# MATHEMATICAL SCIENCES (MAT)

**MAT 94 | BASIC ALGEBRA | 4 quarter hours**
**(Undergraduate)**
The objective of this course is to increase the students' competence in working with ordinary arithmetic, using a large variety of practical problems and situations from basic sciences as motivation. Formerly WRC 104.

**MAT 95 | INTRODUCTORY ALGEBRA | 4 quarter hours**
**(Undergraduate)**
An introduction to functions, linear equations, linear inequalities, absolute values, systems of linear equations, exponents, and polynomials. Formerly WRC 204.
**MAT 094or placement is a prerequisite for this course.**

**MAT 100 | INTRODUCTION TO QUANTITATIVE REASONING | 4 quarter hours**
**(Undergraduate)**
An introduction to the algebra needed for quantitative reasoning with a focus on functions and modeling. This course emphasizes the applications of elementary algebra and the use of functions to model and analyze real-world situations. Topics include functions from graphical, tabular, and symbolic points of view and models using linear, quadratic, power, exponential, and logarithmic functions. Graphing technology is used extensively. This course is prerequisite to LSP 120 and is intended for students continuing on to LSP 120. This course is not recommended for students whose plan of study includes calculus.
**MAT 094or placement is a prerequisite for this course.**

**MAT 101 | INTERMEDIATE ALGEBRA | 4 quarter hours**
**(Undergraduate)**
Functions, factoring, rational expressions, roots, radicals, quadratic equations, quadratic inequalities. Course meets for an additional 1 hour lab session each week for enrichment and problem solving.
**MAT 095 is a prerequisite for this class.**

**MAT 110 | FOUNDATIONS OF MATHEMATICS FOR ELEMENTARY SCHOOL TEACHERS I | 4 quarter hours**
**(Undergraduate)**
This course gives students a deeper understanding of the foundations of elementary mathematics. Topics include problem solving, number systems, the decimal system, the number line, rounding, fractions, percentages, addition and subtraction.
**MAT 101 or LSP 120 or equivalents or placement by test is a prerequisite for this class.**

**MAT 111 | FOUNDATIONS OF MATHEMATICS FOR ELEMENTARY SCHOOL TEACHERS II | 4 quarter hours**
**(Undergraduate)**
This course gives students a deeper understanding of the foundations of elementary mathematics. Topics include problem solving, fractions, percentages, addition, subtraction, multiplication, and division.
**MAT 110 is a prerequisite for this class.**

**MAT 112 | GAMBLING AND GAMES, PROBABILITY AND STATISTICS | 4 quarter hours**
**(Undergraduate)**
Students with very little mathematical background and little or no computing background will be given a brief introduction to the use of Microsoft Excel for mathematical purposes. This will be followed by a brief discussion of chance, gambling, and probability. Several popular games (such as lotteries, roulette, craps, and poker) will be considered both from a theoretical point of view and by means of very simple computer simulation. At the end, we will discuss briefly topics from game theory such as zero-sum games and game with cooperation.
**MAT 094or placement is a prerequisite for this course.**

**MAT 115 | MATHEMATICS FOR ELEMENTARY SCHOOL TEACHERS III | 4 quarter hours**
**(Undergraduate)**
Continuation of Math 110-111.
**MAT 111 is a prerequisite for this class.**

**MAT 120 | QUANTITATIVE REASONING | 4 quarter hours**
**(Undergraduate)**
This course provides a mathematical foundation for students to become confident and critical users of quantitative information of all kinds: numerical, graphical, and verbal. Students analyze data from a wide variety of fields, making and critiquing quantitative arguments. Mathematical topics include proportional reasoning and rates, the making and interpretation of graphs, linear and exponential models, logarithms, and finance. The course is taught in a hands-on laboratory environment where students are introduced to computer tools for data analysis and presentation.
**MAT 100 OR MAT 101 OR Placement Exam**

**MAT 130 | FUNCTIONS AND MATHEMATICAL MODELS | 4 quarter hours**
**(Undergraduate)**
Functions and their graphs, modeling with linear and quadratic functions, polynomial and rational functions, inverse functions, exponential and logarithmic functions, logarithmic scale, exponential growth and decay models, logistic growth.
**MAT 101 or placement by test is a prerequisite for this class.**

**MAT 131 | PRECALCULUS AND TRIGONOMETRY | 4 quarter hours**
**(Undergraduate)**
Functions and their graphs, inverse functions, exponential and logarithmic functions, polynomial and rational functions, trigonometric functions, inverse trigonometric functions, trigonometric identities, polar coordinates.
**MAT 130 or equivalents or placement by test is a prerequisite for this class.**

**MAT 135 | BUSINESS CALCULUS I | 4 quarter hours**
**(Undergraduate)**
Differential calculus of one or more variables with business applications.
**A grade of C- or better in MAT 130 (or equivalent) is a prerequisite for this class.**

**MAT 136 | BUSINESS CALCULUS II | 4 quarter hours**
**(Undergraduate)**
Integral calculus, matrix algebra, and probability theory with business applications.
**A grade of C- or better in MAT 135 (or equivalent) is a prerequisite for this class.**

**MAT 137 | BUSINESS STATISTICS | 4 quarter hours**
**(Undergraduate)**
Basic concepts of statistics and applications; data analysis with the use of Excel; theoretical distributions; sampling distributions; problems of estimation; hypothesis testing; problems of sampling; linear regression and correlation.
**A grade of C- or better in MAT 130 (or equivalent) is a prerequisite for this class.**

**MAT 140 | DISCRETE MATHEMATICS I | 4 quarter hours**
**(Undergraduate)**
Introduction to combinatorics, basic probability, graph theory, propositional logic, singly-quantified statements, operational knowledge of set theory, functions, number systems.
**MAT 130 or above or equivalents or placement by test is a prerequisite for this class.**

**MAT 141 | DISCRETE MATHEMATICS II | 4 quarter hours**
**(Undergraduate)**
Introduction to properties of integers and real numbers, sequences, recursion, mathematical induction, relations, digraphs, graph theory, multiply-quantified statements, complexity.
**MAT 140 is a prerequisite for this class.**

**MAT 147 | CALCULUS WITH INTEGRATED PRECALCULUS I | 6 quarter hours**
**(Undergraduate)**
Limits, continuity, the derivative, rules of differentiation, derivatives of trigonometric and logarithmic functions and their inverses, and applications, with precalculus review included for each topic. The full MAT 147-8-9 sequence covers all the material of MAT 150-1-2 plus additional precalculus material. (6 quarter hours)
**MAT 130 or equivalents or placement by test is a prerequisite for this course.**

**MAT 148 | CALCULUS WITH INTEGRATED PRECALCULUS II | 6 quarter hours**
**(Undergraduate)**
Extrema, curve sketching, related rates, definite and indefinite integrals, applications of the integral, with precalculus review included for each topic. (6 quarter hours)
**MAT 147 (or MAT 150 or MAT 155 or MAT 160 or MAT 170) is a prerequisite for this class.**

**MAT 149 | CALCULUS WITH INTEGRATED PRECALCULUS III | 6 quarter hours**
**(Undergraduate)**
Techniques of integration, L'Hopital's rule, improper integrals, Taylor polynomials, series and sequences, first-order differential equations, with precalculus review included for each topic. (6 quarter hours)
**MAT 148 (or MAT 151 or MAT 161 or MAT 171) is a prerequisite for this class.**

**MAT 150 | CALCULUS I | 4 quarter hours**
**(Undergraduate)**
Limits, continuity, the derivative, rules of differentiation, derivatives of trigonometric and logarithmic functions and their inverses, applications of the derivative, extrema, curve sketching, and optimization. This course meets for an additional 1-hour lab session each week for enrichment and problem solving.
**MAT 131 or placement by test is a prerequisite for this course.**

**MAT 151 | CALCULUS II | 4 quarter hours**
**(Undergraduate)**
Definite and indefinite integrals, the Fundamental Theorem of Calculus, applications of the integral, techniques of integration. This course meets for an additional 1-hour lab session each week for enrichment and problem solving.
**MAT 150 or MAT 155 or MAT 160 or MAT 170 is a prerequisite for this class.**

**MAT 152 | CALCULUS III | 4 quarter hours**
**(Undergraduate)**
L'Hopital's rule, improper integrals, sequences and series, Taylor polynomials. This course meets for an additional 1-hour lab session each week for enrichment and problem solving.
**MAT 151 or MAT 161 or MAT 171 is a prerequisite for this class.**

**MAT 155 | SUMMER CALCULUS I | 6 quarter hours**
**(Undergraduate)**
Limits, continuity, the derivative, rules of differentiation, derivatives of trigonometric and logarithmic functions and their inverses, applications of the derivative, extrema, curve sketching, and optimization. Definite and indefinite integrals, the Fundamental Theorem of Calculus, applications of the integral. (6 quarter hours)
**MAT 131 or placement by Mathematics Diagnostic Test is a prerequisite for this class.**

**MAT 156 | SUMMER CALCULUS II | 6 quarter hours**
**(Undergraduate)**
Further applications of the integral, techniques of integration. L'Hopital's rule, improper integrals, sequences and series, Taylor polynomials. (6 quarter hours)
**MAT 148 or MAT 151 or MAT 155 or MAT 161 or MAT 171 is a prerequisite for this class.**

