Physics

**PHYS 5301** Mathematical Methods of Physics I (3 semester credit hours) Vector analysis (and index notation); Cylindrical and Spherical coordinates; Sturm-Liouville theory; Legendre Functions; Differential Equations (including Green Functions). (3-0) Y

**PHYS 5302** Mathematical Methods of Physics II (3 semester credit hours) Functions of Complex Variable (including contour integration and the residue theorem); Tensor Analysis; Gamma and Beta functions; and Bessel functions. (3-0) Y

**PHYS 5303** Mathematical Methods of Physics III (3 semester credit hours) Continuation and extension of topics from PHYS 5301 and PHYS 5302 with applications related to problems and techniques encountered in physical sciences. (3-0) R

**PHYS 5305** Monte Carlo Simulation Method and its Application (3 semester credit hours) An introductory course on the method of Monte Carlo simulation of physical events. This course covers the generation of 0-1 random number, simulation of arbitrary distributions, modeling, simulation and statistical analysis of experimental activities in physics research and engineering studies. As a comparison the concepts and applications of the Neural Networks will be discussed. Prerequisites: Background knowledge in probability and statistics and in a programming language or instructor consent required. (3-0) T

**PHYS 5311** Classical Mechanics (3 semester credit hours) A course that aims to provide intensive training in problem solving. Rigorous survey of Newtonian mechanics of systems, including its relativity principle; the ellipsoid of inertia and its eigenstructure, with applications, Poinset's theorem; Euler's equations, spinning tops; Lagrangian and Hamiltonian formalism with applications; chaos, small oscillations, velocity dependent potentials, Lagrange multipliers and corresponding constraint forces, canonical transformations, Lagrange and Poisson brackets, Hamilton-Jacobi theory. (3-0) Y

**PHYS 5313** Statistical Physics (3 semester credit hours) Phase space, distribution functions and density matrices; microcanonical, canonical and grand canonical ensembles; partition functions; principle of maximum entropy; thermodynamic potentials and laws of thermodynamics; classical and quantum ideal gases; non-interacting magnetic moments; phonons and specific heat of solids; degenerate electron gas, its specific heat and magnetism; statistics of carriers in semiconductors; Bose-Einstein condensation; Black-body radiation; Boltzmann transport equation and H-theorem; relaxation time and conductivity; Brownian motion, random walks and Langevin equation; Einstein's relation; fluctuations in ideal gases; linear response and fluctuation-dissipation theorem; virial and cluster expansions, van der Waals equation of state; Poisson-Boltzmann and Thomas-Fermi equations; phases, phase diagrams and phase transitions of the first and second order; lattice spin models; ordering, order parameters and broken symmetries; Mean-field theory of ferromagnetism; Landau and Ginzburg-Landau theories; elements of modern theory of critical phenomena. (3-0) Y

**PHYS 5314** Applied Numerical Methods (3 semester credit hours) Core course for Applied Physics Concentration. A hands-on approach to the development and use of computational tools in solving problems routinely encountered in upper level applied physics and engineering. Main topics include curve fitting and regression analysis, significance tests, principles of numerical modeling, verification and
validation of numerical algorithms, and nonlinear model building. Examples from real world applications will be presented and discussed to illustrate the appropriate use of numerical techniques. Prerequisites: PHYS 5301 or equivalent, and proficiency in a programming language. (3-0) Y

**PHYS 5315 Scientific Computing** (3 semester credit hours) An introduction to computational methods for solving systems of ordinary and partial differential equations using numerical techniques. Prerequisite or Corequisite: PHYS 5301. (3-0) Y

**PHYS 5319 (SCI 5326) Astronomy: Our Place in Space** (3 semester credit hours) Focus is on developing student understanding of how our planet fits within a larger astronomical context. Topics include common misconceptions in astronomy, scale in the Solar System and beyond, phases of the Moon, seasons, navigating the night sky, our Sun as a star, space weather, properties and lifecycles of stars, galaxies, and cosmology. (3-0) T

