Course Wise Content Details for M.Sc. in Physics Programme

Semester-I

Course Name: Mathematical Physics

Course Code: PHYS4001

Credits: 3+0+1 (4 credits)

Course Objectives: The purpose of the course is to introduce students to methods of mathematical physics and to develop required mathematical skills to solve problems in quantum mechanics, electrodynamics and other fields of theoretical physics.

Course Contents:

Unit - I

Linear Vector Space: A brief review of linear vector spaces, Schwarz inequality, eigenvalue and eigenvector, Hermitian operators and their properties, unitary operators, orthonormal basis–discrete and continuous.

Unit - II

Complex Variables: General function of complex variable, Cauchy-Riemann differential equation, conformal mapping (translation, rotation, inversion), Cauchy's integral formula, Taylor's and Laurent's series, Residue theorem. Evaluation of definite integrals, around (i) unit circle and (ii) infinite semi-circle; using Jordan's lemma with poles lying on real axis, and of integrals involving multiple valued function-branch point.

Unit - III

Theory of Transform: Fourier Transform and its properties with applications. Representations of Dirac Delta Function, Parseval's Theorem, Convolution Theorem. Green's function as a technique to solve linear ODEs, Homogeneous and Inhomogeneous boundary conditions, Solution of Poisson equation, Symmetry property. Laplace Transform and its properties, solution of differential equations of physical problems, convolution integral.

Unit - IV

Group Theory: Concept of a group (additive and multiplicative), Matrix representation of a group, Reducible and irreducible representation of a group,The Great Orthogonality Theorem, Factor Group, Raman and IR modes analysis.

References:

1. Mathematical Physics by V.Balakrishnan, Ane Books Pvt. Ltd.
2. Mathematical Methods for Physicists by G. Arfken, H. Weber and F.E. Harris (Elsevier).
3. Advanced Engineering Mathematics by Kreyzig.
4. Mathematical Physics by B. S. Rajput (Pragati Prakashan)

5. Mathematical Methods for Physics and Engineering by K.F. Riley, M.P. Hobson and S.J.Bence (Cambridge University Press)
6. Special Functions and their Applications by N.N. Lebedev (Dover Publication)

Course Name: Classical Mechanics

Course Code: PHYS4002

Credits: 3+0+1 (4 credits)

Course Objectives: To demonstrate knowledge and understanding of the following fundamental concepts in:

- the dynamics of system of particles,
- motion of rigid body,
- Lagrangian and Hamiltonian formulation of mechanics

To represent the equations of motion for complicated mechanical systems using the Lagrangian and Hamiltonian formulation of classical mechanics. This is a course which forms the basis ofPhysics of many areas of Physics.

Course Contents:

Unit - I

Vectors: Curvilinear Coordinates, Gradient, Divergence and Curl, Laplace equation in spherical and cylindrical polar coordinates and their solution, Green's theorem, Gauss and Stokes Theorems. **Tensors:** Covariant and Contravariant vectors, Tensors – Addition, Multiplication, Contraction, Symmetry properties; Tensor density, Pseudo-tensors.

Unit - II

Mechanics of a system of particles: Generalized coordinates and Constraints, Generalised coordinates, D' Alembert's principle, Lagrange's Equation. Hamilton'sprinciple, Least action principle, Langrange's equations, symmetry properties and Noether's theorem, Lagrangian formulation for elementary mechanical systems - free particle, simple and double pendulum.

Unit - III

Two Body Problem: Reduction to one-body problem, reduced mass, Virial Theorem, planetary orbits. Scattering: Collision between particles, disintegration of particles, elastic collisions, scattering, Rutherford's formula. **Small oscillations:** Damped and Forced oscillations, coupled vibrations.

Unit - IV

Hamiltonian Formulation: Hamilton equations, canonical transformations, Poisson's bracket, Symplectic approach to canonical transformations; Hamilton Principle function, Hamilton-Jacobi equation, Harmonic Oscillator Problem (3D), Hamilton characteristic Function, separation of variables, Central Force problem.

Unit - V

Rigid Body motion: Kinematics of Rigid Body, Euler angles, the symmetrical top, Inertia tensor, Angular momentum and kinetic energy of a rigid body, Motion in a non-inertial frame of reference, Coriolis force.

References:

1. Vector Analysis and Introductory Tensor Analysis by M.R. Spiegel (Schaum Series)
2. Matrices and Tensors in Physics by A.W. Joshi (New Age)
3. Classical Mechanics by H. Goldstein (Narosa, New Delhi)
4. Classical Mechanics by K.C. Gupta (Wiley Eastern)
5. Classical Mechanics by L.D. Landau (Elsevier)
6. Classical Mechanics by N.C. Rana and P.S. Joag (Tata-McGraw-Hill)

Course Name: Quantum Mechanics

Course Code: PHYS4003

Credits: 3+0+1 (4 credits)

Course Objectives: The primary objective is to teach the students the physical and mathematical basis of quantum mechanics for non-relativistic systems.

Course Contents:

Unit - I

Quantum formulations: Hermitian operators and observables, Discreet and continuous spectrum, Commuting observables, Pure and mixture states; Simple applications: potential well, barrier potential, tunnel effect, unbound states: reflection and transmission of waves. Dirac's bra and ket notation. Matrix representation of operators. Position and momentum representations – connection with wave mechanics. Generalised uncertainty principle, Change of basis and unitary transformation. Expectation values, Ehrenfest theorem.

