Department of Physics, Presidency University

Syllabus (w. e. f. July 2017) for 2-Year 4-Semester M. Sc. Degree Programme

Sem	Paper	Code	Credit
I	Mathematical Methods (Theoretical) Classical Mechanics: Particles and Fields (Theoretical) Quantum Physics-I (Theoretical) PG-Lab I (Lab based Sessional) PG-Lab-II (Lab based Sessional)	PHYS-0701 PHYS-0702 PHYS-0703 PHYS-0791 PHYS-0792	4 4 4 4 4
II	Statistical Mechanics (Theoretical) Classical Electrodynamics (Theoretical) Condensed Matter Physics (Theoretical) PG-Lab III: Computational Techniques (Lab based Sessional) PG-Lab-IV (Lab based Sessional)	PHYS-0801 PHYS-0802 PHYS-0803 PHYS-0891 PHYS-0892	4 4 4 4 4
III	Quantum Physics-II (Theoretical) Special-I (Taught: Choice Based) A] Advanced Condensed Matter Physics-I B] Introduction to Astrophysics Special-II (Taught: Choice Based) A] Advanced Condensed Matter Physics-II B] General Relativity and Cosmology Project-I (Choice based Sessional) Project-II (Choice based Sessional)	PHYS-0901 PHYS-0902 PHYS-0903 PHYS-0991 PHYS-0992	4 4 4 4 4
IV	Elective (Theoretical: Choice Based)** A] Quantum Field Theory B] Physics of Nanostructured Materials C] Non-Linear Physics D] Atomic and Subatomic Physics E] Electronic Materials and Devices Special Lab (Lab based Sessional: Choice Based) A] Condensed Matter Physics Lab B] Astrophysics Lab Project-III (Choice based Sessional) Project-IV (Choice based Sessional) Project-V (Choice based Sessional)	PHYS-1001 PHYS-1091 PHYS-1092 PHYS-1093 PHYS-1094	4 4 4 4 4

**Not all electives will be offered every year)

PHYS-0701: Mathematical Methods (50 Lectures)

Complex Analysis [16]

Complex variables, Analytic functions, Cauchy -Riemann conditions,
Cauchy's theorem, Cauchy's integral formula, Derivatives of analytic functions, Singularities, Taylor and Laurent series, Branch points and cuts, calculus of residues, Evaluations of integrals using residue theorem, Principal value of an integral.Application of complex variables: Complex potentials, application of conformal transformations.

Differential Equations [10]

Sturm-Liouville theory; Hermitian operators; Completeness; Simple applications;
Inhomogeneous equation: Introduction to Green's functions and its application.

Integral Transforms [8]

Fourier and Laplace transforms; Transform of derivative and integral of a function; Solution of partial differential equations using integral transforms.

Group Theory [10]

Preliminaries; Isomorphism and homomorphism, group representation, Character of representation, Finite groups, Reduction of a representation, Rotation group and its applications, Permutation group, Introduction to continuous groups.

Vector Spaces [6]

Infinite dimensional spaces, examples, Cauchy sequences, completeness, Norms,
Inner products, some useful inequalities;Hilbert spaces, Applications in Physics.

PHYS-0702: Classical Mechanics: Particles and Fields (50 Lectures)

Preliminaries [10]

Variational principle and Lagrange's equations of motion – simple applications, Lagrangian for mechanical systems with dissipation and for systems subject to non-holonomic constraints, Hamiltonian formulation, Small Oscillations

Rigid Body [12]

Kinematics, Euler angles, Infinitesimal rotation, Motion of heavy symmetrical top with one point fixed, other applications.

Canonical Transformation and Hamilton-Jacobi Theory [14]

Generating function, Poisson bracket, Canonical invariants, Hamilton-Jacobi theory, Action angle variables, Kepler problem.

Continuous Systems and Fields [10]

Introduction to tensors, Lagrangian and Hamiltonian formulation for continuous systems, Symmetry and conservation principles – Noether's Theorem, Classical field theory

Nonlinear Dynamics and Classical Chaos [4]

Phase space dynamics, Stability analysis

PHYS-0703: Quantum Physics-I (50 Lectures)

Operator formalism in Quantum Mechanics [9]

Stern-Gerlach experiment, Two-level systems, Formulation of quantum mechanics in abstract space, representation of states and operators, uncertainty principle, Schroedinger and Heisenberg picture.

