MATHEMATICS (MATH)

MATH 107. MATHEMATICAL REASONING. 5 Credits.
Pre-requisites: MTHD 104 or MTHD 106 or equivalent course; or placement into MTHD 104 or MTHD 106 with concurrent enrollment in MATH 130; or placement into MATH 107.
Satisfies: Quantitative and Symbolic Reasoning proficiency with a grade ≥C.
The course explores sets, basic logic, truth tables, elementary probability, statistics and basic finance mathematics. The spirit of the course is one of reasoning and problem solving. This is a terminal course intended for students not taking any other mathematics courses for their program of study. This proficiency may be satisfied by examination.

MATH 114. ALGEBRA CONCEPTS. 5 Credits.
Pre-requisites: MTHD 104 or equivalent course, or placement into MTHD 104 with concurrent enrollment in MATH 131, or placement into MATH 114.
Satisfies: completion of this course with a grade ≥C satisfies mathematics competency (additional clearance must be completed for proficiency).
Topics studied are quadratic, rational, and radical equations and functions including an introduction to the algebra of polynomial functions. Problem solving, use of graphing tools, and quantitative and abstract reasoning are emphasized throughout the course.

MATH 121. INTRODUCTORY STATISTICS. 5 Credits.
Pre-requisites: MTHD 104 or MTHD 106 or a satisfactory score on the mathematics placement test.
Satisfies: completion of this course with a grade ≥C satisfies the university proficiencies in mathematics.
This course develops statistical literacy and the ability to think statistically, and understand how probability plays a role in statistical inference. Descriptive statistics and their graphical representations are used to summarize real and simulated data sets. Students understand how the variation present in a population affects the precision of estimates of population attributes. Confidence intervals and hypothesis testing are introduced with an emphasis on understanding their use in context.

MATH 130. ESSENTIALS FOR MATH REASONING. 3 Credits.
Notes: this course is a support for MATH 107, withdrawing from either course will require simultaneous withdrawal from the other.
Pre-requisites: MTHD 103, or placement into MTHD 104, and concurrent enrollment with MATH 107.
Develops conceptual understanding and procedural fluency with linear and exponential expressions and equations through college-level mathematical skills such as building and using multiple representations, using technology, problem-solving, communication, interpreting graphs, and reasoning. Includes unit analysis, percents, proportions, and flexibility with formulas and student success skills needed in college mathematics.

MATH 131. ESSENTIALS FOR ALGEBRA CONCEPTS. 3 Credits.
Notes: Designed to partner with MATH 114 so that concepts, procedures, and skills needed for success in MATH 114 are developed in time for use in MATH 114. Since this course is a support for MATH 114, withdrawing from either course will require simultaneous withdrawal from the other.
Pre-requisites: MTHD 103, or placement into MTHD 104, and concurrent enrollment with MATH 114.
Develops conceptual understanding and procedural fluency within linear, exponential, quadratic, and rational equations, expressions, and functions, and absolute value and rate of change. Uses college-level mathematical skills such as building and using multiple representations, using technology, problem-solving, communication, and reasoning and develops mathematics success skills needed to read, listen, and write in mathematics.

MATH 132. ESSENTIALS FOR FINITE MATH. 3 Credits.
Notes: this course is a support for MATH 200; withdrawing from either course will require simultaneous withdrawal from the other.
Pre-requisites: MTHD 103, or placement into MTHD 104, and concurrent enrollment with MATH 200.
Develops conceptual understanding and procedural fluency with set theory, linear programming, matrices, probability, and statistics. Advances college-level mathematical skills using technology, problem-solving, communication, and reasoning.

MATH 141. PRECALCULUS I. 5 Credits.
Pre-requisites: a grade ≥C in MATH 114 or equivalent course or a satisfactory score on the mathematics placement assessment (MPA).
Satisfies: completion of this course with a grade ≥C satisfies the university proficiencies in mathematics.
This course includes modeling, rates of change and structure of functions; especially polynomial, rational, logarithmic and exponential. Problem solving, use of graphing tools and abstract reasoning are emphasized throughout the course.

MATH 142. PRECALCULUS MATH II. 5 Credits.
Pre-requisites: MATH 141 or equivalent.
Satisfies: completion of this course with a grade ≥C satisfies the university proficiencies in mathematics.
This course includes an in depth treatment of trigonometric and inverse trigonometric functions, identities, complex numbers, sequences, series, conic sections and mathematical induction. Polar coordinates, parametric equations and vectors are introduced. Problem solving, use of graphing tools, and quantitative and abstract reasoning are emphasized throughout the course.

MATH 161. CALCULUS I. 5 Credits.
Cross-listed: HONS 161.
Notes: for the university proficiencies, this course may be substituted for MATH 107.
Pre-requisites: MATH 142.
Satisfies: completion of this course with a grade ≥C satisfies the university proficiencies in mathematics.
This course introduces the concepts of mathematical limits, derivatives, definite and indefinite integrals, and of real-valued functions of a single real variable, with applications.

