, and/or economic phenomena using mathematical models (e.g., topographical maps and level curves, Lagrange multipliers, etc.).
Audience: Undergraduate

6. Offer informal mathematical arguments and formal computations in English using appropriate mathematical terminology, notation, and grammar.
Audience: Undergraduate

MATH/COMP SCI 240 – INTRODUCTION TO DISCRETE MATHEMATICS
3 credits.

Basic concepts of logic, sets, partial order and other relations, and functions. Basic concepts of mathematics (definitions, proofs, sets, functions, and relations) with a focus on discrete structures: integers, bits, strings, trees, and graphs. Propositional logic, Boolean algebra, and predicate logic. Mathematical induction and recursion. Invariants and algorithmic correctness. Recurrences and asymptotic growth analysis. Fundamentals of counting.
Requisites: MATH 217 or 221
Course Designation: Breadth - Natural Science
Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024

MATH 298 – DIRECTED STUDY IN MATHEMATICS
1-3 credits.

Directed study projects as arranged with a faculty member.
Requisites: Consent of instructor
Course Designation: Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2023

MATH/STAT 309 – INTRODUCTION TO PROBABILITY AND MATHEMATICAL STATISTICS I
3 credits.

Probability and combinatorial methods, discrete and continuous, univariate and multivariate distributions, expected values, moments, normal distribution and derived distributions, estimation.
Requisites: MATH 234, 376, or concurrent enrollment. Not open to students with credit for STAT/MATH 431 or STAT 311
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall the definitions of fundamental objects and concepts underlying probability theory (e.g. sample spaces and events, the axioms of probability, the notions of conditional probability and independence, random variables and their probability distributions, mathematical expectation, and the joint distribution of one or more random variables) and demonstrate understanding of their properties
Audience: Undergraduate

2. Perform important operations in probability (e.g. calculate the probabilities of events, derive the probability distributions of random variables, compute moments and the expectation of functions of random variables, calculate covariances and correlations, and obtain conditional distributions and conditional expectations) and interpret the results
Audience: Undergraduate

3. Explain the meaning of key results in probability theory that are especially important in mathematical statistics (e.g. Bayes' Theorem, probabilistic tail inequalities such as Markov's and Chebyshev's inequalities, the Law of Large Numbers, and the Central Limit Theorem)
Audience: Undergraduate

4. Identify, utilize, and understand the key properties of, probability distributions that are especially important in statistics, including discrete families of distributions (e.g. the binomial, Poisson, geometric, and negative binomial distributions) and continuous families of distributions (e.g. the uniform, exponential, gamma, and normal distributions)
Audience: Undergraduate

MATH/STAT 310 – INTRODUCTION TO PROBABILITY AND MATHEMATICAL STATISTICS II
3 credits.

Mathematical statistical inference aims at providing an understanding of likelihood's central role to statistical inference, using the language of mathematical statistics to analyze statistical procedures, and using the computer as a tool for understanding statistics. Specific topics include: samples and populations, estimation, hypothesis testing, and theoretical properties of statistical inference.
Requisites: (STAT/MATH 309, STAT 311, STAT/MATH 431, or MATH 531) and (STAT 240, STAT 301, STAT 302, STAT 324, STAT 371, or ECON 310), or graduate/professional standing
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Construct point estimators including maximum likelihood estimators, understand the theoretical properties of point estimation methods, and evaluate their performance
Audience: Undergraduate

2. Construct hypothesis tests including likelihood ratio tests, interpret their results, evaluate their performance, and understand the theoretical properties of hypothesis testing methods
Audience: Undergraduate

3. Construct interval estimators to quantify uncertainty, understand the theoretical properties of interval estimation methods, and interpret their results
Audience: Undergraduate

4. Mathematically derive key quantities required for statistical inference methods and be familiar with simulation-based techniques for obtaining those quantities
Audience: Undergraduate

5. Describe the Bayesian approach to inference and contrast it with the frequentist approach
Audience: Undergraduate

6. Identify and describe the assumptions underlying methods of statistical inference and explain their importance
Audience: Undergraduate

MATH 319 – TECHNIQUES IN ORDINARY DIFFERENTIAL EQUATIONS
3 credits.

Review of linear differential equations; series solution of linear differential equations; boundary value problems; Laplace transforms; possibly numerical methods and two dimensional autonomous systems.
Requisites: MATH 222 or graduate/professional standing
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions, properties, and theorems associated to ordinary differential equations (e.g. systems of linear ODEs, homogeneous/inhomogeneous ODEs, series solutions, Laplace transform, equilibria, etc.).
Audience: Undergraduate

2. Verify if a mathematical object has a given property used in ODEs (e.g. that a problem is well-posed, that a given function is a solution, etc.).
Audience: Undergraduate

3. Apply algorithms to describe the solutions to various types of ODEs (e.g. separable equations, linear systems, boundary value problems, etc.).
Audience: Undergraduate

4. Check the premises of theorems used in elementary ODEs in order to apply their conclusions (e.g., that a given equation satisfies conditions which guarantee the existence of a solution).
Audience: Undergraduate

5. Apply the presented techniques for solving ODEs to solve problems from physics (e.g. spring problems, pendulum problems, etc.).
Audience: Undergraduate

6. Express informal mathematical arguments in English using appropriate mathematical terminology and notation.
Audience: Undergraduate

MATH 320 – LINEAR ALGEBRA AND DIFFERENTIAL EQUATIONS
3 credits.

An introduction to linear algebra and differential equations with emphasis on the relationship between the theory of linear algebra and analytical and numerical techniques for solving differential equations. Linear algebra topics include linear systems, matrices and their algebra, vector spaces and linear transformations, eigenvalues and eigenvectors. Topics from differential equations include first order ODE, homogeneous and nonhomogeneous linear systems, and numerical methods.
Requisites: MATH 222 or graduate/professional standing
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions, properties, and theorems associated to elementary linear algebra and ordinary differential equations (e.g. existence and uniqueness theorems for first-order ODEs, eigenvalues and eigenvectors, etc.).
Audience: Undergraduate

2. Verify if a mathematical object has a given property used in elementary linear algebra and differential equations (e.g., that a matrix is invertible, that a set is a vector subspace, that a vector is an eigenvector, etc.).
Audience: Undergraduate

3. Check the premises of theorems used in elementary linear algebra in order to apply their conclusions (e.g., that a given matrix has zero determinant and therefore cannot be inverted).
Audience: Undergraduate

4. Resolve algebraic statements related to elementary linear algebra through appropriate computations and compute solutions to elementary systems of ordinary differential equations.
Audience: Undergraduate

5. Express informal mathematical arguments in English using appropriate mathematical terminology and notation.
Audience: Undergraduate

MATH 321 – APPLIED MATHEMATICAL ANALYSIS
3 credits.

Vector analysis: algebra and geometry of vectors, vector differential and integral calculus, theorems of Green, Gauss, and Stokes; complex analysis: analytic functions, complex integrals and residues, Taylor and Laurent series.
Requisites: MATH 376, (MATH 234 and 319), (MATH 234 and 320), (MATH 234 and 340), (MATH 234 and 341), (MATH 234 and 375), or graduate/professional standing
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions, properties, and theorems associated to elementary vector calculus including complex calculus.
Audience: Undergraduate

2. Verify if a mathematical object has a given property used in complex and vector calculus (e.g., that a matrix is invertible, that a of vectors is linearly independent, that a vector field is conservative, etc.)
Audience: Undergraduate

3. Check the premises of theorems used in complex and vector calculus in order to apply their conclusions (e.g., that a vector field is conservative and so one can apply the fundamental theorem of path integrals).
Audience: Undergraduate

4. Resolve algebraic statements and perform standard computations related to vector and complex calculus (e.g., compute residues, perform basis changes, use multivariate substitution in integrals, compute surface areas, etc.).
Audience: Undergraduate

5. Express informal mathematical arguments in English using appropriate mathematical terminology and notation.
Audience: Undergraduate

MATH 322 – APPLIED MATHEMATICAL ANALYSIS
3 credits.

Sturm-Liouville theory; Fourier series, including mean convergence; boundary value problems for linear second order partial differential equations, including separation of variables and eigenfunction expansions.
Requisites: MATH 321 or 376 or graduate/professional standing
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions, properties, techniques, and theorems associated to elementary partial differential equations (e.g., boundary value problem, linearity, eigenfunction, Fourier series, finite difference methods, etc.).
Audience: Undergraduate

2. Verify if a mathematical object has a given property used in elementary partial differential equations (e.g., homogeneous vs. nonhomogeneous PDEs, symmetry, etc.)
Audience: Undergraduate

3. Check the premises of theorems used in complex and vector calculus in order to apply their conclusions (e.g., that a finite series solution minimizes error, etc.).
Audience: Undergraduate

4. Resolve algebraic statements and perform standard computations related to elementary partial differential equations (e.g., derive series solutions to a given PDE, apply the finite element method to approximate a PDE solution, etc.).
Audience: Undergraduate

5. Express informal mathematical arguments in English using appropriate mathematical terminology and notation.
Audience: Undergraduate

MATH 331 – INTRODUCTORY PROBABILITY
3 credits.

Topics covered include axioms of probability, random variables, the most important discrete and continuous probability distributions, expectation and variance, conditional probability and conditional expectations, Markov's and Chebyshev's inequalities, laws of large numbers, and the central limit theorem. Includes a brief introduction to techniques of multivariate integration.
Requisites: MATH 213 or 222
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in basic probability theory (e.g., probability spaces, random variables and their probability distributions, named distributions, conditional probability, independence, etc.).
Audience: Undergraduate

2. Use such definitions to argue that a mathematical object does or does not have the condition of being a particular type or having a particular property (e.g., whether certain events or random variables are independent or not, whether a random variable has one of the named distributions, etc.).
Audience: Undergraduate

3. Recall and state the standard theorems of probability theory. (e.g., Bayes' theorem, the law of large numbers, the central limit theorem, Markov's inequality etc.), and apply these theorems to solve problems in probability theory.
Audience: Undergraduate

4. Use multiple approaches to compute and estimate probabilities and expectations.
Audience: Undergraduate

5. Model simple real-life situations using techniques in probability theory and calculate probabilities and expectations associated with those models.

Audience: Undergraduate

6. Express informal mathematical arguments in English using appropriate mathematical terminology and notation
Audience: Undergraduate

MATH 340 – ELEMENTARY MATRIX AND LINEAR ALGEBRA
3 credits.

An introduction to linear algebra. Topics include matrix algebra, linear systems of equations, vector spaces, sub-spaces, linear dependence, span, basis, rank of matrices, determinants, linear transformations, coordinate representations, kernel, range, eigenvalues and eigenvectors, diagonalization, inner products and orthogonal vectors, symmetric matrices. Covers linear algebra topics in greater depth and detail than MATH 320. Formal techniques in mathematical argument [MATH 341] not covered.
Requisites: MATH 222
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions, properties, and theorems associated to elementary linear algebra (e.g., matrix, eigenvector, rank, linear independence, vector space, etc.).
Audience: Undergraduate

2. Verify if a mathematical object has a given property used in elementary linear algebra (e.g., that a matrix is invertible, that a set is a vector subspace, that a vector is an eigenvector, etc.).
Audience: Undergraduate

3. Check the premises of theorems used in elementary linear algebra in order to apply their conclusions (e.g., that a given matrix has zero determinant and therefore cannot be inverted).
Audience: Undergraduate

4. Resolve algebraic statements related to elementary linear algebra through appropriate computations.
Audience: Undergraduate

5. Express informal mathematical arguments in English using appropriate mathematical terminology and notation.
Audience: Undergraduate

MATH 341 – LINEAR ALGEBRA
3 credits.

