PG Syllabus (CBCS), (Effective from 2019-'20)

Programme: M.Sc. in Physics

Sl No	Course Code	Course Type	Course Details	Credit	Full Marks
SEMESTER I					
1	PHSPCOR01T	Core Theory	Mathematical Methods I	4	50
2	PHSPCOR02T	Core Theory	Classical & Relativistic Mechanics	4	50
3	PHSPCOR03T	Core Theory	Quantum Mechanics I	4	50
4	PHSPCOR04T	Core Theory	Classical Electrodynamics	4	50
5	PHSPCOR05P	Core Practical	General and Computational Lab I	4	50
6	PHSPAEC01M	AECC	Computational Ability Development	2	50
SEMESTER II					
1	PHSPCOR06T	Core Theory	Mathematical Methods II	4	50
2	PHSPCOR07T	Core Theory	Quantum Mechanics II	4	50
3	PHSPCOR08T	Core Theory	Statistical Mechanics	4	50
4	PHSPCOR09T	Core Theory	Electronic Devices & Circuits	4	50
5	PHSPCOR10P	Core Practical	General and Computational Lab II	4	50
6	PHSPSEC01M	SEC	Physics Problem Solving and Teaching Skill	2	50
SEMESTER III					
1	PHSPCOR11T	Core Theory	Atomic and Molecular Physics	4	50
2	PHSPCOR12T	Core Theory	Nuclear and Particle Physics	4	50
3	PHSPCOR13T	Core Theory	Solid State Physics I	4	50
4	PHSPCOR14T	Core Theory	Solid State Physics II	4	50
5	PHSPCOR15P	Core Practical	General and Computational Lab III	4	50
6	HSPGEC01T	GEC	Elements of Modern Physics	4	50
SEMESTER IV					
1	PHSPDSE01T	DSE Theory	(a) Condensed Matter Physics I (b) Electronics I	4	50
2	PHSPDSE02T	DSE Theory	(a) Condensed Matter Physics II (b) Electronics II	4	50
3	PHSPDSE03T	DSE Theory	(a) Astrophysics & Cosmology (b) Physics of Liquid Crystals	4	50
4	PHSPDSE04P	DSE Practical	(a) Condensed Matter Physics Lab (b) Electronics Lab	4	50
5	PHSPCOR16M	Project	Project Work	8	100
Total				**92**	**1200**

SEMESTER I

PHSPCOR01T: MTHEMATICAL METHODS I

Theory of second order linear homogeneous differential equations (8)

Singular points – regular and irregular singular points; Frobenius method; Fuch's theorem; Linear independence of solutions - Wronskian, second solution, Sturm-Liouville theory; Hermitian operators; Completeness.

Special Functions (4)

Basic properties (recurrence and orthogonality relations, series expansion) of Bessel, Legendre, Hermite and Laguerre functions

Partial differential equations (8)

Classification of second order partial differential equations- elliptic, parabolic and hyperbolic equations; Green's function; Poisson, diffusion and wave equations; Dirichlet, Neumann and Cauchy problem; Lagrange's method for first order PDE; Method of variation of parameters.

Integral transforms (6)

Fourier and Laplace transforms and their inverse transforms, Bromwich integral [use of partial fractions in calculating inverse Laplace transforms]; Transform of derivative and integral of a function; Solution of differential equations using integral transforms.

Elements of Tensors Analysis (6)

Transformation properties, metric tensor, raising and lowering of indices, contraction; Symmetric and antisymmetric tensors, Covariant differentiation.

Vector space and matrices (10)

Vector space: Axiomatic definition, linear independence, bases, dimensionality, inner product, Schwarz inequality; Gram-Schmidt orthogonalisation.

Matrices: Representation of linear transformations and change of basis; Eigenvalues and eigenvectors; Functions of a matrix; Cayley-Hamilton theorem; Commuting matrices with degenerate eigenvalues; Orthonormality of eigenvectors.

Tutorials (15)

PHSPCOR02T: CLASSICAL & RELATIVISTIC MECHANICS

An overview of the Lagrangian formalism (6)

Applications of Lagarange's equation, velocity dependent potential, Conservation theorems and Symmetry Properties, Noether's theorem, small oscillations, normal modes and frequencies.

Rigid bodies (5)

Independent coordinates, orthogonal transformations and rotations (finite and infinitesimal), Eider's theorem, Euler angles, Inertia tensor and principal axis system; Euler's equations, Heavy symmetrical top with precession and notation.

Hamilton's principle (6)

Calculus of variations; Hamilton's principle; Lagrange's equation from Hamilton's principle; Legendre transformation and Hamilton's canonical equations; Canonical equations from a variational principle; Principle of least action

Canonical transformations (6)

Generating functions; examples of canonical transformations; group property; Integral variants of Poincare; Lagrange and Poisson brackets; Infinitesimal canonical transformations; Conservation theorem in Poisson bracket formalism; Jacobi's identity; Angular momentum Poisson bracket relations.

Hamilton Jacobi theory (4)

The Hamilton Jacobi equation for Hamilton's principle function; the harmonic oscillator problem; Hamilton's characteristic function; Action angle variables

Lagrangian formulation for continuous systems (6)

Lagrangian formulation of acoustic field in gases; the Hamiltonian formulation for continuous systems; Canonical equations from a variational principle, Poisson's brackets and canonical field variables.

