

MTHSC 800 Probability 3(3,0) Study of basic probability theory with emphasis on results and techniques useful in operations research and statistics. Topics include axiomatic probability, advanced combinatorial probability, conditional informative expectation, functions of random variables, moment generating functions, distribution theory and limit theorems. Offered fall semester only. *Preq:* MTHSC 206.

MTHSC 801 General Linear Hypothesis I 3(3,0) Topics include least-square estimates; Gauss-Markov theorem; confidence ellipsoids, and confidence intervals for estimable functions; tests of hypotheses; one-, two- and higher-way layouts; analysis of variance for other models. Offered fall semester only. *Preq:* MTHSC 311, 403.

MTHSC 802 General Linear Hypothesis II 3(3,0) Continuation of MTHSC 801. Offered spring semester only.

MTHSC 803 Stochastic Processes 3(3,0) Theory and analysis of time series, recurrent events, Markov chains, random walks, renewal theory, application to communication theory and operations research. *Preq:* MTHSC 400 or 800.

MTHSC 804 Statistical Inference 3(3,0) Sampling distributions; maximum likelihood estimation and likelihood ratio tests; asymptotic confidence intervals for Binomial, Poisson and Exponential parameters; two-sample methods; nonparametric tests; ANOVA; regression; model building. Offered fall semester only. *Preq:* MTHSC 400 or equivalent or consent of instructor.

MTHSC 805 Data Analysis 3(3,0) Methodology in analysis of statistical data emphasizing applications to real problems using computer-oriented techniques: computer plots, transformations, criteria for selecting variables, error analysis, multiple and stepwise regression, analysis of residuals, model building in time series and ANOVA problems, jackknife and random subsampling, multidimensional scaling, clustering. *Preq:* MTHSC 301, 400.

MTHSC 806 Nonparametric Statistics 3(3,0) Order statistics; tolerance limits; rank-order statistics; Kolmogorov-Smirnov one-sample statistics; Chi-square goodness-of-fit test; two-sample problem; linear rank statistics; asymptotic relative efficiency. Offered spring semester only. *Preq:* MTHSC 600 or 800.

MTHSC 807 Applied Multivariate Analysis 3(3,0) Applied multivariate analysis: computer plots of multivariate observations; multidimensional scaling; multivariate tests of means, covariances and equality of distributions; univariate and multivariate regressions and their comparisons; MANOVA; principal components analysis; factor analysis; analytic rotations; canonical correlations. Offered fall semester only. *Preq:* MTHSC 403 and 805 or consent of instructor.

MTHSC 808 Reliability and Life Testing 3(3,0) Probability models and statistical methods relevant to parametric and nonparametric analysis of reliability and life testing data. Offered spring semester only. *Preq:* MTHSC 400 or equivalent.

MTHSC 809 Time Series Analysis, Forecasting and Control 3(3,0) Modeling and forecasting random processes; autocorrelation functions and spectral densities; model identification, estimation and diagnostic checking; transfer function models; feedforward and feedback control schemes. Offered spring semester only. *Preq:* MTHSC 605; 600 or 800; or equivalent.

MTHSC 810 Mathematical Programming 3(3,0) Formulation and solution of linear programming models; mathematical development of the simplex method; revised simplex method; duality; sensitivity analysis; parametric programming, implementation and software packages. *Preq:* MTHSC 311.

MTHSC 811 Nonlinear Programming 3(3,0) Theoretical development of nonlinear optimization with applications, classical optimization, convex and concave functions, separable programming, quadratic programming and gradient methods. Offered spring semester only. *Preq:* MTHSC 440, 454.

MTHSC 812 Discrete Optimization 3(3,0) Principal methods used in integer programming and discrete optimization; branch and bound, implicit enumeration, cutting planes, group knapsack, Lagrangian relaxation, surrogate constraints, heuristics (performance analysis), separation/branching strategies, and polynomial time algorithms for specific problems on special structures. Offered fall semester only. *Preq:* MTHSC 810 or equivalent.