MATH 162. CALCULUS II. 5 Credits.
Pre-requisites: MATH 161 or HONS 161.
This course presents techniques of integration and improper integrals, with applications, and introduces transcendental functions.

MATH 163. CALCULUS III. 5 Credits.
Pre-requisites: MATH 162.
This course introduces limits of sequences and Taylor series, polar coordinates and conic sections in the plane, as well as vectors and parametric curves in the plane and in space.

MATH 170. GEOMETRY AND ART. 5 Credits.
Notes: this course will involve an analysis of many geometric structures leading to the creation of tessellations of different types.
Pre-requisites: MTHD 104 or MTHD 106 or equivalent course, or a math placement into any college-level MATH course.
Satisfies: Quantitative and Symbolic Reasoning proficiency with a grade ≥C.
The course will explore the relationship between geometry and art. Topics include Tessellations, Euclidean, Spherical and Hyperbolic Geometry, Projective and Perspective Geometry, and Vector and Raster Graphics. Other topics may be added based on the interest of the instructor and the students enrolled in the class.

MATH 196. EXPERIMENTAL. 1-5 Credits.

MATH 200. FINITE MATHEMATICS. 5 Credits.
Pre-requisites: a grade ≥C in MTHD 104, or a satisfactory score on the mathematics placement assessment (MPA).
Satisfies: Quantitative and Symbolic Reasoning proficiency with a grade ≥C.
This course provides an introduction to the mathematical systems encountered in the study of the behavioral sciences and a study of matrices, linear systems, linear programming, set theory and probability.

MATH 208. MATHEMATICS FOR ELEMENTARY TEACHERS I. 5 Credits.
Pre-requisites: MTHD 106 with a grade ≥C, or a satisfactory score on the mathematics placement assessment (MPA).
Satisfies: Quantitative and Symbolic Reasoning proficiency with a grade ≥C.
This course provides future K–8 teachers foundational understanding of elementary school mathematics for teaching. It includes problem-solving, numeration and number systems, whole number operations, fractions and operations on fractions, decimals and operations on decimals, percent, proportional reasoning, integers and operations on integers. Conceptual understanding and problem solving strongly emphasized.

MATH 209. MATHEMATICS FOR ELEMENTARY TEACHERS II. 4 Credits.
Pre-requisites: MATH 208.
This course promotes a deep conceptual understanding of geometry and measurement taught in grades K–8, and of proportional reasoning as it applies to geometry and measurement. Through a problem-solving approach to learning these concepts and procedures, future teachers also develop and reflect on their proficiencies in the Standards for Mathematical Practices.

MATH 210. MATHEMATICS FOR ELEMENTARY TEACHERS III. 4 Credits.
Notes: this course provides depth and topics required by Washington State Teacher Competencies for K–8 elementary certification.
Pre-requisites: MATH 208 and MATH 209.
This course is designed to give future K–8 teachers a basis for understanding elementary school mathematics. Topics include algebraic reasoning, probability, and data analysis, and ratio and proportional reasoning within the context of algebra, probability and data analysis. There is a strong emphasis on conceptual understanding and problem solving.

MATH 225. FOUNDATIONS OF MATHEMATICS. 5 Credits.
Notes: you may not receive credit for both MATH 225 and MATH 301.
Pre-requisites: MATH 161 or HONS 161.
Provides a transition from freshman-level to higher-level mathematics and is required for higher-level courses. Topics include logic, methods of proof, set theory, relations and functions and cardinality.

MATH 231. LINEAR ALGEBRA. 5 Credits.
Pre-requisites: MATH 142.
Theory and practice of vector geometry in R2 and R3, systems of linear equations, matrix algebra, determinants, vector spaces, bases and dimension, linear transformations, eigenvalues and eigenvectors, rank and nullity and applications.

MATH 241. CALCULUS IV. 5 Credits.
Notes: this course should be taken immediately after MATH 163, when possible.
Pre-requisites: MATH 163.
This course introduces differentials and multiple integrals of functions of several real variables and vector calculus.

MATH 296. EXPERIMENTAL. 1-5 Credits.

MATH 297. WORKSHOP, SHORT COURSE, CONFERENCE, SEMINAR. 3-5 Credits.

MATH 298. SEMINAR. 1-5 Credits.

MATH 299. SPECIAL STUDIES. 1-5 Credits.
Pre-requisites: permission of the instructor, department chair and college dean.

MATH 301. DISCRETE MATHEMATICS. 5 Credits.
Notes: for the university proficiencies, the course may be substituted for MATH 107; you may not receive credit for both MATH 225 and MATH 301.

Pre-requisites: MATH 142.
Satisfies: completion of this course with a grade ≥C satisfies the university proficiencies in mathematics.
This course covers the theory and application of the mathematics most relevant to computer science. Foundation topics include logic, induction and recursion, methods of proof, set theory, relations and functions, and combinatorics. Implementation topics include graphs and matrices, including systems of linear equations, two dimensional rotation matrices and matrix representations of graphs, as well as selected topics in graph theory.