The theory of linear algebra with an introduction to proofs and proof writing. Topics include vector spaces, linear dependence, span, basis, linear transformations, kernel, image, inner products and inner product spaces, geometry, eigenvalues, eigenvectors, standard matrix factorizations. Other content includes basic set theory, logical operations, quantifiers, direct and indirect arguments, and induction. Differential equations [MATH 320] not covered.
Requisites: MATH 234
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Honors - Accelerated Honors (!)
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of mathematical objects and their properties used in elementary linear algebra (e.g., dimension of a vector space, linear dependence of a set of vectors, etc.).
Audience: Undergraduate

2. Use the standard methods and tools of mathematical argument in the context of linear algebra (e.g., direct and indirect methods, the construction of examples and counterexamples, induction arguments, 1st order logic, set theory, quantifiers, etc.).
Audience: Undergraduate

3. Verify if a mathematical construct does or does not have the condition of having a particular property (e.g., that a matrix is invertible, that a set is a vector subspace, that a vector is an eigenvector, etc.).
Audience: Undergraduate

4. Recall and state standard theorems used in elementary linear algebra (e.g., symmetric matrices are diagonalizable, linear operators with non-trivial kernel are not invertible, etc.).
Audience: Undergraduate

5. Verify the premises of standard theorems in elementary linear algebra in order to apply their conclusions in the context of longer arguments (e.g., that a given matrix has zero determinant and therefore has nullity larger than one, etc.).
Audience: Undergraduate

6. Prove or disprove statements related to the definitions, properties, and theorems of elementary linear algebra using the techniques of mathematical argument.
Audience: Undergraduate

7. Perform standard computations in the context of linear algebra (e.g., finding the rank of a matrix, computing the determinant of a square matrix, etc.).
Audience: Undergraduate

8. Convey formal mathematical arguments in English using appropriate mathematical terminology and notation.
Audience: Undergraduate

MATH 375 – TOPICS IN MULTI-VARIABLE CALCULUS AND LINEAR ALGEBRA
5 credits.

Vector spaces and linear transformations, differential calculus of scalar and vector fields, determinants, eigenvalues and eigenvectors, multiple integrals, line integrals, and surface integrals. Freshmen students are invited to enroll by the Department of Mathematics.
Requisites: Consent of Instructor
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Fall 2023

MATH 376 — TOPICS IN MULTI-VARIABLE CALCULUS AND DIFFERENTIAL EQUATIONS
5 credits.

Topics in multi-variable calculus and introduction to differential equations.
Requisites: MATH 375
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Identify the formal definitions of mathematical objects and their properties used in integral multivariable calculus and elementary ordinary differential equations (e.g., multivariate integrals, line and surface integrals, systems of linear ODEs, etc.).
Audience: Undergraduate

2. Understand and use the standard methods and tools of mathematical argument in the context of integral multivariable calculus and elementary ordinary differential equations (e.g direct and indirect methods, the construction of examples and counterexamples, induction arguments, first-order logic, set theory, and quantifiers).
Audience: Undergraduate

3. Distinguish if a mathematical construct does or does not have the condition of having a particular property formally (e.g., that a vector field is conservative, that a given function is a solution, etc.).
Audience: Undergraduate

4. Identify standard theorems in integral multivariable calculus and elementary ordinary differential equations (e.g., Green's theorem, the Divergence theorem, Stokes' theorem, existence and uniqueness theorem for ODEs, etc.) and recall arguments for these theorems and the underlying logic of their proofs.
Audience: Undergraduate

5. Prove or disprove statements related to the definitions, properties, and theorems of integral multivariable calculus and elementary ordinary differential equations using the techniques of mathematical argument.
Audience: Undergraduate

6. Perform standard computations in the context of integral multivariable calculus and elementary ordinary differential equations (e.g. evaluate surface and line integrals, solve simple ordinary differential equations, etc.).
Audience: Undergraduate

7. Write mathematical proofs and concepts in logical, reasonable, and concise ways.
Audience: Undergraduate

MATH 390 — UNDERGRADUATE RESEARCH WITH MADISON EXPERIMENTAL MATHEMATICS LAB
3 credits.

An introduction to mathematical research. Instruction in ancillary skills such as literature review, mathematical software use, technical writing and communication, etc. Requires acceptance to the Madison Experimental Mathematics undergraduate research lab.
Requisites: Consent of instructor
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024
Learning Outcomes: 1. work with a team to investigate open problems in mathematics.
Audience: Undergraduate

2. employ methods of mathematical research (e.g., numerical software, literature review, problem design, etc.)
Audience: Undergraduate

3. communicate mathematics in formal written and oral forms (e.g, journal article, poster presentation, seminar talk, etc.)
Audience: Undergraduate

MATH 407 — TOPICS IN MATHEMATICS STUDY ABROAD
1-5 credits.

Credit is awarded to students who have completed an appropriate math course abroad at the advanced level having no direct equivalence within the math department offerings. The study abroad course must be pre-approved by the math department.
Requisites: None
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: Yes, unlimited number of completions

MATH 415 – APPLIED DYNAMICAL SYSTEMS, CHAOS AND MODELING
3 credits.

An introduction to nonlinear dynamical systems including stability, bifurcations and chaos. The course will give underlying mathematical ideas, but emphasize applications from many scientific fields.
Requisites: MATH 376, (MATH 234 and 319), (MATH 234 and 320), (MATH 234 and 340), (MATH 234 and 341) or (MATH 234 and 375) or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Recall and state the formal definitions, properties, and theorems associated to linear and nonlinear dynamical systems (e.g., periodicity, critical points, chaotic behavior, contraction mapping principle, etc.).
Audience: Undergraduate

2. Verify if a mathematical object has a given property used in elementary linear and nonlinear dynamical systems (e.g., if a set is stable, etc.).
Audience: Undergraduate

3. Identify the type of bifurcation undergone by a dynamical system under a change of parameter values (e.g., saddle-node, pitchfork, and transcritical bifurcations, normal forms, etc.).
Audience: Undergraduate

4. Check the premises of theorems used in elementary linear and nonlinear dynamical systems in order to apply their conclusions (e.g., that a function satisfies a particular inequality and hence must have a fixed point, etc.).
Audience: Undergraduate

5. Resolve algebraic statements and perform standard computations and constructions related to elementary linear and nonlinear dynamical systems (e.g., computing eigenvectors, identifying invariant sets, draw a phase plane portrait, etc.).
Audience: Undergraduate

6. Design a mathematical model that embodies specific features of a physical or biological system (e.g., finite carrying capacity, predation).
Audience: Undergraduate

7. Express informal mathematical arguments in English using appropriate mathematical terminology and notation.
Audience: Undergraduate

MATH 421 – THE THEORY OF SINGLE VARIABLE CALCULUS
3 credits.

Covers material in first and second semester calculus but it is intended to teach math majors to write and understand proofs in mathematics in general and in calculus in particular.
Requisites: MATH 234 or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Understand and use the standard methods and tools of mathematical argument (e.g direct and indirect methods, the construction of examples and counterexamples, induction arguments, first-order logic, set theory, and quantifiers).
Audience: Undergraduate

2. Recall and state the formal definitions of mathematical objects (e.g. sets, functions, and graphs) and their properties used in calculus.
Audience: Undergraduate

3. Distinguish if a mathematical construct does or does not have the condition of having a particular property formally (e.g. limits, continuity, differentiability, and integrability).
Audience: Undergraduate

4. Recall and state standard calculus theorems (e.g. Intermediate Value Theorem, Mean Value Theorems, and Fundamental Theorem of Calculus), and recall arguments for these theorems and the underlying logic of their proofs.
Audience: Undergraduate

5. Prove or disprove statements related to the definitions, properties, and theorems of calculus using the techniques of mathematical argument.
Audience: Undergraduate

6. Write mathematical proofs and concepts in logical, reasonable, and concise ways.
Audience: Undergraduate

MATH/COMP SCI/I SY E 425 – INTRODUCTION TO COMBINATORIAL OPTIMIZATION
3 credits.

Focuses on optimization problems over discrete structures, such as shortest paths, spanning trees, flows, matchings, and the traveling salesman problem. We will investigate structural properties of these problems, and we will study both exact methods for their solution, and approximation algorithms.
Requisites: (MATH 320, 340, 341, or 375) or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Physical Sci. Counts toward the Natural Sci req
Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Identify and use the structural properties of combinatorial optimization problems
Audience: Undergraduate

2. Apply algorithms for the solution -exact or approximate- of a combinatorial optimization problem
Audience: Undergraduate

3. Explain why the algorithms studied are correct and understand their running time
Audience: Undergraduate

MATH/STAT 431 – INTRODUCTION TO THE THEORY OF PROBABILITY
3 credits.

Topics covered include axioms of probability, random variables, the most important discrete and continuous probability distributions, expectation and variance, moment generating functions, conditional probability and conditional expectations, multivariate distributions, Markov's and Chebyshev's inequalities, laws of large numbers, and the central limit theorem.
Requisites: MATH 234 or 376 or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in probability theory (e.g., probability spaces, random variables and random vectors and their probability distributions, named distributions, conditional probability, independence, linearity of expectation, etc.).
Audience: Undergraduate

2. Use such definitions to argue that a mathematical object does or does not have the condition of being a particular type or having a particular property (e.g., whether certain events or random variables are independent or not, whether a random variable has one of the named distributions, whether or not a sequence of random variables is exchangeable, etc.).
Audience: Undergraduate

3. Recall and state the standard theorems of probability theory. (e.g., Bayes' theorem, the law of large numbers, the central limit theorem, etc.), and apply these theorems to solve problems in probability theory.
Audience: Undergraduate

4. Use multiple approaches to compute and estimate probabilities and expectations (e.g., using the indicator method, using conditioning, estimating probabilities using normal or Poisson approximation etc.).
Audience: Undergraduate

5. Construct mathematical arguments related to the above definitions, properties, and theorems, including the construction of examples and counterexamples.
Audience: Undergraduate

6. Convey his or her arguments in oral and written forms using English and appropriate mathematical terminology and notation (and grammar).
Audience: Undergraduate

7. Model simple real-life situations using techniques in probability theory and calculate probabilities and expectations associated with those models.

Audience: Undergraduate

MATH/COMP SCI/E C E 435 — INTRODUCTION TO CRYPTOGRAPHY
3 credits.

Cryptography is the art and science of transmitting digital information in a secure manner. Provides an introduction to its technical aspects.
Requisites: (MATH 320, 340, 341, or 375) or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024

MATH 441 — INTRODUCTION TO MODERN ALGEBRA
3 credits.

The integers, emphasizing general group and ring properties. Permutation groups, symmetry groups, polynomial rings, leading to notions of abstract groups and rings. Congruences, computations, including finite fields and applications. Emphasis on concepts and concrete examples and computations.
Requisites: (MATH 320, 340, 341, or 375) or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2016

MATH 443 — APPLIED LINEAR ALGEBRA
3 credits.

Review of matrix algebra. Simultaneous linear equations, linear dependence and rank, vector space, eigenvalues and eigenvectors, diagonalization, quadratic forms, inner product spaces, norms, canonical forms. Discussion of numerical aspects and applications in the sciences.
Requisites: (MATH 320, 340, 341, or 375) or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in applied linear algebra (e.g., system of equations, matrices, linear transformations, inner product spaces, quadratic forms, etc.).
Audience: Undergraduate

2. Use such definitions to argue that a mathematical object does or does not have the condition of being a particular type or having a particular property (e.g., system of equations has a solution, matrix has an LU factorization, linear transformation is invertible, etc.).
Audience: Undergraduate

3. Recall and state the standard theorems of applied linear algebra. (e.g., Rank-Nullity theorem, Spectral theorem of normal operators, theorems leading to SVD and PCA methods, etc.). Moreover, apply these theorems to solve problems in applied linear algebra.
Audience: Undergraduate

4. Construct mathematical arguments related to the above definitions, properties, and theorems, including the construction of examples and counterexamples. Moreover, the student will learn classical algorithms to solve scientific problems using linear algebra (e.g., Page rank, Recommendation systems, SVD and matrix completion, Least square and Gram Schmidt process, etc.).
Audience: Undergraduate

5. Convey his or her arguments in oral and written forms using English and appropriate mathematical terminology and notation, and justify the applicability of classical linear algebra based algorithms in science.
Audience: Undergraduate

MATH 444 – GRAPHS AND NETWORKS IN DATA SCIENCE
3 credits.

Mathematical foundations of networks with an emphasis on their applications in modern data science, using tools from algorithmic graph theory and linear algebra. Topics include: basics of graph theory, network statistics, graph traversal algorithms and implementation, matrix methods, community detection, PageRank, simulation of random graph models.
Requisites: (MATH 320, 340, 341, or 375) and (COMP SCI 200, 220, 300, 310, 320, or placement in COMP SCI 300), graduate/professional standing, or declared in Mathematics VISP (undergraduate or graduate)
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. State formal definitions in graph theory and networks.
Audience: Both Grad & Undergrad

2. Describe essential network search algorithms (e.g., shortest path and minimum spanning tree) and prove their correctness and computational complexity
Audience: Both Grad & Undergrad

3. Understand how community detection algorithms using spectral analysis works; implement and/or use community detection algorithms and apply them to real-world networks using Python
Audience: Both Grad & Undergrad

4. Simulate various random graph models (Erdos-Renyi, Watts-Strogats, Stochastic Block Model, Configuration model, Preferential Attachement).
Audience: Both Grad & Undergrad

5. Use a programming language to load network data and apply deterministic and randomized algorithms for network data analysis; fit various random graph models to the given real-world network and infer its statistical properties.
Audience: Both Grad & Undergrad

6. Identify applications of course content in areas of modern research.
Audience: Graduate

MATH 461 – COLLEGE GEOMETRY I
3 credits.

