

MATHEMATICS (MA-UY)

MA-UY 492X Independent Study (1-4 Credits)

Typically offered Fall and Spring

In this course, students read, study and investigate selected topics in mathematics. Students discuss and present problems. | Prerequisite: departmental adviser's approval.

Grading: Ugrd Tandon Graded

Repeatable for additional credit: Yes

MA-UY 914 Precalculus for Engineers (4 Credits)

Typically offered Fall, Spring, and Summer terms

This course covers: foundations of algebra, exponents, multiplication of algebraic expressions, factoring algebraic expressions, working with algebraic fractions, proportionality, rates of change, equations of lines, completing squares, the quadratic formula, solving equations, systems of linear equations, inequalities, domain and range of functions, exponential and logarithmic functions, compositions of functions, transformations of functions, right triangles, trigonometry of triangles. | Prerequisite: placement exam. Note: credit for this course may not be used to satisfy the minimum credit requirement for graduation. Corequisite: EX-UY 1

Grading: Ugrd Tandon Graded

Repeatable for additional credit: No

Prerequisites: placement exam.

Corequisites: EX-UY 1.

MA-UY 1000 Math Recitation (0 Credits)

Typically offered Fall, Spring, and Summer terms

Math Recitation

Grading: Class does not print on the transcript

Repeatable for additional credit: Yes

MA-UY 1024 Calculus I for Engineers (4 Credits)

Typically offered Fall, Spring, and Summer terms

This course covers: Library of Functions, functions of one variable. Limits, derivatives of functions defined by graphs, tables and formulas, differentiation rules for power, polynomial, exponential and logarithmic functions, derivatives of trigonometric functions, the product and quotient rules, the chain rule, applications of the chain rule, maxima and minima, optimization. The definite integral, the Fundamental Theorem of Calculus and interpretations, theorems about definite integrals, anti-derivatives. | Prerequisite: Placement Exam or MA-UY 914 | Corequisite: EX-UY 1

Grading: Ugrd Tandon Graded

Repeatable for additional credit: No

Prerequisites: Placement Exam or MA-UY 914 | Corequisite: EX-UY 1.

MA-UY 1044 Linear Algebra (4 Credits)

Typically offered Fall and Spring

Systems of linear equations, Gaussian elimination, matrices, determinants, Cramer's rule. Vectors, vector spaces, basis and dimension, linear transformations. Eigenvalues, eigenvectors, and quadratic forms. Restricted to Tandon math and CS majors and students with a permission code from the math department. Fulfills linear algebra requirement for the BS Math and BS CS degrees. Note: Not open to students who have already taken MA-UY 1533, MA-UY 2034, MA-UY 3113 or MA-UY 3054. | Prerequisite: A grade of C or better in MA-UY 1022 or MA-UY 1024 or MA-UY 1324 or MATH-UH 1012Q or MATH-UH 1013Q or MATH-SHU 121 or MATH-SHU 201

Grading: Ugrd Tandon Graded

Repeatable for additional credit: No

Prerequisites: A grade of C or better in MA-UY 1022 or MA-UY 1024 or MA-UY 1324 or MATH-UH 1012Q or MATH-UH 1013Q or MATH-SHU 121 or MATH-SHU 201, Anti-Requisites: MA-UY 2034 or MA-UY 3054.

MA-UY 1124 Calculus II for Engineers (4 Credits)

Typically offered Fall, Spring, and Summer terms

This course covers techniques of integration, introduction to ordinary differential equations, improper integrals, numerical methods of integration, applications of integration, sequences, series, power series, approximations of functions via Taylor polynomials, Taylor series, functions of two variables, graphs of functions of two variables, contour diagrams, linear functions, functions of three variables. | Prerequisites: MA-UY 1024 or MA-UY 1324 | Corequisite: EX-UY 1.

Grading: Ugrd Tandon Graded

Repeatable for additional credit: No

Prerequisites: MA-UY 1024 or MA-UY 1324 | Corequisite: EX-UY 1.

MA-UY 1414 Basic Practice of Statistics for Social Science (4 Credits)

Typically offered Spring

We are inundated by data, but data alone do not translate into useful information. Statistics provides the means for organizing, summarizing, and therefore better analyzing data so that we can understand what the data tell us about critical questions. If one collects data then understanding how to use statistical methods is critical, but it is also necessary to understand and interpret all the information we consume on a daily basis. This course provides these basic statistical approaches and techniques. This course may not be acceptable as a substitute for any other Probability and Statistics course. For Sustainable Urban Environments (SUE) students, please see your advisor. Note: Not open to math majors or students who have taken or will take MA-UY 2054 or MA-UY 2224 or MA-UY 3014 or MA-UY 3514 or ECE-UY 2233 or equivalent.

