PPST Graduate Courses

Astrophysical Sciences

AST 551/ MAE 525	General Plasma Physics I	An introductory course to plasma physics, with sample applications in fusion, space and astrophysics, semiconductor etching, microwave generation, plasma propulsion, high-power laser propagation in plasma; characterization of the plasma state, Debye shielding, plasma and cyclotron frequencies, collision rates and mean-free paths, atomic processes, adiabatic invariance, orbit theory, magnetic confinement of single-charged particles, two-fluid description, magnetohydrodynamic waves and instabilities, heat flow, diffusion, kinetic description, and Landau damping. May be taken by undergraduates with permission of the instructor.
AST 552	General Plasma Physics II	Introduction to plasma physics at the graduate level. Principles and applications of magnetohydro-dynamic (MHD) and kinetic theory. These principles are fundamental to plasma science, and the illustrative applications are relevant to current magnetic fusion research. Topical areas include MHD equations and their properties; MHD equilibrium and stability; the energy principle; resistive instabilities, including tearing modes; the drift-kinetic equation with collisions; classical and neoclassical transport; drift waves, shear-Alfven waves, and associated low-frequency instabilities; high-frequency microinstabilities; and an introduction to quasilinear theory.
AST 553	Plasma Waves and Instabilities	Wave phenomena in a cold magnetized plasma, including resonances, cut-offs, mode conversion, drift waves, weak collisions, energy transport, and finite-temperature effects over a wide range of frequencies. Development of the full hot-plasma model for waves in locally homogeneous plasmas, including collisionless damping mechanisms such as Landau, cyclotron, and TTMP damping; velocity-space instabilities and Nyquist analysis; hot-plasma mode conversion; and Bernstein waves. Applications to plasma diagnostics, radiofrequency plasma heating and noninductive current drive, and magnetospheric propagation.
AST 554	Plasma Waves and Instabilities	Wave phenomena in a cold magnetized plasma, including resonances, cut-offs, mode conversion, drift waves, weak collisions, energy transport, and finite-temperature effects over a wide range of frequencies. Development of the full hot-plasma model for waves in locally homogeneous plasmas, including collisionless damping mechanisms such as Landau, cyclotron, and TTMP damping; velocity-space instabilities and Nyquist analysis; hot-plasma mode conversion; and Bernstein waves. Applications to plasma diagnostics, radiofrequency plasma heating and noninductive current drive, and magnetospheric propagation.
AST 554	Irreversible Processes in Plasmas	Introduction to the theory of fluctuations and transport in plasma. Origins of irreversibility. Random walks, Brownian motion, and diffusion; Langevin and Fokker-Planck theory. Fluctuation-dissipation theorem; test-particle superposition principle. Statistical closure problem. Derivation of kinetic equations from BBGKY hierarchy and Klimontovich formalism; properties of plasma collision operators. Classical transport coefficients in magnetized plasmas; Onsager symmetry. Introduction to plasma turbulence, including quasilinear theory. Applications to current problems in plasma research.
AST 555	Fusion Plasmas and Plasma	Introduction to experimental plasma physics, with emphasis on high-temperature plasmas for fusion. Requirements for fusion, magnetic, and inertial confinement