Quantum angular momentum [14]

Angular momentum algebra and its representations, matrix representation for j=1, spin,addition of two angular momenta, Clebsh-Gordan coefficients, examples,conservation laws and degeneracies associated to symmetries, continuous symmetries, space and time translations, rotations, rotation matrices, irreducible spherical tensor operators, Wigner-Eckart theorem, discrete symmetries, parity and time reversal.

Approximate Methods in Quantum Mechanics [22]

Time independent non degenerate perturbation theory, first order and second order corrections to the energy eigenvalues, first order correction to energy eigenfunction, degenerate perturbation theory, some applications-relativistic mass corrections of hydrogen spectra, spin-orbit coupling , Zeeman and Stark effects, Variational principle and its applications . Basic idea of WKB method, Construction of wave function, Connection formula, Some applications (e.g., tunnelling through barrier in simple cases, Simple explanation of alpha decay, Intensity of spectral lines and transition probability), Formulation of time dependent perturbation theory, Examples, transition probability, Rabi oscillations, selection rule. Fermi's golden rule, Applications

Identical particles [5]

Identical particles, symmetry under interchange, wave functions for bosons and fermions, Slater determinant, Pauli exclusion principle, 2-particle system (e.g., He atom).

PHYS-0791: PG-Lab-I

The Following Experiments are part of the lab

1. Lande G factor of DPPH using electron spin resonance spectrometer
2. Performance of high pass and low pass filters
3. Michelson's Interferometer
4. Saturation magnetization of ferromagnetic substance using hysteresis loop tracer
5. Characteristics of optical fibre

PHYS-0792: PG-Lab-II

A] Experiments

1. Muon detector
2. Noise Fundamentals
3. Fabry Perrot interferometer

B] Data Analyses and Statistical Techniques

1. Uncertainties in measurements: classification, reporting, propagation.
2. Estimates of mean and error, chi-square test.
3. Least square fit, goodness of fit, hypothesis testing.
4. Normal and Poisson distribution.
5. Plotting of data and preliminary analyses.

PHYS-0801: Statistical Mechanics (50 Lectures)

Fundamentals of Statistical Mechanics [7]

Introduction; thermalization, ergodicity, Microcanonical Ensemble; Entropy and the Second Law; Temperature; Canonical Ensemble; Energy Fluctuations; Chemical Potential; Grand Canonical Ensemble, applications.

Classical and Quantum Gas [25]

Classical Partition Functions; Ideal Gas; Equipartition; Maxwell Distribution; Diatomic Gas; Interactions; van der Waals Equation of State; Cluster Integrals and Mayer-Urshel Expansion, Density of States; Applications, Density matrix formalism, Bose-Einstein Distribution and Bose-Einstein Condensation; Fermi-Dirac Distribution and ideal Bose and Fermi Gas, Applications (e.g., Saha Equation and its application in Stellar Astrophysics, Statistical Mechanics and theory of compact objects, Cold Atoms, Boltzmann equation and early Universe Cosmology, interdisciplinary applications).

Phase transitions [18]

van der Waals equation revisited; Ising Model; Exact solution in one-dimension, Mean Field Theory; Critical Exponents; Low Temperature Expansion and Peierls Droplets; High Temperature Expansion; Landau Theory; Landau-Ginzburg Theory;

Fluctuations and Correlations; Athermal phase transition, Non-equilibrium phenomena

PHYS-0802: Classical Electrodynamics (50 lectures)

Basics
[16]

Concept of Fields - Scalar,vector and tensor fields; Maxwell's equations for electrostatics and magnetostatics: solutions : role of rotational symmetry; electrostatics - Green's functions, multipole expansions, boundary value problems; magnetostatics - Biot-Savart relation, magnetic moments, Larmor precession; action principle for test charges in electromagnetic potentials and Lorentz force equation.

Relativistic Formulation of Electrodynamics
[14]

Vacuum Maxwell equations for potentials and their symmetries; origin of special relativity and Lorentz invariance; relativistic energy and momentum,
relativistic kinematics; relativistically covariant form of Maxwell's equations for potentials: EM waves, propagation in inhomegenous media, transversality and gauge fixing issues; polarization including partial polarization, Stokes parameters, covariant form of Lorentz force equation.