Grading: Ugrd Tandon Graded

Repeatable for additional credit: No

MA-UY 2034 Linear Algebra and Differential Equations (4 Credits)*Typically offered Fall, Spring, and Summer terms*

MA-UY 2034 is an introduction to ordinary differential equations and linear algebra. The course develops the techniques for the analytic and numeric solutions of ordinary differential equations (and systems) that are widely used in modern engineering and science. Linear algebra is used as a tool for solving systems of linear equations as well as for understanding the structure of solutions to linear (systems) of differential equations. Topics covered include the fundamental concepts of linear algebra such as Gaussian elimination, matrix theory, linear transformations, vector spaces, subspaces, basis, eigenvectors, eigenvalues and the diagonalization of matrices, as well as the techniques for the analytic and numeric solutions of ordinary differential equations (and systems) that commonly appear in modern engineering and science. | Prerequisite: MA-UY 1124 or MA-UY 1424. Note: Not open to students who have taken MA-UY 1044 or MA-UY 3054 or MA-UY 3083 or MA-UY 4204.

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** MA-UY 1124 or MA-UY 1424, Anti-Requisite: MA-UY 3044 or MA-UY 3054 or MA-UY 4204.**MA-UY 2034G Linear Algebra and Differential Equations (4 Credits)**

MA-UY 2034 is an introduction to ordinary differential equations and linear algebra. The course develops the techniques for the analytic and numeric solutions of ordinary differential equations (and systems) that are widely used in modern engineering and science. Linear algebra is used as a tool for solving systems of linear equations as well as for understanding the structure of solutions to linear (systems) of differential equations. Topics covered include the fundamental concepts of linear algebra such as Gaussian elimination, matrix theory, linear transformations, vector spaces, subspaces, basis, eigenvectors, eigenvalues and the diagonalization of matrices, as well as the techniques for the analytic and numeric solutions of ordinary differential equations (and systems) that commonly appear in modern engineering and science. | Prerequisite: MA-UY 1124 or MA-UY 1424. Note: Not open to students who have taken MA-UY 1044 or MA-UY 3054 or MA-UY 3083 or MA-UY 4204.

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** MA-UY 1124 or MA-UY 1424, Anti-Requisite: MA-UY 3044 or MA-UY 3054 or MA-UY 4204.**MA-UY 2114 Calculus III: Multi-Dimensional Calculus (4 Credits)***Typically offered Fall, Spring, and Summer terms*

Vectors in the plane and space. Partial derivatives with applications, especially Lagrange multipliers. Double and triple integrals. Spherical and cylindrical coordinates. Surface and line integrals. Divergence, gradient, and curl. Theorems of Gauss and Stokes. | Prerequisite: MA-UY 1124 or MA-UY 1424. Anti-requisite: MA-UY 2514

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** MA-UY 1124 or MA-UY 1424.**MA-UY 2224 Probability and Statistics for Engineers (4 Credits)***Typically offered Fall, Spring, and Summer terms*

An introductory course to probability and statistics. It affords the student some acquaintance with both probability and statistics in a single term. Topics in Probability include mathematical treatment of chance; combinatorics; binomial, Poisson, and Gaussian distributions; the Central Limit Theorem and the normal approximation. Topics in Statistics include sampling distributions of sample mean and sample variance; normal, t-, and Chi-square distributions; confidence intervals; testing of hypotheses; least squares regression model. Applications to scientific, industrial, and financial data are integrated into the course. NOTE: Not open to math majors or students who have taken or will take MA-UY 2054 or MA-UY 3014 or MA-UY 3514 or ECE-UY 2233. | Prerequisite: MA-UY 1124, MA-UY 1424, or MA-UY 1132 or MATH-UH 1020 or MATH-UH 1021 or MATH-SHU 151

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** MA-UY 1124, MA-UY 1424, or MA-UY 1132, or MATH-UH 1020 or MATH-UH 1021 or MATH-SHU 151 Anti-Requisites: Not open to math majors or students who have taken or will take MA-UY 2054 or MA-UY 3014 or MA-UY 3514 or ECE-UY 2233.**MA-UY 2233 Introduction to Probability (3 Credits)***Typically offered Fall*

Standard first course in probability, recommended for those planning further work in probability or statistics. Probability of events, random variables and expectations, discrete and continuous distributions, joint and conditional distributions, moment generating functions, the central limit theorem. | Prerequisites: MA-UY 109, MA-UY 2112, MA-UY 2114 OR MA-UY 2514. Note: Not open to students who have taken MA-UY 2224 or MA-UY 3012 or MA-UY 3022.