	Diagnostics	plasmas: confinement, beta, power, and particle exhaust. Discussion of tokamak fusion and alternative systems. Status of experimental understanding: what we know and how we know it. Key plasma diagnostic techniques: magnetic measurements, Langmuir probes, microwave techniques, spectroscopic techniques, electron cyclotron emission, Thomson scattering.
AST 556	Advanced Plasma Dynamics	An analysis of plasma equilibrium, particle orbits, and those ideal and resistive magnetohydrodynamic instabilities that dominate the behavior of a toroidal fusion plasma, including kink, ballooning, and tearing modes. General magnetic coordinates. Chaos through the destruction of magnetic surfaces. The Hamiltonian formulation of guiding center motion. Symmetry-breaking perturbations such as toroidal field ripple and induced stochastic particle loss. The interaction of a high-energy particle component with a background magnetohydrodynamic plasma, including the TAE and fishbone instabilities.
AST 557/ APC 503	Analytical Techniques in Differential Equations	The use of asymptotic methods in the solution of ordinary differential equations: initial and boundary-value problems, Wronskian, Green's functions, the use of complex variables. The approximate solution of differential equations by series expansions. The use of asymptotic expansions. Evaluation of integrals by stationary phase, saddle points. WKB Theory: Stokes constants, the derivation of Heading's rules, bound states and barrier transmission. Perturbation theory, singular perturbations, Integral representations. The asymptotic evaluation of integrals, Laplace's method, Stirling approximation, the Gamma function, and the Riemann zeta function. Boundary-layer problems, multiple-scale analysis.
AST 558	Seminar in Plasma Physics	Advances in experimental and theoretical studies of laboratory and naturally occurring high-temperature plasmas, including stability and transport, nonlinear dynamics and turbulence, magnetic reconnection, selfheating of "burning" plasmas, and innovative concepts for advanced fusion systems. Advances in plasma applications, including laser-plasma interactions, nonneutral plasmas, high-intensity accelerators, plasma propulsion, plasma processing, and coherent electromagnetic wave generation.
AST 559/ APC 539	Nonlinear Processes in Fluids and Plasmas	A comprehensive introduction to the theory of nonlinear phenomena in fluids and plasmas, with an emphasis on turbulence and transport. Experimental phenomenology; fundamental equations, including Navier-Stokes, Vlasov, and gyrokinetic; numerical simulation techniques, including pseudo-spectral and particle-in-cell methods; coherent structures; transition to turbulence; statistical closures, including the wave kinetic equation and direct-interaction approximation; PDF methods and intermittency; variational techniques. Applications from neutral fluids, fusion plasmas, and astrophysics.
AST 560	Computational Methods in Plasma Physics	Analysis of methods for the numerical solution of the partial differential equations of plasma physics, including those of elliptic, parabolic, hyperbolic, and eigenvalue type. Topics include finite-difference, finite-element, spectral, particle-in-cell, Monte Carlo, moving-grid, and multiple-time-scale techniques, applied to the problems of plasma equilibrium, transport, and stability. Basic parallel programming concepts are discussed.
AST 561	Special Topics in Plasma Physics	The first half of the course, Introduction to Space Plasma Physics, focuses on plasmas in the earth's magnetosphere and in the solar wind; interaction between the solar wind and the earth's dipole magnetic field, formation of the magnetosphere and the magnetopause boundary layer, and geomagnetic tail and its stability; and geomagnetic substorms and auroras. The second half, Inertial Confinement Fusion, focuses on laser-matter interaction; transport, atomic physics, and X-ray conversion; ion-beam interaction; ablation and deflagration fronts; Marshak waves; Rayleigh-Taylor instability; ignition, target gain; and ICF and X-ray lasers.

AST 562	Laboratory in Plasma Physics	Develops skills, knowledge, and understanding of basic and advanced laboratory techniques used to measure and control the properties and behavior of plasmas. Creativity and original research are encouraged. Representative experiments are: cold-cathode plasma formation; ambipolar diffusion and plasma recombination in afterglow plasmas; Langmuir probe measurements of electron temperature and plasma density; fluctuations and transitions to chaos in a glow discharge column; microwave interferometry and cavity resonances for plasma density determination; and momentum generated by a plasma thruster. Three laboratory reports are required.
AST 564/ MAE 522	Applications of Quantum Mechanics to Spectroscopy and Lasers	An intermediate-level course in applications of quantum mechanics to modern spectroscopy. The course begins with an introduction to quantum mechanics as a “tool” for atomic and molecular spectroscopy, followed by a study of atomic and molecular spectra, radiative, and collisional transitions, with the final chapters dedicated to plasma and flame spectroscopic and laser diagnostics. Prerequisite: one semester of quantum mechanics. Offered in alternate years.
AST 565	Physics of Nonneutral Plasmas	A comprehensive introduction to the physics of nonneutral plasmas and charged particle beam systems with intense self fields. The subject matter is developed systematically from first principles, based on fluid, Vlasov, or Klimontovich-Maxwell statistical descriptions, as appropriate. Topics include the development of nonlinear stability and confinement theorems; experimental and theoretical investigations of collective waves and instabilities; phase transitions in strongly coupled nonneutral plasmas; coherent electromagnetic radiation generation by free-electron lasers, cyclotron masers, and magnetrons; nonlinear processes and chaotic particle dynamics in high-intensity periodic-focusing accelerators; and nonlinear processes related to compact plasma-based accelerator concepts.

