Mathematics

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Degrees Offered: B.S. in Mathematics, M.S. in Mathematics with Specialization in Operations Research and Statistics, M.S. in Mathematics with specialization in Analysis, M.S. in Mathematics with Specialization in Industrial Mathematics; Ph.D. in Mathematics with Dissertation in Applied and Industrial Mathematics

Students and faculty in the mathematics department at Tech are involved in many areas of mathematics, from pure mathematics to applied mathematics, operations research, and statistics. The department offers bachelors, masters, and Ph.D. degrees in mathematics, and plays an important role in teaching mathematics to students in other disciplines. Faculty and students are also involved in a number of research projects, many of them in conjunction with researchers in other departments at Tech and at other institutions.

There are career opportunities for mathematics students at both the bachelor's and master's levels. Students in mathematics can prepare for actuarial careers, careers in education, and careers in a number of industries, including telecommunications, aerospace, information technology, and financial engineering.

Preparation for a career in industry should include a broad background in mathematics, modeling skills, computer skills, expertise in an area outside mathematics, and communication skills. Degree requirements are designed to help students develop these important abilities.

Mathematics can also be studied in preparation for more advanced work in a variety of fields including pure mathematics, applied mathematics, operations research, statistics, scientific computing, and business administration. Many students choose to combine a major in mathematics with a major in a second field such as management, computer science, engineering, or physics. A strong background in mathematics can be very helpful in graduate studies.

Students in the mathematics department at both the undergraduate and graduate level have many opportunities to interact with faculty and participate in a variety of mathematical activities. The department has weekly seminars in which faculty, graduate students, and visitors present their research. Both undergraduates and graduates are involved in research projects.

Many students are employed by the department as graders, lab facilitators, teaching assistants, and research assistants. Undergraduate students regularly compete in the William Lowell Putnam mathematics competition and in the COMAP contest in mathematical modeling.

Undergraduate Program

Bachelor of Science in Mathematics

Minimum credit hours required—120
In addition to the General Education and Institute Core Curriculum (page 99), the following courses are required:

Introduction to Computer Science: CSE 113 (4) CSE 107 (4) or ES 111 (3) or EE 251 (3)
Basic Mathematics: MATH 2532 (4), 2420 (3), 335 (3), 336 (3), 352 (3), 372 (3), 382 & 382L (4), 454 (3)
Mathematical Modeling: MATH 430 (3)
Mathematics Electives: Four courses from at least two of the following areas:
- Applied Mathematics: 410 (3), 411 (3), 435 (3), 436 (3), 437 (3), 438 (3)
- Pure Mathematics: 442 (3), 455 (3), 461 (3), 471 (3), 472 (3)
- Operations Research and Statistics: 415 (3), 441 (3), 483 (3), 484 (3) 486 (3), 488 (3)

Electives outside mathematics: A minor in another department or at least 18 related credit hours outside mathematics approved by the advisor. These 18 hours may include classes fulfilling other general education or degree requirements.
Science or Engineering Elective: Eight (8) credit hours from the science and engineering disciplines beyond the general degree requirements.
Minimum of 120 credit hours' coursework: Electives to complete the minimum of 120 credit hours.

Sample Curriculum for the Bachelor of Science in Mathematics

Sample Curriculum Notes: General education requirements should be fulfilled as early as possible. The sequence MATH 352, 372 is a key prerequisite to many advanced courses and should be taken as early as possible, in no case later than the junior year

Semester 1

4	MATH 1510 & 1510L (calculus I)
4	CHEM 1215, 1215L, 1215 R (general chemistry)
4	Science/Engineering Elective
3	ENGL 1110 (college English)
15	Total credit hours

Semester 2

4	MATH 1520 (calculus II)
4	CHEM 1215, 1215L, & 1215R (general chemistry)
4	Science/Engineering Elective
3	ENGL 1120 (college English)
15	Total credit hours

Semester 3

3	MATH 2420 (intro to linear algebra)
4	MATH 2532 (calculus)
5	Phys 1310 & 1310L
3	Elective out of Math
15	Total credit hours

Semester 4

3 MATH 335 (ordinary differential equations)
3 MATH 352 (basic concepts)
5 PHYS 1320 & 1320L (general)
3 or 4 CSE 113 or ES 111
3 Elective outside of Math
17-18 Total credit hours

Semester 5

3 MATH 372 (basic concepts of analysis)
3 MATH 336 (intro to partial differential equations)
4 MATH 382 & 382L (probability & statistics)
3 Humanities/Social Science/Fine Arts
3 Elective outside of Math
16 Total credit hours

Semester 6

3 MATH 454 (linear algebra)
3 ENGL 341 (technical writing)
3 Math Elective
3 Humanities/Social Sciences/Fine Arts
3 Elective outside of Math
15 Total credit hours

Semester 7

3 MATH 430 (mathematical modeling)
3 Math Elective
3 Humanities/Social Science/Fine Arts
3 Humanities/Social Science/Fine Arts
3 Elective outside of Math
15 Total credit hours

Semester 8

3 Math Elective
3 Math Elective
3 Humanities/Social Science/Fine Arts
3 Humanities/Social Science/Fine Arts
3 Elective Outside of Math
15 Total credit hours

Choice of electives must include courses for approved 18-hour sequence. It is strongly recommended that elective choices include advanced science and/or a foreign language.

