Mathematics

Professors Barefoot, Stone (Chair of the Department)
Associate Professors Avramidi, Borchers, Hossain, Kerr, Schaffer
Assistant Professors Aitbayev, Jo, Makhnin, Starrett
Instructors Ballou, Bukowski
Emeritus Faculty: Arterburn, Ball, Dubbs, Sharples, Sherman

Degrees Offered: B.S. in Mathematics, M.S. in Mathematics, M.S. in Mathematics with Operations Research and Statistics Option, M.S. in Mathematics with Emphasis in Industrial Mathematics; Ph.D. 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 plays an important role in teaching mathematics to students in other disciplines. In addition, the department offers bachelor's, master's, and Ph.D. degrees in mathematics. 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, and computer. 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 business administration, 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—130
In addition to the General Degree Requirements (page 48), the following courses are required:

- CS 111 (4)
- MATH 221 (3), 231 (4), 254 (3)
- MATH 335 (3), 352 (3), 372 (3), 382 (3)
- MATH 430 (3), 454 (3)
- One of the following five senior mathematics sequences:
  - Two courses from MATH 435 (3), 436 (3), 437 (3), 438 (3)
  - Two courses from MATH 435 (3), 455 (3), 458 (3), 471 (3)
  - MATH 483 (3) and one of MATH 484 (3), 486 (3), or 488 (3)
  - MATH 415 (3), and one of either MATH 486 (3) or 488 (3)
  - MATH 410 (3) and 411 (3)
- Mathematics electives to bring total credit hours in mathematics courses numbered 200 or above to a minimum of 37.
- Approved sequence of at least 18 credit hours in a single subject area other than mathematics. Courses chosen to satisfy other requirements may be used in the sequence. At least six hours must be in courses numbered 300 or above.
- Electives to complete 130 credit hours

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.

Sample Curriculum for the Bachelor of Science in Mathematics

Semester 1

4	MATH 131 (calculus)
4	CHEM 121 & 121L (general)
4	Biology/Geology/Engineering with lab
3	ENGL 111 (college English)
15	Total credit hours

Semester 2

4	MATH 132 (calculus)
4	CHEM 122 & 122L (general)
4	Biology/Geology/Engineering with lab
3	ENGL 112 (college English)
15	Total credit hours

Semester 3

4	MATH 231 (calculus)
3	MATH 254 (into to linear algebra)
5	PHYS 121 & 121L (general)
3	Humanities
4	CS 111 (computer science)
19	Total credit hours

Semester 4

3	MATH 335 (applied analysis)
3	MATH 352 (basic concepts)
5	PHYS 122 & 122L (general)
3	Humanities
3	Social Science
17	Total credit hours

Semester 5

3	MATH 372 (basic concepts of analysis)
3	MATH 382 (probability)
6	Social Science
6	Electives*
18	Total credit hours

Semester 6

3	MATH 221 (formal logic and discrete mathematics)
3	MATH 454 (linear algebra)
3	ENGL 341 (technical writing)
3	Humanities/Social Science
6	Electives*
18	Total credit hours

Semester 7

3	Senior Mathematics Sequence
3	MATH 430 (mathematical modeling)
9	Electives*
15	Total credit hours

Semester 8

3	Senior Mathematics Sequence
3	Mathematics Elective
9	Electives*
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 254 (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. There is no foreign language requirement for either program. The student must fulfill the requirements for the undergraduate program in mathematics. In addition, MATH 471 and 472 (or equivalent) are required for all programs except the M.S. degree in Mathematics with Emphasis in Industrial Mathematics and the M.S. degree in Mathematics with Operations Research and Statistics Option. The independent study or thesis topic may be selected, subject to approval, from any area of mathematics or from any interdisciplinary area in which mathematics is prominently featured.

Five-Year Bachelor's/Master's Degree Program in Mathematics

The five-year mathematics B.S./M.S. program provides the student the opportunity to obtain both a bachelor's degree and a master's degree in mathematics in five years. A minimum of 158 total credit hours are required to complete the dual degree program.