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** MA-UY 109, MA-UY 2112, MA-UY 2114 OR MA-UY 2514.**MA-UY 2314 Discrete Mathematics (4 Credits)***Typically offered Fall and Spring*

Logic, proofs, set theory, functions, relations, asymptotic notation, recurrences, modeling computation, graph theory. | Prerequisite: Math Diagnostic Exam or MA-UY 914 (minimum calculus level required) | Prerequisite for Shanghai students: MATH-SHU 131. Note: This course and CS-GY 6003 cannot both be taken for credit.

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** Math Diagnostic Exam or MA-UY 914 (minimum calculus level required) | Prerequisite for Shanghai students: MATH-SHU 131.**MA-UY 2314G Discrete Mathematics (4 Credits)**

Logic, proofs, set theory, functions, relations, asymptotic notation, recurrences, modeling computation, graph theory. | Prerequisite: Math Diagnostic Exam or MA-UY 914 (minimum calculus level required) | Prerequisite for Shanghai students: MATH-SHU 131. Note: This course and CS-GY 6003 cannot both be taken for credit.

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** Math Diagnostic Exam or MA-UY 914 (minimum calculus level required) | Prerequisite for Shanghai students: MATH-SHU 131.

MA-UY 2514 Honors Calculus III (4 Credits)*Typically offered Fall and Spring*

Similar to MA-UY 2114 Calculus III, but at a faster pace and deeper level.

Functions of several variables. Vectors in the plane and space. Partial derivatives with applications, especially Lagrange multipliers. Double and triple integrals. Spherical and cylindrical coordinates. Surface and line integrals. Divergence, gradient, and curl. Theorem of Gauss and Stokes. Students pursuing an honors mathematics degree are especially encouraged to consider this course. Prerequisite: (MA-UY 1124 or MA-UY 1424) with a grade of A- or better OR a 5 on the AP Calculus BC Exam and Department Permission. Anti-requisite: MA-UY 2114

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** Prerequisite: (MA-UY 1124 or MA-UY 1424) with a grade of A- or better OR a 5 on the AP Calculus BC Exam and Department Permission.**Antirequisites:** MA-UY 2114.**MA-UY 3014 Applied Probability (4 Credits)***Typically offered Fall and Spring*

An introduction to the mathematical treatment of random phenomena occurring in the natural, physical, and social sciences. Axioms of mathematical probability, combinatorial analysis, binomial distribution, Poisson and normal approximation, random variables and probability distributions, generating functions, the Central Limit Theorem and Laws of Large Numbers, Markov Chains, and basic stochastic processes. Note: Not open to students who have taken MA-UY 2224, MA-UY 2233, ECE-UY 2233 or MA-UY 3022 | Prerequisite: A grade of C or better in (MA-UY 2114 or MA-UY 2514) and (MA-UY 1044 or MA-UY 2034 or MA-UY 3034 or MA-UY 3054).

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** A grade of C or better in (MA-UY 2114 or MA-UY 2514) and (MA-UY 1044 or MA-UY 2034 or MA-UY 3034 or MA-UY 3054).**MA-UY 3054 Honors Linear Algebra (4 Credits)***Typically offered Fall and Spring*

This honors section of Linear Algebra is intended for well-prepared students who have already developed some mathematical maturity. Its scope will include the usual Linear Algebra (MA-UY 3044) syllabus; however, this class will move faster, covering additional topics and going deeper. Vector spaces, linear dependence, basis and dimension, matrices, determinants, solving linear equations, eigenvalues and eigenvectors, quadratic forms, applications such as optimization or linear regression. Note: Not open to students who have already taken MA-UY 1044, MA-UY 1533, MA-UY 2034, or MA-UY 3113. | Prerequisites: A- or better in MA-UY 1024 or MA-UY 1324 or MA-UY 1022

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** A- or better in MA-UY 1024 or MA-UY 1324 or MA-UY 1022, Anti-Requisites: MA-UY 2034 or MA-UY 3044.**MA-UY 3113 Advanced Linear Algebra and Complex Variables (3 Credits)***Typically offered Spring*

This course provides a deeper understanding of topics introduced in MA-UY 2012 and MA-UY 2034 and continues the development of those topics, while also covering functions of a Complex Variable. Topics covered include: The Gram-Schmidt process, inner product spaces and applications, singular value decomposition, LU decomposition. Derivatives and Cauchy-Riemann equations, integrals and Cauchy integral theorem. Power and Laurent Series, residue theory. | Prerequisites: (MA-UY 2114 or MA-UY 2514) AND (MA-UY 2034). Note: Not open to students who have taken MA-UY 1533, MA-UY 3112 or MA-UY 4433.

