

# MATHEMATICS (MATH)

## 100 Level Courses

**MATH 104:** *Trigonometry and Transcendental Functions*. 2 credits.

Exponential and logarithmic functions, trigonometric functions, and analytic trigonometry. This course does not satisfy the university's quantitative reasoning requirement. May not be taken for credit after receiving a C or better in MATH 105 or in any MATH course numbered 113 or higher. May not take MATH 105 for credit after receiving a C or better in MATH 104. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (minimum score of 07 in 'Math Placement Algebra II' or MATH 103T).

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 105:** *Precalculus Mathematics*. 4 credits.

Reviews mathematics skills essential to studying calculus. Topics include equations, inequalities, absolute values, graphs, functions, exponential and logarithmic functions, and trigonometry. This course does not satisfy the university's quantitative reasoning requirement for the BA degree. May not be taken for credit after receiving grade of C or better in any MATH course numbered 113 or higher. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (minimum score of 13 in 'Math Placement Algebra I', MATH 103T or minimum score of 55 in 'Math Placement Aleks').

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 106:** *Quantitative Reasoning*. 3 credits.

Quantitative skills for real world. Topics include critical thinking, modeling by functions, graphs, growth, scaling, probability, and statistics. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Mason Core:** Quantitative Reasoning (<http://catalog.gmu.edu/mason-core/>)

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 108:** *Introductory Calculus with Business Applications*. 3 credits.

Functions, limits, derivative, and integral. Applications of differentiation and integration. Notes: Credit for both MATH 108 and any of the following courses: MATH 113, 115, or 124 will not be given. Offered

by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Mason Core:** Quantitative Reasoning (<http://catalog.gmu.edu/mason-core/>)

**Registration Restrictions:**

**Required Prerequisites:** (minimum score of 13 in 'Math Placement Algebra I', MATH 103T<sup>C</sup> or minimum score of 55 in 'Math Placement Aleks').

<sup>C</sup> Requires minimum grade of C.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 110:** *Introductory Probability*. 3 credits.

Elementary set theory, probability, and statistics. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Mason Core:** Quantitative Reasoning (<http://catalog.gmu.edu/mason-core/>)

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 111:** *Linear Mathematical Modeling*. 4 credits.

Matrix algebra, systems of linear equations, Markov chains, difference equations, and data fitting. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Mason Core:** Quantitative Reasoning (<http://catalog.gmu.edu/mason-core/>)

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 113:** *Analytic Geometry and Calculus I*. 4 credits.

Functions, limits, the derivative, maximum and minimum problems, the integral, and transcendental functions. Notes: credit for both Math 108 and Math 113 will not be given. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts. Equivalent to MATH 115, MATH 124.

**Mason Core:** Quantitative Reasoning (<http://catalog.gmu.edu/mason-core/>)

**Registration Restrictions:**

**Required Prerequisites:** (minimum score of 07 in 'Math Placement Transcendentals', MATH 105<sup>C</sup>, 105<sup>XS</sup>, 104<sup>C</sup> or minimum score of 80 in 'Math Placement Aleks').

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture, Recitation

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 114: *Analytic Geometry and Calculus II*. 4 credits.**

Methods of integration, conic sections, parametric equations, infinite series, and power series. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts. Equivalent to MATH 116.

**Registration Restrictions:**

**Required Prerequisites:** ((MATH 113<sup>C</sup>, 113<sup>XS</sup> or U113) or ((MATH 123<sup>C</sup> or 123<sup>XS</sup>) and (MATH 124<sup>C</sup> or 124<sup>XS</sup>) or MATH 115<sup>C</sup>)).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture, Recitation

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 115: *Analytic Geometry and Calculus I (Honors)*. 4 credits.**

More challenging version of MATH 113. Functions, limits, the derivative, maximum and minimum problems, the integral, and transcendental functions. Notes: credit for both Math 108 and Math 115 will not be given. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts. Equivalent to MATH 113.

**Mason Core:** Quantitative Reasoning (<http://catalog.gmu.edu/mason-core/>)

**Recommended Prerequisite:** Permission of instructor.

**Registration Restrictions:**

**Required Prerequisites:** (minimum score of 65 in 'Math Placement Transcendentals' or minimum score of 80 in 'Math Placement Aleks').

**Schedule Type:** Lecture, Recitation

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 116: *Analytic Geometry and Calculus II (Honors)*. 4 credits.**

More challenging version of MATH 114. Methods of integration, conic sections, parametric equations, infinite series, and power series. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts. Equivalent to MATH 114.

**Registration Restrictions:**

**Required Prerequisites:** MATH 115<sup>C</sup>, 115<sup>XS</sup>, U115, 113<sup>A</sup> or 113<sup>XS</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

<sup>A</sup> Requires minimum grade of A.

**Schedule Type:** Lecture, Recitation

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 123: *Calculus with Algebra/Trigonometry, Part A*. 3 credits.**

Math 123, with 124, is a two semester sequence for students with limited math background who desire careers in the sciences. In two semesters, students progress from algebra through the basic calculus covered in Math 113. Math 123 integrates the beginnings of calculus through the derivative with relevant precalculus algebra and trigonometry. Notes: Students who successfully complete Math 123-124 are considered the same as having successfully completed MATH 113 and can sign up for Math 114, Calculus II. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (((minimum score of 13 in 'Math Placement Algebra I' and minimum score of 07 in 'Math Placement Algebra II') or minimum score of 65 in 'Math Placement Aleks') or MATH 105<sup>C</sup>, 105<sup>XS</sup> or 104<sup>C</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 124: *Calculus with Algebra/Trigonometry, Part B*. 3 credits.**

Math 123, with 124, is a two semester sequence for students with limited math background who desire careers in the sciences. In two semesters, students progress from algebra through the basic calculus covered in Math 113. Math 124 will review basic differentiation and applications and then proceed to cover integration including transcendental functions. Notes: Students who successfully complete Math 123-124 are considered the same as having successfully completed MATH 113 and can sign up for Math 114, Calculus II. Notes: credit for both Math 108 and Math 124 will not be given. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts. Equivalent to MATH 113.

**Mason Core:** Quantitative Reasoning (<http://catalog.gmu.edu/mason-core/>)

**Registration Restrictions:**

**Required Prerequisites:** MATH 123<sup>C</sup> or 123<sup>XS</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 125: *Discrete Mathematics I*. 3 credits.**

Introduces ideas of discrete mathematics and combinatorial proof techniques including mathematical induction, sets, graphs, trees, recursion, and enumeration. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Mason Core:** Quantitative Reasoning (<http://catalog.gmu.edu/mason-core/>)

**Registration Restrictions:**

**Required Prerequisites:** (minimum score of 13 in 'Math Placement Algebra I', MATH 103T, 105<sup>C</sup>, 105<sup>XS</sup>, 108<sup>C</sup>, 108<sup>XS</sup>, 113<sup>XS</sup>, 113<sup>C</sup>, 115<sup>C</sup>, 123<sup>C</sup> or minimum score of 65 in 'Math Placement Aleks').

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture, Recitation

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 175: *Mathematics of Cryptography: An Introduction.*** 3 credits.

Every day, 143,000 terabytes of data are transferred across the internet, including financial transactions, medical records, and sensitive client data. Half of this traffic is secured through encryption, relying on mathematical algorithms such as the RSA to encode the data in a way that only the recipient can decode. In this class, we will see how cryptography works first-hand. We will start with classical ciphers (Atbash and Caesar ciphers) and develop our mathematical techniques and programming abilities until we are able to implement RSA from scratch. Topics covered in the course lead into the following majors: mathematics, computer science, electrical engineering, and cyber security engineering. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Recommended Prerequisite:** B or better in a calculus course.

