110. College Algebra and Finite Mathematics (MTH)
Fall, Spring. 3(3-0) P: MTH 082 or designated score on mathematics placement test. Not open to students with credit in MTH 110 or MTH 111. Functions and graphs. Equations and inequalities, systems of equations, matrices, linear programming, probability. QP: MTH 108 QA: MTH 110

116. College Algebra and Trigonometry (MTH)
Fall, Spring, 3(3-0) P: MTH 082 or designated score on mathematics placement test. Not open to students with credit in MTH 110 or MTH 116. Functions and graphs. Equations and inequalities, exponential and logarithmic functions, trigonometric functions, systems of equations, binomial theorem. QP: MTH 108 QA: MTH 111 MTH 109 MTH 108

120. Algebra and a Survey of Calculus (MTH)
Fall, Spring. 5(5-0) P: MTH 082 or designated score on mathematics placement test. Not open to students with credit in MTH 110 or MTH 116 or MTH 120. Functions and graphs. Equations and inequalities, systems of equations, limits, continuity, derivatives, applications of derivatives, integrals, fundamental theorem of calculus. QP: MTH 109 OR MTH 111

124. Survey of Calculus with Applications I (MTH)
Fall, Spring. 3(3-0) P: Designated score on mathematics placement test. Not open to students with credit in MTH 120 or MTH 122. Study of limits, continuous functions, derivatives, integrals and their applications. QP: MTH 108 OR MTH 111

126. Survey of Calculus with Applications II (MTH)
Fall, Spring. 3(3-0) P: MTH 120 or MTH 122. Not open to students with credit in MTH 120 or MTH 124 or MTH 131H. Application of partial derivatives, integrals, optimization of functions of several variables and infinite series.

132. Calculus I (MTH)
Fall, Spring. 3(3-0) P: MTH 116 or designated score on mathematics placement test. Not open to students with credit in MTH 120 or MTH 124 or MTH 131H. Limits, continuous functions, derivatives and their applications. Integrals and the fundamental theorem of calculus. QP: MTH 109 OR MTH 111 QA: MTH 112 MTH 122

Courses with an asterisk (*) have not been approved by the University Committee on Curriculum.
441. Ordinary Differential Equations
Fall. 3(0-3-0)
P: MTH 314, MTH 320.
Existence and uniqueness theorems, linearity, stability theory, and phase space analysis.
QA: MTH 420

442. Partial Differential Equations
Fall. 3(0-3-0)
P: MTH 320.
Classification and canonical forms for second order partial differential equations. Well posed boundary and initial value problems for the wave equation, the heat equation and the Laplace equation.
QA: MTH 424

443. Boundary Value Problems for Engineers
Fall. 3(0-3-0)
P: MTH 335 or MTH 355H.
QA: MTH 422

451. Numerical Analysis I
Fall. 3(0-3-0)
P: CPS 130 or CPS 230; MTH 314; MTH 320 or MTH 424.
QA: MTH 451

452. Numerical Analysis II
Spring. 3(0-3-0)
P: MTH 451.
A continuation of MTH 451.
QA: MTH 452

461. Metric and Topological Spaces
Fall. 3(0-3-0)
P: MTH 421.
QA: MTH 461

464. Geometric Topology
Spring. 3(0-3-0)
P: MTH 421.
A capstone course. Topology of surfaces and higher dimensional manifolds, studied from combinatorial, algebraic or differential viewpoints.
QA: MTH 464

471. Computational Complexity
Fall. 3(3-0)
P: MTH 310.
QA: MTH 334 QA: MTH 470

472. Mathematical Logic
Spring. 3(0-3-0)
P: MTH 310.
Logics and formal systems, syntax and semantics. Completeness and axiomatizability. Decidable and undecidable theories and Goedel's theorems. Peano arithmetic.
QA: MTH 215 QA: MTH 471

481. Discrete Mathematics I
Fall, Spring. 3(0-3-0)
P: MTH 411.
QA: MTH 215 QA: MTH 382 MTH 383

495. Directed Studies
Fall, Spring. Summer. 1 to 4 credits.
May reenroll for a maximum of 9 credits.
R: Approval of department.
Faculty directed study in a selected mathematical topic.
QA: MTH 490

496. Capstone in Mathematics
Fall, Spring. 3(0-3-0)
R: Approval of department.
A capstone course integrating several areas of mathematics.