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** (MA-UY 2114 or MA-UY 2514) AND (MA-UY 2034).**MA-UY 3204 Linear and Nonlinear Optimization (4 Credits)***Typically offered Fall and Spring*

This course provides an application-oriented introduction to linear programming and convex optimization, with a balanced combination of theory, algorithms, and numerical implementation. Theoretical topics will include linear programming, convexity, duality, and dynamic programming. Algorithmic topics will include the simplex method for linear programming, selected techniques for smooth multidimensional optimization, and stochastic gradient descent. Applications will be drawn from many areas, but will emphasize economics (eg two-person zero-sum games, matching and assignment problems, optimal resource allocation), data science (eg regression, sparse inverse problems, tuning of neural networks) and operations research (eg shortest paths in networks and optimization of network flows). While no prior experience in programming is expected, the required coursework will include numerical implementations, including some programming; students will be introduced to appropriate computational tools, with which they will gain experience as they do the assignments. | Prerequisites: A grade of C or better in (MA-UY 2114 or MA-UY 2514) and (MA-UY 1044 or MA-UY 2034 or MA-UY 3054).

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** A grade of C or better in (MA-UY 2114 or MA-UY 2514) and (MA-UY 1044 or MA-UY 2034 or MA-UY 3054).

MA-UY 3514 Honors Probability (4 Credits)*Typically offered Spring*

The aim of this class is to introduce students to probability theory, with a greater emphasis on rigor, more material, and a faster pace than the Theory of Probability/Applied Probability class. The material will include discrete and continuous probability, and the most fundamental limit theorems (law of large numbers and Central Limit Theorem). Students will be made familiar with the classical models, computations on densities, and convergence to universal distributions. They will also be expected to understand the proofs of all the results seen in class, and be able to argue with mathematical rigor. Note: While B+ or higher is the standard requirement for this course, the department will consider petitions sent to soe.math@nyu.edu if you are on the borderline of that requirement. Not open to students who have taken MA-UY 3014. | Prerequisites: MA-UY 2114 or MA-UY 2514 with a grade of B+ or better, and (MA-UY 1044 or MA-UY 2034 or MA-UY 3034 or MA-UY 3054) with a grade of B+ or better, and MA-UY 2314 with a grade of B+ or better. Anti-Requisites: MA-UY 3014

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No

Prerequisites: MA-UY 2114 or MA-UY 2514 with a grade of B+ or better, and (MA-UY 1044 or MA-UY 2034 or MA-UY 3034 or MA-UY 3054) with a grade of B+ or better, and MA-UY 2314 with a grade of B+ or better.

MA-UY 3604 Mathematical Methods for Physics and Engineering (4 Credits)*Typically offered Fall*

First course of two-semester lecture sequence in mathematical physics for undergraduate students in physics and engineering. Line, surface and volume integrals, gradient, divergence, and curl. Cylindrical and spherical coordinate systems. Tensors and tensor transformations. The Dirac delta function, and integrals and derivatives of the delta function. Functions of complex variables, analytic functions, and the residue theorem. Fourier series, integrals, and transforms. | Prerequisites: PH-UY 2023 and MA-UY 2114; Co-requisites: PH-UY 2033 and (MA-UY 1044 or MA-UY 2034 or MA-UY 3054).

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No

Prerequisites: PH-UY 2023 and MA-UY 2114; Co-requisites: PH-UY 2033 and (MA-UY 1044 or MA-UY 2034 or MA-UY 3054).

MA-UY 4014 Theory of Numbers (4 Credits)*Typically offered Fall*

Divisibility and prime numbers. Linear and quadratic congruences. The classical number-theoretic functions. Continued fractions. Diophantine equations. | Prerequisites: C or better in MA-UY 1124 or MA-UY 1424.

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No

Prerequisites: C or better in MA-UY 1124 or MA-UY 1424.