MATH 307. MATHEMATICAL COMPUTING LABORATORY III. 1 Credit.
Notes: the laboratory may be repeated for credit.
The laboratory consists of exercises, experiments and reports, using applications, calculators or mathematical software such as Maple, Mathematica, Matlab, MINITAB, Geometer's Sketchpad or SAS, on topics closely related to the contents of the designated concurrent mathematics course. However, the laboratory is not required by the designated course. The topics are specified in the section subtitles.

MATH 311. FUNCTIONS AND RELATIONS FOR K-8 TEACHERS. 5 Credits.
Pre-requisites: MATH 114 or MATH 210, or math placement score.
A discussion of the algebraic concepts of functions and relations from numeric, graphic and symbolic viewpoints.

MATH 312. GEOMETRY FOR THE K-8 TEACHER. 5 Credits.
Pre-requisites: MATH 209 and MATH 210.
Concepts from two- and three-dimensional geometry are explored and demonstrated. The course includes geometric proofs and requires the use of technology widely used in the K–12 system (and available in the Mathematics Department).

MATH 313. PATTERNS, RELATIONS AND ALGEBRAIC THINKING FOR PRIMARY TEACHERS. 5 Credits.
Pre-requisites: MATH 114 or MATH 210.
This course is an examination of algebraic and quantitative reasoning with an emphasis on topics related to P-3 mathematics: the meaning and use of variables; the properties of equality and arithmetic; the study and representations of numerical patterns and relationships; the development and use of symbolic, numeric and graphic representations.

MATH 320. HISTORY OF MATHEMATICS. 4 Credits.
Pre-requisites: ENGL 201; MATH 225 or permission of the instructor.
A historical development of mathematical ideas and methods. Emphasizes the individuals involved, the development of the intellectual activity called mathematics and the ebb and flow of mathematics in history.

MATH 321. PRECOLONIAL MATHEMATICS TRADITIONS. 5 Credits.
Pre-requisites: Math and English proficiency.
Satisfies: a university graduation requirement–global studies.
Mathematics and math history tends to focus on the development of the mathematics of Europe and the Middle East. This course provides a survey of the independent mathematical achievements native to Africa, Asia, and the Americas. Topics in this course may vary, but each version of this course will introduce arithmetical, statistical, or geometrical ideas and traditions from each of these three regions. Students will complete a project to revitalize one of the traditions studied.

MATH 331. DISCRETE MATHEMATICS WITH APPLICATIONS. 5 Credits.
Pre-requisites: MATH 225 or both MATH 161 (or HONS 161) and MATH 301.
Graph theory, chaos theory and fractals, combinatorics, combinatorial game theory and the surreal numbers. Selected applications for each topic.

MATH 332. NUMBER THEORY. 5 Credits.
Pre-requisites: MATH 225.
Arithmetic in different bases, fundamental theorem of arithmetic, modular arithmetic, Wilson's and Fermat's theorems, RSA codes, perfect numbers, linear and quadratic congruences, quadratic reciprocity, Pythagorean triples, Gaussian integers and arithmetic in other settings, Fermat's last theorem and the method of descent.

MATH 341. TOPICS IN APPLIED ANALYSIS I. 4 Credits.
Pre-requisites: for MATH 341: MATH 163; for MATH 342 and MATH 343: MATH 241.
Selected topics in applied mathematics such as vector analysis, complex variables, partial differential equations, etc.

MATH 342. TOPICS IN APPLIED ANALYSIS II. 5 Credits.
Pre-requisites: MATH 241.
Selected topics in applied mathematics such as vector analysis, complex variables, partial differential equations, etc.

MATH 343. TOPICS IN APPLIED ANALYSIS III. 4 Credits.
Pre-requisites: for MATH 341: MATH 163; for MATH 342 and MATH 343: MATH 241.
Selected topics in applied mathematics such as vector analysis, complex variables, partial differential equations, etc.

MATH 347. INTRODUCTORY DIFFERENTIAL EQUATIONS. 4 Credits.
Pre-requisites: MATH 163.
This course introduces scalar differential equations with analytical methods of solution, including Laplace transforms, numerical approximations, as well as mathematical models of applications, with other selected topics and uses of software.

MATH 350. BIOMATHEMATICS. 5 Credits.
Pre-requisites: MATH 347 or permission of instructor.
Biomathematics is a 5 credit course containing both analytical and computational methods for studying mathematical models of biological systems. In order to increase interdisciplinary access, the course contains a primer on dynamics and technology. Biological topics include: ecological/population modeling, SIR modeling, the law of mass action, enzyme kinetics, the Hodgkin-Huxley model and simplified conductance based models.

MATH 370. SURVEY OF GEOMETRIES. 5 Credits.
Pre-requisites: MATH 225.
Introduction to various finite and infinite geometries, both Euclidean and non-Euclidean. The logical notions of consistency, independence, interpretation and models and completeness will be explored. Properties and theorems of each geometric system will be developed synthetically, analytically and through use of technology.