Minor in Mathematics

Minimum credit hours required—18
The following courses are required:

- MATH 2420 (3) or MATH 337 (3), 335 (3), 352 (3), 382 (3)
- Six (6) additional hours of upper-division mathematics

Graduate Program

Master of Science in Mathematics

A program fulfilling the general requirements must be completed. Two basic plans are offered: for the program without thesis, MATH 590 (three credit hours) must be completed; for the program with thesis, MATH 591 (six credit hours) must be completed. The student must fulfill the requirements for the undergraduate program in mathematics. In addition, the student must fulfill the requirements of one of the following three specializations. Students interested in continuing for the PhD in Applied and Industrial Mathematics should take care to choose their courses so that they will fit that program as well.

Accelerated Master's Degree Program in Mathematics (Minimum 150 credit hours)

Accelerated Master's Degree Program in Mathematics (Minimum 150 credit hours) The Accelerated Master Degree program provides the opportunity to obtain a BS and MS degree in Mathematics in five years. Accepted students may apply at most 12 credits from 500-level courses towards both their undergraduate and graduate degrees. It is recommended to apply to the program after completion of Math 352 and before enrolling in any graduate courses. The student will work with a professor in the Mathematics Department who will assist the student in developing the course of study and advise the student on their master's thesis or independent study.

Master of Science in Mathematics with Specialization in Industrial Mathematics [Total : 30 cr hrs. of which six credit hours must be approved upper-division or graduate course work from another department]

Industry and business provide many areas for the application of advanced mathematics, and many possibilities for mathematicians to make significant contributions. New Mexico Tech offers a program to prepare students for these opportunities. Students need a basic background in numerical analysis, differential equations, and statistics at the undergraduate level. The graduate requirements are:

1) Modeling courses (3 credits): MATH 430 (Mathematical Modeling); MATH 530 (Modeling Case Studies)
2) Core industrial mathematics courses (6 credits)—two of the following: MATH 511 (Numerical Methods); MATH 518 (Nonlinear Programming); MATH 532 (Perturbation Methods); MATH 535 (Mathematical Physics); MATH 587 (Time Series)
3) A concentration of four related courses (12 credits), at least two at the 500-level (beyond the two in requirement 2) and at least two in one other department, and additional courses to satisfy the general requirements of the Master of Science degree. The courses to satisfy this requirement must be approved by the student's advisory committee.
4) Each student spends one term, usually summer, in an internship in an industrial position. This internship is arranged by the student, with the approval of the student's advisory committee and should involve mathematical modeling, computation and analysis.

Master of Science in Mathematics with Specialization in Operations Research and Statistics [Total 30 cr hrs. of which six credit hours must be approved upper - division or graduate course work from another department]

An interdisciplinary program in operations research and statistics is available at the graduate level within the various departments at New Mexico Tech. To specialize in this area, the student must fulfill the requirements for the undergraduate program in mathematics and complete MATH 415, 483, and one of either MATH 486 ,488 or 582 or the equivalent.

Graduate work would consist of:

1) A minimum of 12 credit hours from MATH 515, 516, 517, 518, 519, 520, 541,582, 583, 586, 587, 588. At least one course (three credit hours) must be chosen from MATH 515, 517, or 518.

2) Additional courses subject to the approval of the student's advisor to complete the requirements of the Graduate School. Related courses include ES 316; MGT 462, 472, 473; CSE 464, 565, and 567.

Master of Science in Mathematics with Specialization in Analysis [Total: 30 cr hrs. of which six credit hours must be approved upper-division or graduate course work from another department.]

To specialize in this area the student must fulfill the requirements of the undergraduate program in mathematics and complete Math 435 and Math 471 or the equivalent.

Graduate work consists of:

1) A minimum of 12 credits from Math 531, 533, 534, 535, 536, 537, 542, 575, 576, and 577.

2) Additional courses subject to the approval of the student's advisor to complete the requirements of the Graduate School.

Doctor of Philosophy in Mathematics with Dissertation in Applied and Industrial Mathematics

Students of exceptional ability, as demonstrated in a master's degree program or in previous courses, may pursue a program leading to the doctoral degree. Although the master's degree is not a requirement for the Ph.D. degree, the experience gained in writing a master's thesis or independent study project is valuable.

Degree Requirements

Up to 30 hours from a master's degree, excluding thesis and S/U courses, may be included.

48 hours of coursework approved by the student's advisory committee, including:

- Preliminary preparation courses may be taken: MATH 410, 411, 435, 437, 438, 471, 483, 486
- 500-level MATH courses (30 credit hours) consisting of:
  1. MATH 530, 532
  2. Three courses from MATH 511, 518, 535, 538, 539, 577, 582.
  3. Three or more of the remaining classes are to be additional core classes from the list above or courses from MATH 509, 510, 512, 519, 520, 531, 533, 536, 537, 583, 584, 586, 587, 588.

