PHYSICS (PHYS)

PHYS 100
Intro to the Profession
Introduction to the physical sciences, scientific method, computing tools, and interrelations of physical sciences with chemistry, biology and other professions.
Lecture: 2 **Lab:** 0 **Credits:** 2
Satisfies: Communications (C)

PHYS 120
Astronomy
A descriptive survey of observational astronomy, the solar system, stellar evolution, pulsars, black holes, galaxies, quasars, the origin and fate of the universe.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 123
General Physics I: Mechanics
Vectors and motion in one, two and three dimensions. Newton's Laws. Particle dynamics, work and energy. Conservation laws and collisions. Rotational kinematics and dynamics, angular momentum and equilibrium of rigid bodies. Gravitation. Oscillations.
Prerequisite(s): MATH 151*, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 **Lab:** 3 **Credits:** 4
Satisfies: Communications (C)

PHYS 200
Introduction to Energy, Waves, Materials, and Forces
This course will address the basic physical principles and concepts associated with energy, power, heat, light, sound, circuits, materials, fluids, and forces. Although quantitative at times, the course will stress conceptual understanding and practical applications.
Lecture: 4 **Lab:** 0 **Credits:** 4
Satisfies: Natural Science (N)

PHYS 221
General Physics II: Electricity and Magnetism
Waves charge, electric field, Gauss' Law and potential. Capacitance, resistance, simple a/c and d/c circuits. Magnetic fields, Ampere's Law, Faraday's Law, induction, and Maxwell's equations. Traveling waves, electromagnetic waves, and light.
Prerequisite(s): (MATH 149 or MATH 151) and MATH 152*, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 **Lab:** 3 **Credits:** 4
Satisfies: Communications (C)

PHYS 223
General Physics III
Sound, fluid mechanics and elasticity. Temperature, first and second laws of thermodynamics, kinetic theory and entropy. Reflection, refraction, interference and diffraction. Special relativity. Quantization of light, charge and energy.
Prerequisite(s): PHYS 221
Lecture: 3 **Lab:** 3 **Credits:** 4

PHYS 224
General Physics III for Engineers
Sound and fluid mechanics. Temperature, first and second laws of thermodynamics, kinetic theory and entropy. Reflection, refraction, interference and diffraction. Special relativity. Light and quantum physics, structure of the hydrogen atom. Atomic physics, electrical conduction in solids, nuclear physics, particle physics and cosmology.
Prerequisite(s): PHYS 123 and MATH 152 and PHYS 221
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 240
Computational Science
This course provides an overview of introductory general physics in a computer laboratory setting. Euler-Newton method for solving differential equations, the trapezoidal rule for numerical quadrature and simple applications of random number generators. Computational projects include the study of periodic and chaotic motion, the motion of falling bodies and projectiles with air resistance, conservation of energy in mechanical and electrical systems, satellite motion, using random numbers to simulate radioactivity, the Monte Carlo method, and classical physical models for the hydrogen molecule and the helium atom.
Prerequisite(s): PHYS 221
Lecture: 2 **Lab:** 3 **Credits:** 3
Satisfies: Communications (C)

PHYS 300
Instrumentation Laboratory
Basic electronic skills for scientific research. Electrical measurements, basic circuit analysis, diode and transistor circuits. Transistor and integrated amplifiers, filters, and power circuits. Basics of digital circuits, including Boolean algebra and design of logic circuits.
Prerequisite(s): PHYS 221
Lecture: 2 **Lab:** 4 **Credits:** 4
Satisfies: Communications (C)

