PHY 011 - Modern Physics for Poets

Culture as a function of our beliefs about space, time, boundaries, the vacuum, chaos. Principle of Relativity–reversal of conventional viewpoints. Special and General Relativity. Warped Space and Time, Topology, Escher's art. Concepts of space and time in the Middle Ages and in naive–primitive–eastern–modern art. Wavefunctions–fuzzy boundaries. Virtual and real. Superposition–Interpretation. Metamorphic Images in Surrealism. The observer (reader, spectator) as a participant in Physics (literature, art). Hypertexts. Aristotelian and Multivalued Logic. Self-Referentiality, Fractals. The Vacuum as a dynamic concept in Physics and Art. Dynamic entities in Postmodern Culture.

PHY 012 - Physics and Applications

PHY 101 - Principles of Physics

Classical Physics: Inertial Frames and Newton's Laws. Conservation of Energy and Momentum. Centre of Mass. Rotational Motion. Modern Physics: Photoelectric effect. The wave-particle character of the microscopic world. The Uncertainty Principle. Nucleus and Radioactivity. Nuclear Fission and Fusion. The Michelson-Morley Experiment. Relativity of Space and Time. The Twin Paradox. Equivalence of gravity field and accelerated frames. Gravity and Geometry.

PHY 102 – Physics for Biologists and Chemists

Mechanics: Work, energy, momentum, torque, angular momentum, oscillations, fluid mechanics. Electricity and Magnetism: Electric fields, potential, dipoles, polarization, dielectrics, electric oscillations, magnetism in matter, diamagnetism, paramagnetism, alternating current circuits, electromagnetic radiation, semiconductors. Wave Motion - Optics: Interference and diffraction of light waves, polarization of light, chemical applications of polarization and of light scattering, Bragg's Law, absorption and emission spectra.

PHY 103 - Physics for Mathematicians

Elements of Lagrangian and Hamiltonian Mechanics (and reference to Hamilton-Jacobi formulation as preparation for the passage to Quantum Mechanics). Elements of Electromagnetism / Classical Electrodynamics (Maxwell-Lorentz theory) – Introduction to the Special Theory of Relativity. Elements of Quantum Mechanics: quantum states as vectors - and observables as (self-adjoint) operators - in Hilbert spaces, position and momentum representations and Fourier transforms, physical meaning of eigenvalues and eigenstates of Hermitian operators, solution of Schrödinger equation (viewed as an ordinary or partial differential equation) in simple quantum systems – Uncertainty Principle – Ehrenfest and Hellmann-Feynman theorems – Symmetries and Generators, gauge symmetry (and some of its nontrivial consequences).

PHY 109 - From Microscopic to Macroscopic Length Scales

Physics at different length scales, dimensional analysis, concepts of quanta and relativity, elementary particles, atoms and molecules, biological physics, nanomaterials, condensed matter physics, optical physics, cosmology and astrophysics, applied physics, physics and computers.

PHY 111 - General Physics I

Measurement Units, Dimensional Analysis, Vectors. Motion in one and more dimensions, Velocity and Acceleration, Reference Frames. Forces, Newton's Laws. Work, Mechanical Energy. Momentum, Centre of Mass. Torque, Angular Momentum, Moment of Inertia. Oscillations. Universal Gravitation, Kepler's Laws. Fluid Mechanics.

PHY 112 - General Physics II

The meaning of electric charge. Coulomb's law. Definition of the electric field. Computation of the electric field of discrete and continuous charge distributions. The meaning of dipole moment. Electric field of a dipole. Torque of an electric dipole in an external electric field. Gauss' law. Electric Fields and Matter. Charging and polarization of insulators and conductors. Electric potential energy and electrostatic potential. Electrostatic potential difference. The meaning of capacitance. Computation of equivalent capacitance for capacitors in serial, parallel or composite connectivities. Energy stored in a charged capacitor. Capacitors with dielectrics. Electric field and current in a conductor. Microscopic model of current. The meaning of Resistance. Ohm's law. Simple circuits. Kirchhoff's rules. The RC circuit.
The magnetic field. Detection of magnetic fields. Magnetic force on a moving charge and a current-carrying wire. Magnetic dipole moment. Torque on a current loop in a uniform magnetic field. Motion of a charge particle in a uniform magnetic field. The Hall effect. Biot-Savart Law. Ampere's law. The magnetic field of simple current distributions. Magnetic flux and Gauss' law in Magnetism. Displacement current and the general form of Ampere's law. The law of Faraday and motional EMF. Induced EMF and electric fields. Generators and motors. Maxwell's equations. Electromagnetic waves. Self induction and mutual induction. The LC and RLC circuit.

