Graduate Courses in Fluid Dynamics and Related Topics at the University of Maryland

Aerospace Engineering

ENAE 414 **Aerodynamics II**

Aerodynamics of inviscid incompressible flows. Aerodynamic forces and moments. Fluid statics/buoyancy force. Vorticity, circulation, the stream function and the velocity potential. Bernoulli's and Laplace's equations. Flows in low speed wind tunnels and airspeed measurement. Potential flows involving sources and sinks, doublets, and vortices. Development of the theory of airfoils and wings.

ENAE 416 **Viscous Flow and Aerodynamic Heating**

Derivation of the conservation equations and applications to viscous flows while the energy equation is simplified for conduction in solids. Exact and approximate solutions for steady and unsteady conduction. Exact solutions for channel flow, couette flow, pipe flow and stagnation point flows. Boundary layer simplifications and exact solutions of the boundary layer equations for flat plates and self similar flows. Approximate and integral solutions of the boundary layer equations. Emphasis on aerodynamic heating and thermal control.

ENAE 631 **Helicopter Aerodynamics I**

A history of rotary-wing aircraft, introduction to hovering theory, hovering and axial flight performance, factors affecting hovering and vertical flight performance, autorotation in vertical descent, concepts of blade motion and control, aerodynamics of forward flight, forward flight performance, operational envelope, and introduction to rotor acoustics.

ENAE 632 **Helicopter Aerodynamics II**

Basic aerodynamic design issues associated with main rotors and tail rotors, discussion of detailed aerodynamic characteristics of rotor airfoils, modeling of rotor airfoil characteristics, review of classical methods of modeling unsteady aerodynamics, the problem of dynamic stall, review of methods of rotor analysis, physical description and modeling of rotor vortical wakes, discussion of aerodynamic interactional phenomena on rotorcraft, advanced rotor tip design, physics and modeling of rotor acoustics.

ENAE 670 **Fundamentals of Aerodynamics**

Introduction to aerodynamics for aerospace engineering students specializing in fields other than aerodynamics. Broad coverage of flight regimes, inviscid theory, incompressible theory, subsonic compressible flow, linearized supersonic flow, hypersonic flow, viscous flows, Navier-Stokes equations, boundary layer theories.

ENAE 672 **Aerodynamics of Incompressible Fluids**

Fundamental equations in fluid mechanics. Irrotational motion. Circulation theory of lift. Thin airfoil theory. Lifting line theory. Wind tunnel corrections. Perturbation methods.

ENAE 674 **Aerodynamics of Compressible Fluids**
One-dimensional flow of a perfect compressible fluid. Shock waves. Two-dimensional linearized theory of compressible flow. Two-dimensional transonic and hypersonic flows. Exact solutions of two-dimensional isotropic flow. Linearized theory of three-dimensional potential flow. Exact solution of axially symmetrical potential flow. One-dimensional flow with friction and heat addition.

ENAE 676 **Aerodynamics of Viscous Fluids**
Derivation of navier stokes equations, some exact solutions: boundary layer equations. Laminar flow-similar solutions, compressibility, transformations, analytic approximations, numerical methods, stability and transition to turbulent flow. Turbulent flow-istropic turbulence, boundary layer flows, free mixing flows.

ENAE 682 **Hypersonic Aerodynamics**
Hypersonic shock and expansion waves, Newtonian theory, Mach methods, numerical solutions to hypersonic inviscid flows, hypersonic boundary layer theory, viscous interactions, numerical solutions to hypersonic viscous flows. Applications to hypersonic vehicles.

ENAE 683 **High Temperature Gas Dynamics**
Aspects of physical chemistry and statistical thermodynamics necessary for the analysis of high temperature flows, equilibrium and nonequilibrium chemically reacting flows, shock waves, nozzle flows, viscous chemically reacting flow, blunt body flows, chemically reacting boundary layers, elements of radiative gas dynamics and applications to hypersonic vehicles.

ENAE 684 **Computational Fluid Dynamics I**
Partial differential equations applied to flow modelling, fundamental numerical techniques for the solution of these equations, elliptic, parabolic, and hyperbolic equations, elements of finite difference solutions, explicit and implicit techniques. Applications to fundamental flow problems.