501. Current Issues in Mathematics
Education
Fall. 3(0-3-0)
P: Approval of Department.
Recent developments in K-16 mathematics curriculum, teaching, learning, and evaluation.
QA: MTH 801 MTH 802

502. Critical Content of School Mathematics: Algebra and Analysis
Spring of odd numbered years. 3(0-3-0)
P: MTH 801, MTH 810, and 829.
Examination of school algebra and analysis. Foundations and development, evolution and applications in the school curriculum, connections among content areas, and the learning and teaching of mathematics.
QA: MTH 802 MTH 803

502B. Critical Content of School Mathematics: Geometry and Discrete Mathematics
Spring of even numbered years. 3(0-3-0)
P: MTH 801, MTH 330, and MTH 841.
R: Graduate
Examination of school geometry and discrete mathematics. Foundations and development, evolution and applications in the school curriculum, connections among content areas, and the learning and teaching of mathematics.
QA: MTH 802 MTH 803

503. Recent Research in Mathematics Education
Spring of odd numbered years. 3(0-3-0)
P: MTH 802A or MTH 806B.
R: Graduate
Research in mathematics education and its effect on policy, curriculum, and the teaching and learning of mathematics.
QA: MTH 803

510. Error-Correcting Codes
Spring. 3(0-3-0)
P: MTH 411 or MTH 414 or MTH 415.
Block codes, maximum likelihood decoding, Shannon's theorem, generalized Reed-Solomon codes, modification of codes, selfdual codes, alternate and Goppa codes, cyclic codes, BCH codes.
QA: MTH 335 MTH 434 QA: MTH 830

511. Algebra I
Fall. 3(0-3-0)
P: MTH 481.
Group theory: Sylow theory, permutation groups, Jordan-Holder theory, Abelian groups, free groups. Ring theory: algebra of ideals, unique factorization, polynomial rings, finitely generated modules over PID.
QA: MTH 434 QA: MTH 834 MTH 835

519. Algebra II
Spring. 3(0-3-0)
P: MTH 412.
Modules and vector spaces, projective modules, tensor algebra, fields and Galois groups, algebraic and transcedental numbers, non-constructive rings, the Jacobson radical, the structure of semi-simple rings with the dec.
QA: MTH 834 QA: MTH 835 MTH 836

528. Real Analysis II
Fall. 3(0-3-0)
P: MTH 421, MTH 481.
Lebesgue measure on real line, general measure theory, convergence theorems, Fubini's theorem, Egoror's theorem, Lips-aces, Fubini's theorem, functions of bounded variation, absolutely continuous functions, Lebesgue differentiation theorem.
QA: MTH 458 QA: MTH 824 MTH 825

529. Complex Analysis I
Spring. 3(0-3-0)
P: MTH 421, MTH 481.
QA: MTH 456 QA: MTH 826

541. Boundary Value Problems I
Fall. 3(0-3-0)
P: MTH 414, MTH 421.
Methods for solving boundary and initial value problems for ordinary and partial differential equations.
QA: MTH 335 MTH 420 QA: MTH 841, MTH 842

542. Boundary Value Problems II
Spring. 3(0-3-0)
P: MTH 841.
Continuation of MTH 841.
QA: MTH 842 QA: MTH 843

548. Ordinary Differential Equations
Fall. 3(0-3-0)
P: MTH 414, MTH 421.
QA: MTH 436 QA: MTH 846 MTH 849

549. Partial Differential Equations
Spring. 3(0-3-0)
P: MTH 414, MTH 421.
QA: MTH 436 QA: MTH 886 MTH 887

550. Numerical Analysis I
Fall. 3(0-3-0)
P: MTH 414, MTH 421.
Convergence and error analysis of numerical methods in applied mathematics.
QA: MTH 335 MTH 420 QA: MTH 851 MTH 852

551. Numerical Analysis II
Spring. 3(0-3-0)
P: MTH 850.
Numerical methods for differential equations based on their discretizations. Introduction to stability and convergence.
QA: MTH 851 QA: MTH 850 MTH 857

Courses are subject to revision and final approval.

Descriptions of Courses

MATHEMATICS
MATHEMATICS

866*. Geometry and Topology I
Fall. 3(03-0)
MTH 422
Fundamental groups and covering spaces, van Kampen's theorem, differentiable manifolds, vector bundles, transversality, calculus on manifolds, differential forms, tensor bundles, de Rham theorem, Frobenius theorem.
QP: MTH 426
869*. Geometry and Topology II
Spring. 3(03-0)
P: MTH 868
Continuation of 866.