Radiation
[20]

Lienard-Wiechert potentials, dipole radiator, radiated power spectrum,
multipole radiation; Scattering of electromagnetic waves, Angular distribution of radiation emitted by an accelerated charge; Total power radiated by an accelerated charge; Synchroton radiation, Radiation Reaction of point like charges and fundamental issues of classical electromagnetism.

PHYS-0803: Condensed Matter Physics (50 Lectures)

Electron States and Band Theory of Solids
[10]

Reciprocal Lattice, Brillouin Zone, Diffraction from periodic structure, Electron States in Crystals, General Properties of Bloch Functions, Boundary Conditions in a Finite Crystal. Density of States. Electron Band Calculations: The Tight Binding Approximation and Wannier Functions, The Nearly Free Electron Approximation and k.p Theory. Example of Band Structures (Si, Ge, GaAs& Zn). Fermi Surfaces. Cyclotron Resonance and Determination of Effective Masses.

Dynamics of Atoms in Crystals and Phonons
[10]

The Potential, The Harmonic Approximation, The Equation of Motion, The Dynamical Matrix, Normal Modes of a One Dimensional Monatomic Bravais Lattice, Normal Modes of a One Dimensional Monatomic Bravais Lattice with a Basis, Normal Modes of Two and Three Dimensional Monatomic Bravais Lattice. Inelastic Neutron Scattering by Phonons. The Density of States, The Thermal Energy of a

Harmonic Oscillator, Lattice Specific Heat Capacity, Anharmonic effects in Crystal: Thermal Expansion and Thermal Conductivity.

Dielectric and Optical Properties of Solids [6]

Phenomenological Theory: Maxwell's Equations, Traveling Waves, Dielectric Function of a Harmonic Oscillator, Kramers-Kronig Relations, Application to Optical Experiments. Optical Properties of Insulators: Polarization, Ferroelectrics, Berry phase theory of polarization, Clausius-Mossotti Relation, Optical Modes in Ionic Crystals, Polaritons, Polarons, Experimental Observations of Polarons. Point Defects and Color Centers, Vacancies, F- Centers.

Magnetic Properties of Solids [10]

Fundamental Concepts, Diamagnetism and Paramagnetism (Quantum Theory). The Exchange Interaction, Exchange Interaction between Free Electrons, Spontaneous Magnetization and Ferromagnetism. The Band Model of Ferromagnetism. The Temperature Behaviour of a Ferromagnet in the Band Model. Ferromagnetic Coupling for Localized electrons, Ferrimagnetism and Anti ferromagnetism. Spin Waves. Magnetic Resonance Phenomena.

Superconductivity [8]

Some fundamental Phenomena Associated with Superconductivity. Phenomenological Description by Means of the London Equation. The BCS Ground State. Consequences of the BCS Theory and Comparison with Experimental Results. Supercurrents and Critical Currents. Quantization of Magnetic Flux. Type-II Superconductors. One-Electron Tunneling in Superconductor Junctions, Cooper Pair Tunneling – The Josephson Effect, Applications

Liquid Crystals [6]

Isotropic. Nematic and Cholesteric Phases. Smectics A and –C. Hexatic Phases. Discotic Phases. Lyotropic Liquid Crystals and micro emulsions, MS theory of nematic liquid crystals.

PHYS-0891: PG-Lab III (Computational Techniques)

A] FORTRAN (or C or C++ or Python) Language [10]

Preparatory courses of writing computer programs

B] Numerical mathematical analysis [15]

Numerical (mathematical) methods for (i) Basic idea of Interpolation, Lagrange and Newton-Gregory type interpolation (ii) Derivations of the formulae for numerical differentiation (iii) Analysis of errors in different methods (iv) Derivations of the formulae for numerical Integration, Trapezoidal rule, Simpson's rule, Gauss quadrature (v) Analysis of errors (vi) Integration by statistical methods, simple sampling, intelligent sampling (vii) Systematic derivations of the numerical methods of solving ordinary differential equations, Euler method, Its modification, Runge-Kutta method, Taylor's method (viii) Method of solving partial differential equations, solution of Laplace's equation on the lattice, iteration method. (ix) Elementary idea of computer simulation, Monte Carlo techniques, Molecular dynamics, Cellular automata.