**PHYS 5320 Electromagnetism I** (3 semester credit hours) Electrostatic boundary value problems, uniqueness theorems, method of images, Green's functions, multipole potentials, Legendre polynomials and spherical harmonics, dielectric and magnetic materials, magnetostatics, time-varying field and Maxwell's equations, energy and momentum of the field, Lienard-Wiechert potentials, electromagnetic radiation, polarization, refraction and reflection at plane interfaces. (3-0) Y

**PHYS 5321 Experimental Operation and Data Collection Using Personal Computers** (3 semester credit hours) Computer interfacing to physical experiments using high level interface languages and environments. The student will have the opportunity to learn how to develop data acquisition software using LabView and LabWindows/CVI as well as how to write drivers to interface these languages to devices over the general purpose interface buss (GPIB). A laboratory is provided for hands-on training in these devices. (3-0) R

**PHYS 5322 Electromagnetism II** (3 semester credit hours) Fields and potentials, Gauge transformations and the wave equation. Electromagnetic waves in unbounded media - non-dispersive and dispersive media. Boundary conditions at interfaces. Solutions to the wave equation in rectangular cylindrical and spherical coordinates. Electromagnetic waves in bonded media - waveguides and resonant cavities. Radiating systems - electric and magnetic dipole radiation, electric quadruple radiation. Fundamentals of scattering and scalar diffraction. Lorentz transformation and covariant forms for Maxwell's equations. Radiation from moving charges - Synchrotron, Cherenkov and Bremstrahlung Radiation. Prerequisite: PHYS 5320 or equivalent. (3-0) Y

**PHYS 5323 Virtual Instrumentation with Biomedical Clinical and Healthcare Applications** (3 semester credit hours) The application of the graphical programming environment of LabView will be demonstrated with examples related to the health care industry. Examples will be provided to highlight the use of the personal computer as a virtual instrument in the clinical and laboratory environment. A laboratory is provided for hands-on training to augment the lecture. (3-0) R

**PHYS 5327 (SCI 5327) Comparative Planetology** (3 semester credit hours) Every world in the solar system is unique, but none more so than our own planet Earth. The course is an exploration of the astrophysical, chemical, and geological processes that have shaped each planet, moons and the myriad of rocky and icy bodies in our solar system with a special emphasis on what each tells us about Earth, and what discoveries of worlds orbiting other stars may tell us about our planetary system and home world. (3-0) T
**PHYS 5331 (SCI 5331)** Conceptual Physics I: Force and Motion (3 semester credit hours) Focus is on deepening the participants' conceptual understanding of physics, emphasizing its applicability to the pre-college and undergraduate classroom. Uses inquiry-based approaches including examples of physics in the everyday world and connections to other fields of science. Topics include foundational concepts of forces, Newton's laws, energy, and momentum. Instructor consent required. (3-0) T

**PHYS 5332 (SCI 5332)** Conceptual Physics II: Particles and Systems (3 semester credit hours) Focus is on deepening the participants' conceptual understanding of physics emphasizing its applicability to the pre-college and undergraduate classroom. Uses an inquiry-based approach including examples of physics in the everyday world and connections to other fields of science. This second class in the Conceptual Physics series builds on concepts from **SCI 5331** to explore transfers of energy and forces within and between systems of particles. Topics include states of matter, fluids, waves and sound, and thermodynamics. Instructor consent required. (3-0) T

**PHYS 5333 (SCI 5333)** Conceptual Physics III: Atoms, Charges, and Interactions (3 semester credit hours) Focus is on deepening the participants' conceptual understanding of physics, emphasizing critical thinking and applications to the pre-college and undergraduate classroom. Uses inquiry-based approaches including examples of physics in the everyday world and connections to other fields of science. This third class in the Conceptual Physics series builds on concepts from **SCI 5331** and **SCI 5332** to explore interactions between particles of matter. Topics include inter- and intra-molecular forces, light, electricity and magnetism, and the nature of the atom. (3-0) T

