)31. ***Transportation and Distribution Research Methods***
Spring of odd-numbered years. 3(3-0)
?: ML 930. R: Open only to Ph.D. students in Business.
Techniques and methodology of system design, customer service and policy formulation.

)32. ***Transportation and Distribution Development Policy***
Fall of even-numbered years. 3(3-0)
?: ML 805. R: Open only to Ph.D. students in College of Business.
The interaction of government, carrier, and user logistics and distribution strategies, particularly at the macro-corporate and national policy levels.

)40. ***International Business Theory***
Fall of even-numbered years. 3(3-0)
P: ML 860 or ML 862.
Theories explaining international business phenomena. Varying perspectives on international business activities, concepts, and frameworks.

941. ***International Business Research Issues***
Spring of odd-numbered years. 3(3-0)
P: ML 940.
Scientific methods of research on international business. Topics include cultural bias and organizing multicountry studies.

995. ***Directed Research Paper***
Fall, Spring, Summer. 1(1-0)
P: ML 921. R: Open only to Ph.D. students in Marketing and Transportation Administration.
Production of research paper under the direction of a senior faculty member.

999. ***Doctoral Dissertation Research***
Fall, Spring, Summer. 1 to 24 credits. A student may earn a maximum of 99 credits in all enrollments for this course.
R: Approval of department.

MATERIALS SCIENCE AND MECHANICS MSM

Department of Materials Science and Mechanics
College of Engineering

160. ***Engineering Communications***
Fall, Spring. 3(2-3)
P: MTH 116 or concurrently.
Computer-aided design and drafting. Freehand sketching. Two and three dimensional visualization. Preparation of spread sheets and technical reports.

205. ***Statics***
Fall, Spring. 3(3-0)
P: MTH 132.
Vector description of forces and moments. Two and three dimensional equilibrium of particles and rigid bodies. Analysis of trusses, frames and machines. Coulomb friction.

211. ***Mechanics of Deformable Solids***
Fall, Spring. 3(3-2)
P: MSM 205, MTH 133 or concurrently.
Tension compression and shear stresses. Axially loaded bars. Torsion of circular shafts. Beam theory. Combined stresses. Mohr's circles. Columns.

250. ***Materials Science and Engineering***
Fall, Spring. 3(3-2)
P: CEM 141 or CEM 151.
Structure of metals, ceramics and polymers. Phase diagrams, thermomechanical treatments, physical and mechanical properties, diffusion, microstructure studies, environmental effects.

306. ***Dynamics***
Fall, Spring. 3(3-0)
P: MSM 205, MTH 235. R: Open only to College of Engineering students.
Kinematics of particles, rigid bodies, and mass moments of inertia. Kinetics of particles and rigid bodies. Energy and momentum principles.

311. ***Introduction to Biomedical Engineering***
Fall. 3(3-0) Interdepartmental with Biomedical Engineering, Mechanical Engineering, and Electrical Engineering. Administered by Biomedical Engineering.
P: BS 111, MTH 235, PHY 184.
Physical and mechanical properties of soft and hard tissues. Biomaterials. Biocompatibility. Biochemical processes, biological transport, and thermodynamics. Bioelectronics and instrumentation.

351. ***Thermochemistry of Materials***
Fall. 3(3-0)
P: CEM 151. C: MTH 234. R: Not open to students with credit in CHE 311 or ME 201.
State variables, laws of thermodynamics, phase and chemical equilibria. Gas and condensed phase relationships, solutions, interfaces, point defects, electrochemistry.

352. ***Diffusion in Solids***
Spring. 3(3-0)
P: MSM 250, MSM 351. R: Open only to Materials Science and Engineering majors or approval of department.
Diffusion and mass transport. Kinetics of diffusion-controlled processes. Point defects, nucleation and growth, interface motion.

