# Rose-Hulman Institute of Technology Course Catalog

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# Mathematics - Course Descriptions

### MA 111 Calculus I 5R-0L-5C F,W

**Prerequisites:** There are no prerequisites for this course.
**Corequisites:** There are no corequisites for this course.
Calculus and analytic geometry in the plane. Algebraic and transcendental functions. Limits and continuity. Differentiation, geometric and physical interpretations of the derivative, Newton's method. Introduction to integration and the Fundamental Theorem of Calculus.

### MA 112 Calculus II 5R-0L-5C F,W,S

**Prerequisites:** MA 111 F,W
**Corequisites:** There are no corequisites for this course.
Techniques of integration, numerical integration, applications of integration. L'Hopital's rule and improper integrals. Separable first order differential equations, applications of separable first order differential equations. Series of constants, power series, Taylor polynomials, Taylor and McLaurin series.

### MA 113 Calculus III 5R-0L-5C F,W,S

**Prerequisites:** MA 112 F,W,S
**Corequisites:** There are no corequisites for this course.
Vectors and parametric equations in three dimensions. Functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems. Applications of partial derivatives and multiple integrals.

### MA 190 Contemporary Mathematical Problems 2R-0L-2C S

**Prerequisites:** There are no prerequisites for this course.
**Corequisites:** MA 113 5R-0L-5C F,W,S
A seminar-style course consisting of an overview of selected contemporary problems and areas in the mathematical sciences. Problems to be discussed will be selected from recent publications in research and applications, famous problems, and outstanding problems of great significance.

### MA 200 Career Preparation 1R-0L-1C W

**Prerequisites:** There are no prerequisites for this course.
**Corequisites:** There are no corequisites for this course.
This course is for mathematics majors to be taken in the second year. The course addresses career choices, summer opportunities, employment and graduate school preparation, and curriculum vitae and resumes preparation. Cross-listed with CHEM 200 and PH200.

### MA 211 Differential Equations 4R-0L-4C F,W,S

**Prerequisites:** MA 113 F,W,S
**Corequisites:** There are no corequisites for this course.

First order differential equations including basic solution techniques and numerical methods. Second order linear, constant coefficient differential equations, including both the homogeneous and non-homogeneous cases. Laplace transforms, Introduction to complex arithmetic, as needed. Applications to problems in science and engineering.

**MA 212 Matrix Algebra & Systems of Differential Equations 4R-0L-4C F,W,S**
**Prerequisites:** MA 113 F,W,S
**Corequisites:** There are no corequisites for this course.
Basic matrix algebra with emphasis on understanding systems of linear equations from algebraic and geometric viewpoints, and eigenvalues and eigenvectors. Solution of systems of first order linear differential equations by eigensystems and investigation of their solution structure determined by eigensystems. Phase portrait analysis and classification of the nature of the stability of critical points for linear and nonlinear systems. Fourier series. Introduction to complex arithmetic, as needed. Applications to problems in science and engineering.

**MA 223 Engineering Statistics I 4R-0L-4C F,W,S**
**Prerequisites:** MA 112 F,W,S
**Corequisites:** There are no corequisites for this course.
This is an introductory course in statistical data analysis. Topics covered include descriptive statistics, introduction to probability concepts, and random variables. A Central Limit Theorem will be presented. Inference (hypothesis testing and confidence intervals) for one mean, two independent means, and two means from a paired sample will be covered. An introduction to one factor analysis of variance and simple linear regression will be presented. Time permitting, inference for a one proportion and one standard deviation/variance are discussed. Both classical methods for inference as well as modern resampling methods are presented. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest to the science and engineering majors enrolled will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. A student cannot take both MA 223 and MA 382 for credit.

**MA 275 Discrete & Combinatorial Algebra I 4R-0L-4C F,W**
**Prerequisites:** MA 112 F,W,S
**Corequisites:** There are no corequisites for this course.
An introduction to enumeration and discrete structures. Permutations, combinations and the pigeonhole principle. Elementary mathematical logic and proof techniques, including mathematical induction. Properties of the integers. Set theory. Introduction to functions.

**MA 323 Geometric Modeling 4R-0L-4C W (Even years)**
**Prerequisites:** MA 113 F,W,S
**Corequisites:** There are no corequisites for this course.
Covers some of the mathematical methods for describing physical or virtual objects in computer aided geometric design (CAGD) and computer graphics. Emphasizes methods for curve and surface modeling, and discusses both the underlying geometric concepts and the practical aspects of constructing geometric models of objects. Topics covered include Bezier curves, Hermite curves, B-splines, Bezier patches, subdivision surfaces. In discussing these, ideas from analytic geometry, differential geometry, affine geometry, combinatorial geometry, and projective geometry will be introduced.