**Schedule Type:** Laboratory, Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

## 200 Level Courses

**MATH 203: *Linear Algebra.*** 3 credits.

Systems of linear equations, linear independence, linear transformations, inverse of a matrix, determinants, vector spaces, eigenvalues, eigenvectors, and orthogonalization. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 114<sup>C</sup>, 114<sup>XS</sup>, 114T, 116<sup>C</sup> or 116<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture, Recitation

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 213: *Analytic Geometry and Calculus III.*** 3 credits.

Partial differentiation, multiple integrals, line and surface integrals, and three-dimensional analytic geometry. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts. Equivalent to MATH 215.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 114<sup>C</sup>, 114<sup>XS</sup>, 114T, 116<sup>C</sup> or 116<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture, Recitation

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 214: *Elementary Differential Equations.*** 3 credits.

First-order ODEs, higher-order ODEs, Laplace transforms, linear systems, nonlinear systems, numerical approximations, and modeling. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts. Equivalent to MATH 216.

**Registration Restrictions:**

**Required Prerequisites:** MATH 213<sup>C</sup>, 213<sup>XS</sup>, 213T, 215<sup>C</sup> or 215<sup>XS</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture, Recitation

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 215: *Analytic Geometry and Calculus III (Honors).*** 3 credits.

Vectors and vectorvalued functions, partial differentiation, multiple integrals, line integrals, surface integrals, and transformation of coordinates. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts. Equivalent to MATH 213.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 114<sup>C</sup>, 114<sup>XS</sup>, 116<sup>C</sup> or 116<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture, Recitation

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 216: *Theory of Differential Equations.*** 3 credits.

First- and second-order equations, existence uniqueness of solutions, systems of differential equations, and phase plane analysis. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts. Equivalent to MATH 214.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 203<sup>C</sup>, 203<sup>XS</sup> or U203) and (MATH 213<sup>C</sup>, 213<sup>XS</sup>, U213, 215<sup>C</sup>, 215<sup>XS</sup> or U215).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 271: *Mathematics for the Elementary School Teachers I.*** 3 credits. Concepts and theories underlying elementary school mathematics including problem solving, patterns, sequences, set theory, numeration, number sense, operations and properties of integers, whole, rational, irrational and real numbers, number theory, ratio, proportion, percent and mathematical systems. Notes: Does not count toward major in mathematics. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Recommended Prerequisite:** Grade of C or better in 3 credits of college math.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 272: *Mathematics for the Elementary School Teachers II.*** 3 credits. Continuation of MATH 271. Concepts and theories underlying elementary school mathematics including functions, algebra, geometry, statistics, and probability. Notes: Intended for school educators; does not count toward major in mathematics. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Mason Core:** Quantitative Reasoning (<http://catalog.gmu.edu/mason-core/>)

**Registration Restrictions:**

**Required Prerequisites:** (MATH 271<sup>C</sup> or 271<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

### 300 Level Courses

**MATH 300: *Introduction to Advanced Mathematics.*** 3 credits. Introduction to proofs and the language of mathematics. Topics include induction, equivalence relations, cardinality, and basic properties of the real numbers. Designated as a writing intensive course for mathematics majors. Notes: Primarily intended for mathematics majors. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts. Equivalent to MATH 290.

**Specialized Designation:** Writing Intensive in Major

**Registration Restrictions:**

**Required Prerequisites:** ((MATH 114<sup>C</sup>, 114<sup>XS</sup>, 114T or 116<sup>C</sup>) and (MATH 125<sup>C</sup>, 125<sup>XS</sup>, 125T or 175<sup>C</sup>)).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 301: *Number Theory.*** 3 credits.

Prime numbers, factorization, congruences, and Diophantine equations. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Recommended Prerequisite:** Completion of 6 hours of MATH.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 302: *Foundations of Geometry.*** 3 credits.

Axioms, theorems and proofs of Euclidean, non-Euclidean, and projective geometry. Fundamental concepts of incidence. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** MATH 114<sup>C</sup>, 114<sup>XS</sup>, 116<sup>C</sup> or 116<sup>XS</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 307: *Mathematical Modeling.*** 3 credits.

Focuses on the development and analysis of mathematical models that make qualitative and quantitative predictions. Students will address particular situations while learning general modeling strategies. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 203<sup>C</sup> or 203<sup>XS</sup>) and (MATH 214<sup>C</sup>, 214<sup>XS</sup> or 216<sup>C</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 312: *Geometry.*** 3 credits.

Two and three dimensional analytic geometry, geometric transformations, projective geometry, conics and quadric surfaces, spherical geometry, vector geometry. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Recommended Prerequisite:** Math 300

**Registration Restrictions:**

**Required Prerequisites:** (MATH 114<sup>C</sup>, 114<sup>XS</sup>, 116<sup>C</sup> or 116<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 313: *Introduction to Applied Analysis*.** 3 credits.

Vector differential calculus, vector integral calculus, and complex analysis. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 213<sup>C</sup>, 213<sup>XS</sup>, 213T, 215<sup>C</sup> or 215<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 314: *Advanced Differential Equations*.** 3 credits.

Qualitative approaches to the study of ODEs. Eigenvalues, eigenvectors and the solution of linear systems of equations. Phase lines and phase planes. Nonlinear ODEs. Linearization, stability and classification of equilibrium. Hamiltonian, gradient and conservative systems. Bifurcations in planar systems. Illustration of concepts using models from physics, biology, chemistry, and ecology. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 214<sup>C</sup>, U214, 214<sup>XS</sup>, 216<sup>C</sup> or U216).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 315: *Advanced Calculus I*.** 3 credits.

Number system, functions, sequences, limits, continuity, differentiation, integration, transcendental functions, and infinite series. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** ((MATH 213<sup>C</sup>, 213<sup>XS</sup>, 215<sup>C</sup> or 215<sup>XS</sup>) and (MATH 300<sup>C</sup> or 300<sup>XS</sup>)).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 316: *Advanced Calculus II*.** 3 credits.

Sequences of functions, Taylor series, vectors, functions of several variables, implicit functions, multiple integrals, and surface integrals. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 315<sup>C</sup>, 315<sup>XS</sup> or L315).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 321: *Abstract Algebra*.** 3 credits.

Theory of groups, rings, fields. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** ((MATH 213<sup>C</sup>, 213<sup>XS</sup>, 215<sup>C</sup> or 215<sup>XS</sup>) and (MATH 300<sup>C</sup> or 300<sup>XS</sup>)).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 322: *Advanced Linear Algebra*.** 3 credits.

Abstract vector spaces, linear independence, bases, linear transformations, matrix algebra, inner product, and special topics. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** ((MATH 203<sup>C</sup>, 203<sup>XS</sup> or U203) and (MATH 300<sup>C</sup> or 300<sup>XS</sup>)).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 325: *Discrete Mathematics II*.** 3 credits.

Advanced counting, binomial identities, generating functions, advanced recurrence, inclusion-exclusion, and network flows. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 125<sup>C</sup>, 125<sup>XS</sup> or 125T).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 351: *Probability*.** 3 credits.