C] Assigned problems in computer laboratory [25]

(i) Interpolation by using difference table and divided difference table
(ii) Derivative by forward difference and central difference method
(iii) Integration by Gauss quadrature method
(iv) Integration by statistical method (simple and intelligent sampling)
(v) Solving ODE by Runge-Kutta and Taylor method
(vi) Solving wave equation and Laplace equation in two dimensions
(vii) Example of Monte Carlo technique
(viii) Example of Molecular dynamics
(ix) Example of cellular automata
(x) Advanced topics in Astrophysics

PHYS-0892: PG-Lab-IV

The Following Experiments are part of the lab

1. Determination of the dissociation energy and anharmonicity constant of the iodine molecule by analysing its absorption spectrum
2. Study of Zeeman pattern of the green line of mercury
3. Calibration of an AF Oscillator
4. Measuring charge to mass ratio (e/m) of electron
5. Construction of sawtooth wave generator using UJT
6. Measuring structural parameters of given helical sample using diffraction pattern
7. Velocity of ultra-sonic waves in a liquid by ultra-sonic diffraction grating
8. Kerr effect

PHYS-0901: Quantum Physics-II (50 Lectures)

Scattering theory [20]

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-Towwnsend effect; Scattering by a rigid sphere and square well; Regge poles, Coulomb scattering; Born approximation; Formal theory of scattering — Green's function in scattering theory; Lippman-Schwinger equation; Collisions of identical particles, applications

Relativistic Quantum Theory [30]

Klein-Gordon equation, Feynman-Stuckelberg interpretation of negative energy states and concept of antiparticles; Preliminaries of free quantum field theory, Canonical quantization of scalar and complex scalar fields, Feynman propagators. Dirac equation, Plane wave solution and momentum space spinors; Spin and magnetic moment of the electron; Non relativistic reduction; Helicity and chirality; Properties of γ matrices; Charge conjugation; Normalisation and completeness of spinors; Bilinear covariants and their transformation under parity and infinitesimal Lorentz transformation; Weyl representation and chirality projection operators, Quantisation of spinor fields.

PHYS-0902-A: Advanced Condensed Matter Physics-I
(50 Lectures)

Fundamentals of Many-Electron Systems: Hartree-Fock Theory [14]

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 Hatree Fock (HF)Theory. The HF Equation. Exchange Interaction and Exchange Hole, Koopmans Theorem. The Occupation Number Representation – The Many Electrons Hamiltonian in Occupation Number Representation,The HF Ground State Energy

The Interacting Free Electron Gas: Quasi Electrons and Plasmon [12]

The HF Approximation of the Free Electron Gas. Single Particle Energy Levels, the Ground state energy. Calculation of the Ground State Energy. Cohesive Energy in Metals. Screening andPlasmons. Experimental Observations of Plasmons, The Dielectric Function of the Electron Gas, Friedel Oscillations. Landau's Quasi Particle Theory of Fermi Liquid. Strongly Correlated Electron Gas, Mott Transition.

Spin and Magnetic System [14]

Overview of Magnetic Properties. The Ising Model: Zero External Magnetic Field; Spontaneous Symmetry Breaking, External Magnetic Field Hysteresis. Critical Fluctuations: Other magnetic models, Multi critical behaviour, Metamagnets, Critical Exponents and Magnetic Susceptibility,Landau Coarse Graining Theory. Renormalization Group Methods, Spin Waves and Goldstone Bosons. Spin Spin Interactions: Ferromagnetic Instability, Localized States and RKKY Exchange Interactions, Topological Phase Transition: Vortices, XY-Model. Kondo Effect: sd interaction, Spin-flip Scattering, Kondo Resonance. Hubbard Model: U=0 solution, Atomic Limit, U>0, Half-filling, Spinglass, Majumder-Ghosh chain for spin systems.

Superconductivity Phenomena [10]

Constructing Bosons from Fermions. Electron Electron Interaction via Lattice, Cooper Pairs, BCS Wave function. Excitation Spectrum of a Superconductor. Ginzburg Landau Theory andLondon Equation. Meissner Effect. TypeII Super Conductors, Characteristics Length. Josephson Effect. Novel High-Temperature Superconductors.