PHY 113 - Modern Physics

Special Relativity: Reference frames, Michelson-Morley experiment, postulates of relativity, simultaneity, time dilation, length contraction, Lorentz transformations, causality, the geometry of spacetime, four-vectors, velocity and acceleration transformations, relativistic paradoxes, Doppler effect, relativistic momentum and energy and their transformations, relativistic collisions. General Relativity: principle of equivalence, curved path of light, warped space and time, black holes. Quantum theory of light: black body radiation, photoelectric effect, Compton effect, wave-particle duality. Atomic nature of matter, the atom of Bohr, De Broglie matter waves, Heisenberg's principle of indeterminacy, quantum diffraction.

PHY 114 - Physics Laboratory I

1. Introduction to Data and Error Analysis (2 Weeks) Experimental measurement, significant figures, experimental uncertainties and propagation of uncertainties, normal distribution, the least square method, graphical plots, (semi)-logarithmic paper, histogram 2. Experimental Exercises (10 Weeks) -Simple pendulum -Collisions in one and two dimensions -Free fall -Projectile motion -Linear motion with constant acceleration -Conservation of energy -Circular motion -Moment of inertia of various rigid bodies -The gyroscope -Aerodynamics of rigid bodies 3. Week of practice and make-up experiments.

PHY 115 - Physics Laboratory II

An introductory lecture and 10 different experimental exercises from the fields of Electricity, Magnetism, Circuits, Kinetic Theory of Gases and Thermodynamics. The exercises include: 1. Maxwell Distribution of Velocities 2. Heat Capacity of Gases 3. Electrolysis 4. Measuring the Magnetic Field of the Earth 5. Charging of Capacitors 6. Measurement of Magnetic Fields 7. Magnetic Moment 8. Magnetic Induction 9. RLC Circuits 10. Radiation – Stephan Boltzmann Law.

PHY 131 - General Physics I: Mechanics and Waves and Thermodynamics

(For the Department of Electrical and Computer Engineering)

Measurement Units, Coordinate Systems. Motion in one and more dimensions, Velocity, Acceleration, Reference frames. Forces, Newton's Laws. Work, Mechanical energy. Momentum, Center of mass. Torque, Angular Momentum, Moment of Inertia. Oscillations. Universal Gravitation, Kepler's Laws. Wave equation, Transverse and Longitudinal waves. Phase and Group velocity. Thermodynamics. Heat and the First and Second Law, Engines, Refrigerators and Entropy, Blackbody Radiation, Planck's Quantum Hypothesis, Photoelectric Effect.

PHY 132 – General Physics II: Electricity, Electromagnetism and Optics

(For the Department of Electrical and Computer Engineering)

Electricity and Electromagnetism: Electric Fields. Gauss' Law. Electric Potential. Capacitance and Dielectrics. Current and Resistance. Magnetic Fields. Sources of Magnetic Field. Faraday's Law. Induction and Motors. Electromagnetic Waves, Doppler Effect for sound and light. Optics: Geometrical Optics, Haygen's and Fermat's principle, Optical Instruments. Interference, Young's Experiment, Michelson's Interferometer, Multiple Beam Interference, Rayleigh's Resolution Criterion, Fraunhofer Diffraction, Diffraction Grading, Bragg's Law, Polarization, Malu's Law, Double Refraction, Production of circularly polarized light.

