952. *Approximation Theory II*

Winter. 3(3-0) 951.

Continuation of 951. Generalized methods of measuring error: Approximation in L^1 and L^p norms, least-square approximation and orthogonal functions; spline functions; approximation in normed linear spaces.

953. *Approximation Theory III*

Spring. 3(3-0) 952.

Continuation of 952.

961. *Topological Groups*

Winter of even-numbered years. 4 credits. 862.

General properties of topological groups, classical groups and Lie groups.

962. *Point Set Topology*

Fall of odd-numbered years. 3(3-0) 823, 861.

Hausdorff continua, Hahn-Mazurkiewicz cyclic element theory, monotone decompositions, indecomposable continua, homogeneity.

964. *Algebraic Topology I*

Fall of even-numbered years. 3(3-0) 834, 862.

Simplicial and singular homotopy theory, Eilenberg-Steenrod axioms, chain complexes, cell complexes, applications to Euclidean spaces.

965. *Algebraic Topology II*

Winter of odd-numbered years. 3(3-0) 964.

Continuation of 964 including category and functor theory, general coefficient and cohomology theory.

966. *Algebraic Topology III*

Spring of odd-numbered years. 3(3-0) 965.

Continuation of 965 including homology groups of products, Eilenberg-Zilber theorems, cohomology products, differential topology.

967. *Homotopy Theory I*

Winter. 3(3-0) 964.

Sets of homotopy, fibrations, higher homotopy groups, CW complexes. homotopy functors.

968. *Homotopy Theory II*

Spring. 3(3-0) 965, 967.

Obstruction theory and the application of spectral sequences and cohomology operations to homotopy theory.

981. *Methods of Complex Analysis I*

Fall of even-numbered years. 3(3-0) 823 or approval of department.

Application of functions of a complex variable to contour integrals, conformal mapping, asymptotic methods, integral transform methods, Weiner-Hopf methods and special functions.

982. *Methods of Complex Analysis II*

Winter of odd-numbered years. 3(3-0) 981.

Continuation of 981.

983. *Methods of Complex Analysis III*

Spring of odd-numbered years. 3(3-0) 982.

Continuation of 982.

990. *Introduction to Research*

Fall, Winter, Spring. 1 to 3 credits. May re-enroll for a maximum of 6 credits. Approval of department.

Introduction to mathematical research through the solution of challenging problems in a variety of fields of mathematics.

991. *Advanced Topics in Geometry*

Fall, Winter, Spring, Summer. Variable credit.

992. *Advanced Topics in Analysis*

Fall, Winter, Spring, Summer. Variable credit.

993. *Advanced Topics in Algebra*

Fall, Winter, Spring, Summer. Variable credit. Approval of department.

Structure of rings and algebras, Lie algebras, Jordan algebras, advanced algebraic number theory, advanced matrix theory, and advanced topics in group theory, Lattice theory.

994. *Advanced Topics in Applied Mathematics*

Fall, Winter, Spring, Summer. Variable credit. Approval of department.

Nonlinear differential equations, asymptotic theory in differential equations, existence theorem, diffraction theory, Wiener-Hopf techniques.

996. *Advanced Topics in Topology*

Fall, Winter, Spring, Summer. Variable credit. Approval of department.

Topological groups, topology of Euclidean spaces, axiomatic homology theory, homotopy theory, function spaces.

999. *Research*

Fall, Winter, Spring, Summer. Variable credit. Approval of department.

MECHANICAL ENGINEERING M E

College of Engineering

230. *Residence Heating*

Fall, Winter. 4(3-2) Building construction majors.

Calculation of heat losses and heat gains for typical residences, and system design and layout for both heating and air-conditioning.

280. *Manufacturing Processes*

Fall, Winter, Spring. 3(3-0)

An introduction to the materials and processes used in manufacturing, to convert ideas into products, machines, and structures for the use of mankind. Extensive use is made of audio-visual techniques.

311. *Thermodynamics I*

Fall, Winter. 4(3-3) MTH 215 or concurrently.

Zeröth, first and second laws of thermodynamics. General energy equation. Process relations. Concepts of equilibrium, reversibility, and irreversibility. Applications of these to systems describable by two independent properties.

312. *Thermodynamics II*

Winter, Spring. 4(3-3) 311.

Continuation of 311; third law, gas and vapor relations, reactive and non-reactive mixtures. Introduction to combustion and equilibrium and to statistical mechanics and kinetic theory.

313. *Thermodynamics III*

Fall, Spring. 3(3-0) 312.

Thermodynamic principles as applied to gas and vapor power cycles for reciprocating and turbo machinery; nozzles and jets. Fundamental principles of energy conversion systems—electrical, chemical and thermal.