**MA 325 Fractals and Chaotic Dynamical Systems 4R-0L-4C Arranged**

**Prerequisites:** CSSE 220 F,W,S or CSSE 221 F, and MA 212 F,W,S *Arranged prerequsite
**Corequisites:** There are no corequisites for this course.
Emphasis on the mathematical and computer graphics foundations behind fractal images and the relationship between chaotic dynamics and fractal geometry. Self-similar fractals, random fractals with Brownian motion, and fractals generated from dynamical systems. Fractal dimensions. Iterated function systems. Chaos in one-dimensional maps. Controlling chaos. Mandelbrot and Julia sets. Computer graphics. Same as CSSE 325.

**MA 327 Low Dimensional Topology 4R-0L-4C W (odd years)**
**Prerequisites:** MA 113 F,W,S or consent of instructor
**Corequisites:** There are no corequisites for this course.
An introduction to the topology of one-, two-, and three-dimensional manifolds and its application to other areas of mathematics and science. Topics may include, but are not restricted to, classification of curves and surfaces, Euler characteristic, tiling and coloring theorems, graph embeddings, vector fields, knots and links, and elementary algebraic topology. Intended for science and engineering majors as well as mathematics majors.

**MA 330 Vector Calculus 4R-0L-4C F,S**
**Prerequisites:** MA 113 F,W,S, and MA 212 F,W,S
**Corequisites:** There are no corequisites for this course.
Calculus of vector- valued functions of one and several variables. Topics include differentiation (divergence, gradient and curl of a vector field) and integration (line integrals and surface integrals). Applications of Green's theorem, Stokes' theorem and the divergence theorem to potential theory and/or fluid mechanics will be provided.

**MA 332 Introduction to Computational Science 4R-0L-4C F,W**
**Prerequisites:** MA 112 F,W,S
**Corequisites:** There are no corequisites for this course.
An introduction to Computational Science using Matlab. Floating point arithmetic, Matlab programming, solution of nonlinear equations, interpolation, least squares problems, numerical differentiation and integration, solution of linear systems.

**MA 335 Introduction to Parallel Computing 4R-0L-4C S (odd years)**
**Prerequisites:** MA 212 F,W,S and programming experience
**Corequisites:** There are no corequisites for this course.
Principles of scientific computation on parallel computers. Algorithms for the solution of linear systems and other scientific computing problems on parallel machines. Course includes a major project on RHIT's parallel cluster. Same as CSSE 335.

**MA 336 Boundary Value Problems 4R-0L-4C F,S**
**Prerequisites:** MA 211 F,W,S, and MA 212 F,W,S
**Corequisites:** There are no corequisites for this course.
Introduction to boundary value problems and partial differential equations. Emphasis on boundary values problems that arise from the wave equation, diffusion equation, and Laplace's equation in one, two and three dimensions. Solutions to such boundary value problems will be discussed using Fourier series, numerical techniques, and integral transforms.

**MA 341 Topics in Mathematical Modeling 4R-0L-4C W**

**Prerequisites:** MA 211 F,W,S, and MA 212 F,W,S
**Corequisites:** There are no corequisites for this course.
An introduction to techniques of mathematical modeling involved in the analysis of meaningful and practical problems arising in many disciplines including mathematical sciences, operations research, engineering, and the management and life sciences. Topics may include creative and empirical model construction, model fitting, models requiring optimization, and modeling dynamic behavior. Student participation in significant individual and group projects will be emphasized.

### MA 342 Computational Modeling 4R-0L-4C S

**Prerequisites:** MA 212 F,W,S, and CHE 310 W* or CE 310 S* or MA 332 F,W* or ME 323 W,S* *one of
**Corequisites:** There are no corequisites for this course.
Computational modeling and simulation of scientific problems using Matlab. Students will create and utilize computer-based models to solve practical problems. Monte Carlo methods, linear systems, solution of ODEs.

### MA 351-6 Problem Solving Seminar 1R-0L-1C F,W,S

**Prerequisites:** consent of instructor
**Corequisites:** There are no corequisites for this course.
An exposure to mathematical problems varying widely in both difficulty and content. Students will be expected to participate actively, not only in the solution process itself but also in the presentation of finished work, both orally and in writing. A student may earn a maximum of six credits in MA 351-6. Cannot count toward mathematics major core hours or the math minor.

### MA 366 Functions of a Real Variable 4R-0L-4C W

**Prerequisites:** MA 275 F,W, and MA 113 F,W,S
**Corequisites:** There are no corequisites for this course.
Calculus of functions of a single variable. A more careful development of the basic concepts of analysis, including sequences, limits, continuity, differentiability, integration, infinite series, power series, Taylor's Theorem, and uniform convergence.