Unit - II

Quantum Dynamics: Schrödinger & Heisenberg picture, Heisenberg equation of motion, Classical limit, Solution of simple harmonic oscillator problem by the operator method, General view of symmetries and conservation laws, Symmetries in Quantum Mechanics: Hydrogen-like atoms and spherical harmonics, Spatial translation – continuous and discrete, Time translation, Parity, Time reversal, Density matrices - properties, pure and mixed density matrices, time-evolution, reduced density matrix.

Unit - III

Approximation Methods: Time-independent perturbation theory, Variational method, WKB method, Interaction picture, Time dependent perturbation theory. Transition to a continuum of final states – Fermi's Golden Rule, Sudden and adiabatic approximations.

Unit - IV

Scattering: Wave packet description of scattering, Formal treatment of scattering by Green's function method, Born approximation and applications, Partial wave analysis, Optical theorem.

Unit - V

Relativistic Quantum Mechanics: Klein-Gordon equation, Dirac equations, Plane wave solutions of Dirac equation, Spin and magnetic moment of the electron, Non-relativistic reduction of the Dirac equation. Covariant form of Dirac equation, Dirac (γ) matrices, Representation and algebra, Infinitesimal and Finite proper Lorentz transformation, Proof of covariance, Plane wave solution and negative energy states; Two component Pauli spin theory.

References:

1. Quantum Mechanics by L.I. Schiff (Tata-McGraw-Hill).

2. Introduction to Quantum Mechanics by D.J. Griffths (Pearson Education).
3. Quantum Mechanics by B.H. Bransden & C.J. Joachain (Pearson Education, 2000).
4. Principles of Quantum Mechanics by R. Shankar (Springer, 3rd Edition, 2008).
5. Relativistic Quantum Fields, Vol. I by J.D. Bjorken and S.D. Drell (McGraw-Hill, 1964).
6. Relativistic Quantum Fields, Vol. II by J.D. Bjorken and S.D. Drell (McGraw-Hill, 1978).
7. Quantum Chemistry by Ira N. Levine (Pearson Education).
8. Quantum Mechanics by Eugen Merzbacher (3rd Ed., Wiley, 1997)
9. Quantum Mechanics by B.K. Agarwal and Hari Prakash (Prentice-Hall, India)
10. The Principles of Quantum Mechanics by P.A.M. Dirac (Oxford University Press)
11. Modern Quantum Mechanics by J.J. Sakurai (Addison Wesley)

Course Name: Solid State Physics

Course Code: PHYS4004

Credits: 3+0+1 (4 credits)

Course Objectives: This course intends to provide knowledge of conceptual solid-state physics. In addition, this course aims to provide a general introduction to theoretical and experimental topics in solid state physics.

Course Contents:

Unit - I

Crystal Lattices: Symmetry operations and classification of Bravais lattices, Crystal Systems, reciprocal lattice, Brillouin zone, Bragg's law, Von Laue's formulation, Geometrical factors; X-rays, Electrons and Neutrons diffractions, Point groups and space groups, Phase analysis in binary mixtures, Types of crystal bindings, hydrogen bonding, cohesive and Madelung energy.

Unit - II

Lattice Dynamics and Defects in Solids: Frenkel & Schottky defects, line defects and dislocations. adiabatic and harmonic approximation, vibrations of linear monoatomic lattice, one-dimensional lattice with basis, models of three dimensional lattices, Einstein and Debye theories of specific heat, phonon density of states, neutron scattering.

Unit - III

Metals: Specific Heat, Dulong & Petit's Law, Drude theory, DC conductivity, Fermi-Dirac distribution, thermal properties of an electron gas, Wiedemann-Franz law, critique of free-electron model, **Band theory of Solids:** Bloch's theorem, weak potential approximation, density of states, Fermi surface and Brillouin zones. Origin of energy bands, effective mass, tight-binding approximation. Motion of electrons in lattices, Wave packets of Bloch electrons, semi-classical equations of motion, motion in static electric and magnetic fields, cyclotron resonance.

Unit – IV

Dielectrics & Ferroelectricity with optical properties: Dielectrics and ferroelectrics, macroscopic electric field, local field at an atom, dielectric constant and polarizability, ferroelectricity, antiferroelectricity, piezoelectric crystals, ferroelasticity, electrostriction. Optical constants and their physical significance, plasmonic properties of metals, defect mediated optical transitions, excitons, photoluminescence, Electroluminesence.

Unit - V

Superconductivity and Magnetism: Thermodynamics of superconductors, London's equation and Meissner effect, Type-I & Type-II superconductors, BCS theory, ac and DC Josephson effect, SQUIDs.

References:

1. Solid state Physics by A.J. Dekkar (McMillan Publishers).
2. Introduction to Solid State Physics by C. Kittel (Wiley Eastern).

3. Elementary Solid State Physics by M. Ali Omar (Pearson Education).
4. Solid State Physics, N.W. Ashcroft and N.D. Mermin, (Harcourt Asia Limited).
5. Principles of the Theory of Solids by J.M. Ziman (Cambridge University Press).
6. Solid State Physics by S.O. Pillai (New Age Publishers).