**MAT 160 | CALCULUS FOR MATHEMATICS AND SCIENCE MAJORS I | 5 quarter hours**
**(Undergraduate)**
Limits, continuity, the derivative, rules of differentiation, derivatives of trigonometric and logarithmic functions and their inverses, applications of the derivative, extrema, curve sketching, and optimization. This course meets for an additional 1.5-hour lab session each week for enrichment and problem solving. (5 quarter hours)
**MAT 131 or placement by test is a prerequisite for this class.**

**MAT 161 | CALCULUS FOR MATHEMATICS AND SCIENCE MAJORS II | 5 quarter hours**
**(Undergraduate)**
Definite and indefinite integrals, the Fundamental Theorem of Calculus, applications of the integral, techniques of integration. This course meets for an additional 1.5-hour lab session each week for enrichment and problem solving. (5 quarter hours)
**MAT 150 or MAT 155 or MAT 160 or MAT 170 is a prerequisite for this class.**

**MAT 162 | CALCULUS FOR MATHEMATICS AND SCIENCE MAJORS III | 5 quarter hours**
**(Undergraduate)**
L'Hopital's rule, improper integrals, sequences and series, Taylor polynomials. This course meets for an additional 1.5-hour lab session each week for enrichment and problem solving. (5 quarter hours)
**MAT 151 or MAT 161 or MAT 171 is a prerequisite for this class.**

**MAT 170 | CALCULUS FOR LIFE SCIENCES I | 5 quarter hours**
**(Undergraduate)**
The course covers the following topics using examples from the sciences: Functions as models, logarithmic scale graphing, exponential growth and decay, difference equations and limits of sequences, geometric series, functions and limits, trigonometric functions and their limits, continuity, limits at infinity, the derivative, differentiation rules, derivatives of trigonometric and exponential functions, related rates, derivatives of inverse and logarithm functions. Course meets for an additional lab session each week during which time students will work on applied mathematics projects based on the topics covered in the course. Students majoring in the sciences should consult with their major department to decide between the 160 and 170 sequences. (5 quarter hours)
**MAT 131 or placement by test is a prerequisite for this class.**

**MAT 171 | CALCULUS FOR LIFE SCIENCES II | 5 quarter hours**
**(Undergraduate)**
The course covers the following topics using examples from the sciences: Applications of the derivative including approximation and local linearity, differentials, extrema and the Mean Value Theorem, monotonicity and concavity, extrema, inflection points, graphing, L'Hospital's Rule, optimization, and the Newton-Raphson method, antiderivaties, the definite integral, Riemann sums, the Fundamental Theorem of Calculus, area, cumulative change, average value of a function, and techniques of integration: substitution rule and integration by parts. Course meets for an additional lab session each week during which time students will work on applied mathematics projects based on the topics covered in the course. Course meets for an additional lab session each week during which time students will work on applied mathematics projects based on the topics covered in the course. (5 quarter hours)
**MAT 150 or MAT 155 or MAT 160 or MAT 170 is a prerequisite for this class.**

**MAT 172 | CALCULUS III WITH DIFFERENTIAL EQUATIONS | 5 quarter hours**
**(Undergraduate)**
This course is designed for students in the life sciences and covers some topics from MAT 152, differential equations and an introduction to the Calculus of functions of several variables. Specific topics are as follows. Numerical integration, partial fraction expansions, Taylor approximations of a function, differential equations, separation of variables, slope fields, Euler's existence theorem, polygonal approximations to solutions of differential equations, the logistic equation and allometric growth models, equilibria of differential equations and their stability, applications of stability theory, functions of several variables, partial derivatives, directional derivative and the gradient. Course meets for an additional lab session each week during which time students will work on applied mathematics projects based on the topics covered in the course. (5 quarter hours)
**MAT 151 or MAT 161 or MAT 171 is a prerequisite for this class.**

**MAT 207 | HISTORY OF PROBABILITY AND STATISTICS | 4 quarter hours**
**(Undergraduate)**
History Of Probability And Statistics.

**MAT 215 | INTRODUCTION TO MATHEMATICAL REASONING | 4 quarter hours**
**(Undergraduate)**
An introduction to basic concepts and techniques used in higher mathematics courses: set theory, equivalence relations, functions, cardinality, techniques of proof in mathematics. The emphasis is on problem solving and proof construction by students.
**MAT 156 OR MAT 149 OR MAT 152 OR MAT 162 OR MAT 172 is a prerequisite for this class.**

**MAT 216 | FOUNDATIONS OF ADVANCED MATHEMATICS | 4 quarter hours**
**(Undergraduate)**
Introduction to abstract mathematics: congruences, modular arithmetic, the Euclidean algorithm, proofs involving manipulation of inequalities and estimation, sequences and their limits.
**MAT 215 (or MAT 141) is a prerequisite for this class.**

**MAT 220 | APPLIED LINEAR ALGEBRA | 4 quarter hours**
**(Undergraduate)**
Systems of linear equations, matrices and matrix algebra, determinants, diagonalization and matrix factorization with MATLAB/Maple, with applications to linear programming and graph theory.
**MAT 141 or MAT 148 or MAT 151 or MAT 155 or MAT 161 or MAT 171 is a prerequisite for this class.**

**MAT 242 | ELEMENTS OF STATISTICS | 4 quarter hours**
**(Undergraduate)**
Descriptive statistics, elements of probability, the binomial and normal probability models; large and small sample hypothesis testing, correlation and regression analysis. Use of computer packages. This course does not count toward mathematics major credit. Cross-listed with SOC 279.
**(MAT 095 and MAT 100) or MAT 101 or placement are prerequisites for this class.**

**MAT 260 | MULTIVARIABLE CALCULUS I | 4 quarter hours**
**(Undergraduate)**
Vectors, dot and cross products, parameterizations of lines and planes in space, functions of several independent variables, partial derivatives, tangent planes and linear approximations, the chain rule, directional derivatives and the gradient vector, extreme values, Lagrange multipliers, double integrals and their applications.
**MAT 156 OR MAT 149 OR MAT 152 OR MAT 162 OR MAT 172 is a prerequisite for this class.**

**MAT 261 | MULTIVARIABLE CALCULUS II | 4 quarter hours**
**(Undergraduate)**
Surface areas, triple integrals, vector functions and space curves, derivatives of vector functions, arc length and curvature, vector fields, line integrals, Green's Theorem, parametric surfaces, surface integrals, curl and divergence, Stokes's Theorem, the Divergence Theorem.
**MAT 260 is a prerequisite for this class.**

**MAT 262 | LINEAR ALGEBRA | 4 quarter hours**
**(Undergraduate)**
Systems of linear equations and matrices; vectors in n-space; vector spaces: linear combinations, linear independence, basis; linear transformations, change of basis, eigenvalues and eigenvectors.
**MAT 260 or Instructor permission are prerequisites for this class.**

**MAT 301 | HISTORY OF MATHEMATICS | 4 quarter hours**
**(Undergraduate)**
History of mathematics with problem solving.
**A grade of C-minus or better in MAT 215 or MAT 141, or instructor permission is a prerequisite for this class.**

**MAT 302 | COMBINATORICS | 4 quarter hours**
**(Undergraduate)**
Methods of counting and enumeration of mathematical structures.
Topics include generating functions, recurrence relations, inclusion
relations, and graphical methods.
**A grade of C-minus or better in MAT 215 or MAT 141, or instructor**
**permission is a prerequisite for this class.**

**MAT 303 | THEORY OF NUMBERS | 4 quarter hours**
**(Undergraduate)**
A study of properties of integers: divisibility; Euclid's Algorithm;
congruences and modular arithmetic; Euler's Theorem; Diophantine
equations; distribution of primes; RSA cryptography.
**A grade of C- or above in MAT 216 (or instructor permission) is a**
**prerequisite for this class.**

**MAT 304 | DIFFERENTIAL EQUATIONS | 4 quarter hours**
**(Undergraduate)**
Linear equations, systems with constant coefficients, series solutions,
Laplace transforms, and applications. Formerly MAT 338.
**MAT 260 is a prerequisite for this class.**

**MAT 305 | GRAPH THEORY | 4 quarter hours**
**(Undergraduate)**
This course studies graph theory and its applications. Topics include
trees, Eulerian circuits, Hamiltonian cycles, matchings, graph coloring
problems, random graphs, and random walks on graphs. Appropriate
background would be a course in introductory linear algebra.
**MAT 141 OR MAT 215 OR MAT 220 OR MAT 262 (or instructor approval).**

**MAT 309 | TEACHING AND LEARNING SECONDARY SCHOOL**
**MATHEMATICS | 4 quarter hours**
**(Undergraduate)**
Theories, methods, and materials for teaching and learning mathematics
in secondary schools. Cross-listed with SEC 309.
**SE 364 is a prerequisite for this class.**