**PHYS 5335** Remote Sensing of the Earth (3 semester credit hours) This course covers the basic physical principles and applications of remote sensing of the earth system (air, land and sea), covering the types of platforms (satellites and aerial vehicles) and sensors used (UV/Visible, IR, Microwave, Radio). (3-0) R

**PHYS 5336** Big Data and Machine Learning for Scientific Discovery (3 semester credit hours) This class introduces a wide range of machine learning techniques suitable for Big Data analysis. The techniques covered include multivariate non-linear non-parametric regression and classification, both supervised and unsupervised. These approaches are directly applicable to many issues of major scientific and societal importance. The practical tools introduced (Neural Networks, Support Vector Regression, Decision Trees, Random Forests, etc) can be readily used in a wide range of applications from research to real time decision support. The data used can come from a wide variety of sources including scientific instrumentation, social media, remote sensing, aerial vehicles, and the internet of things. (3-0) R

**PHYS 5341 (SCI 5341)** Astrobiology (3 semester credit hours) The ultimate integrated science, astrobiology brings together cutting-edge research from the fields of astrophysics, planetary science, terrestrial geosciences, and biology, to build understanding of how the history and diversity of life on our own planet relates to the possibilities for life on other worlds. This graduate-level survey course is designed to challenge participants of all backgrounds in a thoughtful and scientifically-based exploration of the young and dynamic multidisciplinary field of astrobiology. Instructor consent required. (3-0) T

**PHYS 5367** Photonic Devices (3 semester credit hours) Basic principles of Photophysics of Condensed Matter with application to devices. Topics covered include photonic crystals, PBG systems, low threshold lasers, photonic switches, super-prisms and super-lenses. Photodetectors and photocells. (3-0) R

**PHYS 5371 (MSEN 5371)** Solid State Physics (3 semester credit hours) Symmetry description of crystals,
bonding, properties of metals, electronic band theory, thermal properties, lattice vibration, elementary properties of semiconductors. Prerequisites: PHYS 5301 and PHYS 5320 or equivalent. (3-0) Y

PHYS 5372 Solid State Devices (3 semester credit hours) Basic concepts of solid state physics with application to devices. Topics covered include semiconductor homojunctions and heterojunctions, low dimensional physics, one and two dimensional electron gases, hot electron systems, semiconductor lasers, field effect and heterojunction transistors, microwave diodes and infrared and solar devices. Prerequisite: PHYS 5371. (3-0) R

PHYS 5376 (MECH 5300 and MSEN 5300) Introduction to Materials Science (3 semester credit hours) This course provides an extensive overview of materials science and engineering and includes the foundations required for further graduate study in the field. Topics include chemical bonding, crystalline structures, imperfections and diffusion in solids, mechanical properties, strengthening and failure mechanisms, phase diagrams and transformations, corrosion and degradation of materials, metal alloys, ceramics, polymers, composites, as well as their electrical, thermal, magnetic, and optical properties. Quantitative analyses will be emphasized. (3-0) R

PHYS 5377 (MSEN 5377) Computational Physics of Nanomaterials (3 semester credit hours) This course introduces atomistic and quantum simulation methods and their applications to modeling study nanomaterials (nanoparticles, nanowires, and thin films). The course has three main parts: basic theory of materials (thermodynamics, statistical mechanics, and solid state physics), computational methods to model materials systems, and applications to practical problems. There are three main themes of the course: structure-property relationship of nanomaterials; atomistic modeling for atomic structure optimization; and quantum simulations for electronic structure study and functional property analysis. Prerequisite: MSEN 6319 or equivalent. (3-0) R