MTHSC 813 Advanced Linear Programming 3(3,0) Development of linear programming theory using inequality systems, convex cones, polyhedra and duality; solution algorithms, and computational considerations for large scale and special structured problems using techniques of upper bounded variables, decomposition, partitioning and column generation; game theory; nonlinear representations and other methods such as ellipsoid and Karmarkar. Offered spring semester only. *Preq:* MTHSC 440, 810 or equivalent.

MTHSC 814 Network Flow Programming 3(3,0) Max-flow/min-cut theorem, combinatorial applications, minimum cost flow problems (transportation, shortest path, transshipment), solution algorithms (including the out-of-kilter), and implementation and computational considerations. Offered fall semester only. *Preq:* MTHSC 440, 810 or equivalent.

MTHSC 816 Network Algorithms and Data Structures 3(3,0) Design, analysis and implementation of algorithms and data structures associated with the solution of problems formulated as networks and graphs; applications to graph theory, combinatorial optimization and network programming. Offered spring semester only. *Coreq:* MTHSC 640, 810, 854, 863 or consent of instructor.

MTHSC 817 Stochastic Models in Operations Research I 3(3,0) Stochastic control; structure of sequential decision processes; stochastic inventory models; recursive computation of optimal policies; discrete parameter finite Markov decision processes; various optimality criteria; computation by policy improvement and other methods; existence of optimal stationary policies; stopping-rule problems; examples from financial management, maintenance and reliability, search, queuing and shortest path. Offered spring semester only. *Preq:* MTHSC 803.

MTHSC 818 Stochastic Models in Operations Research II 3(3,0) Introduction to queuing theory: Markovian queues, repairman problems, queues with an embedded Markov structure, the queue GI/G/1, queues with a large number of servers, decision making in queues; introduction to reliability theory; failure distributions; stochastic models for complex systems; maintenance and replacement policies; reliability properties of multicomponent structures. Offered fall semester only. *Preq:* MTHSC 817.

MTHSC 819 Multicriteria Optimization 3(3,0) Theory and methodology of optimization problems with vector-valued objective functions; preference orders and domination structures; generating efficient solutions; solving multicriteria decision-making problems; noninteractive and interactive methods with applications. Offered fall se

MTHSC 820 Complementarity Models 3(3,0) Theory, algorithms and applications of linear and nonlinear complementarity; classes of matrices and functions and corresponding algorithms; applications to economics, mechanics and networks; generalizations to fixed-point problems and nonlinear systems of equations. Offered spring semester only. *Preq:* MTHSC 810.

MTHSC 821 Linear Analysis 3(3,0) Normed spaces; Hilbert spaces, Banach spaces, linear functionals, linear operators, orthogonal systems. Offered spring semester and summer session only. *Preq:* MTHSC 454 or 453 and 853.

MTHSC 822 Measure and Integration 3(3,0) Rings and algebras of sets, inner and outer measures; measurability and additivity, examples on the line and in space, Lebesgue integration, types of convergence, Lebesgue spaces; integration and differentiation, product measure, Fubini theorem. Offered fall semester only. *Preq:* MTHSC 454.

MTHSC 823 Complex Analysis 3(3,0) Topological concepts; complex integration; local and global properties of analytic functions; power series; representation theorems; calculus of residues. Designed for nonengineering majors.

MTHSC 825 Introduction to Dynamical Systems Theory 3(3,0) Techniques of analysis of dynamical systems; sensitivity analysis, linear systems, stability and control; theory of differential and difference equations. Offered fall semester only. *Preq:* MTHSC 454 and 311 or 453 and 853.

MTHSC 826 Partial Differential Equations 3(3,0) First-order equations: elliptic, hyperbolic and parabolic. Second-order equations: existence and uniqueness results, maximum principles, finite difference and Hilbert Space methods. Offered fall semester only. *Preq:* MTHSC 821 or consent of instructor.

