Mathematics

http://www.math.utk.edu/

Conrad Plaut, Head
Xiaobing Feng, Director of Graduate Studies

Professors
Alexiades, V., PhD – Delaware
Anderson, D.F., PhD – Chicago
Chen, X., PhD – Rutgers
Conant, J., PhD – California (San Diego)
Dydek, J., PhD – Warsaw (Poland)
Feng, X., PhD – Purdue
Frazier, M., PhD – California (Los Angeles)
Gavrillets, S., PhD – Moscow State
Gross, L., PhD – Cornell
Karakashian, O., PhD – Harvard
Lenhart, S., PhD – Kentucky
Mulyay, S., PhD – Purdue
Plaut, C.P., PhD – Maryland
Rajput, B.S., PhD – Illinois
Richter, S., PhD – Michigan
Rosinski, J., PhD – Wroclaw (Poland)
Schulze, T., PhD – Northwestern
Simpson, H., PhD – California Institute of Technology
Stephenson, K.R., PhD – Wisconsin
Sundberg, C., PhD – Wisconsin
Thistlethwaite, M., PhD – Manchester (UK)
Todorova, G.H., PhD – Moscow State
Wagner, C.G., PhD – Duke

Associate Professors
Brodskiy, N., PhD – Saskatchewan (Canada)
Collins, C., PhD – Minnesota
Denzler, J., PhD – ETH (Zurich)
Finotti, L., PhD – Texas
Freire, A., PhD – Princeton
Nicoara, R., PhD – UCLA
Wise, S., PhD – Virginia

Assistant Professors
Cartwright, D., PhD – California (Berkeley)
Day, J., PhD – Pittsburgh
Jameson, M., PhD – Emory
Lind, J., PhD – Washington
Maroulas, V., PhD – North Carolina
Mengesha, T., PhD – Temple
Phan, T., PhD – Minnesota
Salgado-Gonzales, A., PhD – Texas A & M
Schwartz, F., PhD – Cornell
Xing, Y., PhD – Brown

Joint Faculty
Berry, M., PhD – Illinois
Evans, K., PhD – Georgia Tech
Ganusov, V., PhD – Emory
Hauck, C., PhD – Maryland
Webster, C., PhD – Florida State

Lecturers
Bonee, K., MS – Tennessee
Booth, H., PhD – Princeton
Caldwell, J., PhD – Illinois
Conner, A., MM – Tennessee
Contole, A., MM – Tennessee
Cook, T., MS – Tennessee
Finotti, H., PhD – Ohio State
Fowler, J., MA – Kentucky
Gilbert, M., MS – Tennessee
Guest, R., MS – Baylor
Guldan, D., MS – Kentucky
Hagan, R., MS – Tennessee
Long, J., PhD – Michigan
McAmis, C., MS – Tennessee
Moore, S., MS - Tennessee
Peery, M., MM – Tennessee
Pringle, K., PhD – Oregon
Reagan, R.D., MM – Tennessee
Remus, C., MS – Tennessee
Self, C., MS – Tennessee
Smith, K., MM – Tennessee
Stein, D., MS – Tennessee
Sukanek, K., MS – Mississippi
Unseren, M., PhD – Purdue
White, D., PhD – Washington
Wright, G., MM – Tennessee

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<tr>
<td>Mathematics</td>
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The Mathematics Department has three graduate degrees – the Master of Mathematics degree, intended primarily for teachers; the Master of Science degree, designed to prepare students for industrial employment and for teaching; and the Doctor of Philosophy degree, designed to prepare students for industrial employment and for college and university teaching and research. Contact the department office for additional information.

A graduate minor in mathematics requires at least 6 hours of resident graduate credit in courses numbered above 400. The courses must be approved by both the major department and the Department of Mathematics.

For additional information, please visit the graduate website on the Department of Mathematics' homepage at www.math.utk.edu.

Mathematics Major, MMath
Before admission to the Master of Mathematics program, the applicant must have either (a) certification for teaching secondary mathematics in at least one state, or (b) three years of elementary school, secondary school, or community college teaching experience. Applicants must have successfully completed one year of calculus (141-142 or equivalent) and a course in matrix algebra (251 or equivalent).

Requirements
The following requirements must be met.
- Complete 30 hours of course work of which 21 must be at the 500-level. The course work must include MATH 504, MATH 505, MATH 506, MATH 507, and 6 hours in MATH 509. At most, 6 hours may be taken outside the Department of Mathematics (selected in consultation with the advisor).
- Pass a final examination upon completion of all course work.

In exceptional circumstances, part of admission requirement (b) might be satisfied concurrently with course work.
Mathematics Major, MS
Requirements
The Mathematics Department offers three options for the Master of Science degree: a thesis option, a project option, and a course-work option.

The thesis option requires a written thesis, 6 hours of thesis research, and 24 additional hours in acceptable courses numbered above 400. Of the 24 additional hours, 6 may be in areas outside the department and 15 must be in mathematics courses numbered above 500.