Chemical and Biological Engineering

CBE 504	Chemical Reactor Engineering	The elements of chemical-rate processes; reactor properties in continuous flow; staged, steady-state, and transient operations; optimal distribution of properties; and stability. The effect of physical transport rates, when coupled with chemical rates on reactor design and characteristics, is examined.
CBE 526/ CHM 527/ MSE 526	Surface Science: Processes and Probes	Introduction to processes at surfaces and interfaces. Experimental methods of surface science. Electron spectroscopy, ion scattering, and scanning probe microscopy. Atomic and electronic structure of surfaces and adsorbed layers. Thermodynamics of surface processes. Adsorption and molecular dynamics of gas-surface reactions. Kinetics of adsorption, desorption, diffusion, and reactions. Liquid interfaces. Heterogeneous catalysis. Etching. Film growth and epitaxy. Applications to energy and environmental science and technology.

Chemistry

CHM 501	Introduction to Quantum Chemistry	Basic development of quantum theory and the Schroedinger equation. Single-particle potential problems, an introduction to angular momentum theory, and operator concepts and electron structure.
CHM 502	Advanced Quantum Chemistry	Typical topics covered include advanced aspects of angular momentum theory, scattering, time-dependent processes, and interaction of radiation with matter. Specialized topics are included at the discretion of the instructor.

Electrical Engineering

EE 541	Electronic Materials	The science and technology of materials used in electronics and optoelectronics. Emphases vary from year to year. Subjects include the growth of crystals and of thin

	(also MSE 510)	films, vacuum technology, phase diagrams, defects and atomic diffusion in semiconductors, techniques for analyzing electronic materials, amorphous silicon, and materials for large-area electronics, displays, and solar cells.
EE 542	Surface Properties of Electronically Active Solids	Theoretical aspects and experimental determinations of electronic properties and atomic structures of surfaces and interfaces of solids: surface energy band structure; surface states; atomic reconstructions; metal-semiconductor interfaces, and semiconductor heterojunctions. Experimental techniques such as electron diffraction and fine-structure techniques, Auger and core-level photoemission spectroscopies, angle-resolved valence-band spectroscopy, and scanning probe microscopies and spectroscopies are examined.
EE 543	Transport Processes in Solids	Transport properties in the context of irreversible thermodynamics as well as the Onsager relations and the fluctuation dissipation theorem. Also examines the Boltzmann equation, which is used for systematic study of electrical and thermal transport phenomena in solids, mostly semiconductors, including magnetic field effects.
EE 546	Optical Properties of Solids	Classical and quantum mechanical theories for absorption and dispersion. The optical properties are derived from knowledge of electronic band structure of solids, including excitons and effects of external perturbations; the influence of doping, disorder, and reduced dimensionality; bulk and surface polaritons; nonlinear optical processes, and transient and irreversible phenomena. An overview of major measurement techniques is included.
EE 549	Physics and Technology of VLSI (also MSE 533)	The phenomena encountered in the fabrication of VLSI integrated circuits and the operation of VLSI devices. Processing topics include ion implantation and the role of point defects on oxidation and diffusion. Device topics include scaling theories and submicron MOS and bipolar device design. Examines computer simulation for both devices and processes; as well as speed-power products and fundamental limits in VLSI. Prerequisites: knowledge of I.C. fabrication techniques and ELE 545, or the equivalent.
EE 567	Advanced Solid-State Electron Physics (also PHY 567)	Electron localization in disordered structures—Anderson model and scaling theory of localization; correlated electron systems—Hubbard model, Mott transition; metal-insulator transitions in correlated and disordered materials; quantum hall effect—integer and fractional; and quantum-phase transitions.

Mechanical and Aerospace Engineering

MAE 502	Mathematical Methods of Engineering Analysis II (also APC 502, CHE 502)	An extension of MAE 501. A complementary presentation of theory, analytical methods, and numerical methods. The objective is to impart a set of capabilities commonly used in the research areas represented in the department. Standard computational packages are made available in the courses, and assignments are designed to use them.
MAE 511	Experimental Methods I	A laboratory course that focuses on basic electronics techniques, digital electronics, and data acquisition and analysis. Topics include introduction to digital and analog electronics, digital-to-analog and analog-to-digital conversion, microcomputer sampling, and data analysis. There are four laboratory hours and two lecture hours each week. There is one project. Enrollment is limited.
MAE 512	Experimental Methods II	An exploration of experimental techniques in fluid mechanics and combustion. Introduces experimentation, error analysis, and technical communication. Methods covered include pressure and temperature probes, flow visualization, hot-wire and laser anemometry, line reversal, Raman techniques, fluorescence, absorption, gas chromatography, and mass spectroscopy. There are three lecture hours and