MATH 380. ELEMENTARY PROBABILITY AND STATISTICS. 5 Credits.
Notes: for the university proficiencies, course may be substituted for MATH 107.
Pre-requisites: mathematics proficiency clearance.
Satisfies: completion of this course with a grade ≥C satisfies the university proficiencies in mathematics.
Empirical and theoretical frequency distributions. Discrete and continuous random variables. The binomial random variable and the normal. Descriptive statistics including measures of location, spread and association. An introduction to inferential statistics including confidence intervals and hypothesis testing.

MATH 385. PROBABILITY AND STATISTICAL INFERENCE I. 5 Credits.
Pre-requisites: MATH 163, MATH 225 or MATH 301, or permission of the instructor.
This course introduces mathematical theory of probability and statistical inference. This includes proofs of simple theorems, applications of probability to real world problems, discrete and continuous random variables and their probability distributions, sampling distributions and the central limit theorem, basic properties of estimators including bias, constructions of confidence intervals and hypothesis tests.

MATH 387. REGRESSION CONCEPTS. 3 Credits.
Pre-requisites: MATH 385.
This course is designed to provide an introduction, development and applications of regression concepts including Type 1 and Type 2 errors, statistical power, p-values, t-tests, F-tests, linear and polynomial regression, stepwise regression and the relationship between correlation and regression. Technology will be used throughout the course.

MATH 395. CO-OP FIELDWORK. 1-5 Credits.

MATH 396. EXPERIMENTAL COURSE. 1-5 Credits.

MATH 399. SPECIAL STUDIES IN MATH. 1-5 Credits.
Pre-requisites: permission of the instructor, department chair and college dean.

MATH 401. ADVANCED FORMAL LOGIC. 5 Credits.
Pre-requisites: PHIL 215 or math equivalent and successful completion of ENGL 101 and recommended placement above MTHD 104 on the mathematics placement test or MTHD 104 or equivalent.
Advanced study of formal deductive systems. Develops predicate logic on a rigorous basis, establishes some important metatheorems for logical systems and introduces some concepts in semantics and issues in the philosophy of logic.

MATH 407. MATHEMATICAL COMPUTING LABORATORY IV. 1 Credit.
Notes: the laboratory may be repeated for credit.
The laboratory consists of exercises, experiments and reports, using applications, calculators or mathematical software such as Maple, Mathematica, Matlab, MINITAB, Geometer's Sketchpad or SAS, on topics closely related to the contents of the designated concurrent mathematics course. However, the laboratory is not required by the designated course. The topics are specified in the section subtitles.

MATH 411. DISCRETE MATHEMATICS FOR K-8 TEACHERS. 4 Credits.
Pre-requisites: MATH 161, HONS 161, MATH 210, MATH 311 or MATH 313.
This course introduces the elementary mathematics major to the process of doing mathematics via mathematical proofs and mathematical reasoning. Throughout the course, familiar topics will be approached in a less intuitive, more formal way and in greater depth than previously experienced. Topics to be covered include logic; sets, functions and sequences; methods of proof; and combinatorics.

MATH 413. DATA ANALYSIS AND PROBABILITY FOR MIDDLE LEVEL TEACHERS. 4 Credits.
Pre-requisites: MATH 209, MATH 210 and MATH 311.
Through readings, discussion and a hands-on problem-centered approach, students develop a profound understanding of concepts of data analysis and probability. Students deepen their understanding of the research on the teaching and learning of data analysis and probability in K–9 mathematics.

MATH 416. CALCULUS FOR MIDDLE LEVEL TEACHERS. 4 Credits.
Pre-requisites: MATH 141 or MATH 311.
This course is intended for pre-service middle school teachers and focuses on conceptual and procedural understandings of limit, continuity, differentiation and integration. It includes the techniques and applications of calculus and use of technology to explore and represent fundamental concepts of calculus.

MATH 420. PROBLEM SOLVING FOR K-8 TEACHERS. 4 Credits.
Pre-requisites: MATH 210 or equivalent course approved by the department.
This math content course for prospective K–8 teachers requires students enrolled in the class to solve a large variety of problem-solving problems using a variety of strategies including the use of manipulatives, technology and mathematical representations. Techniques for teaching problem solving are discussed in the course. The use of a variety of types of technology is a required component of the course.

MATH 430. ADVANCED LINEAR ALGEBRA. 5 Credits.
Pre-requisites: MATH 225 and MATH 231.
This course further develops both the theory and applications of linear algebra. Topics include a survey of matrix factorizations, an introduction to inner product spaces, and analysis of applications, such as, Markov chains, least squares regression, principal component analysis, and gradient descents. This course also investigates how core concepts from linear algebra apply to modern techniques in data analysis, such as, image processing, machine learning, deep learning, and neural networks.