ENAE 685 **Computational Fluid Dynamics II**
Continuation of ENAE 684. Basic algorithms for the numerical solution of two and three dimensional inviscid and viscous flows. Applications to internal and external flow problems.

Applied Mathematics & Scientific Computation

AMSC 452 (also MATH 452) **Introduction to Dynamics and Chaos**

An introduction to mathematical dynamics and chaos. Orbits, bifurcations, Cantor sets and horseshoes, symbolic dynamics, fractal dimension, notions of stability, flows and chaos. Includes motivation and historical perspectives, as well as examples of fundamental maps studied in dynamics and applications of dynamics.

AMSC 604 **Numerical Solution of Nonlinear Equations**

Numerical solution of nonlinear equations in one and several variables. Existence questions. Minimization methods. Selected applications.

AMSC 612 **Numerical Methods in Partial Differential Equations**

Finite difference methods for elliptic, parabolic, and hyperbolic partial differential equations. Additional topics such as spectral methods, variational methods for elliptic problems, stability theory for hyperbolic initial-boundary value problems, and solution methods for conservation laws.

AMSC 666 **Numerical Analysis I**

Iterative methods for linear systems, piecewise interpolation, eigenvalue problems, numerical integration.

AMSC 667 **Numerical Analysis II**

Nonlinear systems of equations, ordinary differential equations, boundary value problems.

AMSC 673 (also MATH 673) **Partial Differential Equations I**

Analysis of boundary value problems for Laplace's equation, initial value problems for the heat and wave equations. Fundamental solutions, maximum principles, energy methods. First order nonlinear PDE, conservation laws. Characteristics, shock formation, weak solutions. Distributions, Fourier transform.

AMSC 674 (also MATH 674) **Partial Differential Equations II**

Boundary value problems for elliptic partial differential equations via operator-theoretic methods. Hilbert spaces of functions. Duality, weak convergence. Sobolev spaces. Spectral theory of compact operators. Eigenfunction expansions.

AMSC 685 (also MATH 685) **Modern Methods in Partial Differential Equations I**

Spaces of distributions, Fourier transforms, concept of weak and strong solutions. Existence, uniqueness and regularity theory for elliptic and parabolic problems using methods of functional analysis.

AMSC 686 (also MATH 686) **Modern Methods in Partial Differential Equations II**

Emphasis on nonlinear problems. Sobolev embedding theorems, methods of monotonicity, compactness, applications to elliptic, parabolic and hyperbolic problems.

AMSC 701 **Introduction to Continuum Mechanics**

Background from algebra and geometry, kinematics of deformation. Stress equations of motion, thermodynamics of deforming continua. Theory of constitutive relations. Materials with memory. Initial boundary value problems of nonlinear solid and fluid thermomechanics. Boundary value problems of linear theories of solids and fluids.

AMSC 720 **Fluid Dynamics I**

A mathematical formulation and treatment of problems arising in the theory of incompressible, compressible and viscous fluids.

AMSC 721 **Fluid Dynamics II**

A continuation of MAPL 720.

Astronomy

ASTR 670 **Interstellar Medium and Gas Dynamics**

Content of phases of the interstellar medium: physical processes in the ISM: ionization equilibrium, heating and cooling, interstellar dust; gas dynamics: fluid motions, instabilities, shock waves; magnetohydrodynamics.

Chemical Engineering

ENCH 422 **Transport Processes I**

Principles of fluid dynamics as applied to model development and process design. Mass, momentum and energy conservation. Statics and surface tension. Equation of Continuity and Navier-Stokes Equation with application to laminar flow. Dimensional analysis. Macroscopic balances, Bernoulli Equation and friction factors with application to turbulent flow.

ENCH 424 **Transport Processes II**

Principles of mass and heat transfer as applied to model development and process design. Species continuity equation with application to diffusion, and convection in laminar flow. Macroscopic balances and mass transfer coeffecients with application to turbulent flow. Mircroscopic equation of energy with application to heat conduction, and convection in laminar flow. Macroscopic energy balance and heat transfer coeffecients with application to turbulent flow. Heat exchanger design.