322. *Thermomechanical Continua*

Winter, Spring. 3(3-0) MMM 211; MTH 334.

Thermomechanical continua including energy principles, formulation and solution of boundary value problems in elasticity, plasticity, and viscoelasticity. Dynamic response of mechanical systems via Hamilton's Principle; Euler-Lagrange equations. Rayleigh, Ritz, and Galerkin approximations.

325. *Mechanical Vibrations*

Spring, Summer. 4(4-0) MMM 206; MTH 334 and 341.

Oscillatory phenomena for linear systems with one and two degrees of freedom, non-linear systems, time varying systems with deterministic excitation, and time invariant systems with non-deterministic excitations.

332. *Fluid Mechanics I*

Spring, Summer. 4(3-3) MMM 206.

Fluid statics. Fundamental concepts and analysis techniques. Deformable and non-deformable control volume approach to conservation of mass, linear and moment of momentum, energy. Dimensional analysis, similitude and examples of engineering usage.

406. *Automotive Engines*

Winter. 3(2-3) 312, 424.

Analysis of internal combustion engines for vehicular propulsion.

407. *Automotive Vehicles*

Spring. 3(2-3) 421.

Analysis of the propulsion, braking, steering, and suspension requirements.

411. *Heat Transfer I*

Winter. 3(3-0) 311; MTH 215.

Analysis of steady-state and transient heat conduction; numerical solutions. Radiant heat transfer; principles and applications including radiation networks. Gaseous radiation exchange.

412. *Heat Transfer II*

Spring. 3(3-0) 411, 431.

Natural and forced convection based on boundary layer theory. Heat transfer in fluids with phase change. Heat exchangers, mass transfer.

420. *Kinematics of Machines I*

Fall. 4(3-3) MTH 214; MMM 206 or concurrently; EGR 260.

Absolute and relative displacements, velocities, and accelerations in rigid body systems; analysis and synthesis of multi-bar linkages and rotational mechanisms.

421. *Machine Design I*

Winter. 4(3-3) MMM 211.

Analysis and synthesis of mechanical systems; fatigue resistance; stress concentration; elasticity; non-linear elements.

422. *Machine Design II*

Spring. 3(2-3) 421.

Analysis and synthesis of elements of systems; hydrodynamic theory of lubrication; contact stresses; finite and infinite life design factors.

424. *Dynamics of Machines*

Winter. 3(3-0) 420.

Analysis of static and dynamic forces in rigid body systems; balancing of rotating and reciprocating system elements; inertial guidance; critical speeds.

428. *Control Theory*

Fall. 3(3-0) 325; MTH 322.

Closed-loop control systems; application of transfer function analysis; design for a definite degree of stability; on-and-off controllers.

431. Fluid Mechanics II

Fall. 4(3-3) 332 or approval of department.

Field descriptions, stress-strain relations for a fluid, circulation, vorticity, field equations for continuity and momentum, boundary layers, basic concepts of turbulence, Reynolds equations, phenomeno-logical theories, one-dimensional gas dynamics.

432. Gas Dynamics

(416.) Winter. 3(3-0) 431.

Thermodynamics of flow of compressible fluids. Mach number, energy and continuity equations. Fanno and Rayleigh lines, normal shock, and principles of fluid meters.

436. Cooling Processes

Spring. 3(3-0) 312.

Thermodynamic principles applied to the design of cooling systems in range of normal temperatures to ultra-low cryogenic temperature conditions. Psychrometric principles as applied to air conditioning and evaporating systems.

442. Industrial Engineering

Winter, Spring. 4(3-2) 280; MGT 302.

Theory and techniques used by industry in planning for manufacturing. Process selection and design, work methods planning, production time standards, materials handling, and plant layout planning.

499. Senior Problems

Fall, Winter, Spring, Summer. 1 to 6 credits. May re-enroll for a maximum of 12 credits. Approval of department.

812. Heat and Mass Transfer

Fall. 4(4-0) Graduate students. Not open to students with credit in 411, 412.

Theory and applications of transport of heat and mass in stationary and moving media. Conductive, convective, and radiative heat transfer. Phase-change heat transfer. Mass transfer in laminar and turbulent flows.

813. Convective Heat Transfer

Winter. 3(3-0) 412; MTH 421.

Analysis of convective transfer of heat, mass and momentum in boundary layers and inducted flows. Heat transfer with phase change of fluids.

814. Radiative Heat Transfer

Spring. 3(3-0) 812.

Statistical mechanics and thermodynamics of radiation. Study of spectral properties. Radiative transfer in media. Selected applications.

