The Mathematical Sciences department offers the following graduate degree programs:

Master of Arts - Mathematical Sciences (http://catalog.uah.edu/grad/colleges-departments/science/mathematical-sciences/mathematical-science-ma/)
Master of Science - Mathematical Sciences (http://catalog.uah.edu/grad/colleges-departments/science/mathematical-sciences/mathematical-science-ms/)
Doctor of Philosophy - Applied Mathematics (http://catalog.uah.edu/grad/colleges-departments/science/mathematical-sciences/mathematical-science-phd/)

Admission Requirements
In addition to fulfilling Graduate School admission requirements, all applicants for graduate study in mathematics or applied mathematics should have completed the equivalent of

- a complete calculus sequence,
- courses in linear algebra,
- abstract algebra,
- introduction to real analysis, and
- six additional semester hours in upper-division undergraduate mathematics courses.

Students deficient in more than two undergraduate courses in mathematics must remove these deficiencies before admission to the mathematics graduate program. Such students should consult the graduate program director of the department on how best to remove these deficiencies.

For unconditional admission, applicants must satisfy the requirements of the Graduate School. Only the aptitude portion of the Graduate Record Examination (GRE) is required by the department.

Program Objective
Our objective is to provide excellent instruction and resources for the mathematics education of our students and to help produce the new generations of well-educated mathematicians that are critical for the progress of mankind. Our second objective is to have graduates prepared for careers in government, industry, teaching at a secondary school level, or for graduate study in mathematics, and be admitted to graduate school or employed within one year of graduation.

Learning Outcomes
Students will demonstrate:

- Critical thinking skills to construct clear, valid, and succinct proofs
- Knowledge of a variety of technological tools, including computer algebra systems, probability, statistical packages, or computer programming languages
- Good mathematical communication skills, including the ability to convey mathematical knowledge in a variety of settings, both orally and in writing

Master's Programs in Mathematical Sciences
- Mathematical Sciences, MA (http://catalog.uah.edu/grad/colleges-departments/science/mathematical-sciences/mathematical-science-ma/)
- Mathematical Sciences, MS (http://catalog.uah.edu/grad/colleges-departments/science/mathematical-sciences/mathematical-science-ms/)

Doctoral Program in Applied Mathematics
- Applied Mathematics, PhD (http://catalog.uah.edu/grad/colleges-departments/science/mathematical-sciences/mathematical-science-phd/)
MA 502 - INTRO TO REAL ANALYSIS
Semester Hours: 3

Sequences, limits, continuity, differentiation of functions of one real variable, Riemann integration, uniform convergence, sequences and series of functions, power series, and Taylor series.

MA 503 - INTRO COMPLEX ANALYSIS
Semester Hours: 3

Complex algebra, analytic functions, Cauchy-Riemann equations, exponential, trigonometric, and logarithmic functions, integration, Cauchy integral theorem, Morera’s theorem, Liouville’s theorem, maximum modulus theorem, residue theory, Taylor and Laurent series, and applications.

MA 506 - METHODS PARTIAL DIFF EQUA
Semester Hours: 3

Survey of theory and methods for solving elementary partial differential equations. Topics include first-order equations and the method of characteristics, second-order equations, reduction to canonical form, the wave equation, the heat equation, Laplace’s equation, separation of variables, and Fourier series.

MA 508 - APPLIED LINEAR ALGEBRA
Semester Hours: 3

Fundamental concepts of linear algebra are developed with emphasis on real and complex vector spaces, linear transformations, and matrices. Solving systems of equations, finding inverses of matrices, determinants, vector spaces, linear transformations, eigenvalues and eigenvectors, normal matrices, canonical forms of matrices, applications to systems of linear differential equations, and use of computer software such as MATLAB.

MA 515 - INTRO NUMERICAL ANALYSIS
Semester Hours: 3

Rigorous analysis and derivation of numerical methods for the approximate solution of nonlinear equations; interpolation and integration of functions, and approximating solutions of ordinary differential equations.

MA 520 - INTERM DIFFERENTIAL EQUATIONS
Semester Hours: 3

This is a second course in differential equations. Course topics include series solutions for second order differential equations and the method of Frobenious; eigenvalue and eigenvector methods for solving systems of linear first order equations; the qualitative theory of nonlinear equations; boundary value problems and the Sturm-Liouville theory. No credit given to students who have successfully completed MA 524.