**MAT 310 | ABSTRACT ALGEBRA I | 4 quarter hours**
**(Undergraduate)**
The first quarter of a 3-quarter sequence. Topics in the sequence
include the integers; abstract groups, rings, and fields; polynomial rings;
isomorphism theorems; extension fields; and an introduction to Galois
theory.
**MAT 262 and (a C-minus or better in MAT 216), or instructor permission,**
**are prerequisites for this class.**

**MAT 311 | ABSTRACT ALGEBRA II | 4 quarter hours**
**(Undergraduate)**
A continuation of topics from MAT 310: Groups, rings, fields, polynomial
rings, isomorphism theorems, extension fields, and an introduction to
Galois theory.
**A grade of C-minus or better in MAT 310 or instructor permission is a**
**prerequisite for this class.**

**MAT 312 | ABSTRACT ALGEBRA III | 4 quarter hours**
**(Undergraduate)**
A continuation of topics from MAT 311: Groups, rings, fields, polynomial
rings, isomorphism theorems, extension fields, and an introduction to
Galois theory.
**A grade of C-minus or better in MAT 311 or instructor permission is a**
**prerequisite for this class.**

**MAT 320 | GEOMETRY I | 4 quarter hours**
**(Undergraduate)**
Incidence and separation properties of planes; congruences; the parallel
postulate; area theory; ruler and compass construction.
**A grade of C-minus or better in MAT 215 or MAT 141, or instructor**
**permission is a prerequisite for this class.**

**MAT 321 | GEOMETRY II | 4 quarter hours**
**(Undergraduate)**
Introduction to solid geometry and noneuclidean geometry (hyperbolic
and spherical models); other special topics.
**A grade of C- or better in MAT 320 is a prerequisite for this course.**

**MAT 323 | DATA ANALYSIS AND STATISTICAL SOFTWARE I | 4 quarter**
**hours**
**(Undergraduate)**
Computing with a statistical package. Introduction to data analysis,
elementary statistical inference, regression and correlation. This course
does not count toward mathematics major credit.
**MAT 130 or placement by test is a prerequisite for this class.**

**MAT 324 | DATA ANALYSIS & STATISTICAL SOFTWARE II | 4 quarter**
**hours**
**(Undergraduate)**
Advanced features and applications of the statistical package used in
MAT 323.
**C- or better in MAT 323**

**MAT 326 | SAMPLE SURVEY METHODS | 4 quarter hours**
**(Undergraduate)**
Simple random, stratified, systematic and cluster sampling. Multistage
and area sampling. Random-response and capture-release models.
**MAT 349 or MAT 353 is a prerequisite for this class.**

**MAT 328 | DESIGN OF EXPERIMENTS | 4 quarter hours**
**(Undergraduate)**
Linear models and quadratic forms. Single, two and several-factor
experiments, incomplete designs, confounding and fractional factorial
experiments. Response surfaces and partially balanced incomplete block
designs.
**MAT 349 or MAT 353 is a prerequisite for this class,.**

**MAT 330 | METHODS OF COMPUTATION AND THEORETICAL PHYSICS I |**
**4 quarter hours**
**(Undergraduate)**
Computational and theoretical methods in ordinary differential equations,
complex numbers, systems of equations, phase plane analysis,
and bifurcations. Applications to damped, driven oscillators, and to
electronics.

**MAT 331 | METHODS OF COMPUTATION AND THEORETICAL PHYSICS II**
**| 4 quarter hours**
**(Undergraduate)**
Computational and theoretical methods in ordinary differential equations,
complex numbers, systems of equations, phase plane analysis,
and bifurcations. Applications to damped, driven oscillators, and to
electronics.
**MAT 261 is a prerequisite for this class.**

**MAT 335 | REAL ANALYSIS I | 4 quarter hours**
**(Undergraduate)**
Real number system, completeness, supremum, and infimum, sequences
and their limits, lim inf, lim sup, limits of functions, continuity.
**(MAT 149 or MAT 152 or MAT 156 or MAT 162) and (a grade of C-minus**
**or better in MAT 216) are prerequisites for this class.**

**MAT 336 | REAL ANALYSIS II | 4 quarter hours**
**(Undergraduate)**
Properties of continuous functions, uniform continuity, sequences of functions, differentiation, integration. To follow 335 in the Winter Quarter.
**A grade of C- or better in MAT 335 is a prerequisite for this class.**

**MAT 337 | COMPLEX ANALYSIS | 4 quarter hours**
**(Undergraduate)**
Complex functions; complex differentiation and integration; series and sequences of complex functions.
**MAT 215, MAT 261 and MAT 335 (or instructor permission) are prerequisites or this class.**

**MAT 340 | TOPOLOGY | 4 quarter hours**
**(Undergraduate)**
An introduction to point-set topology: metric spaces, topological spaces, continuity, connectedness, and compactness.
**Grade of C- or above in MAT 335 or instructor permission are prerequisites for this class.**

**MAT 341 | STATISTICAL METHODS USING SAS | 4 quarter hours**
**(Undergraduate)**
The SAS programming language. Data exploration, description and presentation, with emphasis on writing statistical reports. Inference based on continuous and categorical data. Analysis of variance models and regression procedures including logistic regression. Cross-listed with MAT 448.
**Successful completion of the programming course required as part of the Math Core Curriculum or instructor permission is a prerequisite for this class.**

**MAT 342 | ELEMENTS OF STATISTICS II | 4 quarter hours**
**(Undergraduate)**
Multiple regression, correlation, analysis of variance, time series, and sampling. Course content and emphases will vary with students' needs and backgrounds.
**MAT 137 (or MAT 323 or MAT 348) is a prerequisite for this class.**

**MAT 343 | BUSINESS STATISTICS II | 4 quarter hours**
**(Undergraduate)**
Multiple regression, correlation, analysis of variance, time series and sampling. Statistical theory applied to business. Use of statistical computing packages. Course content will vary with the needs and desires of individual students. (FORMERLY BMS 342)
**A grade of C-minus or better in MAT 137 or instructor permission is a prerequisite for this class.**

**MAT 348 | APPLIED STATISTICAL METHODS | 4 quarter hours**
**(Undergraduate)**
Introduction to statistical software (which will be used throughout the course). Descriptive statistics; elementary probability theory; discrete and continuous probability models; principles of statistical inference; Simple linear regression and correlation analysis.
**MAT 130 or equivalent is the prerequisite for this class.**

**MAT 349 | APPLIED PROBABILITY | 4 quarter hours**
**(Undergraduate)**
Probability theory, probability distributions, mathematical expectation, functions of random variables, sampling distributions, estimation, tests of hypotheses, simulation. Focus on applications.
**A grade of C-minus or better in MAT 341 or MAT 348 or CSC 324 or DSC 323 is a prerequisite for this class.**

**MAT 350 | BAYESIAN STATISTICS | 4 quarter hours**
**(Undergraduate)**
Comparison of Bayesian and frequentist methods, conditional probability, Bayes theorem, conjugate distributions, computational methods, hands-on Bayesian data analysis using appropriate software, interpretation and presentation of analysis results. Students will learn to use software packages including OpenBUGS. The free software program R will be utilized for data analysis.
**MAT 349 (or MAT 351) is a prerequisite for this class.**

**MAT 351 | PROBABILITY AND STATISTICS I | 4 quarter hours**
**(Undergraduate)**
Probability spaces, combinatorial probability methods, discrete and continuous random variables and distributions, moment generating functions, development and applications of the classical discrete and continuous distributions.
**MAT 260 is a prerequisite for this class.**

**MAT 352 | PROBABILITY AND STATISTICS II | 4 quarter hours**
**(Undergraduate)**
Joint probability distributions and correlation; law of large numbers and the central limit theorem; sampling distributions and theory of estimation.
**A grade of C-minus or better in MAT 351 or instructor permission is a prerequisite for this class.**

**MAT 353 | PROBABILITY AND STATISTICS III | 4 quarter hours**
**(Undergraduate)**
Principles of hypothesis testing; most powerful tests and likelihood ratio tests; linear regression; one-way analysis of variance; categorical data analysis, nonparametric statistics.
**A grade of C-minus or better in MAT 352 or instructor permission is a prerequisite for this class.**

**MAT 354 | MULTIVARIATE STATISTICS | 4 quarter hours**
**(Undergraduate)**
The multivariate normal distribution. Hypothesis tests on means and variances including the multivariate linear model. Classification using the linear discriminant function. Principal components and factor analysis. PREREQUISTE(S): MAT 353 and 262, or consent of instructor. (CROSS-LISTED WITH MAT 454)
**MAT 262 and MAT 353 are a prerequisite for this class.**

**MAT 355 | STOCHASTIC PROCESSES | 4 quarter hours**
**(Undergraduate)**
Discrete Markov chains and random walks, birth and death processes, Poisson processes, queuing systems, and renewal processes. Cross-listed with MAT 455.
**MAT 353 and (MAT 220 or MAT 262), or instructor permission are prerequisites for this class.**

**MAT 356 | APPLIED REGRESSION ANALYSIS | 4 quarter hours**
**(Undergraduate)**
Simple linear, multiple, polynomial and general regression models. Selection of best regression equation and examination of residuals for homoscedasticity and other diagnostics. Use of statistical software. Cross-listed with MAT 456.
**MAT 262 and MAT 353 are a prerequisite for this class.**