PHYS-0902-B: Introduction to Astrophysics (50 Lectures)

Astronomical Observations [16]

Our current understanding of the Universe (broad idea of cosmology, galaxy clusters, galaxies, stars, and planets), Astronomical distance scale (AU, light year, parsec, megaparsec) and mass scale, Refracting and reflecting telescopes, Concept of angular size and its relation to physical size, Diffraction limit, Astronomical seeing, Need for Space Telescopes, Basic observational techniques in optical, radio and high-energy (Xray/ Gamma-ray) astronomy, outlines of spectroscopic and polarimetric observations, Stellar parameters (mass, radius, temperature) from binary systems, Extrasolar planets, Continuous, emission, and absorption spectra, Formation of spectral lines, HR diagram, Main sequence.

Stellar Astrophysics [18]

Virial theorem, Hydrostatic equilibrium, Concept of Opacity, Stellar energy sources, Solar neutrino, Jeans Criterion, Interstellar medium, Formation of protostars, evolution of stars before, during and after their location on the main sequence, HII region, Stromgren Sphere, Supernovae, Stellar Pulsation, Degeneracy pressure, White dwarfs, Chandrasekhar limit, Neutron stars, Pulsars, Black holes, Close binary systems, accretion disks

Galactic Astrophysics [10]

Spiral, elliptical and irregular galaxies (rotation, spiral structure, dark matter, Faber-Jackson law), Interaction and evolution of galaxies (evolutionary relation of spirals and ellipticals), Super-massive black hole (MBH vs. M_bulge, Black hole-galaxy coevolution), Morphology, Kinematics, Galactic centre.

Extragalactic Astrophysics [6]

Galaxy clusters, Cosmic distance ladder (Parallax, Cepheid variables, Hubble’s law, Type IA supernovae), Observations of active galaxies all over the electromagnetic spectrum, Unification model, Importance in galaxy formation and evolution, Gamma-ray bursts.

PHYS-0903-A: Advanced Condensed Matter Physics-II (50 Lectures)

Interactions of Quasiparticles& Transport Phenomena in Solids[12]

Electron - Phonon Interactions: Deformation Potential Scattering, Piezoelectric Scattering, Frohlich Scattering, Peierls Transition. Electron-Phonon Effects at Defects: Jahn-Teller Effects, Electron- Photon Interactions: Optical Transitions between Semiconductor Bands, Direct &Indirect Transitions, Joint Density of States. The Boltzmann Transport Equation, The RelaxationTime Approximation. Thermal Conductivity, Electrical Conductivity and Magnetoresistance in two Band Model.

Electronic Quasi particles in Solids [8]

Quasiparticles. Two Dimensional Electron Gas. Landau Levels and Quasi articles in Magnetic Field: Density of States in Landau Levels, De Hass van Alphen and Shubnikov De Hass Oscillations, Integer Quantum Hall Effect, Fractional Quantum

Hall Effect and Higher – OrderQuasi particles.

Realistic Calculations in Solids[8]

Numerical Methods: Pseudo potentials and Orthogonalized Planes Waves (OPW), Linear Combination of Atomic Orbitals (LCAO), Plane Waves, Linear Augmented Plane Waves(LAPW)

Non-Crystalline Materials [10]

Microstructure and imperfections. Diffusion in solids and related phenomena. Noncrystalline and glassy materials – Structure, Thermodynamics, Glass transition and related models, tunnelling states, Specific heat estimation, Two – level system. Amorphous semiconductors – Electrical properties, magnetic properties, switching and device applications.

Nanoscale Physics [12]

Quantum Wells: Lattice Matching, Electron States, Exciton and Donors in Quantum Wells, Graphene: Structure, Electron Energy Bands, Eigenvectors, Landau Levels, Electron-Phonon Interaction, Phonons, Carbon Nanotubes: Chirality, Electronic States, Phonon in CarbonNanotubes, Electrical Resistivity.