### MA 367 Functions of a Complex Variable 4R-0L-4C S

**Prerequisites:** MA 212 F,W,S
**Corequisites:** There are no corequisites for this course.
Elementary properties of analytic functions including Cauchy's theorem and its consequences, Laurent series, the Residue Theorem, and mapping properties of analytic functions.

### MA 371 Linear Algebra I 4R-0L-4C F,S

**Prerequisites:** MA 212 F,W,S or consent of instructor
**Corequisites:** There are no corequisites for this course.
Similar to MA373, but with an emphasis on the theory behind matrices and vector spaces. Systems of linear equations, Gaussian elimination, and the LU decomposition of a matrix. Projections, least squares approximations, and the Gram-Schmidt process. Eigenvalues and eigenvectors of a matrix. The diagonalization theorem. The singular value decomposition of a matrix. Introduction to vector spaces. Some proof writing will be required. Those interested in applications of matrices and vector spaces should take MA373. A student cannot take both MA 371 and MA 373 for credit.

### MA 373 Applied Linear Algebra for Engineers 4R-0L-4C W

**Prerequisites:** MA 212 F,W,S or consent of instructor
**Corequisites:** There are no corequisites for this course.
Similar to MA 371, but with emphasis on applications of matrices and vector spaces. Systems of linear equations, Gaussian elimination, and the LU decomposition of a matrix. Projections, least squares approximations, and the Gram-Schmidt process. Eigenvalues and eigenvectors of a matrix. The diagonalization theorem. The singular value decomposition of a matrix. Those interested in the theory behind matrices and vector spaces should take MA 371. A student cannot take both MA 371 and MA 373 for credit.

**MA 375 Discrete & Combinatorial Algebra II 4R-0L-4C W, S**
**Prerequisites:** MA 275 F,W
**Corequisites:** There are no corequisites for this course.
A continuation of MA 275. Relations. An introduction to finite state machines. More advanced enumeration techniques including recurrence relations, generating functions and the principle of inclusion and exclusion.

**MA 376 Abstract Algebra 4R-0L-4C S**
**Prerequisites:** MA 275 F,W
**Corequisites:** There are no corequisites for this course.
An introduction to Group Theory. Topics include: matrix groups, groups of integers modulo a natural number, symmetric and dihedral groups, homomorphisms, subgroups, cosets, quotient groups and group actions. Applications, possibly including games and puzzles, cryptography, and coding theory. Other topics may also be introduced according to time and student interest.

**MA 378 Number Theory 4R-0L-4C S**
**Prerequisites:** consent of instructor
**Corequisites:** There are no corequisites for this course.
Divisibility, congruences, prime numbers, factorization algorithms, RSA encryption, solutions of equations in integers, quadratic residues, reciprocity, generating functions, multiplicative and other important functions of elementary number theory. Mathematical conjecture and proof, mathematical induction.

**MA 381 Introduction to Probability with Applications to Statistics 4R-0L-4C F,W,S**
**Prerequisites:** MA 113 F,W,S
**Corequisites:** There are no corequisites for this course.
Introduction to probability theory; axioms of probability, sample spaces, and probability laws (including conditional probabilities). Univariate random variables (discrete and continuous) and their expectations including these distributions: binomial, Poisson, geometric, uniform, exponential, and normal. Introduction to moment generating functions. Introduction to jointly distributed random variables. Univariate and joint transformations of random variables. The distribution of linear combinations of random variables and an introduction to the Central Limit Theorem. Applications of probability to statistics.

**MA 382 Introduction to Statistics with Probability 4R-0L-4C F**
**Prerequisites:** MA 381 F,W,S
**Corequisites:** There are no corequisites for this course.
This is an introductory course in statistical data analysis and mathematical statistics. Topics covered include descriptive statistics, Sampling distributions (including the entral

Limit Theorem), point estimation, Hypothesis testing and confidence intervals for both one and two populations, linear regression, and analysis of variance. Emphasis will be placed on both data analysis and mathematical derivations of statistical techniques. A computer package will be used for statistical analysis and simulation. Experimental data from a variety of fields of interest will also be used to illustrate statistical concepts and facilitate the development of the student's statistical thinking. A student cannot take both MA 223 and MA 382 for credit.

### MA 383 Engineering Statistics II 4R-0L-4C F

**Prerequisites:** MA 223 F,W,S or MA 382 F
**Corequisites:** There are no corequisites for this course.
Hypothesis testing, confidence intervals, sample size determination, and power calculations for means and proportions; two factor analysis of variance (with and without interactions); analysis of several proportions; confidence and prediction intervals for estimated values using simple linear regression; Pearson (linear) correlation coefficient; introduction to multiple regression to include polynomial regression; review of fundamental prerequisite statistics will be included as necessary.

