

# MATHEMATICS (MATH)

## MATH 107 Mathematics for Business Calculus I (Units: 3)

Prerequisite: Category III or IV placement for QR/Math, or students who have not passed MATH 70 or ESM 70 with a grade of C or better or who have not satisfied the ELM.

Introduction of the necessary business vocabulary. Review of numbers and operations, exponents and radicals, functions in general, and linear, quadratic, polynomial, rational, exponential and logarithmic functions in particular, in context of business, finance and economy. Introduction to mathematics of finance: simple and compound interest, annuities, amortization.

## MATH 108 Mathematics for Business Calculus II (Units: 3)

Prerequisite: MATH 107 with a grade of C or better.

Derivatives and integrals. Applications of differentiation and integration, including optimization. Problems involving business, finance, and economics.

(Note: Successful completion of MATH 107 and MATH 108 will culminate in satisfying the Quantitative Reasoning requirement (GE Area B4). For this course to satisfy General Education, students must earn a grade of C- or CR or higher.)

### Course Attributes:

- B4: Math/QR

## MATH 110 Business Calculus (Units: 3)

Prerequisites: Category I or II placement for QR/Math, or satisfactory completion of ELM requirement, or MATH 70 or ESM 70 with a grade of C or better.

Functions, derivatives, and integrals. Applications of differentiation and integration, including optimization and moving averages. Problems involving business, finance, and economics. Elements of basic calculus. (Note: In order for this course to satisfy General Education, students must earn a C- or CR or higher grade if taken fall 2014 or later.)

### Course Attributes:

- B4: Math/QR

## MATH 112 Support for College Mathematics (Units: 2)

Prerequisites: Category III or IV placement for QR/Math, or students who have not passed MATH 70 or ESM 70 with a grade of C or better or satisfied the ELM. Concurrent enrollment in PHIL 111\* or CSC 110\* required.

Review of numbers and operations, exponents and radicals. Linear, quadratic, polynomial, and rational functions. Exponential and logarithmic functions as needed. Develop and practice strategies for proficiency in quantitative reasoning through problem-solving, communication, and interpretation of data and graphs.

## MATH 122 Mathematics for Statistical Quantitative Reasoning (Units: 2)

Prerequisites: Category III or IV placement for QR/Math, or students who have not passed MATH 70 or ESM 70 with a grade of C or better or satisfied the ELM. Concurrent enrollment in ISED 160\* or PSY 171\* required.

Review of mathematics in the context of elementary statistics: numbers, fractions, decimals, percentages; units; rounding; formulas and scientific notation; order of operations; algebra of equations; graphs and plots; sets; principals of counting.

## MATH 123 Mathematics for Elementary Statistics (Units: 2)

Prerequisites: Category III or IV placement for QR/Math, or students who have not passed MATH 70 or ESM 70 with a grade of C or better or satisfied the ELM. Concurrent enrollment in Math 124\* required.

Review of mathematics in the context of elementary statistics: numbers, fractions, decimals, percentages; units; rounding; formulas and scientific notation; order of operations; algebra of equations; graphs and plots; sets; principals of counting.

## MATH 124 Elementary Statistics (Units: 3)

Prerequisites: Category I or II placement for QR/Math, or satisfactory completion of ELM requirement, or MATH 70 or ESM 70 with a grade of C or better. Students with Category III or IV placement for QR/Math or students who have not passed MATH 70 or ESM 70 with a C or better or satisfied the ELM must concurrently enroll in MATH 123.

Data analysis, probability, and statistical inference. For students in any field where statistics is a means of communication and a tool for decision making.

(Note: In order for this course to satisfy General Education, students must earn a C- or CR or higher grade if taken fall 2014 or later.)

### Course Attributes:

- B4: Math/QR

## MATH 165 Concepts of the Number System (Units: 3)

Prerequisites: Satisfactory completion of ELM requirement or any QR/Math placement category.

Designed for prospective multiple subjects credential candidates. Understanding operations with whole numbers, fractions and decimals. Problem-solving strategies, numeration systems and elementary number theory.

## MATH 197 Prelude to Calculus I (Units: 3)

Prerequisites: Category III or IV placement for QR/Math, or students who have not passed MATH 70 or ESM 70 with a grade of C or better or satisfied the ELM.

Review of numbers and operations, exponents and radicals. Linear, quadratic, polynomial and rational functions. Exponential growth and exponential functions. Logarithmic functions. The transcendental number e and natural logarithms.

## MATH 198 Prelude to Calculus II (Units: 3)

Prerequisite: MATH 197 with a grade of C or better.

