PHYS 411. Modern Physics: Atoms and Molecules. 4 hours.
Hydrogenic atoms, electron spin, external fields, multi-electron atoms, diatomic molecules, line widths, photons, radiation from atoms and other electromagnetic processes, positrons, positronium, elastic electron scattering. Course Information: Prerequisite(s): Credit or concurrent registration in PHYS 411.

PHYS 425. Modern Optics. 4 hours.
Review of electromagnetic wave theory and introductory optics; advanced geometrical optics; Fourier transforms and optics; interference and diffraction; solar cells and LEDs; laser cavities and gain media; introduction to nonlinear and fiber optics. Course Information: Prerequisite(s): PHYS 240; or approval of the department. Class Schedule Information: To be properly registered, students must enroll in one Discussion, one Laboratory and one Lecture.

PHYS 431. Modern Physics: Condensed Matter. 4 hours.
Crystal structures; interatomic binding; lattice vibrations; thermal and magnetic properties; quantum statistical mechanics; free electron theory of metals; electronic band theory; semiconductors and insulators; superconductivity. Course Information: Prerequisite(s): PHYS 411 and PHYS 461; or consent of the instructor.

PHYS 441. Theoretical Mechanics. 4 hours.
Review of Newtonian mechanics, variational calculus, Lagrangian mechanics, central force problems, non-inertial frames, rigid body motion, coupled oscillators, non-linear mechanics, Hamiltonian mechanics, and numerical examples. Course Information: Prerequisite(s): PHYS 215 and Credit or concurrent registration in PHYS 245; or approval of the department.

PHYS 450. Molecular Biophysics of the Cell. 4 hours.
Introduction to force, time energies at nanometer scales; Boltzmann distribution; hydrodynamic drag; Brownian motions; DNA, RNA protein structure and function; sedimentation; chemical kinetics; general aspects of flexible polymers. Course Information: Same as BME 450. Prerequisite(s): PHYS 245 or the equivalent; or approval of the department.

PHYS 451. Modern Physics: Nuclei and Elementary Particles. 4 hours.
Accelerators, detectors, symmetries, conservation laws, leptons, weak interactions, electroweak theory, strong interactions, hadrons, nuclear forces, systematics and reactions, nuclear models, nuclear astrophysics, quarks, quantum chromodynamics. Course Information: Prerequisite(s): PHYS 411.

PHYS 461. Thermal and Statistical Physics. 4 hours.
Thermal equilibrium (Zeroth Law); thermodynamic states (First Law); irreversibility; entropy (Second Law); thermodynamic potentials and properties; phase transitions; kinetic theory of gases; classical statistical mechanics. Course Information: Prerequisite(s): PHYS 245; or approval of the department.

PHYS 469. The Learning and Teaching of Physics. 4 hours.
Provides teacher candidates with the foundations and experiences necessary for teaching physics in secondary schools. For those currently teaching, it will also provide tools and background to improve their physics instruction. Course Information: 4 hours. Extensive computer use required. Prerequisite(s): PHYS 142; or PHYS 107 and PHYS 108; or approval of the department. Class Schedule Information: To be properly registered, students must enroll in one Lecture-Discussion and one Laboratory.
PHYS 470. Educational Practice with Seminar I. 6 hours.
The first half of a two-segment sequence of practice teaching, including
seminar, to meet certification requirements for teaching in grades six
through twelve. Course Information: Graduate credit only with approval
of the department. Prerequisite(s): Good academic standing in a teacher
education program, completion of 100 clock hours of pre-student-
teaching field experiences, and approval of the department. Class
Schedule Information: To be properly registered, students must enroll in
one Lecture-Discussion and one Practice.

PHYS 471. Educational Practice with Seminar II. 6 hours.
The second half of a two-segment sequence of practice teaching,
including seminar, to meet certification requirements for teaching in
grades six through twelve. Course Information: Graduate credit only with
approval of the department. Prerequisite(s): Good academic standing in a
teacher education program, completion of 100 clock hours of pre-
student-teaching field experiences, credit or concurrent registration in
PHYS 470, and approval of the department. Class Schedule Information:
To be properly registered, students must enroll in one Conference and
one Practice.