### MA 384 Data Mining 4R–0L–4C

**Prerequisites:** CSSE 120 F,W,S, and MA 212 F,W,S, and MA 223 F,W,S or MA 381 F,W,S
**Corequisites:** There are no corequisites for this course.
An introduction to data mining for large data sets, include data preparation, exploration, aggregation/reduction, and visualization. Elementary methods for classification, association, and cluster analysis are covered. Significant attention will be given to presenting and reporting data mining results. Same as CSSE 384.

### MA 385 Quality Methods 4R-0L-4C S

**Prerequisites:** MA 223 F,W,S or MA 382 F
**Corequisites:** There are no corequisites for this course.
Introduction to various aspects of statistical quality control and statistical process control to include the following topics: importance of variance reduction and probability concepts influencing product quality and reliability; development and application of control charts (P-charts, NP-charts, C-charts, U-charts, individual’s charts, moving range charts, X-bar and R as well as X-bar and S charts); process capability indices (their use and misuse); introduction to acceptance sampling. Other topics to be included as time allows: 6 sigma thinking, gauge reproducibility and repeatability, and total quality management with the philosophies of Deming, Juran, and Crosby. Review of fundamental prerequisite statistics will be included as necessary. Same as BE 385

### MA 386 Statistical Programming 4R-0L-4C

**Prerequisites:** MA 223 F,W,S or MA 382 F and previous programming course
**Corequisites:** There are no corequisites for this course.
Computational data analysis is an essential part of modern statistics. This course provides a practical foundation for students to compute with data. This course will introduce students to tools for data management, manipulation and analysis that are common in statistics and data science. The R computing language will be introduced. Topics will include data structures in R, writing functions, webscraping, data cleaning (both quantitative and textual data), processing unstructured data, static and interactive graphical presentations of data, and coding of modern algorithms for data analysis (bootstrapping and Monte Carlo methods).

**MA 387 Statistical Methods in Six Sigma 4R-0L-4C**
**Prerequisites:** MA 223 F,W,S or MA 382 F
**Corequisites:** There are no corequisites for this course.
A course on statistical methods used in the Six Sigma /DMAIC (Define, Measure, Analyze, Improve, Control) paradigm. Topics will include, but are not limited to, gauge repeatability and reproducibility, control charts, regression, design of experiments, and response surface optimization.

**MA 390 Topics in the Mathematics of Engineering 1-2C Arranged with consent of instructor**
**Prerequisites:** Consent of instructor
**Corequisites:** There are no corequisites for this course.
A succinct mathematical study that is supportive of the engineering curricula. Topics could be chosen from signal processing, fluid dynamics, thermodynamics, as well as others. A student may take the course for credit more than once provided the topics are different.

**MA 421 Tensor Calculus & Riemannian Geometry 4R-0L-4C Arranged**
**Prerequisites:** MA 330 F,S Arranged prerequisite
**Corequisites:** There are no corequisites for this course.
An introduction to the calculus of tensor fields and the local geometry of manifolds.Topics covered include: manifolds, tangent space, cotangent spaces, vector fields, differential forms, tensor fields, Riemannian metrics, covariant derivative and connections, parallel transport and geodesics, Ricci tensor, Riemannian curvature tensor. Applications will be given in physics (general relativity, mechanics, string theory) and engineering (continuum mechanics).

**MA 423 Topics in Geometry 4R-0L-4C Arranged**
**Prerequisites:** MA 371 F,S or MA 373 W or consent of instructor (Arranged prerequisite)
**Corequisites:** There are no corequisites for this course.
An advanced geometry course with topics possibly chosen from the areas of projective geometry, computational geometry, differential geometry algebraic geometry, Euclidean geometry or non-Euclidean geometry. A student may take the course for credit more than once provided the topics are different.

**MA 430 Topics in Applied Mathematics 4R-0L-4C Arranged**
**Prerequisites:** Instructor permission
**Corequisites:** There are no corequisites for this course.
A topics course in the general area of continuous applied mathematics. Topics may include mathematical physics, mathematical biology, mathematical finance, mathematics of vision, PDEs, image processing methods, continuum mechanics, dynamical systems, and mathematical modeling. A student may take the course for credit more than once provided the topics are different.

**MA 431 Calculus of Variations 4R-0L-4C Arranged**
**Prerequisites:** MA 330 F,S
**Corequisites:** There are no corequisites for this course.
Euler-Lagrange and Hamiltonian equations, with possible applications in mechanics, electrostatics, optics, quantum mechanics and elasticity theory. An introduction to

“direct methods.” Applications will be chosen in accordance with the interest of the students. Both classical and numerical methods have their place in this course.

