PHYS 601 Analytical Mechanics  
Credits 3. 3 Lecture Hours.  
Hamilton approaches to dynamics; canonical transformation and variational techniques; central force and rigid body motions; the mechanics of small oscillations and continuous systems.  
Prerequisites: PHYS 302 or equivalent; MATH 311 and MATH 412 or equivalents; concurrent registration in PHYS 615.

PHYS 603 Electromagnetic Theory  
Credits 3. 3 Lecture Hours.  
Boundary-value problems in electrostatics; basic magnetostatics; multipoles; elementary treatment of ponderable media; Maxwell's equations for time-varying fields; energy and momentum of electromagnetic field; Poynting's theorem; gauge transformations.  
Prerequisites: PHYS 304 or equivalents; PHYS 615.

PHYS 606 Quantum Mechanics  
Credits 3. 3 Lecture Hours.  
Schrödinger wave equation, bound states of simple systems, collision theory, representation and expansion theory, matrix formulation, perturbation theory.  
Prerequisites: PHYS 412 or equivalent; MATH 311 and MATH 412 or equivalents; concurrent registration in PHYS 615.

PHYS 607 Statistical Mechanics  
Credits 3. 3 Lecture Hours.  
Classical statistical mechanics, Maxwell-Boltzmann distribution, and equipartition theorem; quantum statistical mechanics, Bose-Einstein distribution and Fermi-Dirac distribution; applications such as polyatomic gases, blackbody radiation, free electron model for metals, Debye model of vibrations in solids, ideal quantum mechanical gases and Bose-Einstein condensation; if time permits, phase transitions and nonequilibrium statistical mechanics.  
Prerequisites: PHYS 408 and PHYS 412 or equivalents; PHYS 615.

PHYS 611 Electromagnetic Theory  
Credits 3. 3 Lecture Hours.  
Continuation of PHYS 603. Propagation, reflection and refraction of electromagnetic waves; wave guides and cavities; interference and diffraction; simple radiating systems; dynamics of relativistic particles and fields; radiation by moving charges.  
Prerequisites: PHYS 603.

PHYS 615 Methods of Theoretical Physics I  
Credits 3. 3 Lecture Hours.  
Orthogonal eigenfunctions with operator and matrix methods applied to solutions of the differential and integral equations of mathematical physics; contour integration, asymptotic expansions of Fourier transforms, the method of stationary phase and generalized functions applied to problems in quantum mechanics.  
Prerequisites: MATH 311, MATH 407 and MATH 412 or equivalents.

PHYS 616 Methods of Theoretical Physics II  
Credits 3. 3 Lecture Hours.  
Green's functions and Sturm-Liouville theory applied to the differential equations of wave theory; special functions of mathematical physics; numerical techniques are introduced; conformal mapping and the Schwarz-Christoffel transformation applied to two-dimensional electrostatics and hydrodynamics.  
Prerequisites: PHYS 615.

PHYS 617 Physics of the Solid State  
Credits 3. 3 Lecture Hours.  
Crystalline structure and symmetry operations; electronic properties in the free electron model with band effects included; lattice vibrations and phonons; thermal properties; additional topics selected by the instructor from: scattering of X-rays, electrons, and neutrons, electrical and thermal transport, magnetism, superconductivity, defects, semiconductor devices, dielectrics, optical properties.  
Prerequisites: PHYS 606 and PHYS 607.

PHYS 619 Modern Computational Physics  
Credits 3. 2 Lecture Hours.  
Modern computational methods with emphasis on simulation such as molecular dynamics and Monte Carlo; applications to condensed matter and nuclear many-body physics and to lattice gauge theories.  
Prerequisites: PHYS 408 and PHYS 412 or equivalents; knowledge of any programming language.

PHYS 625 Nuclear Physics  
Credits 3. 3 Lecture Hours.  
Nuclear models, nuclear spectroscopy, nuclear reactions, electromagnetic properties of nuclei; topics of current interest.  
Prerequisite: PHYS 606.

PHYS 627 Elementary Particle Physics  
Credits 3. 3 Lecture Hours.  
Fundamentals of elementary particle physics; particle classification, symmetry principles, relativistic kinematics and quark models; basics of strong, electromagnetic and weak interactions.  
Prerequisite: PHYS 606.