Trigonometry, trigonometric identities, trigonometric and inverse trigonometric functions, sequences and series, and limits.

(Note: Note: Successful completion of MATH 197 and MATH 198 will culminate in satisfying the Quantitative Reasoning requirement (GE Area B4). For this course to satisfy General Education, students must earn a grade of C- or CR or higher.)

### Course Attributes:

- B4: Math/QR

**MATH 199 Pre-Calculus (Units: 4)**

Prerequisite: Category I or II placement for QR/Math, or satisfactory completion of ELM requirement, or MATH 70 or ESM 70 with a grade of C or better.

Functions, graphing techniques, exponentials and logarithms, trigonometry. [Formerly MATH 109]

(Note: In order for this course to satisfy General Education, students must earn a C- or CR or higher grade if taken fall 2014 or later.)

**Course Attributes:**

- B4: Math/QR

**MATH 226 Calculus I (Units: 4)**

Prerequisites: MATH 198 or MATH 199 or equivalent with a grade of C or better; or Math 226 or equivalent with a grade of C- or lower completed within the past year. Category I or II placement for QR/Math with a grade of B or better in high school pre-calculus in past year. Category III placement for QR/Math with a grade of B or better in high school pre-calculus in the past year and a score of 15 out of 30 on the Mathematics Diagnostic Testing Project (MDTP) calculus readiness test. Students who completed these prerequisites more than a year ago must score 15 out of 30 on the MDTP or a satisfactory score on the Department's calculus readiness test. Category IV placement for QR/Math must take MATH 197 and MATH 198.

Graphs. Differentiation: theory, techniques, and applications. Integration: Fundamental Theorem of Calculus and applications. Transcendental functions. Lecture, 3 units; seminar, 1 unit.

(Note: In order for this course to satisfy General Education, students must earn a C- or CR or higher grade if taken fall 2014 or later.)

**Course Attributes:**

- B4: Math/QR

**MATH 227 Calculus II (Units: 4)**

Prerequisite: MATH 226 with a grade of C or better.

Techniques of integration, analytic geometry, polar coordinates, vectors, improper integrals. Sequences and series.

**MATH 228 Calculus III (Units: 4)**

Prerequisite: MATH 227 with a grade of C or better.

Three-dimensional analytic geometry, partial differentiation, multiple integrals, vector calculus. Classwork, 3 units; laboratory, 1 unit.

**MATH 245 Elementary Differential Equations and Linear Algebra (Units: 3)**

Prerequisite: MATH 228 with a grade of C or better.

First and second order linear differential equations, Laplace transform methods, Fourier series, matrix algebra.

**MATH 265 Advanced Number Systems (Units: 3)**

Prerequisite: MATH 165 with a grade of C or better.

Designed for prospective multiple subject credential candidates, continues work done in MATH 165 with decimals and percents. Introduces operations with negative numbers. Additional topics include problem solving and elementary number theory.

**MATH 300GW History of Mathematics - GVAR (Units: 3)**

Prerequisites: GE Area A2; MATH 227 or equivalent with a grade of C or higher.

Survey of the history of mathematics focusing on topics of interest to secondary mathematics teachers. Emphasis on telling the story of mathematics through research and writing an expository paper. (ABC/NC grading only)

**Course Attributes:**

- Graduation Writing Assessment

**MATH 301GW Exploration and Proof - GVAR (Units: 3)**

Prerequisites: GE Area A2; MATH 227 with a grade of C or higher.

Informal exploration and proofs in mathematics. Basic concepts of advanced mathematics courses. Exploratory thinking, elementary logic, sets, mathematical induction, the integers, relations, and functions. (ABC/NC grading only)

**Course Attributes:**

- Graduation Writing Assessment

**MATH 310 Elementary Number Theory (Units: 3)**

Prerequisites: MATH 227 and MATH 301GW with grades of C or better.

Divisibility, congruencies, power residues, quadratic reciprocity, diophantine equations. Number theoretic functions, continued fractions and rational approximation, partitions.

**MATH 314 Math Circle Seminar (Units: 3)**

Prerequisite: MATH 226 or equivalent with a grade of C or better.

Opportunity to relate mathematics to the teaching and learning of mathematics and problem-solving skills at the middle and high school levels through participation in math circles. [CSL may be available]

**MATH 324 Probability and Statistics with Computing (Units: 3)**

Prerequisites: MATH 227 with a grade of C or better; computer experience that meets the approval of the instructor; basic concepts of probability and statistics.

Data analysis, probability distributions, confidence intervals, and hypothesis testing. Students use computer software to do statistical analyses.