		laboratory time each week.
MAE 521	Optics and Lasers	An introduction to principles of lasers. Topics include a review of propagation theory, interaction of light and matter, Fourier optics, a survey and description of operational characteristics of lasers, light scattering, and nonlinear optics. Some introductory quantum mechanics is covered to give students an appreciation of the basic tools for the interaction of light with matter and nonlinear optical phenomena.
MAE 522	Applications of Quantum Mechanics to Spectroscopy and Lasers (also AST 564)	An intermediate-level course in applications of quantum mechanics to modern spectroscopy. The course begins with an introduction to quantum mechanics as a "tool" for atomic and molecular spectroscopy, followed by a study of atomic and molecular spectra, radiative, and collisional transitions, with the final chapters dedicated to plasma and flame spectroscopic and laser diagnostics. Prerequisite: one semester of quantum mechanics. Offered in alternate years.
MAE 523	Electric Propulsion	Based on a review of pertinent atomic physics and electromagnetic theory, the particle and continuum representations of ionized gas dynamics are developed and applied to various electro-thermal, electrostatic, and electromagnetic acceleration mechanisms, each illustrated by various thruster designs, contemporary applications, and performances.
MAE 524	Plasma Engineering	The purpose of this course is to expose interested graduate and undergraduate students in engineering and the natural sciences to basic aspects of plasma physics and chemistry applicable to a variety of technologies, such as plasma propulsion, lasers, and materials processing. It involves an extension of classical fluid mechanics, kinetic theory, statistical thermodynamics, and reaction engineering methods to relatively low-temperature plasmas in electric and magnetic fields. Offered in alternate years.
MAE 525	General Plasma Physics I (also AST 551)	An introductory course to plasma physics, with sample applications in fusion, space and astrophysics, semiconductor etching, microwave generation, plasma propulsion, high-power laser propagation in plasma; characterization of the plasma state, Debye shielding, plasma and cyclotron frequencies, collision rates and mean-free paths, atomic processes, adiabatic invariance, orbit theory, magnetic confinement of single-charged particles, two-fluid description, magnetohydrodynamic waves and instabilities, heat flow, diffusion, kinetic description, and Landau damping. May be taken by undergraduates with permission of the instructor.
MAE 527	Physics of Gases	Understanding and prediction of engineering properties of gases, based on physical and chemical properties of atomic and molecular constituents: statistical calculations of thermodynamic properties of gases; chemical and physical equilibria; quantum mechanical analysis of atomic and molecular structure and atomic-scale collision phenomena; transport properties; reaction kinetics, including chemical, vibrational, and ionization phenomena; and propagation, emission, and absorption of radiation.
MAE 549, MAE 550	Advanced Topics in Dynamics and Control I and II	Selected topics in dynamics and control, with an emphasis on advances relevant to research activities represented in the department. Possible topics include bifurcation theory, nonlinear mechanics, system identification, intelligent control, learning control, and applied aerodynamics.

Physics

PHY 501	Electricity and Magnetism	A systematic treatment of the theory of electromagnetic phenomena from an advanced standpoint. Maxwell's equations are discussed, with special attention given to their physical meaning. Other topics include dielectric and magnetic media, radiation, scattering, potential theory, and waves in simple media.
PHY 505	Quantum	The physical principles and mathematical formalism of non-relativistic quantum

	Mechanics I	mechanics. The principles are illustrated by selected applications to topics in atomic physics, particle physics, and condensed matter.
PHY 506	Quantum Mechanics II	A one-term course in advanced quantum mechanics, following PHY 505. After a brief review of some fundamental topics (e.g., the hydrogen atom, perturbation theory), more advanced topics are covered, including many-body theory, operator theory, coherent states, stability of matter and other Coulomb systems, and the theory of the Bose gas.
PHY 511	Thermodynamics, Kinetic Theory, and Statistical Mechanics	The physical principles and mathematical formalism of statistical mechanics, with an emphasis on applications to thermodynamics, condensed-matter physics, physical chemistry, and astrophysics are studied.