Classical Chaos (4)

Periodic motions and perturbations; Attractors; Chaotic trajectories and Liapunov exponents; The logistic equation.

Special theory of relativity (8)

Lorentz transformations; 4-vectors, 4-dimensional velocity and acceleration; 4-momentum and 4-force; Covariant equations of motion; Relativistic kinematics (decay and elastic scattering); Lagrangian and Hamiltonian of a relativistic particle.

Tutorials (15)

PHSPCOR03T: QUANTUM MECHANICS I

Basic Concepts (12)

Wave-packet: Gaussian wave packet: Fourier transforms; Spreading of a wave packet; Fourier Transforms of delta and sine-functions.

Coordinate and Momentum space: Coordinate and Momentum representations; x and p in these representations; Parserval's theorem. One dimensional square well potential

Eigenvalues and eigenfunctions: Momentum and parity operators; Commutativity and simultaneous eigenfunctions; Complete set of eigenfunctions; expansion of wave function in terms of a complete set.

One-dimensional problems: Square well problem (E>0)); Delta-function potential; Double-δ potential; Schrodinger, Heisenberg and interaction pictures

Operator method in Quantum Mechanics (8)

Linear vector space; Linear operators; Hilbert space; Hermitian and unitary operators; Completeness; Matrix representation, change of basis; Formulation of Quantum Mechanics in vector space language; Uncertainty principle for two arbitrary operators; One dimensional harmonic oscillator by operator method.

Three-dimensional problems (6)

Three dimensional problems in Cartesian and spherical polar coordinates, 3-D well and Fermi energy; Radial equation of free particle and 3D harmonic oscillator; Eigenvalue of a 3D harmonic oscillator by series solution; Hydrogen atom problem; Three dimensional square well.

Angular momentum (7)

Stern-Gerlach experiment for spin- 1/2 system Angular momentum algebra; Raising and lowering operators; Matrix representation for j = 1/2 and j = 1; Spin; Addition of two angular momenta - Clebsch-Gordan coefficients, examples

Approximation Methods (12)

Time independent perturbation theory: First and second order corrections to the energy eigenvalues; First order correction to the eigenvector; Degenerate perturbation theory. Application to one-electron system - Relativistic mass correction, Spin-orbit coupling (L-S and j-j), Zeeman effect and Stark effect.

Variational method: He atom as example, Exchange degeneracy; Ritz principle for excited states for Helium atom.

Tutorials (15)

PHSPCOR04T: CLASICAL ELECTRODYNAMICS

Electrostatics and Magnetostatics (6)

Scalar and vector potentials; Gauge transformations; Multipole expansion of (i) scalar potential and energy due to a static charge distribution (ii) vector potential due to a stationary current distribution. Electrostatic and magnetostatic energy. Poynting's theorem. Maxwell's stress tensor.

Radiation from time-dependent sources of charges and currents (7)

Inhomogeneous wave equations and their solutions; Radiation from localised sources and multipole expansion in the radiation zone.

Relativistic electrodynamics (11)

Equation of motion in an electromagnetic field; Electromagnetic field tensor, covariance of Maxwells equations; Maxwell's equations as equations of motion; Lorentz transformation law for the electromagnetic fields and the fields due to a point charge in uniform motion; Field invariants; Covariance of Lorentz force equation and the equation of motion of a charged particle in an electromagnetic field; The generalised momentum; Energy-momentum tensor and the conservation laws for the electromagnetic field; Relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field.

Radiation from moving point charges (12)

Lienard-Wiechert potentials; Fields due to a charge moving with uniform velocity; Fields due to an accelerated charge; Radiation at low velocity; Larmor's formula and its relativistic generalisation; Radiation when velocity (relativistic) and acceleration are parallel, Bremsstrahlung; Radiation when velocity and acceleration are perpendicular, Synchrotron radiation; Cherenkov radiation (qualitative treatment only). Thomson and Compton scattering.

Transmission Lines (6)

Transmission line equation and solution; Reection and transmission coefficient; Standing wave and standing wave ratio; Line impedance and admittance; Smith chart.

Plasma physics (6)

Definition of plasma; Its occurrence in nature; Dilute and dense plasma; Uniform but time-dependent magnetic field: Magnetic pumping; Static non-uniform magnetic field: Magnetic bottle and loss cone; MHD equations, Magnetic Reynold's number; Pinched plasma; Bennett's relation; Qualitative discussion on sausage and kink instability.

Tutorials (15)

PHSPCOR05P: GENERAL AND COMPUTATIONAL LAB I

(120 CLASS HOURS)

General Laboratory

i) Acousto-optical effect using piezo-electric crystal and determination of the velocity of ultrasonic wave in a liquid.

ii) Energy band gap of a semiconductor by four probe method.

iii) Hall coefficient of a semiconductor.

iv) Experiments with optical fiber.

v) Determination of Planck's constant

vi) e/m using Millikan Oil drop experiment

vii) Determination of Rydberg constant by studying Hydrogen/Helium spectrum.