355. ***Mechanical Behavior of Materials***
Fall. 3(3-0)
P: MSM 211, MSM 250. R: Open only to Materials Science and Engineering, Mechanics, Mechanical Engineering majors or approval of department.
Stress and strain, crystal elasticity, anelasticity and viscoelasticity. Mechanical properties in tension and torsion. Crystallographic aspects of plasticity.

356. ***Deformation Mechanisms***
Spring. 3(3-0)
P: MSM 355. R: Open only to Materials Science and Engineering majors.
Elementary dislocation theory, slip and twinning. Deformation of single and polycrystals. Temperature and strain rate effects. Work hardening, solution and particle strengthening. Creep, fatigue and fracture in metals, ceramics and polymers.

365. ***Physical Metallurgy I***
Fall. 3(3-0)
P: MSM 250; MSM 351 or concurrently. R: Open only to Materials Science and Engineering, and Mechanics majors or approval of department.
Complex binary and ternary phase diagrams. Solidification. Recovery, recrystallization and grain growth. Phase transformations.

366. ***Physical Metallurgy II***
Spring of even-numbered years. 3(3-0)
P: MSM 365. R: Open only to Materials Science and Engineering majors.
Theory of alloy phases. Surfaces and interfaces. Diffusion controlled phase transformations in ferrous and non-ferrous alloys. Martensitic transformation. Amorphous structures.

375. ***Materials Science Laboratory I***
Fall. 1(0-3)
P: MSM 355 or concurrently, MSM 365 or concurrently. R: Open only to Materials Science and Engineering, and Mechanics majors.
Phase transformations. Recrystallization. Precipitation and aging. Microscopy. Structure-property relations.

376. ***Materials Science Laboratory II***
Spring. 1(0-3)
P: MSM 355. R: Open only to Materials Science and Engineering, and Mechanics majors.
Strengthening. Yielding, creep, and fracture. Plasticity. Thermal activation. Damping. Marsensite and shape memory.

380. ***Polymeric Materials***
Spring. 3(3-0)
P: CEM 152. R: Open only to Materials Science and Engineering majors.
Polymers and engineering plastics. Chemical, physical and mechanical properties. Environmental effects on polymers. Manufacturing processes. Coatings.

401. ***Intermediate Mechanics of Deformable Solids***
Fall. 3(3-0)
P: MSM 211. R: Open only to College of Engineering majors.
Stress, strain and linearly elastic behavior. Plane stress and plane strain. Torsion. Yield criteria. Elastoplastic behavior of beams, shafts and cylinders. Unsymmetrical bending. Curved beams.

402. ***Computational Mechanics***
Spring. 3(3-0)
P: MSM 401 or ME 471. R: Open only to College of Engineering majors.
Energy methods with applications. Finite element methods. Buckling and stability. Green's functions.

403. ***Intermediate Dynamics***
Fall of even-numbered years. 3(3-0)
P: MSM 306. R: Open only to College of Engineering majors.
Kinematics and kinetics of particle and rigid body systems. Virtual work, Lagrangian method, and Euler equations. Basic vibrations of discrete and continuous systems. Elementary wave propagation.

405. ***Experimental Mechanics***
Fall of odd-numbered years. 3(2-3)
P: MSM 211. R: Open only to College of Engineering majors.
Measurement of stress, strain, vibration, and motion using strain gauges, accelerometers, photoelasticity, holography, Moire patterns, laser speckle and electronic imaging. Transducer design.

424. ***Biomaterials and Biocompatibility***
Spring of even-numbered years. 3(3-0) Interdepartmental with Biomedical Engineering. Administered by Biomedical Engineering.
P: BME 311, PSL 250.
Materials science of human implants. Design requirements imposed by the body's milieu and the need to protect the body.

441. ***Tissue Mechanics***
Spring of odd-numbered years. 3(3-0) Interdepartmental with Biomedical Engineering. Administered by Biomedical Engineering.
P: BME 311.
Application of solid mechanics to understanding mechanical responses of biological tissues. Microstructure and biological function for soft and hard connective tissues and muscle.