**MAT 357 | NONPARAMETRIC STATISTICS | 4 quarter hours**
**(Undergraduate)**
Inference concerning location and scale parameters, goodness of fit tests, association analysis and tests of randomness using distribution free procedures. Bootstrap techniques. Smoothing methodologies. Cross-listed with MAT 457.
**PREREQUISITE: MAT 349 or 353**

**MAT 358 | APPLIED TIME SERIES AND FORECASTING | 4 quarter hours**
**(Undergraduate)**
Development of the Box-Jenkins methodology for the identification, estimation, and fitting of ARIMA, and transfer-function stochastic models for the purpose of analyzing and forecasting stationary, non-stationary, and seasonal time series data. The course emphasizes practical time-series data analysis using computer packages and includes applications to economic, business, and industrial forecasting. Cross-listed with MAT 512.
**(MAT 341 and MAT 353) or (MAT 356) are prerequisites for this class.**

**MAT 359 | SIMULATION MODELS AND MONTE CARLO METHOD | 4 quarter hours**
**(Undergraduate)**
Techniques of computer simulation of the classical univariate and multivariate probability distribution models, and such random processes as random walk, Markov chains, and queues. Cross-listed with MAT 459.
**MAT 341 and MAT 353 are a prerequisite for this class.**

**MAT 360 | GENERALIZED LINEAR MODELS | 4 quarter hours**
**(Undergraduate)**
Applications of generalized linear models. Topics include generalized linear models for non-normal continuous response, models for binary and multinomial response data, models for count data, and analysis of variance and covariance. The class of generalized linear models contains the models most commonly used in statistical practice.
**(CSC 324 or DSC 323 or MAT 341) and (MAT 349 or MAT 351) are prerequisites for this class.**

**MAT 361 | THEORY OF INTEREST | 4 quarter hours**
**(Undergraduate)**
Theory and applications of compound interest to annuities, amortization schedules, sinking funds, bonds, and yield rates.
**MAT 149 (or MAT 152 or MAT 156 or MAT 162) is a prerequisite for this class.**

**MAT 362 | LIFE CONTINGENCIES I | 4 quarter hours**
**(Undergraduate)**
Basic Contingencies: The theory and applications of contingency mathematics in life and health insurance, annuities, and pensions from both a probabilistic and a deterministic viewpoint. Topics include survival distribution and life tables, life insurance, and life annuities.
**A grade of C-minus or better in MAT 361 or instructor permission is a prerequisite and MAT 352 is a corequisite for this class.**

**MAT 363 | LIFE CONTINGENCIES II | 4 quarter hours**
**(Undergraduate)**
Advanced Contingencies: A continuation of Mathematics 362. Topics include net premiums, net premiums reserves, multiple life functions, multiple decrement models, and valuation theory for pension plans.
**A grade of C- or above in MAT 352 and MAT 362 or instructor permission is a prerequisite for this class.**

**MAT 364 | LOSS MODELS I | 4 quarter hours**
**(Undergraduate)**
Severity and frequency models, aggregate models, coverage modifications, risk measures, construction and selection of parametric models. Cross-listed with MAT 464.
**MAT 353 is a prerequisite for this class.**

**MAT 365 | LOSS MODELS II | 4 quarter hours**
**(Undergraduate)**
Bayesian credibility, Buhlmann credibility, insurance and reinsurance coverages, pricing and reserving. Cross-listed with MAT 465.
**MAT 364 is a prerequisite for this course.**

**MAT 366 | MATHEMATICAL DEMOGRAPHY | 4 quarter hours**
**(Undergraduate)**
Introduction to demography; mortality table construction and methods of population and demographic analysis.
**MAT 353 is a prerequisite for this class.**

**MAT 367 | CREDIBILITY THEORY | 4 quarter hours**
**(Undergraduate)**
Credibility theory and loss distributions with applications to casualty insurance classification and finance. Cross-Listed as MAT 467.
**MAT 352 is a prerequisite for this class.**

**MAT 368 | MATHEMATICS FOR FINANCE | 4 quarter hours**
**(Undergraduate)**
The course covers the mathematics of financial derivatives, investment strategies, arbitrage, put-call parity, binomial models for European options and interest rates, Black-Scholes formula, hedging, lognormal models for asset prices, exotic options, valuation using Monte-Carlo, and embedded options in annuity products.
**MAT 260 and (MAT 220 or MAT 262) and (MAT 349 or MAT 353) are prerequisites for this class.**

**MAT 369 | ACTUARIAL SCIENCE SEMINAR | 4 quarter hours**
**(Undergraduate)**
This course is a problem solving seminar that covers relevant topics in probability and statistics in the first actuarial exam: Exam P/1. The course also discusses exam preparation strategies.

**MAT 370 | ADVANCED LINEAR ALGEBRA | 4 quarter hours**
**(Undergraduate)**
Vector spaces, basis and dimension; matrix representation of linear transformations and change of basis; diagonalization of linear operators; inner product spaces; diagonalization of symmetric linear operators, principal-axis theorem, and applications. Cross-listed MAT 470.
**MAT 262 and (a grade of C-minus or better in MAT 215 or MAT 141) or instructor permission is a prerequisite for this class.**

**MAT 372 | LOGIC AND SET THEORY | 4 quarter hours**
**(Undergraduate)**
Topics in axiomatic set theory, formal logic, and computability theory.
**A grade of C-minus or better in MAT 215 or MAT 141, or instructor permission is a prerequisite for this class.**

**MAT 381 | FOURIER ANALYSIS AND SPECIAL FUNCTIONS | 4 quarter hours**
**(Undergraduate)**
The course covers the basic principles of discrete and continuous Fourier analysis and some of its applications currently used in scientific modeling. Students will use the computer to implement the computational algorithms developed in the course. Some of the topics covered will include Fourier transforms and their application to signal and image processing, discrete Fourier series, the fast Fourier transform algorithm and applications to digital filtering, and the Radon transforms and its applications to tomography.
**MAT 262 is a prerequisite for this class.**

**MAT 384 | MATHEMATICAL MODELING | 4 quarter hours**
**(Undergraduate)**
Modeling of real world problems using mathematical methods. Includes a theory of modeling and a study of specific models, selected from deterministic, stochastic, continuous, and discrete models. Cross-listed with MAT 484.
**MAT 262 (or MAT 220) is a prerequisite for this class.**

**MAT 385 | NUMERICAL ANALYSIS I | 4 quarter hours**
**(Undergraduate)**
Use of a digital computer for numerical computation. Error analysis, Gaussian elimination and Gauss-Seidel method, solution of non-linear equations, function evaluation, cubic splines, approximation of integrals and derivatives, Monte Carlo methods. Cross-listed with MAT 485.
**MAT 262 and a programming course required as part of the Math Core Curriculum or consent of the instructor are prerequisites for this class.**

**MAT 386 | NUMERICAL ANALYSIS II | 4 quarter hours**
**(Undergraduate)**
Theory and algorithms for efficient computation, including the Fast Fourier transform, numerical solution of non-linear systems of equations. Minimization of functions of several variables. Sparse systems of equations and corresponding eigenvalue problems. (CROSS-LISTED WITH MAT 486 & CSC 386/486)
**A grade of C-minus or better in MAT 385 or instructor permission is a prerequisite for this class.**

**MAT 387 | OPERATIONS RESEARCH: LINEAR PROGRAMMING | 4 quarter hours**
**(Undergraduate)**
Linear programming, integer programming and LP relaxation, the duality theorem, simplex algorithm, interior point methods, applications to industrial engineering. Students should take an introductory computer programming course before taking this course. (CROSS-LISTED AS MAT 487)
**MAT 260 and MAT 262 are prerequisites for this class.**

**MAT 388 | OPERATIONS RESEARCH: OPTIMIZATION THEORY | 4 quarter hours**
**(Undergraduate)**
Convex optimization, quadratic optimization problems, Lagrange multipliers and generalization to inequality constraints, alternating direction method of multipliers (ADMM), unconstrained minimization, applications to industrial engineering including machine learning. Students should take an introductory computer programming course before taking this course. (CROSS-LISTED AS MAT 488)
**MAT 260 and MAT 262 are prerequisites for this class.**

**MAT 389 | TOPICS IN OPERATIONS RESEARCH | 4 quarter hours**
**(Undergraduate)**
Advanced topics in operations research and optimization theory.
**A grade of C-minus or better in MAT 388 or instructor permission is a prerequisite for this class.**

**MAT 390 | MATHEMATICS READING AND RESEARCH | 4 quarter hours**
**(Undergraduate)**
The course provides students with a hands-on experience about research in mathematical sciences. Students attend seminars and research colloquia, and actively participate at discussions about the topics presented. Students reflect on the connections between various areas of modern mathematics, the challenges of structuring and solving problems, and the personal experience of doing mathematics. As a final project, each student prepares and presents a mathematical expository paper describing a current area of research, emphasizing its relevance to mathematics in general and its connections to real world problems. This course may be used to satisfy the junior-year experiential learning (JYEL) requirement.