12 hours of upper-division or graduate-level courses from outside the math department

Dissertation (24 credit hours): MATH 595

PhD Prelim Exam:

Preliminary exams consist of the following: Differential Equations (MATH 437 and 438), Analysis (Math 372, 435, and 471), Numerical Analysis (Math 410 and 411), and Probability and Statistics (MATH 483 and 486).

A student may choose any three areas listed above and must pass all three preliminary exams by the end of the student's fourth semester to continue in the program. A student who does not pass a preliminary exam after two attempts will be terminated from the PhD program.

Graduate Minor in Applied & Industrial Mathematics

The following courses are required:

MS Level:	Two of Math 430, 437, 438 and Two of Math 530, 531, 532, 533, 535, 537, 538, 539
PhD Level:	MS requirements plus two more of the listed 500 level courses

Graduate Minor in Operations Research & Statistics

The following courses are required:

MS Level:	Math 415, 483, and Two of Math 515, 516, 517, 518, 519, 520,541, 582, 583, 586, 587, 588.
PhD Level:	MS requirements plus two more of the listed 500 level courses

Graduate Minor in Numerical Analysis

The following courses are required:

MS Level:	Math 410, 411, and Two of Math 510, 511, 512, 513
PhD Level:	MS requirements plus two more of the listed 500 level courses

Graduate Minor in Analysis

The following courses are required:

MS Level:	Math 435, 442, 471, and Two of Math 531, 533, 534, 535, 536, 537, 575, 576, 577
PhD Level:	MS requirements plus two more of the listed 500 level courses

Mathematics Courses:

MATH 1215, Intermediate Algebra 3 cr

A study of linear and quadratic functions, and an introduction to polynomial, absolute value, rational, radical, exponential, and logarithmic functions.A development of strategies for solving single-variable equations and contextual problems.

MATH 1220, College Algebra, 3 cr

Prerequisites: ACT math score of at least 21 or MATH 1215 passed with a grade of C- or better

The study of equations, functions and graphs, reviewing linear and quadratic functions, and concentrating on polynomial, rational, exponential and logarithmic functions.

MATH 1230, 1230D, Trigonometry, 3 cr, 2 cl hrs, 3 lab hrs

Prerequisites: ACT math score of at least 25 or MATH 1220 passed with a grade of C- or better or a score of at least 20/25 on the advanced portion of the placement test

A study of plane trigonometry including the definitions of the fundamental trig functions using right angle triangle and unit circle approaches. Trig functions of any real number will be evaluated and the functions graphed along with their transformations. Trigonometric identities will be developed and demonstrated including multiple angle identities and identities developed from them. Inverse Trigonometric functions will be developed and used to solve trigonometric equations. Trigonometric applications will be solved using right angle trigonometry and the laws of sines and cosines. Trigonometric methods will be applied to complex numbers and the use of 2D vectors and vector dot products.

MATH 1240, 1240D, Pre-Calculus, 3 cr, 2 cl hrs, 3 lab hrs

Corequisite: MATH 1230, or a prerequisite of a score of at least 24/30 on the trig and elementary functions placement test

This course extends students' knowledge of polynomial, rational, exponential and logarithmic functions to new contexts, including rates of change, limits, systems of equations, conic sections, and sequences and series.

Math 1430, Application Of Calculus I, 3 cr,

Prerequisite*: Adequate scoring on the Mathematics Placement Exam, or any ACT/SAT and GPA combination that is considered equivalent, or a C– or better in Math 1220 or higher.*

An algebraic and graphical study of derivatives and integrals, with an emphasis on applications on business, social science, economics and sciences.

MATH 1510, Calculus and Analytic Geometry I, 4 cr, 3 cl hrs, 3 lab hrs

Prerequisites: MATH 1230 and 1240 or the equivalent passed with grade C- or better; or ACT Math score of at least 30 or SAT Math score of at least 670 or SAT Redesign Math score of at least 700; or a score of at least 20 on the calculus readiness math placement test; or MATH 1230 and either ACT Math score of at least 26 or SAT Math score of at least 590 or SAT Redesign Math score of at least 610.

Introduces the intuitive numerical and theoretical concepts of limits, continuity, differentiation and integration. Includes the study of extrema, curve sketching, and applications involving algebraic, exponential, logarithmic and trigonometric functions. Designed for mathematics, science and engineering majors.

MATH 1520, Calculus and Analytic Geometry II, 4 cr, 4 cl hrs,

Prerequisites: MATH 1510 passed with grade C- or better

Continuation of MATH 1510.

Continues course of study begun in Calculus I. Covers integration techniques, numerical integration, improper integrals, some differential equations, sequences, series and applications.