Students should apply to the program before their seventh semester. Admission is contingent on academic performance and acceptance of a proposed course of study. Graduate status is granted upon completion of the general requirements for the bachelor's degree in mathematics or one of its options with a 3.0 minimum cumulative grade point average. The master's degree is granted upon completion of the requirements of the master's degree program.

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 Emphasis in Industrial Mathematics

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 (6 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 another 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 Industrial Mathematics group.
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 Industrial Mathematics group and should involve mathematical modeling, computation and analysis.

Industrial Mathematics Committee

Avramidi—Mathematical Physics, Analysis on Manifolds, Quantum Field Theory
Borchers—Optimization, Inverse Problems
Sharples—Applied Analysis, Asymptotic Expansions
Stone—Differential Equations, Mathematical Biology, Industrial Mathematics

Master of Science in Mathematics with Operations Research and Statistics Option

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 or 488, or the equivalent.

Graduate work would consist of:

1) A minimum of 12 credit hours from MATH 515, 516, 517, 518, 519, 582, 583, 584, 586, 587, 589. At least one course (three credit hours) must be chosen from MATH 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; MATH 384, 386, 410, 411, 484, 505, and 521.

Doctor of Philosophy 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. Students are normally expected to take MATH 501 and 502 in their first year, and MATH 503 each semester after that.

- 48 hours of coursework approved by the student's advisory committee, including:
  - All of the following, if not already taken: MATH 410, 411, 435, 437, 438, 471
  - 500-level MATH courses (30 credit hours) consisting of:
    - MATH 530 (3), 532 (3)
    - Six (6) credit hours of core classes: MATH 511, 535, 538, 539, 577
    - Four or more of the remaining classes are to be additional core classes (above), courses from the list of recommended classes (below) or other classes approved in advance by the student's committee. Students are strongly encouraged to include MATH 509, Graduate Internship, in their program. Recommended classes: MATH 509, 510, 512, 518, 531, 533, 536, 537, 587 or other
  - 12 hours of upper-division or graduate-level courses from outside the math department
- Preliminary exams in differential equations, analysis, and numerical analysis (usually taken in the third semester, or in the second semester for students who already have a master's degree). Students may, if necessary, repeat one or more exams the following semester. Students who do not receive satisfactory scores after two attempts will not be accepted into the Ph.D. program.

Mathematics Courses:

Tech's mathematics department offers courses in eight sub-fields of mathematics. The middle digit of each mathematics course number specifies the sub-field in which that course belongs. The middle digits and the sub-fields they represent are:

1—operations research and numerical methods
2—discrete mathematics
3—applied analysis
4—geometry
5—modern algebra
6—topology
7—real analysis (theory)
8—probability, statistics, stochastic processes

Thus, 415 is a course in operations research, etc. The middle digit 0 is used for the basic mathematics courses. The only exception to this system is MATH 581, the standard college number for directed studies.

MATH 101, Intermediate Algebra, 3 cr, 2 cl hrs, 3 lab hrs
The fundamental algebraic operations—factoring, fractions, linear equations and inequalities, quadratic equations, ratio, proportion, variation, functions and their graphs, systems of equations.

MATH 103, College Algebra, 3 cr, 2 cl hrs, 3 lab hrs
Prerequisites: High school algebra (1 yr), plane geometry (1 yr), or MATH 101 passed with grade C- or better
Functions and relations, equations and inequalities, determinants and matrices, simultaneous equations, algebra of polynomials, complex numbers.

MATH 104, Trigonometry, 3 cr, 2 cl hrs, 3 lab hrs
Corequisite: MATH 103 or a score of 20 or higher on the algebra portion of the math placement test (page 19)
Trigonometric functions, identities, related angles, radian measure, graphs, inverse functions, trigonometric equations, logarithms, solution of plane triangles.

MATH 105, Pre-Calculus Mathematics, 5 cr, 4 cl hrs, 3 lab hrs
Prerequisites: Same as for MATH 103
Offered summers only. Class consists of five 25-minute lectures and five 55-minute labs each week of summer session.
A condensed course covering most of the topics of MATH 103 and 104. A maximum of six credits will be allowed for any combination of MATH 103, 104, 105.