Computational Laboratory

Programming in C: Constant and variables, data types, type definitions, control structures, std I/O, strings, functions, pointers, file handling, structure, union, dynamic memory allocation, linked list. **Application of C programming to some typical problems**

PHSPAEC01M: COMPUTATIONAL ABILITY DEVELOPMENT

(30 CLASS HOURS)

Course Outcome: To develope the ability of computer programming. Since Python is one of the most widely used language in academics and industry, a good programming skill in python will enhance the employability of the students in different research labs, IT sector and also in the field of educational content development.

► Language to be used for learning the following basic principles is Python

Constants and Variables, Controls, std I/O, data structures like list, tuple, string, directory, set, user defined functions, functions with default arguments, functions with arbitrary arguments. Lamda function, list comprehension, Class, methods (with self and also with self-other), instantiation, inheritance, operator overruling, Numpy, Scipy, Matplotlib and Sympy.

SEMESTER II

PHSPCOR06T: MATHEMATICAL METHODS II

Complex variable theory (13)

Complex numbers, triangular inequalities, Schwarz inequality, Function of a complex variable - single and multiple-valued function, limit and continuity; Differentiation - Cauchy-Riemann equations and their applications; Analytic and harmonic function; Complex integrals, Cauchy's theorem (elementary proof only), converse of Cauchy's theorem, Cauchy's Integral Formula and its corollaries; Series – Taylor and Laurent expansion; Classification of singularities; Branch point and branch cut; Residue theorem and evaluation of some typical real integrals using this theorem.

Group theory (12)

Definitions; Multiplication table; Rearrangement theorem; Subgroups and cosets; Conjugacy Classes; elements, class and factor groups; Class multiplication; Isomorphism and homomorphism; Illustrations with point symmetry groups; Group representations - faithful and unfaithful representations, reducible and irreducible representations; Schur's lemma; The great orthogonality theorem; Lie groups and Lie algebra, product representation of SU(2) and relation with angular momentum.

Numerical methods (12)

Solution of algebraic and transcendental equations (Iterative, bisection and Newton-Raphson methods), Solution of simultaneous linear equations by Matrix inversion method, Interpolation (Newton and Lagrange formulas), Numerical differentiation, Numerical Integration (Trapezoidal, Simpson and Gaussian quadrature methods), Numerical solution of ordinary differential equations (Euler and Runge-Kutta methods), Generation of random numbers and Monte-Carlo method of integration.

Data Analysis (8)

Data interpretation and analysis; Elementary probability theory, random variables, binomial, Poisson and normal distributions. Central limit theorem; Precision and accuracy, error analysis, propagation of error, Least-square curve fitting, linear and non-linear fits, Criteria for goodness of fit (chi-square test).

Tutorials (15)

PHSPCOR07T: QUANTUM MECHANICS II

WKB Approximation (3)

Quantisation rule, tunnelling through a barrier, qualitative discussion of alpha-decay

Time-dependent Perturbation Theory (6)

Time-dependent Perturbation Theory, interaction picture; Constant and harmonic perturbations; Fermi's Golden rule; Sudden and adiabatic approximations; Radiative transitions and Einstein’s A & B coefficients; Berry’s phase

Scattering theory (12)

Laboratory and centre of mass frames, differential and total scattering cross-sections, scattering amplitude; Scattering by spherically symmetric potentials; Partial wave analysis and phase shifts: Ramsauer-Townsend effect; Relation between sign of phase shift and attractive or repulsive nature of the potential; Scattering by a rigid sphere and square well; Coulomb scattering; Formal theory of scattering- Green's function in scattering theory; Lippman-Schwinger equation; Born approximation; Collisions of identical particles and its application to scattering by screened coulmb potential and excitation of atomic hydrogen atom by electron impact

Symmetries in quantum mechanics (12)

Conservation laws and degeneracy associated with symmetries; Continuous symmetries – space and time translations, rotations; rotation group, homomorphism between SU(3) and su(2); Explicit matrix representation of generators for j=1/2 and j=1; Rotation matrices; Irreducible spherical tensor operators, Wigner-Eckert theorem; Discrete symmetries – parity and time reversal

Identical particles (3)

Meaning of identity and consequences; Symmetric and antisymmetric wave functions; Slater determinant; Symmetric and antisymmetric spin wave functions of two identical particles; Collisions of identical particles

Relativistic quantum mechanics (9)

Klein-Gordon equation, Feynman-Stuckelberg interpretation of negative energy states and concept of antiparticles; Dirac equation, covariant form, adjoint equation; Plane wave solution and momentum space spinors; Spin and magnetic moment of the electron; Non-relativistic reduction; Properties of γ matrices; Normalisation and completeness of spinors. Lorentz covariance of Dirac equation; Hydrogen atom using Dirac equation.

Tutorials (15)

PHSPCOR08T: STATISTICAL MECHANICS

Introduction (6)

Objective of statistical mechanics, macrostates, phase space and ensemble, Ergodic hypothesis, postulate of equal a priori probability (PEAP) and equally of ensemble average and time average, Boltzmann,s postulate of entropy, counting the number of microstates in phase space, entropy of ideal gas, Sackur-Tetrode equation and Gibs' paradox, Liouville's Theorem

Canonical systems (4)

System in contact with a heat reservoir, expression of entropy, canonical partition function, Helmholtz free energy, fluctuation of internal energy

Grand canonical system (3)

System in contact with a particle reservoir, chemical potential, grand canonical partition function and grand potential, fluctuation of particle number, chemical potential of ideal gas

Classical non - ideal gas (4)

Mean field theory and Van der Wall's equation of state; Cluster integrals and Mayer-Ursell expansion

Quantum statistical mechanics (5)

Density Matrix; Quantum Liouville theorem; Density matrices for microcanonical, canonical and grand canonical systems; Simple examples of density matrices-one electron in a magnetic field, particle in a box; Identical particles-B-E and F-D distributions.