**MAT 391 | STUDIES IN DEMOGRAPHY | 4 quarter hours**
**(Undergraduate)**
The course introduces students to the study by statistical methods of human populations in terms of type of data sources, population composition, growth, fertility, mortality, morbidity, health, migration, and urbanization. In addition, the course has a major component that emphasizes the study of current characteristics of the populations of developing countries in comparison with some developed countries including the United States of America. Students are required to present and submit a research project with comparative analysis of demographic statistics obtained on several developing and developed countries.

**MAT 395 | TOPICS IN MATHEMATICS | 4 quarter hours**
**(Undergraduate)**
Consult course schedule for current offerings. Course may be repeated for credit when title and content change. Variable credit allowed.

**MAT 396 | SENIOR THESIS RESEARCH | 2-4 quarter hours**
**(Undergraduate)**
A thesis option is available to mathematics majors who wish to pursue an extended independent project related to a theoretical or applied focus of the program. Students would work under the guidance of a faculty mentor. A total of 4 credits must be completed over the one or two quarters prior to the thesis submission. Interested students are strongly encouraged to enroll in MAT 390 during their junior year. (2 quarter hours)

**MAT 397 | MATHEMATICAL PEDAGOGY: THEORY & PRACTICE | 4 quarter hours**
**(Undergraduate)**
Introduction to current theories and practices in college mathematics instruction; helps undergraduate mathematics majors develop a deeper understanding of fundamental mathematical concepts and an awareness of how people learn mathematical ideas, and prepares them to work as consultants in mathematics instruction. Mathematical tutoring practicum is required. Four credit hour course offered over a two quarter span during the autumn and winter quarters only. See instructor for further information. This course maybe used to satisfy the junior experiential learning requirement, but it does not count toward mathematics major or minor credit. Cross-listed with MAT 697.

**MAT 398 | SENIOR CAPSTONE SEMINAR | 4 quarter hours**
**(Undergraduate)**
Topics vary from year to year. This course does not count toward the mathematical major or minor credit.
**MAT 215 (or MAT 140 and 141) and MAT 262, or instructor permission are prerequisites for this class.**

**MAT 399 | INDEPENDENT STUDY | 1-8 quarter hours**
**(Undergraduate)**
(variable credit)

**MAT 400 | APPLIED ABSTRACT ALGEBRA I | 4 quarter hours**
**(Graduate)**
Applied Abstract Algebra I.

**MAT 401 | APPLIED ABSTRACT ALGEBRA II | 4 quarter hours**
**(Graduate)**
Applied Abstract Algebra II.
**MAT 400 is a prerequisite for this class.**

**MAT 421 | BASIC BIOSTATISTICS | 4 quarter hours**
**(Graduate)**
This course includes both data analysis and experimental design, up to and including survival analysis such as used in the analysis of clinical trials. The course will be supplemented by standard topics with application areas relevant to drug development, including pharmacokinetics, clinical trials, bioequivalence, and pharmacoepidemiology.
**MAT 453 or instructor consent is a prerequisite for this class.**

**MAT 424 | ADVANCED BIOSTATISTICS | 4 quarter hours**
**(Graduate)**
The overall objective is the development of statistical literacy and skills in the analysis of biological and medical data including: generalized linear models, analysis of repeated measures, log-linear models, clinical trials and computer applications.
**MAT 421 is a prerequisite for this class.**

**MAT 425 | SURVIVAL ANALYSIS | 4 quarter hours**
**(Graduate)**
Basic quantities and models in survival analysis, types of censoring and truncation data, estimation for various survival models, nonparametric estimation of hazard and survival functions , comparing survival times between different groups, the proportional hazard and accelerated lifetime models for regression analysis with failure-time data and model checking methods. Appropriate background is one semester of applied statistics or equivalent.

**MAT 426 | GENERALIZED LINEAR MODELS | 4 quarter hours**
**(Graduate)**
Applications of generalized linear models. Topics include generalized linear models for non-normal continuous response, models for binary and multinomial response data, models for count data, and analysis of variance and covariance. The class of generalized linear models contains the models most commonly used in statistical practice.
**(DSC 324 or DSC 323 or MAT 448) and (MAT 349 or MAT 451) are prerequisites for this class.**

**MAT 427 | BAYESIAN STATISTICS | 4 quarter hours**
**(Graduate)**
Comparison of Bayesian and frequentist methods, conditional probability, Bayes theorem, conjugate distributions, computational methods, hands-on Bayesian data analysis using appropriate software, interpretation and presentation of analysis results. Students will learn to use software packages including OpenBUGS. The free software program R will be utilized for data analysis.
**MAT 349 or MAT 351 or MAT 451 is a prerequisite for this class.**

**MAT 434 | TOPOLOGY | 4 quarter hours**
**(Graduate)**
An introduction to point-set topology: metric spaces, topological spaces, continuity, connectedness, and compactness.
**Grade of C-minus or better in (MAT 335 or ECO 435 or MAT 680 or a transfer equivalent) or instructor permission is a prerequisite for this class.**

**MAT 435 | MEASURE THEORY | 4 quarter hours**
**(Graduate)**
This is a course in Lebesgue integration; the study of measure spaces and measurable functions; the basic theorems of Lebesque integration; Egoroff's theorem, the monotone limit theorem, the Lebesgue dominated convergence theorem; an introduction to Lp spaces, Holder's inequality, Minkowski's inequality; Fubini's theorem.
**MAT 336 or MAT 434 is a prerequisite for this course.**

**MAT 436 | FUNCTIONAL ANALYSIS | 4 quarter hours**
**(Graduate)**
This course is an introduction to the basic theory of functional analysis. Students will study normed, Banach, and Hilbert Spaces and the theory of bounded linear functionals and operators acting on them. The contraction mapping and the fixed point theorem are also studied with applications to sequence and function spaces.
**MAT 434 and (MAT 370 or MAT 470) is a prerequisite for this class.**

**MAT 437 | COMPLEX ANALYSIS | 4 quarter hours**
**(Graduate)**
Course topics: Complex functions; complex differentiation and integration; series and sequences of complex functions. Cross-listed with MAT 337.
**(MAT 335 or MAT 434 or MAT 680) is a prerequisite for this class.**

**MAT 441 | APPLIED STATISTICS I | 4 quarter hours**
**(Graduate)**
Parametric and non-parametric statistical inferential methods for the univariate and bivariate situations using SAS and R. Specific topics include classical and exploratory graphical & numerical methods of data descriptions; inference about means, medians, and associations including analysis of variance and linear regression. Data analytic projects are an integral part of the course.

**MAT 442 | APPLIED STATISTICS II | 4 quarter hours**
**(Graduate)**
A continuation of MAT 441. Repeated measures design, association, analysis of covariance, and multivariate relationships. Diagnostics and model building. Methods of categorical data analysis. Logistical regression and log-linear models. Data analytical projects using SAS and R are an integral part of the course.
**MAT 441 or MAT 448 is a prerequisite for this class.**

**MAT 443 | APPLIED STATISTICS III | 4 quarter hours**
**(Graduate)**
A continuation of MAT 442. The course material generalizes univariate methods of inference to multivariate situations using SAS and R. Specific topics include canonical correlation, discriminate analysis, principal component analysis, factor analysis, and multivariate analysis of variance. Emphasis in the curse is on data analytic projects.
**MAT 442 is a prerequisite for this class.**

**MAT 448 | STATISTICAL METHODS USING SAS | 4 quarter hours**
**(Graduate)**
The SAS programming language. Data exploration, description and presentation. Inference methods for continuous and categorical data. Analysis of variance models and regression procedures.

**MAT 449 | STATISTICAL DATA MANAGEMENT | 4 quarter hours**
**(Graduate)**
Students learn data organization and structures, design of statistical databases, statistical software analysis, basic structure of relational databases, SAS Macros, Python and R functions, complex SQL statements, and advanced data manipulation techniques.
**MATT 441 (or MAT 448) is a prerequisite for this class.**

**MAT 450 | ADVANCED STATISTICAL COMPUTING | 4 quarter hours**
**(Graduate)**
Advanced statistical computing methods used in modern scientific investigation. Topics include data management, random number generation, resampling methods, numerical optimization, Markov Chain Monte Carlo, smoothing methods, data mining: clustering and classification.
**MAT 441 and MAT 451 are prerequisites for this class.**

**MAT 451 | PROBABILITY AND STATISTICS I | 4 quarter hours**
**(Graduate)**
The course covers elements of probability theory, distributions of random variables and linear functions of random variables, moment generating functions, and discrete and continuous probability models. Appropriate background would be a course in multivariable calculus.