**MATH 325 Linear Algebra (Units: 3)**

Prerequisites: MATH 227 with a grade of C or better; CSC 230 or MATH 301GW recommended.

Vector spaces, linear transformations, elements of matrix algebra including determinants and eigenvalues.

**MATH 335 Modern Algebra (Units: 3)**

Prerequisites: MATH 301GW with a grade of C or better or consent of instructor; MATH 325 with a grade of C or better.

Introduction to groups, rings, integral domains, fields, and ordering.

**MATH 338 Introduction to SAS (Units: 3)**

Prerequisites: MATH 124 (or equivalent) and one of the following: CSC 210, CSC 309, or consent of instructor, with grades of C or better.

Using SAS software for data management, presentation of data using graphs and reports, calculation of basic statistics such as mean, standard error, percentiles. Analysis of data using t-test, Chi-square test, regression, and analysis of variance.

**MATH 350 Geometry (Units: 3)**

Prerequisites: MATH 228 and MATH 301GW with grades of C or better.

Introduction to the origin and foundations of geometry: Euclidean, non-Euclidean geometries, more recent approaches. Quick survey of high school geometry. Classification and representation of motions and similarities. Projections, homogeneous coordinates.

**MATH 370 Real Analysis I (Units: 3)**

Prerequisites: MATH 228 and MATH 301GW with grades of C or better.

Critical development of analysis: Bolzano-Weierstrass and Heine-Borel theorems; limits, continuity, differentiability, integrability.

**MATH 375 Field Study for Secondary Teachers (Units: 3)**

Prerequisites: MATH 301GW with a grade of C or better, or consent of instructor.

Completion of tuberculosis test and fingerprinting for work in the public schools. Opportunity for students to relate the mathematics they are learning to the teaching and learning of mathematics at the middle and high school levels; at the same time, fulfill the 45-hour field experience requirement for prospective teachers.

**MATH 376 Ordinary Differential Equations I (Units: 3)**

Prerequisites: MATH 228 and MATH 325 with grades of C or better.

First-order differential equations, second-order linear equations with constant coefficients, graphical and numerical methods, systems of differential equations and phase-plane analysis, existence and uniqueness theorems.

**MATH 380 Introduction to Complex Analysis (Units: 3)**

Prerequisite: MATH 301 with a grade of C or better.

Analytic functions of a complex variable. Cauchy's theorem, power series, Laurent series, singularities, residue theorem with applications to definite integrals. Conformal mappings.

**MATH 400 Numerical Analysis (Units: 3)**

Prerequisites: MATH 228, MATH 325, and CSC 210, all with grades of C or better.

Numerical solution of algebra and calculus problems. Interpolation and approximations; direct and iterative methods for solutions of linear equations. Gaussian elimination. Numerical differentiation and integration; solution of ordinary differential equations.

**MATH 414 Analyzing DNA Topology with Math and Computational Methods (Units: 3)**

Prerequisite for MATH 714: Graduate standing or consent of the instructor.

Prerequisite for MATH 414: Upper-division standing; MATH 228 or equivalent with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Introduction to mathematical and computational techniques used to analyze DNA structure for mathematics, computer science, and biology students. The strong interaction between math and biology is emphasized.

(MATH 714/MATH 414 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**MATH 420 Combinatorics (Units: 3)**

Prerequisite: for MATH 720: Graduate Mathematics students or consent of the instructor.

Prerequisites for MATH 420: Upper-division standing; MATH 301GW and CSC 230 or MATH 310 or MATH 325 with grades of C or better; GPA of 3.0 or higher; or consent of the instructor.

An introduction to fundamental combinatorial objects, their uses in other fields of mathematics and its applications, and their analysis. Does an object with certain prescribed properties exist? How many of them are there? What structure do they have?

(MATH 720/MATH 420 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**MATH 424 Introduction to Linear Models (Units: 3)**

Prerequisite for MATH 724: Graduate Mathematics students or consent of the instructor.

Prerequisites for MATH 424: Upper-division standing; MATH 227 and MATH 325 with grades of C or better; GPA of 3.0 or higher; or consent of the instructor.

Theory and applications of Linear Models, Multiple Regression, Analysis of Variance for Fixed and Random Effects, Nested and Crossed Treatments, and Experimental Design.

(MATH 724/MATH 424 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**MATH 430 Mathematics of Optimization (Units: 3)**

Prerequisite: MATH 325 with a grade of C or better.

Modeling and solution of optimization problems as linear, semidefinite, nonlinear, or integer programming problems. Analysis and interpretations of solutions to these problems.