PHYS-0903-B: General Relativity and Cosmology
(50 Lectures)

Foundations of General Relativity and Curved Spacetime [25]

Basic concepts of Relativity, Need for GR, introduction to Einstein's theory of relativity, principle of equivalence, connection between gravity and geometry,
Tensors: Metric tensor and its properties, concept of curved space spacetime, Tensor algebra, Tensor calculus, Covariant differentiation, parallel transport; Riemann curvature tensor; geodesics, Einstein's Field Equations: Field Equations and Schwarzschild Metric; Einstein's equations for weak gravitational fields, the Newtonian limit; derivation of Schwarzschild metric. Nature of R=2M surfaces, concept of black holes; particle and photon trajectories in Schwarzschild metric.
Experimental tests of Einstein's Theory: Gravitational redshift, the precession of the perihelion of Mercury, bending of light, Gravitational Waves: Linearized equations and plane wave solutions, radiation from gravity waves, cosmic sources of gravity waves, detection methods of gravity waves

Cosmology [25]

Standard Model of Cosmology: Historical development of cosmology, Observational triumphs of cosmology, Olber's paradox, Hubble's law and the expanding Universe, Big Bang theory, redshift, scale factor, FRW metric, Cosmological principle, homogeneity and isotropy, Newtonian cosmology, Friedmann equation, conservation and acceleration equations, different components of the Universe, equation of states, Distance measures in cosmology, The Cosmic Microwave Background:
Recombination and decoupling of photons, surface of last scattering, temperature fluctuations in the CMB, acoustic oscillations, primary and secondary temperature anisotropies, measuring the CMB temperature anisotropy, CMB as a probe of cosmology, Big Bang Nucleosynthesis, Structure Formation in the Universe

Gravitational instability, linear perturbation theory, initial conditions, matter power spectrum, large scale structure in the Universe, 2-pt correlation function, observations of large scale structures, hot versus cold dark matter, cosmological simulations
Inflationary Paradigm

PHYS-0991: Project-I

Review of Literature/ Experimental Technique

PHYS-0992: Project-II

Formulation of Project Proposal

PHYS-1001-A: Quantum Field Theory (50 Lectures)

Interacting fields and Feynman Diagrams [8]

The interaction picture, Time evolution operator, S-matrix, Wick's Theorem, Feynman diagram.

Elementary processes of quantum electrodynamics [8]

Elementary scattering processes, Bound States, Crossing Symmetry, Mandelstam Variables

Radiative corrections [10]

Introduction and some formal developments , soft Bremsstrahlung, electron vertex function; Field strength renormalization, LSZ reduction formula, Optical theorem, Ward Takahashi indentity, renormalization of electron mass and charge.

Functional methods [14]

Path integrals, functional quantizations, quantization of the electromagnetic field, symmetries in functional formalism ; Renormalization : systematics of renormalization, Spontaneous symmetry breaking.

Quantum Fields in curved spacetime [10]

Scalar field and its quantization in curved spacetime, Bogolyubov transformations and the particle concept, choice of the vacuum state; quantum scalar fields in FRW universe.

PHYS-1001-B: Physics of Nanostructured Materials (50 Lectures)

Introduction to Nanostructured Materials [8]

Introduction. Size dependence of properties. Metal nanoclusters, bulk to nanotransition, semiconducting nanoparticles. Carbon nanostructures: carbon clusters, carbon nanotubes (CNT), fullerenes and graphenes, nanocomposites and hybrids

Growth, fabrication and measurement techniques for nanostructures [12]

Spontaneous formation and ordering of nanostructures. Top-down and bottom-up approach and templates. Methods of synthesis of nanostructures: RF plasma, chemical methods, Sol-Gel technique, electrochemical methods, thermolysis, pulsed laser methods, Physical vapor deposition, ball milling, vapour-liquid-solid (VLS) method. Methods of carbon nanotube growth. Nanostructures determination: atomic structures, X-ray diffraction and crystallography, small angle X- ray scattering (SAXS), particle size determination, surface structure. Microscopy: Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM), Field Ion Microscopy (FIM), Scanning Tunnelling Electron Microscopy (STEM). Spectroscopy: Infrared and Raman spectroscopy, Photoluminescence, Photoemission and X-ray spectroscopy. Magnetic Resonance

Electron transport in semiconductors and nanostructures [14]

Time and length scales of electrons in solids. Statistics of electrons in solids and nanostructures. The density of states (DOS) of electrons in nanostructures. Electron transport in nanostructures: dissipative transport in short structures, hot electrons, quantum ballistic transport and Landauer formula, single electron transport. Electrons in traditional low-dimentional structures (quantum wells, quantum wires & quantum dots).