Ideal Bose and Fermi gas (6)

Equation of state; Bose condensation; Equation of state of ideal Fermi gas; Fermi gas at finite Temperature

Special topics (7)

Ising model: partition function for one dimensional case; Chemical equilibrium and Saha ionization formula.

Phase transition: first order and continuous, critical exponents and scaling relations. Calculation of exponents from Mean Field Theory and Landau's theory, upper critical dimension

Irreversible Thermodynamics (10)

Flux and affinity; Correlation function of uctuations; Onsager reciprocity theorem (including proof); Thermoelectric effect

Tutorials (15)

PHSPCOR09T: ELECTRONIC DEVICES AND CIRCUITS

Mechanism of Current flow in semiconductors (8)

E-K diagram- direct and indirect bandgap semiconductors, Idea of effective mass, generation and recombination mechanisms, equation of continuity; density of states, carrier concentrations in semiconductors, law of mass-action , drift and diffusion current, Einstein's relation , variation of mobility with temperature.

P-N junction (5)

Band structure, expression for contact potential, transition and diffusion capacitances; basic idea of homo junction and hetero junction, 2DEG; p-n diode current-voltage characteristics; Ebers-Moll equation (basic idea only).

Metal semiconductor junctions (6)

Schottky barriers, Rectifying contacts, Ohmic contacts; Miscellaneous semiconductor devices: Tunnel diode, Photodiode, Solar cell, LED, LDR, p-n-p-n switch, SCR, Unijunction transistor (UJT).

Field effect transistor (4)

Idea of MOS capacitor, MOSFET: working principle, characteristics, operation as a switch and as a voltage variable resistor; Short channel effect, hot channel effect, Structure and operation of CMOS.

Sequential Circuits & Memory (10)

Different type of counter like ripple, up/down, MOD counter etc; Different types of Register (SISO, SIPO, PISO, PIPO), idea of static and dynamic memory.

OPAMs and its applications (4)

Brief review of OPAMs and its applications - Amplifier, instrumentation amplifier, practical integrator and differentiator. first order active (Butterworth) low pass, high pass and band pass filter.

Microprocessor (8)

Introduction to microcomputers, Architecture of 8085 CPU, BUS timings, De-multiplexing the address and data bus, generation of control signals; writing assembly language programs: instruction set, addressing modes

Tutorials (15)

PHSPCOR10P: GENERAL AND COMPUTATIONAL LAB II

General Laboratory II

(i) Studies on SCR

(ii) Filter circuits – Passive (high pass, low pass, notch filter) and Active (high passs, low pass)

(iii) Amplitude modulation and demodulation

(iv) Design of counter using I.C. 7476/7473.

(v) Study of Shift Register using IC 7495

(vi) Study of Intel 8085 Microprocessors : Performing simple problems: Addition, Subtraction, Multiplication and Division.

Computational Laboratory II

Computer Programming (C or FORTRAN) to solve different problems on numerical methods according to the syllabus PHY21.

PHSPSEC01M : PROBLEM SOLVING AND TEACHING SKILLS

(30 Class Hours)

Course outcome: To develop skill of solving innovative problems in core areas of Physics as well as problems of inter-disciplinary nature. To train the learner develops teaching skill in Physics. The course intends to help the learner specifically prepare for taking up a professional career in Physics.

Unit 1: Problem Solving Skill 15 hours

Training of specific skills for solving advanced problems in General Physics covering core courses learnt at the UG level and PG level (1st and 2nd semesters). Standard problems as well as innovative real life problems and techniques of solving them using analytical, graphical and/ or numerical methods. Problems are to be selected from:

(i) Newtonian, Lagrangian and Hamiltonian dynamics; non linear dynamics.

(ii) Electrostatics; Magnetostatics; Maxwell's equations; Special Theory of Relativity.

(iii) Laws of thermodynamics: applications; equilibrium statistical mechanics- classical and quantum statistics; application to elementary problems in astrophysics and condensed matter physics.

(iv) Early quantum theory; non-relativistic quantum mechanics of simple systems: eigenvalue and eigenfunction calculation in bound state problems; applications; application of approximate methods like WKB, Perturbation theories, Variational techniques; applications of scattering theories.

(v) Graph drawing; real analysis; constrained maximization; calculus of variation; complex analysis; differential equations; special functions in mathematical physics; integral transforms; vector analysis and linear algebra; numerical solution of algebraic equations; curve fitting; error analysis.

(vi) X-ray diffraction and crystal structure of solids; free electron theory of metals; energy bands in solids; electrical and optical properties of solids; magnetism; superconductivity. (vii) Phenomenology of nuclear structure; liquid drop and shell models of nuclei; nuclear reactions.