**MATH 435 Modern Algebra II (Units: 3)**

Prerequisite for MATH 735: Graduate Mathematics students or consent of the instructor.

Prerequisites for MATH 435: Upper-division standing; MATH 335 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Group actions, conjugacy classes, and Sylow's Theorem. Rings, modules, vector spaces, and finitely generated modules over PIDs. Field extensions and finite fields.

(MATH 735/MATH 435 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**MATH 440 Probability and Statistics I (Units: 3)**

Prerequisites: MATH 228 with a grade of C or better (may be taken concurrently); MATH 124 or equivalent recommended.

Probability spaces, elementary combinatorics, random variables, independence, expected values, moment generating functions, selected probability distributions, limit theorems and applications. [Formerly MATH 340]

**MATH 441 Probability and Statistics II (Units: 3)**

Prerequisite for MATH 741: Graduate Mathematics students or consent of the instructor.

Prerequisite for MATH 441: Upper-division standing; MATH 440 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Sampling distributions, estimation of parameters, hypothesis testing, goodness-of-fit tests, linear regression, and selected non-parametric methods.

(MATH 741/MATH 441 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**MATH 442 Probability Models (Units: 3)**

Prerequisite: MATH 440 with a grade of C or better.

Advanced topics in probability theory: discrete and continuous time Markov chains, Poisson process, queuing systems, and applications.

**MATH 447 Design and Analysis of Experiments (Units: 3)**

Prerequisites: MATH 325 and MATH 440 with a grade of C or better.

Learn how to plan, design, and conduct experiments and analyze the resulting data.

**MATH 448 Introduction to Statistical Learning and Data Mining (Units: 3)**

Prerequisite: MATH 440 with a grade of C or better or consent of the instructor.

Modern techniques in the statistical analysis of data, including regression, classification, regularization methods, model selection, non-parametric methods, dimensionality reduction, and clustering; employ statistical software to analyze real data using advanced methods from statistics, machine learning, data mining, and pattern recognition.

**MATH 449 Categorical Data Analysis (Units: 3)**

Prerequisite: MATH 440 with a grade of C or better or consent of the instructor.

Descriptive and inferential methods for contingency tables; generalized linear models for discrete data; logistic regression for binary responses; multi-category logistic models for nominal and ordinal responses; log-linear models; inference for matched-pairs and correlated clustered data.

**MATH 450 Topology (Units: 3)**

Prerequisite: MATH 370 with a grade of C or better.

Rigorous development of the theory of metric spaces and topological spaces. Concepts covered include open, closed sets, interior, closure, boundary of sets; connects sets, compact sets, continuous functions defined on metric and topological spaces.

**MATH 451 Introduction to Differential Geometry (Units: 3)**

Prerequisites: MATH 228 and MATH 325 with grades of C or better, and either MATH 370 or MATH 450. These requirements may be waived upon the consent of instructor.

Study of intrinsic surface along with a topological invariant known as the Euler characteristic. Aim is to prove that the Euler characteristic of a compact orientated surface is numerically equal to the total index of any vector field with isolated zeroes (Poincare-Hopf Index theorem), the total Gaussian curvature (Gauss-Bonnet-Chern theorem), and the algebraic total of the number of non-degenerate critical points (Morse theorem).

**MATH 460 Mathematical Modeling (Units: 3)**

Prerequisites: MATH 325 and either MATH 245 or MATH 376, with grades of C or better.

Deterministic and stochastic techniques used in mathematical modeling, illustrated and developed through problems originating in industry and applied research.

**MATH 462 Dynamical Systems with Applications (Units: 3)**

Prerequisites: CSC 210, MATH 227, and MATH 301GW with grades of C or better, or consent of the instructor.

An introduction to the study of iterations (repeated composition) of a function in most basic contexts, including linear and continuous functions of one variable, number-theoretic functions, geometric functions, and Markov chains. Using mathematical software as an investigative tool, explore applications chosen from piecewise linear systems, fractals, chaos, number theory, cryptography, complex networks, and mathematical modeling.

**MATH 470 Real Analysis II: Several Variables (Units: 3)**

Prerequisite for MATH 770: Graduate Mathematics students or consent of the instructor.

Prerequisites for MATH 470: Upper-division standing; MATH 370 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Sequences and series of functions, uniform convergence, real-analytic functions, metric spaces, open and closed sets, compact and connected sets, and continuous functions.

(MATH 770/MATH 470 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**MATH 471 Fourier Analysis and Applications (Units: 3)**

Prerequisite for MATH 771: Graduate standing; MATH 370 with a grade of C or better; or consent of the instructor.