An introduction to Euclidean or non-Euclidean geometry.
Requisites: MATH 234 or (MATH 222 and COMP SCI/MATH 240) or MATH 375 or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of mathematical objects and their properties used in axiomatic and coordinate geometry with a special emphasis on triangles and circles (e.g., pedal triangles, Simson line, perpendicular bisector, etc.).
Audience: Undergraduate

2. Use the above definitions to argue if a mathematical construct does or does not have the condition of having a particular property (e.g., that two triangles are congruent, three points are collinear, etc.).
Audience: Undergraduate

3. Recall and state standard theorems used in axiomatic geometry including their proofs (e.g., opposite angles are congruent, Ceva's Theorem, nine-point circle theorem, etc.).
Audience: Undergraduate

4. Verify the premises of standard theorems in in order to apply their conclusions in the context of longer arguments (e.g., arguing congruence by verifying angle sums, etc.).
Audience: Undergraduate

5. Prove or disprove statements related to the definitions, properties, and theorems of axiomatic geometry using the techniques of mathematical argument. In particular, the student will employ construction and computational techniques as necessary.
Audience: Undergraduate

6. Convey formal mathematical arguments in written and/or verbal English using appropriate mathematical terminology and notation.
Audience: Undergraduate

MATH 467 – INTRODUCTION TO NUMBER THEORY
3 credits.

An introduction to proof writing techniques through a study of classical topics in elementary number theory. Topics include the divisibility, basic properties of primes, congruences, Fermat's theorem.
Requisites: MATH 234, 375, (MATH 222 and COMP SCI/MATH 240), (MATH 222 and 320), or (MATH 222 and 340)
Course Designation: Breadth - Natural Science
Level - Intermediate
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Understand and use the standard methods and tools of mathematical argument (e.g. direct and indirect methods, the construction of examples and counterexamples, induction arguments).
Audience: Undergraduate

2. State and describe the formal definitions of the mathematical objects and their properties used in elementary number theory (e.g., divisibility, prime numbers, congruences, etc.).
Audience: Undergraduate

3. State and apply the main theorems in elementary number theory (e.g. theorems related to modular arithmetic, divisibility, prime numbers, Fermat's Little Theorem).
Audience: Undergraduate

4. Prove or disprove statements and evaluate the validity of arguments related to the definitions, properties, and theorems elementary number theory.
Audience: Undergraduate

MATH/CURRIC 471 – MATHEMATICS FOR SECONDARY SCHOOL TEACHERS
3 credits.

Capstone for future middle and high school teachers, drawing connections between higher mathematics and school mathematics.
Requisites: (MATH 341, 375, or 421) and (MATH 461 or concurrent enrollment)
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2023
Learning Outcomes: 1. Examine the conceptual difficulties, fundamental ideas, and techniques of secondary school mathematics.
Audience: Undergraduate

2. Describe connections between advanced mathematics and the content typically found in middle and high school mathematics curriculum.
Audience: Undergraduate

3. Recall and state alternate definitions, extensions, and constructions of content typically found in middle and high school mathematics curriculum.
Audience: Undergraduate

4. Demonstrate symbolic and computational proficiency.
Audience: Undergraduate

5. Justify mathematical reasoning as a means to deepen understanding.
Audience: Undergraduate

6. Analyze multiple solution strategies from a mathematical perspective (e.g. understanding different approaches to solving a problem, assessing whether a strategy generalizes, making connections between strategies, examining student strategies when appropriate etc.).
Audience: Undergraduate

7. Explain mathematics to others and assess the mathematical understanding of others.
Audience: Undergraduate

MATH/HIST SCI 473 – HISTORY OF MATHEMATICS
3 credits.

An historical survey of the main lines of mathematical development.
Requisites: Consent of instructor
Course Designation: Breadth - Either Humanities or Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in various mathematical topics throughout history (e.g., content from number theory, analysis, algebra, etc.).
Audience: Undergraduate

2. Use such definitions to argue that a mathematical object does or does not have the condition of being a particular type or having a particular property in the context of these topics.
Audience: Undergraduate

3. Recall and state the standard theorems from these topics, and recall the arguments for these theorems and the underlying logic of their proofs.

Audience: Undergraduate

4. Prove or disprove statements related to the above definitions, properties, and theorems using techniques of mathematical argument (direct methods, indirect methods, constructing examples and counterexamples, induction, etc.).
Audience: Undergraduate

5. Convey arguments in oral and written forms using English and appropriate mathematical terminology, notation, and grammar.
Audience: Undergraduate

6. Explain mathematical ideas and describe their historical contexts.
Audience: Undergraduate

MATH/COMP SCI/STAT 475 – INTRODUCTION TO COMBINATORICS
3 credits.

Problems of enumeration, distribution, and arrangement. Inclusion-exclusion principle. Generating functions and linear recurrence relations. Combinatorial identities. Graph coloring problems. Finite designs. Systems of distinct representatives and matching problems in graphs. Potential applications in the social, biological, and physical sciences. Puzzles. Problem solving.
Requisites: (MATH 320, 340, 341, or 375) or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Understand basic counting strategies, such as staged thought-experiments, inclusion/exclusion, generating functions, and recurrence relations, and apply these strategies to solve a wide variety of counting problems.
Audience: Undergraduate

2. Recall basic objects that are used in combinatorics, such as permutations and combinations of sets and multisets, binomial and multinomial coefficients, the Catalan numbers, the Stirling numbers, and the partition numbers.
Audience: Undergraduate

3. Analyze a given combinatorial problem using the standard theorems of combinatorics, such as the pigeonhole principle, the Newton binomial theorem, the multinomial theorem, the Ramsey theorem, the Dilworth theorem, the Burnside theorem, and the Polya counting theorem.
Audience: Undergraduate

4. Construct mathematical arguments related to combinatorial problems using the above definitions, properties, theorems, and counting strategies; including the construction of examples and counterexamples.
Audience: Undergraduate

5. Convey his or her arguments in oral and written form in English, using appropriate mathematical terminology, notation, and grammar.
Audience: Undergraduate

MATH 490 – UNDERGRADUATE SEMINAR
1-3 credits.

Intermediate or upper level topics course in mathematics. Topics vary.
Requisites: Consent of instructor
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2023

MATH 491 – TOPICS IN UNDERGRADUATE MATHEMATICS
3 credits.

Intermediate or upper level topics course in mathematics. Topics vary.
Requisites: Consent of instructor
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024

MATH/COMP SCI 513 – NUMERICAL LINEAR ALGEBRA
3 credits.

Direct and iterative solution of linear and nonlinear systems and of eigenproblems. LU and symmetric LU factorization. Complexity, stability, and conditioning. Nonlinear systems. Iterative methods for linear systems. QR-factorization and least squares. Eigenproblems: local and global methods.
Requisites: (MATH 340, 341, or 375) and (COMP SCI 200, 300, 301, 302, 310, or placement into COMP SCI 300) or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024

MATH/COMP SCI 514 – NUMERICAL ANALYSIS
3 credits.

Polynomial forms, divided differences. Polynomial interpolation. Polynomial approximation: uniform approximation and Chebyshev polynomials, least-squares approximation and orthogonal polynomials. Numerical differentiation and integration. Splines, B-splines and spline approximation. Numerical methods for solving initial and boundary value problems for ordinary differential equations.
Requisites: (MATH 320, 340, 341, or 375), (MATH 322, 376, 421, or 521), and (COMP SCI 200, 220, 300, 310, or 301 prior to Spring 2020, or placement into COMP SCI 300); grad/professional standing; member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in numerical analysis (e.g., Lagrange polynomials, Gibbs phenomenon, Runge phenomenon, orthogonal polynomials, recurrence relation, Gaussian quadrature points, splines, etc.).
Audience: Both Grad & Undergrad

2. Use different techniques of numerical analysis in their appropriate settings (e.g., polynomial interpolation, least square approximation, discrete Fourier transform, the Golub-Welsch algorithm, fast Fourier transform, trapezoidal rule and Simpson's rule, numerical differentiation, forward and backward Euler's method, etc.).
Audience: Both Grad & Undergrad

3. State the main theoretical results related to the error analysis for different methods (e.g., least square error, numerical integration using a Riemann sum, the trapezoidal rule, Simpson's rule and Gaussian quadratures, (semi-)discrete Fourier transform, forward and backward Euler, etc.), and recall the arguments for these theorems and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

4. Convey arguments in oral and written forms using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

5. Identify applications of course content in current areas of research.
Audience: Graduate

MATH 519 — ORDINARY DIFFERENTIAL EQUATIONS
3 credits.

Provides a rigorous introduction to ordinary differential equations and dynamical systems. Intended for math majors and advanced (or graduate) students in other disciplines.
Requisites: (MATH 320, 340, 341, or 375) and (MATH 322, 376, 421, or 521) or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in ordinary differential equations (e.g., systems of differential equations, dependence on initial conditions, exponentials of matrices, Lyapunov functions, etc.).
Audience: Both Grad & Undergrad

2. Use such definitions to argue that a mathematical object does or does not have the condition of being a particular type or having a particular property (e.g., that a function is a solution to an ode, local and global stability of an equilibrium, that an initial value problem has a unique solution, etc.).
Audience: Both Grad & Undergrad

3. Recall and state the standard theorems of ordinary differential equations (e.g., the existence and uniqueness theorem, Hartman-Grobman theorem). Moreover, recall the arguments for these theorems and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

4. Use such theorems in the context of longer arguments by examining their premises (e.g., differentiable dependence upon initial conditions, checking stability via Lyapunov functions, etc.).
Audience: Both Grad & Undergrad

5. Prove or disprove statements related to the above definitions, properties, and theorems using techniques of mathematical argument (direct methods, indirect methods, constructing examples and counterexamples, etc.).
Audience: Both Grad & Undergrad

6. Convey arguments in oral and written forms using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

7. Identify applications of course content in current areas of research.
Audience: Graduate

MATH 521 — ANALYSIS I
3 credits.

The real numbers, elements of set theory, metric spaces and basic topology, sequences and series, limits, continuity, differentiation, integration, sequences and series of functions, uniform convergence.
Requisites: (MATH 234 and 467), (MATH 322, 341, 376, or 421), graduate/professional standing, or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in classical real analysis (e.g., the of a set, continuity of a function, limit of a sequence, etc.).
Audience: Both Grad & Undergrad

2. Use the above definitions to prove if a mathematical construct does or does not have the condition of being a particular mathematical object or having a particular property (e.g., that a given function is continuous, that a given set is compact, that a series converges absolutely, etc.).
Audience: Both Grad & Undergrad

3. Recall and state the standard theorems of classical real analysis. (e.g., the Bolzano- Weierstrass theorem, monotone bounded sequences converge, the fundamental theorem of calculus, etc.). Moreover, the student will be able to recall the arguments for these theorems and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

4. Use the above theorems in the context of longer arguments by examining their premises (e.g., proving that a function has a maximum by verifying that it is continuous on a compact set).
Audience: Both Grad & Undergrad

5. Prove or disprove statements related to the above definitions, properties, and theorems using techniques of mathematical argument (direct methods, indirect methods, constructing examples and counterexamples, induction, etc.).
Audience: Both Grad & Undergrad

6. Convey arguments in oral and written forms using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

7. Identify applications of course content in areas of modern research.
Audience: Graduate

MATH 522 – ANALYSIS II
3 credits.

Special functions, power series, Fourier series, approximation, contraction principle, characterizations of compactness in metric spaces, applications to differential equations. Differential calculus in normed spaces, including implicit and inverse function theorems. Course is essential for graduate work in mathematics.
Requisites: MATH 521 and (MATH 320, 340, 341, or 375) or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in advanced real analysis (e.g., uniform and pointwise convergences, Fourier series, compactness, metric spaces, etc.).
Audience: Both Grad & Undergrad

2. Use the above definitions to prove if a mathematical construct does or does not have the condition of being a particular mathematical object or having a particular property (e.g. that a sequence of functions converges uniformly or not, whether a set in a metric space is compact or not, etc.).
Audience: Both Grad & Undergrad

3. Recall and state the standard theorems of advanced real analysis. (e.g., Arzela-Ascoli theorem, Stone-Weierstrass theorem, the Contraction Principle etc.), and recall the arguments for these theorems and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

4. Use the above theorems in the context of longer arguments by examining their premises (e.g., using the Arzela-Ascoli theorem to check if a set of continuous functions is relatively compact or not).
Audience: Both Grad & Undergrad

5. Prove or disprove statements related to the above definitions, properties, and theorems using techniques of mathematical argument (direct methods, indirect methods, constructing examples and counterexamples, etc.).
Audience: Both Grad & Undergrad

6. Convey arguments in oral and written forms using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

7. Identify applications of course content in current areas of research.
Audience: Both Grad & Undergrad

MATH/COMP SCI/I SY E/STAT 525 – LINEAR OPTIMIZATION
3 credits.