The project option requires 30 hours in acceptable courses numbered above 400. Of these 30 hours, 21 hours (at least 15 of which are in mathematics) must be in courses numbered above 500. Of the 30 hours, 9 may be in areas outside the department. This option requires that a written final examination be passed and 3 hours credit be received for a reading course (MATH 598) in which a term paper or project is required.

The course-work option requires 30 hours in acceptable courses numbered above 400. Of these 30 hours, 21 hours (at least 15 of which are in mathematics) must be in courses numbered above 500. Of the 30 hours, 9 may be in areas outside the department. This option requires that the student pass two written examinations with a PhD level score as required in the PhD program.

Applied Mathematics concentration
Requirements
For this concentration, available under all three options (listed above under requirements heading), the student must complete the following.

- Prerequisites – MATH 371, MATH 471, or MATH 472; MATH 512 or both MATH 431 and MATH 435; MATH 447-MATH 448; or MATH 445-MATH 446; MATH 453.
- One hour of MATH 519 or MATH 589.
- One course from each of the following five areas.
  1. Foundations of Applied Mathematics – MATH 511, MATH 515, MATH 516.
  2. Optimization – MATH 577, MATH 585.
  3. Numerical Mathematics – MATH 571, MATH 572, MATH 578.
  4. Modeling – MATH 475, MATH 537, MATH 581.
  5. Statistics – MATH 525, MATH 527; STAT 537; EEB 560.

Mathematics Major, PhD
Requirements
For the PhD program in mathematics, the student must meet the following five requirements in addition to those of the Graduate Council.

- Demonstrate competency in advanced calculus and linear algebra by either a satisfactory performance on a diagnostic examination or by passing the appropriate 400-level course with a grade of B or better by the end of the student's first year of graduate school. The appropriate course for advanced calculus is the MATH 447-MATH 448 sequence and for linear algebra is the MATH 457-MATH 458 sequence or MATH 453.
- Satisfy either the standard program or the interdisciplinary mathematical ecology/evolution concentration. A student intending to work in mathematical ecology/evolution may complete either but is encouraged to complete the interdisciplinary mathematical ecology/evolution concentration.
- Take at least two different one-semester research seminars and MATH 599.
- Pass an examination in the field of specialization after requirements in bullets 1-3 have been met. This examination will be given by a committee appointed by the department head. A student may take this specialty examination no more than two times.
- Pass a one-year, 600-level sequence in mathematics outside the student's area of specialization. The sequence selected to fulfill this requirement must be approved by the department head and the student's doctoral committee.

These requirements must be completed no later than the start of the student's seventh year (as a mathematics graduate student at UT).

Standard Program
A student must pass written examinations on two of the following year-long sequences – algebra (MATH 551-MATH 552), analysis (MATH 545-MATH 546), computational and applied mathematics (MATH 571-MATH 572), differential equations (MATH 535-MATH 536), stochastics (MATH 523-MATH 524), and topology-geometry (MATH 561-MATH 562). A student
must pass one examination by the middle of his/her third year and both examinations by the middle of his/her fourth year. A student may not take any examinations after four failures.

In addition to the two year-long sequences chosen for the written examinations, a student must take six other one-semester 500-600 level courses. At least five of these courses must be chosen from the following list grouped by examination area – algebra (MATH 551-MATH 552, MATH 555-MATH 556), analysis (MATH 545-MATH 546, MATH 545-MATH 547), computational and applied mathematics (MATH 571-MATH 572, MATH 574, MATH 577, MATH 578), differential equations (MATH 513-MATH 514, MATH 515-MATH 516, MATH 531-MATH 532, MATH 535-MATH 536, MATH 537-MATH 538, MATH 581-MATH 582, MATH 585), stochastics (MATH 521-MATH 522, MATH 523-MATH 524, MATH 525-MATH 526), and topology-geometry (MATH 561-MATH 562, MATH 567-MATH 568). The sixth course may be either a 500-level course listed above or a 600-level mathematics course not used to satisfy bullet #5. These six courses must contain a year-long sequence in an area different from the two written examinations and at least two areas different from the two written examinations. A grade of B or better is required in each of the six courses.

**Mathematical Ecology/Evolution concentration**
A student must pass written examinations on mathematical ecology (MATH 581-MATH 582) and one of the following year-long sequences – analysis (MATH 545-MATH 546), computational and applied mathematics (MATH 571-MATH 572), differential equations (MATH 535-MATH 536), and stochastics (MATH 523-MATH 524). A student must pass one examination by the middle of his/her third year and both examinations by the middle of his/her fourth year. A student cannot take any examinations after four failures.

In addition to the two year-long sequences chosen for the written examinations, a student must take six other one-semester 500-600 level courses. At least five of these courses must be chosen from the following list grouped by examination area – analysis (MATH 545-MATH 546, MATH 545-MATH 547), computational and applied mathematics (MATH 571-MATH 572, MATH 574, MATH 577, MATH 578), differential equations (MATH 513-MATH 514, MATH 515-MATH 516, MATH 531-MATH 532, MATH 535-MATH 536, MATH 537-MATH 538, MATH 585), stochastics (MATH 521-MATH 522, MATH 523-MATH 524, MATH 525-MATH 526, MATH 527), and mathematical ecology/evolution (MATH 583, EEB 509, EEB 511). The sixth course may be either a 500-level course listed above or a 600-level mathematics course not used to satisfy bullet #5.