Prerequisite for MATH 471: Upper-division standing; MATH 370 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Sequences and series of functions, modes of convergence, Fourier series and integrals, and wavelet analysis.

(MATH 771/MATH 471 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**MATH 475 Capstone Course for Secondary Teachers of Mathematics (Units: 3)**

Prerequisites: MATH 335 with a grade of C or better and one of the following: concurrent enrollment in MATH 370 or consent of instructor.

Builds on student's work in upper division mathematics to deepen understanding of the math taught in secondary school. Active exploration of topics in algebra, analysis, geometry and statistics.

**MATH 477 Partial Differential Equations (Units: 3)**

Prerequisite for MATH 777: Graduate Mathematics students or consent of the instructor.

Prerequisites for MATH 477: Upper-division standing; MATH 376 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Study of partial differential equations in rectangular and polar coordinates. Initial and boundary value problems for the heat equation and wave equation. Study of Fourier series, Bessel series, harmonic functions, and Fourier transforms.

(MATH 777/MATH 477 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**MATH 491 Game Theory (Units: 3)**

Prerequisite: MATH 227 with a grade of C or better.

Normal, extensive and network forms. Strategy, best reply and Nash equilibrium. Equilibrium path, information and beliefs, sequential rationality and perfect equilibria. Applications to learning, signaling, screening and deterrence. [Formerly a topic under MATH 490]

**MATH 492 Group Representations (Units: 3)**

Prerequisite: MATH 335 with a grade of C or better.

Basics of the representation theory of finite groups such as irreducible decompositions, Maschke's theorem, and characters. Presented using symmetric group; focus on combinatorics that arise: young tableau, Knuth-Robinson-Schensted correspondence, and hook formula. [Formerly a topic under MATH 490]

**MATH 493 Introduction to Actuarial Mathematics (Units: 3)**

Prerequisites: MATH 228 and MATH 324 or MATH 440 with grades of C or better.

Measurement of interest including accumulation and present value factors, annuities certain, survival distributions and life tables, life insurance and annuity functions, and net premium reserves. [Formerly a topic under MATH 490]

**MATH 494 Non-Parametric Statistics (Units: 3)**

Prerequisite: Any introductory statistics course with grade of C or better, or consent of instructor.

Point and interval estimates, univariate hypotheses tests, multiple comparison measures. Applications to a wide variety of fields. [Formerly a topic under MATH 490]

**MATH 495 Introduction to Wavelets and Frames with Applications (Units: 3)**

Prerequisites: MATH 325 or MATH 370 with grades of C or better, or consent of instructor.

Fundamentals of wavelets, time frequency analysis, and frames, as well as applications in engineering and physics. [Formerly a topic under MATH 490]

**MATH 565 Concepts of Geometry, Measurement, and Probability (Units: 3)**

Prerequisite: MATH 165 with a grade of C or better.

Designed for prospective multiple subjects credential candidates. Spatial relationships and inductive reasoning in geometry, measurement emphasizing the metric system, and elementary statistics and probability.

**MATH 575 Mathematics in the Middle School Classroom (Units: 3)**

Prerequisite: MATH 565 with a grade of C or better, or consent of instructor.

Designed for current or prospective middle school teachers of mathematics. Topics in algebra, number theory, and geometry. (Plus-minus letter grade only)

**MATH 576 Math in Middle Schools II (Units: 3)**

Prerequisite: MATH 575 with a grade of C or better.

Continues to prepare students with content knowledge needed to teach algebra in middle school. Begins work in probability and statistics.

**MATH 577 Math in Middle School III (Units: 3)**

Prerequisite: MATH 576 with a grade of C or better.

Continues the work begun in MATH 575 and MATH 576 to prepare students with content knowledge needed to teach algebra, geometry, and probability and statistics in middle school.

**MATH 578 Mathematics in the High School (Units: 3)**

Prerequisites: MATH 577 or MATH 227 with a grade of C or better, or consent of instructor.

Designed for current or prospective high school teachers to focus on high school mathematics from an advanced perspective. Content from functions, calculus, and statistics.

**MATH 690 Capstone Research for Mathematics Majors (Units: 3)**

Prerequisites: Grades of C or better in MATH 325, MATH 335, and MATH 370; grades of C or better in a subset of the following MATH courses: MATH 310, MATH 324 or MATH 440 [formerly MATH 340], MATH 376, MATH 380, MATH 400, MATH 420, or MATH 491, MATH 492, MATH 493, MATH 494, MATH 495; or consent of instructor.