Random variables, probability functions, special distributions, and limit theorems. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:****Required Prerequisites:** MATH 213<sup>C</sup>, 213<sup>XS</sup>, 215<sup>C</sup>, 215<sup>XS</sup> or 215T.<sup>C</sup> Requires minimum grade of C.<sup>XS</sup> Requires minimum grade of XS.**Schedule Type:** Lecture**Grading:**This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)**MATH 352: Statistics.** 3 credits.Estimation, decision theory, testing hypothesis, correlation, linear models, and design. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.**Registration Restrictions:****Required Prerequisites:** (MATH 351<sup>C</sup>, 351<sup>XS</sup> or L351).<sup>C</sup> Requires minimum grade of C.<sup>XS</sup> Requires minimum grade of XS.**Schedule Type:** Lecture**Grading:**This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)**400 Level Courses****MATH 400: History of Math (Topic Varies).** 3 credits.Explores internal controversies and dynamics of mathematics in larger intellectual and social settings. Topics vary but might include differential equations devised for mechanics and astronomy by Euler, Lagrange, and Laplace; foundation of mathematical analysis from Cauchy to Weierstrass; algebras of Galois and Boole; or creation of non-Euclidean geometry and Cantor's transfinite sets. Notes: Credits may not be used toward "upper division" math hours required of math majors. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.**Mason Core:** Synthesis (<http://catalog.gmu.edu/mason-core/>)**Specialized Designation:** Topic Varies**Registration Restrictions:****Required Prerequisites:** MATH 300<sup>C</sup> or 300<sup>XS</sup>.<sup>C</sup> Requires minimum grade of C.<sup>XS</sup> Requires minimum grade of XS.**Schedule Type:** Lecture**Grading:**This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)**MATH 401: Mathematics through 3D Printing.** 3 credits.Incorporates new mathematics from a large variety of fields into the design and creation of 3D printed models, as well as the written and oral communication of these mathematical ideas. Topics vary but might include regular and quasiregular tilings, Platonic and Archimedean solids and their duality, orientable and non-orientable surfaces, fractals, chaotic attractors, Riemann surfaces, and data visualization. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.**Mason Core:** Capstone (<http://catalog.gmu.edu/mason-core/>)**Recommended Prerequisite:** MATH 300 and at least 3 credits of Mathematics above MATH 300.**Schedule Type:** Lecture**Grading:**This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)**MATH 405: Honors Thesis in Mathematics I.** 3 credits.A project, which is intended to result in a thesis, is to be chosen and completed under the guidance of a full-time faculty member. An oral presentation is required for MATH 405. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.**Specialized Designation:** Mason Impact.**Recommended Prerequisite:** MATH 315, three additional credits of MATH above the 300 level (excluding MATH 400) and admission to the Honors Program in Mathematics.**Schedule Type:** Independent Study**Grading:**This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)**MATH 406: RS: Honors Thesis in Mathematics II.** 3 credits.A project, which is intended to result in a thesis, is to be chosen and completed under the guidance of a full-time faculty member. Oral and written presentations are required in MATH 406. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.**Specialized Designation:** Research/Scholarship Intensive**Registration Restrictions:****Required Prerequisite:** (MATH 405<sup>C</sup>).<sup>C</sup> Requires minimum grade of C.**Schedule Type:** Independent Study**Grading:**This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)**MATH 411: Functions of a Complex Variable.** 3 credits.Analytic functions, contour integration, residues, and applications to such topics as integral transforms, generalized functions, and boundary value problems. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.**Recommended Prerequisite:** Math 300**Registration Restrictions:****Required Prerequisites:** (MATH 214<sup>C</sup>, 214<sup>XS</sup> or 214T) or (MATH 216<sup>C</sup> or 216T).<sup>C</sup> Requires minimum grade of C.<sup>XS</sup> Requires minimum grade of XS.**Schedule Type:** Lecture**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 413: Modern Applied Mathematics I.** 3 credits.

Synthesis of pure mathematics and computational mathematics. Emphasizes interplay between discrete and continuous mathematics. Mathematical structure revealed from equilibrium models in discrete and continuous systems. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 203<sup>C</sup>, 203<sup>XS</sup> or 203T) and (MATH 214<sup>C</sup>, 214<sup>XS</sup> or 214T) or (MATH 216<sup>C</sup> or 216T).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 414: Modern Applied Mathematics II.** 3 credits.

Continuation of MATH 413, which involves synthesis of pure mathematics and computational mathematics. Fourier analysis and its role in applied mathematics developed (differential equations and approximations). Discrete aspects emphasized in computational models. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** MATH 413<sup>C</sup> or 413<sup>XS</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 421: Abstract Algebra II.** 3 credits.

Expands on the algebraic structure of groups from the first course in abstract algebra to introduce rings and fields. All three structures are explored via Galois theory, which shows the vital interconnectivity of the three structures, and how this can be applied to obtain deep theorems about the symmetries among roots of a polynomial. Topics include: rings, ideals, homomorphisms, polynomial rings, factorization, divisibility, vector spaces, extension fields (algebraic and transcendental), the fundamental theorem of field theory, splitting fields, classification of finite fields, constructible numbers, impossibility theorems for angle trisection and circle squaring, the fundamental theorem of Galois theory, and solvability of polynomials by radicals. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 321<sup>C</sup> or 321<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 431: Topology.** 3 credits.

Metric spaces, topological spaces, compactness, and connectedness. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 315<sup>C</sup> or 315<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 432: Differential Geometry.** 3 credits.

Explores the geometry of curves and surfaces, with a focus on differential (smooth) spaces. Students will explore precise characterizations of length of curves, curvature, dimension, and vector fields on curves and surfaces. Additional topics may include the geometry of the Gauss Map, intrinsic and extrinsic properties of curves and surfaces, and the Gauss-Bonnet Theorem. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 315<sup>C</sup> or 315<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 433: Algebraic Geometry.** 3 credits.

Integrates topics from algebra directly into the geometric context through the study of algebraic varieties. Methods require the use of fields, rings, ideals to describe geometric objects. Topics include affine varieties, Hilbert's Basis Theorem, Gröbner bases, Buchberger's Criterion and Algorithm, parametrizations, Hilbert's Nullstellensatz, and the Algebra-Geometry Dictionary. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 321<sup>C</sup> or 321<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 441: Deterministic Operations Research.** 3 credits.

Survey of deterministic methods for solving real-world decision problems. Programming model and simplex method of solution, duality and sensitivity analysis, transportation and assignment problems, shortest

path and maximal flow problems, project networks including PERT and CPM, introduction to integer and nonlinear programming, dynamic programming, and game theory. Emphasizes modeling and problem solving. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts. Equivalent to OR 441.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 203<sup>C</sup>, 203<sup>XS</sup> or 203T).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 442: Stochastic Operations Research.** 3 credits.

Survey of probabilistic methods for solving decision problems under uncertainty, probability review, decision theory, queuing theory, inventory models, forecasting, Markov chain models, and simulation are covered. Emphasis on modeling and problem solving. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts. Equivalent to OR 442.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 351<sup>C</sup> or 351<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 446: Numerical Analysis I.** 3 credits.

Significant figures, round-off errors, iterative methods of solution of nonlinear equations of a single variable, solutions of linear systems, iterative techniques in matrix algebra, interpolation and polynomial approximation. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts. Equivalent to OR 481.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 203<sup>C</sup>, 203<sup>XS</sup> or 203T) and (CS 112<sup>C</sup>, 112<sup>XS</sup> or 112T).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 447: Numerical Analysis II.** 3 credits.

Numerical differentiation and integration, initial-value and boundary-value problems for ordinary differential equations, methods of solution of partial differential equations, iterative methods of solution of nonlinear systems, approximation theory. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts. Equivalent to CDS 410.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 214<sup>C</sup>, 214<sup>XS</sup>, 214T, 216<sup>C</sup> or 216T) and (MATH 446<sup>C</sup> or 446<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 453: Advanced Mathematical Statistics.** 3 credits.

Topics from statistics relevant to the field of actuarial science, such as: forecasting and time series, maximum likelihood tests, sufficiency, most powerful tests, distributions of quadratic forms, topics from nonparametric statistics, Bayesian statistics, and linear models. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** MATH 352<sup>C</sup>, 352<sup>XS</sup> or STAT 356<sup>C</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 462: Mathematics of Machine Learning and Industrial Applications I.** 2 credits.