### MA 433 Numerical Analysis 4R-0L-4C W

**Prerequisites:** MA 212 F,W,S
**Corequisites:** There are no corequisites for this course.
Root-finding, computational matrix algebra, nonlinear optimization, polynomial interpolation, splines, numerical integration, numerical solution of ordinary differential equations. Principles of error analysis and scientific computation. Selection of appropriate algorithms based on the numerical problem and on the software and hardware (such as parallel machines) available.

### MA 434 Topics in Numerical Analysis 4R-0L-4C Arranged

**Prerequisites:** MA 433 W Arranged prerequisite
**Corequisites:** There are no corequisites for this course.
An extension of the material presented in MA433. Topics may include numerical problems, numerical solution of partial differential equations (finite differences, finite elements, spectral methods), sparse matrices, global optimization, approximation theory. A student may take the course for credit more than once provided the topics are different.

### MA 435 Finite Difference Methods 4R-0L-4C W

**Prerequisites:** MA 332 F,W or MA 371 F,S or MA 373 W or MA 433 W
**Corequisites:** There are no corequisites for this course.
An introduction to finite difference methods for linear parabolic, hyperbolic, and elliptic partial differential equations. Consistency, stability, convergence, and the Lax Equivalence Theorem. Solution techniques for the resulting linear systems.

### MA 436 Introduction to Partial Differential Equations 4R-0L-4C F (even years)

**Prerequisites:** MA 330 F,S
**Corequisites:** There are no corequisites for this course.
Partial differential equations, elliptic, hyperbolic, and parabolic equations. Boundary and initial value problems. Separation of variables, special functions. Eigenfunction expansions. Existence and uniqueness of solutions. Sturm-Liouville theory, Green’s function.

### MA 439 Mathematical Methods of Image Processing 4R-0L-4C F

**Prerequisites:** MA 212 F,W,S
**Corequisites:** There are no corequisites for this course.
Mathematical formulation and development of methods used in image processing, especially compression. Vector space models of signals and images, one- and two-dimensional discrete Fourier transforms, the discrete cosine transform, and block transforms. Frequency domain, basis waveforms, and frequency domain representation of signals and images. Convolution and filtering. Filter banks, wavelets and the discrete wavelet transform. Application to Fourier based and wavelet based compression such as the JPEG compression standard. Compression concepts such as scalar quantization and measures of performance.

### MA 444 Deterministic Models in Operations Research 4R-0L-4C W

**Prerequisites:** MA 212 F,W,S, and MA 371 F,S or MA 373 W
**Corequisites:** There are no corequisites for this course.

Formulation of various deterministic problems as mathematical optimization models and the derivation of algorithms to solve them. Optimization models studied include linear programs, integer programs, and various network models. Emphasis on model formulation and algorithm development “from the ground up.”

**MA 445 Stochastic Models in Operations Research 4R-0L-4C S (even years)**
**Prerequisites:** MA 223 F,W,S or MA 381 F,W,S
**Corequisites:** There are no corequisites for this course.
Introduction to stochastic mathematical models and techniques that aid in the decision-making process. Topics covered include a review of conditional probability, discrete and continuous Markov chains, Poisson processes, queueing theory (waiting line problems), and reliability.

**MA 446 Combinatorial Optimization 4R-0L-4C S (even years)**
**Prerequisites:** MA 375 W, S
**Corequisites:** There are no corequisites for this course.
An introduction to graph- and network-based optimization models, including spanning trees, network flow, and matching problems. Focus is on the development of both models for real-world applications and algorithms for their solution.

**MA 450 Mathematics Seminar 1R-0L-1C F,W,S**
**Prerequisites:** Instructor permission
**Corequisites:** There are no corequisites for this course.
A student must attend at least 10 mathematics seminars or colloquia and present at one of the seminars, based on material mutually agreed upon by the instructor and the student. A successful presentation is required for a passing grade. As seminars may not be offered every week during the quarter a student may extend the course over more than one quarter, but it must be completed within two consecutive quarters. A student may take this course a maximum of four times.

**MA 460 Topics in Analysis 4R-0L-4C Arranged**
**Prerequisites:** Instructor permission
**Corequisites:** There are no corequisites for this course.
An advanced topics course in analysis. Topic of the course could be advanced topics in real analysis, advanced topics in complex analysis, analysis on manifolds, measure theory or an advanced course in applied analysis (differential equations). May be taken more than once provided topics are different

**MA 461 Topics in Topology 4R-0L-4C Arranged**
**Prerequisites:** MA 366 W or consent of instructor
**Corequisites:** There are no corequisites for this course.
Introduction to selected topics from point-set topology or algebraic topology from a rigorous point of view. Possible topics include metric spaces, general topological spaces, compactness, connectedness, separation axioms, compactification and metrization theorems, homotopy and homology, and covering spaces. Intended for mathematics majors planning to pursue graduate study in mathematics.