Introduces optimization problems whose constraints are expressed by linear inequalities. Develops geometric and algebraic insights into the structure of the problem, with an emphasis on formal proofs. Presents the theory behind the simplex method, the main algorithm used to solve linear optimization problems. Explores duality theory and theorems of the alternatives.
Requisites: MATH 320, 340, 341, 375, or 443 or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Use linear programming to formulate real world decision problems.
Audience: Both Grad & Undergrad

2. Apply algorithms to solve linear programming problems and demonstrate their correctness.
Audience: Both Grad & Undergrad

3. Combine different proving techniques explored in class in an original way to show new results.
Audience: Graduate

MATH 531 – PROBABILITY THEORY
3 credits.

A rigorous introduction to probability theory at an advanced undergraduate level. Only a minimal amount of measure theory is used, in particular, the theory of Lebesgue integrals is not needed. It is aimed at math majors and Master's degree students, or students in other fields who will need probability in their future careers. Gives an introduction to the basics (Kolmogorov axioms, conditional probability and independence, random variables, expectation) and discusses some classical results with proofs (DeMoivre-Laplace limit theorems, the study of simple random walk on the one dimensional lattice, applications of generating functions).
Requisites: MATH 376, 421, or 521 or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. State, explain, and apply the axioms, principal results, definitions, and theorems of undergraduate probability theory. This includes concepts such as probability spaces, random variables and random vectors and their probability distributions, conditional probability, independence, law of large numbers, and the central limit theorem.
Audience: Undergraduate

2. Calculate probabilities and expectations in simple model problems.
Audience: Undergraduate

3. Use probability theory to model simplified real-world situations with random outcomes. In particular, students can identify and apply the most common probability distributions, including the Bernoulli, binomial, geometric, Poisson, uniform, normal, and exponential distributions.
Audience: Undergraduate

4. Analyze long-term behavior in simple model problems using the law of large numbers, the central limit theorem, and the Borel-Cantelli lemma.
Audience: Undergraduate

5. Construct proofs of simple theorems in probability theory.
Audience: Undergraduate

MATH 535 – MATHEMATICAL METHODS IN DATA SCIENCE
3 credits.

A rigorous introduction to mathematical concepts important for modern data science. Topics include: matrix factorizations, optimization theory and algorithms, probabilistic models, finite Markov chains. Mathematical techniques are motivated by and illustrated on a range of applied problems from machine learning and statistics.
Requisites: (MATH 320, 340, 341, 375 or M E/COMP SCI/E C E 532) and (STAT/MATH 309, 431, MATH 531, STAT 311 or E C E 331) and (MATH 322, 341, 375, 421, 467, or COMP SCI 577), graduate/professional standing, or member of Pre-Masters Mathematics (Visiting Intl) Prgrm
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. State and calculate eigenvalue, singular value and QR decompositions and apply them to data science techniques such as spectral clustering, principal components analysis and least-squares problems.
Audience: Both Grad & Undergrad

2. State and derive properties of multivariate normal distributions and apply them to data science problems based on Gaussian models such as mixtures of Gaussians and Gaussian graphical models.
Audience: Both Grad & Undergrad

3. Formulate certain machine learning and statistics problems as optimization problems, solve these problems using simple optimization algorithms such as first-order methods and state results about the convergence of these algorithms.
Audience: Both Grad & Undergrad

4. State and derive basic properties of finite Markov chain models and apply them to data science techniques such as Markov chain Monte Carlo.
Audience: Both Grad & Undergrad

5. Construct proofs of simple theorems in matrix factorizations, Gaussian modeling, optimization theory, and finite Markov chains.
Audience: Both Grad & Undergrad

6. Implement data science methods based on matrix factorizations, Gaussian modeling, optimization theory, and finite Markov chains in a programming language such as Python.
Audience: Both Grad & Undergrad

7. Identify and use course content in the context of current/modern research in mathematics and data science.
Audience: Graduate

MATH 540 – LINEAR ALGEBRA II
3 credits.

Review of linear transformations, duality. Diagonalization of linear transformations.The Cayley Hamilton Theorem. Minimal polynomials. The Jordan canonical form. Exponential function. Inner product spaces, orthonormal bases and Gram-Schmidt orthogonalization. Operators on inner product spaces. Self-adjoint, unitary and positive operators. Spectral theorem. singular value decomposition. Bilinear and quadratic forms. Norms, bounded linear operators, matrix norms. Basic multilinear algebra. This is a second course in linear algebra.
Requisites: (MATH 234 or 375), (MATH 320, 340, 341, or 375), and (MATH 341, 375, 421, 467, or 521), or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in advanced linear algebra (e.g., diagonalizable matrices, minimal polynomials, inner product spaces, and their operators, canonical forms, etc.).
Audience: Both Grad & Undergrad

2. Use such definitions to argue that a mathematical object does or does not have the condition of being a particular type or having a particular property (e.g., whether a matrix is diagonalizable, whether a space is an inner product space, etc.).
Audience: Both Grad & Undergrad

3. Recall and state the standard theorems of advanced linear algebra (e.g., the spectral theorem, Sylvester's theorem, the Gram-Schmidt algorithm, etc.), and recall the arguments for these theorems and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

4. Use such theorems in the context of longer arguments by examining their premises (e.g,. establishing results on canonical forms, applying algorithms to diagonalize matrices, find canonical forms, etc.).
Audience: Both Grad & Undergrad

5. Prove or disprove statements related to the above definitions, properties, and theorems using techniques of mathematical argument (direct methods, indirect methods, constructing examples and counterexamples, induction, etc.).
Audience: Both Grad & Undergrad

6. Convey arguments using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

7. Identify applications of course content in areas of modern research (Graduate only).
Audience: Graduate

MATH 541 – MODERN ALGEBRA
3 credits.

Groups, normal subgroups, Cayley's theorem, rings, ideals, homomorphisms, polynomial rings, abstract vector spaces.
Requisites: (MATH 234 or 375), (MATH 320, 340, 341, or 375), and (MATH 341, 375, 421, 467, or 521), or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in modern abstract algebra (e.g., groups and their actions, rings, fields, homomorphisms, standard examples of these, etc.).
Audience: Both Grad & Undergrad

2. Use such definitions to argue that a mathematical object does or does not have the condition of being a particular type or having a particular property (e.g., whether a group is abelian, whether a homomorphism is an isomorphism, etc.).
Audience: Both Grad & Undergrad

3. Recall and state the standard theorems of abstract algebra. (e.g., the isomorphism theorems, the Sylow theorems, Lagrange's theorem, etc.), and recall the arguments for these theorems and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

4. Use such theorems in the context of longer arguments by examining their premises (e.g., to classify groups of a given order, prove that alternating groups are simple, etc.).
Audience: Both Grad & Undergrad

5. Prove or disprove statements related to the above definitions, properties, and theorems using techniques of mathematical argument (direct methods, indirect methods, constructing examples and counterexamples, induction, etc.).
Audience: Both Grad & Undergrad

6. Convey arguments using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

7. Identify applications of course content in areas of modern research.
Audience: Graduate

MATH 542 – MODERN ALGEBRA
3 credits.

Field extensions, roots of polynomials, splitting fields, simple extensions, linear transformations, matrices, characteristic roots, canonical forms, determinants.
Requisites: MATH 541 or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in advanced abstract algebra (e.g., rings, modules, fields, Galois groups, etc.).
Audience: Both Grad & Undergrad

2. Use such definitions to argue that a mathematical object does or does not have the condition of being a particular type or having a particular property (e.g. whether a field extension is normal, whether a ring is a principal ideal domain, classifying abelian groups, etc.).
Audience: Both Grad & Undergrad

3. Recall and state the standard theorems of advanced abstract algebra (e.g. the fundamental theorem of Galois theory, the classification of modules over principal ideal domains, results on canonical forms of matrices, etc.) and recall the arguments for these theorems and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

4. Use such theorems in the context of longer arguments by examining their premises (e.g., determining if a polynomial is solvable over a given field, finding the normal and Jordan canonical forms of linear transformations and applying these to problems in various fields like differential equations, etc.).
Audience: Both Grad & Undergrad

5. Prove or disprove statements related to the above definitions, properties, and theorems using techniques of mathematical argument (direct methods, indirect methods, constructing examples and counterexamples, induction, etc.).
Audience: Both Grad & Undergrad

6. Convey arguments using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

7. Identify applications of course content in current areas of research.
Audience: Graduate

MATH 551 – ELEMENTARY TOPOLOGY
3 credits.

Topological spaces, connectedness, compactness, separation axioms, metric spaces.
Requisites: (MATH 234 or 375), (MATH 320, 340, 341, or 375), and (MATH 341, 375, 421, 467, or 521), or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in elementary point set topology (e.g., abstract topological spaces, metric spaces, Hausdorff spaces, compact spaces, etc.).
Audience: Both Grad & Undergrad

2. Use such definitions to argue that a mathematical object does or does not have the condition of being a particular type or having a particular property (e.g., connected, compact Hausdorff).
Audience: Both Grad & Undergrad

3. Recall and state the standard theorems of point set topology (e.g., Extension theorems, Tychnoff Theorem, etc.) and recall the arguments for these theorems and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

4. Use such theorems in the context of longer arguments by examining their premises (e.g., proving a map is a homeomorphism).
Audience: Both Grad & Undergrad

5. Prove or disprove statements related to the above definitions, properties, and theorems using techniques of mathematical argument (direct methods, indirect methods, constructing examples and counterexamples, induction, etc.).
Audience: Both Grad & Undergrad

6. Convey arguments using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

7. Identify applications of course content in areas of modern research.
Audience: Graduate

MATH 552 – ELEMENTARY GEOMETRIC AND ALGEBRAIC TOPOLOGY
3 credits.

Introduction to algebraic topology. Emphasis on geometric aspects, including two-dimensional manifolds, the fundamental group, covering spaces, basic simplicial homology theory, the Euler-Poincare formula, and homotopy classes of mappings.
Requisites: (MATH 551 and 541) or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in algebraic topology (e.g., covering spaces, universal covering spaces, fundamental group, CW-complexes, closed oriented surfaces, homology, euler characteristic, etc.).
Audience: Both Grad & Undergrad

2. Use such definitions to argue that a mathematical object does or does not have the condition of being a particular type or having a particular property (e.g., a set is simply connected, two sets are homotopic, etc.).
Audience: Both Grad & Undergrad

3. Recall and state the standard theorems of algebraic topology (e.g., the classification of closed oriented surfaces, etc.), and recall the arguments for these theorems and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

4. Use such theorems in the context of longer arguments by examining their premises.
Audience: Both Grad & Undergrad

5. Prove or disprove statements related to the above definitions, properties, and theorems using techniques of mathematical argument (direct methods, indirect methods, constructing examples and counterexamples etc.).
Audience: Both Grad & Undergrad

6. Convey arguments using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

7. Identify applications of course content in current areas of research.
Audience: Graduate

MATH 561 – DIFFERENTIAL GEOMETRY
3 credits.

Theory of curves and surfaces by differential methods.
Requisites: (MATH 320, 340, 341, or 375) and (MATH 322, 376, 421, or 521) or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in differential geometry in n-dimensional real space (e.g., vector spaces and inner product spaces, manifolds, Riemannian metric on a manifold, arc length, curvature, torsion, geodesic curves, etc.).
Audience: Both Grad & Undergrad

2. Recall and state the standard theorems of differential geometry (e.g., Frenet-Serret equations, Hopf winding number theorem, four vertex theorem for convex curves, etc.), and recall the arguments for these theorems and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

3. Compute various quantities related to curves and surfaces in the n-dimensional real space using the definitions and theorems (e.g., the fundamental forms, arc length, curvature, total derivative, etc.).
Audience: Both Grad & Undergrad

4. Use the covered theorems in the context of longer arguments by examining their premises (e.g., arguing paths are geodesics, applying the inverse function theorem to show a level set is a manifold, etc.).
Audience: Both Grad & Undergrad

5. Prove or disprove statements related to the above definitions, properties, and theorems using techniques of mathematical argument (direct methods, indirect methods, constructing examples and counterexamples, induction, etc.).
Audience: Both Grad & Undergrad

6. Convey arguments using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

7. Identify applications of course content in current areas of research.
Audience: Graduate

MATH 567 – MODERN NUMBER THEORY
3 credits.