Course Name: General Lab I

Course Code: PHYS4005

Credits: 0+4+0 (4 credits)

Course Objectives: The major objective of this course is to revise the basic concepts of electronics, mathematical physics and quantum mechanics through standard set of experiments. In addition, the continuous evaluation processallows each and every student to not only understand and perform the experiment but also suitably correlate them with the corresponding theory.

Course Contents:

Unit – I: Experimental Techniques

1. Production and measurement of low pressures
2. Production and measurement of high pressures
3. Measurement and control of low temperatures
4. Production and characterization of plasma
5. Electron Spin Resonance
6. Nuclear Magnetic Resonance

Unit – II: Electrical Transport Properties

1. Measurement of resistivity–Four probe and van der Paw techniques; determination of band gap
2. Measurement of Hall coefficient – determination of carrier concentration
3. Measurement of magneto resistance
4. Measurement of thermoelectric power
5. Measurement of minority carrier lifetime in semiconductors Hyne Shockley experiment.

Unit – III: Phase Transitions and Crystal Structure

1. Determination of transition temperature in ferrites
2. Determination of transition temperature in ferroelectrics
3. Determination of transition temperature in high T_c superconductors
4. Determination of transition temperature in liquid crystalline materials
5. Crystal structure determination by X-ray diffraction powder photograph method

Unit – IV: Computational Physics and Programming

1. Jacobi Method of Matrix Diagonalization
2. Solution of transcendental or polynomial equations by the Newton Raphson method
3. Numerical integration using the Simpson's method
4. Solution of first order differential equations using the Runge-Kutta method
5. Fast Fourier Transform

Semester-II

Course Name: Thermal and Statistical Physics

Course Code: PHYS4006

Credits: 3+0+1 (4 credits)

Course Objectives: The objective is to understand the physics of large collections of particles. The course focuses on the laws of thermodynamics, entropy and equilibrium, classical and quantum gasses, statistical mechanics, and phase transitions.

Course Contents:

Unit – I

Kinetic theory of matters, Browninan Motion, Second law of thermodynamics, Entropy and Probability, Thermodynamic Potentials, Thermodynamic Equilibrium, Third law of thermodynamics, First and Second order phase transistions: Clausius - Clapeyron and Ehrenfest's equations; Chemical potential and phase equilibria, Gibb's phase rule.

Unit – II

Thermodynamic properties of liquid Helium II, The lambda - transition, London's explanation, Quantum liquid, Tisza two fluid model, Landau spectrum, concept of second sound. Conditions for Equilibrium, Entropy of an Ideal Boltzmann gas, Gibb's paradox, Sackur -Tetrode equation.

Unit – III

Classical ensemble theory: Phase space, microstates and macrostates. Liouville's equation, Postulates of statistical mechanics. Microcanonical ensemble, Boltzmann relation for entropy. derivation of the laws of thermodynamics for macroscopic systems. Sackur-Tetrode equation. Canonical & Grand-Canonical ensemble; partition function; Helmholtz free energy. Entropy of a system in contact with heat reservoir, Ideal gas in canonical ensemble, Maxwell velocity distribution, Thermodynamics of photons, Translational, Rotational & Vibrational partition functions of a molecule and their applications.

Unit – IV

Quantum statistical mechanics: Indistinguishable particles in quantum mechanics. Bosons and Fermions, Bose-Einstein statistics, ideal Bose gas, photons, Bose-Einstein condensation. Fermi-Dirac statistics, Fermi energy, ideal Fermi gas. Fermi temperature, Density operator, Quantum Liouville equation. Pure and mixed states, applications of degeneracy to free electrons in metals, Magnetic susceptibility, White dwarfs and Chandrashekhar limit.

Unit – V

Interacting systems and phase transitions: Interacting spin systems. The Ising model and its exact solution in 1-dimension, mean-field solution in higher dimensions. Paramagnetic and ferromagnetic phases, Critical exponents, Order parameter, Landau theory, Universality.

References:

1. A Treatise on Heat by M.N. Saha and B.N. Srivastava (Indian Press Limited, Allahabad).
2. Heat and Thermodynamics by M.W. Zemansky and R.H. Dittman (McGraw Hill).
3. Statistical Mechanics by R.K. Pathria (Elsevier).
4. Fundamentals of Statistical and Thermal Physics by F. Reif (McGraw-Hill).
5. Statistical Mechanics by K. Huang (John Wiley & Sons).
6. Statistical Mechanics and Properties of Matter by E.S.R. Gopal (Macmillan Ltd., Delhi).
7. Statistical Mechanics by B. K. Agarwal and M. Eisner (Wiley Eastern).

Course Name: Electrodynamics

Course Code: PHYS4007

Credits: 3+0+1 (4 credits)

Course Objectives: To acquire the knowledge of Electrodynamics that allows the students to have a solid theoretical foundation to be able in the future to design emission, propagation and reception of electro-magnetic wave systems.

Course Contents:

Unit – I

Review of Maxwell's Equations: Microscopic and Macroscopic fields, Macroscopic Maxwell equations, Fields D and H, Dielectric tensor, Principal dielectric axes. Potential and Gauges: Scalar and vector potentials, Gauge transformation, Lorentz and Transverse gauge, Maxwell equations in terms of electromagnetic potentials, Covariance of Maxwell's equations.