MATH 131, Calculus and Analytic Geometry I, 4 cr, 3 cl hrs, 3 lab hrs
Prerequisites: MATH 103 and 104, or the equivalent passed with grade C- or better, or a combined score of at least 34 on the two components of the math placement tests (page 19)
First course in calculus and analytic geometry. Includes introductory concepts in analytic geometry, limits, continuity, differentiation, applications of the derivative, the mean value theorem, the definite and indefinite integral, and applications of integration.

MATH 132, Calculus and Analytic Geometry II, 4 cr, 4 cl hrs
Prerequisite: MATH 131 passed with grade C- or better
Continuation of MATH 131. Transcendental functions, techniques of integration, polar coordinates, infinite series, and applications.

MATH 221, Formal Logic and Discrete Mathematics, 3 cr, 3 cl hrs
Prerequisite: MATH 132 passed with a grade C- or better
Analytical reasoning and critical thinking skills. Induction and recursion. Mathematical proofs. Propositional calculus and predicate calculus. Discrete and combinatorial mathematics: sets, functions, relations, trees, and graphs, permutations and combinations.

MATH 231, Calculus and Analytic Geometry III, 4 cr, 4 cl hrs
Prerequisite: MATH 132 passed with grade C- or better
Vectors in the plane and 3-space, vector calculus in two dimensions, partial differentiation, multiple integration, topics in vector calculus, and complex numbers and functions.

MATH 254, Introduction to Applied Linear Algebra, 3 cr, 3 cl hrs
Prerequisite: MATH 131 passed with grade C- or better
Solution of linear systems. Matrix algebra. Rank. Determinants. Eigenvalues and eigenvectors. Numerical aspects of matrix calculation. Introduction to vector spaces and linear transformations. Applications. (Same as BCS 254)

MATH 283, Introduction to Applied Statistics, 3 cr, 3 cl hrs
Corequisite: MATH 132
Exploratory data analysis. Introduction to probability and random variables. Concepts of population and sample. Estimation and hypothesis testing. Simple linear regression and one-way analysis of variance. Techniques in data analysis using statistical computer packages. (Same as BCS 283)

MATH 332, Vector Analysis, 3 cr, 3 cl hrs
Prerequisite: MATH 231 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, Applied Analysis I, 3 cr, 3 cl hrs
Prerequisite: MATH 132 passed with grade C- or better
Ordinary differential equations, series solutions, transform calculus.

MATH 335L, Applied Analysis I Computer Lab, 1 cr, 1 cl hr
Corequisite: MATH 335 or equivalent.
Optional lab to accompany MATH 335. Basic introducton to the "Maple" syntax 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, Applied Analysis II, 3 cr, 3 cl hrs
Prerequisites: MATH 254 and 335, 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 352, Basic Concepts of Mathematics, 3 cr, 3 cl hrs
Prerequisite: MATH 132 passed with grade C- or better
Mathematical proofs, set theory, mathematical induction and recursion, binary relations, 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
Dedekind cuts, sequences, limits, differentiation, integrals, infinite series.

MATH 382, Probability, 3 cr, 3 cl hrs
Prerequisite: MATH 132 passed with grade C- or better
Basic concepts of discrete and continuous probability. Common types of univariate distribution functions. Expected values. The weak law of large numbers. Uses of the central limit theorem and its applications. Introduction to stochastic processes and applications.

MATH 384, Applied Regression and Design of Experiments, 3 cr, 3 cl hrs
Prerequisite: MATH 283 or 382 passed with grade C- or better
Design of experiments, analysis of variance and covariance, linear and nonlinear curve fitting. Applications taken from metallurgy, mining and petroleum engineering, hydrology, and other disciplines.

MATH 386, Nonparametric Statistics, 3 cr, 3 cl hrs
Prerequisite: MATH 283 or 382 passed with grade C- or better
Tests based on ranks for one-sample and two-sample problems, nonparametric estimates, multiple comparisons, nonparametric methods in regression. Applications in science and engineering.

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 for Scientists and Engineers I, 3 cr, 3 cl hrs
Prerequisite: CS 111 or ES 111
Corequisite: MATH 335
Floating point arithmetic, solution of linear and nonlinear systems of equations, interpolation, numerical differentiation and integration, numerical solution of ordinary differential equations.