These six courses must contain a year-long sequence in an area different from the two written examinations and at least two areas different from the two written examinations. A grade of B or better is required in each of the six courses.

**Interdisciplinary Graduate Minor in Computational Science (IGMCS)**
The Department of Mathematics participates in the interdisciplinary graduate minor in computational science (IGMCS) program. Any student pursuing a master’s or PhD with a major in mathematics can receive a minor in computational science by completing the appropriate IGMCS requirements. For additional information, see the description of the Interdisciplinary Graduate Minor in Computational Science listed under Department of Electrical Engineering and Computer Science or visit the IGMCS website at http://igmcs.utk.edu/. The Department of Mathematics also contributes courses to the IGMCS program curriculum.
College: Arts and Sciences  
Department: Mathematics  

Mathematics (MATH)  

MATH 400 - History of Mathematics  
3 Credit Hours Development of major ideas in mathematics from ancient to modern times and the influence of these ideas in science,  
technology, philosophy, art, and other areas. Includes at least one in-class essay examination and 3,000 words of writing outside  
classroom.  
(RE) Prerequisite(s): 251 or 257.  
(DE) Prerequisite(s): 300 or 307.  

MATH 403 - Mathematical Methods for Engineers and Scientists  
3 Credit Hours Matrix computations, numerical methods, partial differential equations, Sturm-Liouville Theory and special functions as  
used in engineering and science.  
(RE) Prerequisite(s): 231; 241 or 247.  
Comment(s): Knowledge of high-level programming language required.  

MATH 404 - Applied Vector Calculus  
3 Credit Hours Topics from multivariable and vector calculus; line and surface integrals, divergence theorem and the theorems of Gauss  
and Stokes.  
(RE) Prerequisite(s): 241 or 247.  

MATH 405 - Models in Biology  
3 Credit Hours Difference and differential equation models of biological systems.  
Cross-listed: (Same as Ecology and Evolutionary Biology 406.)  
Credit Restriction: May not be applied toward a mathematics graduate degree.  
(RE) Prerequisite(s): 142 or 148 or 152.
MATH 411 - Mathematical Modeling  
3 Credit Hours  Construction and analysis of mathematical models used in science and industry. Projects emphasized.  
(RE) Prerequisite(s): 231; 241 or 247; 200 or 251 or 257.

MATH 421 - Combinatorics  
3 Credit Hours  Introduction to problems of construction and enumeration for discrete structures such as sequences, partitions, graphs, finite fields and geometries, and experimental designs.  
(RE) Prerequisite(s): 300 or 307.

MATH 423 - Probability  
3 Credit Hours  Axiomatic probability, univariate and multivariate distributions, conditional distributions and expectations, moment generating functions, laws of large numbers and central limit theorem.  
(RE) Prerequisite(s): 241 or 247; 300 or 307.  
(DE) Prerequisite(s): 323.

MATH 424 - Stochastic Processes  
3 Credit Hours  Markov chains, Poisson processes and Brownian motion. Other topics as selected by instructor.  
(RE) Prerequisite(s): 423.

MATH 425 - Statistics  
3 Credit Hours  Standard statistical distributions, independence of mean and variance for a Gaussian sample, basic limit theorems; point and interval estimation, tests of statistical hypotheses, Neyman-Pearson theorem; likelihood ratio and other parametric and nonparametric tests.  
(RE) Prerequisite(s): 423.

MATH 431 - Differential Equations II  
3 Credit Hours  A second course in ordinary differential equations. Linear systems of differential equations, Frobenius method, Sturm-Liouville eigenvalue problems, phase plane analysis.  
(RE) Prerequisite(s): 231; 200 or 251 or 257.

MATH 435 - Partial Differential Equations  
3 Credit Hours  Separation of variables, Fourier series, solution of Laplace, wave, and heat equations.  
(RE) Prerequisite(s): 231; 241 or 247.

MATH 443 - Complex Variables  
3 Credit Hours  Introduction to the theory of functions of a complex variable, including residue theory and contour integrals.  
(RE) Prerequisite(s): 241 or 247.

MATH 445 - Advanced Calculus I  
3 Credit Hours  Introduction to the theory of sequences, series, differentiation, and Riemann integration of functions of one or more variables.  
(RE) Prerequisite(s): 241 or 247; 300 or 307.

MATH 446 - Advanced Calculus II  
3 Credit Hours  Continuation of 445.  
(RE) Prerequisite(s): 445.

MATH 447 - Honors: Advanced Calculus I  
3 Credit Hours  Honors version of 445.  
(RE) Prerequisite(s): 341.

MATH 448 - Honors: Advanced Calculus II  
3 Credit Hours  Continuation of 447.  
(RE) Prerequisite(s): 447.

MATH 453 - Matrix Algebra II  
3 Credit Hours  Advanced topics in matrix theory including Jordan canonical form.  
(RE) Prerequisite(s): 200 or 251 or 257.