870*. Set Theory and Foundations of Mathematics
Spring. 3(03-0)
P: MTH 411 or MTH 421
Zermelo-Fraenkel axioms, cardinals and ordinals and their arithmetic, axiom of choice and maximal principles, transfinite induction and recursion, consistency and independence.
QP: MTH 345 MTH 426 QA: MTH 800
880*. Combinatorics
Fall. 3(03-0)
P: MTH 411
Enumerative combinatorics, recurrence relations, generating functions, asymptotics, applications to graphs, partially ordered sets, generalized Moebius inversion, combinatorial algorithms.
QP: MTH 434 QA: MTH 817
881*. Graph Theory
Spring. 3(03-0)
P: MTH 880
Fundamental concepts of graph theory, connectivity, algebraic and topological methods, networks, graph algorithms, Hamiltonian and Eulerian graphs, extremal graph theory, random graphs.
QP: MTH 817 QA: MTH 818
890*. Readings in Mathematics
Fall, Spring, Summer. 1 to 3 credits.
May reenroll for a maximum of 12 credits.
P: Approval of Department
Individualized study for Master's level students.
QA: MTH 890
910*. Commutative Algebra I
Fall of odd-numbered years. 3(03-00)
P: MTH 819
Noetherian rings and modules, localization and tensor products, primary decomposition, Krull dimensions, graded rings and modules, Hilbert's Nullstellensatz, integral extensions, discrete valuation rings, Dedekind domains.
QP: MTH 836
911*. Commutative Algebra II
Spring of even-numbered years.
QP: MTH 910
912*. Group Theory I
Fall of odd-numbered years. 3(03-00)
P: MTH 819
Permutation groups, solvable and nilpotent groups, simple groups, representation and character theory. Extension theory and cohomology groups.
QP: MTH536 QA: MTH934 MTH935
913*. Group Theory II
Spring of odd-numbered years.
P: MTH 912
Groups of Lie type, linear groups, locally finite groups, free groups and free products, the subgroup theorems.
QP: MTH 934 QA: MTH 935 MTH 936
914*. Lie Groups and Algebras I
Fall of odd-numbered years. 3(03-00)
P: MTH 819
Nilpotent and semisimple algebras, the adjoint representation, root spaces, Weyl groups, Dynkin diagrams, classification of simple algebras.
QP: MTH 836
915*. Lie Groups and Algebras II
Spring of even-numbered years. 3(03-00)
P: MTH 914
Weights, symmetric spaces, groups of Lie type, finite groups of Lie type, Lang's theorem.
920*. Functional Analysis I
Fall. 3(03-0)
P: MTH 828
QP: MTH 825 QA: MTH 824 MTH 825
921*. Functional Analysis II
Spring. 3(03-0)
P: MTH 829, MTH 820
QP: MTH 924 QA: MTH 925 MTH 926
922*. Harmonic Analysis
Spring. 3(03-0)
P: MTH 829, MTH 820
Fourier series, mean and pointwise convergence, conjugate functions, Fourier transform, Plancherel theorem, Paley-Wiener theorem, interpolation of operators, Hausdorff-Young theorem.
QP: MTH 928 QA: MTH 880 MTH 828
926*. Real Analysis II
Fall. 3(03-0)
P: MTH 828 C: MTH 920
QP: MTH 924
929*. Complex Analysis II
Spring. 3(03-0)
P: MTH 828, 829
QP: MTH 836
930*. Riemannian Geometry I
Fall. 3(03-0)
P: MTH 899
Riemannian metrics, connections, curvature, geodesics. First and second variation, Jacobi fields, conjugate points. Rauch comparison theorems, Hodge theory, Bochner technique, spin, Further topics on curvature or submanifold theory.
QP: MTH 861 QA: MTH 814A MTH 814B
931*. Riemannian Geometry II
Spring. 3(03-0)
P: MTH 950
Continuation of MTH 960.
QA: MTH 814B MTH 814C
935*. Complex Manifolds I
Fall of odd-numbered years. 3(03-0)
P: MTH 899, MTH 829
QP: MTH 829 MTH 861
938*. Complex Manifolds II
Spring of even-numbered years. 3(03-0)
P: MTH 935
Continuation of MTH 935.
940*. Applied Analysis I
Fall. 3(03-0)
P: MTH 848, MTH 849 C: MTH 920
Sobolev spaces, trace theorem, imbedding theorems, sectorial forms. Linear elliptic boundary and eigenvalue problems.
QA: MTH 844 MTH 845
941*. Applied Analysis II
Spring. 3(03-0)
P: MTH 940
Fixed point theorems. Variational methods. Applications to nonlinear integral and elliptic differential equations. Semigroup theory.
QP: MTH 844 QA: MTH 845 MTH 846
942*. Foundations of Applied Mathematics
Fall. 3(03-0)
P: MTH 848, MTH 849
QP: MTH 847 MTH 886 QA: MTH 881 MTH 882
943*. Foundations of Applied Mathematics II
Spring. 3(03-0)
P: MTH 942
Continuation of MTH 942.
QP: MTH 881 QA: MTH 882 MTH 883
950*. Advanced Numerical Analysis I
Fall. 3(03-0)
P: MTH 851, MTH 849
Finite difference methods for ordinary and partial differential equations.
QP: MTH 853 QA: MTH 850 MTH 858
951*. Advanced Numerical Analysis II
Spring. 3(03-0)
P: MTH 850
Finite element methods for ordinary and partial differential equations.
QP: MTH 858 QA: MTH 859
960*. Algebraic Topology
Fall. 3(03-0)
P: MTH 960
QP: MTH 863 QA: MTH 964 MTH 965
961*. Algebraic Topology II
Spring. 3(03-0)
P: MTH 960
Continuation of MTH 960.
QA: MTH 965 MTH 966
990*. Reading in Mathematics
Fall, Spring, Summer. 1 to 3 credits.
May reenroll for a maximum of 8 credits.
P: Approval of department
Individualized study for Doctoral level students.
Courses are subject to revision and final approval.