MATH 411, Numerical Linear Algebra, 3 cr, 3 cl hrs
Prerequisites: MATH 254; CS 111 or ES 111
Direct and iterative methods for solving linear systems, conditioning and stability, methods for computing eigenvalues and eigenvectors, linear least squares problems, applications, performance, software.

MATH 414, Introduction to High Performance Computing, 3 cr, 3 cl hrs
Prerequisite: MATH 410 passed with grade C- or better
Solving scientific problems in high-performance computing systems. Topics include: numerical methods, using software libraries and packages such as MATLAB, Mathematica, NAG, LAPACK, etc., matching algorithms to machines, measuring performance and scientific visualization. A number of computing architectures—such as high-performance workstations, the Cray Y-MP, and the Connection Machine—will be used to solve a small set of prototype problems.

MATH 415, Introduction to Operations Research: Deterministic Methods, 3 cr, 3 cl hrs
Prerequisite: MATH 254 passed with grade C- or better
A survey of operations research techniques including linear programming, nonlinear models, and graph theoretical models. (Same as BCS 415)

MATH 430, Mathematical Modeling, 3 cr, 3 cl hrs
Prerequisites: MATH 254 and 335; MATH 283 or 382; 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.

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 254 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 442, Introduction to Differential Geometry, 3 cr, 3 cl hrs
Prerequisite: MATH 254 passed with grade C- or better
Introduction to the theory of curves and surfaces, geometry on a surface. Tensor notation will be developed and used.

MATH 454, Linear Algebra, 3 cr, 3 cl hrs
Prerequisites: MATH 254 and 352, each passed with grade C- or better
Finite dimensional vector spaces. Linear transformations. Equivalence and similarity of matrices. Eigenvectors and eigenvalues, canonical forms.

MATH 455, 456, 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 458, Introduction to Theory of Numbers, 3 cr, 3 cl hrs
Prerequisite: MATH 352 passed with grade C- or better
Properties of integers, primes, congruences, related topics.

MATH 461, Introduction to Topology, 3 cr, 3 cl hrs
Prerequisite: MATH 372 passed with grade C- or better
Fundamental concepts of point-set topology, abstract topological spaces, metric spaces, continuous mappings, separation axioms, compactness, connectedness.

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
Prerequisites: 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 254 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. (Same as BCS 486)

MATH 488, Introduction to Operations Research: Probabilistic Methods, 3 cr, 3 cl hrs
Prerequisite: MATH 283 or 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. (Same as BCS 488)

MATH 491, Directed Study, 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 505, Neural Nets, 3 cr, 3 cl hrs
Prerequisites: CS 344; MATH 254 and 382; or consent of instructor
Neuron modeling. The perceptron and multilayer perceptrons. Learning algorithms. The Kohonen model, the Grossberg model, the Hopfield model. Associative memory. Applications. Recent developments in the field. (Same as CS 565)

MATH 509 Graduate Internship, credit to be arranged
Prerequisite: Graduate standing

MATH 510 Computational Fluid Dynamics, 3 cr, 3 cl hrs
Prerequisite: MATH 254, 336, 410 or equivalent
Equations of fluid dynamics, flow models, discretization techniques, analysis of numerical schemes, numerical methods for solving linear and nonlinear systems of equations, numerical methods for inviscid and viscous flows.

MATH 511, 512, Numerical Methods for Partial Differential Equations, 3 cr, 3 cl hrs each semester
Prerequisite: MATH 410 or consent of instructor
Finite difference methods for parabolic and elliptic partial differential equations. Convergence and stability. Finite element methods. Advanced numerical linear algebra.

MATH 513, Advanced Topics in Numerical Analysis, 3 cr, 3 cl hrs
Prerequisite: MATH 410 or consent of instructor
Topics chosen from areas in numerical analysis, numerical partial differential equations, multigrid and domain decomposition methods, 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
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
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
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, Methods of Nonlinear Programming, 3 cr, 3 cl hrs
Prerequisites: MATH 410 or 415 or consent of instructor
Theory of constrained and unconstrained optimization. Methods for nonlinear programming, including quasi-Newton methods, conjugate direction methods, Levenberg-Marquardt methods, sequential quadratic programming, and sequential unconstrained minimization techniques.