**MA 466 Introduction to Functional Analysis 4R-0L-4C Arranged**
**Prerequisites:** MA 366 W
**Corequisites:** There are no corequisites for this course.

An introduction to the theory of Banach spaces emphasizing properties of Hilbert spaces and linear operators. Special attention will be given to compact operators and integral equations.

**MA 470 Topics in Algebra 4R-0L-4C Arranged**
**Prerequisites:** Consent of instructor
**Corequisites:** There are no corequisites for this course.
An advanced topics course in algebra. Topic of the course could be commutative algebra, Galois theory, algebraic geometry, Lie groups and algebras, or other advanced topics in algebra. May be taken more than once provided topics are different.

**MA 471 Linear Algebra II 4R-0L-4C S (even years)**
**Prerequisites:** MA 371 F,S or MA 373 W
**Corequisites:** There are no corequisites for this course.
Continuation of Linear Algebra I. Properties of Hermitian and positive definite matrices and factorization theorems (LU, QR, spectral theorem, SVD). Linear transformations and vector spaces.

**MA 473 Design & Analysis of Algorithms 4R-0L-4C F**
**Prerequisites:** MA 375 W, S, CSSE 230 W,S
**Corequisites:** There are no corequisites for this course.
Students study techniques for designing algorithms and for analyzing the time and space efficiency of algorithms. The algorithm design techniques include divide-and-conquer, greedy algorithms, dynamic programming, randomized algorithms and parallel algorithms. The algorithm analysis includes computational models, best/average/ worst case analysis, and computational complexity (including lower bounds and NP-completeness). Same as CSSE 473.

**MA 474 Theory of Computation 4R-0L-4C W**
**Prerequisites:** MA 375 W, S, and CSSE 230 W,S
**Corequisites:** There are no corequisites for this course.
Students study mathematical models by which to answer three questions: What is a computer? What limits exist on what problems computers can solve? What does it mean for a problem to be hard? Topics include models of computation (including Turing machines), undecidability (including the Halting Problem) and computational complexity (including NP-completeness). Same as CSSE 474.

**MA 475 Topics in Discrete Mathematics 4R-0L-4C Arranged**
**Prerequisites:** MA 375 W, S
**Corequisites:** There are no corequisites for this course.
An extension of the material presented in MA 275 and 375. Topics may include combinatorial design, Fibonacci numbers, or the Probabilistic Method, among others. A student may take the course for credit more than once provided the topics are different.

**MA 476 Algebraic Codes 4R-0L-4C S (odd years)**
**Prerequisites:** MA 375 W, S or consent of instructor
**Corequisites:** There are no corequisites for this course.
Construction and theory of linear and nonlinear error correcting codes. Generator matrices, parity check matrices, and the dual code. Cyclic codes, quadratic residue codes, BCH codes, Reed-Solomon codes, and derived codes. Weight enumeration and information rate of optimum codes.

**MA 477 Graph Theory 4R-0L-4C S (even years)**
**Prerequisites:** MA 375 W, S or consent of instructor
**Corequisites:** There are no corequisites for this course.
An introduction to the theory and applications of directed and undirected graphs. Possible topics include the following: Connectivity, subgraphs, graph isomorphism, Euler trails and circuits, planarity and the theorems of Kuratowski and Euler, Hamilton paths and cycles, graph coloring and chromatic polynomials, matchings, trees with applications to searching and coding, and algorithms dealing with minimal spanning trees, articulation points, and transport networks

**MA 478 Topics in Number Theory 4R-0L-4C Arranged**
**Prerequisites:** MA 378 S or MA 375 W, S or consent of instructor
**Corequisites:** There are no corequisites for this course.
Advanced topics in Number Theory. Topics may include elliptic curve cryptography, the Fermat-Wiles Theorem, elliptic curves, modular forms, p-adic numbers, Galois theory, diophantine approximations, analytic number theory, algebraic number theory. A student may take the course for credit more than once provided the topics are different.

**MA 479 Cryptography 4R-0L-4C S**
**Prerequisites:** MA 275 F,W, and CSSE 220 F,W,S
**Corequisites:** There are no corequisites for this course.
Introduction to basic ideas of modern cryptography with emphasis on mathematical background and practical implementation. Topics include: the history of cryptography and cryptanalysis, public and private key cryptography, digital signatures, and limitations of modern cryptography. Touches upon some of the societal issues of cryptography (same as CSSE 479)

**MA 480 Topics in Probability or Statistics 4R-0L-4C Arranged**
**Prerequisites:** Consent of instructor
**Corequisites:** There are no corequisites for this course.
An advanced course in probability or statistics. Possible topics include (but are not restricted to) reliability, discrete event simulation, multivariate statistics, Bayesian statistics, actuarial science, nonparametric statistics, categorical data analysis, and time series analysis. May be taken more than once provided topics are different.