PHYS 631 Quantum Theory of Solids  
Credits 3. 3 Lecture Hours.  
Second quantization, and topics such as plasmons; many-body effects for electrons; electron-phonon interaction; magnetism and magnons; other elementary excitations in solids; BCS theory of superconductivity; interactions of radiation with matter; transport theory in solids.  
Prerequisites: PHYS 617 and PHYS 624.

PHYS 632 Condensed Matter Theory  
Credits 3. 3 Lecture Hours.  
Prerequisites: PHYS 601, PHYS 617 and PHYS 624.

PHYS 634 Relativistic Quantum Field Theory  
Credits 3. 3 Lecture Hours.  
Classical scalar, vector and Dirac fields; second quantization; scattering matrix and perturbation theory; dispersion relations; renormalization.  
Prerequisite: PHYS 624.
PHYS 638 Quantum Field Theory II
Credits 3. 3 Lecture Hours.
Functional integrals; divergences, regularization and renormalization; non-abelian gauge theories; other topics of current interest.
Prerequisite: PHYS 634.

PHYS 639 Methods of Experimental Particle Physics
Credits 3. 2 Lecture Hours. 2 Lab Hours.
Methods of particle detection and data analysis techniques in experimental particle physics; computational and statistical methods in modern research; next challenges in experimental particle physics; use of statistical and computational techniques, Monte Carlo simulation methods, presenting and documenting scientific findings using LaTeX.
Prerequisites: PHYS 305 and PHYS 412; working knowledge of C or C++; or approval of instructor.

PHYS 641/ASTR 601 Extragalactic Astronomy
Credits 3. 3 Lecture Hours.
Overview of observations of galaxies and large-scale structures in the Universe to understand their formation and evolution from theoretical and observational perspectives; galaxy luminosity functions; evolution of stellar populations and chemical enrichment; clusters and AGN.
Prerequisites: PHYS 601; or ASTR 314 and PHYS 302; or approval of instructor.
Cross Listing: ASTR 601/PHYS 641.

PHYS 642/ASTR 602 Astronomical Observing Techniques and Instrumentation
Credits 3. 3 Lecture Hours.
Theory and practice of obtaining and analyzing astrometric, photometric, spectroscopic, and interferometric measurements of astronomical sources across the electromagnetic spectrum; principles of design, fabrication, assembly, test, deployment, and use of astronomical instruments.
Prerequisites: PHYS 615 or equivalent; or approval of instructor.
Cross Listing: ASTR 602/PHYS 642.

PHYS 643/ASTR 603 Stellar Astrophysics
Credits 3. 3 Lecture Hours.
Theoretical and observational aspects of stellar astrophysics; thermodynamic properties of stellar interiors; energy sources; nuclear processes and burning stages; convective and radiative energy transport; evolutionary models; atmospheres; stability and pulsations; chemical enrichment processes; population synthesis.
Prerequisites: PHYS 606 and PHYS 607 or equivalents; or approval of instructor.
Cross Listing: ASTR 603/PHYS 643.

PHYS 644/ASTR 604 Cosmology
Credits 3. 3 Lecture Hours.
Basic principles of modern cosmology and particle physics; general relativity; cosmic inflation; Big Bang nucleosynthesis; expansion of the universe; cosmic microwave background; large-scale structure of the Universe; properties of particles; dark matter; dark energy.
Prerequisites: PHYS 615 or equivalent; or approval of instructor.
Cross Listing: ASTR 604/PHYS 644.

PHYS 645/ASTR 605 Galactic Astronomy
Credits 3. 3 Lecture Hours.
Basic nature and structure of constituents of Milky Way galaxy; distribution and motions of stars and gas; origin evolution and distribution of large-scale chemical abundances and kinematic patterns across populations; models of galaxy formation and implications of modern observations.
Prerequisites: PHYS 601 and PHYS 607 or equivalents; or approval of instructor.
Cross Listing: ASTR 605/PHYS 645.

PHYS 646/ASTR 606 Radiative Transfer
Credits 3. 3 Lecture Hours.
Fundamental radiative processes in stellar and planetary atmospheres; radiative fields; Stokes parameters; Mueller matrix formalism; radiation from moving charges; Compton scattering; plasma effects; atomic structure and radiative transitions; molecular structure and spectra; multiple scattering.
Prerequisites: PHYS 302, PHYS 304, PHYS 408, and PHYS 412 or equivalents; or approval of instructor.
Cross Listing: ASTR 606/PHYS 646.