The specifics in that subset depend on the chosen research problem. Research problem, chosen by the instructor, to explore the interrelationships among the cornerstones in a typical undergraduate math major's course. These cornerstones are algebra, analysis, and probability and statistics. (Plus-minus letter grade only)

**MATH 696 Applied Mathematics Project I (Unit: 1)**

Prerequisite: MATH 460 with a grade of C or better. May be replaced by consent of instructor.

Preparation under faculty guidance of feasibility study and outline of a project in applied mathematics.

**MATH 697 Applied Mathematics Project II (Units: 2)**

Prerequisite: Successful completion of MATH 696 in a previous semester. May not be taken concurrently with MATH 696.

Completion of applied mathematics project. Presentation of oral and written report.

**MATH 699 Independent Study (Units: 1-3)**

Prerequisite: Approval of the department and consent of the instructor.

Special study of a particular problem under the direction of a member of the department. The student must present a written report of the work accomplished to the department. May be repeated for a total of 6 units.

**MATH 700 Graduate Teaching Workshop (Units: 3)**

Prerequisite: GTA status.

Discussion and analysis of teaching techniques, peer evaluation, peer classroom observations, guided groups and self analysis of videotapes; group project developing and studying common lesson materials.

**MATH 710 Measure and Integration (Units: 3)**

Prerequisite: MATH 470 with a grade of C or better or consent of the instructor.

Outer measure, Lebesgue measure and integration; convergence theorems; bounded variation, absolute continuity, and Lebesgue's theory of differentiation.

**MATH 711 Functional Analysis (Units: 3)**

Prerequisites: MATH 710 and MATH 725 with grades of B- or better or consent of the instructor.

Banach and Hilbert spaces, bounded linear operators, dual spaces; the Hahn-Banach, closed graph, and open mapping theorems with applications; functional analysis topics.

**MATH 714 Analyzing DNA Topology with Math and Computational Methods (Units: 3)**

Prerequisite for MATH 714: Graduate standing or consent of the instructor.

Prerequisite for MATH 414: Upper-division standing; MATH 228 or equivalent with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Introduction to mathematical and computational techniques used to analyze DNA structure for mathematics, computer science, and biology students. The strong interaction between math and biology is emphasized.

(MATH 714/MATH 414 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**MATH 720 Combinatorics (Units: 3)**

Prerequisite: for MATH 720: Graduate Mathematics students or consent of the instructor.

Prerequisites for MATH 420: Upper-division standing; MATH 301GW and CSC 230 or MATH 310 or MATH 325 with grades of C or better; GPA of 3.0 or higher; or consent of the instructor.

An introduction to fundamental combinatorial objects, their uses in other fields of mathematics and its applications, and their analysis. Does an object with certain prescribed properties exist? How many of them are there? What structure do they have?

(MATH 720/MATH 420 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**MATH 724 Introduction to Linear Models (Units: 3)**

Prerequisite for MATH 724: Graduate Mathematics students or consent of the instructor.

Prerequisites for MATH 424: Upper-division standing; MATH 227 and MATH 325 with grades of C or better; GPA of 3.0 or higher; or consent of the instructor.

Theory and applications of Linear Models, Multiple Regression, Analysis of Variance for Fixed and Random Effects, Nested and Crossed Treatments, and Experimental Design.

(MATH 724/MATH 424 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**MATH 725 Advanced Linear Algebra (Units: 3)**

Prerequisite: MATH 335 with a grade of C or better.

Vector spaces and linear maps on them. Inner product spaces and the finite-dimensional spectral theorem. Eigenvalues, the singular-value decomposition, the characteristic polynomial, and canonical forms.

**MATH 728 Mathematical Projects and Partnerships (Unit: 1)**

Prerequisite: Graduate standing or consent of instructor.

Discussion and analysis of teaching techniques, peer classroom observations; guided group and self analysis of group projects developing and studying innovative mathematical projects for middle and high school students. (Concurrent involvement in middle/high school projects required.).

**MATH 729 Communicating Mathematics (Units: 3)**

Prerequisite: Formal commitment to write an MA thesis or expository paper.

Practice of written and oral communication of advanced and research mathematics: prepare research article or monograph, design research poster, prepare and present short and long research talks, write grant proposal.

**MATH 730 Theory of Functions of a Complex Variable (Units: 3)**

Prerequisites: MATH 470 with a grade of C or better, and consent of instructor.

Elementary topology of the Euclidean plane, analytic functions, power series, conformal mapping, Cauchy integral formula, residue theorems, power series, Laurent series, analytic continuation, normal families and Riemann mapping theorem.