MATH 455 - Abstract Algebra I  
3 Credit Hours  Introduction to algebraic structures such as groups, rings, fields, vector spaces, and linear transformations.  
(RE) Prerequisite(s): 251 or 257; 300 or 307.

MATH 456 - Abstract Algebra II  
3 Credit Hours  Continuation of 455.  
(RE) Prerequisite(s): 455.

MATH 457 - Honors: Abstract Algebra I  
3 Credit Hours  Honors version of 455.  
(RE) Prerequisite(s): 351.

MATH 458 - Honors: Abstract Algebra II  
3 Credit Hours  Continuation of 457.  
(RE) Prerequisite(s): 457.
MATH 460 - Geometry
3 Credit Hours Axiomatic and historical development of neutral, Euclidean, and hyperbolic geometry stressing proof technique and critical reasoning. Models of Non-Euclidean geometries.
(RE) Prerequisite(s): 300 or 307.

MATH 462 - Differential Geometry
3 Credit Hours Classical differential geometry of curves and surfaces: Frenet frames, first and second fundamental forms, Gauss curvature and mean curvature, geodesics and parallel transport, the Gauss-Bonnet theorem, geometry of the hyperbolic plane.
(RE) Prerequisite(s): 241 or 247.

MATH 467 - Honors: Topology
3 Credit Hours Includes topology of line and plane, separation properties, compactness, connectedness, continuous functions, homeomorphisms, continua, and topological invariants.
(RE) Prerequisite(s): 300 or 307.
(DE) Prerequisite(s): 241 or 247.

MATH 461 - Numerical Analysis
3 Credit Hours Introduction to computation, instabilities, and rounding. Interpolation and approximation by polynomials and piecewise polynomials. Quadrature and numerical solution of initial and boundary value problems of ordinary differential equations, stiff systems.
Cross-listed: (Same as Computer Science 471.)
(RE) Prerequisite(s): 231; 200 or 251 or 257.
(DE) Prerequisite(s): 371.
Comment(s): Knowledge of a high-level programming language required.

MATH 472 - Numerical Algebra
3 Credit Hours Direct and iterative methods for systems of linear equations. Solution of single nonlinear equation and nonlinear systems. Orthogonal decomposition, least squares and algebraic eigenvalue problem.
Cross-listed: (Same as Computer Science 472.)
(RE) Prerequisite(s): 231; 200 or 251 or 257.
(DE) Prerequisite(s): 371.
Comment(s): Knowledge of a high-level programming language required.

MATH 475 - Industrial Mathematics
3 Credit Hours Modeling, analysis, and computation applied to scientific/technical/industrial problems.
(RE) Prerequisite(s): 231.
Recommended Background: Familiarity with operating system and programming language.

MATH 490 - Readings in Mathematics
1-3 Credit Hours Open to superior students. Independent study with faculty guidance.
Comment(s): Consent of faculty mentor to supervise independent work required.
Registration Permission: Consent of department head.

MATH 499 - Seminar in Mathematics
1-3 Credit Hours Topics vary. Requires out-of-class projects and in-class presentations by students. Students must register for the number of credit hours announced for a particular seminar.
Repeatability: May be repeated. Maximum 9 hours.
Registration Permission: Consent of instructor.

MATH 500 - Thesis
1-15 Credit Hours Grading Restriction: P/NP only.
Repeatability: May be repeated.
Credit Level Restriction: Graduate credit only.
Registration Restriction(s): Minimum student level – graduate.

MATH 502 - Registration for Use of Facilities
1-15 Credit Hours Required for the student not otherwise registered during any semester when student uses university facilities and/or faculty time before degree is completed.
Grading Restriction: Satisfactory/No Credit grading only.
Repeatability: May be repeated.
Credit Restriction: May not be used toward degree requirements.
Credit Level Restriction: Graduate credit only.
Registration Restriction(s): Minimum student level – graduate.

MATH 504 - Discrete Mathematics for Teachers
3 Credit Hours Mathematical logic and methods of argument, sets, functions and relations, combinatorics. Normally, the first graduate course for students seeking Master of Mathematics degree.
Credit Restriction: May not apply toward mathematics major (Master of Science).
Recommended Background: 1 year of calculus or equivalent.
Comment(s): For students in Master of Mathematics program and for students in graduate programs in the College of Education, Health, and Human Sciences.
MATH 505 - Analysis for Teachers
3 Credit Hours Development of differential and integral calculus, proofs of basic theorems.
Credit Restriction: May not apply toward mathematics major (Master of Science).
Recommended Background: 1 year of calculus or equivalent.
Comment(s): For students in Master of Mathematics program and for students in graduate programs in the College of Education, Health, and Human Sciences.

MATH 506 - Algebra for Teachers
3 Credit Hours Algebraic structures: integral domains and fields and their applications to algebra of integers and polynomials.
Credit Restriction: May not apply toward mathematics major (Master of Science).
Recommended Background: 1 year of calculus or equivalent.
Comment(s): For students in Master of Mathematics program and for students in graduate programs in the College of Education, Health, and Human Sciences.