MATH 2350, Statistical Methods, 3 cr, 3 cl hrs, 1.5 lab hrs

Prerequisites: MATH 1220 or higher

Exploratory data analysis. Introduction to probability, random variables and probability distributions. Concepts of Central Limit Theorem and Sampling Distributions such as sample mean and sample proportion. Estimation and hypothesis testing single population parameter for means and proportions and difference of two population parameters for means and proportions. Analysis categorical data for goodness of fit. Fitting simple linear regression model and inference for regression parameters. Analysis of variance for several population means. Techniques in data analysis using statistical packages. Techniques in data analysis using statistical computer packages.

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MATH 2420, Applied Linear Algebra, 3 cr, 3 cl hrs, 1.5 lab hrs

Prerequisite: MATH 1510 passed with grade C- or better

An introductory study of the analysis and applications of systems of linear equations, vector spaces, matrices, and linear transformations, including computer-based linear algebra, matrix diagonalization, orthogonal decomposition, and Gram-Schmidt method.

MATH 2532, Calculus and Analytic Geometry III, 4 cr, 4 cl hrs

Prerequisite: MATH 1520 passed with grade C- or better

Vectors and vector operations in two and three dimensions, partial differentiation, multiple integration, topics in vector calculus in two and three dimensions.

Math 289 Vector Calculus, 1 cr

Prerequisite: MATH 2530

offered during spring, summer, and fall semesters.

Students enrolled in Math 289, will attend the last ¼ of Math 2532.

An introduction to topics in two and three dimension of vector calculus such as curl and divergence, line integrals and surface integrals, the Fundamental Theorem of Line Integrals, Green's Theorem, Stokes' Theorem and the Divergence Theorem will be covered.

MATH 332, Vector Analysis, 3 cr, 3 cl hrs

Prerequisite: MATH 2532 passed with grade C- or better

Scalar and vector fields, gradient, divergence, curl, del operator, general orthogonal curvilinear coordinates, line integrals, surface and volume integrals, divergence theorem, Green's theorem, Stokes's theorem, applications.

MATH 335, Ordinary Differential Equations, 3 cr, 3 cl hrs

Prerequisite: MATH 1520 passed with grade C- or better

Solution methods for first order ordinary differential equations of various types, including separable, linear, Bernoulli and exact. Solution methods for second (and higher) order linear differential equations with constant coefficients. Series solutions. Laplace transforms. Applications.

MATH 335L, Ordinary Differential Equations Computer Lab, 1 cr, 1 cl hr

Corequisite: MATH 335 or equivalent.

Optional lab to accompany MATH 335. Basic introduction to the "Maple" syntax required to solve ordinary differential equations with computers. Emphasis on modeling, using graphing capabilities to illustrate how responses (solutions) are influenced by changes in the initial data and physical parameters.

MATH 336, Introduction to Partial Differential Equations, 3 cr, 3 cl hrs

Prerequisites: MATH 2532, 335, and one of MATH 2420 or MATH 337, each passed with grade C- or better

Orthogonal functions, Sturm-Liouville theory, Fourier series and integrals, heuristic derivation of examples of partial differential equations taken from heat conduction, vibration problems, electromagnetism, etc.; separation of variables, application to boundary value problems.

MATH 337, Engineering Mathematics, 3 cr, 3 cl hrs

Prerequisites: MATH 2532

Corequisite: MATH 335

Selected topics from linear algebra are discussed, including vectors, matrices, determinants, Gaussian elimination, vector spaces and basis as well as Eigenvalues, eigenvectors and diagonalization of matrices. Of particular interest will be linear algebra techniques which are utilized of solving systems of (linear) algebraic equations and solving systems of coupled ordinary differential equations using Laplace transforms and linear algebra tools.

MATH 352, Basic Concepts of Mathematics, 3 cr, 3 cl hrs

Prerequisite: MATH 1520 passed with grade C- or better

Mathematical proofs, set theory, mathematical induction and recursion, relations and binary operations, functions, definition and development of some common number systems, cardinal numbers, abstract algebra.

MATH 372, Basic Concepts of Analysis, 3 cr, 3 cl hrs

Prerequisite: MATH 352 or equivalent passed with grade C- or better

Real numbers, sequences, limits, continuity, uniform continuity, differentiation, Reimann integral.

MATH 382, Probability and Statistics, 3 cr, 3 cl hrs

Prerequisite: MATH 1520 passed with grade C- or better

Exploratory data analysis, random variables, estimation and hypothesis testing, linear regression and analysis of variance, basic concepts of discrete and continuous probability distributions, bivariate probability distribution functions, expected values, moment generating function and weak law of large numbers. Uses of the central limit theorem and its applications. This course provides an introduction to probability theory and statistical inference. The theory of probability is the primary mathematical tool used in statistical inference and therefore this course will concentrate heavily on probability and statistics. The course has been designed for computer science and engineering students; however, it is broad enough for students from outside these disciplines.

MATH 382L, Probability and Statistics Lab, 1 cr, 1 cl hrs

Corequisite: MATH 382 or equivalent

Entering data, descriptive statistics, graphing data, cross tabulation, hypothesis testing, and calculation of probabilities from different probability distributions. Each lab introduces a problem, provides some scientific background, suggests investigations for the data, and provides a summary of the theory used in the investigations.