PHYS 301
Mathematical Methods of Physics
Real and complex numbers and their properties. Vectors, matrices, eigenvalues, eigenvectors, diagonalization of matrices and quadratic forms, and applications. Fourier series, integrals, and transform. Basic probability. Orthogonal polynomials and special functions. Partial differential equations and separation of variables method. Calculus of complex variables.
Prerequisite(s): MATH 252 and MATH 251
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 304
Thermodynamics and Statistical Physics
Statistical basis of thermodynamics, including kinetic theory, fundamentals of statistical mechanics, fluctuations and noise, transport phenomena and the Boltzmann equation. Thermodynamic functions and their applications, first and second laws of thermodynamics.
Prerequisite(s): PHYS 223 or PHYS 224
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 308
Classical Mechanics I
Newton's Laws, one-dimensional motion, vector methods, kinematics, dynamics, conservation laws, and the Kepler problem. Collisions, systems of particles, and rigid-body motion. Approximation techniques, Lagrangian and Hamiltonian formulations of classical mechanics, small oscillations.
Prerequisite(s): MATH 252 and (PHYS 223 or PHYS 224)
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 309
Classical Mechanics II
Newton's Laws, one dimensional motion, vector methods, kinematics, dynamics, conservation laws, and the Kepler problem. Collisions, systems of particles, and rigid-body motion. Approximation technique, Lagrangian and Hamiltonian formulations of classical mechanics, small oscillations.
Prerequisite(s): MATH 252 and (PHYS 223 or PHYS 224) and PHYS 308
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 348
Modern Physics for Scientists and Engineers
An introduction to modern physics with the emphasis on the basic concepts that can be treated with elementary mathematics. Subjects covered include Bohr atom, elementary wave mechanics and an introduction to quantum mechanics, atom and molecular spectra, nuclear, and particle physics.
Prerequisite(s): PHYS 223
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 360
Introduction to Astrophysics
This course provides an overview of astrophysics and introduces the student to the many conventions, units, coordinate systems, and nomenclature used in astrophysics. The course will survey observational, stellar, and extragalactic astrophysics as well as cosmology. The course will also include planetary astronomy including extrasolar planets.
Prerequisite(s): PHYS 221 and (CHEM 122 or CHEM 124)
Lecture: 3 **Lab:** 0 **Credits:** 3
Satisfies: Natural Science (N)

PHYS 361
Observational Astrophysics
This lecture/lab class covers the basics of multiwavelength observational astrophysics. Topics covered include statistical analysis techniques, multi-wavelength telescope design, instrument design (including CCDs, spectrographs and PMTs), and best practices applicable in different observational bands.
Prerequisite(s): PHYS 221 and PHYS 360 and (CHEM 122 or CHEM 124)
Lecture: 3 **Lab:** 1 **Credits:** 4
Satisfies: Natural Science (N)