444. ***Introduction to Composite Materials***
Spring. 3(3-0)
P: MSM 211. R: Open only to Materials Science and Engineering or Mechanics majors or approval of department.
Constituents and interfacial bonding. Manufacturing techniques. Microstructure and micromechanics. Theory of anisotropy. Classical laminate theory. Material characterization. Failure and damage. Composite structure design.

451. X-Ray Crystallography
Fall. 3(2-3)
P: MSM 250, PHY 184. R: Open only to Materials Science and Engineering seniors and graduate students.
General properties, generation and detection of x-rays. Interaction with solids. Crystallography, reciprocal lattice, diffraction analysis and techniques. Single crystal methods, stereographic projection. X-ray microanalysis.

454. Ceramic and Refractory Materials
Fall. 3(3-0)
P: MSM 365. R: Open only to Materials Science and Engineering majors.
Ceramic and glassy materials. High temperature processes. Mechanical and physical properties of technical ceramics.

455. Theory of Solids
Spring. 3(3-0)
P: MSM 250, PHY 184. R: Open only to Materials Science and Engineering majors or approval of department.
Atomic theory of materials. Free electron theory of metals. Electrons in a periodic field. Insulators, semiconductors. Thermal properties. Dielectric and magnetic behavior. Superconductivity.

465. Design and Application of Engineering Materials
Spring. 3(3-0)
P: MSM 355, MSM 365. R: Open only to Materials Science and Engineering majors.
Fundamental principles of strengthening; toughening, specific strength and stiffness. Material development based on environmental, temperature, wear, damping, fatigue and economic considerations.

466. Failure Analysis
Spring. 3(3-0)
P: MSM 355. R: Open only to Materials Science and Engineering or Mechanics majors or approval of department.
Modes and causes of failure in mechanical components. Non-destructive evaluation. Legal and economic aspects of materials failure. Analysis illustrated through student projects requiring integration of knowledge from several courses.

475. Deformation Processing of Materials
Fall of odd-numbered years. 3(3-0)
P: MSM 355. R: Open only to Material Science and Engineering, Mechanical Engineering majors.
Theories of metal forming. Forging, rolling, extrusion, wire drawing, sheet metal forming, machining, powder pressing, sintering, hot pressing, composite processing.

476. Physical Processing of Materials
Spring of even-numbered years. 3(3-0)
P: MSM 365. R: Open only to College of Engineering majors.
Heat treatment and properties of ferrous alloys. Casting and solidification. Effects of alloying elements, high strength low alloy steels, hardenability, case hardening. Joining of materials, welding.

480. Chemical Processing of Materials
Fall. 3(3-0)
P: MSM 352, or CHE 312. R: Open only to Materials Science and Engineering, and Chemical Engineering seniors and graduate students.
Processing of metals, ceramics, and polymers. Material and energy balances. Reduction and oxidation. Extractive technology of iron, steel, and principal non-ferrous metals. Colloidal preparation of ceramics.

481. Manufacturing Systems I
Fall. 3(3-0)
P: MSM 205, MSM 250. R: Open only to Materials Science and Engineering or Engineering Arts majors.
Manufacturing process planning and design. Discrete parts and assembly processes. Producibility, cost estimation, time standards, materials handling, plant layout principles.

482. Manufacturing Systems II
Spring. 3(3-0)
P: MSM 481. R: Open only to Materials Science and Engineering or Engineering Arts majors.
Operations scheduling and control. Applications of artificial intelligence. Optimization of multiple stage manufacturing activities. Manufacturing resource planning. Principles of synchronous manufacturing.

483. Environmental Effects on Materials
Fall of odd-numbered years. 3(3-0)
P: MSM 352. R: Open only to Materials Science and Engineering majors.
Electrochemical processes and kinetics. Metallic corrosion and protection. Degradation of ceramics, polymers and composites.