ENCH 426 **Transport Processes III**

Separation by staged operations. Rate dependent separation processes. Design applications in distillation, gas absorption, liquid extraction, drying, adsorption and ion exchange.

ENCH 470 **The Science and Technology of Colloidal Systems**

Introduction to colloidal systems. Preparation, stability and coagulation kinetics of colloidal suspensions. Introduction to DLVO theory, electrokinetic phenomena, rheology of dispersions, surface/interfacial tension, solute absorption at gas-liquid, liquid-liquid, liquid-solid and gas-solid interfaces and properties of micelles and other microstructures.

ENCH 471 **Particle Science and Technology**

Theory and modeling techniques for particle formation and particle size distribution dynamics. Science and technology of multiphase systems, powder and aerosol technology. Industrial, environmental and occupational applications: dry powder delivery of drugs, aerosol generation methods, nanoparticles, biowarfare agent detection, dry powder mixing, particulate emissions. Design particle synthesis and processing systems,particle removal systems.

ENCH 472 **Control of Air Pollution**

Effects and sources of air pollutants, legislation and regulatory trends; meteorology, atmospheric dispersion models; distribution functions, particle size distributions; particulate control.

ENCH 494 **Polymer Technology Laboratory**

Polymer processing and characterization of polymer products. Extrusion, injection molding, blown film production with mechanical, thermal and rheological characterization.

ENCH 495 **Manufacturing with Polymers**

Introduction to issues associated with the use, manufacturing and processing of polymers; blending of materials, design and production of a polymer formulation, characterization of material properties. Teams work on an open-ended design problem of producing and characterizing a polymer formulation for advanced materials use.

ENCH 496 **Processing of Polymer Materials**

A comprehensive analysis of the operations carried out on polymeric materials to increase their utility. Conversion operations such as molding, extrusion, blending, film forming, and calendaring. Development of engineering skills required to practice in the high polymer industry.

ENCH 630 **Transport Phenomena**

Heat, mass and momentum transfer theory from the viewpoint of the basic transport equations. Steady and unsteady state; laminar and turbulent flow; boundary layer theory, mechanics of turbulent transport; with specific application to complex chemical engineering situations.

ENCH 751 **Turbulent and Multiphase Transport Phenomena**

Basic equations and statistical theories for transport of heat, mass, and momentum in turbulent fluids with applications to processing equipment. Fundamental equations of multiphase flow for dilute systems with applications to particles, drops and bubbles. Current approaches for analysis of concentrated suspensions including deterministic models and population balance approaches.

ENCH 753 **Aerosols and Particulate Science**

Fundamentals of aerosol science - electrical and aerodynamic properties, coagulation and diffusion. Current techniques for experimental measurements with emphasis on particle characterization, environmental sampling, and data inversion procedures. Recent developments in computation for aerosol reactors and population balances.

ENCH 786 **Polymer Processing and Applications**

Application of theoretical knowledge of polymers to industrial processes. An analysis of polymerization, stabilization, electrical, rheological, thermal, mechanical and optical properties and their influence on processing conditions and end use applications.

Civil and Environmental Engineering

ENCE 431 **Hydrologic Engineering**

An introduction to basic principles of hydrologic science including the hydrologic cycle, rainfall, surface runoff and streamflow. Special emphasis is placed on hydrologic engineering design of stormwater management and flood control facilities. Design projects are used to illustrate design practices.

ENCE 432 **Ground Water Hydrology**

Concepts related to the development of the ground water resources, hydrology, hydrodynamics of flow through porous media, hydraulics of wells and basin-wide ground water development. Fundamentals of ground water pollution are introduced.

ENCE 630 **Environmental and Water Resource Systems I**

Application of statistical and systems engineering techniques in the analysis of information necessary for the design or characterization of environmental or hydrologic processes; emphasis on the fundamental considerations that control the design of information collection programs, data interpretation, and the evolution of simulation models used to support the decision-making process.