PHYS 403
Relativity
Introduction to the special and general theories of relativity. Lorentz covariance. Minkowski space. Maxwell's equations. Relativistic mechanics. General coordinate covariance, differential geometry, Riemann tensor, the gravitational field equations. Schwarzschild solution, astronomical and experimental tests, relativistic cosmological models.
Prerequisite(s): PHYS 308 and MATH 251
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 404
Subatomic Physics
Historical introduction; general survey of nuclear and elementary particle physics; symmetries and conservation laws; leptons, quarks, and vector bosons; unified electromagnetic and weak interactions; the parton model and quantum chromodynamics.
Prerequisite(s): PHYS 348
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 405
Fundamentals of Quantum Theory I
A review of modern physics including topics such as blackbody radiation, the photoelectric effect, the Compton effect, the Bohr model of the hydrogen atom, the correspondence principle, and the DeBroglie hypothesis. Topics in one-dimensional quantum mechanics such as the particle in an infinite potential well, reflection and transmission from potential wells, barriers, and steps, the finite potential well and the quantum harmonic oscillator. General topics such as raising and lowering operators, Hermitian operators, commutator brackets and the Heisenberg Uncertainty Principle are also covered. Many particle systems and the Pauli Exclusion Principle are discussed. Three-dimensional quantum mechanical systems, orbital angular momentum, the hydrogen atom.
Prerequisite(s): PHYS 348 and MATH 252
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 406
Fundamentals of Quantum Theory II
Zeeman and Stark Effects. Addition of spin and orbital angular momenta, the matrix representation of quantum mechanical operators, the physics of spin precession and nuclear magnetic resonance. Time independent and time dependent perturbation theory, Fermi's Golden Rule and the physics of radiation emitted in the course of atomic transitions. Indistinguishable particles in quantum mechanics, the helium atom. Scattering theory, using partial wave analysis and the Born approximation.
Prerequisite(s): PHYS 405
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 410
Molecular Biophysics
The course covers thermodynamic properties of biological molecules, irreversible and open systems, information theory, biophysical measurements, the structure and properties of proteins, enzyme action, the structure and properties of nucleic acids, genetics at the molecular level, and molecular aspects of important biological systems.
Prerequisite(s): CHEM 343 or PHYS 348
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 412
Modern Optics and Lasers
Geometrical and physical optics. Interference, diffraction, and polarization. Coherence and holography. Light emission and absorption. Principles of laser action, characterization of lasers, and laser applications.
Prerequisite(s): PHYS 348 and CS 105
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 413
Electromagnetism I
Differentiation and integration of vector fields, and electrostatics and magnetostatics. Calculation of capacitance, resistance, and inductance in various geometries.
Prerequisite(s): PHYS 221 and MATH 252
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 414
Electromagnetism II
Propagation and generation of electromagnetic radiation. Antennas and waveguides. Maxwell's equations. Electromagnetic properties of materials. Classical electrodynamics; special relativity.
Prerequisite(s): PHYS 413
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 415
Solid State Electronics
Energy bands and carrier transport in semi-conductors and metals. Physical principles of p-n junction devices, bipolar junction transistors, FETS, Gunn diodes, IMPATT devices, light-emitting diodes, semiconductor lasers.
Prerequisite(s): PHYS 348
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 418
Introduction to Lasers
Nature of light. Coherence and holography. Light emission and absorption. Principles of laser action. Characteristics of gas lasers, organic dye lasers, solid state lasers. Laser applications.
Prerequisite(s): PHYS 348
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 420
Bio-Nanotechnology
In this multidisciplinary course, we will examine the basic science behind nanotechnology and how it has infused itself into areas of nanofabrication, biomaterials, and molecular medicine. This course will cover materials considered basic building blocks of nanodevices such as organic molecules, carbon nanotubes, and quantum dots. Top-down and bottom-up assembly processes such as thin film patterrning through advanced lithography methods, self-assembly of molecular structures, and biological systems will be discussed. Students will also learn how bionanotechnology applies to modern medicine, including diagnostics and imaging and nanoscale, as well as targeted, nanotherapy and finally nanosurgery.
Prerequisite(s): PHYS 348
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 425
High Energy Astrophysics
High-energy astrophysics covers interactions in the most extreme physical conditions across the cosmos. Included in this course are the physics of black holes, neutron stars, large scale jets, accretion, shocks, and particle acceleration. Emission mechanisms resulting from relativistic particle acceleration are covered including synchrotron radiation and Bremsstrahlung and Compton processes. Recent observations of X-ray to TeV gamma-ray energies have contributed significantly to understanding these phenomena and will be highlighted.
Prerequisite(s): PHYS 348 and MATH 251 and MATH 252
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 427
Advanced Physics Laboratory I
Experiments related to our present understanding of the physical world. Emphasis is on quantum phenomena in atomic, molecular, and condensed matter physics, along with the techniques of measurement and data analysis. The second semester stresses project-oriented experiments on modern topics including spectroscopy, condensed matter physics, and nuclear physics.
Prerequisite(s): PHYS 348
Lecture: 3 **Lab:** 2 **Credits:** 3
Satisfies: Communications (C)