Unit - II

Propagation of Electromagnetic Waves: Propagation of electromagnetic waves in free space, conducting and non-conducting medium, skin depth, Boundary conditions on EM Fields, Reflection and refraction at a plane interface between dielectrics. Polarisation of EM Waves: Fresnel's Formula, Normal- and anomalous- Dispersion, metallic reflection. EM Wave in rectangular and circular wave guides, TE, TM and TEM Modes, Cut-off frequency and Wavelength. resonant cavities and optical fibers

Unit – III

Radiation: Green function for relativistic wave equation. Radiation from localized oscillating charges. Near and far zone fields. Multipole expansion. Dipole and quadrupole radiation. Centre-fed linear antenna. Radiation from an accelerated point charge. Lienard-Wiechert potentials. Power radiated by a point charge: Lienard's formula and its nonrelativistic limit (Larmor's formula). Angular distribution of radiated power for linearly and circularly accelerated charges. Bremsstrahlung, method of virtual quanta, radiation damping.

Unit – IV

Basics in Quantum electrodynamics: Electromagnetic field in quantum theory, wave equation for particles with spin zero, helicity states of a particle, wave equation for particles with spin ½, four dimensional spinors, Dirac equation in the spinor representation, Dirac equation for an electron in an external field, Intrduction to relativistic electrodynamics.

References:

1. Introduction to Electrodynamics by D.J. Griffiths (Prentice - Hall, New Delhi).
2. Quantum Electrodynamics, Greiner, Walter, Reinhardt, Joachim, Springer, 2009.

3. The Classical theory of Fields by L.D. Landau and E.M. Lifshitz (Elsevier).
4. Classical Electrodynamics by J.D. Jackson (Wiley Eastern).
5. Quantum Electrodynamics, Richard P. Feynman lecture.
6. Introduction to Plasma Physics by F.F. Chen (Plenum Press, New York).
7. Plasma Physics by S.N. Sen (Pragati Prakashan).

Course Name: Electronics

Course Code: PHYS4008

Credits: 3+0+1 (4 credits)

Course Objectives: To buildup on the basic knowledge of electronics with the introduction of advanced topics like circuit analysis and applications of semiconductor devices in analog and digital circuits.

Course Contents:

Unit – I

Circuit Analysis: Admittance, impedance, scattering and hybrid matrices for two and three-port networks and their cascade and parallel combinations. Review of Laplace Transforms. Response functions, location of poles and zeros of response functions of active and passivesystems (Nodal and Modified Nodal Analysis).

Unit - II

Semiconductor Devices and Circuits: BJT, JFET, equivalent circuits and high frequency effects, SCR: Basic structure, I-V characteristics and two- transistor model of SCR, SCR controlled half and full wave rectifier circuit and their analysis. UJT, equivalent circuit, I-V characteristics, Saw tooth wave generation, MOSFET: I-V, C-V characteristics. Enhancement and depletion mode MOSFET, Metal-semiconductor junctions; Ohmic and rectifying contacts, Schottky diode, I-V, C-V relations, Op-Amp & its applications,

Unit - III

Digital Electronics: Boolean algebra, SOP and POS forms, Karnaugh map, design of logic circuits, adders and substractors, parallel adder, shift registers, counters, memory, A/D and D/A converters, microprocessor and microcontroller and applications.

Unit – IV

Elements of Logic Families: Transistor as a switch, FAN IN , FAN OUT, Noise Immunity, propagation delay, RTL, DTL, TTL logic, Sourcing and Sinking logic, TTL loading and Fan out, ECL logic.

Unit – V

Analog and Digital Communication Systems: Analog & Digital Modulation Techniques: Generation and detection, Model ofcommunication system, classification of signals, representation of signals, Band width of PCM, DPCM, DM, ADM, Adaptive DPCM, receivers, External and internal source of noise.

References:

1. Network Analysis and Synthesis by F.F. Kuo.
2. Network Analysis with Applications by W.D. Stanley.
3. Electronic Devices and Circuits by J. Millman and C.C. Halkias.
4. Integrated Electronics by J. Millman and C.C. Halkias(McGraw-Hill).
5. Communication Systems by B. Ram.
6. Solid State Electronic Devices by B.G. Streetman.

7. Physics of Semiconductors Devices by S.M.Sze.
8. Introduction to Semiconductor Materials and Devices by M.S. Tyagi.
9. Digital Design by M. Mano.
10. Digital Fundamentals by Thomas Floyd.
11. Digital principles and Applications by A.P. Malvino and D.P.Leach (McGraw-Hill).
12. Modern Digital Electronics by R.P. Jain (Tata McGraw-Hill).

Course Name: Atomic and Molecular Physics

Course Code: PHYS4009

Credits: 3+0+1 (4 credits)

Course Objectives: To buildup on the basic knowledge of atomic and molecular (diatomic) structures with quantum mechanical approach leading to their fundamental spectroscopies.

Course Contents:

Unit – I

Angular Momentum and Identity of Particles: Orbital, spin and total angular momentum operators: eigen value equations and matrix representations, Distinguishability of identical particles, exchange degeneracy and operator, construction of symmetric and antisymmetric wave functions, Pauli's exclusion principle and Slater's determinant, Electron spin hypothesis, spin matrices and eigen value equations, symmetric and antisymmetric wave functions for hydrogen molecule.