Note: *Emphasis is to be given on application of basic theory/ formulae to given problems rather than memorizing them.*

Unit 2: Teaching Skill 15 hours

Micro-teaching by students on topics selected from the following broad areas:

(i) Classical Mechanics

(ii) Classical Electromanetism

(iii) Thermodynamics and Statistical Mechanics

(iv) Modern Physics including Quantum Theory

(v) Mathematical Methods of Physics

SEMESTER III

PHSPCOR11T: ATOMIC & MOLECULAR PHYSICS

One Electron Atom (2)

Review of the theory of one-electron atom; Atomic orbital; Parity of the wave function; Angular and radial distribution functions.

Interaction of Radiation with Matter (5)

Review of time dependent perturbation theory; Coupling of two discrete states via sinusoidal perturbation- the resonance phenomenon; Interaction of an atom with electromagnetic wave; Selection rule for dipole (E1) transition in one-electron atom; Transition rate

Fine & Hyperfine Structure (8)

Qualitative idea of the solution of Dirac equation for atomic Hydrogen; Fine structure corrections of hydrogen spectra; Elementary treatment on Hyperfine structure and isotope shift; Selection rule for electric quadrupole (E2) and magnetic dipole (M1) transitions; Concepts of QED effect and Lamb shift.

Interaction of electric and magnetic field with atom (5)

Stark effect; Zeeman effect; Paschen Bach effect

Two-Electron Atom (5)

Pauli exclusion principle and exchange degeneracy; Spin wave functions for two-electron atom; The independent particle model; Perturbation and variational calculation for ground state of helium; Spectroscopic terms; Energy level diagram; Singly and doubly excited states; Auger effect.

Many Electron Atom (5)

Central field approximation for many electron atoms with special reference to helium atom; Slater determinant: L-S and j-j coupling; Hunds rule; Lande interval rule; Alkali spectra; Concept of Self consistent field and Hartree-Fock theory.

Molecular Electronic State (10)

Concept of molecular potential, Separation of electronic and nuclear wave functions, Born-Oppenheimer approximation, Electronic states of diatomic molecules, Electronic angular momenta, Approximation methods for the calculation of electronic Wave function. The LCAO approach, MO theory for hydrogen molecular ion; Heitler-London theory of molecular hydrogen; Symmetries of electronic wave functions, Shapes of molecular orbital: π and σ bond; Term symbol for simple molecules.

Spectra of Diatomic Molecules (8)

vibration-rotation spectra: Pure vibrational transitions, Pure rotational transitions, vibration-rotation transitions, Electronic transitions: Structure, Franck-Condon principle, Raman effect, Molecular Polarizability, Pure rotational Raman Spectra of Diatomic molecules, Vibrational Rotational Raman Spectrum of diatomic Molecule.

Laser Physics (8)

Basic elements of a laser; Threshold condition; Four-level laser system, CW operation of laser; Critical pumping rate; Population inversion and photon number in the cavity around the threshold; Output coupling of laser power.

Tutorials (10)

PHSPCOR12T: NUCLEAR AND PARTICLE PHYSICS

Nuclear Properties (4)

Basic nuclear properties: nuclear size, Rutherford scattering, nuclear radius and charge distribution nuclear form factor, mass and binding enemy. Angular momentum, parity and symmetry, Magnetic dipole moment and electric quadrupole moment, experimental determination, Rabi's method

Two-body bound state (4)

Properties of deuteron, Schrodinger equation and its solution for ground state of deuteron, rms radius, spin dependence of nuclear forces, electromagnetic moment and magnetic dipole moment of deuteron and the necessity of tensor forces.

Two-body scattering (7)

Experimental n-p scattering data, Partial wave analysis and phase shifts, scattering length, magnitude of scattering length and strength of scattering, Significance of the sign of scattering length; Scattering from molecular hydrogen and determination of singlet and triplet scattering lengths, effective range theory, low energy p-p scattering, Nature of nuclear forces: charge independence, charge symmetry and iso-spin invariance of nuclear forces.

β-decay (4)

β emission and electron capture, Fermi's theory of allowed β decay, Selection rules for Fermi and Gamow-Teller transitions, Parity non-conservation and Wu's experiment.

Nuclear Structure (7)

Liquid drop model, Bethe-Weizsacker binding enetgy/mass formula, Fermi model, Shell model and Collective model

Nuclear Reactions and Fission (10)

Different types of reactions, Quantum mechanical theory, Resonance scattering and reactions – Breit-Wigner dispersion relation; Compound nucleus formation and break-up, Statistical theory of nuclear reactions and evaporation probability, Optical model; Principle of detailed balance, Transfer reaction, Nuclear fission: Experimental features, spontaneous fission, liquid drop model, barrier penetration, statistical model, Super-heavy nuclei.

Particlc Physics (10)

Symmetries and conservation laws, Hadron classification by isospin amid hypercharge, SU(2) and SU(3) Groups, algebras and generators; Young tableaux rules for SU(2) and SU(3) Quarks; Colour: elementary ideas of electroweak interactions and standard model.