MTHSC 827 Dynamical System Neural Networks 3(3,0) Modeling problems in the context of dynamical systems theory; useful methods from Lyapunov stability, local linearization, qualitative analysis using graph theory and numerical approximations; several dynamical systems neural networks including binary code recognizers and binary matrix choosers. *Preq:* MTHSC 206, 311.

MTHSC 831 Fourier Series 3(3,0) Fourier series with applications to solution of boundary value problems in partial differential equations of physics and engineering. Introduction to Bessel functions and Legendre polynomials.

MTHSC 837 Calculus of Variations and Optimal Control 3(3,0) Fundamental theory of the calculus of variations; variable end points; the parametric problem; the isoperimetric problem; constraint inequalities; introduction to the theory of optimal control; connections with the calculus of variations; geometric concepts. *Preq:* MTHSC 453 or 463.

MTHSC 841 Applied Mathematics I 3(3,0) Derivation of equations from conservation laws, dimensional analysis, scaling and simplification; methods such as steepest descent, stationary phase, perturbation series, boundary layer theory, WKB theory, multiple-scale analysis, and ray theory applied to problems in diffusion processes, wave propagation, fluid dynamics and mechanics. Offered fall semester only. *Preq:* MTHSC 208 and 453 or 463.

MTHSC 850 Computational Algebraic Geometry 3(3,0) Covers algebraic geometry and commutative algebra via Grobner bases. Includes ideals and varieties (affine and projective), Grobner bases, elimination theory, dimensions, solving polynomial systems via eigenvalues and eigenvectors. Selected applications may include coding theory, computer vision, geometric theorem proving, integer programming, or statistics. *Preq:* MTHSC 311, 412.

MTHSC 851 Abstract Algebra I 3(3,0) Basic algebraic structures: groups, rings and fields; permutation groups, Sylow theorems, finite abelian groups, polynomial domains, factorization theory and elementary field theory. Offered spring semester only.

MTHSC 852 Abstract Algebra II 3(3,0) Continuation of MTHSC 851 including selected topics from ring theory and field theory. Offered fall semester only.

MTHSC 853 Matrix Analysis 3(3,0) Topics in matrix analysis that support an applied curriculum: similarity and eigenvalues; Hermitian and normal matrices; canonical forms; norms; eigenvalue localizations; singular value decompositions; definite matrices. *Preq:* MTHSC 311, 453 or 463.

MTHSC 854 Theory of Graphs 3(3,0) Connectedness; path problems; trees; matching theorems; directed graphs; fundamental numbers of the theory of graphs; groups and graphs. Offered spring semester only. *Preq:* Consent of instructor.

MTHSC 855 Combinatorial Analysis 3(3,0) Combinations; permutations; permutations with restricted position; Polya's theorem; principle of inclusion and exclusion; partitions; recurrence relations; generating functions; Mobius inversion; enumeration techniques; Ramsey numbers; finite projective and affine geometries; Latin rectangles; orthogonal arrays; block designs; error detecting and error correcting codes. Offered fall semester only. *Preq:* MTHSC 311.

MTHSC 856 Theory of Error-Correcting Codes 3(3,0) Topics include code constructions such as Hammig, cyclic, BCH, Reed-Solomon, Goppa, algebraic geometry, finite geometry, low-density parity check, convolutional and polynomial codes; code parameters and bounds; and decoding algorithms *Preq:* MTHSC 853 or consent of instructor.

MTHSC 857 Cryptography 3(3,0) Classical and modern cryptography and their uses in modern communication systems are covered. Topics include entropy, Shannon's perfect secrecy theorem, Advanced Encryption Standard (AES), integer factorization, RSA cryptosystem, discrete logarithm problem, Diffie-Hellman key exchange, digital signatures, elliptic curve cryptosystems, hash functions and identification schemes. *Preq:* MTHSC 311, 400 or 600, 412 or 851.