490. Independent Study
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 6 credits in all enrollments for this course.
R: Open only to Materials Science and Engineering majors. Approval of department.
Individualized reading and research.

491. Selected Topics
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 6 credits in all enrollments for this course.
R: Open only to majors in Materials Science and Engineering or in Mechanics.
Topics in materials science or mechanics of current interest.

499. Senior Research and Design Project (W)
Fall, Spring, Summer. 2 to 4 credits. A student may earn a maximum of 6 credits in all enrollments for this course.
R: Open only to seniors in Materials Science and Engineering, Engineering Arts, and Mechanics. Completion of Tier I writing requirement. Approval of department.
Design and analysis to solve a materials related problem. Preparation of written report, oral presentation, and defense of the project.

801. Advanced Dynamics
Fall. 3(3-0)
P: MSM 403.
Dynamics of systems of particles and rigid bodies. Energy and momentum principles. Lagrangian and Hamiltonian methods. Euler angles. Applications in system dynamics and vibrations.

805. Experimental Mechanics
Spring. 3(2-3)
R: Approval of department.
Measurement of strain, displacement, velocity, acceleration using resistance strain gages, accelerometers, and related methods. Detailed study of strain gages and accelerometers. Transducer design. Basic modal analysis.

809. Finite Element Method
Fall. 3(3-0) Interdepartmental with Agricultural Engineering, Civil Engineering, and Mechanical Engineering.
R: Approval of department.
Theory and application of the finite element method to the solution of continuum type problems in heat transfer, fluid mechanics, and stress analysis.

810. Continuum Mechanics
Fall. 3(3-0)
Mathematical tools of continuum mechanics, stress principles, kinematics of deformation and motion, fundamental laws and equations. Applications in linear elasticity and classical fluids.

813. Linear Elasticity
Spring. 3(3-0)
P: MSM 810.
Fundamentals of isotropic linear elasticity. Solution of plane elasticity problems. St. Venant bending and torsion. Singular solutions. Basic three-dimensional solutions.

814. Mechanics of Composite Materials (MTC)
Fall. 3(3-0) A student may earn a maximum of 6 credits in all enrollments for this course.
Applications of anisotropic elasticity theory, and the inhomogeneity approach, to systems such as macroscopic laminated structures and microscopic fiber-matrix interactions.

815. Advanced Strength of Materials
Spring of odd-numbered years. 3(3-0)
P: MSM 401.
General theory of torsion, nonsymmetric bending, transverse shear, thin-walled beams, beams on elastic foundations, thick-walled cylinders. Basic contact mechanics. Failure criteria for solids.

816. Fracture Mechanics and Fatigue
Spring of even-numbered years. 3(3-0)
P: MSM 813.
Brittle and ductile fracture. Elastic stress fields near cracks. Elastic-plastic analysis of crack extension. Plastic instability. Cyclic crack propagation. Models of cyclic deformation and fatigue failure. Environmental effects. Case studies.

817. Plasticity
Spring of odd-numbered years. 3(3-0)
P: MSM 813.
Yield conditions, stress-strain relations, plastic potential, hardening theories, torsion, bending. Thick walled shells under internal pressure. Limit analysis. Slip line theory.

820. Energy Methods in Mechanics
Spring of even-numbered years. 3(3-0)
P: MSM 813.
Calculus of variations. Variational principles in mechanics. Approximate methods. Energy criteria for stability. Applications to structural dynamics.

835. Wave Propagation in Solids
Fall of odd-numbered years. 3(3-0)
P: MSM 810.
Plane waves in elastic media, reflection of waves at interfaces. Surface waves, waveguides. Application to nondestructive evaluation. Introduction to wave propagation in anisotropic and nonelastic solids.

840. Plates and Shells
Fall of odd-numbered years. 3(3-0) Interdepartmental with Civil Engineering.
P: MSM 815.
Deformation and stress analysis of plates and shells with different types of geometry, thickness, and boundary conditions.