**MATH 735 Modern Algebra II (Units: 3)**

Prerequisite for MATH 735: Graduate Mathematics students or consent of the instructor.

Prerequisites for MATH 435: Upper-division standing; MATH 335 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Group actions, conjugacy classes, and Sylow's Theorem. Rings, modules, vector spaces, and finitely generated modules over PIDs. Field extensions and finite fields.

(MATH 735/MATH 435 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**MATH 741 Probability and Statistics II (Units: 3)**

Prerequisite for MATH 741: Graduate Mathematics students or consent of the instructor.

Prerequisite for MATH 441: Upper-division standing; MATH 440 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Sampling distributions, estimation of parameters, hypothesis testing, goodness-of-fit tests, linear regression, and selected non-parametric methods.

(MATH 741/MATH 441 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**MATH 742 Advanced Probability Models (Units: 3)**

Prerequisite: MATH 440 with a grade of C or better or consent of the instructor.

Advanced topics in probability theory including discrete and continuous time Markov chains, Markov chain Monte Carlo simulations, Poisson process, renewal theory and applications, queuing systems, and applications.

**MATH 747 Design and Analysis of Experiments (Units: 3)**

Prerequisites: MATH 325 and MATH 440 with a grade of C or better.

Learn how to plan, design, and conduct experiments and analyze the resulting data.

**MATH 748 Theory and Applications of Statistical and Machine Learning (Units: 3)**

Prerequisites: MATH 448 and MATH 441, each with a grade of C or better; or consent of instructor.

Study of the fundamental concepts of statistical and machine learning theory.

**MATH 760 Multivariate Statistical Methods (Units: 3)**

Prerequisite: MATH 441 with a grade of C or better or consent of the instructor.

Multivariate Statistical Methods are used to analyze the joint behavior of more than one random variable. There are a number of multivariate techniques available including Factor Analysis, Principle Component Analysis, Canonical Correlation, Multidimensional Scaling, MANOVA, and Discriminant Analysis.

**MATH 761 Computational Statistics (Units: 3)**

Prerequisite: Graduate standing; or upper-division standing and MATH 440 or equivalent; or consent of the instructor.

Exploration of efficient methods for obtaining numerical solutions to statistically formulated problems. Emphasis on basic R programming, random variable generation, bootstrap, Jackknife and its applications, methods for variance reduction, Monte Carlo simulation and integration, optimization techniques, Newton-Raphson algorithm, EM algorithm, Metropolis-Hasting algorithm, and Gibbs samplers.

**MATH 770 Real Analysis II: Several Variables (Units: 3)**

Prerequisite for MATH 770: Graduate Mathematics students or consent of the instructor.

Prerequisites for MATH 470: Upper-division standing; MATH 370 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Sequences and series of functions, uniform convergence, real-analytic functions, metric spaces, open and closed sets, compact and connected sets, and continuous functions.

(MATH 770/MATH 470 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**MATH 771 Fourier Analysis and Applications (Units: 3)**

Prerequisite for MATH 771: Graduate standing; MATH 370 with a grade of C or better; or consent of the instructor.

Prerequisite for MATH 471: Upper-division standing; MATH 370 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Sequences and series of functions, modes of convergence, Fourier series and integrals, and wavelet analysis.

(MATH 771/MATH 471 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**MATH 777 Partial Differential Equations (Units: 3)**

Prerequisite for MATH 777: Graduate Mathematics students or consent of the instructor.

Prerequisites for MATH 477: Upper-division standing; MATH 376 with a grade of C or better; GPA of 3.0 or higher; or consent of the instructor.

Study of partial differential equations in rectangular and polar coordinates. Initial and boundary value problems for the heat equation and wave equation. Study of Fourier series, Bessel series, harmonic functions, and Fourier transforms.

(MATH 777/MATH 477 is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**MATH 814 Seminar on Modern Math Methods in Molecular Biology (Units: 3)**

Prerequisite: Graduate standing or consent of instructor.

Seminar on research in computational biology. Introduction to tools from pure and applied mathematics. Approaches to problems through common computational techniques. Topics to include DNA structure and effects of internal and external agents. Intended for students from a variety of disciplines such as math, computer science, biology and biochemistry.

**MATH 850 Algebra (Units: 3)**

Prerequisite: MATH 435/MATH 735 with a grade of C or better, or consent of instructor.

Rings and modules; further material is selected from such topics as Wedderburn theory, Noetherian ring theory, field theory, and general algebraic systems.