MTHSC 858 Number Theory 3(3,0) Covers topics and techniques from modern number theory including unique factorization, elementary estimates on the distribution of prime numbers, congruences, Chinese remainder theorem, primitive roots, n-th powers modulo an integer, quadratic residues, quadratic reciprocity, quadratic characters, Gauss sums and finite fields. *Preq:* MTHSC 853 or consent of instructor.

MTHSC 860 Introduction to Scientific Computing 3(3,0) Floating point models, conditioning and numerical stability, numerical linear algebra, integration, systems of ordinary differential equations and zero finding; emphasis is on the use of existing scientific software. *Preq:* CP SC 110, MTHSC 208, 311.

MTHSC 861 Advanced Numerical Analysis I 3(3,0) Consideration of topics in numerical linear algebra: eigenvalue problems, the singular value decomposition, iterative algorithms for solving linear systems, sensitivity of linear systems, and optimization algorithms. *Preq:* MTHSC 311 and 460; or 860.

MTHSC 863 Digital Models I 3(3,0) Experimental mathematics; pseudostochastic processes; analytical and algebraic formulations of time-independent simulation; continuous-time simulation and discrete-time simulation; digital optimization; Fibonacci search; ravine search; gradient methods; current research in digital analysis. Offered fall semester only. *Preq:* MTHSC 311, 453, digital computer experience.

MTHSC 865 Data Structures 3(3,0) Representation and transformation of information; formal description of processes and data structures; tree and list structures; pushdown stacks; string and formula manipulation; hashing techniques; interrelation between data structure and program structure; storage allocation methods. Offered fall semester only. *Preq:* Computational maturity, consent of instructor.

MTHSC 866 Finite Element Method 3(3,0) Discusses the basic theory of the finite element method (FEM) for the numerical approximation of partial differential equations. Topics include Sobolev spaces, interpolation theory, finite element spaces, error estimation, and implementation of FEM in one and higher dimensions. *Preq:* MTHSC 860 or consent of instructor.

MTHSC 874 Integration through Optimization 3(3,0) Theory, methodology and applications of decomposition, integration and coordination for large-scale or complex optimization problems encountered in engineering design. Topics include conventional and non-conventional engineering optimization algorithms, analysis models and methods, multidisciplinary optimization, analytic target cascading, multisenario optimization, and multicriteria optimization. Case studies are included. *Preq:* MTHSC 810, 860, or M E 871, or equivalent.

MTHSC 881 Mathematical Statistics 3(3,0) Fundamental concepts of sufficiency, hypothesis testing and estimation; robust estimation; resampling (jackknife, bootstrap, etc.) methods; asymptotic theory; two-stage and sequential sampling problems; ranking and selection procedures. Offered spring semester only. *Preq:* MTHSC 403 or equivalent.

MTHSC 884 Statistics for Experimenters 3(3,0) Statistical methods for students who are conducting experiments; introduction to descriptive statistics, estimation and hypothesis testing as they relate to design of experiments; higher-

order layouts, factorial and fractional factorial designs, and response surface models. Offered fall semester only. *Preq:* MTHSC 206 or equivalent.

MTHSC 885 Advanced Data Analysis 3(3,0) Continuation of MTHSC 805 covering alternatives to ordinary least squares, influence and diagnostic considerations, robustness, special statistical computation methods. Offered spring semester only. *Preq:* MTHSC 603, 800, 805.

MTHSC 891 Master's Thesis Research 1-12

MTHSC 892 Master's Project Course 1(0,1) For students in the nonthesis option of the MS degree program in Mathematical Sciences. Successful completion includes a presentation of the master's project to the student's advisory committee and acceptance of the paper by the committee.