ENCE 631 **Hydrologic and Nonpoint Pollution Models**

The physical processes controlling the spatial distribution of run off and constituent transport during rainfall and snowmelt events. Emphasis on the processes and practical models of runoff simulation, stormwater management and environmental impact assessment.

ENCE 632 **Free Surface Flow**

Application of fundamentals of fluid mechanics to problems of free surface flow; computation of steady and transient water surface profiles; stratified flows in reservoirs and estuaries; diffusion; transition structures; sediment transport.

ENCE 730 **Environmental and Water Resource Systems II**

Advanced topics in operational research. Applications to complex environmental and water resource systems. The use of systems simulation and probabalistic modeling.

Fire Protection Engineering

ENFP 415 **Fire Dynamics**

Introduction to premixed and diffusion flames; ignition, flame spread and rate of burning; fire plumes; flame radiation.

ENFP 611 **Fire Induced Flows**

Theoretical basis is presented for fire induced bouyancy driven flows. Plumes, ceiling jets, vent flows, compartment flows. Dimensional analysis for correlations and scale model applications. Smoke movement and combustion products.

ENFP 620 **Fire Dynamics Laboratory**

Laboratory experiments are designed to illustrate fire phenomena and test theoretical models. Diffusion flames, ignition and flame spread on solids, liquid pool fires, wood crib fires, fire plumes, compartment fires.

ENFP 630 **Diffusion Flames and Burning Rate Theory**

Basic principles of diffusion flames for gaseous, liquid, and solid fuels. Droplet burning, B number, jet combustion, boundary layer combustion, generalized methods.

ENFP 631 **Fire and Combustion**

Basic fluid mechanics, heat transfer and combustion principles are used to obtain simple analytical solutions, different fire initiation and spread cases. Specific fire problems such as smoldering, boil-over or flame spread are addressed as case studies.

Mathematics

MATH 462 **Partial Differential Equations for Scientists and Engineers**

Linear spaces and operators, orthogonality, Sturm-Liouville problems and eigenfunction expansions for ordinary differential equations. Introduction to partial differential equations, including the heat equation, wave equation and Laplace's equation. Boundary value problems, initial value problems and initial-boundary value problems.

MATH 463 **Complex Variables for Scientists and Engineers**

The algebra of complex numbers, analytic functions, mapping properties of the elementary functions. Cauchy integral formula. Theory of residues and application to evaluation of integrals. Conformal mapping.

MATH 464 **Transform Methods for Scientists and Engineers**

Fourier series, Fourier and Laplace transforms. Evaluation of the complex inversion integral by the theory of residues. Applications to ordinary and partial differential equations of mathematical physics: solutions using transforms and separation of variables. Additional topics such as Bessel functions and calculus of variations.

MATH 634 **Harmonic Analysis**

L1 theory: Fejer theorem, inversion theorem, ideal structure, Tauberian theorem. L2 theory: Plancherel-Parseval theorems, Paley-Wiener theorem. Lp theory: Hausdorff-Young theorem. Distribution theory: Bochner's theorem, Wiener continuous measures theorem, Malliavin theorem, Schwartz theory, almost periodic functions.

MATH 642 **Dynamical Systems I**

Foundations of topological dynamics, homeomorphisms, flows, periodic and recurrent points, transitivity and minimality, symbolic dynamics. Elements of ergodic theory, invariant measures and sets, ergodicity, ergodic theorems, mixing, spectral theory, flows and sections. Applications of dynamical systems to number theory, the Weyl theorem, the distribution of values of polynomials, Vander Waerden's theorem on arithmetic progressions.

MATH 643 **Dynamical Systems II**

Entropy theory, variational principle for the entropy, expansiveness, measures with maximal entropy. Smooth systems on manifolds, diffeomorphisms and flows, periodic points, stable and unstable manifolds, homoclinic points, transversality, the Krupka-Smale theorem, Morse-Smale systems. Hyperbolicity, Anosov systems, distributions and foliations, strange attractors, Bowen's measure.

MATH 660 **Complex Analysis I**

Linear transformations, analytic functions, conformal mappings, Cauchy's theorem and applications, power series, partial fractions and factorization, elementary Riemann surfaces, Riemann's mapping theorem.