PHYS 5381 Space Science (3 semester credit hours) Introduction to the dynamics of the middle and upper atmospheres, ionospheres and magnetospheres of the earth and planets and the interplanetary medium. Topics include: turbulence and diffusion, photochemistry, aurorae and airglow, space weather and the global electric circuit. (3-0) R

PHYS 5382 Space Science Instrumentation (3 semester credit hours) Design, testing and operational criteria for space flight instrumentation including retarding potential analyzers, drift meters, neutral and ion mass spectrometers, auroral particle spectrometers, fast ion mass spectrometers, Langmuir probes, and optical spectrometers; ground support equipment; microprocessor design and operations. (3-0) R

PHYS 5383 (EEMF 5383 and MSEN 5383) Plasma Technology (3 semester credit hours) Hardware oriented study of useful laboratory plasmas. Topics will include vacuum technology, gas kinetic theory, basic plasma theory and an introduction to the uses of plasmas in various industries. (3-0) T

PHYS 5385 Natural And Anthropogenic Effects on The Atmosphere (3 semester credit hours) An examination of the physical, chemical and electrical effects on the atmosphere and clouds due to varying solar photon and solar wind inputs; and of the physical and chemical effects on ozone and atmospheric temperature following anthropogenic release of CFC's and greenhouse gases into the atmosphere. Suitable for Science Education and other non-physics majors. (3-0) R

PHYS 5391 Relativity I (3 semester credit hours) Mach's principle and the abolition of absolute space; the principle of relativity; the principle of equivalence; basic cosmology; four-vector calculus; special relativistic
kinematics, optics, mechanics, and electromagnetism; basic ideas of general relativity. (3-0) T

**PHYS 5392** Relativity II (3 semester credit hours) Tensor calculus and Riemannian geometry; mathematical foundation of general relativity; the crucial tests; fundamentals of theoretical relativistic cosmology; the Friedmann model universes; comparison with observation. Normally follows **PHYS 5391**. (3-0) T

**PHYS 5395** Cosmology (3 semester credit hours) The course is an overview of contemporary cosmology including: cosmological models of the universe and their parameters; large scale structure of the universe; dark matter; cosmological probes and techniques such as gravitational lensing, cosmic microwave background radiation, and supernova searches; very early stages of the universe; dark energy and recent cosmic acceleration. (3-0) T

**PHYS 5V48** Topics in Physics (1-6 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). Instructor consent required. ([1-6]-0) R

**PHYS 5V49** Special Topics in Physics (1-6 semester credit hours) Pass/Fail only. May be repeated for credit as topics vary (9 semester credit hours maximum). ([1-6]-0) R

**PHYS 6300** Quantum Mechanics I (3 semester credit hours) Dirac formalism, kets, bras, operators and position, momentum, and matrix representations, change of basis, Stern-Gerlach experiment, observables and uncertainty principle, translations, wave functions, time evolution, the Schrödinger and Heisenberg pictures, simple harmonic oscillator, wave equation, WKB approximation, rotations, angular momentum, spin, Clebsch-Gordan coefficients, perturbation theory, variational methods. Prerequisite: **PHYS 5311** or consent of instructor. (3-0) Y

**PHYS 6301** Quantum Mechanics II (3 semester credit hours) Non-relativistic many-particle systems and their second quantization description with creation and annihilation operators; Interactions and Hartree-Fock approximation, quasi-particles; attraction of fermions and superconductivity; repulsion of bosons and super fluidity; lattice systems, classical fields and canonical quantization of wave equations; free electromagnetic field, gauges and quantization: photons; coherent states; Interaction of light with atoms and condensed systems: emission, absorption and scattering; vacuum fluctuations and Casimir force; elements of relativistic quantum mechanics: Klein-Gordon and Dirac equations; particles and antiparticles; spin-orbit coupling; fine structure of the hydrogen atom; micro-causality and spin-statistics theorem; non-relativistic scattering theory: scattering amplitudes, phase shifts, cross-section and optical theorem; Born series; inelastic and resonance scattering; perturbative analysis of the interacting fields: Time evolution and interaction representation, S-matrix and Feynman diagrams; simple scattering processes; Dyson's equation, self-energy and renormalization. Prerequisite: **PHYS 6300**. (3-0) Y