MTHSC 900 Seminar in Preparing for College Teaching in the Mathematical Sciences 3(3,0) Elements involved in being a college professor with emphasis on broadening the student's mathematical experiences within a framework of improving classroom performance. *Preq:* Completion of the departmental PhD qualifying examinations.

MTHSC 901 Probability Theory I 3(3,0) Axiomatic theory of probability; distribution functions; expectation; Cartesian product of infinitely many probability spaces, and the Kolmogorov consistency theorem; models of convergence; weak and strong laws of large numbers. *Preq:* MTHSC 400 and 822, or MTHSC 800 and 822 or consent of instructor.

MTHSC 902 Probability Theory II 3(3,0) Continuation of MTHSC 901; characteristic functions, infinitely divisible distributions, central limit theorems, laws of large numbers, conditioning, and limit properties of sums of dependent random variables, conditioning, martingales. *Preq:* MTHSC 901.

MTHSC 927 Functional Analysis 3(3,0) Linear operators on specific spaces, spectral theory, semigroups of operators and the Hille-Yosida theorem, applications of linear spaces and operators, convexity. *Preq:* MTHSC 821.

MTHSC 951 Algebraic Number Theory 3(3,0) Covers arithmetic of number fields and number rings. Covers prime decomposition, ideal class groups, unit groups of number fields and distribution of prime ideals in number fields. Provides an overview of completions absolute values and valuation theory. *Preq:* MTHSC 851.

MTHSC 952 Analytic Number Theory 3(3,0) The theory of Fourier analysis and complex analysis are essential to modern number theory. Course focuses on applications of this theory to number theory, such as the proof of the prime number theorem and the connection of complex L-series to the distribution of primes and to arithmetic geometry. *Preq:* MTHSC 821 or consent of instructor.

MTHSC 954 Advanced Graph Theory 3(3,0) Continuation of MTHSC 854 including the four-color theorem, domination numbers, Ramsey theory, graph isomorphism, embeddings, algebraic graph theory and tournaments. Research papers are also examined. Offered fall semester only. *Preq:* MTHSC 854 or consent of instructor.

MTHSC 970 Directed Studies in Mathematical Sciences 1-3(1-3,0) Directed individual studies on topics in the mathematical sciences supervised by faculty. May be repeated for a maximum of 18 credits. *Preq:* Consent of instructor.

MTHSC 974 Selected Topics in Mathematical Sciences 3(3,0) Advanced topics in the mathematical sciences from current areas of interest presented in lecture format. May be repeated for a maximum 24 credits, but only if different topics are covered. *Preq:* Consent of instructor.

MTHSC 981 Selected Topics in Mathematical Statistics and Probability 1-3(1-3,0) Advanced topics in mathematical statistics and probability of current interest. May be repeated for credit, but only if different topics are covered.

MTHSC 982 Selected Topics in Analysis 1-3(1-3,0) Advanced analysis topics from current problems of interest. May be repeated for credit, but only if different topics are covered.

MTHSC 983 Selected Topics in Computational Mathematics 1-3(1-3,0) Advanced topics in computational mathematics and numerical analysis from current problems of interest. May be repeated for credit, but only if different topics are covered.

MTHSC 985 Selected Topics in Algebra and Combinatorics 1-3(1-3,0) Advanced topics in algebra and combinatorics from current problems of interest. May be repeated for credit, but only if different topics are covered.

MTHSC 986 Selected Topics in Geometry 1-3(1-3,0) Advanced topics in geometry from current problems of interest. May be repeated for credit, but only if different topics are covered.

MTHSC 988 Selected Topics in Operations Research 1-3(1-3,0) Advanced topics in operations research from current problems of interest. May be repeated for credit, but only if different topics are covered.

MTHSC 989 Selected Topics in Mathematical Education 3(3,0) Advanced topics in the mathematical sciences from the area of mathematics education. May be repeated for credit, but only if different topics are covered. *Preq:* Consent of instructor.

MTHSC 991 Doctoral Dissertation Research 1-12