PHYS 475. Learning and Teaching of Physical Sciences. 3 hours.
Provides teacher candidates with the foundation and experience
necessary to teach physical sciences in secondary schools. Course
Information: Same as CHEM 475. Prerequisite(s): Senior standing or
above; or approval of the department. Recommended background:
Knowledge of first-year college physics and chemistry. Class Schedule:
To be properly registered students must enroll in one Conference and
one Laboratory.

PHYS 480. Elements of Machining Scientific Equipment. 1 hour.
Elements of machining scientific equipment, including the use of
machine shop tools and technical drawing of scientific apparatus.
Course Information: Same as CHEM 480 and EAES 478. Satisfactory/
Unsatisfactory grading only. Prerequisite(s): Graduate standing; and
approval of the department.

PHYS 481. Modern Experimental Physics I. 4 hours.
Theory and experimental use of linear circuits, semiconductor devices,
amplifiers, oscillators. Techniques and experiments in atomic, molecular
and solid-state physics. Course Information: Prerequisite(s): PHYS 240;
or approval of the department. Requires concurrent registration in PHYS
499 for students enrolled in the BA or BS in Physics programs. Class
Schedule Information: To be properly registered, students must enroll in
one Laboratory and one Lecture-Discussion.

PHYS 482. Modern Experimental Physics II. 4 hours.
Techniques and experiments in nuclear and particle physics. Gamma-
gamma correlations, muon lifetime, Compton scattering, alpha particle
scattering. Computer-based experimentation. Course Information:
Prerequisite(s): PHYS 481; or approval of the department. Class
Schedule Information: To be properly registered, students must enroll in
one Laboratory and one Lecture-Discussion.

PHYS 491. Special Topics in Physics. 1-4 hours.
Selected topics of current interest in Physics. Course Information: May be
repeated. Prerequisite(s): PHYS 215 and sophomore standing or above;
or approval of the department.

PHYS 494. Special Topics in Physics Teaching. 2-4 hours.
Seminar on various topics related to the teaching of physics. Subjects
are announced. Course Information: May be repeated. Students
may register in more than one section per term. Supervised teaching
practice included. Prerequisite(s): Graduate standing or approval of the
department.

PHYS 499. Survey of Physics Problems. 1 hour.
Problem-solving techniques applied to the variety of undergraduate
physics topics. Course Information: No graduation credit for
graduate students. Grade of C or better required to graduate with an
undergraduate degree in physics. Co-requisite(s): Concurrent registration
in PHYS 481.

PHYS 501. Electrodynamics I. 4 hours.
Maxwell's equations, static and time dependent fields in material media
and in vacuo. Boundary value problems, wave propagation. Classical
theory of radiation. Course Information: Prerequisite(s): PHYS 402 or
approval of the department.

PHYS 502. Electrodynamics II. 4 hours.
Special relativity in electrodynamics. Covariant form of Maxwell's
equations. Lagrangian form of electrodynamics. Applications to modern
physics problems. Course Information: Prerequisite(s): PHYS 501 or
consent of the department.

PHYS 511. Quantum Mechanics I. 3 hours.
Linear operators, vector spaces. Schroedinger equation. Heisenberg
formalism. Multi/identical particle systems, approximation methods,
perturbation theory, symmetries and groups, conservation laws,
angular momentum, spin. Wigner-Eckart theorem. Course Information:
Prerequisite(s): PHYS 412 or approval of the department.

PHYS 512. Quantum Mechanics II. 4 hours.
Scattering theory, partial waves. Born approximation, density matrix,
interaction of radiation with matter; Klein-Gordon and Dirac equations,
free-particle solutions, antiparticles, relativistic hydrogen atom. Second
quantization. Course Information: Prerequisite(s): PHYS 511 or approval
of the department.

PHYS 513. Quantum Field Theory I. 3 hours.
Lagrangian formulation of relativistic wave equations. Quantum
electrodynamics; Feynman rules, trace theorems, lowest-order
calculations for several processes, self-energy, renormalization, higher-
order diagrams. Course Information: Prerequisite(s): PHYS 512.

PHYS 514. Quantum Field Theory II. 3 hours.
Path integrals, gauge theories, Weinberg-Salam model, electroweak
processes, quantum chromodynamics, non-perturbative methods,
topological objects in field theories, instantons. Course Information:
Prerequisite(s): PHYS 513.

PHYS 515. Methods in Mathematical Physics. 3 hours.
Applications of mathematical methods to physics problems, linear
operators, orthogonal functions, Green's functions, ordinary and partial
differential equations, Sturm-Liouville problem, Hilbert space, group
theory. Course Information: Prerequisite(s): PHYS 215.