**PHYS 6302** Quantum Mechanics III (3 semester credit hours) Advanced topics in quantum mechanics. Prerequisite: **PHYS 6300** and **PHYS 6301**. (3-0) R

**PHYS 6303** Applications of Group Theory In Physics (3 semester credit hours) Group representation theory and selected applications in atomic, molecular and elementary-particle physics. Survey of abstract group theory and matrix representations of SU(2) and the rotation group, group theory and special functions, the role of group theory in the calculation of energy levels, matrix elements and selection rules, Abelian and non-Abelian gauge field theories, the Dirac equation, representations of SU(3), and the standard model of elementary-particle physics. Prerequisite: **PHYS 5301**. (3-0) R
**PHYS 6313** Elementary Particles (3 semester credit hours) Elementary particles and their interaction; classification of elementary particles; fermions and bosons; particles and antiparticles; leptons and hadrons; mesons and baryons; stable particles and resonances; hadrons as composites of quarks and antiquarks; fundamental interactions and fields; electromagnetic, gravitational, weak and strong interactions; conservation laws in fundamental interactions; parity, isospin, strangeness, G-parity; helicity and chirality; charge conjugation and time reversal; strong reflection and CPT theorem; gauge invariance; quarks and gluons; discovery of c, b and t quarks and the W+ and Z0 particles; recent discoveries. (Normally follows PHYS 6300 or 6301.) (3-0) T

**PHYS 6314** High Energy Physics (3 semester credit hours) Electromagnetic and nuclear interactions of particles with matter; particle detectors; accelerators and colliding beam machines; invariance principles and conservation laws; hadron-hadron interactions; static quark model of hadrons; weak interactions; lepton-quark interactions; the parton model of hadrons; fundamental interactions and their unification; generalized gauge invariance; the Weinberg-Salam Model and its experimental tests: quantum chromodynamics; quark-quark interactions; grand unification theories; proton decay, magnetic monopoles, neutrino oscillations and cosmological aspects; supersymmetries. (3-0) R

**PHYS 6339** Special Topics In Quantum Electronics (3 semester credit hours) Topics vary from semester to semester. May be repeated for credit (9 semester credit hours maximum). (3-0) R

**PHYS 6341** Nuclear Physics I: The Principles of Nuclear Physics (3 semester credit hours) Atomic physics; atomic spectra, x-rays and atomic structure. The constitution of the nucleus; isotopes, natural radioactivity, artificial nuclear disintegration and artificial radioactivity; alpha-, beta-, and gamma-decay; nuclear reactions, nuclear forces and nuclear structure. Nuclear models, neutron physics and nuclear fission. (3-0) R

**PHYS 6342** Nuclear Physics II: Physics and Measurement Of Nuclear Radiations (3 semester credit hours) Interaction of nuclear radiation with matter; electromagnetic interaction of electrons and photons; nuclear interactions. Operation and construction of counters and particle track detectors; electronic data acquisition and analysis systems. Statistical evaluation of experimental data. (3-0) R

**PHYS 6349** Special Topics in High Energy Physics (3 semester credit hours) Topics vary from semester to semester. May be repeated for credit as topics vary (9 semester credit hours maximum). (3-0) R

**PHYS 6353** Atomic and Molecular Processes (3 semester credit hours) Study of theory and experimental methods applied to elastic scattering, excitation and ionization of atoms and molecules by electron and ion impact, electron attachment and detachment, and charge transfer processes. (3-0) R

**PHYS 6369** Special Topics in Optics (3 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). Department consent required. (3-0) R