815. Advanced Classical Thermodynamics

Fall of odd-numbered years. 3(3-0) 313; MTH 422 or 424 or concurrently.

Postulational treatment of the laws of thermodynamics. Equilibrium and maximum entropy postulates. Development of formal relationships. Principles for general systems. Applications to chemical, magnetic, electric and elastic systems.

817. Conductive Heat Transfer

Fall. 3(3-0) 411, MTH 341 or 422 concurrently.

Theory of steady or unsteady heat conduction in isotropic and anisotropic media. Treatment of concentrated and distributed heat sources. Heat transfer from extended surfaces. Numerical solutions.

818. Estimation in Heat and Mass Transfer

Spring. 3(3-0) 411; MTH 334.

Nonlinear estimation of properties and parameters appearing in differential equations from experimental data. Inverse heat conduction problem. Optimization in estimation. Error analysis. Numerical methods. Model-building in heat and mass transfer.

823. Theory of Vibrations I

Fall. 4(4-0) 325. Interdepartmental with the Metallurgy, Mechanics and Materials Science Department.

Discrete and continuous parameter systems with linear and non-linear characteristics. Variational principles; equations of motion. Matrices, quadratic forms; self-adjoint operators; eigenvalues. Transient and random excitations. Theory developed through physical problems.

826. Kinematics of Machines II

Fall. 3(3-0) 420.

Analysis and synthesis of mechanisms using complex variables. Euler-Savary equation. Polynomial cam design. Synthesis of function generators. Computer mechanisms.

827. Machine Design III

Spring, Summer. 3(3-0) 421.

Strain energy method for analyzing statically indeterminate machine members, theories of failure, fatigue, use of statistics in selection of tolerances for parts in mass production. Optimum design.

828. Machine Design IV

(423.) Winter. 3(3-0) 421.

Application of design theory to the synthesis of complete mechanical and hydraulic systems. Stress waves due to impact loading. Critical speed.

832. Refrigeration

Fall. 3(3-0) 436.

Characteristics of refrigerants; application details pertaining to comfort cooling, food refrigeration, and ultra-low temperature units; refrigeration controls, and control systems.

834. Low Temperature Thermal Analysis

(934.) Winter of odd-numbered years. 3(3-0) 436.

Low temperature environments and thermal transport fluids. Cryogenic systems: space simulation, super insulations, vacuum technology, ultra low temperature physical phenomenon with helium and magnetic cooling systems.

841. Advanced Gas Dynamics

Spring. 3(3-0) 432; MTH 322 or 422 or 424 or approval of department.

Compressible subsonic and supersonic flow, shock waves, expansion fans, inviscid equations, perturbation theory, similarity rules, methods of measurement, method of characteristics, hodograph methods.

842. Inviscid Fluids

Spring. 3(3-0) MMM 810; MTH 322 or MTH 423.

Kinematics; dynamical equations; potential flows, transformations, Helmholtz flows; added masses, forces and moments; vortex motion; wave motion.

843. Turbulence

Winter, Summer. 4(4-0) MMM 810 or approval of department.

Reynolds equations; turbulence energy equations; turbulence structure descriptions: correlation and spectrum functions, macro, micro and time scales; basic elements of: isotropic turbulence, phenomenological theories, hot-wire anemometry; free-shear and conduit flows.

850. Advanced Space and Orbit Ballistics

(950.) Fall of odd-numbered years. 3(3-0) MMM 206; MTH 215, 309.

Particle motion; missile trajectories; motion of a rocket; orbits; effects of oblateness on satellite orbit; orbital lifetime; rendezvous transfer in earth-moon system; optimization; low thrust space propulsion systems; trip to Mars.

862. Mechanical and Aero-Space Optimization

Winter. 3(3-0) MTH 424.

Elementary fundamentals of calculus of variations, maximum principle. Optimization techniques applied to fluids, gas dynamics, optimization of airfoil shapes, fuel consumption, heat transfer, wave propagation in solids and physical properties in plasmas.

873. Thermal Stresses

Spring of odd-numbered years. 3(3-0) MTH 422; MMM 810; or approval of department.

Thermomechanical behavior of continua; thermoelastic, thermoviscoelastic and thermoplastic models; coupled and uncoupled thermomechanical behavior; thermally induced vibrations; instability and inelasticity; thermal shock; thermomechanical ablation.

899. Research

(EGR 899.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

917. Statistical Thermodynamics and Kinetic Theory of Gases

Fall of even-numbered years. 3(3-0) 313; MTH 322 or 422 or 424 or concurrently; or approval of department.