**MATH 852 Algebraic Topology (Units: 3)**

Prerequisites: MATH 335\* and MATH 450\* with grades of C or better; or consent of the instructor.

The fundamental group of topological spaces, construction of surfaces, simplicial and singular homology and cohomology with basic calculations, exact sequences, and Mayer-Vietoris theorem. [Formerly MATH 452]

**MATH 870 Computational Discrete Geometry (Units: 3)**

Prerequisites: CSC 210, CSC 230, and MATH 325; or consent of instructor.

A comprehensive overview of basic topics in computational discrete geometry including generating functions, complexity theory, convex hull, nearest-neighbor problems, and efficient algorithms. (This course is offered as MATH 870 and CSC 870. Students may not repeat the course under an alternate prefix.)

**MATH 881 Selected Topics in Combinatorics (Units: 3)**

Prerequisites: Graduate standing; MATH 301GW and MATH 335; or consent of instructor.

Review of fundamental combinatorial objects, addressing questions of existence, structure, and enumeration, then treating a well-established area of combinatorics in detail. May be repeated once, as topics vary. [Formerly a topic under MATH 890]

**MATH 882 Advanced Number Theory (Units: 3)**

Prerequisites: MATH 310, MATH 335, MATH 370, or consent of instructor.

Topics in computational, analytic, and algebraic number theory, including recognition of primes, modern methods of factorization, partitions, modular forms, elliptic curves, class numbers and quadratic fields. May be repeated once, as topics vary. [Formerly a topic under MATH 890]

**MATH 883 Polytopes and Varieties (Units: 3)**

Prerequisites: Either MATH 435 with a grade of C or better and consent of instructor; or MATH 735 or MATH 850 with a grade of C or better.

Central concepts in polytope theory and simplicial complexes, elements of affine and projective algebraic geometry, commutative algebra of special ideals and related effective methods, applications to one of the following: discrete geometry, toric varieties, algebraic statistics, polytope theory, optimization. May be repeated once, as topics vary. [Formerly a topic under MATH 890]

**MATH 884 Algebraic Geometry (Units: 3)**

Prerequisite: Graduate standing or consent of instructor.

Examination of current topics in the field of algebraic geometry. May be repeated once, as topics vary. [Formerly a topic under MATH 890]

**MATH 885 Advanced Frame Theory and Its Applications (Units: 3)**

Prerequisites: MATH 471 or MATH 470, and MATH 725 or MATH 770, or consent of instructor.

Frames in Hilbert spaces, finite frame theory, frames vs. Riesz bases, particular frames structures including frames of translates, Gabor frames, wavelet frames, frame multi-resolution, compressed sensing and sampling theory, and applications. [Formerly a topic under MATH 890]

**MATH 886 Discrete Geometry (Units: 3)**

Prerequisite: Graduate standing or consent of instructor.

Theory of polytopes. Counting lattice points in polytopes. Unimodular triangulations and unimodular coverings. May be repeated once, as topics vary. [Formerly a topic under MATH 890]

**MATH 887 Advanced Analysis on Manifolds (Units: 3)**

Prerequisite: MATH 710 or consent of the instructor; math major.

Differentiable maps, inverse and implicit function theorems;  $n$ -dimensional Riemann integral, change of variables in multiple integrals, manifolds, differential forms,  $n$ -dimensional version of Stokes theorem, and abstract differentiable manifolds. May be repeated once, as topics vary. [Formerly MATH 890-topic course]

**MATH 896EXM Culminating Experience Examination (Units: 0-3)**

Prerequisites: Consent of instructor, committee chair, and approval of Advancement to Candidacy (ATC) and Culminating Experience (CE) forms by Graduate Studies. ATC and Proposal for Culminating Experience Requirement forms must be approved by the Graduate Division before registration.

Enrollment in 896EXAM required for students whose culminating experience consists of an examination only. Not for students enrolled in a culminating experience course numbered MATH 898 (or in some cases, MATH 890 - see program's graduate advisor for further information). (CR/NC, RP)

**MATH 898 Master's Thesis (Units: 3)**

Prerequisites: Consent of instructor and graduate adviser; and approval of Advancement to Candidacy (ATC) and Culminating Experience (CE) forms by Graduate Studies. ATC and Proposal for Culminating Experience Requirement forms must be approved by the Graduate Division before registration. (CR/NC grading only)

**MATH 899 Independent Study (Units: 1-3)**

Prerequisite: Approval of the department and consent of the instructor.

Special study of a particular problem under the direction of a member of the department. The student must present a written report of the work accomplished to the staff of the department. May be repeated.