Basic mathematical optimization and probability theory in the context of classical learning and gradient based methods including neural networks. Incorporates modern tools such as Python, shell tools, and version control. Includes industrial applications in satellite imagery, physics, biology and engineering. Computational and analytic assignments are given. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** ((MATH 203<sup>C</sup> or 203<sup>XS</sup>) and MATH 213<sup>C</sup> or 213<sup>XS</sup>) and (CS 112<sup>C</sup> or 112<sup>XS</sup>).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 463: Mathematics of Machine Learning and Industrial Applications II.** 2 credits.

Basic mathematical and probabilistic models and derivations for convolutions, stability, regularization, inverse and optimal control problems, and dynamical systems in the context of semi-supervised learning. Mathematical and numerical aspects of stochastic descent methods, Nesterov accelerated gradient, AdaGrad, Adam, with applications to convolutional, deep, and ODE networks. Further applications include imaging and computer vision, saliency maps, segmentation, satellite Imagery, and physics informed learning. Offered



by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 462<sup>\*C</sup> or 462<sup>\*XS</sup>).

\* May be taken concurrently.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 464:** *Linear Algebra with Data Applications*. 3 credits.

Structure of linear spaces and the operator algebra, duality, invariants, Jordan and singular value decompositions, spectral theorem. Rigorous derivation of foundational data science methods such as PCA, MDS, and SVM. Computational and analytic assignments are given. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** ((MATH 322<sup>C</sup> or 322<sup>XS</sup>) and (CS 112<sup>C</sup> or 112<sup>XS</sup>)).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 465:** *Mathematics of Data Science*. 3 credits.

Covers mathematical aspects of data science including theory of linear and nonlinear dimension reduction, elements of spectral graph theory, function spaces and regularity in regression, and data-driven dynamics identification and discovery. Computational and analytic assignments are given. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Recommended Prerequisite:** MATH 352 or STAT 350 or STAT 360 or STAT 356

**Registration Restrictions:**

**Required Prerequisites:** ((MATH 214<sup>C</sup> or 214<sup>XS</sup>) and (MATH 464<sup>C</sup> or 464<sup>XS</sup>)).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 478:** *Introduction to Partial Differential Equations with Numerical Methods*. 3 credits.

Introduces basic facts about partial differential equations, including elliptic equations, parabolic equations and hyperbolic equations. Methods of solution, characteristics, initial/boundary-value problems, and numerical approximation techniques. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 203<sup>C</sup>, 203<sup>XS</sup> or 203T) and (MATH 214<sup>C</sup>, 214<sup>XS</sup> or 214T) or (MATH 216<sup>C</sup> or 216T).

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 490:** *Internship*. 1-3 credits.

Professional work experience for Mathematics majors and minors working in education, industry and government laboratories, including summer programs. Students looking for experiential credit in mathematics teaching may also use this course. Supervision and approval of this course must be arranged with the department before registering. Notes: Credit will be assigned based on the number of hours participating in the internship: 1 Credit for every 45 hours of internship work. At least one substantive piece of work will be assessed for each internship credit being undertaken. Students may take up to 3 internship credits per semester. Up to 3 credits may be used toward "upper division" math hours required of math majors. May be repeated within degree and in combination with Math 491 for a total of 12 credits between the two classes. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May be repeated within the degree for a maximum 12 credits.

**Registration Restrictions:**

Enrollment limited to students with a class of Junior Plus, Junior, Senior Plus or Senior.

Enrollment is limited to students with a major, minor, or concentration in Mathematics.

**Schedule Type:** Internship

**Grading:**

This course is graded on the Satisfactory/No Credit scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 491:** *Reading and Undergraduate Research in Mathematics*. 1-3 credits.

For mathematical sciences majors only. Independent study or directed research project in mathematics. Notes: Must be arranged with instructor before registering. Up to 6 credits may be used toward "upper division" math hours required of math majors. May be repeated within term and in combination with Math 490 for a total of 12 credits between the two classes. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May be repeated within the term for a maximum 12 credits.

**Specialized Designation:** Topic Varies

**Recommended Corequisite:** For mathematical science majors only.

**Schedule Type:** IND/INT #1, IND/INT #2, IND/INT #3, IND/INT #4, IND/INT #5, IND/INT #6, IND/INT #7, IND/INT #8, IND/INT #9, Independent Study

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 493: Topics in Applicable Mathematics.** 3 credits.

Topics that have been successfully used in applications of mathematics. Notes: Subject determined by instructor. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May be repeated within the degree for a maximum 12 credits.

**Specialized Designation:** Topic Varies

**Recommended Prerequisite:** 6 credits of MATH at or above the 310 level.

**Schedule Type:** Lecture, Recitation

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 494: Topics in Pure Mathematics.** 3 credits.

Topics of pure math not covered in other courses. Topics might include Galois theory, cardinal and ordinal arithmetic, measure theory, mathematical logic, and differential geometry. Notes: Subject determined by instructor. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May be repeated within the term for a maximum 12 credits.

**Specialized Designation:** Topic Varies

**Recommended Prerequisite:** 6 hours of MATH at or above the 310 level.

**Schedule Type:** Lec/Sem #1, Lec/Sem #2, Lec/Sem #3, Lec/Sem #4, Lec/Sem #5, Lec/Sem #6, Lec/Sem #7, Lec/Sem #8, Lec/Sem #9, Lecture, Sem/Lec #10, Sem/Lec #11, Sem/Lec #12, Sem/Lec #13, Sem/Lec #14, Sem/Lec #15, Sem/Lec #16, Sem/Lec #17, Sem/Lec #18

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 495: Undergraduate Seminar.** 1 credit.

Seminars on selected topics in mathematics focused on preparing students for research opportunities, internships, careers, or graduate school in mathematics. Topics will vary. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May be repeated within the degree for a maximum 3 credits.

**Schedule Type:** Seminar

**Grading:**

This course is graded on the Undergraduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**500 Level Courses****MATH 551: Regression and Time Series.** 3 credits.

Mathematics of regression, exponential smoothing, time series, and forecasting. Material included in this course constitutes Society of Actuaries Validation by Educational Experience (VEE) for applied statistics and corresponds to part of Casualty Actuary Society Exam 3. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 352, STAT 652, SOA exam P, or permission of instructor.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 553: Advanced Mathematical Statistics in Actuarial Sciences.** 3 credits.

Topics from statistics relevant to the field of actuarial science, such as: forecasting and time series, maximum likelihood tests, sufficiency, most powerful tests, distributions of quadratic forms, topics from nonparametric statistics, Bayesian statistics, and linear models. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Registration Restrictions:**

**Required Prerequisites:** MATH 352<sup>C</sup>, 352<sup>XS</sup>, STAT 356<sup>C</sup>, 356<sup>XS</sup>, MATH 554<sup>C</sup> or 554<sup>XS</sup>.

<sup>C</sup> Requires minimum grade of C.

<sup>XS</sup> Requires minimum grade of XS.

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 554: Financial Mathematics.** 3 credits.

Simple and compound interest, annuities, present and future value, yield rates, capital budgeting, amortization schedules, mortgages, bonds. Material corresponds to the Society of Actuaries Exam: Financial Mathematics (FM). Not appropriate for graduate science and engineering majors not considering actuarial or financial career. Cannot be counted toward MS or PhD degree in mathematics. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 113.

**Recommended Corequisite:** MATH 114.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 555: Actuarial Modeling I.** 3 credits.