PHYS 428
Advanced Physics Laboratory II
Experiments related to our present understanding of the physical world. Emphasis is on quantum phenomena in atomic, molecular, and condensed matter physics, along with the techniques of measurement and data analysis. The second semester stresses project-oriented experiments on modern topics including spectroscopy, condensed matter physics and nuclear physics.
Prerequisite(s): PHYS 348
Lecture: 2 **Lab:** 3 **Credits:** 3
Satisfies: Communications (C)

PHYS 437
Solid State Physics
Crystal structure and binding, lattice vibrations, phonons, free electron model, band theory of electrons. Electrical, thermal, optical, and magnetic properties of solids. Superconductivity.
Prerequisite(s): PHYS 348
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 440
Computational Physics
Root finding using the Newton-Raphson method; interpolation using Cubic Splines and Least Square Fitting; solving ordinary differential equations using Runge-Kutta and partial differential equations using Finite Difference and Finite Element techniques; numerical quadrature using Simpson's Rule, Gaussian Quadrature and the Monte Carlo method; and spectral analysis using Fast Fourier Transforms. These techniques are applied to a wide range of physics problems such as finding the energy levels of a finite quantum well using a root finding technique, solving the Schrodinger equation using the Runge-Kutta-Fehlberg method, using random numbers to simulate stochastic processes such as a random walk, using the Fast Fourier Transform method to perform a spectral analysis on non-linear chaotic systems such as the Duffing oscillator, and using auto-correlation functions to simulate sonar or radar ranging problems.
Prerequisite(s): PHYS 240 and PHYS 348
Lecture: 1 **Lab:** 4 **Credits:** 3
Satisfies: Communications (C)

PHYS 460
Stellar Astrophysics
This course will cover the formation, structure, and evolution of stars. Stellar remnants (white dwarfs, neutron stars, and black holes) will also be covered. Aspects of the interstellar medium relevant to star formation will be covered as well.
Prerequisite(s): PHYS 360
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 461
Extragalactic Astrophysics
This course will cover galaxy morphology, dynamics, and structure. This course will also cover cosmology including dark matter, dark energy, and fate of the universe.
Prerequisite(s): PHYS 360
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 465
Electrical, Magnetic, and Optical Properties
Electronic structure of solids, semiconductor devices, and their fabrication. Ferroelectric and piezoelectric materials. Magnetic properties, magnetocrystalline anisotropy, magnetic materials and devices. Optical properties and their applications, generation, and use of polarized light. Same as MMAE 465.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 485
Physics Colloquium
Lectures by prominent scientists. This course exposes students to current and active research in physics both within and outside the IIT community. It helps prepare students for a career in research. It is complementary to our academic courses and provides examples of professional/scientific presentations. This course may not be used to satisfy the natural science general education requirement.
Prerequisite(s): PHYS 223 or PHYS 224
Lecture: 1 **Lab:** 0 **Credits:** 1

PHYS 491
Undergraduate Research
Recommendation of advisor and approval of the department chair. Student participation in undergraduate research, usually during the junior or senior year.
Credit: Variable
Satisfies: Communications (C)

PHYS 494
Research Project
Special research and development projects in X-ray optics, instrumentation, X-ray techniques for industrial applications, mechanical and opto-mechanical design and instrumentation, and thermal management techniques and systems.
Credit: Variable

PHYS 497
Special Topics in Physics
Special topics in physics.
Credit: Variable
Satisfies: Communications (C)

PHYS 498
Research Honors Thesis Preparation
Background and research following a summer research honors project, preparing to write a research honors thesis in Physics 499. Student will organize a review committee to direct and review the research.
Credit: Variable

PHYS 499
Research Honors Thesis
Background and laboratory research and thesis writing following a summer research project and thesis preparation. The student will meet regularly with his or her committee during thesis preparation and will write and defend thesis.
Credit: Variable