A course in number theory covering fundamentals and modern applications in topics of recent interest: Modular arithmetic, quadratic reciprocity, arithmetic functions, zeta function, Diophantine equations, transcendental numbers, Roth's theorem, continued fractions, and the circle method. Optional material from probability including random matrix theory.
Requisites: MATH 541 or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Honors - Honors Optional (%)
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in the field of Number Theory (e.g., congruence, quadratic residue, arithmetic function, elliptic curves, etc.).
Audience: Both Grad & Undergrad

2. Use such definitions to argue that a mathematical object does or does not have the condition of being a particular type or having a particular property (e.g., a number is transcendental, a continued fraction is positive, etc.).
Audience: Both Grad & Undergrad

3. Recall and state the standard theorems of number theory. (e.g., quadratic reciprocity, Roth's theorem, etc.). Moreover, the student will be able to recall the arguments for these theorems and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

4. Use such theorems in the context of longer arguments by examining their premises (e.g., Applying the euclidean algorithm to show that rational numbers have a finite continued fraction expansion , etc.)
Audience: Both Grad & Undergrad

5. Prove or disprove statements related to the above definitions, properties, and theorems using techniques of mathematical argument (direct methods, indirect methods, constructing examples and counterexamples, induction, etc.).
Audience: Both Grad & Undergrad

6. Convey arguments using English with appropriate mathematical terminology and notation.
Audience: Both Grad & Undergrad

7. Identify applications of course content in areas of modern research.
Audience: Graduate

MATH 570 – FUNDAMENTALS OF SET THEORY
3 credits.

Introduces the basic concepts of Set Theory including: Set-theoretical paradoxes and means of avoiding them, sets, relations, functions, orders and well-orders, proof by transfinite induction and definitions by transfinite recursion, cardinal and ordinal numbers and their arithmetic, construction of the real numbers, the axiom of choice and its consequences.
Requisites: (MATH 234 and 467) or (MATH 341, 375, 421 or 521) or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2022
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in set theory (e.g., sets, power sets, cardinality, ordinals, Zermelo-Fraenkel Axiom System etc.).
Audience: Both Grad & Undergrad

2. Use such definitions to argue that sets do or do not have the condition of a particular property (e.g., that a set is countable, enumerable, well ordered, etc.).
Audience: Both Grad & Undergrad

3. Describe the role of the axiom system of Zermelo-Fraenkel set theory.
Audience: Both Grad & Undergrad

4. Recall and state the standard theorems of set theory (e.g., the Axiom of Choice, Zorn's Lemma, the Well-ordering Theorem, construction of the real numbers from the natural numbers, etc.) and recall the arguments for these theorems and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

5. Prove or disprove statements related to the above definitions, properties, and theorems using techniques of mathematical argument (direct methods, indirect methods, constructing examples and counterexamples, induction, etc.).
Audience: Both Grad & Undergrad

6. Convey arguments using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

7. Identify applications of course content in areas of modern research.
Audience: Graduate

MATH/PHILOS 571 – MATHEMATICAL LOGIC
3 credits.

Basics of logic and mathematical proofs; propositional logic; first order logic; undecidability.
Requisites: (MATH 234 or 375), (MATH 320, 340, 341, or 375), and (MATH 341, 375, 421, 467, or 521), or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2021
Learning Outcomes: 1. Recall and state the formal definitions of the first-order logic and their properties used in formal logic (e.g., truth assignments, syntax, semantics, theories, models, etc.).
Audience: Both Grad & Undergrad

2. Use such definitions to argue certain objects do or do not have the condition or property (e.g., decidability, compactness, undecidability, etc.).

Audience: Both Grad & Undergrad

3. Recall and state the standard theorems of logic. (e.g., Soundness and Completeness Theorems, the Compactness Theorem, Godel's Incompleteness Theorem, etc.) and recall the arguments for these theorems and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

4. Use concepts from logic in the context of larger arguments (e.g., nonstandard models of arithmetic, etc.).
Audience: Both Grad & Undergrad

5. Prove or disprove statements related to the above definitions, properties, and theorems using techniques of mathematical argument (direct methods, indirect methods, constructing examples and counterexamples, induction, etc.).
Audience: Both Grad & Undergrad

6. Convey arguments using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

7. Identify applications of course content in areas of modern research .
Audience: Graduate

MATH 605 – STOCHASTIC METHODS FOR BIOLOGY
3 credits.

Intended to provide a rigorous foundation for stochastic modeling of biological systems. The mathematical emphasis is in stochastic analysis and simulation. Biological applications include epidemiological phenomena, biochemical reaction networks and population dynamics.
Requisites: (STAT/MATH 431, 309, STAT 311 or MATH 531) and (MATH 320, 340, 341, 375, 421 or 531) or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2015

MATH 607 – TOPICS IN MATHEMATICS STUDY ABROAD
1-5 credits.

Credit is awarded to students who have completed an appropriate math course abroad at the advanced level having no direct equivalence within the math department offerings. The study abroad course must be pre-approved by the math department.
Requisites: None
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: Yes, unlimited number of completions

MATH/B M I/BIOCHEM/BMOLCHEM 609 – MATHEMATICAL METHODS FOR SYSTEMS BIOLOGY
3 credits.

Provides a rigorous foundation for mathematical modeling of biological systems. Mathematical techniques include dynamical systems and differential equations. Applications to biological pathways, including understanding of bistability within chemical reaction systems, are emphasized.
Requisites: MATH 415 and (MATH 320, 340, 341, or 375) or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties in systems biology (e.g., reaction networks, reaction rate equations, mass-action kinetics models, detailed balanced and complex balanced systems, Lyapunov functions, etc.).
Audience: Both Grad & Undergrad

2. Use such definitions to argue that a mathematical object does or does not have the condition of being a particular type or having a particular property (e.g., reversible, weakly reversible, mass-action, detailed balanced, complex balanced, globally stable, oscillatory, persistent, permanent, etc.).
Audience: Both Grad & Undergrad

3. Recall and state the standard theorems of the field (e.g., the Horn-Jackson theorem, the deficiency zero theorem, theorems on characterization of mass-action systems, theorems on persistence and permanence, theorems on dynamical equivalence, etc.) and recall the arguments for these theorems and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

4. Construct mathematical arguments related to the above definitions, properties, and theorems, including the construction of examples and counterexamples.
Audience: Both Grad & Undergrad

5. Convey arguments using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

6. Model real biological systems by means of systems of differential equations, and be able to use software (such as Matlab) for visualization of their dynamics. Example models could include: (i) Enzymes, substrates and saturating kinetics, (ii) Glycolytic oscillations, (iii) Cell cycle control, budding yeast cell cycle models, (iv) Activator-inhibitor and positive feedback systems.
Audience: Both Grad & Undergrad

7. Identify applications of course content in current areas of research.
Audience: Graduate

MATH 616 – DATA-DRIVEN DYNAMICAL SYSTEMS, STOCHASTIC MODELING AND PREDICTION
3 credits.

An introduction to data-driven dynamical systems, including mathematical theory, methodology, numerical algorithms, applications and the use of a programming language to solve related coding problems. Topics include stochastic toolkits for dynamical systems and data science, linear Gaussian processes, nonlinear stochastic systems, elementary stochastic differential equations, data assimilation, parameter estimation, forecasting and prediction.
Requisites: (MATH 320, 340, 341 or 375) and (STAT/MATH 309, 431, STAT 311 or MATH 531) and (MATH 322, 341, 375, 421, or 467), graduate/professional standing, or declared in Mathematics VISP
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Learning Outcomes: 1. Conduct numerical simulations of stochastic dynamical systems and implement data assimilation methods.
Audience: Both Grad & Undergrad

2. Analyze data from a stochastic dynamical system and characterize the system's properties in terms of its statistics, such as mean, variance, and autocorrelation function.
Audience: Both Grad & Undergrad

3. Calculate analytical formulas for the solutions of discrete-time stochastic processes and stochastic differential equations.
Audience: Both Grad & Undergrad

4. Recall and state the basic properties of Brownian motion and the Wiener process.
Audience: Both Grad & Undergrad

5. Illustrate the basic properties of Brownian motion and the Wiener process using numerical simulations.
Audience: Both Grad & Undergrad

6. Estimate the parameters of a dynamical system using simulated data.
Audience: Both Grad & Undergrad

7. Predict the future evolution of a dynamical system using analytical formulas and numerical simulations.
Audience: Both Grad & Undergrad

8. Assess the accuracy of a prediction in terms of different definitions of error and uncertainty.
Audience: Both Grad & Undergrad

9. Identify applications of course content in areas of modern research.
Audience: Graduate

MATH 619 – ANALYSIS OF PARTIAL DIFFERENTIAL EQUATIONS
3 credits.

A rigorous introduction to the theoretical underpinnings of the basic methods and techniques in the modern theory of PDEs. It is aimed at math majors, but will also be useful to some students in the sciences, engineering and economics who feel the need for a deeper understanding of the theory of PDEs. The emphasis is on the exposure to a number of different methods of solution of PDEs and their connection to physical phenomena modeled by the equations. The goals include both learning to solve some basic types of PDEs as well as to understand the motivation behind and inner workings of the techniques involved.
Requisites: (MATH 322, 421, or 521) and (MATH 319, 320, 376, 415, or 519) or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2024

MATH 621 – INTRODUCTION TO MANIFOLDS
3 credits.

Integration in Euclidean spaces, change of variables, multilinear algebra, vector fields and differential forms, manifolds and tangent spaces, integration on manifolds, Stokes theorem. Classical vector analysis. Cauchy integral theorem.
Requisites: MATH 522, (MATH 521 and 561), graduate/professional standing, or declared in Mathematics VISP
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Use the techniques of multilinear algebra and apply them to differential forms in Euclidean space and on abstract differentiable manifolds. This includes being able to compute with the exterior derivative.
Audience: Both Grad & Undergrad

2. Identify and/or construct differentiable manifolds. This includes being able to identify spaces as differentiable manifolds and to endow abstract topological spaces with differentiable manifold structures.
Audience: Both Grad & Undergrad

3. Extend calculus concepts from Euclidean space in order to apply them to abstract differentiable manifolds. This includes being able to identify and work with differentiable maps between differentiable manifolds in computations and proofs
Audience: Both Grad & Undergrad

4. Use the essential definitions and theorems from calculus on manifolds in the context of computations and proofs. This includes taking Lie derivatives of vector fields on differentiable manifolds, computing integrals of curves, integrating differential forms, and Stokes' theorem.
Audience: Both Grad & Undergrad

5. Identify applications of course content in current areas of research.
Audience: Graduate

MATH 623 – COMPLEX ANALYSIS
3 credits.

Elementary functions of a complex variable; conformal mapping; complex integrals; the calculus of residues.
Requisites: MATH 321 or 521 or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in complex analysis (e.g., principle branches, conjugates, holomorphic and analytic functions, etc.).
Audience: Both Grad & Undergrad

2. Use such definitions to argue that a mathematical object does or does not have the condition of being a particular type or having a particular property (e.g., that a function is complex differentiable, that an infinite product converges, classification of singularities, etc.).
Audience: Both Grad & Undergrad

3. Recall and state the standard theorems of complex analysis (e.g., Cauchy's Integral formula, the maximum modulus principle, the Riemann mapping Theorem), and recall the arguments for these theorems and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

4. Use such theorems in the context of longer arguments by examining their premises (e.g., computation of real integrals using path integration techniques, computation of residues of meromorphic functions, that a given function has an analytic continuation, etc.).
Audience: Both Grad & Undergrad

5. Prove or disprove statements related to the above definitions, properties, and theorems using techniques of mathematical argument (direct methods, indirect methods, constructing examples and counterexamples, induction, etc.).
Audience: Both Grad & Undergrad

6. Convey arguments in oral and written forms using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

7. Identify applications of course content in current areas of research.
Audience: Graduate

MATH 627 – INTRODUCTION TO FOURIER ANALYSIS
3 credits.