PHYS 521. Molecular Physics. 3 hours.
Rotational and vibrational energies of molecules, potential curves,
electronic transitions, transition moments, intensity rules, thermodynamic
properties. Applications. Course Information: Prerequisite(s): PHYS 411
and PHYS 421; or approval of the department.

PHYS 522. Laser Physics/Quantum Electronics. 3 hours.
Laser physics; population inversion; quantum theoretical calculation;
modern laser systems; coherence phenomena; applications of lasers.
Course Information: Prerequisite(s): PHYS 521 or approval of the
department.

PHYS 524. Group Theory in Physics. 3 hours.
Applications of group theory and symmetry principles to problems in
elementary particle, solid state, atomic and molecular physics. Course
Information: Prerequisite(s): PHYS 512 or approval of the department.
PHYS 525. Optics and Photonics. 2 hours.
Electromagnetic wave theory; advanced geometrical, nonlinear, fiber, and Fourier optics; Fourier transforms; interference; diffraction; solar cells; LEDs; laser cavities; gain media. More challenging problem sets, exams, labs than in Phys 425. Course Information: Corequisites: Requires concurrent registration in PHYS 425. To be properly registered, students must enroll in one Lecture, one Laboratory, and one Discussion.

PHYS 531. Solid State Physics I. 3 hours.
Crystal structure, reciprocal lattice, X-ray methods, crystal forces, phonons, heat capacity, thermal expansion. Classification of solids, band structure. Metals: free-electron model, band-structure effects, transport. Course Information: Prerequisite(s): PHYS 412 AND PHYS 461.

PHYS 532. Solid State Physics II. 3 hours.
Semiconductor physics, electron-electron and electron-phonon interactions, superconductivity, spin systems, diamagnetism, paramagnetism, ferromagnetism, and anti-ferromagnetism. Course Information: Prerequisite(s): PHYS 531.

PHYS 533. Theory of Solids: Magnetism and Superconductivity. 3 hours.
The main body problem; many-particle states; functional integrals; Green's functions; Feynman diagrams; perturbation expansions; tree diagrams. Course Information: Prerequisite(s): PHYS 512 and PHYS 532.

PHYS 534. Theory of Solids: Semiconductor Physics. 3 hours.
Spin systems; magnetism; equilibrium Green's functions; Landau theory of Fermi liquids; Hubbard model; Luttinger model, non-equilibrium Green's functions, Keldysh, Kadanoff-Baym approach. Course Information: Prerequisite(s): PHYS 512 and PHYS 532.

PHYS 540. Physics of Semiconductor Devices. 4 hours.
Electrons in periodic lattice; equilibrium carrier distribution; energy band diagrams in junctions, in homogeneious semiconductors; recombination and generation; non-equilibrium processes, radiation and electric fields; diodes. Course Information: Same as ECE 540. Prerequisite(s): ECE 346 or the equivalent.

PHYS 545. Introduction to General Relativity. 3 hours.
Principle of equivalence, the metric field and geodesics, tensor analysis and differential geometry, Einstein's equations and the action principle, gravitational fields and waves, black holes. Course Information: Prerequisite(s): PHYS 502 and PHYS 541 or approval of the department.

PHYS 551. Elementary Particle Physics I. 3 hours.
Phenomenology and theories of modern day particle physics. Classification of particles and their interactions. Survey of experimental techniques, accelerators and detectors. Course Information: Prerequisite(s): PHYS 512 or approval of the department.

PHYS 552. Elementary Particle Physics II. 3 hours.
Lagrangian formulation of electromagnetic, weak and strong interactions. Transition rates. Unification of electroweak and strong interactions. Gauge theories. Modern topics. Course Information: Prerequisite(s): PHYS 551 or approval of the department.

PHYS 561. Statistical Mechanics. 3 hours.
Density matrix. Information theory; Boltzmann-Gibbs distribution; the n-vector model; renormalization group theory; cellular automata. Course Information: Prerequisite(s): PHYS 461 or approval of the department.

PHYS 581. Advanced Experimental Physics. 2 hours.
Experimental techniques in atomic, molecular and solid-cular and solid-state physics. Course Information: Prerequisite(s): PHYS 431 or consent of the instructor.