MATH 507 - Probability and Statistics for Teachers
3 Credit Hours Probability models. Discrete random variables. Binomial, hypergeometric, and Poisson distributions.
Credit Restriction: May not apply toward mathematics major (Master of Science).
Recommended Background: 1 year of calculus or equivalent.
Comment(s): For Students in Master of Mathematics program and for students in graduate programs in the College of Education, Health, and Human Sciences.

MATH 509 - Seminar for Teachers
3 Credit Hours Repeatability: May be repeated. Maximum 12 hours.
Credit Restriction: May not apply toward mathematics major (Master of Science).
Comment(s): For Students in Master of Mathematics program and for students in graduate programs in the College of Education, Health, and Human Sciences.
Registration Permission: Consent of instructor.

MATH 511 - Methods in Applied Mathematics I
3 Credit Hours Fundamentals and techniques associated with discrete models of physical, engineering and biological systems: difference equations, networks and graphs, optimization, and other topics.
Recommended Background: Courses in advanced calculus and linear algebra.

MATH 512 - Methods in Applied Mathematics II
3 Credit Hours Fundamentals and techniques associated with continuous models of physical, engineering, and biological systems: development, solution and qualitative analysis of ordinary and partial differential equations, and calculus of variations.
(DE) Prerequisite(s): 511.

MATH 513 - Mathematical Principles of Fluid Mechanics I
3 Credit Hours Equations of motion, incompressible and compressible potential flow, shock waves, viscous flows. Navier-Stokes equations.
Recommended Background: Advanced courses in ordinary and partial differential equations and advanced calculus.

MATH 514 - Mathematical Principles of Fluid Mechanics II
3 Credit Hours Continuation of 513.
(DE) Prerequisite(s): 513.

MATH 515 - Analytical Applied Mathematics I
3 Credit Hours Analysis of advanced techniques in modern context for applied problems: dimensional analysis and scaling, perturbation theory, variational approaches, transform theory, wave phenomena and conservation laws, stability and bifurcation, distributions, integral equations.
Recommended Background: Courses in advanced calculus, linear algebra, and either advanced differential equations or 512.

MATH 516 - Analytical Applied Mathematics II
3 Credit Hours Continuation of 515.
(DE) Prerequisite(s): 515.

MATH 517 - Mathematical Methods in Physics I
3 Credit Hours Cross-listed: (See Physics 571.)

MATH 518 - Mathematical Methods in Physics II
3 Credit Hours Cross-listed: (See Physics 572.)

MATH 519 - Seminar in Applied Mathematics
1-3 Credit Hours Repeatability: May be repeated. Maximum 12 hours.

MATH 521 - Enumerative Combinatorics I
3 Credit Hours Sieve methods, recursion, generating functions, and permutation groups applied to enumeration of discrete structures. Incidence algebras and combinatorics of partially ordered sets.

MATH 522 - Enumerative Combinatorics II
3 Credit Hours Continuation of 521.
(DE) Prerequisite(s): 521.
MATH 523 - Probability I
3 Credit Hours Probability spaces and random variables, expectation, characteristic functions, convergence of random variables.
Recommended Background: One year of advanced calculus and 323.

MATH 524 - Probability II
3 Credit Hours Continuation of 523. Law of large numbers, central limit theorem, conditional expectation, martingales. Other topics as selected by instructor.
(DE) Prerequisite(s): 523.

MATH 525 - Statistics I
3 Credit Hours Formulation of statistical models, sufficiency; methods of estimation and optimal theory, asymptotic efficiency; the confidence procedures and hypothesis testing, uniformly most powerful tests; Bayesian statistics.
Recommended Background: One year of advanced calculus and 425.

MATH 526 - Statistics II
3 Credit Hours Continuation of 525. Estimation and tests in general linear models; non-parametric models, rank methods for comparison, robust tests. Other topics as selected by instructor.
(DE) Prerequisite(s): 525.

MATH 527 - Stochastic Modeling
3 Credit Hours Variable topics in probability applied to real world situations. Topics may include queuing theory, branching processes, Monte Carlo simulation, stochastic finance and other topics as selected by instructor.
Recommended Background: One year of advanced calculus and one year of undergraduate probability or mathematical statistics.

MATH 529 - Seminar in Stochastics
1-3 Credit Hours Repeatability: May be repeated. Maximum 12 hours.

MATH 531 - Ordinary Differential Equations I
3 Credit Hours Existence, uniqueness, extendibility, and dependence on parameters for solutions of differential equations. The theory of linear systems of differential equations including boundary value problems and series methods.
Recommended Background: One year of advanced calculus and undergraduate differential equations.

MATH 532 - Ordinary Differential Equations II
3 Credit Hours Continuation of 531. The nonlinear theory of differential equations including Liapunov stability, critical point analysis, and Poincare-Bendixson theory.
(DE) Prerequisite(s): 531.

MATH 534 - Calculus of Variations
3 Credit Hours Necessary and sufficient conditions for weak and strong extrema in one-dimensional variation problems; Lagrangian mechanics. Multiple integrals. Basic elements of direct methods.
Recommended Background: At least one senior-level course in differential equations or advanced calculus. Mathematical maturity.