**PHYS 6371 (MSEN 6371)** Advanced Solid State Physics (3 semester credit hours) Continuation of MSEN 5371 or PHYS 5371. transport properties of semiconductors, ferroelectricity and structural phase transitions, magnetism, superconductivity, quantum devices, surfaces. Prerequisite: MSEN 5371 or PHYS 5371 or equivalent. (3-0) R

**PHYS 6372** Physical Materials Science (3 semester credit hours) Advanced concepts of Materials Science. New directions in fabrication routes and materials design, such as biologically-inspired routes to electronic
materials. Advanced materials and device characterization. Prerequisite: PHYS 5376 or equivalent. (3-0) R

**PHYS 6374 (MSEN 6374)** Optical Properties of Solids (3 semester credit hours) Optical response in solids and its applications. Lorentz, Drude and quantum mechanical models for dielectric response function. Kramers-Kronig transformation and sum rules considered. Basic properties related to band structure effects, excitons and other excitations. Experimental techniques including reflectance, absorption, modulated reflectance, Raman scattering. Prerequisite: MSEN 5371 or PHYS 5371 or equivalent. (3-0) R

**PHYS 6376** Electronics and Photonics of Molecular and Organic Solids (3 semester credit hours) Electronic energy bands in molecular solids and conjugated polymers. Elementary excitations: Frenkel, Wannier and charge transfer excitons. Polarons, bipolarons and solitons. Mobility of excitons and charge carriers, photoconductivity. Charge generation and recombination, electroluminescence, photovoltaic phenomena. Spin selective magnetic effects on excitons and carriers. Superconductivity: granular SC, and field induced SC in organic FETs. (3-0) R


**PHYS 6379** Special Topics in Solid State Physics (3 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). Department consent required. (3-0) R

**PHYS 6383 (EEMF 6383 and MECH 6383)** Plasma Science (3 semester credit hours) Theoretically oriented study of plasmas. Topics to include: fundamental properties of plasmas, fundamental equations (kinetic and fluid theory, electromagnetic waves, plasma waves, plasma sheaths), plasma chemistry and plasma diagnostics. Prerequisite: EENG 6316 or equivalent. (3-0) T

**PHYS 6388** Ionospheric Electrodynamics (3 semester credit hours) Generation of electric fields in the earth's ionosphere. The role of internal dynamos and external generators from the interaction of the earth with the solar wind. Satellite and ground-based observations of ionospheric phenomena such as ExB drift, the polar wind and plasma instabilities. Prerequisites: PHYS 5320 and PHYS 6383. (3-0) R

**PHYS 6389** Special Topics in Space Physics (3 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). Department consent required. (3-0) S

**PHYS 6398** Thesis (3 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. (3-0) R

**PHYS 6399** Special Topics in Relativity (3 semester credit hours) May be repeated for credit as topics vary (9 semester credit hours maximum). Department consent required. (3-0) R

**PHYS 7V10** Internal Research (3-6 semester credit hours) On campus research for Masters in Applied Physics. May be repeated for credit. Instructor consent required. (3-6)-0 S
**PHYS 7V20** Industrial Research (3-6 semester credit hours) Industrial research for Masters in Applied Physics. May be repeated for credit. Instructor consent required. ([3-6]-0) S

**PHYS 8V10** Research in High Energy Physics and Elementary Particles (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

**PHYS 8V20** Research in Cosmology and Astrophysics (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

**PHYS 8V30** Research in Quantum Electronics (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

**PHYS 8V40** Research in Applied Physics (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

**PHYS 8V50** Research in Atomic and Molecular Physics (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

**PHYS 8V60** Research in Optics (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

**PHYS 8V70** Research in Materials Physics (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

**PHYS 8V80** Research in Atmospheric and Space Physics (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

**PHYS 8V90** Research in Mathematical Physics (3-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([3-9]-0) S

**PHYS 8V99** Dissertation (1-9 semester credit hours) Pass/Fail only. May be repeated for credit. Instructor consent required. ([1-9]-0) S