M.Sc Electives

Electives have to be taken from at least two different groups. One of the electives can be taken from Institute electives available.

**Group-I: Condensed Matter**

**PH521: Topics in Condensed Matter Physics**

Second Quantization, Diagrammatic Perturbation Theory, Bose and Fermi Liquid Examples; Electron Gas, Hartree Fock Approximation, Dielectric Response, Hubbard Model; Electron-Phonon Interaction, Superconductivity, BCS Theory; Low Dimensional Magnetic Systems, Spin Representations, Linear and Nonlinear Spin Wave Theory, Heisenberg Antiferromagnet, XY Model.

References:


**PH522: Physics of Semiconductors**


References:

PH523: Magnetism and Superconductivity

Magnetism: Review of diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism, ferri magnetism. Circular and helical order. Direct, exchange, double exchange, indirect and RKKY interactions. Environmental effects: crystal field, tetrahedral and octahedral sites; Jahn-Teller effect; Hund's rule and rare earth ions in solids. Consequences of broken symmetry, phase transition, Landau's theory, rigidity, excitation, magnons, domains and domain walls, magnetic hysteresis, pinning effects. Magneto resistance, giant magneto resistance, nuclear magnetic resonance, technological aspects of magnetic materials. Superconductivity: Properties of conventional (low temperature) superconductors, London and Pippard equation, Type II superconductors, intermediate state, vortex lines; flux pinning; Non-ideal behaviour of Type II superconductors; Thermodynamics of Type I and II superconductors; Ginzburg Landau (G-L) theory; G-L equations; current density; Josephson equations; superconducting quantum interference device. Cooper pairs and BCS theory; Energy gap; magic number; experimental determination of energy gap from I-V characteristics; McMillan's upper limit of Tc. Properties of high Tc superconductors, flux pinning, current density, granular nature. Technological aspects of superconductors.

References:


PH524: Thin Film Phenomena


References:

PH525: Optoelectronic Materials and Devices

Materials for optoelectronics: Structural properties of crystalline, polycrystalline, amorphous materials, liquid crystals, interfaces, and defects in materials; Electronic properties of semiconductors: band structures, doping and carrier transport; Optical properties of semiconductors: interband and intraband transitions, charge injection and radiative/nonradiative recombination, excitonic effects; Light detection and imaging: Solar cell, Photodetectors, Phototransistor, Metal-semiconductor detector, Charge coupled devices; Light emitting diode: Operation and advanced structures, Laser diode: Spontaneous and stimulated emission, Laser structures, time response of lasers, advanced semiconductor laser structures, temperature dependence of laser output. Liquid crystal display, Electro-optic modulators, Interferometric modulators, directional couplers, properties of optical fibers; Fabrication and processing of devices: Bulk crystal growth and epitaxial crystal growth, lithography, etching, fabrication of optical fibers, fibre coupling and splicing.

Texts:


References:


PH526: Soft Condensed Matter

References:


**PH 527: Nanostructured Materials**

- Wave function, Quantum confinement, 2 dimensional, 1 dimensional and 0 dimensional systems, Energy quantization and quantum phenomena
- Phenomena at nanoscale: Nanoscale electrical transport, nano-magnetics, nanoscale thermal transport
- Nanomaterial systems: Metallic, semiconducting, Quantum dot and quantum superlattice, polymer, nanocomposites, carbon based nanostructures, nanowires, photonic crystals, self-assembled nanostructures
- Synthesis of nanomaterials, clusters, particles, fullerenes, nanostructures
- Characterization of nanomaterials: X-ray diffraction, transmission electron microscopy, Scanning electron microscopy, Scanning near-field optical microscopy, other Scanning probes for imaging and manipulation, optical and vibrational spectroscopy, electrical, magnetic and electrochemical methods
- Applications of nanomaterials in electronics, photonics, biotechnology, nanoelectromechanical systems (NEMS)

References:


**PH528: Spintronics: Physics and Technology**

(Pre-requisite: PH505 or equivalent)

History and overview of spin electronics, quantum mechanics of spin, spin-orbit interaction, exchange interaction, spin relaxation mechanisms, spin-dependent electron transport, spin-dependent tunneling, basic theory of Andreev reflection, ferromagnet/ superconductor/ ferromagnet double junctions, spin-transfer torque and its magnetic dynamics, current-driven switching of domain wall motion, domain wall scattering and current-induced switching in ferromagnetic wires, spin injection, spin accumulation, spin current, spin Hall effect, spin photoelectronic devices, electron spin filtering, materials for spin electronics, nanostructures
for spin electronics, fabrication techniques, spin-valve and spin-tunneling devices, spintronic biosensors, quantum computing with spins.