Tutorials (15)

PHSPCOR13T: SOLID STATE PHYSICS I

Crystal structure (12)

Bravais lattice - primitive vectors, primitive unit cell, conventional unit cell, Wigner-Seitz cell; Symmetry operations and classification of 2- and 3-dimensional Bravais lattices; Crystal structures: basis, crystal class, point group and space group (I nformation only); Common crystal structures: NaCl and CsCl structure, crystals of alkali and noble metals, close-packed structure, cubic ZnS structure; Reciprocal lattice and Brillouin zone; Bragg-Laue formulation of X-ray diffraction by a crystal; Atomic and crystal structure factors; Experimental methods of X-ray diffraction: Laue, rotating crystal and powder method; Electron and neutron diffraction by crystals (qualitative discussion); Intensity of diffraction maxima; Extinctions due to lattice centering.

Band theory of solids (10)

Sommerfeld theory of electrical conductivity Bloch equation; Empty lattice band; nearly free electron bands; Band gap; Number of states in a band; Tight binding method; Effective mass of an electron in a band: concept of holes; Band structures in copper, GaAs and silicon; Classification of metal, semiconductor and insulator; topology of Fermi-surface; cyclotron resonance - de Haas - van Alphen effect; Boltzmann transport equation relaxation time approximation,.

Lattice dynamics (7)

Classical theory of lattice vibration under harmonic approximation; Vibrations of linear monatomic and diatomic lattices, acoustical and optical modes, long wavelength limits; Optical properties of ionic crystal in the infrared region; Adiabatic approximation (qualitative discussion); Normal modes and phonons; Inelastic scattering of neutron by phonon; Lattice heat capacity, models of Debye and Einstein, comparison with electronic heat capacity; Anharmonic effects in crystals - thermal expansion and thermal conductivity; Mossbauer effect.

Magnetic properties of solids (8)

Origin of magnetism; Diamagnetism: quantum theory of atomic diamagnetism; Landau diamagnetism (qualitative discussion); Paramagnetism: classical and quantum theory of paramagnetism; case of rare-earth and iron-group ions; quenching of orbital angular momentum; Van-Vleck paramagnetism and Pauli paramagnetism; Ferromagnetism: Curie-Weiss law, temperature dependence of saturated magnetisation, Heisenberg's exchange interaction, ferromagnetic domains; Ferrimagnetism and antiferromagnetism.

Superconductivity (8)

Phenomenological description of superconductivity - occurrence of superconductivity, destruction of superconductivity by magnetic field, Meissner efect; Type-I and type-II superconductors; Heat capacity, energy gap and isotope effect; Outlines of the BCS theory; Giaver tunnelling; Flux quantisation; a.c. and d.c. Josephson effect; Vortex state (qualitative discussions); High Tc superconductors (information only).

Tutorials (15)

PHSPCOR14T: SOLID STATE PHYSICS II

Dielectric properties of solids (6)

Static dielectric constant: electronic and ionic polarisation of molecules, orientational polarisation, static dielectric constant of gases; Lorentz internal field; Static dielectric constants of solids; Complex dielectric constant and dielectric losses, relaxation time; Classical theory of electronic polarisation and optical absorption; Ferroelectricity - dipole theory, case of BaTiO.

Imperfections in solids and optical properties (6)

Frenkel and Schottky defects, defects in growth of crystals; The role of dislocations in plastic deformation and crystal growth; Colour centers and photoconductivity; Luminescence and phosphors; Alloys - order-disorder phenomena, Bragg-Williams theory; Extra specific heat in alloys.

Nuclear Magnetic Resonances (4)

Nuclear magnetic resonances, Bloch equation, longitudinal and transverse relaxation time; Hyperfine field, Electron Spin Resonances

Nomaterials- growth and characterization (4)

Different form of nanostructures, idea of 2-d, 1-d and 0-d nanostructures; determination of particle size from TEM, XRD pattern and light scattering experiments;

Synthesis of nanomaterials (5)

Bottom up: Atom manipulation by SPM, Dip pen nanolithography, Cluster beam evaporation, Ion beam deposition, chemical bath deposition with capping techniques, Self assembled mono layers.

Top down: UV and electron beam lithography, Ball milling.

Physics of Nanomaterials (10)

Magnetic and electronic (band structure) of nanomaterials, density of states, 2-d electron gas in triangular well potential, subband, surface electron density; exciton, quantum size effect, electron confinement - strong and weak limit, spherical well, effect of confinement. Graphene and its electronic properties- application to Carbon nanotube.

Transport in nanostructures (4)

Semi classical and Ballistic transport, quantized conductance, Landauer formula; transport of spin- spintronic devices and applications

Single electron – phenomena and devices (3)

Coulomb blockade, single electron transistor (SET), Carbon nanotube transistors, molecular electronics,

Tutorials (15)

PHSPCOR15P: GENERAL AND COMPUTATIONAL LAB III

General Laboratory III

i) Interferometry with Michelson's interferometer
ii) Determination of Lande g factor by ESR spectroscopy
iii) Molecular absorption spectroscopy (Iodine absorption)
iv) Study of photo-conductivity of a semiconductor material
v) Franck – Hertz Experiment
vi) Experiments on He-Ne laser
vii) Characterization of p-n junction (band gap, carrier concentration)
viii) Study of solar cell.

Computational Laboratory III

A computing software (Matlab /Mathematica / Octave)- Arrays, matrices, Calculus, Plots, Functions, scripts, Curve fitting, building simple GUIs.