PHYS 501
Methods of Theoretical Physics I
Vector analysis including curvilinear coordinates. Tensor algebra. Ordinary differential equations. Method of infinite series. Regular singularities, Frobenius method. First look at special functions. Gamma-, beta-, error functions. Airy function. Fourier series. Hilbert space, its basic properties. Sturm-Liouville theory. Orthogonal polynomials. Legendre, associated Legendre, Hermite, Laguerre etc. polynomials. Bessel functions, their properties, basic applications. Partial differential equations, their classification. Boundary conditions. Physical models with PDE. Separation of variables method, Cartesian system of coordinates. Separation of variables in cylindrical and spherical system of coordinates. Spherical functions. Fourier transform method.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 502
Methods of Theoretical Physics II
Group theory. Discrete groups, elementary examples and properties. Lie groups, Lie algebras, generators. Their fundamental properties. Group representations. O(3), SU(2), SU(3), Lorentz groups and their applications. Complex variables: algebra, Cauchy-Riemann conditions, harmonic functions. Complex variables integrals: Cauchy theorem, Cauchy formula. Laurent series. Residues calculus: isolated singular points, poles, calculation of integrals using residues, other applications. Branches, singularities on the path of integration. Conformal mapping and its applications. Green functions. Their connection to complex variables calculus. Advanced, retarded, causal GF, application in physics. Integral equations.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 505
Electromagnetic Theory
Special relativity, its kinematics and dynamics. Lorentz transformations. 4D tensors and their algebra. Covariant formulation of electrodynamics. Electromagnetic field strength tensor, Maxwell equations. Gauge transformations and gauge invariance. Electrostatics, boundary value problems. Multipole expansion. Magnetostatics. Electric charge motion in an external electromagnetic field. Macroscopic electrodynamics. Electromagnetic waves..Dipole, quadruple and magnetodipole radiation. Light scattering, radiation damping. Optics. Electromagnetic field of a relativistic charge. Synchrotron radiation. Vavilov-Cherenkov radiation.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 508
Analytical Dynamics
Hamilton's Principle, Lagrange's formalism, function, and equations. Invariance properties and conservation laws. One dimensional motion. Central force problem. Small harmonic oscillations. Nonlinear oscillations. Scattering theory. Rigid body motion. Non-inertial reference frames. Hamilton's formalism, function, and equations. Canonical transformations. Hamilton-Jacobi theory. Integrable systems and canonical perturbation theory.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 509
Quantum Theory I
Survey of solutions to the Schrodinger Equation in one, two, and three dimensions. Hydrogen, helium, and other atoms. Spin 1/2 particles. Entangled states. EPR Paradox. Bell's Theorem. Formalism of quantum mechanics. Magnetic fields in quantum mechanics. Aharonov-Bohm Effect. Berry's Phase. Time Independent Perturbation Theory. Spin-orbit coupling. Variational method. WKB Method. Many electron wavefunction. Pauli Principle. More detailed look at excited states of helium atom. Time Dependent Perturbation Theory. Fermi's Golden Rule. Lifetime of excited atomic states.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 510
Quantum Theory II
Second quantization. Multiparticle systems. Applications of second quantization. Rotations and angular momentum. Angular momenta algebra. Group theory applications in quantum mechanics. Spin and spinors. Scattering theory. Particle in a magnetic field. Landau levels. Path integral formulation of classical and quantum mechanics. Relativistic quantum mechanics. Klein-Gordon equation. Multiparticle interpretation. Dirac equation. Gamma-matrices and their algebra. Bispinors. Gauge invariance in QM. Spontaneous symmetry breaking.
Prerequisite(s): (PHYS 405 with min. grade of C and PHYS 406 with min. grade of C) or PHYS 509 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 515
Statistical Mechanics
Ensembles and distribution functions. Classical gases and magnetic systems. Ideal Quantum Gases. Interacting systems. Real Space Renormalization group and critical phenomena. Quantum Statistical Mechanics: Superfluidity and superconductivity. Fluctuations and dissipation.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 518
General Relativity
Lorentz transformations, Minkowski space, 4D vectors and tensors, kinematics and dynamics of special relativity. Riemann geometry, Christoffel symbols, covariant derivatives, geodesics, curvature tensor, Einstein equations. Classical experiments of general relativity, Schwarzschild solution, physics of black holes. Cosmology, Big Bang theory, gravitational waves. Instructor permission required.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 520