PHY 134 - Physics for Engineers

(For the Department of Civil Engineering)

Introduction to Thermodynamics: Temperature, Thermal Dilation, Heat and Mechanisms of Heat Propagation, Internal Energy, First Thermodynamic Law. Ideal Gases: Law, Thermodynamic Processes, Internal Energy, Heat Capacity. Kinematics: Instantaneous and Average Velocity-Acceleration, Projectile Motion. Newton's Laws and Applications, Friction, Drag, Circular-Relative Motion. Kinetic-Potential Energy, Work, Principle of Energy Conservation. Linear Momentum and Momentum Conservation, Collisions, Center of Mass. Dynamics of Rotational Motion: Angular Velocity-Acceleration, Angular Momentum and Angular Momentum Conservation. Periodical Motion: Harmonic Oscillator, Equations and Energy, Simple and Natural Pendulum. Mechanical Waves: Mathematical Description, Wave Velocity-Acceleration-Energy.

PHY 137 - Physics for the Medical School

Elements of Mechanics (Newton's laws; Forces and Translational Equilibrium; Torques and Rotational Equilibrium; Work and Energy; Collisions; Elements of Elasticity Theory; Statics, Kinematics, and Mechanical Properties of the Human Body). Fluids (Pressure and Density; Principles of Archimedes and Pascal; Continuity equation; Bernoulli Equation; Viscosity and Poiseuille Flow; Pressure and flow of Blood in the Human Body). Harmonic Motion and Waves (Properties of Sound; Doppler Effect; Ultrasounds; the Human Ear and Hearing). Elements of Electricity (Insulators and Conductors; Coulomb Law; Electric Field; Electric Potential; Capacity; Dielectrics; Electric Current and Ohm's Law; Nerve Conduction; ECG); Geometrical Optics (Index of refraction; Mirrors; Diffraction; Snell's law; The Lens Equation; the Camera; the Magnifying Glass; the Microscope; the Human Eye; Vision-correcting Lenses).Elements of Nuclear Physics (Nuclear Forces; Radioactivity; α, β, γ Decay; Interaction of Radiation with Matter; Dosimetry). Medical Applications of Molecular Biophysics (Relation between Structure and Dynamics of Macromolecules; Applications in Drug Design.

PHY 140 - Introduction to Scientific Computing

Introduction to the Linux operating system, Emacs editor, computer implementation of numbers. • Introduction to shell commands and simple script writing. • Introdiuction to the commands of the Python programming languages. • Construction of simple programs • File input and output • Control statements to loops and decisions • Introduction to Functions • Importing and using Python modules, mathematical functions, graphs • Use methods to structure the algorithmic aspects of programs • Key concepts of Object Oriented programming • Analysis of problem statements to produce simple OO designs • Data types through classes declaration • Building collections of data within a program • Use of exceptions and exceptions handling for robustness • Ways to debug a program • Use of packages for scientifc programming and visalisation • Writing simple graphical applications to visualize experimental results and physics problem cases.

PHY 145 - Computational Methods in Physics

Introduction:The Linux operating system, Emacs editor, plotting, computer implementation of numbers, basic commands of the Python/C/Fortran programming languages. Ordinary differential equations: Numerical differentiation, Euler method, Runge-Kutta method. Applications to simple physical systems: planetary orbits, electronic circuits. Algebraic equations: Bisection method, Newton-Raphson algorithm. Systems of linear equations:

Inverse matrices, matrix diagonalization. Applications in Classical Mechanics. Data analysis: Probability distributions, least squares method, fits. Numerical integration: Simpson method, Gaussian quadrature, multiple integrals in Physics. Deterministic randomness: Random number generators, simple simulations, Monte Carlo evaluation of integrals. High level programming languages: Introduction to the program Mathematica, symbolic computations, numerical and analytical evaluations of integrals and equations. Applications in Physics.

PHY 210 - Thermal Physics

Classification of systems. Intensive and Extensive variables. Reversible and irreversible processes. The concept of temperature. The 0th and 1st Laws of Thermodynamics. The Carnot cycle and the thermodynamic definition of entropy. The 2nd Law of Thermodynamics. Alternative formulations and their equivalency. Thermodynamic potentials (Availability, Helmholtz Free Energy, Enthalpy, Gibbs Free Energy, the Grand Potential). Thermal engines. The equation of Euler and the Gibbs-Duhem relation. The Clausius-Clapeyron equation. Maxwell relations and thermodynamic inequalities. The 3rd Law of Thermodynamics.