MATH 661 **Complex Analysis II**

Topics in conformal mappings, normal families, Picard's theorem, classes of univalent functions, extremal properties, variational methods, elliptic functions, Riemann surfaces.

MATH 668 **Selected Topics in Complex Analysis**

Material selected to suit interests and background of the students. Typical topics: Kaehler geometry, automorphic functions, several complex variables, symmetric spaces.

MATH 680 **Eigenvalue and Boundary Value Problems I**

Operational methods applied to ordinary differential equations. Introduction to linear spaces, compact operators in Hilbert space, study of eigenvalues.

MATH 681 **Eigenvalue and Boundary Value Problems II**

Boundary value problems for linear paritial differential equations. Method of energy integrals applied to Laplace's equation, heat equations and the wave equations. Study of eigenvalues.

Mechanical Engineering

ENME 442 **Fluid Mechanics II**

Hydrodynamics with engineering applications. Stream function and velocity potential, conformal transformations, pressure distributions, circulation, numerical methods and analogies.

ENME 489A **Air Pollution**

Sources of air pollution, regulation, meteorology, atmospheric dispersion model and pollution control. The course is intended to give students an understanding of air pollution, its sources and how it can be controlled. Control techniques to reduce or minimize air pollution will be described with emphasis on emission reduction from industrial processes.

ENME 632 **Advanced Convection Heat Transfer**

Statement of conservation of mass, momentum and energy. Laminar and turbulent heat transfer in ducts, separated flows, and natural convection. Heat and mass transfer in laminar boundary layers. Nucleate boiling, film boiling, Leidenfrost transition and critical heat flux. Interfacial phase change processes; evaporation, condensation, industrial applications such as cooling towers, condensers. Heat exchangers design.

ENME 640 **Fundamentals of Fluid Mechanics**

Equations governing the conservation of mass, momentum, vorticity and energy in fluid flows. Equations illustrated by analyzing a number of simple flows. Emphasis on physical understanding facilitating the study of advanced topics in fluid mechanics.

ENME 641 **Viscous Flow**

Fluid flows where viscous effects play a significant role. Examples of steady and unsteady flows with exact solutions to the Navier-Stokes equations. Boundary layer theory. Stability of laminar flows and their transition to turbulence.

ENME 642 **Hydrodynamics** I

Exposition of classical and current methods used in analysis of inviscid, incompressible flows. Topics covered include airfoil theory, conformal transformations, the dynamics of underwater explosions, cavitation bubbles, and water waves.

ENME 644 **Fundamentals of Acoustics**

This course will cover the fundamental principles of acoustics allowing the students to go on to more advanced course in acoustics, sauch as Underwater Sound Propagation, Active Noise Control, or Radiation and Scattering from Elastic Structures.

ENME 646 **Computational Fluid Dynamics and Heat Transfer II**

Numerical solution of inviscid and viscous flow problems. Solution of potential flow problem, Euler equations, boundary layer equations and Navier-Stokes equations. Applications to turbulent flows.

ENME 647 **Multiphase Flow and Heat Transfer**

Boiling and condensation in stationary systems, phase change heat transfer phenomenology, analysis and correlations. Fundamentals of two-phase flow natural circulation in thermal hydraulic multi-loop systems with applications to nuclear reactors safety. Multiphase flow fundamentals. Critical flow rates. Convective boiling and condensation. Multiphase flow and heat transfer applications in power and process industries.

ENME 656 **Physics of Turbulent Flow**

Definition of turbulence and its physical manifestations. Statistical methods and the transport equations for turbulence quantities. Laboratory measurement and computer simulation methods. Isotropic turbulence. Physics of turbulent shear flows.

ENME 657 **Analysis of Turbulent Flow**

Mathematical representation of turbulent transport, production and dissipation. Closure schemes for predicting flows. Recent advances in direct and large eddy numerical simulation techniques.