851. Thermodynamics of Solids
Fall. 3(3-0)
Use of Jacobians. Thermodynamic functions. Thermodynamics of solid-solid phase transformation. Thermoelastic solids, rubber elasticity, and stressed solids. Surfaces and interfaces, point defects in solids. Thermodynamics of solids under high pressure.

855. Advanced Rate Theory and Diffusion
Spring. 3(3-0)
P: MSM 851.
Review of Fick's Laws. Atomistic aspects of diffusion. Defects in solids. Probabilistic basis of random walk. Green's function solutions.

860. Theory of Vibrations
Fall. 3(3-0) Interdepartmental with Mechanical Engineering. Administered by Mechanical Engineering.
P: ME 452.
Discrete systems and continua. Analytical mechanics. Variational principles. Modal analysis. Function spaces. Eigenfunction expansions. Integral transforms. Stability. Approximations. Perturbations.

862. Dislocation Theory
Spring. 3(3-0)
P: MSM 451.
Advanced theory of dislocations and other crystal defects in metals, ceramics, aggregates and ordered compounds. Elasticity theory of straight dislocations, dislocation strain energy, mobility, obstacle interactions, reactions, and core effects.

865. Advanced Theory of Solids
Spring. 3(3-0)
Quantum mechanics. Free electron theory. Energy bands, semiconductors. Dielectrics and ferroelectrics. Dia-, para-, ferro-, and antiferro-magnetism. Superconductivity. Thermal properties.

870. Electron Microscopy in Materials Science
Spring. 3(2-3)
P: MSM 451. R: Open only to majors in Materials Science or approval of department.
Theory of electron diffraction. Electromagnetic lenses. Image formation in transmission electron microscopy. Defect analysis and diffraction contrast.

871. Material Surfaces and Interfaces
Fall of odd-numbered years. 3(3-0) Interdepartmental with Chemical Engineering. Administered by Chemical Engineering.
P: CEM 362 or MSM 351. R: Open only to Chemical Engineering, Materials Science, Chemistry, or Packaging majors.
Physical and chemical nature of solid surfaces and their interaction with gases, liquids, and other solids. Characterization of surfaces and solid-solid interfaces. Relation of surface and interfacial structure to engineering phenomena.

875. Engineering Ceramics
Fall of odd-numbered years. 3(3-0)
P: MSM 851.
Physical properties of engineering ceramics. Transport properties of ceramics, especially in ferrites and garnets. Optical ceramic materials.

876. Advanced Polymeric Materials
Fall of even-numbered years. 3(3-0)
C: MSM 810.
Advanced topics in polymer structure and properties. Thermoplastics, thermosets, polyblends and elastomers. Processing techniques. Deformation and mechanical properties. Thermal, optical and chemical properties. Composites.

885. Seminar
Fall, Spring. 1(1-0)
Oral presentations of students' research or literature survey.

890. Independent Study
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 6 credits in all enrollments for this course.
R: Approval of department.
Individualized reading and research of student's interest.

891. Selected Topics
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 6 credits in all enrollments for this course.
R: Approval of department.
Special topics in materials science or mechanics of current importance.

899. Master's Thesis Research
Fall, Spring, Summer. 1 to 8 credits. A student may earn a maximum of 24 credits in all enrollments for this course.

902. Random Vibration of Structural and Mechanical Systems
Spring of odd-numbered years. 3(3-0) Interdepartmental with Civil Engineering and Mechanical Engineering. Administered by Civil Engineering.
P: CE 802 or ME 860; CE 810.
Probabilistic modeling of random excitations (e.g., earthquake, aerodynamic, and ocean wave loadings). Response of single and multiple degree-of-freedom systems to random excitation. Designing against failure. Nonstationary and nonlinear problems.

905. Optical Methods of Measurement
Fall of even-numbered years. 3(2-3)
R: Approval of department.
Measurement of dimension, position, motion, strain, using optical methods including holography, speckle interferometry, Moire, photoelasticity, laser Doppler, electronic imaging, model analysis. Relevant optics theory.