**MA 481 Mathematical Statistics 4R-0L-4C W (even years)**
**Prerequisites:** MA 382 F or MA 381 F,W,S and consent of instructor
**Corequisites:** There are no corequisites for this course.
An introduction to mathematical statistics. Review of distributions of functions of random variables. Moment generating functions. Limiting distributions. Point estimation and sufficient statistics. Fisher information and Rao-Cramer inequality. Theory of statistical tests.

**MA 482 Bioengineering Statistics 4R-0L-4C S**
**Prerequisites:** MA 223 F,W,S or MA 382 F
**Corequisites:** There are no corequisites for this course.
This course introduces statistical techniques for addressing the challenges that arise in the analysis of data from the biological sciences (including biology, biomedical engineering, and the medical community). Topics include linear regression modeling, nonlinear regression, repeated measures analysis (including mixed models), and survival/reliability analysis (analysis of time-to-event data). Flexible modeling strategies

including relaxing linearity and distributional assumptions are discussed. Additional topics are introduced when discussing articles found in the literature, including properties of study design, power, meta-analysis, missing data, and causal inference. No prerequisite knowledge of biology is assumed. Review of fundamental prerequisite statistics will be included as necessary. Same as BE 482.

### MA 485 Applied Regression Analysis & Introduction to Time Series 4R-0L-4C W (odd years)

**Prerequisites:** MA 212 F,W,S, and MA 223 F,W,S or MA 382 F
**Corequisites:** There are no corequisites for this course.
Review of simple linear regression; confidence and prediction intervals for estimated values using simple linear regression; introduction to such concepts as model fit, misspecification, multi-collinearity, heterogeneous variances and transformation of both independent and dependent variables; introduction to multiple regression to include polynomial regression; use of dummy variables and diagnostics based on residuals; sequential variable selection to include forward inclusion and backward exclusion of variables; best subset regression; introduction to time series; autocorrelation; moving averages and exponential smoothing.

### MA 487 Design of Experiments 4R-0L-4C W (even years)

**Prerequisites:** MA 223 F,W,S or MA 382 F
**Corequisites:** There are no corequisites for this course.
Review of one factor analysis of variance; tests for homogeneity of variance and model assumptions; multiple comparisons, post hoc comparisons, and orthogonal contrasts; two factor analysis of variance (with and without interactions); three factor and higher full factorial designs; analysis of covariance and repeated measures designs; screening designs to include 2 to the k and 3 to the k design; fractional factorial designs; introduction to General Linear Models. Other topics that may be included as time allows: fixed, random, and mixed designs as well as nested designs. Review of fundamental prerequisite statistics will be included as necessary.

### MA 490 Topics in Mathematics Variable credit

**Prerequisites:** Consent of instructor
**Corequisites:** There are no corequisites for this course.
This course will cover advanced topics in mathematics not offered in listed courses.

### MA 491 Introduction to Mathematical Modeling 2C F

**Prerequisites:** Senior Standing or permission of the instructor
**Corequisites:** There are no corequisites for this course.
An introduction to the process of mathematically modeling a problem, including data collection, defining the appropriate mathematical model and interpreting the results of the proposed model. Emphasis placed on the modeling process, using examples from both continuous and discrete mathematics.

### MA 492 Senior Project I 2C F

**Prerequisites:** Senior Standing or permission of the instructor
**Corequisites:** There are no corequisites for this course.
Either participation in a sponsored project or investigation of a problem with a substantial mathematical application, modeling and/or computational content. Students either work individually or in a team typically of 2 or 3, under the supervision of the faculty adviser (course instructor), interacting with the sponsor (if there is one).

Problems vary considerably, depending upon student interest, but normally require computer implementation and documentation. All work required for completion of the Senior Project must be completed in a form acceptable to the adviser and the sponsor if there is one. A submitted written report and public presentation to department are required

### MA 493 Senior Project II 2C F,W

**Prerequisites:** MA 492 F or consent of instructor
**Corequisites:** There are no corequisites for this course.
Either participation in a sponsored project or investigation of a problem with a substantial mathematical application, modeling and/or computational content. Students either work individually or in a team typically of 2 or 3, under the supervision of the faculty adviser (course instructor), interacting with the sponsor (if there is one). Problems vary considerably, depending upon student interest, but normally require computer implementation and documentation. All work required for completion of the Senior Project must be completed in a form acceptable to the adviser and the sponsor if there is one. A submitted written report and public presentation to department are required