MATH 535 - Partial Differential Equations I
3 Credit Hours First order partial differential equations, classification of second order partial differential equations, properties of elliptic, parabolic and hyperbolic partial differential equations.
Recommended Background: One year of advanced calculus.

MATH 536 - Partial Differential Equations II
3 Credit Hours Continuation of 535. Properties and representation formulas for elliptic, parabolic and hyperbolic partial differential equations.
(DE) Prerequisite(s): 535.

MATH 537 - Mathematical Principles of Continuum Mechanics I
3 Credit Hours Conservation principles, equations of equilibrium and motion for fluids and elastic solids, constitutive relations and stress, convexity properties, bifurcation phenomena, existence theory.
Recommended Background: Courses in advanced calculus and advanced differential equations.

MATH 538 - Mathematical Principles of Continuum Mechanics II
3 Credit Hours Continuation of 537.
(DE) Prerequisite(s): 537.

MATH 539 - Seminar in Differential Equations
1-3 Credit Hours Repeatability: May be repeated. Maximum 12 hours.

MATH 545 - Real Analysis
3 Credit Hours Measure theory, Lebesgue integration, Holder and Minkowski inequalities, Radon-Nikodym theorem, Fubini's theorem.
Recommended Background: One year of advanced calculus.

MATH 546 - Complex Analysis
3 Credit Hours Holomorphic functions, Cauchy's theorem, Maximum Modulus theorem, Schwarz's lemma, normal families, Riemann mapping theorem.
(DE) Prerequisite(s): 545.

MATH 547 - Applied Linear Analysis
3 Credit Hours Banach and Hilbert spaces, linear operators and spectral theory, Sobolev spaces, applications.
(DE) Prerequisite(s): 545.
MATH 549 - Seminar in Analysis
1-3 Credit Hours  Repeatability: May be repeated. Maximum 12 hours.

MATH 551 - Modern Algebra I
3 Credit Hours Groups and rings.
Recommended Background: One year of undergraduate abstract algebra.

MATH 552 - Modern Algebra II
3 Credit Hours Continuation of 551; modules, fields and Galois theory.
(DE) Prerequisite(s): 551.

MATH 555 - Number Theory I
3 Credit Hours Introduction to algebraic number theory.
Recommended Background: One year of undergraduate abstract algebra.

MATH 556 - Number Theory II
3 Credit Hours Continuation of 555.
(DE) Prerequisite(s): 555.

MATH 559 - Seminar in Algebra
1-3 Credit Hours  Repeatability: May be repeated. Maximum 12 hours.

MATH 561 - Topology I
3 Credit Hours Topological spaces and continuous functions, separation axioms, product and quotient topologies, connectedness, compactness, complete metric spaces.
Recommended Background: One year of advanced calculus.

MATH 562 - Topology II
3 Credit Hours Continuation of 561. Fundamental group and covering spaces.
(DE) Prerequisite(s): 561.

MATH 567 - Riemannian Geometry I
3 Credit Hours Riemannian and Lorentzian manifolds. Variations of arc length, Jacobi fields, comparison theorems. Constant curvature spaces. Curvature and topology of manifolds.
Recommended Background: One year of advanced calculus.

MATH 568 - Riemannian Geometry II
3 Credit Hours Continuation of 567.
(DE) Prerequisite(s): 567.

MATH 569 - Seminar in Topology and Geometry
1-3 Credit Hours  Repeatability: May be repeated. Maximum 12 hours.

MATH 571 - Numerical Mathematics I
Cross-listed: (Same as Computer Science 571.)
Recommended Background: Courses in advanced calculus and basic numerical analysis.

MATH 572 - Numerical Mathematics II
Cross-listed: (Same as Computer Science 572.)
(DE) Prerequisite(s): 571.

MATH 574 - Finite Element Methods
3 Credit Hours Finite element techniques for solution of boundary and initial-boundary value problems. Variational formulation. Finite dimensional subspaces and their approximating properties; rates of convergence. Computer implementation.
Cross-listed: (Same as Computer Science 574.)
Recommended Background: Courses in partial differential equations, linear algebra and numerical analysis.

MATH 577 - Optimization
3 Credit Hours Mathematical foundations of constrained and unconstrained optimization. Lagrange multipliers, the Farkas lemma, the Kuhn-Tucker-Karush theorem. Analysis of major algorithms and applications to real world problems.
Recommended Background: Courses in numerical algorithms, linear algebra and advanced calculus.

MATH 578 - Numerical Methods for Partial Differential Equations
3 Credit Hours Numerical approximation of solutions of partial differential equations including conservation laws and hyperbolic, parabolic, and elliptic problems. Derivation, physical meaning, and implementation of schemes.
Recommended Background: A course in partial differential equations or 512 or 515, and familiarity with an operating system and a programming language.