PHYS 647/ASTR 607 Galactic Physics
Credits 3. 3 Lecture Hours.
Special relativity; equivalence principle; theory of gravitation; Einstein’s theory of general relativity; classic tests of general relativity; simple black hole and cosmological solutions; global aspects; penrose diagrams; stationary black holes; Hawking radiation.
Prerequisites: PHYS 611 and PHYS 615.

PHYS 648 Quantum Optics and Laser Physics
Credits 3. 3 Lecture Hours.
Line widths of spectral lines; laser spectroscopy; optical cooling; trapping of atoms and ions; coherence; pico- and femto-second spectroscopy; spectroscopic instrumentation.
Prerequisite: Approval of instructor.

PHYS 649 Physics of Optoelectronic Devices
Credits 3. 3 Lecture Hours.
Overview of basic concepts: laser physics, optics of semiconductors, heterostructures with quantum confinement and their interaction with light; physical principles of state of the art optoelectronic devices; emerging concepts and technologies: integrated photonics, nanophotonics, plasmonics, metamaterials, terahertz optoelectronics, quantum information processing, etc.
Prerequisites: Quantum mechanics (PHYS 412 and PHYS 414 or PHYS 606 or equivalent).

PHYS 651 Superstring Theory I
Credits 3. 3 Lecture Hours.
Overview of basic concepts: bosonic string, conformal field theory, strings with worldsheet and space-time supersymmetry, as well as the higher dimensional extended objects called D-branes.
Prerequisites: PHYS 634 and PHYS 653; PHYS 647 recommended.

PHYS 652 Superstring Theory II
Credits 3. 3 Lecture Hours.
M-theory unification of superstring theories into a single eleven-dimensional theory; duality symmetries relating string theories; string geometry; Calabi-Yau manifolds and exceptional holonomy manifolds; flux compactifications; black holes in string theory; AdS/CFT correspondence; string and M-theory cosmology.
Prerequisites: PHYS 651; PHYS 647 recommended.
PHYS 653 Introduction to Supersymmetry and Supergravity
Credits 3. 3 Lecture Hours.
Core material on supersymmetric field theories and their coupling to supergravity theories.
Prerequisite: PHYS 634.

PHYS 654 The Standard Model and Beyond
Credits 3. 3 Lecture Hours.
The standard model of particle physics in detail; general principles of gauge theories, including spontaneous breaking and applications to Electro-Weak Interactions and Quantum Chromodynamics; extension of the standard model involving Grand Unified Theories (GUT), Supersymmetry (SUSY) and Supergravity (SUGRA).
Prerequisites: PHYS 624 and PHYS 634.

PHYS 655 String Phenomenology
Credits 3. 3 Lecture Hours.
Physical applications of string theory; rudiments of string theory; compactification of extreme dimensions in string theory; free-fermionic formulation; dualities, M-theory, intersection D-Branes, and D-Brane phenomenology; model building.
Prerequisites: PHYS 634 and PHYS 651.

PHYS 666 Scientific Instrument Making
Credits 3. 2 Lecture Hours. 2 Lab Hours.
Theory and techniques for designing and constructing advanced scientific instruments such as spectrometers, cryostats, vacuum systems, etc.; mechanical and electronic shop procedures utilizing the lathe and mill; welding and soldering; drafting and print reading; circuit design.
Prerequisite: Approval of instructor.

PHYS 674/ECEN 674 Introduction to Quantum Computing
Credits 3. 3 Lecture Hours.
Introduces the quantum mechanics, quantum gates, quantum circuits and quantum hardware of potential quantum computers; algorithms, potential uses, complexity classes, and evaluation of coherence of these devices.
Prerequisites: MATH 304; PHYS 208.
Cross Listing: ECEN 674/PHYS 674.

PHYS 681 Seminar
Credit 1. 1 Lecture Hour.
Subjects of current importance; normally required of all graduate students in physics.

PHYS 685 Directed Studies
Credits 1 to 9. 1 to 9 Other Hours.
Individual problems not related to thesis.
Prerequisite: Approval of instructor.

PHYS 689 Special Topics in...
Credits 1 to 4. 1 to 4 Lecture Hours. 0 to 4 Lab Hours.
Selected topics in an identified area of physics. May be repeated for credit.
Prerequisite: Approval of instructor.

PHYS 691 Research
Credits 1 to 23. 1 to 23 Other Hours.
Research toward thesis or dissertation.
Prerequisite: Baccalaureate degree in physics or equivalent.