ENME 670 **Continuum Mechanics**

Mechanics of deformable bodies, finite deformation and strain measures, kinematics of continua and global and local balance laws. Thermodynamics of continua, first and second laws. Introduction to constitutive theory for elastic solids, viscous fluids and memory dependent materials. Examples of exact solutions for linear and hyper elastic solids and Stokesian fluids.

ENME 705 **Non-Newtonian Fluid Dynamics**

This course offers the specific techniques and understanding necessary for being able to compute and understand issues associated with non-newtonian fluid dynamics. Issues of rheology and analytic techniques are covered.

ENME 707 **Combustion and Reacting Flow**

This course covers thermochemistry and chemical kinetics of reacting flows in depth. In particular, we focus on the combustion of hydrocarbonf uels in both a phenomenological and mechanistic approach. The course co vers the specifics of premixed and nonpremixed flame systems, as well as ignition and extinction. Combustion modeling with equilibrium and chemical kinetic methods will be addressed. Environmental impact and emissi ons minimization will be covered in detail. Finally, the course will cover available combustion diagnostic methods and their application in laboratory and real-world systems.

Meteorology

METO 431 **Meteorology for Scientists and Engineers I**

The general character of the atmosphere and its weather and climate systems, phenomena and distributions of variables (winds, temperature, pressure and moisture). The formal framework of the science; the application of basic classical physics, chemistry, mathematics and computational sciences to the atmosphere.

METO 432 **Meteorology Scientists and Engineers II**

The general character of the atmosphere and its weather and climate systems, phenomena and distributions of variables (winds, temperature, pressure and moisture). The formal framework of the science; the application of basic classical physics, chemistry, mathematics and computational sciences to the atmosphere.

METO 434 **Air Pollution**

Production, transformation, transport and removal of air pollutants. The problems of photochemical smog, the greenhouse effect, stratospheric ozone, acid rain and visibility. Analytical techniques for gases and particles.

METO 602 **Mesoscale Meteorology**

Mesoscale approximations, cyclones and fronts, quasi- versus semi-geostrophic theory, piece-wise PV inversion, waves and instability, isolated convection, organized convective systems, numericalmodeling and convective parameterization.

METO 610 **Dynamics of the Atmosphere and Ocean I**

Equations of motion and their approximation, scale analysis for the atmosphere and the ocean. Conservation properties. Fluid motion in the atmosphere and oceans. Circulation and vorticity, geostrophic motion and the gradient wind balance. Turbulence and Ekman Layers.

METO 611 **Dynamics of the Atmosphere and Oceans II**

Waves and instabilities in the atmosphere and the ocean. Gravity, Rossby, coastal and equatorial waves. Flow over topography. Dynamic instabilities including barotropic, baroclinic, inertial, and instabilities of the coupled ocean-atmosphere system. Stationary waves and multiple equilibria.

METO 614 **Atmospheric Modeling, Data Assimilation and Predictability**

Solid foundation for atmospheric and oceanic modeling and numerical weather prediction: numerical methods for partial differential equations, an introduction to physical parameterizations, modern data assimilation, and predictability.

METO 617 **Atmospheric and Oceanic Climate**

The general circulation of the atmosphere and oceans, historical perspective, observations, and conceptual models; wind-driven and thermohaline circulation of the oceans. Seasonal cycle and monsoon circulations; interannual to interdecadal climate variability; climate change.

METO 620 **Physics and Chemistry of the Atmosphere I**

Air parcel thermodynamics and stability; constituent thermodynamics and chemical kinetics. Cloud and aerosol physics and precipitation processes.

METO 630 **Statistical Methods in Meteorology and Oceanography**

Parametric and non-parametric tests; time series analysis and filtering; wavelets. Multiple regression and screening; neural networks. Empirical orthogonal functions and teleconnections. Statistical weather and climate prediction, including MOS, constructed analogs. Ensemble forecasting and verification.

METO 670 **Physical Oceanography**

Ocean observations. Water masses, sources of deep water. Mass, heat, a nd salt transport, gochemical tracers. Western boundary currents, maintenance of the thermocline. Coastal and estuarine processes. Surface waves and tides. Ocean climate.

