

# PHYSICS (PHYS)

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## 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, quadrupole 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 patterning 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 and engineering principles governing challenging real-world problems or needs. Each student selects a topic based on her or his background and interest such as the development of novel or new scientific instruments, medical devices, consumer products, energy (conservation, transport, and storage) system, thermal management devices and systems, sustainability, etc.). Experimental, theoretical, numerical techniques or a combination thereof are used, as needed, in the development of new or improved designs, methodologies, systems, and solutions. No specific background is required other than curiosity, interest, and dedication.

**Lecture: 3 Lab: 0 Credits: 3**

**PHYS 526****Applied Physics Case Studies for Scientists and Engineers**

This is the second of a two-part course designed to provide science and engineering students with the opportunity to investigate the underlying physics and engineering principles governing challenging real-world problems or needs. Each student selects a topic based on her or his background and interest such as the development of novel or new scientific instruments, medical devices, consumer products, energy (conservation, transport, and storage) system, thermal management devices and systems, sustainability, etc.). Experimental, theoretical, numerical techniques or a combination thereof are used, as needed, in the development of new or improved designs, methodologies, systems, and solutions.

**Prerequisite(s):** PHYS 525 with min. grade of B

**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 540****Computational Accelerator Physics**

Single-particle dynamics and numerical integration; transverse and longitudinal motion; phase space distributions and ellipses; transfer map methods; periodic systems; advanced beam optics modules; magnetic fields and FEM; RF cavities; errors and resonances; symplectic integration; other topics (final presentations).

**Corequisite(s):** PHYS 505

**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****Radiation Instrumentation Laboratory**

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 scalars to high speed multi-channel analyzers are used. Computer-linked instrumentation and computer-based applications are applied to practical problems.

**Prerequisite(s):** PHYS 571 with min. grade of C

**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.

**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.

**Lecture: 2 Lab: 0 Credits: 2**

**PHYS 567****Radiological Emergency Preparedness and Response**

This course is designed to provide students an introduction of the nature of the nuclear and radiological emergencies arising from either accidents or malicious acts, and the management actions in the preparedness and response. The lecture content is to familiarize students with emergency management guidance documents. It will focus on several aspects of emergency preparedness and response. In the process it will also include the recovery from the incident.

**Lecture: 3 Lab: 0 Credits: 3**

**PHYS 568****Radiation Source Security and Management**

This course is designed to introduce radioactive sources that are currently used in all applications including defense, industry and medical areas. It will address the necessity to control and manage the licensed sources, particularly those designated by the International Atomic Energy Agency (IAEA) as Category I or II sources. The discussion will cover the potential consequences and impact of the lost sources either by lack of management or by theft. The course will also address the potential use of radioactive sources for malicious intents, such as for the radiological dispersal device (RDD, or "dirty bomb") or for the improvised nuclear device (IND).

**Lecture: 3 Lab: 0 Credits: 3**

**PHYS 569****Seminars on Radiological Emergency Field Experience**

This course will provide a series of discussions on the practical aspects in radiological emergency management by acquiring experiences from speakers representing various organizations in the emergency management community across the federal, state and local level. It is intended to provide students with valuable experiences in radiological emergency preparedness and response.

**Lecture: 3 Lab: 0 Credits: 3**

**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.

**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. This course should be taken in a student's final semester.

**Prerequisite(s):** PHYS 571 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 572 with min. grade of C

**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****Intro 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.

**Prerequisite(s):** PHYS 550 with min. grade of C

**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 Forensics 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**

Continuation of Residence.

**Lecture:** 0 **Lab:** 0 **Credits:** 0

**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