MA-UY 4044 Algebra (4 Credits)*Typically offered Fall and Spring*

Introduction to abstract algebraic structures, including groups, rings, and fields. Sets and relations. Congruences and unique factorization of integers. Groups, permutation groups, homomorphisms and quotient groups. Rings and quotient rings, Euclidean rings, polynomial rings. Fields, finite extensions. | Prerequisites: A grade of C or better in (MA-UY 2114 or MA-UY 2514) and (MA-UY 1044 (formerly 3044) or MA-UY 3054 or MA-UY 3113). Additionally, it is suggested for students to have taken MA-UY 4614 or MA-UY 4644 as a prerequisite. Note: Cannot receive credit for both MA-UY 4044 and MA-UY 4054.

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No

Prerequisites: C or better in (MA-UY 2114 or MA-UY 2514) and (MA-UY 1044 or MA-UY 3054 or MA-UY 3113).

Antirequisites: MA-UY 4054.**MA-UY 4054 Honors Algebra I (4 Credits)***Typically offered Fall*

Introduction to abstract algebraic structures, including groups, rings, and fields. Sets and relations. Congruences and unique factorization of integers. Groups, permutation groups, group actions, homomorphisms and quotient groups, direct products, classification of finitely generated abelian groups, Sylow theorems. Rings, ideals and quotient rings, Euclidean rings, polynomial rings, unique factorization. | Prerequisites: (A grade of A- or better in MA-UY 2114 or a grade of B+ or better in MA-UY 2514) and (a grade of A- or better in MA-UY 1044 (formerly 3044) or MA-UY 3113 or a grade of B+ or better in MA-UY 3054). Additionally, it is suggested for students to have taken MA-UY 4614 or MA-UY 4644 as a prerequisite. Note: Cannot receive credit for both MA-UY 4044 and MA-UY 4054.

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No

Prerequisites: (A- or better in MA-UY 2114 or B+ or better in MA-UY 2514) and (A- or better in MA-UY 1044 or MA-UY 3113 or B+ or better in MA-UY 3054).

MA-UY 4064 Honors Algebra II (4 Credits)*Typically offered Spring*

Fields, finite extensions, constructions with ruler and compass, Galois theory, solvability by radicals. | Prerequisite: C or better in MA-UY 4054 or (a grade of A in MA-UY 4044 and instructor permission)

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No

Prerequisites: C or better in MA-UY 4054 or (a grade of A in MA-UY 4044 and instructor permission).

MA-UY 4114 Applied Statistics (4 Credits)*Typically offered Spring*

An introduction to the mathematical foundations and techniques of modern statistical analysis for the interpretation of data in the quantitative sciences. Mathematical theory of sampling; normal populations and distributions; chi-square, t, and F distributions; hypothesis testing; estimation; confidence intervals; sequential analysis; correlation, regression; analysis of variance. Applications to the sciences. Use of Matlab for doing computations of the statistical measures listed above. | Prerequisite: MA-UY 3014 or MA-UY 3514. Anti-requisite: MA-UY 2224

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No

Prerequisites: MA-UY 3014 or MA-UY 3514.

Antirequisites: MA-UY 2224.

MA-UY 4204 Ordinary Diff Equations (4 Credits)*Typically offered Fall and Spring*

A first course in ordinary differential equations, including analytical solution methods, elementary numerical methods, and modeling. Topics to be covered include: first-order equations including integrating factors; second-order equations including variation of parameters; series solutions; elementary numerical methods including Euler's methods, Runge-Kutta methods, and error analysis; Laplace transforms; systems of linear equations; boundary-value problems. Restricted to Tandon math majors and students with a permission code from the math department. Fulfills ordinary differential equations requirement for the BS Math degree. | Prerequisites: C or better in (MA-UY 2114 or MA-UY 2514 or MATH-UH 1020 or MATH-UH 1021 or MATH-SHU 151) and (MA-UY 1044 or MA-UY 3054 or MA-UY 3113 or MATH-UH 1022 or MATH-SHU 140 or MATH-SHU 141). Note: Not open to students who have taken or will take MA-UY 2034 or MA-UY 4254

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No

Prerequisites: C or better in (MA-UY 2114 or MA-UY 2514 or MATH-UH 1020 or MATH-UH 1021 or MATH-SHU 151) and (MA-UY 1044 or MA-UY 3054 or MA-UY 3113 or MATH-UH 1022 or MATH-SHU 140 or MATH-SHU 141), Anti-Requisites: MA-UY 2034 or MA-UY 4254.