Unit – II

Atomic Physics: Quantum state of one electron atoms, Fine structure of hydrogenic atoms, Mass correction, Intensity of fine structure lines. Effect of magnetic and electric fields: Zeeman, Paschen-Back and Stark effects. Many-electron atoms – Central Field Approximation-LS and jj coupling schemes, Lande interval rule. The Hartree-Fock equations. Hyperfine structure in spectra of monovalent atoms, origin of X-rays spectra, screening constants, fine structure of X-ray levels, spin-relativity and screening doublet-laws, Auger process.

Unit - III

Molecular Structure: Born-Oppenheimer approximation for diatomic molecules, rotation, vibration and electronic structure of diatomic molecules. Spectroscopic terms, Centrifugal distortion, Electronic structure-Molecular symmetry and the states. Molecular orbital and valence bond methods for H_2^+ and H_2, Morse potential, Basic concepts of correlation diagrams for heteronuclear molecules.

Unit - IV

Molecular Spectra: Rotational spectra of diatomic molecules-rigid and non-rigid rotors, isotope effect, Vibrational spectra of diatomic molecules, Intensity of spectral lines, dissociation energy, vibration-rotation spectra, Electronic spectra of diatomic molecules, Rotational structure of electronic bands (Fine structure)-P,Q,R branches. Fortrat diagram. Intensities in electronic bands-The Franck Condon principle. Raman Effect. Electron Spin Resonance. Nuclear Magnetic Resonance.

Unit – V

Lasers: Life time of atomic and molecular states, Multilevel rate equations and saturation, Coherence and profile of spectral lines, Laser pumping and population inversion, He-Ne Laser, Solid State laser, Non-linear phenomenon. Harmonic generation.

References:

1. Physics of Atoms and Molecules by B. H. Bransden and C. J. Jochain (2nd Ed., PearsonEducation, 2003)
2. Atomic Spectra and Atomic Structure by G. Herzberg (Dover Publications, 2003)
3. Molecular Spectra and Molecular Structure by G. Herzberg (Van Nostrand, 1950)
4. Atoms, Molecules and Photons by W. Demtroder (Springer, 2006)
5. Fundamentals of Molecular Spectroscopy by C. N. Banwell (McGraw Hill, 1983)
6. Basic atomic & Molecular Spectrocopy by J. M. Hollas (Royal Society of Chemistry, 2002)
7. Principles of Lasers by O. Svelto (5th Ed., Springer, 2010)
8. Laser Spectroscopy by W. Demtroder (3rd Ed., Springer, 2003)
9. Molecular Quantum Mechanics by P. Atkins & R. Friedman (Oxford Univ. Press, 2005)
10. Quantum Chemistry by I. N. Levine

Course Name: General Lab II

Course Code: PHYS4010

Credits: 0+4+0 (4 credits)

Course Objectives: The major objective of this course is to revise the basic concepts of Solid State Physics, Thermodynamics and Optics through standard set of experiments. In addition, the continuous evaluation process allows each and every student to not only understand and perform the experiment but also suitably correlate them with the corresponding theory.

Course Contents:

Unit – I: Device Characteristics and Application

1. p-n junction diodes-clipping and clamping circuits.
2. FET – characteristics, biasing and its applications as an amplifier
3. MOSFET – characteristics, biasing and its applications as an amplifier.
4. UJT – characteristics, and its application as a relaxation oscillator.
5. SCR – Characteristics and its application as a switching device.

Unit – II: Linear Circuits

1. Filters-passive and active, all pass (phase shifters)
2. Power supply-regulation and stabilization
3. Multivibrators-astable, monostable and bistable with applications
4. Design and study of a triangular wave generator
5. Design and study of sample and hold circuits

Unit – III: Digital Circuits and Microprocessors

1. Combinational circuits
2. Sequential circuits
3. A/D and D/A converters
4. Digital Modulation
5. Microprocessor application

Unit – IV: Optical Spectroscopy

1. Constant deviation spectrometer-fine structure of Hg spectral lines
2. e/m or hyperfine structure using Fabry Perot's interferometer
3. Band spectrum in liquids
4. Raman scattering using a laser source
5. Luminescence

Unit – V: Laser Based Experiments

1. Optical interference and diffraction
2. Holography

3. Electro-optic modulation
4. Magneto-optic modulation
5. Acousto-optic modulation
6. Sound modulation of carrier waves

Semester-III

Course Name: Nuclear and Particle Physics

Course Code: PHYS4011

Credits: 3+0+1 (4 credits)

Course Objectives: The primary objective is to introduce the basic concept of Nuclear & Particle Physics and impart of knowledge for particle and radiations detectors.

Course Contents:

Unit – I

Nuclear Models: Liquid Drop Models, Evidence of Nuclear shell Structure; Shell Model , Semi-empirical mass formula, Nuclear Potential and sequenceof energy levels of nucleons, spin orbit potential and explanation of magic numbers, Collective model. **Nuclear Reactions:** Cross section; partial wave analysis, optical theorem and shadow scattering, Compound nucleus hypothesis, Breit-Wigner one level formula, Direct Reactions; pickup and stripping reactions.

Unit – II

Theory of Alpha & Beta Decay: Alpha decay, Pauli's neutrino hypothesis, Fermi theory of beta (β)-decay, Fermi-Kurie Plot and comparative half lives, selection rules and classification of transitions, Paritynon-conservation and Wu's experiment. **Nuclear forces:** Deuteron problem, low energy (n-p) and (p-p) scattering, scattering length, effective range theory, Spin-dependence of (n-p) interaction.