Relation of statistical mechanics and kinetic theory to thermodynamics. Maxwell-Boltzman, Bose-Einstein, and Fermi-Dirac statistics. Information and communication theory. Jayne's formalism. Applications.

920. Theory of Vibrations II

(MMM 904.) Winter of odd-numbered years. 4(4-0) MTH 422; 823 or approval of department. Interdepartmental with and administered by the Metallurgy, Mechanics and Materials Science Department.

Vibrations of one, two, and three-dimensional models of elastic and inelastic continua. Interaction phenomena. Stability. Variational methods. Applications to aeronautics, aerospace and undersea technology.

921. Theory of Vibrations III

(MMM 903.) Spring of odd-numbered years, Summer. 4(4-0) MMM 920 or approval of department. Interdepartmental with and administered by the Metallurgy, Mechanics and Materials Science Department.

Nonlinear oscillations. Resonance; subharmonics; self-sustained motions; stability. Methods of Poincare, van der Pol, etc. Random vibrations. Parametric excitations; stochastic processes; power spectra. Applications.

923. Wave Motion in Continuous Media I

Winter of even-numbered years. 4(4-0) MTH 422; MMM 810; or approval of department.

Linear and non-linear wave propagation. Reflection, refraction, diffraction. Dispersion. Shock and acceleration waves. Acoustical and optical analogies. Applications to elastic, plastic, viscoelastic, fluid, electromagnetic, elastic dielectric, and stochastic media.

924. Wave Motion in Continuous Media II

Spring of even-numbered years. 4(4-0) 923.

Continuation of 923.

925. Mechanical Engineering Problems

Fall, Winter, Spring, Summer. Variable credit. May re-enroll for a maximum of 9 credits. Approval of department.

Analysis of advanced engineering problems involving design, thermodynamics, fluid dynamics, gas dynamics, space.

930. *Seminar*

Fall, Winter, Spring. 1 credit. May re-enroll for a maximum of 3 credits in master's program; 6 credits in doctoral program. Open to graduate students of all colleges and departments.

Recent developments in space orbit theory, theory of space propulsion, magnetohydrodynamics, re-entry phenomena, ionosphere, space radiation phenomena, design of space vehicles, and developments in the field pertinent to space technology such as external environmental conditions, internal environmental conditions, effects upon space vehicle construction, etc.

941. *Advanced Gas Dynamics II*

Fall of odd-numbered years. 3(3-0) 841.

Transonic flows, blunt bodies in supersonic flows, three-dimensional supersonic flows, hodograph methods, characteristics, unsteady phenomena, physical gas dynamics.

942. *Viscous Fluids*

Fall of even-numbered years. 3(3-0) MMM 810 or CHE 841.

Exact solutions of Navier-Stokes equations, i.e., Oscillatory Motion, Laminar Jet, Converging Channel, etc.; Hydrodynamic Stability including free convection, surface tension, gravitational and free-surface instabilities, and Tollmien-Schlichting waves.

952. *Slip and Free (Newtonian) Molecular Flows*

Spring. 3(3-0) 412, 432.

Distribution function; Boltzmann equation; solutions of Enskog-Burnett, Grad; slip flow; drag coefficient; heat transfer. Free molecule flow; elastic and inelastic reflections; flow around bodies; resistance coefficient; heat; oblation; meteors.

953. *Plasma Dynamics (Magneto-Gas Dynamics)*

Winter. 3(3-0) 432; PHY 467.

Fundamental equations of hydrodynamics; Maxwell equations; continuum; channel flow; boundary layer; shocks; Alfven wave propagation; one and two fluid theories; discrete particle approach; plasma oscillations; flow around bodies and in nozzles; space propulsion systems.

954. *Ion Flow Dynamics*

Spring. 3(3-0) 953.

Continuation of 953 as applied to the ion flow; extension of the neutral flow turbulence into electromagnetic turbulence, and method of characteristics applied to the ion flow dynamics.

999. *Research*

(EGR 999.) Fall, Winter, Spring, Summer. Variable credit. Approval of department.

MEDICAL TECHNOLOGY M T

College of Human Medicine

College of Veterinary Medicine

201. *Medical Technology*

Fall. 1(1-0) Approval of school.

Relationship of medical technology to medicine and research, and the necessary interaction with other paramedical sciences.

401. *Seminar in Medical Technology*

Fall. 1 credit. Seniors.

Acquaints students with the operation and administration of a hospital, the philosophy and understanding of the entire profession of medical technology.

MEDICINE MED

College of Human Medicine

590. *Special Problems in Medicine*

Fall, Winter, Spring. Summer. 1 to 6 credits. May re-enroll for a maximum of 12 credits. Human Medicine students.

