Mathematics

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

Conrad Plaut, Head
Xiaobing Feng, Director of Graduate Studies

Professors
Alexiades, V., PhD – Delaware
Brodskiy, N., PhD – Saskatchewan (Canada)
Chen, X., PhD – Case Western
Collins, C., PhD – Minnesota
Dydek, J., PhD – Warsaw (Poland)
Feng, X., PhD – Purdue
Frazier, M., PhD – California (Los Angeles)
Gavrilits, S., PhD – Moscow State
Gross, L., PhD – Cornell
Karakashian, O., PhD – Harvard
Lenhart, S., PhD – Kentucky
Mulay, 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
Simmons, 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 (Russia)
Webster, C., PhD – Florida State
Wise, S., PhD – Virginia

Associate Professors
Day, J., PhD – Pittsburgh
Denzler, J., PhD – ETH (Zurich)
Fefferman, N., PhD – Tufts
Finotti, L., PhD – Texas
Freire, A., PhD – Princeton
Ganusov, V., PhD – Emory
Lind, J., PhD – Washington
Maroulias, V., PhD – North Carolina
Nicoara, R., PhD – UCLA
Salgado-Gonzales, A., PhD – Texas A & M

Assistant Professors
Bourni, T., PhD – Stanford
Chen, Y., PhD – British Columbia
Cartwright, D., PhD – California (Berkeley)
Jameson, M., PhD – Emory
Langford, M., PhD – Australian National
Mengesha, T., PhD – Temple
Phan, T., PhD – Minnesota
Strickland, W., PhD – Colorado State
Joint Faculty
Berry, M., PhD – Illinois
Evans, K., PhD – Georgia Tech
Hauck, C., PhD – Maryland

Lecturers
Bonee, K., MS – Tennessee
Booth, H., PhD – Princeton
Caldwell, J., PhD – Illinois
Clark, J., PhD – Tennessee
Conner, A., MM – Tennessee
Contole, A., MM – Tennessee
Cook, T., MS – Tennessee
Fowler, J., MA – Kentucky
Fridman, T., PhD – Rutgers
Gelantalis, M., PhD – Indiana
Gilbert, M., MS – Tennessee
Guest, R., MS – Baylor
Long, J., PhD – Michigan
Peery, M., MM – Tennessee
Papadopulos, P., PhD – Rochester
Pringle, K., PhD – Oregon
Remus, C., MS – Tennessee
Self, C., MS – Tennessee
Smith, K., MM – Tennessee
Stein, D., MS – Tennessee
Sukanek, K., MS – Mississippi
Swenson, M., PhD – Texas
Unseren, M., PhD – Purdue
Von Herrmann, A., PhD – Colorado State
Wolf, A., PhD – Emory
Wright, G., MM – Tennessee

MAJOR DEGREES
Mathematics MMath
Mathematics MS
Applied mathematics concentration
Mathematics PhD
Mathematical ecology/evolution concentration

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 credit 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 graduate credit 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 credit hours in MATH 509. At most, 6 credit 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 credit hours of thesis research, and 24 additional graduate credit hours in acceptable courses numbered above 400. Of the 24 additional graduate credit hours, 6 may be in areas outside the department and 15 must be in mathematics courses numbered above 500.

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

The course-work option requires 30 graduate credit hours in acceptable courses numbered above 400. Of these 30 graduate credit hours, 21 (at least 15 of which are in mathematics) must be in courses numbered above 500. Of the 30 graduate credit 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 453.
- One credit 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 either by 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 yearlong 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 yearlong 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
(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 441 - Advanced Calculus
3 Credit Hours
Introduction to the topology of R^n, functions of multiple variables, and multivariable advanced calculus.
Credit Restriction: Students who receive a grade of C or better in 447 may not subsequently receive credit for 441.
(RE) Prerequisite(s): 341.

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

MATH 447 - Honors: Analysis I
3 Credit Hours
Honors-level introduction to the theory of sequences, series, differentiation, and integration of functions of one or more variables.
(RE) Prerequisite(s): 341 or honors mathematics concentration.

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

MATH 450 - Number Theory
3 Credit Hours
Primes, Diophantine equations, quadratic reciprocity, cryptography, and other topics in number theory.
(RE) Prerequisite(s): 351.

MATH 451 - Abstract Algebra
3 Credit Hours
Topics in groups, rings, and fields.
Credit Restriction: Students who receive a grade of C or better in 457 may not subsequently receive credit for 451.
(RE) Prerequisite(s): 351.

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
Topics in abstract algebra, including groups, rings, fields, vector spaces, and linear transformations.
(RE) Prerequisite(s): 351 or honors concentration.

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 471 - 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
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.
Repeatability: May be repeated. Maximum 9 hours.
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
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 519 - Seminar in Applied Mathematics
1-3 Credit Hours
Repeatability: May be repeated. Maximum 12 hours.