MA 524 - DYNAMICAL SYSTEMS I
Semester Hours: 3

Scalar autonomous equations; existence, uniqueness, stability, elementary bifurcations; planar autonomous equations; general properties and geometry, conservative systems, elementary bifurcations linear systems, reduction to canonical forms, stability and instability from linearization. Liapunov functions, center manifolds, Hopf bifurcation.

MA 526 - PARTIAL DIFF EQUA I
Semester Hours: 3

Introduction to the theory for solving partial differential equations. No graduate credit given to students who have completed MA 506 for graduate credit. Topics include second-order equations, reduction to canonical form, well-posedness, the classical equations (wave, heat, and Laplace’s) in one and several dimensions, separation of variables, Fourier series, general eigenfunction expansions, Sturm-Liouville theory, first-order linear and quasilinear equations, and shocks. Prerequisite: MA 502.

MA 536 - INTRO P-ADIC ANALYSIS
Semester Hours: 3

Introduction to p-adic analysis. Topics include rings; fields; ideals; congruences; valued fields; non-archimedean valued fields; field of p-adic numbers; field of complex p-adic numbers; ultrametric Banach spaces; p-adic Hilbert space; p-adic functions; strictly differentiable functions; Volkenborn Integral; Benoulli numbers; p-adic Gamma function; p-adic Riemann function; and p-adic Zeta function.

MA 538 - METRIC SPACES W/APPLICA
Semester Hours: 3

MA 539 - MULTIDIMENSIONAL ANALYSIS
Semester Hours: 3
Finite-dimensional Euclidean space and sequential approach to its topology, continuous functions and their properties, differentiability and implicit function theorem, Riemann integral, elements of vector calculus, flows and their generating vector fields, introduction to metric spaces. Prerequisite: MA 544.

MA 540 - COMBINATORIAL ENUMERATION
Semester Hours: 3
Counting, pigeonhole principle, permutations and combinations, generating functions, principle of inclusion and exclusion, Polya's theory of counting.

MA 542 - ALGEBRA
Semester Hours: 3
Topics from group theory and ring theory: subgroups, normal subgroups, quotient groups, homomorphisms, isomorphism theorems, ideals, principal ideal domains, Euclidean domains, fields, extension fields, elements of Galois theory.

MA 544 - LINEAR ALGEBRA
Semester Hours: 3
Vector spaces over a field, bases, linear transformations, matrices, determinants, eigenvalues, similarity, Jordan canonical forms, dual spaces, orthogonal and unitary transformations.

MA 561 - INTRO TO FOURIER ANALYSIS
Semester Hours: 3
See MA 460. This course is taught as MA 460/561. Course completion and/or grade requirements for the MA 561 course will differ from those for the MA 460 course.

MA 562 - INTERMEDIATE FOURIER ANALYSIS
Semester Hours: 3
(Formerly MA 560). Brief review of classical Fourier analysis, Parseval's equality, Gaussian test functions. Introduction to generalized functions, the generalized transform, the generalized derivative, sequences and series of generalized functions, regular periodic arrays of delta functions, sampling, the discrete transform, the fast Fourier transform (other topics as time and interest permit).

MA 565 - INTERM MATH MODELING
Semester Hours: 3
Designed for beginning graduate students. No prior experience in formal mathematical modeling is required. In-depth discussion of some types of models from physics, the life sciences, and/or the social sciences, with formulation, analysis, and criticism of the models. Process of and factors involved in formulating a model is of prime importance. Content is divided into approximately one-half deterministic modeling and one-half stochastic modeling.

MA 585 - PROBABILITY
Semester Hours: 3
Course topics include probability spaces, random variables, conditional probability, independence, modes of convergence, and an introduction to sigma-algebras and measurability; distributions, including discrete, continuous, joint and marginal distributions, transformations of random variable, distribution and quantile functions, and convergence in distribution; expected value, including properties of general expected value, mean, variance, covariance, generating functions, and conditional expected value; special models and distributions, including Bernoulli trials and the binomial and negative binomial distributions, the Poisson model and the Poisson and gamma distributions, the normal distribution, finite sampling models and the hypergeometric distribution; the law of large numbers and the central limit theorem.