**MAT 452 | PROBABILITY AND STATISTICS II | 4 quarter hours**
**(Graduate)**
A continuation of MAT 451. More continuous probability model. Laws of large numbers and the central limit theorem. Sampling distributions of certain statistics. An introduction to the theory of estimation and principals of hypothesis testing.
**MAT 451 is a prerequisite for this class.**

**MAT 453 | PROBABILITY AND STATISTICS III | 4 quarter hours**
**(Graduate)**
A continuation of MAT 452. More on hypothesis testing, most powerful, uniformly most powerful, and likelihood ratio tests. Introduction to the analysis of variance; linear regression; categorical data analysis, and nonparametric methods of inference.
**MAT 452 is a prerequisite for this class.**

**MAT 454 | MULTIVARIATE STATISTICS | 4 quarter hours**
**(Graduate)**
The multivariate normal distribution. The general linear model. Multivariate regression and analysis of variance; discriminant analysis; principal component and factor analysis; applications and use of statistical software. Cross-listed with MAT 354.
**MAT 453 is a prerequisite for this class.**

**MAT 455 | STOCHASTIC PROCESSES | 4 quarter hours**
**(Graduate)**
Discrete Markov chains and random walks, birth and death processes, Poisson process, queuing systems, and renewal processes.Cross-listed as MAT 355.
**MAT 452 is a prerequisite or a co-requisite for this class.**

**MAT 456 | APPLIED REGRESSION ANALYSIS | 4 quarter hours**
**(Graduate)**
Simple linear, multiple, polynomial and general linear regression models. Model diagnostics; Model selection and Validation. Cross-listed with MAT 356.
**MAT 453 is a prerequisite for this class.**

**MAT 457 | NONPARAMETRIC STATISTICS | 4 quarter hours**
**(Graduate)**
Inference concerning location and scale parameters, goodness of fit tests, association analysis and tests of randomness using distribution free procedures. Bootstrap techniques. Smoothing methodologies. Cross-listed with MAT 357.
**MAT 453 is a prerequisite for this class.**

**MAT 458 | STATISTICAL QUALITY CONTROL | 4 quarter hours**
**(Graduate)**
History; Deming guide to quality; graphical techniques of process control; Schewhart's control charts for means, ranges, standard deviations, individual measurements, and attributes; process capabilities and statistical tolerance; cumulative-sum charts. product liability; acceptance sampling; product and process design; applications and case studies.

**MAT 459 | SIMULATION MODELS AND MONTE CARLO METHOD | 4 quarter hours**
**(Graduate)**
Techniques of computer simulation of the classical univariate and multivariate probability models, and such random processes as random walks, Markov chains, and queues. Cross-listed with MAT 359.
**MAT 453 is a prerequisite or a co-requisite for this class.**

**MAT 460 | TOPICS IN STATISTICS | 4 quarter hours**
**(Graduate)**
One of the following topics: Clinical trials; Reliability and life testing; Categorical data analysis; Bootstrapping; Data Mining; Response Surface Methodology; Meta analysis; Survival Models.
**MAT 453 or instructor consent is a prerequisite for this class.**

**MAT 461 | ACTUARIAL SCIENCE I: THEORY OF INTEREST | 4 quarter hours**
**(Graduate)**
Theory of Interest: Theory and application of compound interest to annuities, amortization schedules, sinking funds, bonds, and yield rates. Cross-listed as MAT 361.

**MAT 462 | ACTUARIAL SCIENCE II: BASIC CONTINGENCIES | 4 quarter hours**
**(Graduate)**
Basic Contingencies: The theory and applications of contingency mathematics in life and health insurance annuities and pensions, from both a probabilistic and a deterministic viewpoint. Topics include survival distribution and life tables, life insurance and life annuities. Cross-listed as MAT 362.
**MAT 461 is a prerequisite for this class and MAT 452 is a corequisite for this class.**

**MAT 463 | ACTUARIAL SCIENCE III: ADVANCED CONTINGENCIES | 4 quarter hours**
**(Graduate)**
Advanced Contingencies: A continuation of MAT 462. Topics include net premiums, net premium reserves, multiple life functions, multiple decrement models, and valuation theory for pension plans. Cross-listed with MAT 363.
**MAT 462 is a prerequisite for this class.**

**MAT 464 | LOSS MODELS I | 4 quarter hours**
**(Graduate)**
Severity and frequency models, aggregate models, coverage modifications, risk measures, construction and selection of parametric models. Cross-listed with MAT 364.
**MAT 453 is a prerequisite for this class.**

**MAT 465 | LOSS MODELS II | 4 quarter hours**
**(Graduate)**
Bayesian credibility, Buhlmann credibility, insurance and reinsurance coverages, pricing and reserving. Cross-listed with MAT 365.
**MAT 464 is a prerequisite for this class.**

**MAT 466 | MATHEMATICAL DEMOGRAPHY | 4 quarter hours**
**(Graduate)**
Introduction to demography, mortauty table construction and methods of population and demographic analysis.
**MAT 453 is a prerequisite for this class.**

**MAT 467 | CREDIBILITY THEORY | 4 quarter hours**
**(Graduate)**
Credibility theory and loss distributions with applications to casualty insurance classification and ratemaking.
**MAT 462 is a prerequisite for this class.**

**MAT 468 | MATHEMATICS FOR FINANCE | 4 quarter hours**
**(Graduate)**
The course covers the mathematics of financial derivatives, investment strategies, arbitrage, put-call parity, binomial models for European options and interest rates, Black-Scholes formula, hedging, lognormal models for asset prices, exotic options, valuation using Monte-Carlo, and embedded options in annuity products. Cross-listed with MAT 368. MAT 451 is a co-requisite for this course.
**MAT 451 is a co-requisite for this course.**

**MAT 469 | STOCHASTIC CALCULUS | 4 quarter hours**
**(Graduate)**
The course introduces students to the mathematical tools and techniques used in modern Financial Theory. Topics include Brownian motion and Ito's lemma, stochastic integrals, stochastic differential equations, jump processes, applications to option pricing and interest rate models.
**MAT 455 and MAT 468 are prerequisites for this course.**

**MAT 470 | ADVANCED LINEAR ALGEBRA | 4 quarter hours**
**(Graduate)**
Vector spaces and subspaces, basis and dimension; matrix representation of linear transformations and change of basis; null spaces and ranges; dual spaces; eigenvalues, eigenvectors, and diagonalization; Cayley-Hamilton Theorem; inner product spaces and Gram-Schmidt orthogonalization; Jordan canonical form and applications. Cross-listed with MAT 370.
**(Grade of C-minus or better in MAT 262 or MAT 672) and (Grade of C-minus or better in MAT 141 or MAT 215 or MAT 660) or instructor permission is a prerequisite for this course.**

**MAT 471 | GROUP THEORY | 4 quarter hours**
**(Graduate)**
Course topics: Classes of groups; actions of groups on sets; Sylow theorems; decomposition of groups; structure of finite abelian groups.
**.Grade of C-minus or better in MAT 310 or instructor permission is a prerequisite for this class**

**MAT 472 | FIELDS AND GALOIS THEORY | 4 quarter hours**
**(Graduate)**
Course topics: Commutative rings and fields; irreducible polynomials and field extensions, adjunction of roots, algebraic extensions, splitting and normal fields, cyclic extensions, the Galois group, and the Fundamental theorem of Galois theory. Cross-listed with MAT 312.
**(MAT 311 or MAT 473) and MAT 471 are prerequisites for this course.**

**MAT 473 | RINGS AND MODULES | 4 quarter hours**
**(Graduate)**
Course topics: Rings and Algebras; classes of unique factorization domains; modules and principal isomorphism theorems, classes of modules, decomposition of finitely generated modules; Jordan and rational canonical form of a matrix.
**MAT 311 or MAT 471**

**MAT 481 | FOURIER ANALYSIS AND SPECIAL FUNCTIONS | 4 quarter hours**
**(Graduate)**
The course covers the basic principles of discrete and continuous Fourier analysis and its applications. Some of the topics covered are Fourier series, discrete Fourier transforms, fast Fourier transforms, and Fourier transforms. Appropriate background would be calculus and a course in introductory linear algebra.

**MAT 482 | PARTIAL DIFFERENTIAL EQUATIONS | 4 quarter hours**
**(Graduate)**
Introduction to partial differential equations and their applications. Topics include separation of variables; the heat, wave and Laplace equations; boundary-value problems; Fourier series. Some time will be spent on physical applications and non-homogeneous or time-dependent boundary conditions.
**MAT 304 or MAT 335 or MAT 437 or MAT 644 is a prerequisite for this class.**

**MAT 484 | MATHEMATICAL MODELING | 4 quarter hours**
**(Graduate)**
Modeling of real world problems using mathematical methods. Includes a theory of modeling and a study of specific models, selected from deterministic, stochastic, continuous, and discrete models. Appropriate background would be a course in introductory linear algebra. (CROSS-LISTED WITH MAT 384.)

**MAT 485 | NUMERICAL ANALYSIS I | 4 quarter hours**
**(Graduate)**
Use of a digital computer for numerical computation. Error analysis, Gaussian elimination and Gauss-Seidel method, solutions of linear and nonlinear equations, function evaluation, cubic splines, approximation of integrals and derivatives, Monte Carlo methods. Appropriate background would be calculus, introductory linear algebra, and a programming course. (CROSS-LISTED WITH MAT 385.)