MA-UY 4204G Ordinary Diff Equations (4 Credits)

A first course in ordinary differential equations, including analytical solution methods, elementary numerical methods, and modeling. Topics to be covered include: first-order equations including integrating factors; second-order equations including variation of parameters; series solutions; elementary numerical methods including Euler's methods, Runge-Kutta methods, and error analysis; Laplace transforms; systems of linear equations; boundary-value problems. Restricted to Tandon math majors and students with a permission code from the math department. Fulfills ordinary differential equations requirement for the BS Math degree. | Prerequisites: C or better in (MA-UY 2114 or MA-UY 2514 or MATH-UH 1020 or MATH-UH 1021 or MATH-SHU 151) and (MA-UY 1044 or MA-UY 3054 or MA-UY 3113 or MATH-UH 1022 or MATH-SHU 140 or MATH-SHU 141). Note: Not open to students who have taken or will take MA-UY 2034 or MA-UY 4254

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No

Prerequisites: C or better in (MA-UY 2114 or MA-UY 2514 or MATH-UH 1020 or MATH-UH 1021 or MATH-SHU 151) and (MA-UY 1044 or MA-UY 3054 or MA-UY 3113 or MATH-UH 1022 or MATH-SHU 140 or MATH-SHU 141).

MA-UY 4254 Honors Ordinary Differential Equations (4 Credits)*Typically offered Fall*

This class will develop rigorously the basic theory of Ordinary Differential Equations (ODEs). Existence and uniqueness of solutions to ODEs are first investigated, for linear and nonlinear problems, set on the real line or the complex plane. More qualitative questions are then considered, about the behavior of the solutions, with possible prolongations to various topics in Dynamical Systems theory. Applications to Physics and Biology will appear naturally when discussing examples. | Prerequisites: A grade of A- or higher in MA-UY 4614 or a grade of B+ or higher in MA-UY 4644. Anti-requisite: MA-UY 4204 or MA-UY 2034

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No

Prerequisites: A grade of A- or higher in MA-UY 4614 or a grade of B+ or higher in MA-UY 4644.

Antirequisites: MA-UY 4204 or MA-UY 2034.**MA-UY 4314 Combinatorics (4 Credits)***Typically offered Spring*

Techniques for counting and enumeration including generating functions, the principle of inclusion and exclusion, and Polya counting. Graph theory. Modern algorithms and data structures for graph-theoretic problems. | Prerequisite: C or better in MA-UY 1124 or MA-UY 1424.

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** C or better in MA-UY 1124 or MA-UY 1424.**MA-UY 4324 Mathematics of Finance (4 Credits)***Typically offered Fall and Spring*

Introduction to the mathematics of finance. Topics include: Linear programming with application pricing and quadratic. Interest rates and present value. Basic probability: random walks, central limit theorem, Brownian motion, lognormal model of stock prices. Black-Scholes theory of options. Dynamic programming with application to portfolio optimization. | Prerequisites: A grade of C+ or better in (MA-UY 2114 or MA-UY 2514) and a grade of C+ or better in (MA-UY 2054 or MA-UY 2224 or MA-UY 2414 or MA-UY 3014 or MA-UY 3022 or MA-UY 3514 or MA-UY 4114).

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No

Prerequisites: A grade of C+ or better in (MA-UY 2114 or MA-UY 2514) and a grade of C+ or better in (MA-UY 2054 or MA-UY 2224 or MA-UY 2414 or MA-UY 3014 or MA-UY 3022 or MA-UY 3514 or MA-UY 4114).

MA-UY 4414 Applied Partial Differential Equations (4 Credits)*Typically offered Fall and Spring*

This course gives an overview of PDEs that occur commonly in the physical sciences with applications in heat flow, wave propagation, and fluid flow. Analytical as well as some numerical solution techniques will be covered, with a focus on applications rather than analysis. | Prerequisites: MA-UY 2034 or MA-UY 4204 or MA-UY 4254

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** MA-UY 2034 or MA-UY 4204 or MA-UY 4254.**MA-UY 4424 Intro Numerical Analysis (4 Credits)***Typically offered Spring*

In numerical analysis one explores how mathematical problems can be analyzed and solved with a computer. As such, numerical analysis has very broad applications in mathematics, physics, engineering, finance, and the life sciences. This course gives an introduction to this subject for mathematics majors. Theory and practical examples using Matlab will be combined to study a range of topics ranging from simple root-finding procedures to differential equations and the finite element method. | Prerequisites: A grade of C or better in (MA-UY 2114 or MA-UY 2514) and (MA-UY 1044 or MA-UY 3034 or MA-UY 3054 or MA-UY 3113) | Anti-Requisite: MA-UY 4524

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No

Prerequisites: A grade of C or better in (MA-UY 2114 or MA-UY 2514) and (MA-UY 1044 or MA-UY 3034 or MA-UY 3054 or MA-UY 3113) | Anti-Requisite: MA-UY 4524.