MATH 520 - Internship
1-6 Credit Hours
Supervised off-campus experience in applications of mathematical principles and methods in business, industry, or government. Written report required.
Grading Restriction: Satisfactory/No Credit grading only.
Repeatability: May be repeated. Maximum 6 hours.
Recommended Background: 4 courses in graduate-level mathematics, and consent of departmental director of graduate studies in consultation with advisor.
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  
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
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
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
3 Credit Hours
Cross-listed: (Same as Computer Science 571.)
Recommended Background: Courses in advanced calculus and basic numerical analysis.

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

MATH 574 - Finite Element Methods
3 Credit Hours
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.

MATH 581 - Mathematical Ecology I  
3 Credit Hours  
Deterministic and stochastic models of populations, communities, and ecosystems.  
Cross-listed: (Same as Ecology and Evolutionary Biology 581.)  
(DE) Prerequisite(s): 431 and 453.

MATH 582 - Mathematical Ecology II  
3 Credit Hours  
Continuation of 581.  
Cross-listed: (Same as Ecology and Evolutionary Biology 582.)  
(DE) Prerequisite(s): 581.

MATH 583 - Mathematical Evolutionary Theory  
3 Credit Hours  
Population genetics and evolutionary ecology.  
Cross-listed: (Same as Ecology and Evolutionary Biology 585.)  
(DE) Prerequisite(s): 431 and 453.

MATH 585 - Optimal Control Theory  
3 Credit Hours  
Deterministic optimal control. Examples involving calculus of variations, optimal trajectories, and engineering control problems. Introduction to stochastic control.  
Recommended Background: One year of advanced calculus and undergraduate differential equations.

MATH 589 - Seminar in Mathematical Ecology  
1-3 Credit Hours  
Repeatability: May be repeated. Maximum 12 hours.

MATH 590 - Seminar in Teaching College Mathematics  
1-3 Credit Hours  
Selected topics in research, theory, and techniques for teaching collegiate mathematics.  
Repeatability: May be repeated. Maximum 12 hours.  
Credit Restriction: May not be applied toward mathematics major (Master of Science).  
Registration Permission: Consent of department head.

MATH 593 - Independent Study  
1-12 Credit Hours  
Repeatability: May be repeated. Maximum 12 hours.

MATH 597 - Graduate Student Seminar in Mathematical Research  
1 Credit Hours  
Grading Restriction: Satisfactory/No Credit grading only.  
Repeatability: May be repeated. Maximum 12 hours.  
Credit Restriction: May not be applied towards Mathematics major for Master of Science degree.

MATH 598 - Graduate Reading in Mathematics  
1-3 Credit Hours  
Independent study with faculty guidance.  
Repeatability: May be repeated. Maximum 6 hours.  
Comment(s): Graduate standing required.  
Registration Permission: Consent of instructor.
MATH 599 - Seminar in Mathematical Presentations
1 Credit Hours

MATH 600 - Doctoral Research and Dissertation
3-15 Credit Hours
Grading Restriction: P/NP only.
Repeatability: May be repeated.
Registration Restriction(s): Minimum student level – graduate.

MATH 619 - Seminar in Applied Mathematics
1-3 Credit Hours
Repeatability: May be repeated. Maximum 12 hours.
Registration Restriction(s): Minimum student level – graduate.

MATH 623 - Advanced Probability I
3 Credit Hours
Selected topics in modern theory of probability and stochastic processes.
Repeatability: May be repeated. Maximum 12 hours.
(DE) Prerequisite(s): 523 and 524.
Registration Restriction(s): Minimum student level – graduate.

MATH 624 - Advanced Probability II
3 Credit Hours
Continuation of 623.
Repeatability: May be repeated. Maximum 12 hours.
(DE) Prerequisite(s): 623.
Registration Restriction(s): Minimum student level – graduate.

MATH 629 - Seminar in Stochastics
1-3 Credit Hours
Repeatability: May be repeated. Maximum 12 hours.
Registration Restriction(s): Minimum student level – graduate.

MATH 635 - Advanced Partial Differential Equations I
3 Credit Hours
Selected topics in classical and modern theoretical partial differential equations.
Repeatability: May be repeated. Maximum 12 hours.
(DE) Prerequisite(s): 535 and 536.
Registration Restriction(s): Minimum student level – graduate.

MATH 636 - Advanced Partial Differential Equations II
3 Credit Hours
Continuation of 635.
Repeatability: May be repeated. Maximum 12 hours.
(DE) Prerequisite(s): 635.
Registration Restriction(s): Minimum student level – graduate.

MATH 639 - Seminar in Differential Equations
1-3 Credit Hours
Repeatability: May be repeated. Maximum 12 hours.
Registration Restriction(s): Minimum student level – graduate.

MATH 641 - Functional Analysis I
3 Credit Hours
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 679 - Seminar in Numerical Mathematics
1-3 Credit Hours
Repeatability: May be repeated. Maximum 12 hours.
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.

MATH 689 - Seminar in Mathematical Ecology
1-3 Credit Hours
Repeatability: May be repeated. Maximum 12 hours.
Registration Restriction(s): Minimum student level – graduate.