MATH 431. APPLIED GROUP THEORY. 5 Credits.
Pre-requisites: MATH 225 and MATH 231.
Groups, cyclic and permutation groups, cosets and Lagrange's theorem, Cayley graphs, group actions, counting theorems with applications, tilings and groups of symmetries with applications.

MATH 432. RINGS AND POLYNOMIALS. 5 Credits.
Pre-requisites: MATH 225 and MATH 231.
Binary operations and algebras, rings and polynomials, factor rings and ideals, integral domains and fields (both finite and infinite), factor theorems, prime, irreducible and unique factorizaton, power series and differential operators, applications including computer algebra techniques, digital communication and encryption.

MATH 433. GALOIS THEORY. 5 Credits.
Pre-requisites: MATH 432.
Field theory, splitting fields, Galois groups, fundamental theorem of Galois theory, applications to classical problems of Euclidean constructability and solvability by radicals, applications of the theory to encryption and digital communication.

MATH 443. NUMERICAL METHODS. 5 Credits.
Pre-requisites: MATH 163 and MATH 231.
This course introduces students to scientific computing. This course provides a survey of computational techniques to solve scalar non-linear equations, numerical integration and differentiation, and initial value problems. Additional topics may include Monte Carlo simulation, curve fitting, and linear programming.

MATH 444. NUMERICAL LINEAR ALGEBRA. 5 Credits.
Pre-requisites: junior, senior or graduate standing; MATH 163, MATH 231, and MATH 443.
This course develops numerical linear algebra and error estimates essential for scientific computing: machine arithmetic, algorithms for solving systems of linear equations, algorithms for computing eigenvalues and singular values, and the theory of error estimates through condition numbers and backward analysis.

MATH 445. NUMERICAL ANALYSIS. 5 Credits.
Pre-requisites: junior or higher standing; MATH 444.
This course focuses equally on mathematical analysis of accuracy and computational implementation of numerical schemes to approximate solutions to mathematical problems. Topics considered include: curve fitting, numerical differentiation and integration, and tracking the associated accuracy in the introduced schemes. In addition, numerical methods to approximate solutions to initial value problems, boundary value problems, and partial differential equations will be covered.

MATH 447. DIFFERENTIAL EQUATIONS. 5 Credits.
Pre-requisites: MATH 231 and MATH 347.
This course is an advanced study of ordinary differential equations focusing on linear and nonlinear systems, with analytical, qualitative, and numerical methods of solution including Euler's method, matrix exponential, stability, phase plane analysis, linearization, Lyapunov functions, existence and uniqueness and applications. This course provides experience with mathematical software.

MATH 448. PARTIAL DIFFERENTIAL EQUATIONS. 5 Credits.
Pre-requisites: MATH 347.
This course is a study of partial differential equations via boundary value problems and Fourier series representations, centered on classical and numerical solutions of the heat equation, wave equation, advection equation and Laplace equation, modeling applications and use of technology through mathematical software. Topics may include Bessel's inequality, energy methods, existence and uniqueness, eigenfunction expansions and integral transforms.

MATH 460. CONTINUOUS FUNCTIONS. 5 Credits.
Pre-requisites: MATH 163 and MATH 225.
The course lays out the foundations for calculus and analytical geometry; the course develops the topology of the n-dimensional real Euclidean space. Topics include the completeness of the real numbers, topological spaces, continuity and properties preserved by continuous functions: compactness and connectedness.

MATH 461. ADVANCED CALCULUS I. 5 Credits.
Pre-requisites: MATH 241 and MATH 460.
This course applies notions from linear algebra and continuous functions to develop the calculus of functions of several variables. Topics include differentiability, the derivative as a linear transformation, extreme value problems and the implicit and inverse function theorems.

MATH 462. ADVANCED CALCULUS II. 5 Credits.
Pre-requisites: MATH 461.
This course builds on topics introduced in MATH 461, and develops integration with differential forms. Topics include line integrals, exterior algebra and a general form of Stokes's theorem; the course includes selected applications to algebraic topology and fluid dynamics, if time permits.

MATH 470. FOUNDATIONS OF GEOMETRY. 5 Credits.
Pre-requisites: MATH 225 and MATH 231 or concurrent enrollment.
The course includes the study of Euclidean and non-Euclidean isometries. Selected topics in advanced geometry stressing applications to other branches of mathematics, physics, chemistry and biology will be explored.

MATH 481. COMPLEX ANALYSIS. 5 Credits.
Notes: MATH 225 and MATH 460 are recommended.
Pre-requisites: MATH 163.
The course proves relations between derivatives, integrals along curves, Maclaurin series, and singularities of complex-valued functions of a complex variable, in particular, theorems of Abel, Cauchy-Goursat, Green, Laurent, Liouville, Morera, Riemann and Rouch {\'{e}}. Applications include the solution of Laplace's partial differential equation by Green's functions (Cauchy's and Poisson's integral formulae) or Fourier Transforms. Detailed proofs of theorems also provide a theoretical foundations for the corresponding theorems from calculus with one or two variables: differentiation and integration of power series and Fourier series, differentiation relative to parameters of integrals along curves and the fundamental theorem of algebra.