Bio-Nanotechnology
In this multidisciplinary course, we will examine the basic science behind nanotechnology and how it has infused itself into areas of nanofabrication, biomaterials, and molecular medicine. This course will cover materials considered basic building blocks of nanodevices such as organic molecules, carbon nanotubes, and quantum dots. Top-down and bottom-up assembly processes such as thin film patterrning through advanced lithography methods, self-assembly of molecular structures, and biological systems will be discussed. Students will also learn how bionanotechnology applies to modern medicine, including diagnostics and imaging and nanoscale, as well as targeted, nanotherapy and finally nanosurgery.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 525
Applied Physics Methods for Scientists and Engineers
This is the first of a two-part course designed to provide science and engineering students with the opportunity to investigate the underlying physics principles governing a challenging real-world problem. Problems are selected by each student based on her or his background and interest from a set of topics provided by the faculty. Experimental, theoretical, numerical techniques or a combination thereof are used, as needed, to develop new or improved designs, methodologies, devices, systems, or solutions. Prerequisite: Instructor permission required.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 526
Applied Physics Case Studies for Scientists and Engineers
This is the second part of a two-part course designed to provide science and engineering students with the opportunity to investigate the underlying physics principles governing a challenging real-world problem. Problems are selected by each student, based on her or his background and interest, from a set of topics provided by the faculty. Experimental, theoretical, numerical techniques or a combination thereof are used, as needed, to develop new or improved designs, methodologies, devices, systems, or solutions. Prerequisite: Instructor permission required.
Prerequisite(s): PHYS 525 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 537
Solid State Physics I
Crystal structure and crystal binding. Free electron model of metals and semiconductors. Energy band theory. Elastic Properties. Lattice Waves, Dielectric properties.
Prerequisite(s): (PHYS 405 with min. grade of C and PHYS 406 with min. grade of C) or PHYS 509 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 538
Solid State Physics II
Higher order susceptibility, spin-orbit coupling, optical absorption, superconductivity. Properties of metals, semiconductors, and insulators. Device physics. Magnetic properties of materials.
Prerequisite(s): PHYS 510* with min. grade of C, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 539
Physical Methods of Characterization
A survey of physical methods of characterization including x-ray diffraction and fluorescence surface techniques including SEM, TEM, AES and ESCA, thermal methods and synchrotron radiation methods. Same as CHEM 509.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 545
Particle Physics I
The course is an introduction to and overview of the field of elementary particle physics. No previous exposure is assumed. The first third of the course is devoted to the symmetries of the strong interaction. The second third is a modern introduction to the gauge theories of the electromagnetic, strong, and weak interactions, and their leading evaluation via Feynman diagrams. The final third introduces topics of current and speculative research.
Prerequisite(s): PHYS 510 with min. grade of C and PHYS 509 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 546
Particle Physics II
The course is a continuation of PHYS 545, but it is self-contained. The goal is to provide a functional understanding of particle physics phenomenology of QED, QCD, and electroweak physics. Topics include QED: Spin-dependent cross sections, crossing symmetries, C/P/CP; QCD: Gluons, parton model, jets; Electroweak interactions: W, Z, and Higgs. Weak decays and production of weak bosons; Loop calculations: Running couplings, renormalization.
Prerequisite(s): PHYS 510 with min. grade of C and PHYS 509 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 550
Instrumentation for Health Physics
Detecting and measuring radioactive material and radiation levels depends upon many types of detectors and instrumentation. Theory of detectors ranging from chambers operating in pulse and current producing modes to solid state detectors is applied to measuring and monitoring systems. Electronics ranging from simple rate meters and scalers to high speed multi-channel analyzers are used. Computer-linked instrumentation and computer-based applications are applied to practical problems.
Lecture: 1 **Lab:** 4 **Credits:** 3