METO 671 **Air-Sea Interaction**

Observations and theories of the seasonal changes in the ocean circulation and temperature, and interactions with the atmosphere. Equations of motion and theories of wind-driven circulation. Mixed layer observations and theories. Midlatitude and equatorial waves. Seasonal budgets of momentum, fresh water, and heat. El Nino/Southern Oscillation. Interannual variability and atmosphere-ocean coupling.

Natural Resources Sciences

NRSC 417 **Soil Hydrology and Physics**

A study of soil water interactions: the hydrologic cycle; the unique properties of water and soil; the soil components and their interactions; the field water cycle; transport processes involving water, heat and solutes; human effects on soil and groundwater; as well as the measurement, prediction, and control of the physical processes taking place in and through the soil.

NRSC 423 **Soil-Water Pollution**

Reaction and fate of pesticides, agricultural fertilizers, industrial and animal wastes in soil and water with emphasis their relation to the environment.

Nuclear Engineering

ENNU 485 Nuclear Reactor **Thermalhydraulics**

Thermalhydraulic response of nuclear power plant systems. Accident analysis and impact of emergency systems. Boiling phenomena, nucleate boiling, critical heat flux, condensation. Containment thermalhydraulic analysis. Overview of principal thermalhydraulic computer codes.

ENNU 615 **Transport Phenomena in Solids and Single-Phase Media**

Momentum transport-viscosity, laminar flow, isothermal system equations, transient and multidimensional analysis, axisymmetric laminar flows, turbulent flows, phase transport; Energy transport-mechanisms, temperature distributions, nonisothermal system equations, microscale heat transfer, turbulent flow, phase transport; Mass transport-mechanisms, concentration distributions, diffusion, interphase transport.

ENNU 632 **Thermohydraulics in Nuclear Systems**

Thermal analysis of fuel elements; heat conduction; thermal properties; temperature distribution; heat channel transient analysis; flow loops - steady state and transient, single and two phase; scaling methodologies; core and subchannel analysis; two-phase flow instabilities; uncertainties in thermal analysis.

ENNU 633 **Convective Transport Phenomena in Single- and Multi-Phase Systems**

Single medium - single phase systems, two-phase systems; Two media - solid-fluid systems: continuous interface, large interfacial area, fluid-fluid systems; Three media - solid-solid-fluid systems, solid- liquid-gas systems.

Physics

PHYS 404 **Introduction to Statistical Thermodynamics**

Introduction to basic concepts in thermodynamics and statistical mechanics.

PHYS 461 **Introduction to Fluid Dynamics**

Kinematics of fluid flow, properties of incompressible fluids, complex variable methods of analysis, wave motions.

PHYS 474 **Computational Physics**

Introduction to computational physics. Topics covered include numerical integration of ordinary and partial differential equations, image analysis, Fourier transforms, statistical methods, analysis of data using prepackaged routines, and the Unix programming environment. Emphasis is on the equations of physical systems as applied to physics and astronomy, and on manipulation of laboratory and observational field data. Students complete semester projects.

PHYS 603 **Methods of Statistical Physics**

Foundations and applications of thermodynamics and statistical mechanics.

PHYS 607 **Advanced Classical Physics**

Selected topics in advanced classical physics will be studied from among the fields of radiation theory, spin-carrying waves, solitons and general non-linear dynamics.

PHYS 704 **Statistical Mechanics**

A study of the determination of behavior of matter from microscopic models. Microcanonical, canonical, and grand canonical models. Applications of solid state physics and the study of gases.

PHYS 715 **Chaotic Dynamics**

Theory and applications of chaos in dynamical systems including such topics as strange attractors, Lyapanov exponents, quasiperiodicity, period doubling, intermittency, crises, fractal basin boundaries, chaotic scattering, KAM tori, and quantum chaos.

PHYS 761 **Plasma Physics I: Survey**

A detailed study of plasma physics. The first semester treats particle orbit theory, magnetohydrodynamics, plasma waves, and transport phenomena.

PHYS 762 **Plasma Physics II**

Vlasov theory, including waves, stability, and weak turbulence, kinetic equation theories of correlations and radiative processes.

PHYS 769 **Seminar in Plasma Physics**