909. Boundary Element Method
Spring of odd-numbered years. 3(3-0)
P: MSM 813.
Theory and application of the boundary element method to the solution of continuum type problems in heat transfer, fluid mechanics and stress analysis. Computer applications.

915. Nonlinear Elasticity
Spring of even-numbered years. 3(3-0)
P: MSM 813.
Kinematics and kinetics of large deformations. Incompressible and compressible finite elasticity. Solution of basic problems. Nonuniqueness, stability and buckling. Singular fields near cracks and flaws.

918. Thermoelasticity and Viscoelasticity
Spring of even-numbered years. 3(3-0)
P: MSM 810, MTH 443.
Thermomechanics of solids. Theory of thermoelasticity. Boundary value problems in thermoelasticity. Linear and nonlinear viscoelasticity. Model representation. Boltzmann superposition. Correspondence principle.

922. Micromechanics
Spring of odd-numbered years. 3(3-0)
P: MSM 813.
Models of microstructures. Inclusion problems. Eigenstrain method. Upper and lower bounds. Methods of statistical elasticity. Approximate methods. Mechanics of random networks. Percolation models of damage.

960. Advanced Physical and Mechanical Properties of Materials (MTC)
Fall. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course.
Topics vary each semester. Topics such as microcracking in brittle materials, anisotropic crystalline properties, or surfaces, interfaces and thin film structures.

970. Advanced Analytical Techniques (MTC)
Fall. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course.
Topics vary each semester. Topics such as advanced techniques in electron microscopy, advanced analytical methods in materials science, or advanced X-ray methods.

980. Advanced Processing Techniques (MTC)
Spring. 3(3-0) A student may earn a maximum of 9 credits in all enrollments for this course.
Topics vary each semester. Topics such as ceramic processing, or high temperature deformation and processing, or laser and plasma processing.

990. Independent Study
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 6 credits in all enrollments for this course.
Individualized reading and research.

991. Selected Topics
Fall, Spring, Summer. 1 to 3 credits. A student may earn a maximum of 6 credits in all enrollments for this course.
R: Approval of department.
Special advanced topics in materials science and engineering, and mechanics.

999. Doctoral Dissertation Research
Fall, Spring, Summer. 1 to 24 credits. A student may earn a maximum of 72 credits in all enrollments for this course.

MATHEMATICS MTH

Department of Mathematics
College of Natural Science

103. College Algebra
Fall, Spring, Summer. 3(3-0)
P: MTH 1825 or designated score on mathematics placement test. R: Not open to students with credit in MTH 110 or MTH 116 or MTH 120 or LBS 117.
Number systems; functions and relations; exponents and logarithms; elementary theory of equations; inequalities; and systems of equations.

104. Trigonometry
Fall, Spring, Summer. 3(3-0)
P: MTH 103. R: Not open to students with credit in MTH 116.
Radian and degree measure of angles. Definitions and graphs of trigonometric functions and their inverses. Solving trigonometric equations. Applications including identities, law of sines, law of cosines, vectors in the plane, and polar coordinates.

110. College Algebra and Finite Mathematics
Fall, Spring, Summer. 5(5-0)
P: MTH 1825 or designated score on mathematics placement test. R: Not open to students with credit in MTH 103 or MTH 116 or MTH 120 or LBS 117.
Functions and graphs. Equations and inequalities. Systems of equations. Matrices. Linear programming. Simplex algorithm. Probability and statistics.

116. College Algebra and Trigonometry
Fall, Spring, Summer. 5(5-0)
P: MTH 1825 or designated score on mathematics placement test. R: Not open to students with credit in MTH 103 or MTH 110 or MTH 120 or LBS 117.
Functions and graphs. Equations and inequalities. Exponential and logarithmic functions. Trigonometric functions. Systems of equations. Binomial theorem.