PHYS 553
Quantum Field Theory
Quantum field theory is a language to understand large numbers of degrees of freedom in most areas of physics such as high energy, statistical, and condensed matter physics. Topics covered include: canonical quantization of fields; path integral quantizations of scalar, Dirac, and gauge theories; symmetries and conservation laws; perturbation theory and generating functionals; regularization and renormalization.
Prerequisite(s): PHYS 510 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 561
Radiation Biophysics
Energy loss by ionizing radiation. Target theory. Direct and indirect action. Radiation effects in biomolecules. Radiation inactivation of enzymes, nucleic acids, and viruses. Biological effects of ultraviolet radiation. Photosensitization. Radiation protection and sensitization. Radiation effects in vivo, radiation therapy, and phototherapy.
Prerequisite(s): PHYS 410 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 563
Project Management: Business Principles
The course will cover a wide range of business principles highlighting project management and the components of business that employees may encounter. The goal of the course is to help the student understand basic business principles and project management skills, help the student understand the application of organizational behavior in today's workplace and equip the student to function more effectively both independently and as a team in today's organizations.
Lecture: 2 **Lab:** 0 **Credits:** 2

PHYS 566
Environmental Health Physics
Impact of ionizing radiation and radionuclides on the environment. Identifying environmental effects of specific natural and artificial nuclides. Models for deposition and transport of nuclides, including air and water disbursement. Environmental dosimetry and remediation. Facility decommissioning and decontamination.
Prerequisite(s): PHYS 572 with min. grade of C
Lecture: 2 **Lab:** 0 **Credits:** 2

PHYS 570
Introduction to Synchrotron Radiation
Production and characterization of synchrotron radiation, dynamical and kinematical diffraction, absorption and scattering processes, x-ray optics for synchrotron radiation and x-ray detectors. Overview of experimental techniques including XAFS, XPS, SAXS, WAXS, diffraction, inelastic x-ray scattering, fluorescence spectroscopy, microprobe, tomography and optical spectroscopy.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 571
Radiation Physics
Fundamentals of Radiation Physics will be presented with an emphasis on problem-solving. Topics covered are review of atomic and nuclear physics; radioactivity and radioactive decay law; and interaction of radiation with matter, including interactions of heavy and light charged particles with matter, interactions of photons with matter, and interactions of neutrons with matter.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 572
Introduction to Health Physics
Health Physics profession; Units in radiation protection; Radiation sources; Interaction of ionizing radiation with matter; Detectors for radiation protection; Biological effects of ionizing radiation; Introduction to microdosimetry; Medical health physics; Fuel cycle health physics; Power reactor health physics; University health physics; Accelerator health physics; Environmental health physics; Radiation accidents.
Prerequisite(s): PHYS 571 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 573
Standards, Statutes and Regulations
This course studies the requirements of agencies that regulate radiation hazards, their basis in law and the underlying US and international standards. An array of overlapping requirements will be examined. The effect regulatory agencies have upon the future of organizations and the consequences of noncompliance are explored.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 574
Introduction to the Nuclear Fuel Cycle
This course introduces the concept and components of the nuclear fuel cycle that originated from the mining of uranium through the production and utilization of nuclear fuel to the nuclear/radioactive waste generation and disposal. The mechanisms of normal operations through the fuel cycle process will be discussed, as well as the accidental situations, with expanded coverage on nuclear reactor issues. Emphasis will be placed on the radiological health and safety aspects of the operations. The study will also include key regulatory compliance issues.
Lecture: 2 **Lab:** 0 **Credits:** 2