Two-semester sequence covering portions of the material corresponding to the Society of Actuaries Exam M, Casualty Actuary Society Exam 3, and Joint Board Exam EA1. The remaining material for these exams is covered in MATH 551 and 653. Topics include survival distribution and life tables, life insurance, life annuities, net premiums, net premium reserves, multiple life and multiple decrement models, pensions, insurance models including expense, and nonforfeiture benefits and cash values. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 554 and either MATH 351 or STAT 344.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 556: Actuarial Modeling II.** 3 credits.

Two-semester sequence covering portions of the material corresponding to the Society of Actuaries Exam M, Casualty Actuary Society Exam 3, and Joint Board Exam EA1. The remaining material for these exams is covered in MATH 551 and 653. Topics include survival distribution and life tables, life insurance, life annuities, net premiums, net premium reserves, multiple life and multiple decrement models, pensions, insurance models including expense, and nonforfeiture benefits and cash values. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 554 and either MATH 351 or STAT 344.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 557: Financial Derivatives.** 3 credits.

Fundamentals of pricing derivative securities, including Black-Scholes formalism and no-arbitrage pricing models. Exotic options, Monte-Carlo simulation, and interest rate models. Material corresponds to the Society of Actuaries Exam MFE: Act. Models and Fin. Econ. Offered

by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 554 and either MATH 351 or STAT 344, or permission of instructor.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**600 Level Courses****MATH 600: Special Topics in Mathematics.** 1-6 credits.

Mathematical workshops, special courses, or other projects. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May be repeated within the term for a maximum 12 credits.

**Specialized Designation:** Topic Varies

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lec/Sem #1, Lec/Sem #2, Lec/Sem #3, Lec/Sem #4, Lec/Sem #5, Lec/Sem #6, Lec/Sem #7, Lec/Sem #8, Lec/Sem #9, Lecture, Sem/Lec #10, Sem/Lec #11, Sem/Lec #12, Sem/Lec #13, Sem/Lec #14, Sem/Lec #15, Sem/Lec #16, Sem/Lec #17, Sem/Lec #18

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 601: Analysis I for Teachers.** 3 credits.

Develops continuous ideas of calculus with particular emphasis on concepts as opposed to computational aspects of calculus. Specific topics include decimal representation of real numbers, sequences, series, and limits; differentiation to find speed, slopes of curves, and tangents; integration to find volumes and distances and area under curves. Optimization problems including maximization of area and volume, and modeling of these concepts. Graphing techniques supported by theory of calculus and graphing utilities such as TI-83 calculator or computer software such as Maple. Notes: Background in mathematics desirable but not necessary. Some topics from college algebra will be reviewed in class, but thorough understanding of high school algebra and trigonometry expected. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Corequisite:** Open only to inservice math teachers at the middle or secondary level, or by permission of instructor.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 602: *Analysis II for Teachers.* 3 credits.**

Develops continuous ideas of calculus with particular emphasis on concepts as opposed to computational aspects of calculus. Specific topics include decimal representation of real numbers, sequences, series, and limits; differentiation to find speed, slopes of curves, and tangents; integration to find volumes and distances and area under curves. Optimization problems including maximization of area and volume, and modeling of these concepts. Graphing techniques supported by theory of calculus and graphing utilities such as TI-83 calculator or computer software such as Maple. Notes: Background in mathematics desirable but not necessary. Some topics from college algebra will be reviewed in class, but thorough understanding of high school algebra and trigonometry expected. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Corequisite:** Open only to inservice math teachers at the middle or secondary level, or by Permission of Instructor.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 604: *Geometry for Teachers.* 3 credits.**

Covers standard topics from Euclidean geometry, and includes discussion of non-Euclidean geometries. Emphasizes informal and explorative approach to geometry, and makes use of geometry sketchpad. Other topics include geometric constructions, and role of proof in geometry. Notes: Background in mathematics desirable but not necessary. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Corequisite:** Open only to inservice math teachers at the middle or secondary level, or by permission of instructor.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 605: *Discrete/Finite Mathematics for Teachers.* 3 credits.**

Thorough understanding of high school algebra assumed. Discusses finite mathematics in juxtaposition to continuous ideas of calculus. Topics may consist of elementary counting and combinatorics including recursion and difference equations and their analogy to calculus; thorough discussion of probability and central measures of statistics; and graph theory and its connection to geometry. Notes: Background in mathematics desirable but not necessary. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Corequisite:** Open only to inservice math teachers at the middle or secondary level, or by permission of instructor.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 607: *Algebraic Structure for Teachers.* 3 credits.**

Expands on customary operations on integers and rationals to discuss systems that mimic these operations. Emphasizes multiplicative and additive inverses and their corresponding identities as they occur in other systems. Topics might include permutation groups, rigid transformations, groups of symmetry of the plane and connection to geometry, and matrices treated as linear transformations and connections to solutions of systems of equations. Notes: Background in mathematics desirable but not necessary. Thorough understanding of high school algebra assumed. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Corequisite:** Open only to inservice math teachers at the middle or secondary level, or by permission of instructor.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 608:** *Problem Solving in Mathematics*. 3 credits.

Introduces variety of challenging mathematical problems appropriate for middle school student to analyze, and solving problems using mathematics learned in previous courses. Also asks students to search for such problems and orally present solutions. Notes: Background in mathematics or science desirable but not necessary. Assumes exposure to most of topics covered in MATH 601, 604, 605, and 607. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Corequisite:** Open only to inservice math teachers at the middle or secondary level, or by Permission of Instructor.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 610:** *Number Systems and Number Theory for K-8 Teachers*. 3 credits.

This course covers the topics: ways of representing numbers, relationships between numbers, number systems, the meanings of operations and how they relate to one another, and computation within the number system as a foundation for algebra. It also includes episodes in history and development of the number system, and will examine the developmental sequence and learning trajectory as children learn this material. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 611:** *Geometry and Measurement for K-8 Teachers*. 3 credits.

The course explores the foundations of informal measurement and geometry 'in one, two, and three dimensions. The van Hiele model for geometric learning is used as a framework for how children build

their understanding of length, area, volume, angles, and geometric relationships. Visualization, spatial reasoning, and geometric modeling are stressed. As appropriate, transformational geometry, congruence, similarity, and geometric constructions will be discussed. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 612:** *Probability and Statistics for K-8 Teachers*. 3 credits.

An introduction to probability, descriptive statistics, and data analysis. Topics studied will include the exploration of randomness, data representation, modeling. Descriptive statistics will include measures of central tendency, dispersion, distributions, and regression. The analysis of experiments requiring hypothesizing, experimental design and data gathering will also be discussed. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 613:** *Algebra and Functions for K-8 Teachers*. 3 credits.

The course will examine representing and analyzing mathematical situations and structures using generalization and algebraic symbols and reasoning. Attention will be given to the transition from arithmetic to algebra, working with quantitative change, and the description of and prediction of change. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 614: *Rational Numbers and Proportional Reasoning for K-8 Teachers.*** 3 credits.

This course will cover the basic number strands in fractions and rational numbers, decimals and percents, and ratios and proportions in the school curriculum. Instruction will cover interpretations, computations, and estimation with a coordinated program of activities that develop both rational number concepts and skills and proportional reasoning. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 619: *Topics in Mathematical Logic.*** 3 credits.

Special topics in foundations of mathematics not included in regular mathematics curriculum. May be repeated for credit. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May be repeated within the term for a maximum 12 credits.

**Specialized Designation:** Topic Varies

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lec/Sem #1, Lec/Sem #2, Lec/Sem #3, Lec/Sem #4, Lec/Sem #5, Lec/Sem #6, Lec/Sem #7, Lec/Sem #8, Lec/Sem #9, Lecture, Sem/Lec #10, Sem/Lec #11, Sem/Lec #12, Sem/Lec #13, Sem/Lec #14, Sem/Lec #15, Sem/Lec #16, Sem/Lec #17, Sem/Lec #18

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 621: *Algebra I.*** 3 credits.