MATH 519, Inverse Problems, 3cr, 3 cl hrs
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 521, Advanced Combinatorics, 3 cr, 3 cl hrs
Prerequisite: MATH 221
Graph theory and applications. Graphs, trees, connectivity, Euler tours and Hamiltonian cycles, matchings, planar graphs, directed graphs, networks, cycle space, and bond space.

MATH 530, Modeling Case Studies, 3 cr, 3 cl hrs
Prerequisite: MATH 430 or equivalent
Open-ended modeling projects from actual applications.

MATH 531, Topics in Ordinary Differential Equations, 3 cr, 3 cl hrs each semester
Prerequisite: MATH 437 or equivalent
Study of a special topic in ordinary differential equations not usually treated. Normally one related to a field of research interest at Tech.

MATH 532, Perturbation Methods, 3 cr, 3 cl hrs
Prerequisite: MATH 437 or equivalent
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
Study of a special topic in partial differential equations not usually treated. Normally one related to a field of research interest at Tech.

MATH 535, 536, Methods of Mathematical Physics, 3 cr, 3 cl hrs each semester
Prerequisite: MATH 436
Advanced topics selected from asymptotic expansions of integrals and ordinary differential equations, integral equations, singular integral equations, Wiener-Hopf technique, generalized functions.

MATH 537, Bifurcation Theory, 3 cr, 3 cl hrs
Prerequisite: MATH 437 or equivalent
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, Wave Phenomena, 3 cr, 3 cl hrs
Prerequisite: MATH 438 or equivalent or consent of instructor
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 Fluid Dynamics, 3 cr, 3 cl hrs
Prerequisite: MATH 438 or equivalent
The Navier-Stokes equations, inviscid flow, irrotational fluids, viscosity, and turbulence. Other topics as time and interest permit.

MATH 561, 562, Topology, 3 cr, 3 cl hrs each semester
Prerequisites: MATH 471, 472; or MATH 461
Point-set topology, abstract topological spaces, generalized convergence, product and quotient spaces, metric spaces, uniform spaces; elementary concepts of algebraic topology.

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
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
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, Statistical Inference, 3 cr, 3 cl hrs
Prerequisite: MATH 483 or consent of instructor
Topics include limit theorems and convergence concepts, maximum likelihood estimator, sufficiency and completeness, Neyman Pearson lemma, Cramer Rao inequality, likelihood ratio test, uniformly most powerful tests, and inference for regression models.

MATH 583, 584, Topics in Probability and Statistics, 3 cr, 3 cl hrs each semester
Prerequisites: MATH 384 or 483; MATH 486 or consent of instructor
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.

MATH 585, Statistics for Technology Managers, 3 cr, 3 cl hrs
Prerequisite: Enrollment in the Engineering Management program
Probability and random variables; simple and multiple linear regression using least squares and other methods; experimental design; other topics including nonlinear regression; applications to decision making.

MATH 586, Spatial Variability and Geostatistics, 3 cr, 3 cl hrs
Prerequisites: MATH 382
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, Analysis of Time Series and Spatial Data, 3 cr, 3 cl hrs
Offered in alternate years

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 HYD 587 and GEOP 505)

MATH 589, Applied Multivariate Analysis, 3 cr, 3 cl hrs
Prerequisite: MATH 382; MATH 283 or 384 recommended

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 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

Staff Research Interests

Aitbayev—Methods for Numerical Partial Differential Equations, Numerical Analysis
Avramidi—Mathematical Physics, Analysis on Manifolds, Quantum Field Theory
Barefoot—Graph Theory, Applied Mathematics
Borchers—Optimization, Inverse Problems
Hossain—Theory and Application of Statistics, Regression Diagnostics
Jo—Fluid Dynamics, Modeling
Kerr—Thermoelasticity, Integral Equations, Applied Mathematics
Makhnin—Stochastic Processes, Statistics
Schaffer—Applied Mathematics, Numerical Analysis
Sharples—Applied Analysis, Asymptotic Expansions
Starrett—Dynamical Systems, Physics Models
Stone—Differential Equations, Mathematical Biology, Industrial Mathematics