Unit – III

Nuclear Reactors: Fission Reactor: Neutron multiplication factor, Fermi's four factor formula, resonance escape probability and thermal utilization factor, Basic reactor theory and reactor materials, Basic idea of breeding and fast neutron reactors. **Fusion Reactor:** Fusion reaction, reaction rate and critical temperature, Lawson's criteria; magnetic confinement techniques, Tokamak and magnetic mirror devices.

Unit – IV

2-Body Problem: Deuteron problem, Tensor force, S and D states, Neutron-Proton and proton-proton scattering, Effective range theory, Spin-dependence of nuclear forces, Charge independence and charge symmetry of nuclear forces, Isospin formalism.

Unit - V

Elementary Particles: Fundamental interactions, Classification of elementary particles, symmetry and conservation laws, Concept of isospin, Quarks and colors, Quark model, Eightfold way, Mesons and Baryons, Bound states and resonance states. Elementary idea of CP and CPT invariance, Classification of Hadrons, Quantum numbers in strong interaction, GellMannNishijima formula, Lie algebra, SU(2)-SU(3) multiplets, Quark model of Hadrons, Parity and parity operators.

References:

1. Atomic and Nuclear Physics Vol II by S.N. Ghoshal (S. Chand and Co. Ltd.).
2. Introductory Nuclear Physics by Kenneth S. Krane (John Wiley & Sons).
3. Nuclear Physics by Irvin Kaplan (Addison-Wesley).
4. Concepts of Nuclear Physics by B.L. Cohen (Tata McGraw Hill).
5. Nuclear Physics (Theory and Experiment) by R.R. Roy and B.P. Nigam (WileyEastern).
6. Nuclear Physics Vol I by Y.M. Shirikov and N.P. Yudin, (Mir Publisher, Moscow 1982).
7. Nuclear and Particle Physics by E.B. Paul (North Holland Publishing).
8. Facts and Mysteries in Elementary Particle Physics by M. Veltman (World Scientific).

Course Name: General Lab III

Course Code: PHYS4012

Credits: 0+4+0 (4 credits)

Course Objectives: The major objective of this course is to revise the basic concepts of computation and simulations through standard set of experiments. In addition, the continuous evaluation process allows each and every student to not only understand and perform the experiment but also suitably correlate them with the corresponding theory.

Course Contents:

1. Introduction to Linux and Computer Programming Language (C/C++).
2. Introduction to Graphics (Gnuplot etc.)
3. Finite & Infinite Series
4. Root Finding (Bisection, Secant and Newton-Raphson Methods)
5. Solving First & Second Order differential Equations including Simultaneous Equations (Euler & Runge Kutta Method)
6. Numerical Integration (Trapezoidal, Simpson and Quadrature methods)
7. Schrödinger Equation- Finding the Eigenvalues & Eigenfunctions.
8. Matrices- Arrays of variable Size, Matrix Operations, Eigenvalues & Eigenvectors, Matrix Inversion
9. Solving Systems of Linear Equations.

References:

1. Numerical Recipes in C++: The Art of Scientific Computing 2nd Edition by William H. Press, Saul A. Teukolsky, William T. Vetterling , Brian P. Flannery, 2002.
2. Numerical Recipes in C: The Art of Scientific Computing, Second Edition 2nd Edition by William H. Press , Brian P. Flannery, Saul A. Teukolsky, William T. Vetterling, 2002 .
3. Mathematical Methods for Physicists, 7th Edition by George Arfken, Hans Weber, Frank E. Harris; Academic Press, 2012.
4. Lab. Manual for Computer Programming & Numerical Methods, Dept. of Physics & Astrophysics, University of Delhi, 2017.

Semester-IV

Course Name: Experimental Methods in Physics of Materials

Course Code: PHYS4013

Credits: 0+4+0 (4 credits)

Course Objectives: The student will obtain good understanding of materials characterization by introducing the basic principles and performing experiences of a large range of techniques used to characterize different types of materials. After completion of the course, the student shall have the ability to recommend appropriate methods for particular problems; be able to apply the knowledge obtained to elaborate a work plan in solving a particular problem; be able to explain the data obtained and the phenomena exhibited in the materials analysis.

Course Contents:

X-ray diffraction technique. Neutron diffraction; UV-vis Spectroscopy, Fundamentals of electron microscopy (SEM, TEM, Electron diffraction, STEM); Electron Probe Micro Analisys (EPMA) (EDS, WDS); Electron Energy-Loss Spectroscopy (EELS); Scanning tunneling microscopy and atomic force microscopy; Electron emission spectroscopies (XPS, AES, UPS); X-Ray Fluorescence (XRF); Ion scattering techniques and mass spectroscopy; Vibrational spectroscopy (IR, Raman); Resonance techniques (NMR, ESR); Thermal analysis (DSC and DTA); Low temperature techniques.

Laboratory:

1. Qualitative and quantitative analysis of XRD patterns
2. UV-vis Spectroscopy
3. Interpretation of XPS spectra
4. Electrical conduction at low temperatures
5. Differential thermal analysis
6. Presentation of experimental equipments for materials characterization (SEM, XRD, XPS, XRF, AFM, IR, Raman etc.)