MA 590 - SELECTED TOPICS IN MATH
Semester Hours: 3
Requested selected topics.

MA 607 - MATHEMATICAL METHODS I
Semester Hours: 3
Review of vector calculus and coordinate systems, introduction to tensors, matrices, infinite series, complex variables with applications to calculus of residues, partial differential equations, and Sturm-Liouville theory. Orthogonal functions, gamma functions, Bessel functions, Legendre functions, special functions, Fourier series, integral transform and equations. (Same as PH 607.)

MA 609 - MATHEMATICAL METHODS II
Semester Hours: 3
Continuation of MA 607. (Same as PH 609.) Prerequisite: MA 607.
MA 614 - NUM METHODS/LINEAR ALGEBRA  
Semester Hours: 3  
Norms and vector spaces, matrix factorizations and direct solution methods, stability and conditioning, iterative methods for large linear systems, the algebraic eigenvalue problem. Prerequisites: MA 515 and either MA 508 or MA 544.

MA 615 - NUM METHODS PARTIAL DIFF EQ  
Semester Hours: 3  
Finite difference methods for parabolic, elliptic, and hyperbolic partial differential equations, error analysis, stability, and convergence of finite difference methods. Prerequisites: MA 515 and (either MA 506 or MA 526) and (either MA 508 or MA 544 or MA 614).

MA 624 - DYNAMICAL SYSTEMS II  
Semester Hours: 3  
Brief review of linear systems; local theory for nonlinear systems; existence, uniqueness, differentiability, asymptotic behavior, the stable manifold theorem, Hartman-Grobman theorem, Hamiltonian systems; global theory for nonlinear systems; limit sets and attractors, the Poincare map, the Poincare-Bendixson theorem; some aspects of bifurcation theory and chaos; bifurcations at nonhyperbolic fixed points and periodic orbits, homoclinic bifurcations, Melnikov's method, chaos. Prerequisite: MA 524 and either MA 508 or MA 544.

MA 626 - PARTIAL DIFF EQUA II  
Semester Hours: 3  
Continuation of MA 526. Qualitative results for solutions to the classical equations (energy inequalities, propagation of discontinuities, maximum principles, smoothness of solutions, existence and uniqueness, etc.), non-homogeneous equations, Poisson's equation, Green's functions, and the Cauchy-Kowalewski theorem. Prerequisite: MA 526.

MA 633 - GEOMETRY  
Semester Hours: 3  
Axioms of incidence and order, affine and metric properties, isometries, similarities, transformation groups, projective planes.

MA 638 - GENERAL TOPOLOGY  
Semester Hours: 3  
Set theory, logic, well-ordering principle, axiom of choice, topological spaces, product spaces, quotient spaces, continuous functions, connectedness, path connectedness, local connectedness, compactness, local compactness, countability and separation, generalized products, Tychonoff theorem.

MA 640 - GRAPH THEORY  
Semester Hours: 3  
Graphs, subgraphs, trees, connectivity, Euler tours, Hamilton cycles, matchings, edge colorings, independent sets, vertex colorings, planar graphs, Kuratowski's theorem, four color theorem, directed graphs, networks, cycle and bond spaces. Prerequisite: MA 540 or MA 542.

MA 643 - GROUP THEORY  
Semester Hours: 3

MA 644 - MATRIX THEORY  
Semester Hours: 3  
Functions of matrices, invariant polynomials, elementary divisors, similarity of matrices, normal forms of a matrix, matrix equations, generalized inverses, non-negative matrices, localization of eigenvalues. Prerequisites: MA 508 or MA 503 or MA 544.

MA 645 - COMBINATORIAL DESIGN  
Semester Hours: 3  
Systems of distinct representatives, difference sets, coding theory, block designs, finite geometries, orthogonal Latin squares, and Hadamard matrices. Prerequisite: MA 540 and MA 544.