MA-UY 4434 Applied Complex Variables (4 Credits)*Typically offered Spring*

A first course in complex analysis, with a focus on applications. Topics to be covered include the complex plane, analytic functions, complex differentiation, the Cauchy-Riemann equations, branch cuts, contour integration, the residue theorem, conformal mapping, applications to potential theory and fluid flow. | Prerequisite: A grade of C or better in (MA-UY 2114 or MA-UY 2514) and (MA-UY 1044 or MA-UY 2034 or MA-UY 3054). Note: Not open to students who have taken MA-UY 3113.

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** A grade of C or better in (MA-UY 2114 or MA-UY 2514) and (MA-UY 1044 or MA-UY 2034 or MA-UY 3054).**Antirequisites:** MA-UY 3113.**MA-UY 4444 Intro to Math Modeling (4 Credits)***Typically offered Fall and Spring*

Formulation and analysis of mathematical models. Mathematical tools include dimensional analysis, optimization, simulation, probability, and elementary differential equations. Applications to biology, sports, economics, and other areas of science. The necessary mathematical and scientific background will be developed as needed. Students participate in formulating models as well as in analyzing them. | Prerequisites: A grade of C or better in (MA-UY 2114 or MA-UY 2514) and (MA-UY 2034 or MA-UY 1044 (formerly MA-UY 3044) or MA-UY 3054).

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** A grade of C or better in (MA-UY 2114 or MA-UY 2514) and (MA-UY 2034 or MA-UY 1044 (formerly MA-UY 3044) or MA-UY 3054).**MA-UY 4474 Chaos and Dynamical Systems (4 Credits)***Typically offered Spring*

Topics will include dynamics of maps and of first order and second-order differential equations, stability, bifurcations, limit cycles, dissection of systems with fast and slow time scales. Geometric viewpoint, including phase planes, will be stressed. Chaotic behavior will be introduced in the context of one-variable maps (the logistic), fractal sets, etc. Applications will be drawn from physics and biology. There will be homework and projects, and a few computer lab sessions (programming experience is not a prerequisite). | Prerequisites: C or better in (MA-UY 1124, MA-UY 1424 or MA-UY 1132) and (MA-UY 1044, MA-UY 3054 or MA-UY 3113)

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** C or better in (MA-UY 1124, MA-UY 1424, or MA-UY 1132) and (MA-UY 1044, MA-UY 3054 or MA-UY 3113).**MA-UY 4524 Honors Numerical Analysis (4 Credits)***Typically offered Spring*

This course will cover the analysis of numerical algorithms which are ubiquitously used to solve problems throughout mathematics, physics, engineering, finance, and the life sciences. Topics include: algorithms for solving nonlinear equations; optimization; finding eigenvalues/eigenvectors of matrices; computing matrix factorizations and performing linear regressions; function interpolation, approximation, and integration; basic signal processing using the Fast Fourier Transform; Monte Carlo simulation. An introduction to programming will be provided as it is an integral part of numerical analysis, but students should feel quite comfortable programming on their own (or be exceptionally willing to learn along the way). | Prerequisites: (Grade of A- or above in MA-UY 2114 OR grade of B+ or above in MA-UY 2514) AND ((grade of A- or above in MA-UY 1044 OR MA-UY 3113) OR grade of B+ or above in MA-UY 3054) AND programming experience strongly recommended (e.g. julia, Matlab, or numpy) but not required (there is a programming component to this course). Anti-Requisites: MA-UY 4424

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** (A- or above in MA-UY 2114 OR B+ or above in MA-UY 2514) AND ((A- or above in MA-UY 1044 OR MA-UY 3113) OR B+ or above in MA-UY 3054) AND program experience recommended (eg julia, Matlab or numpy).**MA-UY 4614 Applied Analysis (4 Credits)***Typically offered Fall and Spring*

Limits of real and complex sequences and series; topology of metric spaces; continuity and differentiability of functions; definition, properties, and approximations of Riemann integrals; convergence of sequences and series of functions; Fourier series and other orthogonal systems of functions, approximations theorems. | Prerequisites: (MA-UY 2114 or MA-UY 2514) and (MA-UY 1044 or MA-UY 2034 or MA-UY 3034 or MA-UY 3054) and Junior level standing or above. | Anti-Requisite: MA-UY 4644