Nanostructured ferromagnetism [6]

Magnetic properties of nanostructured materials. Dynamics of nanomagnets. Dilute magnetic semiconductor (DMS), Spintronics. Nanocarbon ferromagnets. Ferrofluids. Super paramagnetism. Ferromagnetic resonance (FMR).

Self-assembly and catalysis [4]

Self-assembly: process of self-assembly, semiconductor islands, monolayers. Catalysis: nature of catalysis, surface area of nanoparticles, porous materials, pillared clays and colloids.

Applications and future of nanomaterials [6]

Nanoelectronics: single electron transistor, resonant tunnelling diodes. Micro and nanoelectro mechanical systems. Nanosensors. Nanocatalysis. Role of nanomaterials in food and agriculture industry & water treatment. Nano-medical applications. Defence and space applications. Nanomaterials for non conventional energy source and energy storage

PHYS-1001-C: Non-Linear Physics (50 Lectures)

Preliminaries [7]

Brief overview of non-linearities in physics, One-dimensional phase space, Flows, Fixed points and stability, Bifurcations – perfect and imperfect and their classification.

Non-linear Dynamics [28]

Two-dimensional phase space and phase portrait, Classification of fixed points and bifurcations in two-dimensions, Limit cycles, Closed orbits, Poincare-Bendixon theorem, Forced non-linear oscillators – van der Pol, Duffing, One-dimensional maps, Logistic map, period doubling,Lyapunov exponent, Lorenz map, Strange attractor, Chaos, Feigenbaum's theory, Interdisciplinary applications of non-linear dynamics.

Non-linear waves [7]

Solitons, KdV equation, Solutions and symmetries.

Quantum Chaos [8]

Quantum billiards, Random matrices – symmetries, universality classes, Gaussian ensembles, Spectral correlation

PHYS-1001-D: Atomic and Subatomic Physics (50 Lectures)

Atomic and Molecular Physics [20]

Fine structure of spectral lines; Selection rules; Lamb shift. Hyperfine interaction and isotope shift; Hyperfine splitting of spectral lines; selection rules, Many electron atoms: Equivalent and nonequivalent electrons; Energy levels and spectra; Hunds rule; Lande interval rule; Alkali spectra, Born- Oppenheimer approximation, Electronic states of diatomic molecules, Approximation methods for the calculation of electronic Wave function, The LCAO approach, States for hydrogen molecular ion, Coulomb, Exchange and Overlap integral, Symmetries of electronic wave functions; Shapes of molecular orbital and bond Term symbol for simple molecules.

Rotation and Vibration of Molecules: Solution of nuclear equation; Molecular rotation: Non-rigid rotator, Centrifugal distortion, Symmetric top molecules, Molecular vibrations: Harmonic oscillator and the anharmonic oscillator approximation, Morse potential.Spectra of Diatomic Molecules:Transition matrix elements, Vibration-rotation spectra: Pure vibrational transitions, Pure rotational transitions, Vibration-rotation transitions, Electronic transitions: Structure, Franck-Condon principle, Rotational structure of electronic transitions, Fortrat diagram, Dissociation energy of molecules, Continuous spectra, Raman transitions and Raman spectra, Group theory approach

Nuclear Physics [18]

Properties of nuclei, Nuclear models, Ground state of deuteron, Experimental results on low energy n-p and p-p scattering, spin dependence of nuclear forces, Necessity of tensor forces, Isospin symmetry, Exchange interaction., Beta decay, Selection rules, Double beta decay, Gamma decay, selection rules Nuclear reaction, Breit-Wigner dispersion relation, Nuclear fission.