Fourier series and integrals, and their applications.
Requisites: MATH 521 or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties relevant to the analysis of Fourier series, the Fourier transform, and their applications in mathematics (e.g., convergence, divergence, convolution, Lipschitz property, Schwartz space, etc.).
Audience: Both Grad & Undergrad

2. Use the above definitions to prove if a mathematical construct does or does not have the condition of being a particular mathematical object or having a particular property used in Fourier analysis (e.g., that a sequence is equidistributed, that a set of functions is uniformly bounded, etc.).
Audience: Both Grad & Undergrad

3. Recall and state the standard theorems and results of elementary Fourier analysis (e.g., the Fourier series of an integrable function converges to that function on its domain, etc.), and recall the arguments for these results and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

4. Use the above theorems in the context of longer arguments by examining their premises (e.g., verifying integrability of a function in order to conclude that its Fourier series converges, etc.).
Audience: Both Grad & Undergrad

5. Prove or disprove statements related to the above definitions, properties, and theorems using techniques of mathematical argument (direct methods, indirect methods, constructing examples and counterexamples, induction, etc.).
Audience: Both Grad & Undergrad

6. Convey arguments in oral and written forms using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

7. Identify applications of course content in current areas of research.
Audience: Graduate

MATH 629 – INTRODUCTION TO MEASURE AND INTEGRATION
3 credits.

Lebesgue integral and measure, abstract measure and integration, differentiation, spaces of integrable functions.
Requisites: MATH 522 or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in measure theory (e.g., measures and measurability, Lebesgue integral, absolute continuity, product measures, Lp spaces, etc.).
Audience: Both Grad & Undergrad

2. Use such definitions to argue that a mathematical object does or does not have the condition of being a particular type or having a particular property (e.g., that a measure is absolutely continuous with respect to another one, that a sequence of functions converge almost everywhere or in measure, etc.).
Audience: Both Grad & Undergrad

3. Recall and state the standard theorems of measure theory (e.g., Fatou's Lemma, Egoroff's theorem, Hahn decomposition theorem, monotone convergence theorem, dominated convergence theorem, Holder's inequality, etc.), and recall the arguments for these theorems and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

4. Prove or disprove statements related to the above definitions, properties, and theorems using techniques of mathematical argument (direct methods, indirect methods, constructing examples and counterexamples, etc.).
Audience: Both Grad & Undergrad

5. Convey arguments in oral and written forms using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

6. Identify applications of course content in current areas of research.
Audience: Graduate

MATH/I SY E/OTM/STAT 632 – INTRODUCTION TO STOCHASTIC PROCESSES
3 credits.

Topics include discrete-time Markov chains, Poisson point processes, continuous-time Markov chains, and renewal processes. Applications to queueing, branching, and other models in science, engineering and business.
Requisites: (STAT/MATH 431, 309, STAT 311 or MATH 531) and (MATH 320, 340, 341, 375, 421 or 531) or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties for stochastic processes (e.g., discrete space Markov chains, Poisson processes, renewal processes, branching processes, etc.).
Audience: Both Grad & Undergrad

2. Use such definitions to argue that a mathematical object does or does not have the condition of being a particular type or having a particular property (e.g., irreducibility, aperiodicity, recurrence, transience, the Markov property, etc.).
Audience: Both Grad & Undergrad

3. Recall and state the standard theorems of stochastic processes. (e.g., laws of large numbers for Markov chains, existence of limiting/stationary distributions, law of large numbers for renewal processes, etc.) and recall the arguments for these theorems and the underlying logic of their proofs.

Audience: Both Grad & Undergrad

4. Construct mathematical arguments related to the above definitions, properties, and theorems, including the construction of examples and counterexamples.
Audience: Both Grad & Undergrad

5. Convey arguments in oral and written forms using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

6. Model simple real life situations by means of discrete-space stochastic processes and calculate probabilities associated with those processes.
Audience: Both Grad & Undergrad

7. Identify applications of course content in current areas of research.
Audience: Graduate

MATH 635 – AN INTRODUCTION TO BROWNIAN MOTION AND STOCHASTIC CALCULUS
3 credits.

Presents an introduction to Brownian motion and its application to stochastic calculus. Sample path properties of Brownian motion, Ito stochastic integrals, Ito's formula, stochastic differential equations and properties of their solutions, and various applications will be included.
Requisites: (MATH 521 and STAT/I SY E/MATH/OTM 632) or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in stochastic calculus (e.g., martingale, stopping time, filtration, Brownian motion, stochastic integral etc.).
Audience: Both Grad & Undergrad

2. Use such definitions to argue that a mathematical object does or does not have the condition of being a particular type or having a particular property (e.g., checking if a discrete or continuous time process is a martingale, using characteristic functions to characterize a distribution, identifying different methods of convergence, etc.).
Audience: Both Grad & Undergrad

3. Recall and state the standard theorems of stochastic calculus. (e.g., martingale convergence, optional stopping theorem, existence results related to the Ito integral, Ito's formula, etc.), and recall the arguments for these theorems and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

4. Solve simple stochastic differential equations.
Audience: Both Grad & Undergrad

5. Convey arguments in oral and written forms using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

6. Model simple financial situations by means of stochastic processes and calculate probabilities associated with those processes (e.g., the Black-Scholes formula).
Audience: Both Grad & Undergrad

7. Identify applications of course content in current areas of research.
Audience: Graduate

MATH/E C E 641 – INTRODUCTION TO ERROR-CORRECTING CODES
3 credits.

Coding theory. Codes (linear, Hamming, Golay, dual); decoding-encoding; Shannon's theorem; sphere-packing; singleton and Gilbert-Varshamov bounds; weight enumerators; MacWilliams identities; finite fields; other codes (Reed-Muller, cyclic, BCH, Reed-Solomon) and error-correction algorithms.
Requisites: MATH 541 or graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Breadth - Natural Science
Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2017

MATH 681 – SENIOR HONORS THESIS
3 credits.

Individual study for honors math majors writing a thesis in mathematics.
Requisites: Consent of instructor
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Honors - Honors Only Courses (H)
Repeatable for Credit: No
Last Taught: Spring 2024

MATH 682 – SENIOR HONORS THESIS
3 credits.

Individual study for honors math majors writing a thesis in mathematics.
Requisites: Consent of instructor
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Honors - Honors Only Courses (H)
Repeatable for Credit: No
Last Taught: Fall 2023

MATH 691 – UNDERGRADUATE THESIS
2-4 credits.

Individual study for students writing a thesis in mathematics.
Requisites: Consent of instructor
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Fall 2002

MATH 692 – UNDERGRADUATE THESIS
2-4 credits.

Individual study for students writing a thesis in mathematics.
Requisites: Consent of instructor
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Repeatable for Credit: No
Last Taught: Spring 2018

MATH 698 – DIRECTED STUDY
1-3 credits.

Directed study projects as arranged with a faculty member.
Requisites: Consent of instructor
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024
Learning Outcomes: 1. Recall and state the formal definitions of the mathematical objects and their properties used in an area of mathematics.

Audience: Both Grad & Undergrad

2. Use such definitions to argue that a mathematical object does or does not have the condition of being a particular type or having a particular property.
Audience: Both Grad & Undergrad

3. Recall and state the standard theorems of an area of mathematics and recall the arguments for these theorems and the underlying logic of their proofs.
Audience: Both Grad & Undergrad

4. Use such theorems in the context of longer arguments by examining their premises.
Audience: Both Grad & Undergrad

5. Prove or disprove statements related to the above definitions, properties, and theorems using techniques of mathematical argument (direct methods, indirect methods, constructing examples and counterexamples, induction, etc.).
Audience: Both Grad & Undergrad

6. Convey arguments using English and appropriate mathematical terminology, notation and grammar.
Audience: Both Grad & Undergrad

7. Identify applications of course content in areas of modern research.
Audience: Graduate

MATH 699 – DIRECTED STUDY
1-6 credits.

Directed study projects as arranged with a faculty member.
Requisites: Consent of instructor
Course Designation: Level - Advanced
L&S Credit - Counts as Liberal Arts and Science credit in L&S
Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024

MATH 703 – METHODS OF APPLIED MATHEMATICS 1
3 credits.

Study of the linear algebraic structure underlying discrete equilibrium problems. Boundary value problems for continous equilibria: Sturm-Liouville equations, Laplace's equation, Poisson's equation, and the equations for Stokes flow. Contour integration and conformal mapping. Applications of dynamics leading to initial value problems for ODEs and PDEs. Green's functions for ODEs and introduction to asymptotic methods for ODEs, e.g. WKB analysis. Separation of variables and eigenfunction expansions for linear PDEs. Examples from physics and engineering throughout. Knowledge of undergraduate linear algebra, analysis and complex analysis is strongly recommended.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023

MATH 704 – METHODS OF APPLIED MATHEMATICS-2
3 credits.

Derivation, nature and solution of canonical partial differential equations of applied mathematics. Conservation laws, advection, diffusion. First order PDEs, characteristics, shocks. Traffic flow, eikonal and Hamilton-Jacobi equations. Higher order PDEs: classification, Fourier analysis, well-posedness. Series solutions and integral transforms. Green's functions and distributions. Similarity solutions. Asymptotics of Fourier integrals. Laplace's method, stationary phase. Ship waves. Perturbation methods. Knowledge of undergraduate linear algebra, analysis and complex analysis is strongly recommended.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024

MATH 705 – MATHEMATICAL FLUID DYNAMICS
3 credits.

Advanced introduction to fluid dynamics. Basic concepts; elementary viscous flow; Navier-Stokes equations. Elementary airfoil theory; boundary layers. Vortex motion. Waves. Very viscous flow. Compressible flows. Instabilities, bifurcations, turbulence. Requires working knowledge of multivariate calculus, differential equations and mechanics.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024

MATH/STAT 709 – MATHEMATICAL STATISTICS
4 credits.

Introduction to measure theoretic probability; derivation and transformation of probability distributions; generating functions and characteristic functions; conditional expectation, sufficiency, and unbiased estimation; methods of large sample theory including laws of large numbers and central limit theorems; order statistics.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Understand foundations of mathematical statistics, including key notations, important concepts, and basic definitions
Audience: Graduate

2. Develop proof-based theoretical skills for analyzing statistical problems
Audience: Graduate

3. Familiarize various theoretical tools relevant to statistical research, including modern probability theory, optimization, and information theory
Audience: Graduate

4. Prepare for statistical research by learning recent development in high-dimensional statistics and shrinkage estimation
Audience: Graduate

MATH/STAT 710 – MATHEMATICAL STATISTICS
4 credits.

Estimation, efficiency, Neyman-Pearson theory of hypothesis testing, confidence regions, decision theory, analysis of variance, and distribution of quadratic forms.
Requisites: STAT/MATH 709
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024

MATH/COMP SCI 714 – METHODS OF COMPUTATIONAL MATHEMATICS I
3 credits.

Development of finite difference methods for hyperbolic, parabolic and elliptic partial differential equations. Analysis of accuracy and stability of difference schemes. Direct and iterative methods for solving linear systems. Introduction to finite volume methods. Applications from science and engineering. Students are strongly encouraged to have programming skills (e.g. COMP SCI 200) and some undergraduate numerical analysis (e.g. MATH/COMP SCI 514 or COMP SCI 412), analysis and differential equations (e.g. MATH 322 and MATH 521) and linear algebra (e.g. MATH 341).
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023

MATH/COMP SCI 715 – METHODS OF COMPUTATIONAL MATHEMATICS II
3 credits.

Introduction to spectral methods (Fourier, Chebyshev, Fast Fourier Transform), finite element methods (Galerkin methods, energy estimates and error analysis), and mesh-free methods (Monte-Carlo, smoothed-particle hydrodynamics) for solving partial differential equations. Applications from science and engineering. Applications from science and engineering. Students are strongly encouraged to have programming skills (e.g. COMP SCI 200), undergraduate numerical analysis (e.g. MATH/COMP SCI 514 or COMP SCI 412), analysis (MATH 322 and 521) and linear algebra (e.g. MATH 341 or equiv.)
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024

MATH 716 – ORDINARY DIFFERENTIAL EQUATIONS
3 credits.

Existence, uniqueness, and continuous dependence theorems, linear systems, stability, singular points, and boundary value problems. Qualitative behavior of nonlinear equations, stability, Lyapunov functions, invariant manifolds, bifurcation theory, periodic orbits, and connecting orbits.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2021

MATH 717 – STOCHASTIC COMPUTATIONAL METHODS
3 credits.

Introduction to computational methods that use stochastic algorithms and/or methods that are applied to random or stochastic mathematical problems. The main emphasis will be placed on learning practical tools, while some aspects of theoretical foundations will also be covered (e.g., basic error analysis for numerical solution of stochastic differential equations (SDEs), and basic convergence of Monte Carlo methods). Topics include Monte Carlo methods, Bayesian inference and Bayesian sampling, simulation of Markov chains, numerical analysis for SDEs, data assimilation / state estimation, stochastic optimization methods and random sketching. Applications to science, engineering, finance, data science, and other practical problems also included.
Requisites: Graduate/professional standing or declared in Mathematics Visiting International Student Program (graduate or dissertator)
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Implement a range of Monte Carlo solvers.
Audience: Graduate

2. Write clear and well-reasoned mathematical arguments that explain the convergence of Monte Carlo methods.
Audience: Graduate

3. Implement stochastic optimization methods, and understand the basic proofs for convergence.
Audience: Graduate

4. Explain and implement a range of data assimilation methods.
Audience: Graduate

5. Apply the Monte Carlo solvers, stochastic optimization solvers and data assimilation solvers to practical problems.
Audience: Graduate

6. Conduct error analysis for computational stochastic differential equations.
Audience: Graduate

MATH 718 – RANDOMIZED LINEAR ALGEBRA AND APPLICATIONS
3 credits.