MATH 485. PROBABILITY AND STATISTICAL INFERENCE II. 5 Credits.
Pre-requisites: MATH 231, MATH 241 and MATH 385 or permission of the instructor.
This course covers a variety of statistical methods for research in the natural sciences, including analysis of variance, multiple regression, general linear models and nonparametric statistical procedures. One or more additional topics will be selected by the students in consultation with the instructor teaching the course. Use of statistical software will be emphasized.

MATH 486. PROBABILITY AND STATISTICAL INFERENCE III. 5 Credits.
Pre-requisites: MATH 485 or permission of the instructor.
This course covers advanced topics in probability and statistical inference including discrete and continuous multivariate distributions, moment generating functions, proof of the central limit theorem, properties of estimators including efficiency and sufficiency, best linear unbiased estimators (BLUE), maximum likelihood estimation, the Neyman-Pearson lemma and likelihood ratio tests. The course concludes with a practical student-project component in which students apply methods learned to the analysis of a real-world data set.

MATH 491. SENIOR THESIS. 2-5 Credits.
Pre-requisites: senior standing and permission of the instructor.
Satisfies: a university graduation requirement–senior capstone.
This course provides students with an opportunity to research a mathematical topic and present their findings in writing and orally.

MATH 492. PROBLEM SOLVING SEMINAR. 5 Credits.
Pre-requisites: MATH 225, MATH 301, MATH 411 or permission of the instructor; and MATH 380, MATH 385, MATH 413 or MATH 485.
The course examines various problem solving strategies and techniques for teaching problem solving at the secondary level such as direct proof, indirect proof, inferences, mathematical representations and the use of technology.

MATH 494. SENIOR SEMINAR. 2 Credits.
Pre-requisites: for students pursuing the BA in Mathematics: prior or concurrent enrollment in MATH 462 and MATH 432; for students pursuing the BAE Secondary: prior or concurrent enrollment in MATH 432.

The Senior Seminar course will explore the culture of mathematics through readings and classroom discussions. The students will be required to write a paper on some aspect of mathematics. At the same time, students will review the core mathematics they have studied and comprehensive tests will be administered in order to assess the knowledge they have acquired in their degree programs.

MATH 495. INTERNSHIP. 1-15 Credits.
Internship.

MATH 496. EXPERIMENTAL COURSE. 1-5 Credits.

MATH 497. WORKSHOP, SHORT COURSE, CONFERENCE, SEMINAR. 1-5 Credits.
Selected topics to be arranged in consultation with the requesting organization.

MATH 498. SEMINAR. 1-5 Credits.

MATH 499. DIRECTED STUDY. 1-5 Credits.
Pre-requisites: permission of the instructor, department chair and college dean.

MATH 507. MATHEMATICAL COMPUTING LABORATORY. 1 Credit.
Notes: the laboratory may be repeated for credit.
Pre-requisites: concurrent enrollment in or prior credit for a 500-level mathematics course designated by the Department of Mathematics each academic term.
The laboratory consists of exercises, experiments and reports, with applications or calculators or with such mathematical software as Maple, Mathematica, Matlab, MINITAB, Geometer's Sketchpad or SAS, on topics closely related to the contents of the designated concurrent mathematics course. However, the laboratory is not required by the designated course. The topics are specified in the section subtitles.

MATH 510. NUMBER SENSE FOR TEACHERS. 3 Credits.
Pre-requisites: graduate standing.
Through readings, discussion and a hands-on problem-centered approach, students will develop a profound understanding of the concepts of numeration systems, base ten and place value, operations, fractions, decimals, percents, integers, real numbers and number theory and will deepen their understanding of the research on the teaching and learning of these topics in K–9 mathematics. Major emphases will be learners' cognitive development through and across different grade levels, including that of diverse and exceptional learners, typical student conceptions and misconceptions, meaningful use of representations and technology in developing understanding and state and national standards related to these number-sense topics.

MATH 511. RATIO AND PROPORTION - TEACHERS. 3 Credits.
Pre-requisites: graduate standing.
Through readings, discussion and a hands-on problem-centered approach, students will develop a profound understanding of the concepts of ratio and proportion and deepen their understanding of the research on the teaching and learning of ratio and proportion in K–9 mathematics. Major emphases will be learners' cognitive development through and across different grade levels, including that of diverse and exceptional learners, typical student conceptions and misconceptions, meaningful use of representations and technology in developing understanding and state and national standards related to ratio and proportion.

MATH 512. GEOMETRIC REASONING - TEACHERS. 3 Credits.
Pre-requisites: graduate standing.
Through readings, discussion and a hands-on problem-centered approach, students will develop a profound understanding of geometry concepts and deepen their understanding of the research on the teaching and learning of geometry concepts in K–9 mathematics. Major emphases will be learners' cognitive development through and across different grade levels, including that of diverse and exceptional learners, typical student conceptions and misconceptions, meaningful use of representations and technology in developing understanding and state and national standards related to geometry.