MATH 383, Introduction to Biostatistics, 3 cr, 3 cl hrs

Prerequisite: Math 1520 passed with a grade of C- or better

This course covers the fundamental statistical concepts related to the practice of public health: descriptive statistics, design of biological research studies, probability, sampling, statistical distributions, confidence intervals, hypothesis testing, comparison of means and proportions, chi-squared tests, one-way & two-way ANOVA, simple and multiple linear regression, Fisher's Exact test and Mantel Hansel test for comparing several 2x2 tables. The course also uses the R statistical software and includes many applications of statistics to health sciences and medical studies, emphasizing concepts and interpretation of results. Optional topics: principal components and factor analysis.

MATH 391, Special Studies, hrs and cr to be arranged

MATH 401, Putnam Competition, 1 cr, 1 cl hr
Graded S/U
Students in this course will prepare for and then participate in the annual William Lowell Putnam Competition in mathematics. In preparation for the competition, students will learn problem-solving strategies and practice on problems from previous competitions. May be taken multiple times for credit.

MATH 410, Numerical Methods, 3 cr, 3 cl hrs
Prerequisite: CSE 107, CSE 113, ES 111, or EE 251
Corequisite: MATH 335
Floating point arithmetic, solution of linear and nonlinear systems of equations, interpolation, approximation, numerical differentiation and integration, numerical solution of ordinary differential equations.

MATH 411, Numerical Linear Algebra, 3 cr, 3 cl hrs
Prerequisites: MATH 2420; CSE 107, CSE 113, ES 111, or EE 251
Direct and iterative methods for solving linear systems, conditioning and stability, methods for computing eigenvalues and eigenvectors, linear least squares problems, singular value decomposition, computational cost, and implementation of algorithms.

MATH 415, Introduction to Operations Research: Linear Programming, 3 cr, 3 cl hrs
Prerequisite: MATH 2420 passed with grade C- or better
Linear Programming, applications of LP, the simplex method, duality theory, computational complexity of LP, interior point methods.

MATH 430 Mathematical Modeling, 3 cr, 3 cl hrs
Prerequisites: MATH 335; one of MATH 2420 or MATH 337; MATH 382, each passed with grade C- or better
Corequisite or Prerequsite: MATH 336 passed with grade C- or better
Introduction to the process of developing, analyzing, and refining mathematical models. Deterministic and probabilistic models considered for both discrete and continuous problems. Applications to a variety of fields. *Shares lectures with MATH 530, with additional work for the graduate level.* **(cross-listed with Math 530)**

MATH 435, Complex Analysis, 3 cr, 3 cl hrs
Prerequisite: MATH 336 passed with grade C- or better
Algebra of complex numbers, analytic functions and Cauchy-Riemann equations, complex integration and Cauchy's theorem, integral formulae, power series, residues and contour integration, analytic continuation, Riemann surfaces.

MATH 436, Applications of Complex Analysis, 3 cr, 3 cl hrs
Prerequisite: MATH 435 passed with grade C- or better
Topics selected from linear ordinary differential equations in the complex plane, special functions, conformal mapping, Laplace transform, Fourier and Hilbert transforms.

MATH 437, Systems of Ordinary Differential Equations, 3 cr, 3 cl hrs
Prerequisites: MATH 2420 or MATH 337, and 335, each passed with grade C- or better
Theory and application of systems of ordinary differential equations, linear and nonlinear systems, two-dimensional autonomous systems, stability, periodic solutions and limit cycles, interspecies competition and predator/prey problems, pendulum equation, Duffing equation, Van der Pol equation, Lienard equation.

MATH 438, Partial Differential Equations, 3 cr, 3 cl hrs
Prerequisite: MATH 336 passed with grade C- or better
Classification of classical partial differential equations of mathematical physics, boundary conditions, uniqueness theorems, first and second order equations, characteristics, boundary value problems, Green's functions, maximum principle.

MATH 441, Statistical Machine Learning (cross-listed as Math 541) 3 cr, 3 cl hrs
Prerequisite: MATH 382 and MATH 2420 or consent of the instructor
Basics of statistical learning. Data visualization. Linear, nonlinear and logistic regression, variable selection and regularization. Linear classification methods. Smoothing methods. Tree-based methods. Support vector machines. Unsupervised learning: principal components analysis and clustering. The R and/or Python software will be used

MATH 442, Introduction to Differential Geometry, 3 cr, 3 cl hrs
Prerequisite: MATH 2420 and MATH 2532 passed with grade C- or better
Introduction to the theory of manifolds, vector fields, tensors, differential forms, exterior derivative, integration of differential forms Stokes' theorem, Lie derivative, covariant derivative, connection, curvature, tensor analysis, geodesics.