MATH 579 - Seminar in Numerical Mathematics
1-3 Credit Hours  Repeatability: May be repeated. Maximum 12 hours.
<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credit Hours</th>
<th>Description</th>
<th>Prerequisite(s)</th>
<th>Repeatability</th>
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<tr>
<td>MATH 581</td>
<td>Mathematical Ecology I</td>
<td>3</td>
<td>Deterministic and stochastic models of populations, communities, and ecosystems. Cross-listed: (Same as Ecology and Evolutionary Biology 581.)</td>
<td>(DE) 431 and 453.</td>
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<tr>
<td>MATH 582</td>
<td>Mathematical Ecology II</td>
<td>3</td>
<td>Continuation of 581. Cross-listed: (Same as Ecology and Evolutionary Biology 582.)</td>
<td>(DE) 581.</td>
<td></td>
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<tr>
<td>MATH 583</td>
<td>Mathematical Evolutionary Theory</td>
<td>3</td>
<td>Population genetics and evolutionary ecology. Cross-listed: (Same as Ecology and Evolutionary Biology 585.)</td>
<td>(DE) 431 and 453.</td>
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<tr>
<td>MATH 589</td>
<td>Seminar in Mathematical Ecology</td>
<td>1-3</td>
<td>Repeatability: May be repeated. Maximum 12 hours.</td>
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<tr>
<td>MATH 590</td>
<td>Seminar in Teaching College Mathematics</td>
<td>1-3</td>
<td>Selected topics in research, theory, and techniques for teaching collegiate mathematics. Repeatability: May be repeated. Maximum 6 hours. Credit Restriction: May not be applied toward mathematics major (Master of Science). Registration Permission: Consent of department head.</td>
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<tr>
<td>MATH 593</td>
<td>Independent Study</td>
<td>1-12</td>
<td>Repeatability: May be repeated. Maximum 12 hours.</td>
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<tr>
<td>MATH 598</td>
<td>Graduate Reading in Mathematics</td>
<td>1-3</td>
<td>Independent study with faculty guidance. Repeatability: May be repeated. Maximum 6 hours. Comment(s): Graduate standing required. Registration Permission: Consent of instructor.</td>
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<tr>
<td>MATH 599</td>
<td>Seminar in Mathematical Presentations</td>
<td>1</td>
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<tr>
<td>MATH 600</td>
<td>Doctoral Research and Dissertation</td>
<td>3-15</td>
<td>Grading Restriction: P/NP only. Repeatability: May be repeated. Registration Restriction(s): Minimum student level – graduate.</td>
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<td>Minimum student level – graduate.</td>
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<tr>
<td>MATH 619</td>
<td>Seminar in Applied Mathematics</td>
<td>1-3</td>
<td>Repeatability: May be repeated. Maximum 12 hours. Repeatability: May be repeated. Maximum 12 hours. Registration Restriction(s): Minimum student level – graduate.</td>
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<td>Minimum student level – graduate.</td>
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<tr>
<td>MATH 624</td>
<td>Advanced Probability II</td>
<td>3</td>
<td>Continuation of 623. Repeatability: May be repeated. Maximum 12 hours. (DE) 623. Registration Restriction(s): Minimum student level – graduate.</td>
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<td>Minimum student level – graduate.</td>
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<tr>
<td>MATH 636</td>
<td>Advanced Partial Differential Equations II</td>
<td>3</td>
<td>Continuation of 635. Repeatability: May be repeated. Maximum 12 hours. (DE) 635. Registration Restriction(s): Minimum student level – graduate.</td>
<td></td>
<td></td>
<td>Minimum student level – graduate.</td>
</tr>
</tbody>
</table>
MATH 641 - Functional Analysis I
3 Credit Hours  Topological vector spaces, distributions, and Banach algebras with applications to Fourier analysis and differential equations: theorems of Krein-Milman, Paley-Wiener, Lax, Malgrange-Ehrenpreis, Gelfand-Naimark, and spectral theory of normal operators.
Repeatability: May be repeated. Maximum 6 hours.
(DE) Prerequisite(s): 545.
(DE) Corequisite(s): 546 or 443.
Registration Restriction(s): Minimum student level – graduate.

MATH 642 - Functional Analysis II
3 Credit Hours  Continuation of 641.
Repeatability: May be repeated. Maximum 6 hours.
(DE) Prerequisite(s): 641.
Registration Restriction(s): Minimum student level – graduate.

MATH 645 - Advanced Analysis I
3 Credit Hours  Selected topics in real, complex, or discrete analysis.
Repeatability: May be repeated. Maximum 12 hours.
(DE) Prerequisite(s): 545 and 546.
Registration Restriction(s): Minimum student level – graduate.

MATH 646 - Advanced Analysis II
3 Credit Hours  Continuation of 645.
Repeatability: May be repeated. Maximum 12 hours.
(DE) Prerequisite(s): 645.
Registration Restriction(s): Minimum student level – graduate.

MATH 649 - Seminar in Analysis
1-3 Credit Hours  Repeatability: May be repeated. Maximum 12 hours.
Registration Restriction(s): Minimum student level – graduate.