PHY 211 - Classical Mechanics

Inertial Frames of Reference and Generalized Coordinates, Newtonian Mechanics, Lagrangian Formalism, Conservation Laws, Motion in a Central Potential, Gravitational Fields, Small Amplitude Oscillations, Nonlinear Oscillations and Chaos, Scattering, Non-inertial Frames of Reference, Rigid Body Motion, Hamilton Equations.

PHY 213 - General Physics III

Wave Equation, Transverse and longitudinal waves, Phase and group velocity, Electromagnetic waves, Doppler effect for sound and light, Geometrical optics, Huygen's and Fermat's principle, Optical instruments, Interference, Young's experiment, Michelson's interferometer, Michelson's and Morley's experiment, Multiple-beam interference, Rayleigh's resolution criterion, Fraunhofer diffraction, Diffraction grating, Bragg's law, Polarization, Malus' law, Brewster's law, Double refraction, Production of circular polarized light.

PHY 216 - Physics Laboratory III

Introductory experiment: understanding the use of an oscilloscope for visualizing and analysis signals 1. Wave oscillations in strings / Standing waves in springs 2. Propagation and Doppler effect of ultrasound waves in air 3. Thin lenses laws-Geometrical Optics 4. Measurement of the speed of light 5. Fraunhofer diffraction 6. Prism and Diffraction spectrometers 7. Thin film interference 8. Michelson Interferometer 9. Polarization of light - Malus law 10. Polarization by reflection – Fresnel laws.

PHY 221 - Mathematical Methods of Physics I

Vector Calculus and Applications: Multiple integrals, Line and surface integrals. Gradient, divergence, curl. The theorems of Green, Gauss, Stokes. Applications in the mechanics of rigid bodies, Hydrodynamics and Electromagnetism. Systems with axial and spherical symmetry. Fourier Series: Fourier series and integrals. Convergence criteria. Applications in wave mechanics. Orthogonal functions in Electrostatics and in Quantum Mechanics. Applications of Ordinary Differential Equations in Mechanics, Electromagnetism, Quantum Mechanics: Classification. Existence and uniqueness of solutions. Physical systems with linear, nonlinear and chaotic behavior. Conservative systems, driving forces. Analytic methods for solving second order equations. Systems of equations. Power series solutions. Laplace transform. The Dirac function.

PHY 222 - Mathematical Methods of Physics II

Boundary value problems for ordinary and Partial Differential Equations (PDEs), Sturm-Liouville Theory, Self-adjoint Boundary Conditions. Separation of Variables in the Wave, Heat, the Schrödinger and the Laplace Equations, Bessel Functions, Legendre Polynomials, Spherical Harmonics. Continuous Sets of Eigenfunctions, the Dirac δ-function, the Heaviside θ-function, Concept and Use of Propagator. Green's Functions, Poisson Equation, Inhomogeneous Helmholtz Equation, Quantum Scattering and Born Series. Finite Regions and the Method of Images. Minimal substitution in Schrödinger's equation and application to the Physics of Landau Levels.

PHY 225 - Quantum Mechanics I

Schrödinger's Equation and the Wavefunction. The Statistical Interpretation, Wavefunction Normalization, Position/Momentum Operators, the Hamiltonian. The Heisenberg Uncertainty Principle. Stationary States. Solutions of Schrödinger's Equation for the following One-dimensional Potentials: Infinite Square Well, Harmonic Oscillator, Free particle, Delta Function Potential, Finite Square Well. The Formalism of Quantum Mechanics, Hilbert space. Operators and Commutation Relations. Generalized Statistical Interpretation and Uncertainty Relations. Angular Momentum and Three-Dimensional Potentials.

PHY 231 - Electromagnetism I

Mathematical introduction: Gradient, Divergence and Curl theorems. Electrostatics: Electrostatic field, potential, work and energy. Conductors. Mathematical techniques for the solution of electrostatic potentials and applications. Electrostatic fields in matter: The polarization and the displacement fields. Linear dielectrics. Magnetostatics: Magnetic field, Lorentz force, Biot-Savart law, Magnetic vector potential. Magnetostatic fields in materials: Magnetization and the H field. Electrodynamics: Electromotive force, Faraday's law. Maxwell equations.