**MATHEMATICS**

991. Special Topics in Algebra
Fall, Spring. 3 to 6 credits in increments of 3 credits. May enroll for a maximum of 18 credits.
P: Approval of department
Advanced topics in algebra.
QA: MTH 991

992. Special Topics in Analysis
Fall, Spring. 3 to 6 credits in increments of 3 credits. May enroll for a maximum of 18 credits.
P: Approval of department
Advanced topics in analysis.
QA: MTH 992

993. Special Topics in Geometry
Fall, Spring. 3 to 6 credits in increments of 3 credits. May enroll for a maximum of 18 credits.
P: Approval of department
Advanced topics in geometry.
QA: MTH 993

994. Special Topics in Applied Mathematics
Fall, Spring. 3 to 6 credits in increments of 3 credits. May enroll for a maximum of 18 credits.
P: Approval of department
Advanced topics in applied mathematics.
QA: MTH 994

995. Special Topics in Numerical Analysis and Operations Research
Fall, Spring. 3 to 6 credits in increments of 3 credits. May enroll for a maximum of 18 credits.
P: Approval of department
Advanced topics in numerical analysis or operations research.

996. Special Topics in Topology
Fall, Spring. 3 to 6 credits in increments of 3 credits. May enroll for a maximum of 18 credits.
P: Approval of department
Advanced topics in topology.

997. Special Topics in Combinatorics and Graph Theory
Fall, Spring. 3 to 6 credits in increments of 3 credits. May enroll for a maximum of 18 credits.
P: Approval of department
Advanced topics in combinatorics and graph theory.

998. Doctoral Dissertation Research
Fall, Spring, Summer. 1 to 9 credits. May enroll for a maximum of 89 credits.
P: Approval of department R: Mathematics
QA: MTH 999

**MECHANICAL ENGINEERING**

201. Thermodynamics
Fall, Spring. 3-0-0
P: CEM 141, MTH 224 or concurrently.
R: Not open to students with credit in CEM 311 or MTH 351.
QF: MTH 215 CEM 141 QA: MTH 411

322. Fluid Mechanics
Fall, Spring. 4(3-3)
P: MMM 306, CHE 311 or ME 261 or MMM 351; ME 332 or concurrently. R: Open only to Mechanical Engineering and Mechanics students.
Statics, control volume equations, similarity, exact fluid solutions, turbulence, pipe flow, boundary layer flow, external flow.
QF: ME 311 MMM 306S 351 QA: ME 332

371. Mechanical Design I
Fall, Spring. 3(3-0)
P: MMM 306 or concurrently. R: Open only to Mechanical Engineering and Mechanics majors.
Analysis of displacement, velocity and acceleration in mechanical linkages. Kinematics and dynamics of machines.
QF: MMM 306 QA: ME 320