Application of the software to the following topics

Classical & Relativistic Mechanics: Motion with constant and variable acceleration, Free falling object, parabolic throw with and without air resistance, Simple pendulum with small and large amplitude, Parachute driving, Time dilation, Relativistic energies

Electromagnetism: Electric potentials and fields, Magnetic fields

Optics: Interference and Diffraction pattern.

Quantum Physics: Schrödinger equation: time-independent and time dependent. Variational methods. Spectral methods.

Statistical Mechanics: Random systems, Random walks and diffusion, Monte-Carlo techniques, Ising Model, Phase Transitions.

SEMESTER IV

PHSPDSE01T: (a) CONDENSED MATTER PHYSICS I

Fundamentals of many-electron system: Hartree-Fock theory (8)

The basic Hamiltonian in a solid: electronic and ionic parts, the adiabatic approximation. Single particle approximation of the many-electron system- single product and determinantal wave functions, matrix elements of one and two-particle operators; The Hartree-Fock (H-F) theory: the H-F equation, exchange interaction and exchange hole, Koopmans theorem; The occupation number representation: the many electron Hamiltonian in occupation number representation; the H-F ground state energy.

The interacting free-electron gas: Quasi electrons and Plasmon (12)

The H-F approximation of the free electron gas: exchange hole, single-particle energy levels, the ground state energy; Perturbation: theoretical calculation of the ground state energy; Correlation energy – difficulty with the second-order perturbation theoretic calculation, Wigner's result at high density, low density limit and Wigner interpolation formula; Cohesive energy in metals; Screening and Plasmons; Experimental observation of plasmons, The dielectric function of the electron gas; Friedel oscillation; Quasi-electrons; Landau's quasi-particle theory of Fermi liquid; Strongly correlated electron gas; Mott transition.

Spin-spin interaction: Magnons (9)

Absence of magnetism in classical statistics;, Origin of the exchange interaction; Direct exchange, superexchange, indirect exchange and itinerant exchange; Spin-waves in ferromagnets – magnons, spontaneous cousticalon, thermodynamics of magnons; Spin-waves in lattices with a basis – ferri and antiferromagnetism; Measurement of magnon spectrum; Ordered magnetism of valence and conduction electrons, the Hubbard Model; Stoners criterion for coustic ferromagnet; Kondo effect.

Superconductivity (8)

Electron-electron interaction via lattice: Cooper pairs; BCS theory; Bogoliubov transformation – notion of quasi particles ; Ginzburg-Landau theory and London equation Meissner effect; Type II superconductors – characteristic length; "Novel High Temperature" superconductors.

Superfluidity (5)

Basic Phenomenology; Transition and Bose-Einstein condensation; Two fluid model; Roton spectrum and specific heat calculation, Critical velocity.

Disordered systems (8)

Disorder in condensed matter – substitutional, positional and topograpfical disorder; Short- and long range order; Atomic correlation function and structural descriptions of glasses and liquids; Anderson model for random systems and electron localization; mobility edge; Qualitative application of the idea to amorphous semiconductors and hopping conduction

PHSPDSE01T: (b) ELECTRONICS I

Syllabus yet not finalized

PHSPDSE02T: (a) CONDENSED MATTER PHYSICS II

Symmetry in crystals (7)

Concepts of point group; Point groups and Bravais lattices; Crystal symmetry - space groups; Symmetry and degeneracy - crystal field splitting; Kramer's degeneracy; Quasicrystals: general idea, approximate translational and rotational symmetry of two-dimensional Penrose tiling, Frank-Casper phase in metallic glass.

Lattice dynamics (12)

Classical theory of lattice vibrations in 3-dimensions under harmonic approximation; Dispersion relation: accoustical and optical, transverse and longitudinal modes; Lattice vibrations in a monatomic simple cubic lattice; Frequency distribution function; Normal coordinates and phonons; Occupation number representation of the lattice Hamiltonian; Thermodynamics of phonons; The long wavelength limits of the acoustical and optical branches; Neutron diffraction by lattice vibrations; Debye-Waller factor; Atomic displacement and melting point; Phonon-phonon interaction - interaction Hamiltonian in occupation number representation; Thermal conductivity in insulators.

Density Functional Theory (8)

Basics of DFT, Comparison with conventional wave function approach, Hohenberg-Kohn Theorem; Kohn-Sham Equation; Thomas-Fermi approximation and beyond; Practical DFT in a many body calculation and its reliability.

Electronic properties: I (8)

The Boltzmann transport equation and relaxation time; Electrical conductivity of metals – impurity scattering, ideal resistance at high and low temperatures, U-processes; Thermo-electric effects; Thermal conductivity; The Wiedemann-Franz law.

Electronic properties: II (8)

Electronic properties in a magnetic field; Classical theory of magneto-resistance; Hall effect and magnetoresistance in two-band model; K-space analysis of electron motion in a uniform magnetic field; Idea of closed, open and extended orbits, cyclotron resonance; Azbel-Kaner resonance; Energy levels and density of states in a magnetic field; Landau diamagnetism; de Haas-van Alphen effect; Quantum Hall effect.