MATH 513. DATA ANALYSIS AND PROBABILITY FOR TEACHERS. 3 Credits.
Pre-requisites: graduate standing.
Through readings, discussion and a hands-on problem-centered approach, students will develop a profound understanding of concepts of data analysis and probability and deepen their understanding of the research on the teaching and learning of data analysis and probability in K–9 mathematics. Major emphases will be learners' cognitive development through and across different grade levels, including that of diverse and exceptional learners, typical student conceptions and misconceptions, meaningful use of representations and technology in developing understanding and state and national standards related to data analysis and probability.

MATH 514. ALGEBRAIC REASONING - TEACHERS. 3 Credits.
Pre-requisites: graduate standing.
Through readings, discussion and a hands-on problem-centered approach, students will develop a profound understanding of algebraic reasoning and deepen their understanding of the research on the teaching and learning of algebraic reasoning in K–9 mathematics. Major emphases will be learners' cognitive development through and across different grade levels, including that of diverse and exceptional learners, typical student conceptions and misconceptions, meaningful use of representations and technology in developing understanding and state and national standards related to algebraic reasoning.

MATH 515. MEASUREMENT FOR TEACHERS. 3 Credits.
Pre-requisites: graduate standing.
Through readings, discussion and a hands-on problem-centered approach, students will develop a profound understanding of measurement concepts and deepen their understanding of the research on the teaching and learning of measurement in K–9 mathematics. Major emphases will be learners' cognitive development through and across different grade levels, including that of diverse and exceptional learners, typical student conceptions and misconceptions, meaningful use of representations and technology in developing understanding and state and national standards related to measurement.

MATH 516. CALCULUS FOR MIDDLE LEVEL TEACHERS. 4 Credits.
Pre-requisites: graduate standing and MATH 311 or equivalent.
This course is intended for middle school teachers and focuses on conceptual and procedural understandings of limit, continuity, differentiation and integration. It includes the techniques and applications of calculus and use of technology to explore and represent fundamental concepts of calculus. It also addresses the historical development of calculus and the contributions to its development from many cultures. Students will create a project focusing on connections between calculus, the middle school curriculum and current understandings of how students learn mathematics.

MATH 528. PROBLEM-CENTERED LEARNING. 3 Credits.
Pre-requisites: graduate standing.
This course explores how to create classroom environments where rich tasks form the basis for mathematical learning. Special emphasis will be placed on task construction, selection and problem-posing. Participants will engage in a series of non-routine problem-solving activities. They will also be expected to develop non-routine problem-solving activities addressing specific mathematical ideas. These activities will serve as a basis for examining and reflecting on the research about and the implications of such an approach to the teaching and learning of mathematics.

MATH 530. APPLIED MATHEMATICS. 5 Credits.
Pre-requisites: acceptance into the graduate program.
This course provides theory and practice with vector spaces, Hilbert spaces, and continuous processes making use of finite elements, the Fourier, Laplace, and Wavelet transforms. Methods may include solutions of integral equations with applications to computer assisted tomography and magnetic resonance imaging.

MATH 531. APPLIED GROUP THEORY. 5 Credits.
Pre-requisites: admission to graduate program.
This course uses the structure of group theory to analyze real problems. Topics may include: tesselations and crystal structure, molecular symmetries, electronic structures, representation of vibrations, spin and double groups, virology.

MATH 534. METHODS OF DISCRETE MATHEMATICS. 5 Credits.
Pre-requisites: admission to graduate program.
This course provides theory and practice with discrete mathematical modeling. Topics may include chaos theory and fractals, linear programming, graph theory, computational complexity.

MATH 535. CRYPTOGRAPHY. 5 Credits.
Pre-requisites: admission to graduate program.
This course is an introduction to Cryptography. Topics may include; public key encryption, digital signatures, identification protocols, key agreement protocols, DES and AES blockciphers, RSA and ElGamal public-key encryption, cryptographic hash functions, information-theoretic and complexity-theoretic security.

MATH 539. SEMINAR IN SPECIAL TOPICS. 1-5 Credits.

MATH 541. ADVANCED PDE WITH APPLICATION. 5 Credits.
Notes: may be stacked with MATH 448.
Pre-requisites: admission to graduate program.
This course is an advanced study of partial differential equations (PDEs). The course is principally focused classical solutions of the heat equation, wave equation, advection equation, and Laplace equation. Students will learn how to model a variety of applications where PDEs arise. In addition, the method of finite differences and the use of technology through mathematical software will be covered. Additional topics may include energy methods, existence and uniqueness, and integral transforms.

MATH 544. NUMERICAL LINEAR ALGEBRA. 5 Credits.
Pre-requisites: admission to graduate program.
This course provides theory and practice with machine arithmetic, propagation, analysis, and alleviation of rounding errors and other perturbations. Methods include conditioning, matrix factorisations (LU, QR, SVD) and backward analysis. Typical applications are Google PageRank, Kalman filtering, data compression and image processing with wavelets. This course requires the use of computers and software available at EWU.