References:

1. V. Pop, I. Chicinaş, N. Jumate, Fizica Materialelor: Metode experimentale, Presa Universitară Clujeană, 2001.
2. P.E.J. Flewitt, R.K. Wild, Physical Methods for Materials Characterisation, Institute of Physics, Bristol and Philadelphia, 1994.
3. R.C. Brundle et al., Encyclopedia of materials characterization: Surfaces, interfaces, thin films London: Butterworth-Heinemann, 1992.

Semester-III
Elective Courses

Course Name: Materials Science-I

Course Code: PHYS4101

Credits: 3+0+1 (4 credits)

Course Objectives: One of the main objectives of the course is to familiarize the students with the fundamental concepts of Materials Science. The course provides an introduction to the type of materials, structure, properties, characteristics and applications, with special emphasis on the relationships between internal structure and properties.

Course Contents:

Unit - I

Introduction to Nanoscience: Introduction to Nanoscience and Nanotechnology, Significance of Nanoscale, Quantum confined systems: Quantum confinement and its consequences, quantum wells, quantum wires and quantum dots and artificial atoms. Electronic structure from bulk to quantum dot. Electron states in direct and indirect gap semiconductors nanocrystals. Confinement in disordered and amorphous systems. Bragg's Law, Powder X-ray Diffraction, Scherrer equation and Williamson-Hall plot. Types of Material: Metals, Semiconductors, Composite materials, Ceramics, Alloys, Polymers.

Unit - II

Dielectric properties: Coulomb interaction in nanostructures. Concept of dielectric constant for nanostructures and charging of nanostructure. Quasi-particles and excitons: Excitons in direct and indirect band gap semiconductor nanocrystals. Quantitative treatment of quasi-particles and excitons. Charging effects.

Unit - III

Optical properties: Optical properties and radiative processes: General formulationabsorption, emission and luminescence; Optical properties of heterostructures and nanostructures. **Carrier transport in nanostructures:** Coulomb blockade effect, scattering and tunneling of 1D particle; applications of tunneling, single electron transistors. Defects and impurities: Deep level and surface defects.

Unit - IV

Materials Characterization techniques: X-ray Diffraction, Neutron diffraction, Scanning Electron Microscopy based techniques (Secondary electron imaging, backscattered electron imaging, Electron backscattered diffraction (EBSD)), transmission electron microscope, and scanning probe techniques, TEM based techniques (diffraction contrast imaging, Electron diffraction, High resolution imaging, Thermal analysis, NMR, Scanning probe microscopies (Atomic Force Microscopy, Piezeo Force Microscopy, Scanning Tunneling Microscopy), Laser Raman spectroscopy.

Electrical measurement techniques: resistivity, polarization, Electrochemical techniques (cyclic voltametry).

Unit - V

Basics of nanoelectronics: Introduction: Recent, past, the present and its challenges, Future, Overview of basic Nano electronics. Spintronics: Introduction, Overview, History & Background, Generation of Spin Polarization Theories of spin Injection, spin relaxation and spin dephasing, Spintronic devices and applications. Various types of transducers.

References:

1. Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles, 2nd Edition byEisberg, Robert; Resnick, Robert.
2. Quantum Physics – A. Ghatak.
3. Handbook of Spin Transport and Magnetism, by Evgeny Y. Tsymbal and Igor Zutic.
4. Introduction to Solid State Physics - C. Kittel, 7th edition, Publisher: Wiley India Pvt. Ltd.
5. Materials Science & Engineering: An Introduction- William D. Callister, Jr, 7th edition, Publisher: Wiley India Pvt. Ltd.
6. Solid State Chemistry and its applications -Anthony R. West, Publisher: John Wiley & Sons.
7. Characterization of Nanophase Materials by Z. L. Wang (Ed.) (Wiley-VCH, 2000).
8. Semiconductor Nanocrystal Quantum Dots by A. L. Rogach (Ed.) (Springer Wien NY, 2008).
9. Introduction to Nanotechnology by C.P. Poole Jr. & F.J. Owens (Wiley-Interscience, 2003).

Course Name: Condensed Matter Physics-I

Course Code: PHYS4102

Credits: 3+0+1 (4 credits)

Course Objectives: This course intends to provide knowledge of conceptual advanced level solid-state physics. In addition, this course aims to provide a general introduction to theoretical and experimental topics in solid state physics by covering symmetry properties in solids and disordered solids.

Course Contents:

Unit – I

Symmetry Properties of Crystal Lattice: Mathematical group representation, Double valued representation, The crystalline structure; Transformation of crystal lattice; Symmetries in Bravais lattice; Point groups; Space group; Classes, Transformation and construction.

Unit – II

Crystalline Solids: Free electron theory; Fermi gas at finite temperature, Mean energy, Methods of Energy Band Calculation; Electron dynamics in periodic lattice, Wigner-Seitz method and cohesive energy of metals, Orthogonalized plane wave (OPW), Pseudo potential, Augmented plane wave (APW) and Green function methods, Transition metal bands.

Unit - III

Fermi Surface: Construction of Fermi surface, Cyclotron resonance, Electron, hole and open orbits, Anomalous skin effect, De Haas Van Alphen effect. Lattice Vibration and Thermal Properties: Quantization of lattice vibration, Phonon momentum Inelastic scattering of photon by photon and neutron by photon, Local phonon modes, phonon dispersion relation, Debye model of lattice heat capacity, Anharmonicity and thermal expansion.