**Texts and References:**


**PH 530: Organic Electronics and Optoelectronics 3-0-0-6**

Molecules to Aggregates-Organic molecules; covalent bond-sigma and pi bonds, electronic structures of atoms and molecules; energy levels; organic films; organic solids; excited states of aggregated films; excitons and exciton diffusion; Conducting polymers-oligomers, semiconducting small organic molecules and their properties; Charge transport and optical processes in organic films. Organic light emitting diodes (OLED); fabrication techniques, performance, way to perceive colors, conventional, transparent, inverted and flexible OLEDs, OLED based flexible display technology; Organic thin films transistors (OTFT) - Fabrication techniques, performance, applications, single molecule switch and memory element, organic nanotube transistors, OTFT based display technology; Organic laser-Lasing process, optically pumped lasing structures, applications; Organic multilayer photodetectors; organic photovoltaic cells; Organic spintronics-spin transport through organic films, spin valves, applications.

**Texts and references:**

PH542: Phase Transitions and Critical Phenomena


Transfer matrix: Setting up the transfer matrix, Calculation of free energy and correlation functions, Results of Ising model. Series Expansion: High and low temperature series, application in 1-d Ising model, Analysis of series. Monte Carlo: Importance sampling, Metropolis algorithm, Data analysis, statistical error, finite-size effect. Examples

Renormalization Group: Definition of a RG transformation, Flow in parameter space, Universality, Scaling and critical exponents, scaled variables. Application in 1-d Ising model.

References:


PH552: Topological Phases of Matter

Symmetries of the Hamiltonian, Inversion and time reversal symmetries, Kramer’s theorem, Kramer’s degeneracy, simple one dimensional systems, Su-Shrieffer-Heeger model of polyacetylene, bulk-edge correspondence, edge states, chiral symmetry, topological invariant, Kitaev model, Majorana modes, $4\pi$ Josephson effect, Andreev conductance quantization.

Quantum Hall effect, TKNN invariant, Anomalous quantum Hall effect, Haldane model, Chern insulator, accidental degeneracy, Berry curvature, Berry phase, Chern number.

Two dimensional topological insulators, spin-orbit couplings, Graphene, Chiral edge modes in Graphene, Kane Mele model, band inversion, strained semiconductors, topological phase in HgTe-CdTe quantum wells, spin Hall effect, Quantum spin Hall insulators, conductance characteristics, spin polarized conductance, helical edge modes, applications to spintronics.

Semi-Metals: Topological aspects of semi-metals, Weyl equation, Weyl semi-metal, Weyl nodes, Fermi arcs, violation of inversion and time reversal symmetries, surface states, simple two band models, type-I and type-II semi-metals, Dirac semi-metals, experimental scenario, Quantum oscillations.

Texts/References


**Group-II: Lasers and Photonics**

**PH 531: Laser Physics**

Interaction of radiation with matter, semi classical theory, stimulated emission, life times and line widths, Laser rate equations, gain coefficient, threshold conditions, gain saturation, optimum output coupling, cw and pulsed operation, pumping mechanism theory of optical resonator, longitudinal and transverse modes, Q switching, mode locking, pulse compression, different types of lasers, laser amplifier, applications of laser

**References:**


**PH 532: Laser Spectroscopy**

Interaction of radiation with matter, strong field approximation, Rabi oscillations, line widths, Doppler limited spectroscopy, laser induced absorption and fluorescence spectroscopy, optogalvanic spectroscopy, high resolution spectroscopy, double resonance techniques, Laser Raman spectroscopy, time resolved laser spectroscopy, homodyne and heterodyne spectroscopy, measurement of ultra short pulses, pump and probe techniques, quantum beat spectroscopy, photon echo, correlation spectroscopy, single ion spectroscopy, atom interferometry, polarization spectroscopy, Laser cooling, multiphoton transitions.