MATH 454, Linear Algebra, 3 cr, 3 cl hrs
Prerequisites: MATH 2420 and 352, each passed with grade C- or better
Vector spaces, linear transformations, linear systems, eigenvalues and eigenvectors, Jordan canonical forms, inner product spaces, least squares problems, normal, unitary, and Hermitian transformations.

MATH 455, Introduction to Abstract Algebra, 3 cr, 3 cl hrs each semester
Prerequisite: MATH 352 passed with grade C- or better
A study of abstract algebraic structures, semi-groups, groups, rings, ideals, integral domains, fields, vector spaces, field extensions.

MATH 471, 472, Introduction to Analysis, 3 cr, 3 cl hrs each semester
Prerequisite: MATH 372 passed with grade C- or better
Basic concepts of the real-number system, elements of point-set theory, infinite sequences, limits, continuity, differentiation of functions of one variable, Riemann-Stieltjes integral, series, functions of several variables.

MATH 483, Mathematical Statistics, 3 cr, 3 cl hrs
Prerequisite: MATH 382 passed with grade C- or better
Introduction to decision theory. Multivariate distributions. Sampling distributions for the normal case. Convergence of random variables. Different methods of estimation. Principles of hypothesis testing.

MATH 484, Reliability and Quality Control, 3 cr, 3 cl hrs

Prerequisite: MATH 382 passed with grade C- or better

Order statistics, testing and estimation for common lifetime distributions in reliability, accelerated life tests, Bayesian methods in reliability. Statistical techniques of industrial quality control, sampling methods, control charts. Applications in industry.

MATH 486, Introduction to Stochastic Processes, 3 cr, 3 cl hrs

Prerequisites: MATH 2420 and 382, each passed with grade C- or better

Conditioning. The Poisson process. Theory of Markov chains, continuous time Markov and semi- Markov processes. Topics from renewal theory and Markov renewal theory. Queuing Theory. Applications in science and engineering.

MATH 488, Introduction to Operations Research: Probabilistic Methods, 3 cr, 3 cl hrs

Prerequisite: MATH 382, passed with grade C- or better

Monte Carlo Simulation Theory. Application of simulation to problems in science, engineering, and business. Queuing systems simulation. Inventory theory.

MATH 491, Directed Study, hrs and cr to be arranged

MATH 500, Directed Research, hrs and cr to be arranged

MATH 501, 502, Professional Development Seminar, 3 cr, 3 cl hrs each semester

A seminar in which students will develop skills in problem solving, communication, and research. Students will be expected to actively participate in the seminar by attending presentations, solving assigned problems, and preparing written and oral presentations. Graded S/U.

MATH 503, Graduate Seminar, 0-1 cr, 1 cl hr

Prerequisite: Graduate standing.

Attend and participate in departmental seminars. Graded on an S/U basis.

MATH 509 Graduate Internship, credit to be arranged

Prerequisite: Graduate standing

MATH 510 Computational Fluid Dynamics, 3 cr, 3 cl hrs

Prerequisite: MATH 336, 410 or equivalent; passed with a C– or better

Equations of fluid dynamics, flow models, discretization, analysis of numerical schemes, numerical methods for basic partial differential equations, numerical methods for inviscid and viscous flows.

MATH 511, Numerical Methods for Partial Differential Equations, 3 cr, 3 cl hrs

Prerequisite: MATH 410 or equivalent; passed with a C– or better

Finite difference or finite element methods for parabolic, hyperbolic and elliptic partial differential equations; implementation, approximation, stability, and convergence.

MATH 512, Numerical Methods for Wave Propagation, 3 cr, 3 cl hrs

Prerequisite: MATH 410 or equivalent; passed with a C– or better

Finite volume methods for hyperbolic partial differential equations; Riemann problems; Godunov's and Roe's methods; high resolution methods; applications.

MATH 513, Advanced Topics in Numerical Analysis, 3 cr, 3 cl hrs

Prerequisite: MATH 410 or equivalent; passed with a C– or better

Topics chosen from areas in numerical analysis, numerical partial differential equations, and numerical linear algebra. May be taken multiple times for credit.

MATH 515, Topics in Deterministic Operations Research, 3 cr, 3 cl hrs

Prerequisite: MATH 415 or consent of instructor and advisor; passed with a C– or better

Study of a special topic in deterministic operations research. May be taken multiple times for credit.

MATH 516, Topics in Stochastic Operations Research, 3 cr, 3 cl hrs

Prerequisites: MATH 486 or consent of instructor and advisor; passed with a C– or better

Study of a special topic in stochastic operations research. May be taken multiple times for credit.

MATH 517, Combinatorial Optimization, 3 cr, 3 cl hrs

Prerequisite: MATH 415 or consent of instructor and advisor; passed with a C– or better

Maximum flow, shortest path, and minimum cost flow problems on networks. Matching. Matroids. Cutting plane and branch and bound methods for integer programming. Computational complexity of combinatorial optimization problems.

MATH 518, Convex Optimization and Nonlinear Programming, 3 cr, 3 cl hrs

Prerequisite: MATH 410 or 415 or consent of instructor and advisor; passed with a C– or better

Theory and applications of constrained and unconstrained optimization, convexity, Lagrangian duality theory, Newton and quasi-Newton methods, first order methods.