Groups, linear algebra, and matrix groups. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** Familiarity with basic properties of groups and rings or permission of instructor.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 624: *Euclidean Geometry.*** 3 credits.

Euclidean space, geometry of k-dimensional planes, the affine structure of Euclidean space, rigid motions and similarities, parallelotopes and volumes, convex polytopes, quadric surfaces, and additional topics by instructor's choice. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 315 and MATH 322, or equivalent.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 625: *Numerical Linear Algebra.*** 3 credits.

Theory and development of numerical algorithms for solving variety of matrix problems: linear systems, least squares problems, eigenvalue problems, and singular value decomposition. Direct and iterative method, analysis of sensitivity to rounding errors, and applications. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit. Equivalent to CSI 740.

**Recommended Prerequisite:** Computer literacy, including some programming experience.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 629:** *Topics in Algebra*. 3 credits.

Special topics in pure and applied algebra not covered in regular algebra. May be repeated for credit when topic varies. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May be repeated within the term for a maximum 12 credits.

**Specialized Designation:** Topic Varies

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lec/Sem #1, Lec/Sem #2, Lec/Sem #3, Lec/Sem #4, Lec/Sem #5, Lec/Sem #6, Lec/Sem #7, Lec/Sem #8, Lec/Sem #9, Lecture, Sem/Lec #10, Sem/Lec #11, Sem/Lec #12, Sem/Lec #13, Sem/Lec #14, Sem/Lec #15, Sem/Lec #16, Sem/Lec #17, Sem/Lec #18

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 631:** *Topology I: Topology of Metric Spaces*. 3 credits.

Covers definition and basic examples of metric spaces, open and closed sets, subspaces and finite products, sequences and convergence, compactness and separability, continuous functions, uniform continuity, metric space  $C(X)$  and uniform convergence, and homotopy. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 315 or equivalent.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 639:** *Topics in Geometry and Topology*. 3 credits.

Special topics in geometry and topology not covered in regular geometry and topology sequence. May be repeated for credit when topic varies. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May be repeated within the term for a maximum 12 credits.

**Specialized Designation:** Topic Varies

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lec/Sem #1, Lec/Sem #2, Lec/Sem #3, Lec/Sem #4, Lec/Sem #5, Lec/Sem #6, Lec/Sem #7, Lec/Sem #8, Lec/Sem #9, Lecture, Sem/Lec #10, Sem/Lec #11, Sem/Lec #12, Sem/Lec #13, Sem/Lec #14, Sem/Lec #15, Sem/Lec #16, Sem/Lec #17, Sem/Lec #18

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 641:** *Combinatorics and Graph Theory*. 3 credits.

Covers enumerative combinatorics, including partially ordered sets; Moebius inversion and generating functions; and major topics in graph theory such as graph coloring, Ramsey theory, and matching. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 321 or equivalent.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 644:** *Convex and Discrete Geometry*. 3 credits.

Basic properties of Euclidean space, convex sets and convex cones, convex hulls, extremal structure of convex sets, support and separation properties, polyhedra and polytopes, special classes of convex sets, Helly-type theorems, selected problems of discrete geometry. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 315 and MATH 322, or equivalent.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 649:** *Topics in Combinatorics*. 3 credits.

Special topics in combinatorics not covered in regular combinatorics sequence. May be repeated for credit. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May be repeated within the term for a maximum 9 credits.

**Specialized Designation:** Topic Varies

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lec/Sem #1, Lec/Sem #2, Lec/Sem #3, Lec/Sem #4, Lec/Sem #5, Lec/Sem #6, Lec/Sem #7, Lec/Sem #8, Lec/Sem #9, Lecture, Sem/Lec #10, Sem/Lec #11, Sem/Lec #12, Sem/Lec #13, Sem/Lec #14, Sem/Lec #15, Sem/Lec #16, Sem/Lec #17, Sem/Lec #18

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 653: Construction and Evaluation of Actuarial Models I.** 3 credits.

Economics of insurance, individual risk models for short term, collective risk models for single period, collective risk models over an extended period, and applications of risk theory. Material included in this course corresponds to portions of the Society of Actuaries Exam M and Casualty Actuary Society Exam 3. The remaining material for these exams is covered in MATH 551, 555, and 556. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 351 or STAT 644 required. MATH 555 recommended but not required.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 654: Construction and Evaluation of Actuarial Models II.** 3 credits.

Nature and properties of survival and loss models, methods of estimates from complete and incomplete data, tabular and parametric models, and practical issues in survival model estimation. Material included in this course corresponds to most of the Society of Actuaries Exam C and Casualty Actuary Society Exam 4. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 556 or permission of instructor.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 655: Pension Valuation.** 3 credits.

Basic mathematics used in pension actuarial work without regard to pension law. Material included in this course corresponds to all of the Joint Board Exam EA-2A and portions of the Society of Actuaries Exam 8. This course cannot be counted toward the MS or PhD degree in mathematics. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 556, SOA Exam EA-1, or permission of instructor.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 661: Complex Analysis I.** 3 credits.

Topology of complex numbers, holomorphic functions, series, complex integration. Meromorphic, multivalued, and elliptic functions. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 662: Mathematics of Machine Learning and Industrial Applications I.** 2 credits.

Basic mathematical and probabilistic models and derivations for linear and logistic regression including regularization and application to SVM and PCA. Mathematical and numerical aspects of classical learning methods such as Kernel methods and gradient based methods including neural networks. Incorporates modern tools such as Python, shell tools, and version control. Includes industrial scale applications in satellite imagery, physics, biology and engineering. Computational and analytic assignments are given. Offered by Mathematics (<http://catalog.gmu.edu/>)



colleges-schools/science/mathematical-sciences/). Limited to three attempts.

**Recommended Prerequisite:** CS 112 or equivalent.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 663: *Mathematics of Machine Learning and Industrial Applications II.*** 2 credits.

Basic mathematical and probabilistic models and derivations for convolutions, stability, regularization, inverse and optimal control problems, and dynamical systems in the context of semi-supervised learning. Mathematical and numerical aspects of stochastic descent methods, Nesterov accelerated gradient, AdaGrad, Adam, with applications to convolutional, deep, and ODE networks. Further applications include imaging and computer vision, saliency maps, segmentation, satellite Imagery, and physics informed learning. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 662<sup>\*B-</sup> or 662<sup>\*XS</sup>).

\* May be taken concurrently.

<sup>B-</sup> Requires minimum grade of B-.

<sup>XS</sup> Requires minimum grade of XS.

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 664: *Linear Algebra with Data Applications.*** 3 credits.

Structure of linear spaces and the operator algebra, duality, invariants, Jordan and singular value decompositions, spectral theorem. Rigorous derivation of foundational data science methods such as PCA, MDS, and SVM. Computational and analytic assignments are given. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Recommended Prerequisite:** MATH 322 or equivalent and basic programming experience.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 665: *Mathematics of Data Science.*** 3 credits.

Covers mathematical aspects of data science including theory of linear and nonlinear dimension reduction, elements of spectral graph theory, function spaces and regularity in regression, and data-driven dynamics identification and discovery. Computational and analytic assignments are given. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). Limited to three attempts.

**Registration Restrictions:**

**Required Prerequisites:** (MATH 664<sup>B-</sup> or 664<sup>XS</sup>).

<sup>B-</sup> Requires minimum grade of B-.

<sup>XS</sup> Requires minimum grade of XS.

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 671: *Fourier Analysis.*** 3 credits.