MATH 545. METHODS OF COMPUTATIONAL MODELING. 5 Credits.
Pre-requisites: admission to graduate program.
This survey course provides the computational foundations of Simulation, Optimization and Analysis (SOMA). To this end the course introduces the computational toolset necessary to investigate numerical solutions to differential equations and linear systems and method of optimization, including iterative methods, with analysis of stability and error.

MATH 547. NON-LINEAR DYNAMICS. 5 Credits.
Pre-requisites: admission to graduate program.
A course in dynamical systems theory. We discuss characterizations of stability, flows on stable, unstable, and center manifolds, and invariant sets. Other topics may include planar dynamics, Lyapunov functions, conservative systems, and the Hartman-Grobman theorem.

MATH 548. ADVANCED PARTIAL DIFFERENTIAL EQUATIONS. 5 Credits.
Pre-requisites: admission to graduate program.
This course is an investigation of partial differential equations and boundary value problems. Topics may include a parallel between solving a linear system of equations and a boundary value problem, approximate solution of parabolic PDE by projection onto the appropriate finite dimensional subspace, and solution of hyperbolic PDE with the method of characteristics. Throughout is discussed the finite element method.

MATH 550. MATHEMATICAL BIOLOGY. 5 Credits.
Pre-requisites: admission to graduate program.
This course provides advanced theory and practice with analytical and computational studies of biological systems. The course contains sophisticated mathematical models from physiological systems, ranging from single cell models to dynamics of coupled cells to behavior of systems or networks.

MATH 561. CONTINUOUS OPTIMIZATION. 5 Credits.
Pre-requisites: admission to graduate program.
This course provides theory and practice with continuous optimization (for instance, general, non-necessarily linear least-squares, with non-necessarily linear constraints, or convex analysis), with such applications as geodetic coordinates, non-linear curve and surface fitting, or machine learning. This course requires the use of computers and software available at EWU.

MATH 573. TOPICS IN APPLIED MATHEMATICS. 5 Credits.
Notes: may be repeated for credit (provided the topic is different).
Pre-requisites: graduate standing or permission of the instructor.
The course focuses on the mathematics of applications, depending on the interests of the class and the instructor. Topics will be specified in the section subtitle.

MATH 581. APPLIED COMPLEX ANALYSIS. 5 Credits.
Pre-requisites: admission to graduate program.
This course provides theory and practice with complex analysis and its applications, for instance, linear and non-linear initial-boundary-value problems in electrostatics, electrodynamics, fluid dynamics, as well as Fourier and Radon Transforms in inverse problems of geologic, medical, oceanographic, and radar imaging. This course requires the use of computers and software available at EWU.

MATH 582. COMPLEX ANALYSIS II. 4 Credits.
Pre-requisites: MATH 581.
Continues MATH 581 through the proofs of advanced results, such as the general Riemann Mapping Theorem, or properties of the special functions of Riemann and Weierstrass. If time permits, may include application to Algebraic Geometry, Number Theory and Coding or extensions to several complex variables, for example.

MATH 585. APPLIED LINEAR STATISTICAL MODELING. 5 Credits.
Pre-requisites: MATH 385 and admission to the graduate program, or permission of the instructor.
This course provides theory and practice with linear statistical models. Topics include: multiple regression, analysis of variance, non-parametric models. The course will include both a theoretical component as well as a practical component in the form of a student project.

MATH 586. ADVANCED TOPICS IN STATISTICS. 5 Credits.
Pre-requisites: MATH 585 and admission to graduate program, or permission of the instructor.
This course provides theory and practice with advanced topics in statistics chosen based on faculty expertise and student interests. Topics may include: generalized linear models, time series analysis, survival analysis. The course will include both a theoretical component as well as a practical component in the form of a student project.

MATH 596. EXPERIMENTAL COURSE. 1-5 Credits.

MATH 597. WORKSHOP, SHORT COURSE, CONFERENCE, SEMINAR. 1-5 Credits.
Notes: only one workshop course for up to 3 credits may be used to fulfill graduate degree requirements.

MATH 598. SEMINAR. 1-5 Credits.
Pre-requisites: permission of the instructor.

MATH 599. DIRECTED STUDY. 1-6 Credits.
Pre-requisites: permission of the instructor, department chair and college dean.

MATH 600. THESIS. 1-15 Credits.
Pre-requisites: permission of the instructor, department chair and college dean.
A research thesis under the direction of a graduate committee.

MATH 601. RESEARCH REPORT. 1-15 Credits.
Pre-requisites: permission of the instructor, department chair and college dean.
A research study in lieu of a bound thesis conducted as partial fulfillment of a master's degree in K–9 mathematics education or applied mathematics under the direction of a graduate committee.

MATH 696. APPLIED MATHEMATICS INTERNSHIP. 1-10 Credits.
Pre-requisites: an approved internship.
This course will consist of an internship with an approved business or research facility.