Random solvers have been playing increasingly crucial roles in the modern computational tasks. The recent breakthroughs in applied and computational linear algebra that incorporate techniques of randomization have proven to be of great importance in modern applied math, computational sciences and data science, such as inverse problems, machine learning and scientific computing. The guiding principle is that one may greatly reduce computational and storage expenses at the cost of a small probability of failure. Systematic study of these modern methods of randomized linear algebra solvers will be provided, presenting mathematical backgrounds, algorithms, and concrete applications. Core theoretical topics include randomized Kaczmarz and its generalization to stochastic gradient descent, randomized singular value decomposition, random sketching, matrix completion, and compressive sensing, and corresponding applications.
Requisites: Graduate/professional standing or declared in Mathematics VISP (graduate or dissertator)
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Learning Outcomes: 1. Implement, in a computer language, the principal linear algebra solvers, namely, matrix completion, randomized SVD, matrix sketching, and the Kaczmarz algorithm.
Audience: Graduate

2. Identify the conditions, assumptions, and effectiveness of the principal linear algebra solvers.
Audience: Graduate

3. Reproduce the proof strategies for effectiveness of these algorithms and summarize the main parts of these proofs.
Audience: Graduate

4. Apply random linear algebra solvers to problems from image reconstruction, inverse problems and topic modeling.
Audience: Graduate

5. Model problems from the physical or social sciences in matrix form and identify regimes to apply linear algebra solvers.
Audience: Graduate

MATH 719 – PARTIAL DIFFERENTIAL EQUATIONS
3 credits.

Classical theory of partial differential equations, together with an introduction to the modern theory based on functional analysis. Familiarity with basic measure theory (e.g. MATH 629 or 721) or concurrent registration in MATH 721 is strongly recommended.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Recall and state the basic theorems regarding solutions to the transport, Laplace, heat, and wave equations.
Audience: Graduate

2. Use the above theorems to analyze solutions to first and second order linear partial differential equations of the above types, with novel initial data or boundary values.
Audience: Graduate

3. Apply basic tools for studying first order nonlinear partial differential equations to analyze conservation laws and equations of Hamilton-Jacobi type.
Audience: Graduate

4. Recall and state the definitions and basic theorems of Sobolev spaces.
Audience: Graduate

5. Analyze novel second order elliptic equations by establishing existence, regularity, and maximum principles of solutions, given initial or boundary data with various properties.
Audience: Graduate

MATH 720 – PARTIAL DIFFERENTIAL EQUATIONS
3 credits.

Linear elliptic, parabolic and hyperbolic equations, continuing with calculus of variations and then nonlinear initial value problems.
Requisites: Graduate/professional standing or declared in Mathematics VISP (graduate or dissertator)
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Analyze notions of weak solutions to linear and nonlinear initial value problems defined by partial differential equations.
Audience: Graduate

2. Analyze proof methods to establish uniqueness and existence of weak solutions to partial differential equations.
Audience: Graduate

3. Illustrate the general theory by applying it to concrete examples.
Audience: Graduate

4. Investigate parameter dependence of weak solutions to both linear and nonlinear PDE
Audience: Graduate

MATH 721 – A FIRST COURSE IN REAL ANALYSIS
3 credits.

Real analysis concentrating on measures, integration, and differentiation and including an introduction to Hilbert spaces. Knowledge of undergraduate analysis (e.g. the sequence MATH 521 and 522) is strongly recommended.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023

MATH 722 – COMPLEX ANALYSIS
3 credits.

The basic theory of functions of one complex variable including Cauchy formula, singularities and residues, meromorphic functions, conformal mappings, harmonic functions, approximation and the nonhomogeneous d-bar equation. Requires knowledge of undergraduate analysis (e.g. the sequence MATH 521 and 522).
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024

MATH 725 — A SECOND COURSE IN REAL ANALYSIS
3 credits.

Continuation of MATH 721. An introduction to further topics in real analysis: Banach spaces, Fourier transforms, elements of distribution theory, and applications.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024

MATH/COMP SCI/I SY E/STAT 726 — NONLINEAR OPTIMIZATION I
3 credits.

Theory and algorithms for nonlinear optimization, focusing on unconstrained optimization. Line-search and trust-region methods; quasi-Newton methods; conjugate-gradient and limited-memory methods for large-scale problems; derivative-free optimization; algorithms for least-squares problems and nonlinear equations; gradient projection algorithms for bound-constrained problems; and simple penalty methods for nonlinearly constrained optimization. Students are strongly encouraged to have knowledge of linear algebra and familiarity with basic mathematical analysis.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024

MATH/COMP SCI/I SY E 728 — INTEGER OPTIMIZATION
3 credits.

Introduces optimization problems over integers, and surveys the theory behind the algorithms used in state-of-the-art methods for solving such problems. Special attention is given to the polyhedral formulations of these problems, and to their algebraic and geometric properties. Applicability of Integer Optimization is highlighted with applications in combinatorial optimization. Key topics include: formulations, relaxations, polyhedral theory, cutting planes, decomposition, enumeration. Students are strongly encouraged to have knowledge of Linear Programming (e.g., MATH/COMP SCI/I SY E/STAT 525), including algorithms, duality and polyhedral theory.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Describe and explain the basics of polyhedral theory, which consists in the study of systems of linear inequalities both from an algebraic and a geometric point of view
Audience: Graduate

2. Define perfect formulations and identify what properties are desirable in an integer programming formulation of a problem
Audience: Graduate

3. Explain how valid inequalities can be used as cutting planes to strengthen integer programming formulations
Audience: Graduate

MATH/COMP SCI/I SY E 730 — NONLINEAR OPTIMIZATION II
3 credits.

Theory and algorithms for nonlinearly constrained optimization. Relevant geometric concepts, including tangent and normal cones, theorems of the alternative, and separation results. Constraint qualifications. Geometric and algebraic expression of first-order optimality conditions. Second-order optimality conditions. Duality. Nonlinear programming algorithms: merit functions and filters; interior-point, augmented Lagrangian, and sequential quadratic programming algorithms.
Requisites: STAT/COMP SCI/I SY E/MATH 726
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2022

MATH/STAT 733 — THEORY OF PROBABILITY I
3 credits.

An introduction to measure theoretic probability and stochastic processes.Topics include foundations, independence, zero-one laws, laws of large numbers, convergence in distribution, characteristic functions, central limit theorems, random walks, conditional expectations. Familiarity with basic measure theory (e.g. MATH 629 or 721) or concurrent registration in MATH 721 is strongly recommended.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2023

MATH/STAT 734 — THEORY OF PROBABILITY II
3 credits.

Possible topics include martingales, weak convergence of measures, introduction to Brownian motion.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024

MATH 735 — STOCHASTIC ANALYSIS
3 credits.

Foundations of continuous time stochastic processes, semimartingales and the semimartingale integral, Ito's formula, stochastic differential equations, stochastic equations for Markov processes, application in finance, filtering, and control. The course relies on measure theoretic probability theory that can be reviewed at the beginning of the semester.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2022

MATH 740 – ENUMERATIVE COMBINATORICS/SYMMETRIC FUNCTIONS
3 credits.

Inclusion-exclusion principle, permutation statistics, sieve methods, unimodal sequences, posets, lattice theory, Mobius functions, generating functions, bases and transition matrices for symmetric functions, Young tableaux, plane partitions, polytopes, poset homology, Stanley-Reisner rings.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2020

MATH 741 – ABSTRACT ALGEBRA
3 credits.

Usually a study of finite groups and noncommutative rings. Group theoretic topics may include: permutation groups, Lagrange's theorem, Cauchy's theorem and the Sylow theorems, solvable and nilpotent groups. Ring theoretic topics may include: Artinian rings and modules, the Wedderburn theorems, the Hopkins-Levitzki theorem, the Jacobson radical and density theorem. The basic prerequisite for all advanced graduate courses in algebra. Familiarity with topics in undergraduate algebra (e.g. MATH 541 and 542) is strongly recommended.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023

MATH 742 – ABSTRACT ALGEBRA
3 credits.

Continuation of MATH 741. Usually the study of commutative rings and fields. Ring theoretic topics may include: modules over PIDs, Noetherian rings and the Hilbert basis theorem, the Lasker-Noether theorem, the Krull intersection theorem, integrality and the Hilbert Nullstellensatz. Field theoretic topics may include: algebraic extensions, Galois theory, solvability of polynomials and classical constructability problems.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024

MATH 746 – TOPICS IN RING THEORY
3 credits.

Will alternate between commutative and noncommutative ring theory. Commutative topics include localization; local rings; dimension theory; Cohen-Macaulay rings. Noncommutative topics include projective modules; injective modules; flat modules; homological and global dimension; Wedderburn and Goldie rings. Basic graduate algebra courses (e.g. MATH 741 and 742) are strongly recommended.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023

MATH 747 – LIE ALGEBRAS
3 credits.

Lie algebras and matrix groups. Topics: tangent spaces; exponentials; Baker-Campbell-Hausdorff formula; (nilpotent, solvable, semisimple) Lie algebras; Engel's and Lie's theorems; Levi decomposition; Killing form; sl(2)-representations; root systems; Dynkin diagrams; Weyl groups; Cartan and Borel subalgebras; Serre's theorem. Basic graduate algebra courses (e.g. MATH 541 and 542 or MATH 741 and 742) are strongly recommended.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024

MATH 748 – ALGEBRAIC NUMBER THEORY
3 credits.

A rigorous introduction to the arithmetic of number fields; algebraic integers, geometry of numbers, Dirichlet's Unit Theorem, ideal class groups, first case of Fermat's Last Theorem; prime decompositions, Galois automorphisms. Basic graduate algebra courses (e.g. MATH 741 and 742) are strongly recommended.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2022

MATH 749 – ANALYTIC NUMBER THEORY
3 credits.

An introduction to the Riemann zeta function and Dirichlet L-functions, and their application to topics such as the distribution of prime numbers and the arithmetic of quadratic fields. Familiarity with elementary number theory [such as MATH 567] and complex analysis [such as MATH 623] is strongly recommended.
Requisites: Graduate/professional standing or declared in Mathematics VISP (graduate or dissertator)
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023
Learning Outcomes: 1. Examine a range of mathematical proofs and identify underlyingprinciples and techniques.
Audience: Graduate

2. Write clear and well-reasoned mathematical arguments.
Audience: Graduate

3. Explain the methods used to establish the analytic continuation andfunctional equation of the Riemann zeta function and Dirichlet L-functions.
Audience: Graduate

4. Apply tools from complex analysis to analyze the distribution ofzeros of L-functions.
Audience: Graduate

5. Apply the above results on the zeros of L-functions to analyze thedistribution of prime numbers.
Audience: Graduate

MATH 750 – HOMOLOGICAL ALGEBRA
3 credits.

Topics include: complexes, cohomology, double complexes, spectral sequences; abelian categories, derived categories, derived functors; Tor and Ext, Koszul complexes; group cohomology; sheaf cohomology, hypercohomology. Basic graduate algebra courses (e.g. MATH 741 and 742) are strongly recommended
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2023

MATH 751 – INTRODUCTORY TOPOLOGY I
3 credits.

An introduction to algebraic and differential topology. Elements of homotopy theory, fundamental group, covering spaces. Differentiable manifolds, tangent vectors, regular values, transversality, examples of compact Lie groups. Homological algebra, chain complexes, cell complexes, singular and cellular homology, calculations for surfaces, spheres, projective spaces, etc. Familiarity with undergraduate algebra and topology MATH 541 or 551) is strongly recommended.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023

MATH 752 – INTRODUCTORY TOPOLOGY II
3 credits.

Continuation of MATH 751. Cohomology, Universal Coefficient Theorem, Kunneth Formula, cup and cap products, applications to manifolds, orientability, Poincare Duality. Differential forms, integration and Stokes Theorem, De Rham Theorem. Calculations, further duality theorems, Euler class, Lefschetz Fixed-Point Theorem.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024

MATH 753 – ALGEBRAIC TOPOLOGY I
3 credits.