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** (MA-UY 2114 or MA-UY 2514) and (MA-UY 1044 or MA-UY 2034 or MA-UY 3034 or MA-UY 3054) and Junior level standing or above.**MA-UY 4634 Vector Analysis (4 Credits)***Typically offered Spring*

Brief review of multivariate calculus: partial derivatives, chain rule, Riemann integral, change of variables, line integrals. Lagrange multipliers. Inverse and implicit function theorems and their applications. Introduction to calculus on manifolds: definition and examples of manifolds, tangent vectors and vector fields, differential forms, exterior derivative, line integrals and integration of forms. Gauss' and Stokes' theorems on manifolds. | Prerequisites: C or better in MA-UY 4613

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**Prerequisites:** MA-UY 4613 (C or better).

MA-UY 4644 Honors Analysis I (4 Credits)*Typically offered Fall*

This is an introduction to the rigorous treatment of the foundations of real analysis in one variable. It is based entirely on proofs. Students are expected to know what a mathematical proof is and are also expected to be able to read a proof before taking this class. Topics include: properties of the real number system, sequences, continuous functions, topology of the real line, compactness, derivatives, the Riemann integral, sequences of functions, uniform convergence, infinite series and Fourier series.

Additional topics may include: Lebesgue measure and integral on the real line, metric spaces, and analysis on metric spaces. | Prerequisites: A grade of A- or better in (MA-UY 2114 or MA-UY 2514) and (MA-UY 1044 or MA-UY 2034 or MA-UY 3054) and Junior level standing or above.

Recommended: MA-UY 2514 Honors Calculus III and MA-UY 3054 Honors Linear Algebra with a grade of B+ or better. | Anti-Requisite: MA-UY 4614

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**MA-UY 4654 Honors Analysis II (4 Credits)***Typically offered Spring*

This is a continuation of MATH-UA 328/MA-UY 4644 Honors Analysis I. Topics include: metric spaces, differentiation of functions of several real variables, the implicit and inverse function theorems, Riemann integral on \mathbb{R}^n , Lebesgue measure on \mathbb{R}^n , the Lebesgue integral. | Prerequisites: A grade of C or better in MA-UY 4644 or a grade of A in MA-UY 4614 in conjunction with permission by instructor

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No

Prerequisites: A grade of C or better in MA-UY 4644 or a grade of A in MA-UY 4614 in conjunction with permission by instructor.

MA-UY 4674 Differential Geometry (4 Credits)*Typically offered Spring*

The differential properties of curves and surfaces. Introduction to manifolds and Riemannian geometry. | Prerequisites: C or better in (MA-UY 2114 or MA-UY 2514) and (MA-UY 1044, MA-UY 3054 or MA-UY 3113).

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No

Prerequisites: C or better in (MA-UY 2114 or MA-UY 2514) and (MA-UY 1044, MA-UY 3054 or MA-UY 3113).

MA-UY 4684 Topology (4 Credits)*Typically offered Spring*

Set-theoretic preliminaries. Metric spaces, topological spaces, compactness, connectedness, covering spaces, and homotopy groups. | Prerequisites: A grade of C or better in (MA-UY 4614 or MA-UY 4644)

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No

Prerequisites: A grade of C or better in (MA-UY 4614 or MA-UY 4644).

MA-UY 4814 Honors I (4 Credits)*Typically offered Fall and Spring*

A lecture/seminar course on advanced topics. Topics vary yearly and are updated from time to time. Detailed course descriptions are available during preregistration. | Prerequisite varies according to topic. Department Consent Required for Enrollment.

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**MA-UY 4824 Honors II (4 Credits)***Typically offered Fall and Spring*

A lecture/seminar course on advanced topics. Topics vary yearly and are updated from time to time. Detailed course descriptions are available during preregistration. | Prerequisite varies according to topic. Department Consent Required for Enrollment.

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**MA-UY 4834 Honors III (4 Credits)***Typically offered Fall and Spring*

A lecture/seminar course on advanced topics. Topics vary yearly and are updated from time to time. Detailed course descriptions are available during preregistration. | Prerequisite varies according to topic. Department Consent Required for Enrollment.

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No**MA-UY 4844 Honors IV (4 Credits)***Typically offered Fall and Spring*

A lecture/seminar course on advanced topics. Topics vary yearly and are updated from time to time. Detailed course descriptions are available during preregistration.

Grading: Ugrd Tandon Graded**Repeatable for additional credit:** No