PHY 235 - Electromagnetism II - Special Theory of Relativity

Electromagnetic (E/M) Waves: *Waves in one dimension (wave equation, sinusoidal waves, boundary conditions, reflection and transmission, polarization). E/M waves in vacuum (the wave equation for E and B monochromatic plane waves, energy and momentum in E/M waves). E/M waves in matter (propagation in linear media, reflection and transmission). Absorption and dispersion (E/M waves in conductors, reflection at a conducting surface, the frequency dependence of permittivity). Guided waves (waveguides, EH waves in a rectangular waveguide, the coaxial transmission line).* ***Potential and fields:*** *The potential formulation (scalar and vector potentials, Gauge transformations, the Coulomb and Lorentz gauge). Retarded and advanced potentials. Lienard-Wiechert potentials. The fields of a moving point charge.* ***Electromagnetic radiation:*** *Dipole radiation (electric and magnetic dipole radiation, radiation from an arbitrary source, power radiated by point charge, radiation reaction).* ***Electrodynamics and relativity:*** *The special theory of relativity (Einstein's postulates, the geometry of relativity, the Lorentz transformations, the structure of space-time, applications). Relativistic mechanics (proper time and proper velocity, relativistic energy and momentum, relativistic kinematics, relativistic dynamics, applications). Relativistic electrodynamics (the transformation of the fields, the field tensor, electrodynamics in tensor notation, relativistic potentials).*

PHY 301 - Solid State Physics

Crystal Structure, Crystal Lattice and Reciprocal Lattice • Bragg and Laue Equations, X-ray Diffraction from Crystals • Crystal Bonds, Madelung Energy • Crystal Vibrations, Phonons • Specific Heat of Solids, Einstein and Debye Models, Thermal Conductivity • Free Electron Gas, Electrical Conductivity, Classical Hall Effect • Energy Band Theory, Theorem Bloch • Semiconductors: Energy gap, Holes, Effective Mass, Impurity Conductivity • Propagation of Electromagnetic Waves in Crystals, Optical Constants, Absorption, Excitons, Luminescence • Electrons in High Magnetic Fields, Landau Levels, Quantum Hall Effect. • Phenomenology of Superconductivity, Meissner Effect.

PHY 302 - Junior Physics Laboratory I

The course consists of the following experiments: 1. Energy gap of Silicon - Determination of the silicon energy gap using optical spectroscopy. 2. Identify the properties of a focused laser beam with a micron spatial resolution using a lock amplifier technique. 3. Determine the emission from various light emitting diodes using a grating to resolve its spectral content. 4. Measurement of optical coupling in single-mode optical fiber using a He-Ne laser free space coupling. 5. Michelson interferometer and measurements of optical properties in the material. 6. Electrical conduction and Hall phenomena in Germanium. 7. Photovoltaic phenomena and measurements of the performance of monocrystalline and polycrystalline silicon solar cells 8. Hall Effects on Cu and Zn. 9. The study of photoelectric phenomena and the determination of the Planck constant. 10. The study of X-ray diffraction and the determination of the Planck constant using the Bragg dispersion from crystalline NaCl. 11. The study of electromagnetic phenomena in the microwave area of the spectrum. 12. Study of semiconductor devices and transistors using various electrical circuits.

PHY 321 - Nuclear Physics

1. Introduction 2. Rutherford atomic model and scattering cross sections 3. Collisions particle kinematics 4. Properties of atomic nuclei – nuclear radii and masses 5. Nuclear *reactions and their kinematics 6. Radioactivity and radioactive chain decays 7. Alpha decay 8. Beta decay 9. Gamma decay 10. Nuclear fission, nuclear fusion and applications 11. Elements of "big bang" cosmology and nuclear astrophysics 12. Nuclear models.*

PHY 322 - Junior Physics Laboratory II

Introduction: 1.1 Gauss and Poisson Distributions 1.2 Least Squares Method 1.3 Interaction of Charged Particles with Matter 1.4 Basic Nuclear Electronics Experiments: 2.1 Measurement of the Specific Charge of the Electron 2.2 Observation of the Zeeman Effect 2.3 Electron Spin Resonance 2.4 The Compton Effect 2.5 X-Ray Fluorescence and Moseley´s Law 2.6 Rutherford Scattering 2.7 Spectroscopy of α-Particles 2.8 Spectroscopy of β-Particles 2.9 Spectroscopy of γ-Rays 2.10 The Geiger-Müller Counter.