Higher homotopy groups, elements of obstruction theory, fibrations, bundle theory, classifying spaces, applications to smooth mainfolds, differential forms, vector bundles, characteristic classes, cobordism, applications and calculations. Basic graduate topology courses (e.g. MATH 751 and 752) are strongly recommended.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023

MATH 754 – ALGEBRAIC TOPOLOGY II
3 credits.

Continuation of MATH 753. Topics include: spectral sequences and their applications, topology of Lie Groups, H-spaces, Hopf Algebras, homotopy classification of bundles, the Steenrod Algebra and its applications, intorduction to generalized cohomology theories, spectra, elements of K-theory.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2018

MATH 758 – INTRODUCTION TO ERGODIC THEORY AND DYNAMICS
3 credits.

An introduction to ergodic theory and dynamics covering fundamental theorems of ergodic theory, classical examples of one and two dimensional dynamics as well as applications to study of group actions.
Requisites: Graduate/professional standing
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024
Learning Outcomes: 1. Analyze a range of mathematical proofs in discrete and continuous dynamical systems and recognize the underlying principles and techniques.
Audience: Graduate

2. Write clear and well-reasoned mathematical arguments to describe the long time behavior of measure preserving transformations.
Audience: Graduate

3. State the Birkhoff, von Neumann, and maximal ergodic theorems and reproduce their proofs.
Audience: Graduate

4. Apply fundamental ergodic theorems from classical dynamics to low-dimensional examples such as the circle rotation, interval exchange transformations, and geodesic and horocycle flows on two dimensional manifolds.
Audience: Graduate

5. Apply results in ergodic theory and dynamics to solve novel problems in geometric group theory and geometric topology.
Audience: Graduate

MATH 761 – DIFFERENTIABLE MANIFOLDS
3 credits.

Differentiable manifolds, vector bundles, implicit function theorem, submersions and immersions, vector fields and flows, foliations and Frobenius theorem, differential forms and exterior calculus, integration and Stokes' theorem, De Rham theory, Riemannian metrics. Familiarity with basic undergraduate analysis courses MATH 521 and 522 or MATH 621) is strongly recommended.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024

MATH 763 – INTRODUCTION TO ALGEBRAIC GEOMETRY
3 credits.

Algebraic preliminaries, including local rings; valuation theory, and power series rings; geometry of algebraic varieties with emphasis on curves and surfaces.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023

MATH 764 – INTRODUCTION TO ALGEBRAIC GEOMETRY
3 credits.

Continuation of MATH 763.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2023

MATH 765 – DIFFERENTIAL GEOMETRY
3 credits.

Covers the metric properties of Riemannian manifolds. The following topics will be covered: Vector bundles and connections, Riemannian metrics, submanifolds and second fundamental form, first variation of arc length, geodesics, Hopf-Rinow theorem, second variation of arc length, Jacobi fields and index lemmas, Bonnet-Meyer theorem, Rauch comparison theorem, spaces of constant curvature, Hodge-de Rham theory. Familiarity with the topics in a differential manifolds course (e.g. MATH 761) is strongly recommended.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2023

MATH 770 – FOUNDATIONS OF MATHEMATICS
3 credits.

First-order logic syntax and semantics, Completeness and Compactness Theorems, Lowenheim-Skolem Theorem, computable and computably enumerable sets, Incompleteness Theorem, axioms of Zermelo-Fraenkel set theory with choice, ordinal and cardinal arithmetic.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2023

MATH 771 – SET THEORY
3 credits.

Martin's Axiom, Suslin and Aronszajn trees, diamond principle, absoluteness and reflection, constructible universe, and one-step forcing constructions. Familiarity with the topics in a basic Foundations course such as MATH 770 is strongly recommended.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2021

MATH 773 – COMPUTABILITY THEORY
3 credits.

Turing degree and jump, strong reducibilities, arithmetic hierarchy, index sets, simple and (hyper)hypersimple sets, easy forcing arguments in computability theory, finite and infinite injury, Friedberg-Muchnik and Sacks Splitting Theorem, Sacks Jump and Sacks Density Theorems, computable ordinals. Familiarity with the topics in a basic Foundations course such as MATH 770 is strongly recommended.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2024

MATH 776 – MODEL THEORY
3 credits.

Review of compactness and some consequences. Quantifier elimination with examples. The omitting types theorem. Categoricity. Baldwin-Lachlan theory. Strongly minimal and o-minimal theories. Saturated models. Morley's theorem. Familiarity with the topics in a basic Foundations course such as MATH 770 is strongly recommended.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2022

MATH/CBE/E C E 777 – NONLINEAR DYNAMICS, BIFURCATIONS AND CHAOS
3 credits.

Advanced interdisciplinary introduction to qualitative and geometric methods for dissipative nonlinear dynamical systems. Local bifurcations of ordinary differential equations and maps. Chaotic attractors, horseshoes and detection of chaos.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2016

MATH 790 – MASTERS THESIS
1-3 credits.

Work on a Master's thesis under the supervision of a faculty member.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, for 2 number of completions
Last Taught: Spring 2024

MATH 801 – TOPICS IN APPLIED MATHEMATICS
3 credits.

Selected topics in applied mathematics, applied analysis or numerical analysis and scientific computing.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2023

MATH/STAT 803 – EXPERIMENTAL DESIGN I
3 credits.

Summary of matrix algebra required, theory of estimable functions, incomplete blocks, balanced incomplete block designs, partially balanced incomplete block designs.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Fall 2020

MATH 807 – DYNAMICAL SYSTEMS
3 credits.

Treats the qualitative behavior of continuous and discrete dynamical systems, including Hamiltonian systems of differential equations. Typical topics include periodic and almost periodic solutions, the fixed point theorem of Poincare and Birkhoff, invariant curves and KAM theory, celestial mechanics, and chaotic behavior.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2023

MATH 821 – ADVANCED TOPICS IN REAL ANALYSIS
3 credits.

Topics in partial differential equations and real analysis.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2023

MATH 823 – ADVANCED TOPICS IN COMPLEX ANALYSIS
3 credits.

Several complex variables. Basic several complex variables or more special topics.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2023

MATH 825 – SELECTED TOPICS IN FUNCTIONAL ANALYSIS
3 credits.

Topics will vary and may include spectral theory, nonlinear functional analysis or abstract harmonic analysis.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2021

MATH 826 – ADVANCED TOPICS IN FUNCTIONAL ANALYSIS AND DIFFERENTIAL EQUATIONS
3 credits.

Topics in functional analysis and differential equations.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2016

MATH 827 – FOURIER ANALYSIS
3 credits.

Introduction to Fourier analysis in Euclidean spaces and related topics that may include singular and oscillatory integrals and trigonometric series.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2023

MATH 828 – ADVANCED TOPICS IN HARMONIC ANALYSIS
3 credits.

Continuation of MATH 827. Advanced topics in harmonic analysis.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024

MATH/STAT 833 – TOPICS IN THE THEORY OF PROBABILITY
3 credits.

Advanced topics in probability and stochastic processes.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2023

MATH/E C E 842 – TOPICS IN APPLIED ALGEBRA
3 credits.

Applied topics with emhasis on algebraic constructions and structures. Examples include: algebraic coding theory; codes (algebraic-geometric, convolutional, low-density-parity-check, space-time); curve and lattice based cryptography; watermarking; computer vision (face recognition, multiview geometry).
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024

MATH 843 – REPRESENTATION THEORY
3 credits.

Introduction to the representation theory of Lie groups and their combinatorics. Universal enveloping algebras, highest weight modules, induction, restriction, weights, characters, multiplicity formulas, tensor products, Shapovalov forms, filtrations, Kazhdan-Zetlin patterns, Littelmann paths.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2023

MATH 844 – ARITHMETIC GEOMETRY
3 credits.

An introduction to arithmetic geometry with emphasis on arithmetic of elliptic curves.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: No
Last Taught: Spring 2022

MATH 845 – CLASS FIELD THEORY
3 credits.

Introduction to local and global class field theory. Theory of local fields; local and global class field theory; complex multiplication, adeles, ideles, idele class characters, Tchebotarev's Density Theorem, CM elliptic curves, construction of class fields of imaginary quadratic fields.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024

MATH 846 – TOPICS IN COMBINATORICS
3 credits.

Topics in algebraic combinatorics such as (but not limited to) association schemes, hypergeometric series, classical orthogonal polynomials, codes, lattices, invariant theory, alternating sign matrices and domino tilings, statistical mechanical models, 6j-symbols, buildings and diagram geometries, matroids.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2023

MATH 847 – TOPICS IN ALGEBRA
3 credits.

Topics may include: Lie groups, algebraic groups, Chevalley groups, simple groups and associated geometries, group cohomology, group rings, Hopf algebras, enveloping algebras, quantum groups, infinite-dimensional Lie algebras, Hecke algebras, automorphic forms, Galois representations, zeta and L-functions, abelian varieties.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2022

MATH 848 – ADVANCED TOPICS IN NUMBER THEORY
3 credits.

This is an advanced graduate topic course in number theory. Topics will vary. Target audience: Advanced graduate students in number theory, representation theory, and algebraic geometry.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2021

MATH 849 – AUTOMORPHIC FORMS
3 credits.

Classical and/or modern theory of automorphic forms. Representation theory of GL(2).
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2022

MATH 851 – TOPICS IN GEOMETRIC TOPOLOGY
3 credits.

Advanced Topics in Geometric Topology.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2023

MATH 853 – TOPICS IN ALGEBRAIC TOPOLOGY
3 credits.

Topics in Algebraic Topology.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2022

MATH 856 – TOPICS IN DIFFERENTIAL TOPOLOGY
3 credits.

The theory of differential manifolds such as differential forms and de Rham theorem, cobordism groups, Lie groups, homogeneous spaces, fiber bundles, characteristic classes.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2021

MATH 863 – ADVANCED TOPICS IN ALGEBRAIC GEOMETRY
3 credits.

Geometry of several complex variables; algebraic groups, abelian varieties; topological aspects of algebraic geometry, including sheaf theory and homology theory; advanced theory of local rings; intersection theory of algebraic varieties.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2023

MATH 865 – ADVANCED TOPICS IN GEOMETRY
3 credits.

Selected from advanced projective geometry, non-Euclidean geometry, Riemannian geometry, distance geometry and the geometry of convex surfaces, geometry of numbers.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2022

MATH 867 – ANALYTIC NUMBER THEORY
3 credits.

Prime number theory, prime number theory for arithmetic progressions, additive number theory, density theorems.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2015

MATH 873 – ADVANCED TOPICS IN FOUNDATIONS
3 credits.

Advanced topics from all areas of mathematical logic.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024

MATH/E C E/STAT 888 – TOPICS IN MATHEMATICAL DATA SCIENCE
1-3 credits.

Advanced topics in the mathematical foundations of data science
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2023
Learning Outcomes: 1. Apply advanced mathematical concepts to solve a variety of data science problems
Audience: Graduate

2. Analyze rigorously the mathematical properties of methods used in data science
Audience: Graduate

MATH 900 – GRADUATE TEACHING SEMINAR
1 credit.

Focuses on theory and practical skills relevant to teaching mathematics at the graduate or post-secondary level.
Requisites: Declared in Mathematics PhD
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Fall 2023
Learning Outcomes: 1. Design lesson plans and curricular activities based on research-supported approaches to teaching mathematics at the university level.
Audience: Graduate

2. Develop individualized strategies to foster inclusive learning environments in the mathematics classroom.
Audience: Graduate

3. Critically evaluate a variety of teaching approaches through self and peer evaluations and examination of case studies.
Audience: Graduate

4. Apply best practices in teaching and learning in a low-stakes environment to practice and receive feedback on the performance of those skills.
Audience: Graduate

MATH 921 – SEMINAR IN ANALYSIS
1-3 credits.

Selected topics in Analysis.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024

MATH 941 – SEMINAR-ALGEBRA
1-3 credits.

Selected topics in Algebra.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024

MATH 951 – SEMINAR IN TOPOLOGY
1-3 credits.

Selected topics in Topology.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024

MATH 967 – SEMINAR IN NUMBER THEORY
1-3 credits.

Selected topics in Number Theory.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024

MATH 975 – SEMINAR-THE FOUNDATIONS OF MATHEMATICS
1-3 credits.

Selected topics in Mathematical Logic.
Requisites: Graduate/professional standing or member of the Pre-Masters Mathematics (Visiting International) Program
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024

MATH 990 – READING AND RESEARCH
1-3 credits.

Reading and research in all areas of Mathematics.
Requisites: Consent of instructor
Course Designation: Grad 50% - Counts toward 50% graduate coursework requirement
Repeatable for Credit: Yes, unlimited number of completions
Last Taught: Spring 2024