Elementary Particle Physics [12]

Interaction and fields, Particle classification – hadron and lepton, Quantum numbers, invariance principles and conservation laws, Quark model of hadrons. Basic discussion of the Standard Model including brief elucidation of the key experiments that led to the development of the model, Brief introduction to Beyond the Standard Model Physics

PHYS-1001-E: Electronic Materials and Devices (50 Lectures)

1. Carrier Transport Phenomena (10)

Boltzmann Transport Equation, temperature dependence of mobility, negative differential mobility; Tensor representation of electrical and thermal conductivity, Hall coefficient and magnetoresistance, Quantum Hall effect; recombination of electron hole pairs, recombination centres, surface states, pinning of Fermi level; determination of mobility, diffusion constant and lifetime of minority carriers, Hayens Shockley experiment, thermionic emission, tunnelling process, high-field effects

2. Fabrication Techniques (8)

Bulk and epitaxial crystal growth techniques: Growth of single crystals by Czochralski and Bridgman techniques, purification by float-zone process, epitaxial growth, vapour phase epitaxy, metal organic chemical vapor deposition, molecular beam epitaxy, thermal diffusion and ion implantation processes for doping,

Thin Films: conductivity and other properties of thin films, thermal oxidation, dielectric deposition, polysilicon deposition, metallization, lithographic techniques, integrated devices.

3. Characterization techniques (10)

X-ray diffraction and crystallography, small angle X- ray scattering (SAXS), particle size determination, surface structure, thermal effects on diffraction patterns,

Microscopy: Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM), Field Ion Microscopy (FIM), Scanning Tunneling Electron Microscopy (STEM).

Spectroscopy: Infrared and Raman spectroscopy, Photoluminescence, Photoemission and X-ray spectroscopy. Magnetic Resonance

4. Microwave Devices (8)

Basic microwave technology, tunnel diode, IMPATT diode: static and dynamic characteristics, transferred-electron devices: negative differential resistance, device operation, quantum-effect devices: resonant tunnelling diode, unipolar resonant tunnelling transistor, hot-electron devices.

5. Photonic Devices (14)
Radiative transitions and optical absorption, light-emitting diodes (LEDs): visible and infrared LEDs, semiconductor laser: materials, laser operation, basic laser structure, quantum-well lasers, photoconductor, photodiode, solar cell: solar radiation, p-n junction solar cell, conversion efficiency, silicon and compound semiconductor solar cells, multijunction, heterojunction and thin film solar cells.

PHYS-1091A: Condensed Matter Physics Lab

The Following Experiments are part of the lab

1. Determination of Space Group and Crystal Structure of a Single Crystal Material by Laue Diffraction Method.

2. Determination of Crystal Structure and Lattice Parameters of a Polycrystalline Material by Powder Diffraction (Debye Scherrer) Method.

3. Determination of Hall Effect &Magnetoresistance of Polycrystalline Bismuth Sample at RT.

4. Determination of Magnetic Susceptibility of Paramagnetic Salts by Guoy Balance

Method.

5. Determination of AC Conductivity and Dielectric Constants of Composites Materials by LCR Bridge.

6. Study of Dielectric Constants of Ferroelectric Crystals at Elevated Temperatures and determine the Curie Temperature.

7. Study of F Centers of Xray Irradiated Alkali Halides (KCl&KBr) Samples.

8. Study of the Nature of Band Gap and Determination of Optical Constants (n, k) of

Semiconductor (Crystalline and Amorphous) Thin Films using UV-VIS (Dual and Single beam) Spectrophotometer.

9. FTIR Study of Si Based Oxide/ Carbon Nano Composites.

10. Study of the variation of Hall Coefficient of a given extrinsic semiconductor as a

function of temperature using Temperature dependence Hall – effect setup.

11.Study of the electrical properties of given thin films of different materials (metal,

insulator and semiconductor) using Four – Probe Setup.

12. Measurement of electrical resistivity of superconductors at low temperature.

(Students will do 6-8 experiments among these)

PHYS-1091B: Astrophysics Lab

Data Analysis Projects

1. Determining parameters of Extra-Solar planets.

2. Main sequence fitting of a star cluster.

3. Statistics of the Cosmic Microwave Background

4. Galaxy Spectral Fitting

Experimental Projects

1. Solar Limb Darkening

2. Characterizing radio antennae.

3. Characterization of Charged Coupled Device

4. Faraday Rotation

PHYS-1092: Project-III

Report and Viva 1

PHYS-1093: Project-IV

Presentation 2 and Viva 2

PHYS-1094: Project-V

Supervisor’s Assessment and Presentation 3