PHYS 575
Case Studies in Health Physics
This is a non-instructional course designed to promote the understanding of radiation safety through lessons learned from the past incidents. The focus will be on the means for improving the future operations of the facilities/devices. The course is recommended to be among the last courses taken by students who have gained at least one year of academic exposure in health physics and with some level of capability to address the underlying technical aspects.
Prerequisite(s): PHYS 571 with min. grade of C and PHYS 573 with min. grade of C and PHYS 572 with min. grade of C
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 576
Radiation Dosimetry
This course is designed to study the science and technique of determining radiation dose and is fundamental to evaluating radiation hazards and risks to humans. This course covers both external dosimetry for radiation sources that are outside the human body and internal dosimetry for intake of radioactive materials into the human body. Topics will include: dosimetry recommendations of ICRP for occupational exposure; US NRC and DOE requirements for particular work environments; and MIRD methodology for medical use of radionuclides.
Prerequisite(s): PHYS 571* with min. grade of C and PHYS 572* with min. grade of C, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 577
Operational Health Physics
Covers the basic principles for establishing and maintaining an effective institutional radiation safety program including the following: facility design criteria; organizational management issues; training; internal and external radiation control; radioactive waste disposal; environmental monitoring; radiation safety instrumentation; ALARA program; and emergency response planning. The course will also cover facility licensing/registration with state and federal agencies and legal issues such as institutional and individual liability, fines, violations, and worker rights and responsibilities.
Lecture: 2 **Lab:** 0 **Credits:** 2

PHYS 578
Medical Health Physics
Medical Health Physics (MHP) profession; sources of radiation in the medical environment; radioisotopes in nuclear medicine; diagnostic use of X-rays (radiography, mammography, CT, fluoroscopy); therapeutic use of X-ray and gamma radiation (Co-60 and LINAC based radiation therapy); radiotherapy using sealed radioisotopes (brachytherapy); radiation protection in diagnostic and interventional radiology; radiation protection in nuclear medicine; radiation protection in external beam radiotherapy; radiation protection in brachytherapy; radiation accidents in medicine.
Lecture: 2 **Lab:** 0 **Credits:** 2

PHYS 580
Introduction to Radiochemistry
This course is designed to introduce the fundamental principle of radiation science for students majoring in radiochemistry.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 581
Radiochemistry Laboratory
This laboratory-related course will offer opportunities for students to have hands-on experience in sample preparation, source preparation, and counting measurements.
Lecture: 1 **Lab:** 2 **Credits:** 3

PHYS 582
Applications of Radiochemistry
This course will provide discussion and overview of practical applications of radiochemistry. Various special topics in the following five general series of practical radiochemistry will be offered. Each series covers different topics related to that particular discipline. 1. Actinide Chemistry Series 2. Environmental Radiochemistry/Bioassay 3. Nuclear Fuel Cycle Series 4. Nuclear Forensicsi 5. Radioelement Compounds.
Lecture: 3 **Lab:** 0 **Credits:** 3

PHYS 585
Physics Colloquium
Lectures by invited scientists in areas of physics generally not covered in the department. May be taken twice by M. S. students to fulfill course credit requirements.
Lecture: 1 **Lab:** 0 **Credits:** 1

PHYS 591
Research and Thesis M.S.
(Credit: variable)Prerequisite: Instructor permission required.
Credit: Variable

PHYS 594
Research Project
Research project.
Credit: Variable

PHYS 597
Reading and Special Problems
Independent study to meet the special needs of graduate students in department-approved graduate degree programs. Requires the written consent of the instructor. May be taken more than once. Receives a letter grade. (Credit: variable) Prerequisite: Instructor permission required.
Credit: Variable

PHYS 600
Continuation of Residence
Lecture: 0 **Lab:** 1 **Credits:** 1

PHYS 685
Physics Colloquium
Lectures by invited scientists in areas of physics generally not covered in the department. Must be taken twice by M. S. students and four times by Ph. D. students. May be substituted by PHYS 585 for M. S. students.
Lecture: 1 **Lab:** 0 **Credits:** 0

PHYS 691
Research and Thesis Ph.D.
(Credit: Variable)
Credit: Variable