PHY 326 - Quantum Mechanics II

The Hydrogen Atom, Angular Momentum and Spin, Addition of Angular Momenta, Identical Particles, The Periodic Table, Time Independent Perturbation Theory, The Variational Method, Time Dependent Perturbation Theory, Zeeman and Stark Effects, Radiation, Einstein Coefficients, The Aharonov-Bohm Effect, Measurement Theory, Basic Principles of Atomic Physics, Modern Developments.

PHY 331 - Particle Physics

B*rief historical background, particles of matter and fundamental interactions. The Standard Model, particle lifetime and decays, processes and cross- sections. Interactions of particles and radiation with matter, particle detectors and accelerator systems. Applications of Particle Physics in Medicine, Technology and Industry. Symmetries, quantum numbers and conservation laws. Symmetry violations, local gauge transformations, Quantum Electrodynamics. Introduction to Feynman diagrams, electromagnetic interactions and coupling constant. Weak Interactions, charged and neutral currents, the π, μ and τ- lepton decays. The CKM matrix. Quantum Chromodynamics, asymptotic freedom and confinement. The parton model, e+e- scattering to hadrons. Scattering of e/p, deep inelastic scattering and the hadron quark model. Isospin and parton structure functions. Properties of intermediate Vector Bosons, Electroweak Theory. Spontaneous symmetry breaking, the Higgs Mechanism and the discovery of the Higgs boson. Neutrino masses and oscillations. CP violation and recent experimental results. Problems of the Standard Model and the need for physics beyond the Standard Model.*

PHY 341 - Electronics

DC and AC circuits. Semiconductors and applications to circuits. PN junction diodes, Bipolar transistors, Field-effect transistors, operational amplifiers. In parallel with these lectures there are associated experiments in the above areas, giving the student hands-on experience with electronics.

PHY 342 - Statistical Physics and Thermodynamics

The concept of phase space. The statistical mechanical definition of entropy. Microcanonical ensemble and examples (two-level system,classical and quantum ideal gas, classical and quantum harmonic oscillator). Canonical ensemble (derivation of the Boltzmann factor, relation between partition function and thermodynamic quantities, classical ideal gas, classical harmonic oscillator, the equipartition theorem, paramagnetism, rotational partition function. The grand-canonical ensemble. Derivation of the mean occupation number in Bose-Einstein, Fermi-Dirac statistics. The quantum ideal gas. Applications of Fermi-Dirac and Bose-Einstein statistics (Einstein and Debye models for the heat capacity of solids,the photon gas, free electrons in metals, white dwarves, Bose-Einstein condensation.) Ising model in one dimension.

PHY 347 - Computational Physics

A C++ based computational physics course covering topics such as solving problems in linear algebra, finding of eigenvectors and eigenvalues, solutions of ordinary and partial differential equations, methods for chaotic and stochastic situations, use of Markov chains, Monte Carlo simulations with applications in physics, Metropolis algorithm and applications in physics problems, random walks and the 2-D Ising model, fitting techniques with and without constraints.

PHY 350 - Advanced Physics Laboratory

A selection of the following experiments in modern optics, material, condensed matter, high energy and particle physics: 1. LabView programming for interfacing programming 2. FPGA programming 3. Quantum cryptography 4. Quantum Eraser/Interference 5. Optical tweezers 6. Atomic force microscope 7. Optical tunneling microscope 8. Magneto optic phenomena (Kerr effect) 9. Fizeau – measurement of speed of light 10. Measurement of Muon lifetime 11. Measurement of dE/dx.

PHY 351 - Research in Physics

There is no specific content – for every seminar, the content is determined by the faculty member who gives the talk.