### MA 494 Senior Project III 2C W,S

**Prerequisites:** MA 493 F,W
**Corequisites:** There are no corequisites for this course.
Either participation in a sponsored project or investigation of a problem with a substantial mathematical application, modeling and/or computational content. Students either work individually or in a team typically of 2 or 3, under the supervision of the faculty adviser (course instructor), interacting with the sponsor (if there is one). Problems vary considerably, depending upon student interest, but normally require computer implementation and documentation. All work required for completion of the Senior Project must be completed in a form acceptable to the adviser and the sponsor if there is one. A submitted written report and public presentation to department are required

### MA 495 Research Project in Mathematics Variable Credit

**Prerequisites:** Consent of instructor
**Corequisites:** There are no corequisites for this course.
An undergraduate research project in mathematics or the application of mathematics to other areas. Students may work independently or in teams as determined by the instructor. Though the instructor will offer appropriate guidance in the conduct of the research, students will be expected to perform independent work and collaborative work if on a team. The course may be taken more than once provided that the research or project is different.

### MA 496 Senior Thesis I 4C F

**Prerequisites:** Senior Standing or permission of the instructor
**Corequisites:** There are no corequisites for this course.
Individual study and research of a topic in mathematics. Topic is expected to be at an advanced level. Research paper and public presentation to department are required.

### MA 497 Senior Thesis I 2C F,W

**Prerequisites:** MA 496 F or consent of instructor
**Corequisites:** There are no corequisites for this course.

Individual study and research of a topic in mathematics. Topic is expected to be at an advanced level. Research paper and public presentation to department are required.

**MA 498 Senior Thesis III 2C W,S**
**Prerequisites:** MA 497 F,W or consent of instructor
**Corequisites:** There are no corequisites for this course.
Individual study and research of a topic in mathematics. Topic is expected to be at an advanced level. Research paper and public presentation to department are required.

**MA 534 Management Science 4R-0L-4C F (even years)**
**Prerequisites:** Senior or graduate standing
**Corequisites:** There are no corequisites for this course.
A study of the development and analysis of various mathematical models useful in managerial decision-making. This includes discussions of what models are, how to create them, how they are used, and what insights they provide. Spreadsheets will be used to do much of the computational work. Topics considered include linear, integer, and nonlinear programming, network models, inventory management, project management, and simulation models. Examples from all areas of business and industry will be investigated. We will also investigate how companies are using these techniques to solve current problems. Same as EMGT 534.

**MA 580 Topics in Advanced Probability Theory & Its Applications 4R-0L-4C Arranged**
**Prerequisites:** MA 381 F,W,S
**Corequisites:** There are no corequisites for this course.
Advanced topics in probability theory as well as applications that are not offered in the listed courses.

**MA 581 Topics in Advanced Statistics 4R-0L-4C Arranged**
**Prerequisites:** MA 223 F,W,S or MA 381 F,W,S Consent of instructor
**Corequisites:** There are no corequisites for this course.
This course will cover advanced topics in mathematical statistics as well as applied statistics that are not offered in the listed courses.

**MA 590 Graduate Topics in Mathematics Variable Credit**
**Prerequisites:** Consent of instructor
**Corequisites:** There are no corequisites for this course.
This course will cover graduate-level topics in mathematics not offered in listed courses.

**MA CPT Curricular Practical Training 1R-0L-1C**
**Prerequisites:** Consent of department head
**Corequisites:** There are no corequisites for this course.
Any international student with an F-1 Visa employed by any company in the form of an internship, co-op, or practicum must enroll in a CPT course. The CPT experience is to be complimentary training to the student's curriculum and should contribute substantially to his/her learning experience. Students must have an offer of employment from a company prior to registering for this course. The CPT must be approved by the Department Head, Director of International Student Services, and the student's advisor. Students are required to submit a report at the conclusion of the employment to his/her instructor to receive a grade for the CPT experience.

**MAFTC Calculus I, Calculus II, Calculus III - Fast Track Calculus 15R-0L-15C**

**Prerequisites:** At least one year of high school Calculus, at least a 700 Math Score or 680 math/700 critical reading or better on the SAT (31 Math or 30 Math/31 English ACT score), and approval by the Fast Track Selection Committee.
**Corequisites:** There are no corequisites for this course.
A 5-week fast paced course equivalent to Calculus I, II and III. Taught in the summer only to incoming freshmen. Review of differential calculus. Introduction to integration and the Fundamental Theorem of Calculus. Techniques of integration, numerical integration, applications of integration. L'Hopital's rule (and improper integrals). Separable first order differential equations, applications of separable first order differential equation. Series of constants, power series, Taylor polynomials, Taylor and McLaurin series. Vectors and parametric equations in three dimensions. Functions of several variables, partial derivatives, maxima and minima of functions of several variables, multiple integrals, and other coordinate systems. Applications of partial derivatives and multiple integrals. This course may be taken as Pass/Fail only.

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