Each student will work under direction of a staff member on an experimental, theoretical or applied problem.

METALLURGY, MECHANICS AND MATERIALS SCIENCE MMM

College of Engineering

205. *Mechanics I*

Fall, Winter, Spring. 4(4-0) MTH 214 or concurrently.

Vector description of forces, moments, and motion. Statics. Dynamics of particles and particle systems. Energy and momentum principles. Stability of equilibrium.

206. *Mechanics II*

Fall, Winter, Spring. 4(4-0) 205; MTH 215 or concurrently.

Dynamics of rigid bodies in general motion, plane motion, rotation, statics, variational methods.

211. *Mechanics of Deformable Solids*

Fall, Winter, Spring, Summer. 4(4-0) 205 or statics; MTH 215.

Deformable solids, stress and strain, principal axes, material behavior (elastic, plastic, viscoelastic, temperature dependent). Boundary value problems, torsion, beams. Instability, columns.

215. *Materials Testing Laboratory*

Fall, Winter, Spring, Summer. 1(0-3)

Physical properties of engineering materials, resistance to primary types of static loading.

230. *Introduction to Materials Science*

Fall. 4(4-0) Sophomores.

A qualitative survey of the atomic and molecular structure of materials and their related mechanical, thermal, electrical, and magnetic properties.

304. *Dynamics*

Fall. 4(5-0) Statics; MTH 215 or concurrently.

Dynamics of particles and rigid bodies for those students who have had statics.

320. *Analytical Mechanics I*

Fall. 3(3-0) MTH 215; PHY 289.

Measures of point motion, indicial notation, vector space and time transformations. Newton's, Lagrange's and Hamilton's equations. Motions of point objects; limiting wave forms.

321. *Analytical Mechanics II*

Winter. 3(3-0) 320.

Schrodinger's equation. Particle motions in various potentials; hydrogen-like atoms and molecules. Continuum models of particle systems; tensor properties, rigid and elastic solids, transfer of heat and electricity, flow relations.

322. *Analytical Mechanics III*

Spring. 3(3-0) 321.

Quantum and statistical models of particle systems; the Maxwell-Boltzmann, Einstein-Bose and Fermi-Dirac distributions; analysis of ideal atomic, electron and photon gases; properties of dense gases and liquids; thermal, elastic and electrical properties of crystals.

340. *Materials Chemistry I*

(440.) Fall. 4(4-0) CEM 153.

MMM 340, 341 and 342 present an integrated theory of chemical properties and phase transformations in metals and other engineering materials. Classical thermodynamics and thermochemistry of solids and solid solutions.

341. *Materials Chemistry II*

(441.) Winter. 4(4-0) 340.

Homogeneous and heterogeneous equilibria in solids; diffusion and solid-state reactions; nucleation phenomena. Metallurgy and electrochemistry. Theory of the periodic relations among the properties of the elements.

342. *Materials Chemistry III*

(442.) Spring. 4(4-0) 341.

Continuation of 341. The influence of atomic properties in the formation of alloys and solid compounds. Cohesive forces and bonding in solids. Introduction to the statistical theory of the properties of engineering materials.

360. *General Metallurgy*

Fall. 4(4-0) CEM 153 or approval of department.

Properties of metals, states of heterogeneous equilibrium and non-equilibrium, deformation processes.

361. *Physical Metallurgy I*

Winter. 4(4-0) 360.

Application of fundamental metallurgical theory to nonferrous metals and alloys.

362. *Physical Metallurgy II*

Spring. 4(4-0) 360.

Carbon and alloy steels: composition, influence of heat treatments, etc.

370. *Metals and Alloys I*

Winter. 4(3-3)

Principles of physical metallurgy applied to engineering metals and alloys.

371. *Metals and Alloys II*

Spring. 3(3-0) 370.

Continuation of 370.

372. *Metals and Alloys III*

Fall. 3(3-0) 371.

Continuation of 371.

380. *Metallurgy Laboratory I*

Fall. 1(0-3) 360 or concurrently

First of an integrated sequence of laboratory courses designed to illustrate the parallel theory courses.

381. *Metallurgy Laboratory II*

Winter. 1(0-3) 380; 361 concurrently.

Continuation of 380.

382. *Metallurgy Laboratory III*

Spring. 1(0-3) 381; 362 concurrently.

Continuation of 381.

400. *Special Problems*

Fall, Winter, Spring, Summer. 1 to 3 credits. May re-enroll for a maximum of 9 credits. Approval of department.

Individualized readings and research for students of high intellectual promise.