**MAT 486 | NUMERICAL ANALYSIS II | 4 quarter hours**
**(Graduate)**
Theory and algorithms for efficient computation including the Fast Fourier Transform. Numerical solution of nonlinear systems of equations. Minimization of functions of several variables. Sparse systems of equations and eigenvalue problems. Cross-listed with CSC 386/486, MAT 386.
**MAT 485 is a prerequisite for this class.**

**MAT 487 | OPERATIONS RESEARCH: LINEAR PROGRAMMING | 4 quarter hours**
**(Graduate)**
Linear programming, integer programming and LP relaxation, the duality theorem, simplex algorithm, interior point methods, applications to industrial engineering. Appropriate background would be introductory linear algebra and computer programming. (CROSS-LISTED AS MAT 387)

**MAT 488 | OPERATIONS RESEARCH: OPTIMIZATION THEORY | 4 quarter hours**
**(Graduate)**
Convex optimization, quadratic optimization problems, Lagrange multipliers and generalization to inequality constraints, alternating direction method of multipliers (ADMM), unconstrained minimization, applications to industrial engineering including machine learning. Appropriate background would be introductory linear algebra and computer programming. (CROSS-LISTED AS MAT 388)

**MAT 489 | QUEUING THEORY WITH APPLICATIONS | 4 quarter hours**
**(Graduate)**
Discrete and continuous-time Markov chain models, Queuing systems, and topics from renewal and reliability theory.
**MAT 453 is a prerequisite for this class.**

**MAT 491 | DATA MINING | 4 quarter hours**
**(Graduate)**
This course will provide students with methodologies of mining varied data and discovering knowledge from data. Students will learn classification, regularized regression, smooth spline, neural network, decision tree, SVM, PCA and clustering. The lectures will be complemented with hands-on experience with data mining software R to allow students develop some practical skills.
**MAT 452 and MAT 456 are prerequisites for this class.**

**MAT 494 | GRAPH THEORY | 4 quarter hours**
**(Graduate)**
This course studies graph theory and its applications. Topics include trees, Eulerian circuits, Hamiltonian cycles, matchings, graph coloring problems, random graphs, and random walks on graphs. Appropriate background would be a course in introductory linear algebra.

**MAT 495 | DYNAMIC PROGRAMMING | 4 quarter hours**
**(Graduate)**
Optimization of sequential decision processes. Markov decision models. Contraction mapping methods. Applications drawn from inventory theory and production control.

**MAT 496 | GAME THEORY | 4 quarter hours**
**(Graduate)**
The minimax theorem for two-person, zero-sum games. Two-person general-sum games and noncooperative person games; Nash equilibrium.

**MAT 498 | PROBLEM SOLVING IN MATHEMATICS | 2-4 quarter hours**
**(Graduate)**
Course topics: problem solving in various topics from GRE Subject examination in Mathematics. Consult course schedule for current offerings. Course may be repeated for credit when title and content change. (2 quarter hours)

**MAT 512 | APPLIED TIME SERIES AND FORECASTING | 4 quarter hours**
**(Graduate)**
Development of the Box-Jenkins methodology for the identification, estimation and fitting of ARIMA, and transfer-function stochastic models for the purpose of analyzing and forecasting stationary, non-stationary, and seasonal time series data. The course emphasizes practical time series data analysis, using computer packages and includes applications to economic, business and industrial forecasting.
**MAT 441 or MAT 448 or MAT 453 is a prerequisite for this class.**

**MAT 515 | FINANCIAL MODELING | 4 quarter hours**
**(Graduate)**
The course expounds on probabilistic methods used in risk-based capital allocation and risk management. Topics include Gaussian and Non-Gaussian modeling, including modeling of volatility and correlations, copulas, Extreme Value Theory, VaR, TVaR and applications to portfolio allocation and stress testing.
**MAT 456 and MAT 512 are prerequisites for this course.**

**MAT 526 | SAMPLING THEORY AND METHODS | 4 quarter hours**
**(Graduate)**
Simple random, stratified, systematic and cluster sampling. Multistage and area sampling. Random-response and capture-release models. Cross-listed as MAT 326.
**MAT 453 is a prerequisite for this class.**

**MAT 528 | DESIGN AND ANALYSIS OF EXPERIMENTS | 4 quarter hours**
**(Graduate)**
Single-factor fixed, random and mixed designs with and without restrictions on randomizations, including randomized block designs, Latin & Graeco-Latin squares. Factorial and fractional factorial experiments. Nested and split-plot designs. Confounding and response surface methodology.
**MAT 453 is a prerequisite for this class.**

**MAT 595 | GRADUATE THESIS RESEARCH | 2-4 quarter hours**
**(Graduate)**
A thesis option is available to graduate students who wish to pursue an extended independent project. Students would work under the guidance of a faculty mentor. Course may be repeated for credit. (2 quarter hours)

**MAT 596 | ADVANCED TOPICS IN ALGEBRA | 4 quarter hours**
**(Graduate)**
Consult course schedule for current offerings. Course may be repeated for credit when title and content change.

**MAT 597 | ADVANCED TOPICS IN ANALYSIS | 4 quarter hours**
**(Graduate)**
Consult course schedule for current offerings. Course may be repeated for credit when title and content change.

**MAT 598 | ADVANCED PROBLEM SOLVING IN ALGEBRA AND ANALYSIS |**
**2-4 quarter hours**
**(Graduate)**
Course topics: problem solving in various topics in Algebra and Analysis. Consult course schedule for current offerings. Course may be repeated for credit when title and content change. (2 quarter hours)

**MAT 599 | INDEPENDENT STUDY | 1-4 quarter hours**
**(Graduate)**
Offered by arrangement. Approval by department chair required. (variable credit)

**MAT 600 | EXPERIMENTATION, CONJECTURE, AND REASONING WITH NUMBERS | 4 quarter hours**
**(Graduate)**
This course will focus on furthering the participants' number sense together with providing them with opportunities to: 1) Use and discuss the roles of experimentation, conjecture, and logical reasoning in developing mathematical understanding; 2) Appreciate the value of algebraic notation in problem solving by comparing solutions done both with and without algebra; 3) Engage in mathematical speaking and writing with discussion of (a) how to evaluate accurate vs. inaccurate statements, (b) what level of detail is appropriate in an answer given the point of the problem, (c) what ways of presenting solutions are suitable for various audiences; 4) Discuss the distinction between "how" a mathematical strategy works and "why" it works, and articulate the pedagogical value of knowing the "why.

**MAT 605 | GEOMETRY FOR MIDDLE SCHOOL TEACHERS | 4 quarter hours**
**(Graduate)**
An introduction to geometry designed to engage students in the construction, description, and analysis of geometric objects, including three-dimensional objects. These activities will be used to generate questions and hypotheses that will lead to more abstract concepts and general arguments. Emphasis throughout will be on informal reasoning, experimental methods, inductive as well as deductive arguments, local organization, and the development of mathematical thinking. Appropriate technology will be used to explore hypotheses and support mathematical reasoning. Topics will include: polyhedra, and their nets, cross sections, and projections; triangles, quadrilaterals, and polygons; congruence and similarity; the Pythagorean theorem; perimeter, area, and volume; circles and spheres, symmetry and transformations; and tessellations. The course will also include discussion and reflection on learning mathematics.

**MAT 608 | INVESTIGATING HIGH SCHOOL MATHEMATICS | 4 quarter hours**
**(Graduate)**
Drawing on high school mathematics content, students will identify and explore the mathematical themes that might form the content of a 12th grade capstone course. In the process, they will reflect on and discuss the major issues encountered when learning the mathematical concepts that form the basis of high school mathematics, identify ways to collaborate in order to improve mathematics learning, and identify ways in which they can take leadership roles in mathematics teaching and learning.

**MAT 609 | TEACHING AND LEARNING SECONDARY SCHOOL MATHEMATICS | 4 quarter hours**
**(Graduate)**
Theories, methods, materials and techniques for teaching and learning mathematics in secondary and upper elementary schools. This course is required for students seeking secondary math certification.

**MAT 610 | CALCULUS I | 4 quarter hours**
**(Graduate)**
A review of topics from precalculus using algebraic, numerical, and graphical perspectives including linear functions, exponential functions, logarithms, polynomials, and trigonometric functions. An introduction to limits, continuity, the derivative, and basic properties of real numbers.