MATH 651 - Advanced Modern Algebra I
3 Credit Hours  Selected topics in algebra, algebraic geometry, or number theory.
Repeatability: May be repeated. Maximum 12 hours.
(DE) Prerequisite(s): 551 and 552.
Registration Restriction(s): Minimum student level – graduate.

MATH 652 - Advanced Modern Algebra II
3 Credit Hours  Continuation of 651.
Repeatability: May be repeated. Maximum 12 hours.
(DE) Prerequisite(s): 651.
Registration Restriction(s): Minimum student level – graduate.

MATH 659 - Seminar in Algebra
1-3 Credit Hours  Repeatability: May be repeated. Maximum 12 hours.
Registration Restriction(s): Minimum student level – graduate.

MATH 661 - Modern Topology I
3 Credit Hours  Selected topics in topology.
Repeatability: May be repeated. Maximum 12 hours.
(DE) Prerequisite(s): 561 and 562.
Registration Restriction(s): Minimum student level – graduate.

MATH 662 - Modern Topology II
3 Credit Hours  Continuation of 661.
Repeatability: May be repeated. Maximum 12 hours.
(DE) Prerequisite(s): 661.
Registration Restriction(s): Minimum student level – graduate.

MATH 663 - Algebraic Topology I
3 Credit Hours  Homology, cohomology and homotopy theories: duality theorems and Hurewicz isomorphism theorem.
Repeatability: May be repeated. Maximum 9 hours.
(DE) Prerequisite(s): 561 and 562.
Recommended Background: One year of abstract algebra.
Registration Restriction(s): Minimum student level – graduate.

MATH 664 - Algebraic Topology II
3 Credit Hours  Continuation of 663.
Repeatability: May be repeated. Maximum 9 hours.
(DE) Prerequisite(s): 663.
Registration Restriction(s): Minimum student level – graduate.
MATH 667 - Modern Geometry I
3 Credit Hours Selected topics in Riemannian geometry and geometric analysis.
Repeatability: May be repeated. Maximum 12 hours.
(DE) Prerequisite(s): 561 and 562 or 567 and 568.
Registration Restriction(s): Minimum student level – graduate.

MATH 668 - Modern Geometry II
3 Credit Hours Continuation of 667.
Repeatability: May be repeated. Maximum 12 hours.
(DE) Prerequisite(s): 667.
Registration Restriction(s): Minimum student level – graduate.

MATH 669 - Seminar in Topology and Geometry
1-3 Credit Hours Repeatability: May be repeated. Maximum 12 hours.
Registration Restriction(s): Minimum student level – graduate.

MATH 673 - Advanced Topics in Numerical Partial Differential Equations I
3 Credit Hours Theoretical aspects of finite difference and finite element methods for initial and boundary value problems.
Repeatability: May be repeated. Maximum 12 hours.
(DE) Prerequisite(s): 571 and 572.
Registration Restriction(s): Minimum student level – graduate.

MATH 674 - Advanced Topics in Numerical Partial Differential Equations II
3 Credit Hours Continuation of 673.
Repeatability: May be repeated. Maximum 12 hours.
(DE) Prerequisite(s): 673.
Registration Restriction(s): Minimum student level – graduate.

MATH 681 - Advanced Mathematical Ecology I
3 Credit Hours Selected topics in theoretical and applied mathematical ecology; population, community, ecosystem ecology and applied topics such as demography, ecotoxicology, epidemiology, environmental change, and resource management.
Cross-listed: (Same as Ecology and Evolutionary Biology 681.)
Repeatability: May be repeated. Maximum 6 hours.
(DE) Prerequisite(s): 581 and 582.
Registration Restriction(s): Minimum student level – graduate.

MATH 682 - Advanced Mathematical Ecology II
3 Credit Hours Continuation of 681.
Cross-listed: (Same as Ecology and Evolutionary Biology 682.)
Repeatability: May be repeated. Maximum 6 hours.
(DE) Prerequisite(s): 681.
Registration Restriction(s): Minimum student level – graduate.

College: Education, Health and Human Sciences
Department: Theory and Practice in Teacher Education

Mathematics Education (MEDU)

MEDU 445 - Teaching Algebra in the Middle Grades
3 Credit Hours Examines the algebraic content and teaching strategies associated with the teaching of algebra in the middle grades; the study of how adolescents learn algebra, various representations for algebraic concepts, and strategies to support the development of mathematical habits of mind that are essential for success in more advanced mathematics courses.
Registration Restriction(s): Admission to Teacher Education or consent of instructor.

MEDU 446 - Teaching Geometry in the Middle Grades
3 Credit Hours Examines the geometric content and teaching strategies associated with the teaching of geometry in the middle grades; the study of how adolescents learn geometry, geometric transformations, informal proof and reasoning, and strategies to support the development of mathematical habits of mind that are essential for success in more advanced mathematics courses.
Registration Restriction(s): Admission to Teacher Education or consent of instructor.

MEDU 485 - Teaching Mathematics in the Secondary School
3 Credit Hours Preparation of teaching plans, evaluation, materials for teaching mathematics. Teaching simulation and directed observation in schools.
Registration Restriction(s): Admission to Teacher Education or consent of Instructor.