**References:**

PH 533: Non Linear Optics


Texts:


References:


PH 534: Fibre Optics


Texts:


References


**PH 535: Integrated Optics Devices**

Ray and modal analysis of planner step-index/graded index waveguides, Guided and radiation modes, Ray and modal analysis of asymmetric waveguides, Strip and channel waveguides, segmented waveguides. Integrated optic devices: Directional couplers & optical switches Coupled mode theory, Co-directional & contra-directional coupling, Phase & amplitude modulators, Filters, Y-junction, Power splitters, Arrayed waveguide devices, Waveguide amplifiers, Distributed Feed-back lasers. Fabrication of integrated optical waveguides and devices: Ion-exchange, Epitaxial Growth, Ion implantation; Waveguide loss measurement: Scattering and Absorption loss; End-fire and prism coupling, Fiber pig-tailing, End-butt coupling

**Texts**


**References**


**PH 536: Quantum Optics**


References:


**PH537: Imaging and Fourier Optics**


Text and References:


**Group-III: Theoretical Physics**

**PH541: Quantum Computation and Quantum Information**


**Text Book:**


**References:**


**PH543: Quantum Field Theory**

Action principle, Canonical Transformations, Poisson Brackets, Symmetries and conservation laws, Green’s functions, Klein Gordon equation, Dirac equation, Free propagators Quantization of fields, Real and charged scalars, Massless and massive vector and spinor fields Perturbation
Theory, Feynman Rules, Regularization schemes, Renormalizability, Renormalization group equations, QED and Electroweak Interactions.

References:


**PH 544: High Energy Physics**


Text:


Reference:


**PH545: General Theory of Relativity**

Review of Riemannian geometry: Metric tensor, covariant differentiation, curvature tensor, Bianchi Identities, Ricci tensor. Motion of a particle in a gravitational field, geodesic. Equations of electrodynamics in the presence of a gravitational field. Gravitational field

References:


**PH-546: String Theory**

3-0-0-6

Prerequisites: PH-403, PH-406, PH-501 (Classical Mechanics, Quantum Mechanics II, Electrodynamics II), or equivalent courses.


Quantization of relativistic open and closed strings: Light-cone Hamiltonian, string as harmonic oscillator, Virasoro operators, Lorentz generators, state space, photon states, Tachyons and D-brane decay, dilaton and string coupling. D-branes and gauge fields: Open strings on Dp branes, and between parallel branes. T-duality of closed and open strings: winding closed strings, left and right movers, state space of compactified closed strings, T-duality and D-branes, U(1) gauge transformation, Wilson lines. Electromagnetic fields on D-branes. String interactions, Riemann surfaces, Schwarz-Christoffel map, moduli spaces.

Text Book:

References:


PH 547: Statistical Field Theory

Prerequisite: PH-404 Statistical Mechanics (or equivalent)


Texts and References:


PH 548: Atomistic Simulation Techniques

Molecular Dynamics (MD) Simulation: Interatomic potentials; Pair potentials and many-body potentials; System-size effects and Periodic Boundary Conditions; Equations of motion; Time integration of atomic trajectories; Energy and momentum conservation; Initialization of simulation; Controlling the temperature; Equilibration; Calculation of thermodynamic
properties; Simulation of molecular systems; Long range interactions: Ewald summation techniques; Monte Carlo (MC) Simulation: Markov process and Markov chain; Random number generators; Metropolis algorithm; Calculation of thermodynamic properties; Molecular Dynamics simulation in canonical and iso-thermal isoobaric ensembles: Nose-Hoover and Parrinello-Rahman methods; Calculation of structural and dynamic properties; Time correlation functions; Calculation of transport coefficients; Error estimation.

**Text and References:**


**Lab components:**

The lab assignments will involve piece-wise implementation of the theoretical concepts into program units: (i) Generation of simple crystal lattices such as an fcc or bcc lattice. (ii) Assignment of velocities from Maxwellian velocity distributions. (iii) Implementation of periodic boundary conditions. (iv) Implementation of time integrators: Verlet and Gear predictor-corrector schemes. (v) Efficient calculation potential energy and forces between atoms. (vi) Random number generation and quality tests. (vii) Implementation of basic MC moves, and calculation thermodynamic averages. (viii) Calculation of structural properties, such as radial distribution functions. (ix) Calculation of time correlation functions. (x) Calculation of transport coefficients such as self-diffusion coefficient. (xi) Error estimation using block averages.

**PH 549: Physics around Compact Objects**

Accretion power: Accretion as a source of energy, Black Hole accretors, Radiation from accretion flows; Formation and evolution of accretion-powered binaries; Steady-state accretion disks: Conservation Laws, Source of viscosity, Radial structure of steady-state disks, Shakura-Sunyaev disk; Accretion disk outbursts; High-energy radiation from relativistic accretors; Relativistic outflows: Relativistic beaming, Superluminal motion, Jet formation and collimation; Gamma-ray bursts: Discovery, Properties and Signatures, Models and Constraints; Ultra High Energy Cosmic Rays: Its sources and propagation.

**Text and Reference Books:**