Study of fundamental ideas in Fourier analysis. Topics include orthonormal systems, Fourier series, continuous and discrete Fourier transform theory, generalized functions, and introduction to spectral analysis. Uses applications to physical sciences, linear systems theory, and signal processing to integrate topics. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 673: *Dynamical Systems.*** 3 credits.

Contemporary topics in nonlinear dynamical systems illustrated in mathematical models from physics, ecology, and population dynamics. Traditional qualitative analysis of difference and differential equations provides background for understanding chaotic behavior when it occurs in these models. Topics include stability theory, fractals, Lyapunov exponents, and chaotic attractors. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit. Equivalent to MATH 661.

**Recommended Prerequisite:** Elementary courses in linear algebra and differential equations.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 674:** *Stochastic Differential Equations*. 3 credits.

Introduces stochastic calculus and differential equations. Includes Wiener process, Ito and Stratonovich integrals, Ito formula, martingales, diffusions, and applications, including financial applications. Simulations and numerical approximations of solutions. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 214 and 351.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 675:** *Linear Analysis*. 3 credits.

Metric spaces, normed linear spaces, completeness, compactness, continuous (bounded) linear transformations, Banach spaces, Hilbert spaces, and orthogonal series. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 315 and MATH 322, or equivalent.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 677:** *Ordinary Differential Equations*. 3 credits.

Qualitative and quantitative theory of ordinary differential equations. Phase portrait analysis of linear and nonlinear systems, including

classification of stable and unstable equilibrium states and periodic orbits. Poincare-Bendixson theorem, Lyapunov stability and Lyapunov functions, and bifurcation theory. Optional topics include averaging and perturbation methods, numerical solution techniques, and chaos. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 214 or equivalent.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 678:** *Partial Differential Equations*. 3 credits.

Physical examples, characteristics, boundary value problems, integral transforms, and other topics, such as variational, perturbation, and asymptotic methods. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** Elementary differential equations course.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 679:** *Topics in Analysis and Potential Theory*. 3 credits.

Special topics not covered in regular analysis or potential theory sequence. May be repeated for credit when topic varies. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May be repeated within the term for a maximum 12 credits.

**Specialized Designation:** Topic Varies

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lec/Sem #1, Lec/Sem #2, Lec/Sem #3, Lec/Sem #4, Lec/Sem #5, Lec/Sem #6, Lec/Sem #7, Lec/Sem #8, Lec/Sem #9, Lecture, Sem/Lec #10, Sem/Lec #11, Sem/Lec #12, Sem/Lec #13, Sem/Lec #14, Sem/Lec #15, Sem/Lec #16, Sem/Lec #17, Sem/Lec #18

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 680: *Industrial Mathematics*.** 3 credits.

Takes examples from industry and goes through complete solution process: formulation of mathematical model of problem; solution, possibly by numerical approximation; and interpretation and presentation of results. Emphasizes working in groups, relating mathematics to concrete situations, and communication and presentation skills. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 683: *Modern Optimization Theory*.** 3 credits.

Introduces basic mathematical ideas and methods for solving linear and nonlinear programming problems, with emphasis on mathematical aspects of optimization theory. Reviews classical topics of linear programming, and covers recent developments in linear programming, including interior point method. Considers basic results in nonlinear programming, including very recent developments in this field. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 685: *Numerical Analysis*.** 3 credits.

Computational techniques for solving problems arising in science and engineering. Includes theoretical development as well as implementation, efficiency, and accuracy issues in using algorithms and interpreting results. Specific topics include linear and nonlinear systems of equations, polynomial interpolation, numerical integration, and introduction to numerical solution of differential equations. Offered by Mathematics

(<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit. Equivalent to CSI 690, OR 682.

**Recommended Prerequisite:** Computer literacy, including some programming experience.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 686: *Numerical Solutions of Differential Equations*.** 3 credits.

Finite difference methods for initial value problems, two-point boundary value problems, Poisson equation, heat equation, and first-order partial differential equations. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 214 and MATH 446 or 685.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 687: *Variational Methods*.** 3 credits.

Weak formulation of partial differential equations, energy principles, Galerkin approximations, and finite element methods. Includes review and development of necessary analysis. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 446 or 685, and elementary differential equations course.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 689: *Topics in Applied and Computational Mathematics*.** 3 credits. Special topics in applied and computational mathematics not covered in the regular applied and computational mathematics sequence. May be repeated for credit when topic varies. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May be repeated within the term for a maximum 12 credits.

**Specialized Designation:** Topic Varies

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lec/Sem #1, Lec/Sem #2, Lec/Sem #3, Lec/Sem #4, Lec/Sem #5, Lec/Sem #6, Lec/Sem #7, Lec/Sem #8, Lec/Sem #9, Lecture, Sem/Lec #10, Sem/Lec #11, Sem/Lec #12, Sem/Lec #13, Sem/Lec #14, Sem/Lec #15, Sem/Lec #16, Sem/Lec #17, Sem/Lec #18

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 690: *Graduate Internship*.** 1-6 credits.

Professional work experience for Mathematics MS and PhD candidates working in education, industry and government laboratories, including summer programs. Students looking for experiential credit in mathematics teaching may also use this course. Supervision and approval of this course must be arranged with the department before registering. Notes: Credit will be assigned based on the number of hours participating in the internship: 1 Credit for every 45 hours of internship work. At least one substantive piece of work will be assessed for each semester of internship. Students may take up to 6 internship credits per semester. Up to 3 credits may be used toward the MS degree in mathematics; a maximum of 6 credits may be used toward the PhD degree in mathematics. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May be repeated within the degree for a maximum 6 credits.

**Recommended Prerequisite:** A grade of 'B' or better in four core courses (including MATH 675), and permission of the internship coordinator.

**Registration Restrictions:**

**Required Prerequisite:** MATH 675<sup>B</sup>.

<sup>B</sup> Requires minimum grade of B.

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to students with a major in Mathematics.

Enrollment limited to students in a Doctor of Philosophy or Master of Science degrees.

**Schedule Type:** Internship

**Grading:**

This course is graded on the Satisfactory/No Credit scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 697: *Independent Reading and Research*.** 1-6 credits.

In areas of importance, but with insufficient demand to justify a regular course, students may undertake a course of study under the supervision of a consenting faculty member. Written statement of the content of the course and a tentative reading list is normally submitted as part of the request for approval. Literature review, project report, or other written product is normally required. May be repeated for credit. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May be repeated within the term.

**Specialized Designation:** Topic Varies

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** IND/INT #1, IND/INT #2, IND/INT #3, IND/INT #4, IND/INT #5, IND/INT #6, IND/INT #7, IND/INT #8, IND/INT #9, IND/INT #10, IND/INT #11, IND/INT #12, Independent Study, IND/INT #13, IND/INT #14, IND/INT #15, IND/INT #16, IND/INT #17, IND/INT #18, IND/INT #19, IND/INT #20, IND/INT #21

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

## 700 Level Courses

**MATH 721: *Algebra II*.** 3 credits.

Rings, fields, and Galois theory. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 621.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 722: *Algebraic Topology*.** 3 credits.

Covers simplices and simplicial complexes, cycles and boundaries, simplicial homology, homological algebra, homotopy and the fundamental group, cohomology. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 621 and MATH 631 or equivalent.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 723: *Combinatorial Structures*.** 3 credits.

Studies structural properties of objects encountered in pure and applied combinatorics. Topics include partially ordered sets, codes, designs, matroids, buildings, symmetrical structures, permutation groups, and face lattices of polytopes. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 321 or equivalent.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 724: *Commutative Algebra*.** 3 credits.