MATH 519, 519D, Inverse Problems, 3cr, 3 cl hrs

Prerequisite: MATH 335 or consent of instructor and advisor; passed with a C– or better

Theory and practice of the various techniques of inverting geophysical data to obtain models. Primary emphasis is on the understanding and use of linear inverse techniques. **(Same as GEOP 529.)**

MATH 520, Applied Multivariate Analysis, 3 cr, 3 cl hrs

Prerequisite: MATH 382; MATH 483; passed with a C– or better

Multivariate normal distribution and tests assessing multivariate normality. Estimation and hypotheses testing regarding the parameters of multivariate normal populations. Principal component analysis, factor analysis, canonical correlations analysis, classification and discriminant analysis, cluster analysis, multivariate linear models, and multivariate analysis of variance and covariance. Applications in science and engineering.

MATH 530 Mathematical Modeling, 3 cr, 3 cl hrs

Prerequisites: MATH 335; one of MATH 2420 or MATH 337; MATH 382, each passed with grade C- or better
Corequisite or Prerequsite: MATH 336 passed with grade C- or better

Introduction to the process of developing, analyzing, and refining mathematical models. Deterministic and probabilistic models considered for both discrete and continuous problems. Applications to a variety of fields. Shares lectures with MATH 430, with additional work for the graduate level (MATH 530 students will complete an additional term project). **Cross-listed as MATH 430**

MATH 531, 531D, Topics in Ordinary Differential Equations, 3 cr, 3 cl hrs each semester

Prerequisite: MATH 437 or equivalent; passed with a C– or better

Study of a special topic in ordinary differential equations not usually treated. Normally one related to a field of research interest at Tech. May be taken multiple times for credit.

MATH 532, 532D, Perturbation Methods, 3 cr, 3 cl hrs

Prerequisite: MATH 437 or equivalent; passed with a C– or better

A survey of expansion techniques. Regular and singular perturbations. Poincaré-Linstedt method. Matched asymptotic expansions. Multiple scales.

MATH 533, 534, Topics in Partial Differential Equations, 3 cr, 3 cl hrs each semester

Prerequisite: MATH 438 or equivalent; passed with a C– or better

Study of a special topic in partial differential equations not usually treated. Normally one related to a field of research interest at Tech. May be taken multiple times for credit.

MATH 535, 536, Methods of Mathematical Physics, 3 cr, 3 cl hrs each semester

Prerequisite: MATH 372 or consent of instructor and advisor; passed with a C– or better

Hilbert spaces, orthonormal systems, spectral theory of self-adjoint operators, integral equations, ordinary and partial differential operators, distributions and fundamental solutions, asymptotic expansions, Laplace method, stationary phase method, asymptotic expansion of fundamental solutions, mathematical foundations of quantum mechanics.

MATH 537, 537D, Bifurcation Theory, 3 cr, 3 cl hrs

Prerequisite: MATH 437 or equivalent; passed with a C– or better

Discrete and continuous models. Nonlinear buckling, expansion of the bifurcated solution, stability analysis, Hopf bifurcation, degree theory, the Rabinowitz theorem, and other topics.

MATH 538, 538D, Wave Phenomena, 3 cr, 3 cl hrs

Prerequisite: MATH 438 or equivalent or consent of instructor and advisor; passed with a C– or better

Hyperbolic and dispersive waves. Characteristic methods, breaking and shock fitting, and weak solutions. Examples drawn from water waves, traffic flow problems, supersonic flight, and other areas.

MATH 539, 539D, Fluid Dynamics, 3 cr, 3 cl hrs

Prerequisite: MATH 438 or equivalent; passed with a C– or better

The Navier-Stokes equations, inviscid flow, irrational fluids, viscosity, and turbulence. Other topics as time and interest permit.

MATH 540, Calculus of Variations, 3 cr, 3 cl hrs

Prerequisite: MATH 437 or graduate standing; passed with a C– or better

Development of the classical theorems of Calculus of Variations, applications, some numerical approaches. Includes Euler equations, broken extremals an the Weierstrass-Erdmann conditions, the second variation and Hamilton-Jacobi equation, the Weierstrass E-function, and the Ritz method.

MATH 541, Statistical Machine Learning (cross-listed as MATH 441) 3cr, 3 cl hrs

Prerequisites: MATH 382 and MATH 2420 or consent of the instructor

Basics of statistical learning. Data visualization. Linear, nonlinear and logistic regression, variable selection and regularization. Linear classification methods. Smoothing methods. Tree-based methods. Support vector machines. Unsupervised learning: principal components analysis and clustering. The R and/or Python software will be used.
Shares lectures with Math 441, with additional work for the graduate level (Math 541 students will have extra in-depth questions on the homework and stronger requirements for the final project).