410. Heat Transfer
Fall, Spring. 3(3-0)
P: ME 332; R: Open only to Mechanical Engineering and Mechanics majors.
QF: ME 332 QA: ME 411

411. Applied Thermal Science
Fall, Spring. 3(3-0)
P: ME 410 or concurrently. R: Open only to Mechanical Engineering majors.
Thermodynamic principles as applied to gas and vapor power and refrigeration cycles for reciprocating and turbo machinery. Combustion, analysis, and design of heat exchangers. Numerical analysis of heat conduction.
QF: ME 411 QA: ME 412

412. Heat Transfer Laboratory
Fall, Spring. 1(1-2)
P: ME 411 or concurrently. R: Open only to Mechanical Engineering majors.
Practices and measurement techniques for heat transfer and thermal systems. Experimental problem solving applied to heat transfer.
QF: ME 332 ME 411 QA: ME 413

415. Solar Energy Conversion
Spring. 3(3-0)
P: ME 410; R: Open only to Mechanical Engineering majors.
QF: ME 411 QA: ME 413

416. Computer Assisted Design of Thermal Systems
Fall. 3(0-0)
P: ME 411; R: Open only to Mechanical Engineering majors.
Classifying, cataloging and processing design information. Modeling of thermal equipment. Simulation and optimization of thermal systems. Computer-based design projects.
QF: ME 312

422. Introduction to Combustion
Fall. 3(3-0)
P: ME 332; R: Open only to Mechanical Engineering majors.
Thermodynamics, chemistry, fluid mechanics, and heat transfer principles applied to combustion.
QF: ME 332

432. Intermediate Fluid Mechanics
Spring. 3(3-0)
P: ME 332. R: Open only to Mechanical Engineering and Mechanics majors.
Deformable control volumes, Navier-Stokes equations, vorticity and circulation. Exact solutions. Turbulence, boundary layer flows, compressible flows.
QF: ME 333 QA: ME 333

433. Intermediate Fluid Mechanics Laboratory
Fall. 0(4-0)
P: ME 432 or concurrently. R: Open only to Mechanical Engineering majors.
Visualization and measurement of flow, jets and wakes. Flow separation and boundary layers.
QF: ME 333

440. Aerospace Engineering I
Fall. 3(3-3)
P: ME 332. R: Open only to Mechanical Engineering and Mechanics majors.
Aerodynamics, propulsion, and flight mechanics. Vehicle and propulsion engine performance and design characteristics.
QF: ME 332 QA: ME 432

441. Aerospace Engineering II
Spring. 3(3-3)
P: ME 440. R: Open only to Mechanical Engineering and Mechanics majors.
Computer analysis experiments associated with aerospace vehicle design. Application of aeroelasticity and aerodynamics in design such as propulsion, aerodynamics, stability and control.
QF: ME 432 QA: ME 443

451. Control Systems
Fall, Spring. 4(3-3)
P: ME 391, MMM 306, EE 345. R: Open only to Mechanical Engineering and Mechanics majors.
QF: MMM 306 ME 351E 345 QA: ME 458

461. Mechanical Vibrations
Fall, Spring. 4(3-3)
P: ME 451. R: Open only to Mechanical Engineering and Mechanics majors.
Computer analysis experiments associated with aerospace vehicle design. Application of aeroelasticity and aerodynamics in design such as propulsion, aerodynamics, stability and control.
QF: ME 458 QA: ME 455

463. Computer Aided Design of Dynamic Systems
Spring. 3(3-0)
P: ME 451. R: Open only to Mechanical Engineering and Mechanics majors.
Modeling and design of mechanical and mixed-energy dynamic systems. State-space equation representation. Simulation methods.
QF: ME 458 QA: ME 332

465. Computer Aided Optimal Design
Fall, Spring. 3(3-0)
P: ME 471 or concurrently. R: Open only to Mechanical Engineering majors.
QF: ME 421 QA: ME 465

471. Mechanical Design II
Fall, Spring. 3(3-3)
P: ME 371, ME 391. R: Open only to Mechanical Engineering and Mechanics majors.
Engineering design of machine elements and mechanical systems. Computer-based analysis in support of design. Design for static and fatigue strength, deflection and reliability.
QF: ME 351 ME 320 QA: ME 421

Courses with an asterisk (*) have not been approved by the University Committee on Curriculum.