Study of commutative rings and their ideals, and of modules over commutative rings and their homological properties. More specific topics include Noetherian rings, primary decomposition, completions, graded rings and dimension theory with applications to algebraic geometry. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 621.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 725: *Algebraic Geometry*.** 3 credits.

This course is an introduction to Algebraic Geometry. Topic include: Affine Varieties, Projective Varieties, Morphisms, Rational Maps, Nonsingular varieties and curves, Sheaves, Schemes, Divisors, Projective Morphisms, Differentials, and Sheaf Cohomology. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 724

**Registration Restrictions:**

**Required Prerequisites:** (MATH 621<sup>B</sup> or 621<sup>XS</sup>).

<sup>B</sup> Requires minimum grade of B-

<sup>XS</sup> Requires minimum grade of XS.

Enrollment limited to students with a class of Advanced to Candidacy, Graduate or Non-Degree.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 732: *Topology II: Set-Theoretic Topology*.** 3 credits.

Topics include review of basic set theory (including cardinal numbers products of sets, the Axiom of Choice), definition of topological spaces, bases for topological spaces, forming new topological spaces by taking subspace, quotients, and products, separation properties (Hausdorff, regular, Tychonoff, and normal spaces) compactness, the Lindelof property, separability, connectedness, continuity and homeomorphism, manifolds. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 631 or equivalent.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 740: *Differential Topology*.** 3 credits.

Differential forms, manifolds, smooth maps, vector fields, the Euler characteristic, integration on manifolds, and de Rham cohomology. Notes: MATH 740 will be an elective course acceptable (but not required) for the PhD Degree in the Mathematical Sciences offered by the Department of Mathematical Sciences. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 621 and MATH 631, or equivalent.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 741: *Lie Groups*.** 3 credits.

The course is an introduction to Lie Theory. Topics include: Lie Groups and Their Lie Algebras, Homomorphisms, Lie Subgroups, Coverings, Simply Connected Lie Groups, Exponential Map, Continuous Homomorphisms, Closed Subgroups, The Adjoint Representation, Correspondence between Lie groups and Lie algebras, Root Systems, Dynkin Diagrams, Classification of simple Lie algebras, Introduction to Representations of Lie Groups. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>).

catalog.gmu.edu/colleges-schools/science/mathematical-sciences/). May not be repeated for credit.

**Recommended Prerequisite:** MATH 740

**Registration Restrictions:**

**Required Prerequisites:** (MATH 621<sup>B-</sup> or 621<sup>XS</sup>).

<sup>B-</sup> Requires minimum grade of B-.

<sup>XS</sup> Requires minimum grade of XS.

Enrollment limited to students with a class of Advanced to Candidacy, Graduate or Non-Degree.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 762: *Complex Analysis II*.** 3 credits.

Harmonic functions, generalizations of the maximum principle, entire and meromorphic functions, analytic continuation, and the Riemann mapping theorem. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 661.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 763: *Functions of Several Complex Variables*.** 3 credits.

Covers the important results for analytic functions in several variables, including analyticity in several variables and the differences between the theory of one and the theory of several complex variables. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 661 and MATH 762 or an equivalent preparation in one complex variable.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 772: *Wavelet Theory*.** 3 credits.

Study of the theory and computational aspects of wavelets and the wavelet transform. Emphasizes computational aspects of wavelets, defining the Fast Wavelet Transform in one and two dimensions. Developing the appropriate numerical algorithms. Includes developing

the theory of wavelet bases on the real line, discussing multiresolution analysis, splines, time-frequency localization, and wavelet packets. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 315 or equivalent.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 776: *Measure and Integration*.** 3 credits.

Lebesgue measure and integration. Theory of  $L_p$  spaces with  $p$  between one and infinity on the real line. Theory of linear operators on Banach spaces, including the Hahn-Banach theorem, open mapping theorem, closed graph theorem and the uniform boundedness principle. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 675.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 781: *Advanced Methods in Applied Mathematics*.** 3 credits.

Bifurcation theory and perturbation methods for solutions in ordinary and partial differential equations. This course will develop and apply these mathematical tools in current scientific fields, such as biology, materials science, or financial mathematics. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 677 or permission of instructor.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 784: *Nonlinear Functional Analysis*.** 3 credits.

Techniques in nonlinear functional analysis with applications. Contraction mapping principle, Frechet and higher derivatives, the implicit function theorem, Lyapunov-Schmidt method, and bifurcation theory. Finite and infinite dimensional degree theory with applications in partial differential equations. Notes: Different backgrounds may be appropriate, but generally, a student is expected to be an upper level graduate

student who has already taken Linear Analysis. Since the applications given in the course are for differential equations, some familiarity with differential equations is extremely useful. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 675 or permission of instructor.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 790: *Classical Potential Theory*.** 3 credits.

Potential theory of Laplace's equation in Euclidean space. Harmonic functions, superharmonic functions, potentials, polar sets and capacity, the Dirichlet problem, the Martin boundary, boundary behavior of superharmonic functions using real variable techniques, and minimal fine limit techniques. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** MATH 675 and MATH 776.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Lecture

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 795: *Graduate Seminar*.** 1 credit.

Mandatory for all PhD students. Weekly seminar graded on presentations and attendance. Faculty presentations on potential thesis topics and presentations by students. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May be repeated within the degree for a maximum 9 credits.

**Recommended Prerequisite:** Enrolled in the PhD program in Mathematics.

**Registration Restrictions:**

Enrollment is limited to Graduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Seminar

**Grading:**

This course is graded on the Graduate Regular scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 799: *MS Thesis*.** 1-6 credits.

Original or compilatory work evaluated by committee of three faculty members. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>).

schools/science/mathematical-sciences/). May be repeated within the degree.

**Registration Restrictions:**

Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

**Schedule Type:** Thesis

**Grading:**

This course is graded on the Satisfactory/No Credit scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

## 800 Level Courses

**MATH 800: *Studies for the Doctor of Philosophy in Education*.** 1-6 credits.

Program of studies designed by student's discipline director and approved by student's doctoral committee, which brings the student to participate in current research of discipline director and results in paper reporting the original contributions of student. Enrollment may be repeated. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May not be repeated for credit.

**Recommended Prerequisite:** Admission to the Ph.D. in Education program to study in mathematical sciences.

**Registration Restrictions:**

Enrollment is limited to Graduate level students.

**Schedule Type:** Independent Study

**Grading:**

This course is graded on the Graduate Special scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

## 900 Level Courses

**MATH 998: *Doctoral Dissertation Proposal*.** 1-9 credits.

Work on research proposal that forms basis for doctoral dissertation. May be repeated for credit. No more than 24 credit hours of 998 and 999 may be applied to doctoral degree requirements. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May be repeated within the degree.

**Recommended Prerequisite:** Successful completion of qualifying exam.

**Registration Restrictions:**

Enrollment is limited to Graduate level students.

**Schedule Type:** Dissertation

**Grading:**

This course is graded on the Satisfactory/No Credit scale. (<http://catalog.gmu.edu/policies/academic/grading/>)

**MATH 999: *Doctoral Dissertation*.** 1-12 credits.

Formal record of commitment to doctoral dissertation research under the direction of a faculty member. May be repeated for credit. No more than 24 credit hours of 998 and 999 may be applied to doctoral degree requirements. Offered by Mathematics (<http://catalog.gmu.edu/colleges-schools/science/mathematical-sciences/>). May be repeated within the degree.

**Registration Restrictions:**

Enrollment limited to students with a class of Advanced to Candidacy.

Enrollment is limited to Graduate level students.

**Schedule Type:** Dissertation

**Grading:**

This course is graded on the Satisfactory/No Credit scale. (<http://catalog.gmu.edu/policies/academic/grading/>)