Optical properties of solids (7)

The dielectric function: the dielectric function for a harmonic oscillator, dielectric losses of electrons, Kramers-Kronig relations; Interaction of phonons and electrons with photons; Interband transition - direct and indirect transition; Absorption in insulators; Polaritons; One-phonon absorption; Optical properties of metals, skin effect and anomalous skin effect; Thermally stimulated processes.

PHSPDSE02T: (b) ELECTRONICS II

Syllabus yet not finalized

PHSPDSE03T: (a) ASTROPHYSICS AND COSMOLOGY

Basic Background of stellar physics (6)

Measurement of distance, mass and luminosity of stars, Apparent and absolute magnitudes. Mass-Luminosity relation, Binary stars and star clusters – open and globular, Spectral classification of stars, Saha's equation. Hertzsprung-Russell diagram,

Astrophysical Instrumentation (4)

Optical and radio telescopes, Fourier transform methods, detectors and image processing, Active and Adaptive optics, Optical and radio interferometry.

Stellar stability and energy transport (6)

Stellar structure and stability equations; hydrostatic equilibrium; Sources of stellar energy: gravitational collapse, fusion reactions (p-p chain, CNO cycle); formation of heavy elements; elementary radiative transfer equations, absorption and mission, atomic processes, continuum and line emission; stellar convection.

Evolution of Stars (5)

Protostars, disks, bipolar outfows, evolution of low-mass and high-mass stars; Chandrasekhar limit; Pulsars, Neutron stars, and Black holes.

Astroseismology (4)

Radial and nonradial oscillation of stars, Helio and Asteroseismology (Elementary idea only).

Basic galactic physics (4)

Galaxy – elliptic and spiral. Classification of galaxies. Density wave theory of galactic structure. Galactic rotation curve and Dark matter.

Elements of General Relativity (8)

Curved space-time; Eotvos experiment and the equivalence principle; Equation of geodesic; Christoffel symbols; Riemann curvature; Einstein equations; Schwarzschild geometry and black holes; FRW geometry and the expanding universe;

Λ CDM Cosmology (13)

Hubble's observation and expanding universe; Friedmann cosmology; Red shift and expansion; Big bang theory; Constituents of the universe; Dark matter and dark energy (as a nonzero cosmological constant); Early universe and decoupling; Neutrino temperature, nucleosynthesis, relative abundances of hydrogen, helium, deuterium; Radiation and matter-dominated phases; Cosmic microwave background radiation, its isotropy and anisotropy properties; COBE and WMAP experiments; CMBR anisotropy as a hint to large scale structure formation; Inflation.

PHSPDSE03T: (b) PHYSICS OF LIQUID CRYSTAL

Structure and classification of mesophases (5)

Thermotropic and Iyotropic liquid crystals, different molecular order- nematic, smectic and cholesteric phases; Recent interests in liquid crystals; X-ray analysis of unoriented and oriented liquid crystals; Measurement of nematic order parameter by NMR; Polymer liquid crystals.

Molecular theory of nematic liquid crystals (14)

Symmetry and order parameter; Molecular potential: Distribution function; Nematic-isotropic (N-1) phase transition – Maier-Saupe theory; Generalized mean field theory; The even-odd effect – Marcelja's calculation; Hard rod model of N-1 phase transition; Derivation of the Onsager equation, solution of Onsager equation in a simple case.

Molecular theory of smectic A liquid crystals (5)

Symmetry, structure and order parameter; Phase diagram of homologous series, McMillan's theory

Elastic continuum theory of liquid crystals (10)

General expression of free energy of a deformed nematic liquid crystal: Franck's elastic constants; Distortion due to external electric or magnetic field; Freederickz's transition; The twisted nematic cell.

Numerical methods for studying liquid crystal phase transition (4)

Monte-Carlo simulation; Lebhwol-Lasher simulation of N-1 transition; Gey-Berne potential.

Landau's theory of phase transition (8)

Generalization of Landau's theory to liquid crystals; Fourth order and sixth order Landau expansion for studying N-1 transition; de Gennes' Generalization to smectic phase; Critical fluctuation

Liquid crystal displays (2)

Optical properties of on ideal helix, agents influencing the pitch; Basic principle of liquid crystal displays; Advantages of liquid crystal displays; Twisted nematic crystal and cholesteric liquid crystal displays.

Discotic liquid crystals (2)

Symmetry and structure, mean field description of discotic liquid crystals

Lyotropic liquid crystals (5)

Models for different phases, biomembrane

PHSPDSE04P: (a) CONDENSED MATTER PHYSICS LAB

i) Measurement of Magnetoresistance of semiconductor

ii) Dependence of Hall coefficient on temperature

iii) To determine dielectric constant of insulating and ferroelectric materials at room and elevated temperatures

iv) Study of phase transition of ferrite

v) Measurement of magnetic susceptibility of $FeCl_3$, $MnSO_4$ by Quincke's method

vi) Dispersion relation in a periodic electrical circuit: an analog of monatomic and diatomic lattice vibration

PHSPDSE04P: (b) ELECTRONICS LAB

Syllabus yet not finalized

PHSPCOR16M: PROJECT WORK

For students to enter into preliminary research field both in theory and experiment the concept of Project has been introduced in the final Semester. In the Project the student will explore new developments from the books and journals, collecting literature / data and write a Dissertation based on his / her work and studies. The Project Work can also be based on experimental work.