**MAT 611 | CALCULUS II | 4 quarter hours**
**(Graduate)**
A continuation of Math 610. The derivative and its applications, including optimization and related rates. Introduction to integration and numerical algorithms using graphing calculators. Offered every Winter.
**MAT 610 is a prerequisite for this class.**

**MAT 612 | CALCULUS III | 4 quarter hours**
**(Graduate)**
A continuation of Math 611. Techniques of symbolic and numerical integration with geometric applications. Sequences, series, and power series. Offered every Spring.
**MAT 611 is a prerequisite for this class.**

**MAT 618 | TOPICS IN CALCULUS AND DIFFERENTIAL EQUATIONS | 4 quarter hours**
**(Graduate)**
Taylor series and Taylor's theorem, parametric equations, separable differential equations, slope fields, Euler's method. Offered every Summer.
**MAT 612 is a prerequisite for this class.**

**MAT 620 | GEOMETRY | 4 quarter hours**
**(Graduate)**
Axiom systems, types of reasoning used in proofs, Euclidean geometry results with concentration on triangles and circles, introduction to non-Euclidean geometry, and introduction to geometry classroom software. Offered every other winter.
**MAT 660 is a prerequisite for this course.**

**MAT 621 | TRANSITION TO ALGEBRA FOR MIDDLE SCHOOL TEACHERS | 4 quarter hours**
**(Graduate)**
In this course, teachers will begin the study of algebra as a generalization of number and operation, building on their new understanding of those topics from previous courses. Careful attention to reasoning about the use of variables and understanding the logic behind solving equations and inequalities will aid in the transition to a full treatment of high school algebra. Teachers will be introduced to high quality resources that will help them create effective algebraic learning environments for their students.
**MAT 600, MMT 401 and MAT 605 are a prerequisite for this class.**

**MAT 622 | ALGEBRA FOR MIDDLE SCHOOL TEACHERS I | 4 quarter hours**
**(Graduate)**
This course is the first of a 3-quarter sequence designed in part to prepare elementary and middle grade teachers to teach an algebra class to qualified 8th grade students in their schools. It is based on a vision of mathematics instruction throughout the grades that continuously builds students' algebraic skills and thinking. This first course in the sequence emphasizes problem-solving as an entry point into algebra for mathematics learners. Students see algebra as an active process for solving problems and as arising naturally as a way to generalize the laws of arithmetic, analyze patterns, and describe relationships in tables, graphs, and equations. In addition, students review and examine foundational concepts in algebra (variables, equations, relations, graphs, slopes of lines, and equations of lines) and are introduced to research on the development of algebraic thinking in middle grade students.

**MAT 623 | ALGEBRA FOR MIDDLE SCHOOL TEACHERS II | 4 quarter hours**
**(Graduate)**
The second course in the algebra sequence builds on the first and maintains emphases on problem-solving, deeper understanding of the central concepts of beginning algebra, and awareness of difficulties students have when encountering the subject for the first time. Topics include systems of linear equations, solving linear inequalities and systems of inequalities, absolute values equations and inequalities, and quadratic functions.

**MAT 624 | FUNCTIONS AND MODELING | 4 quarter hours**
**(Graduate)**
Advanced concepts in beginning algebra provide a basis for a deeper treatment of the relationship between functions and data, and lay the groundwork for the development of polynomial, exponential, and logarithmic models. The course will integrate the use of technology such as graphing calculators and spreadsheets.

**MAT 631 | HISTORY OF MATHEMATICS THROUGH PROBLEM SOLVING | 4 quarter hours**
**(Graduate)**
Topics include the development of calculus, probability theory, number theory, non-Euclidean geometry, and set theory. Offered every Winter.
**MAT 620 and MAT 670 are co-requisites for this class.**

**MAT 632 | HISTORY AND CULTURAL FOUNDATIONS OF MATHEMATICS | 4 quarter hours**
**(Graduate)**
This course is a cross-cultural survey of the history of mathematics, with emphasis placed on the development of concepts encountered by students in elementary and middle school. The course will also serve as a capstone for the program in that it will include references to content from all the earlier courses and will explicitly ask teachers to make connections across the middle school mathematics curriculum. The students will complete a small group research project in which they choose a mathematical concept from the program and use it as a focal point to study the development of mathematical ideas across time and across cultures.

**MAT 640 | MULTIVARIABLE CALCULUS I | 4 quarter hours**
**(Graduate)**
Functions of several variables, vectors, dot products and cross products, partial differentiation, directional derivatives, optimization, Lagrange multipliers, polar and spherical coordinates. Use of software packages to illustrate three dimensional objects. Offered Fall 2017 and every Summer as of 2018.
**MAT 618 is a co-requisite for this class.**

**MAT 641 | MULTIVARIABLE CALCULUS WITH LINEAR ALGEBRA FOR MATHEMATICS TEACHERS | 4 quarter hours**
**(Graduate)**
Multiple integration, line and surface integrals, change of variable in multiple integration, Green's and Stokes' theorems. An introduction to matrices, determinants, linear transformations, and eigenvalues.
**MAT 640 and MAT 671**

**MAT 642 | MULTIVARIABLE CALCULUS II | 4 quarter hours**
**(Graduate)**
Double and iterated integrals, area by double integrals, triple integrals, triple integrals in cylindrical and spherical coordinates, change of variable in multiple integration, line and surface integrals, theorems of Green, Stokes, and Gauss. Offered Winter 2018 and every Fall as of 2018.
**MAT 640 is a prerequisite for this class.**

**MAT 643 | IDEAS OF CALCULUS IN THE MIDDLE SCHOOL CURRICULUM | 4 quarter hours**
**(Graduate)**
The course will introduce students to the "big ideas" of Calculus including limits, derivatives, and integrals. The course will emphasize how the mathematics in the middle school curriculum can lay a foundation for the study of continuous mathematics and to the role that Calculus plays in the sciences. In particular, direct connections to the topics of this course and the middle school curriculum will be made by studying activities from curriculum materials currently used in CPS that are relevant to the topics of Calculus. Trigonometry from the perspective of the middle school classroom will be used as the launching point for introducing the major ideas of the course. The course will also give the students the opportunity to understand the interplay between the concepts and tools they learned in the MMT 415-417 sequence and Calculus.

**MAT 644 | DIFFERENTIAL EQUATIONS | 4 quarter hours**
**(Graduate)**
This course will continue the study of differential equations (DEs) begun in MAT 618. Topics include solutions and applications of linear DEs, second order DEs with constant coefficients; linear systems: eigenvalues and eigenvectors of matrices, phase portraits and explicit solutions; nonlinear planar systems: linearization and stability analysis. Offered every other Spring as of 2018.
**MAT 618 is a prerequisite for this class.**

**MAT 649 | DATA ANALYSIS AND PROBABILITY | 4 quarter hours**
**(Graduate)**
This course covers the fundamental concepts of probability that are part of the middle school curriculum and recent research findings on student learning of probability and classroom implications of this research. In addition, it covers the principles of graphically displaying, collecting and analyzing data with and without the use of technology. Topics will include measures of central tendency and dispersion, graphical representations of data (histograms, boxplots, bar charts, pie charts, and line graphs), and the design of experiments and simulations.

**MAT 650 | PROBABILITY & STATISTICS FOR MATHEMATICS TEACHERS I | 4 quarter hours**
**(Graduate)**
Combinatorics, sets, probability, random variables, distribution and density functions, multiple integration, standard probability laws, jointly distributed random variables. Use of graphing calculators, applets, and software packages to illustrate concepts. Offered every Winter.
**MAT 640 and MAT 660 are prerequisites for this course.**

**MAT 651 | PROBABILITY & STATISTICS FOR MATHEMATICS TEACHERS II | 4 quarter hours**
**(Graduate)**
Central limit theorem, point and interval estimation of parameters, hypothesis testing, least squares and regression. Offered every Spring.
**MAT 650 is a prerequisite for this class.**

**MAT 660 | DISCRETE MATHEMATICS | 4 quarter hours**
**(Graduate)**
Logic and techniques of proof, mathematical induction, sets and functions, relations, introduction to number theory and combinatorics. Offered every Fall.

**MAT 665 | DISCRETE STRUCTURES WITH A TRANSITION TO HIGHER MATHEMATICS | 4 quarter hours**
**(Graduate)**
A transition to advanced courses having a greater emphasis on proof and abstraction. Techniques of proof, logic, sets and functions, number theory, recursive sequences, mathematical induction, and an introduction to combinatorics.

**MAT 670 | ABSTRACT ALGEBRA I | 4 quarter hours**
**(Graduate)**
Examines the integers, prime numbers, the Euclidean algorithm, the uniqueness of prime factorization, equivalence relations, rational numbers, real numbers, and complex numbers. Provides examples of groups, rings, and fields and also covers the Fundamental Theorem of Algebra and roots of polynomials of small degree. Offered every other Winter as of 2018.
**MAT 660 is a prerequisite for this course.**

**MAT 671 | ABSTRACT ALGEBRA II | 4 quarter hours**
**(Graduate)**
Examines modular arithmetic, the irreducibility of polynomials over different fields, criteria for solvability by radicals, rational values of trigonometric functions, difference functions, partial fraction decomposition, and geometric constructions with ruler and compass. Along with Math 670, this course provides the theoretical foundation for many topics covered in high school mathematics courses. Offered every other Spring as of 2018.
**MAT 670 is a prerequisite for this class.**

**MAT 672 | LINEAR ALGEBRA | 4 quarter hours**
**(Graduate)**
Vector spaces, linear combinations, spanning sets, linear independence, basis, dimension, systems of linear equations, matrices, linear transformation, eigenvalues and eigenvectors.
**MAT 660 is a prerequisite for this course.**

**MAT 680 | REAL ANALYSIS | 4 quarter hours**
**(Graduate)**
Construction and properties of the real numbers. Proofs of essential results from calculus such as the intermediate value theorem, extreme value theorem, mean value theorem, existence of the Riemann integral, and Taylor's theorem. Offered every Fall.
**MAT 618 and MAT 660 are a prerequisite for this class.**

**MAT 699 | TOPICS IN MATHEMATICS FOR TEACHERS | 4 quarter hours**
**(Graduate)**
Diverse topics in mathematical modeling or mathematical appreciation germane to the secondary school classroom.