PHY 361 - Principles and Practice of Physics

Selected Topics from: Mechanics and Thermodynamics: Kinematics, Newton's Laws and Momentum Conservation, Energy forms and Energy Conservation, Rigid Body Motion and Angular Momentum conservation, Gravity, Oscillations, Reference Frames and Elements of Relativity, Elements of Thermodynamics.Electromagnetism: Electric Fields, Electric Potential, Circuits, Magnetic Fields, Induction, alternating currents, Maxwell's Equations, Electromagnetic waves.Waves and Optics: Classification and characteristics of waves, the wave equation, wave interference and diffraction, nature and propagation of sound, sound sources, nature and propagation of light, geometric optics and optical instruments, interference and diffraction.

PHY 405 - Cosmology and General Theory of Relativity

Observations leading to General Relativity. Phenomena studied by Cosmology. Spacetime in General Relativity. Geodesics and gravitational potential. Stress-energy tensor. Riemann curvature tensor. Einstein equations. The Schwarzschild solution. Classic tests of General Relativity: Calculation and experimental verification. Black holes: Schwarzschild, Kerr. Their thermodynamics, evaporation. Observations. Gravitational radiation, detectors, power of gravitational radiation. The expanding Universe. Robertson-Walker metric. Friedmann models. Event horizon. Particle horizon. Big Bang: The evidence for it. Physical processes at various stages of the Universe. Dark matter and dark energy.

PHY 415 - Biophysics

Description of the various biomolecular classes. Intra- and intermolecular interactions. The role of water. The 20 naturally occurring amino acids and their physicochemical properties. Protein primary, secondary and tertiary structure. Protein thermodynamics and folding. Importance of heteropolymeric character for the stabilization of a unique native structure. Application of the Random Energy Model in protein stability. The helix-coil transition. Examples of protein action. Hemoglobin and models of allostery. Basic elements of biomolecular modeling. Typical energy functions used in biomolecular modeling. Normal mode calculations and their application in the study of protein properties. Biomolecular dynamics simulations.
Implicit solvent models. Continuum electrostatic approximations (Poisson-Boltzmann and Generalized Born). MD-based Free-energy calculations (method of thermodynamics integration and thermodynamic perturbation). Application of implicit-solvent and MD-based free-energy methods in the study of biomolecular association).

PHY 427 - Atomic and Molecular Physics

Atomic Physics: Angular momentum and spin. The hydrogen atom. Approximate methods for the solution of the Schrodinger equation. Atomic structure and spectra. Molecular Physics: The Born-Oppenheimer approximation. The chemical bond: The H2+ molecular ion, the H2 molecule, valence-bond and molecular-orbital theories. The Hartree-Fock method. Molecular electonic structure and spectra.

PHY 435 - Theoretical Physics

Symmetries: Definition, physical consequences of symmetries, Symmetries in Classical mechanics, Symmetries in Quantum mechanics, Heisenberg equations. Classical fields: Scalar fields, Gauge invariance, electromagnetism, energy and momentum tensor. Relativistic quantum mechanics: Klein Gordon equation, Dirac equation, introduction to second quantization. Scattering theory: Green's functions, asymptotic states, potential scattering, resonances. Feynman path integrals: Classical action, transition amplitude of a non-relativistic quantum mechanical system, the propagator of a free particle, particle in a electromagnetic field, numerical simulation.

PHY 445 - Electronic Systems

Semiconductor Physics (Basic properties, energy bands and band gap, doping, carrier transport and carrier statistics, excitation/recombination).• Transport processes and devices • Bipolar junctions (p-n junction. Junction technology. Junction formation and band structure. Depletion region. Carrier transport processes. I-V curve. Junction breakdown) • Metal-Semiconductor Junctions (Junction formation and band structure. Depletion region. Schottky effect. Carrier transport processes. I-V curve. Ohmic contacts) • Optoelectronics • Optoelectronic devices (Introduction. Radiative transitions. Light emitting diodes. Laser diodes) • Photodetectors (Photodiode. Avalanche photodiode. Phototransistor) • Solar Cells (Introduction. p-n junction based solar cells. Thin film photovoltaics • Nanoelectronics - Spintronics (Introduction. Magnetic memory physics. Magnetic Sensors. Spin for future magnetic memories. Nanoparticles and their applications in biotechnology and photovoltaics).

PHY 501 - Placement to Organization