MATH 542, Topics in Differential Geometry, 3 cr, 3 cl hrs

Prerequisite: MATH 442 or consent of instructor and advisor; passed with a C– or better

Study of advanced topics in differential geometry such as: Brouwer degree, fundamental group, homology groups, De Rham cohomology, Betti numbers, fibre bundles, Morse theory, Lie groups, covering spaces, homotopy groups. May be taken multiple times for credit.

MATH 575, 576, Functions of a Real Variable, 3 cr, 3 cl hrs each semester

Prerequisites: MATH 471, 472; MATH 461 or MATH 561 recommended; passed with a C– or better

Topological concepts, category, measure theory, Lebesgue measure and integration, derivatives and the Radon-Nikodym theorem, product spaces and measures, function spaces, normed linear spaces.

MATH 577 Functional Analysis, 3 cr, 3 cl hrs

Prerequisite: MATH 471 or equivalent; passed with a C– or better

Normed vector spaces, Banach spaces, Banach fixed point theorem. Lebesgue integral, Lebesgue measure. Hilbert spaces and orthonormal systems, strong and weak convergence. Linear operators on Hilbert spaces, self-adjoint operators, compact operators, spectral theory, Fourier transform. Applications to integral and differential equations, Fredholm theory. Distributions and partial differential equations, fundamental solutions, resolvent, Green's functions, weak solutions.

MATH 581, Directed Study, hrs and cr to be arranged

An advanced course offered on demand under the guidance of a senior staff member.

MATH 582, Linear Statistical Models with Applications, 3 cr, 3 cl hrs

Prerequisite: MATH 483 or consent of instructor and advisor; passed with a C– or better

An in-depth study of regression and analysis of variance models. Topics include multiple regressions and model building, analysis of residuals, analysis of variance as regression analysis, generalized linear models, generalized linear mixed models, nonlinear models, multi-factor models with equal and unequal sample sizes, random and fixed effects models, randomized complete block designs, and analysis of covariance. The statistical packages SAS and Minitab will be used for data analysis.

MATH 583, 584, Topics in Probability and Statistics, 3 cr, 3 cl hrs each semester

Prerequisites: MATH 483; MATH 486 or consent of instructor and advisor; passed with a C– or better

Advanced topics selected from linear regression analysis, the design of experiments, decision theory. Bayes and empirical Bayes procedures. Markov chains, Markov and semi-Markov processes, renewal theory. May be taken multiple times for credit.

MATH 586, 586D, Spatial Variability and Geostatistics, 3 cr, 3 cl hrs

Prerequisite: MATH 382; passed with a C– or better

Introduction to spatial and temporal variability. Stationary and intrinsic random fields, variograms and estimation. Kriging, co-kriging, and simulation of random fields. Conditioning and conditional simulation. Indicator kriging and simulation. Applications from hydrology, mining, petroleum engineering, and other fields of science and engineering.

MATH 587, 587D, Analysis of Time Series and Spatial Data, 3 cr, 3 cl hrs

Offered in alternate years on demand

An introductory overview of methods for analyzing temporal and spatial series with an emphasis on scientific applications. Linear systems in continuous and discrete time, Fourier analysis, spectral estimation, convolution and deconvolution, filtering, the z and Laplace transforms, stationary and nonstationary time series, ARIMA modeling, forecasting, and generalizations to multidimensional and multichannel applications. **(Same as GEOP 505)**

MATH 588, Advanced Data Analysis, 3 cr, 3 cl hrs

Prerequisite: MATH 483 or consent of instructor and advisor; passed with a C– or better

Topics include linear regression, inferential tools for regression, model checking and refinement, experimental design, repeated measures and other multivariate responses, comparisons of proportions or odds, logistic regressions and power analysis. Principal components and factor analysis are also introduced.

MATH 590, Independent Study, cr to be arranged

Under the direction of a faculty member appointed by the department, the student shall prepare a paper making use of standard reference sources on some topic not covered by other course work.

MATH 591, Thesis (master's program), cr to be arranged

MATH 595 Dissertation (doctoral degree program), credit to be arranged

Prerequisite: Successful completion of PhD candidacy exam and Academic Advisor recommendation for candidacy.

Faculty Research Interests

Aitbayev — Numerical Methods for Partial Differential Equations, Numerical Analysis

Avramidi — Mathematical Physics, Analysis on Manifolds,Quantum Field Theory

Borchers — Optimization, Inverse Problems

Gonzalez-Parra — Applied Mathematics, Mathematical Biology, Dynamical Systems, Numerical Analysis

Hossain — Multivariate Analysis, Survival Analysis, Estimation Reliability and Regression Diagnostics

Kerr — Compact Models for Circuit Simulators, Applied Mathematics, Mixed Boundary Value Problems

Makhnin — Stochastic Processes, Statistics

Stone — Differential Equations, Mathematical Biology, Industrial Mathematics

Orizaga—Applied Mathematics, numerical solutions to PDE's math modeling and application.

Wang — Partial Differential Equations, Dynamical Systems, Applied Mathematics

Zhang — Applied Mathematics, Mathematical Biology, Dynamical Systems and Differential Equations