MA 653 - REAL ANALYSIS I  
Semester Hours: 3  

MA 654 - REAL ANALYSIS II  
Semester Hours: 3  
Differentiability of monotone functions, functions of bounded variation, absolute continuity, convex functions, Minkowski and Holder inequalities, $L_p$ spaces, Riesz-Fischer representation theorem, Fubini's theorem and selected topics. Prerequisite: MA 653.
MA 656 - COMPLEX ANALYSIS I  
Semester Hours: 3  
Topological of the complex plane, analytic functions of one complex variable, elementary functions and their mapping properties, power series, complex integration, Cauchy's theorem and its consequences, isolated singularities, Laurent series, residue theory.

MA 658 - INTRO TO FUNCTIONAL ANALYSIS  
Semester Hours: 3  
Normed and inner product spaces, finite dimensional spaces, product and quotient spaces, equivalent norms, Hahn-Banach theorem, principle of uniform boundedness, open mapping theorem, Riesz representation theorem, complete orthonormal sets, Bessel's inequality, Parseval's identity, and conjugate spaces. Prerequisite: MA 538.

MA 661 - SPECIAL FUNCTIONS  
Semester Hours: 3

MA 662 - ASYMPT/PERTURBATION METHOD  
Semester Hours: 3  
Asymptotic series, regular and singular perturbation theory, asymptotic matching, Laplace's method, stationary phase, steepest descents, WKB theory. Prerequisites: MA 502, and one of the following: MA 503, MA 504, MA 624.

MA 667 - CALC VAR/OPTIMAL CONTROL  
Semester Hours: 3  
Euler necessary condition for local extremum, Euler-Lagrange equation, Weierstrass necessary condition, Jacobi's necessary condition, corner conditions, problems of optimal control, Pontryagin maximum principles, transversality conditions, applications.

MA 685 - STOCHASTIC PROC/APPLI I  
Semester Hours: 3  
Discrete and continuous Markov chains, Poisson processes, counting and renewal processes, and applications. Prerequisite: MA 585.

MA 686 - STOCHASTIC PROC/APPLI II  
Semester Hours: 3  
Gaussian and Wiener processes, general Markov processes, special types of processes from queueing and risk theory, and selected advanced topics. Prerequisite: MA 685.

MA 690 - SP TOPICS IN MATHEMATICS  
Semester Hours: 3  
Offered upon demand. Advanced selected topics of interest in areas such as discrete mathematics, numerical analysis, differential equations, and stochastic processes.

MA 695 - GRADUATE SEMINAR  
Semester Hour: 1  
Selected topics in advanced mathematics, conducted as a research seminar.

MA 699 - MASTER'S THESIS  
Semester Hours: 3-9  
Required each semester a student is receiving direction on a master's thesis. A minimum of two terms is required. Maximum of nine hours credit awarded upon successful completion of the master's thesis.

MA 715 - NUM METHODS PART DIFF EQ II  
Semester Hours: 3  
Finite element methods for parabolic, elliptic, and hyperbolic partial differential equations; error analysis stability, and convergence. Prerequisites: MA 538 and MA 615.

MA 726 - THRY PART DIFFERNTL EQUA  
Semester Hours: 3  
Hilbert space theory of existence, uniqueness, and regularity for partial differential equations.

MA 740 - COMBINATORIAL ALGORITHMS  
Semester Hours: 3  
Linear, polynomial and exponential graph theoretic algorithms, generating combinatorial objects, and NP-completeness.
MA 756 - COMPLEX ANALYSIS II
Semester Hours: 3
Applications of residue theory, harmonic functions and their applications, Mittag-Leffler theorem, infinite products, Weierstrass product theorem, conformal mapping and Riemann mapping theorem, univalent functions, analytic continuation and Riemann surfaces, Picard's theorems, and selected topics.

MA 785 - ADV PROBABILITY THEORY
Semester Hours: 3
Measure and integration, probability spaces, convergence concepts, law of large numbers, random series, characteristic functions, central limit theorem, random walks, conditioning, Markov properties, conditional expectations, and elements of martingale theory.

MA 790 - SPECIAL TOPICS
Semester Hours: 3
Offered upon demand. Advanced selected topics of interest in areas such as discrete mathematics, numerical analysis, differential equations, and stochastic processes.

MA 795 - GRADUATE SEMINAR
Semester Hour: 1
Selected topics in advanced mathematics, conducted as a research seminar.

MA 799 - DOCTORAL DISSERTATION
Semester Hours: 3-9
Required each semester a student is receiving direction on a Ph.D. dissertation.