Unit – IV

Disordered Materials: Structure, Short range order and dangling bond; Random network model; Amorphous semiconductor; Density of states and mobility gap; Electrical transport, Optical and switching properties.

Unit -V

Optical properties: Optical constants and their physical significance, Reflectivity in metals, plasmonic properties of metals, determination of band gap in semiconductors: direct and indirect band gap, defect mediated optical transitions, excitons, photoluminescence, Electroluminesence.

References:

1. Principle of theory of solid by J.M. Ziman (Cambridge University Press, London).
2. Theoretical Solid State Physics by W. Jones and N.H. March (John Wiley and Sons, London).

3. Quantum Theory of Solid by C. Kittel (John Wiley and Sons, London).
4. Quantum Theory of Solids by R.E. Peirls (Oxford University Press, London).

Course Name: Laser Spectroscopy and Advanced Optics

Course Code: PHYS4103

Credits: 3+0+1 (4 credits)

Course Objectives: To provide a broad introduction to major types of lasers and modern types of spectroscopy.

- Understand the fundamental processes that occur during the interactionof light and matter.
- Be familiar with applications of laser spectroscopy in industry and incutting edge research.

Course Contents:

Unit - I

Laser: Einstein coefficients, Light amplification; Population inversion; pumping processes; rate equation for three and four level systems; Cavity modes, polarization of cavity media; Quality factor of cavity and ultimate line width, Characteristic properties, Basic principles of Ruby, He-Ne, CO_2, Threshold condition for Oscillation in Semiconductor Laser. Homostructure and Heterostructure p–n junction lasers, Nd-YAG lasers. Principle of Excimer Laser. Principle and Working of Dye Laser. Free Electron Laser.

Unit - II

Holography: Basic principle of holography, Method of hologram Recording and Reconstruction; Basic theory of plane hologram; practical consideration of holography and its application.

Unit - III

Non Linear Processes: Non-linear polarizability tensors, Coupled amplitude equation; Manely Rowe relationship; Parametric amplification and oscillation, Phase matching, Second harmonic generation. **Fibre Optics:** Types of fibres, Single mode and multi-mode fibres; dispersion and loss in fibre; Principles of optical communication, Optical elements. Fiber Lasers, Stimulated Raman Scattering and Raman Lasers, CARS, Saturation and Two photon Absorptions.

Unit – IV

Quantum Optics: Spatial and temporal coherence, classical and quantum coherence function; Glauber's theory of optical coherence, Over completeness of coherentstates and its properties; Quasi phase distribution function.

Unit – V

Novel Applications of Laser: Cooling and Trapping of Atoms, Principles of Doppler and Polarization Gradient Cooling, Qualitative Description of Ion Traps, Optical Traps and Magneto-Optical Traps, Evaporative Cooling and Bose Condensation.

References:

1. Laser Spectroscopy and Instrumentation: W. Demtroder.

2. Principles of Lasers: O. Svelto.
3. Optical Electronics: A.K. Ghatak and K. Thyagrajan (Cambridge University Press).
4. Laser Cooling and Trapping: P.N. Ghosh.
5. Frontiers in Atomic, Molecular and Optical Physics: S.P. Sengupta.

Course Name: Nanostructure and Quantum Devices

Course Code: PHYS4104

Credits: 3+0+1 (4 credits)

Course Objectives: The course focuses on the topics of solid state physics in nanostructures for further understandings of advanced semiconductor devices based on the fundamental of solid state physics.

Course Contents:

Unit - I

Background to Nanoscience: Definition of Nano, Scientific revolution-Atomic Structure and atomic size, emergence and challenges of nanoscience and nanotechnology, carbon age-new form of carbon (CNT to Graphene), influence of nano over micro/macro, size effects and crystals, large surface to volume ratio, surface effects on the properties.

Unit - II

Types of nanostructure and properties of nanomaterials: One dimensional, Two dimensional and Three dimensional nanostructured materials, Quantum Dots shell structures, metal oxides, semiconductors, composites, mechanical-physical-chemical properties.

Unit - III

Quantum Devices: Charge and spin in single quantum dots, Coulomb blockade, Electrons in mesoscopic structures, single electron transfer devices (SETs), Electron spin transistor, resonant tunnel diodes, tunnel Field Effect Transistors (FET), quantum interference transistors (QUITs), quantum bits (qubits).

Unit - IV

Nanoelectronic Devices: Electronic transport in 1, 2 and 3 dimensions, Quantum confinement, energy sub-bands, Effective mass, Drude conduction, mean free path in 3D , ballistic conduction, phase coherence length, quantized conductance, Buttiker-Landauer formula, electron transport in pn junctions, short channel Nano Transistor, Metal Oxide Semiconductor (MOS)FETs, Advanced MOSFETs, Trigate FETs, Fin-FETs, CMOS.

Unit - V

Spintronics: Spin tunneling devices, Magnetic tunnel junctions, Tunneling spin polarization, Giant tunneling using MgO tunnel barriers, Tunnel-based spin injectors, Spin injection and spin transport in hybrid nanostructures, spin filters, spin-diodes, Magnetic tunnel transistor, Memory devices and sensors, ferroelectric random access memory (RAM), Magnetic RAMS-Field Sensors, Multiferro electric sensors, Spintronic Biosensors.

References:

1. Chemistry of nanomaterials: Synthesis, properties and applications by CNR Rao et.al.
2. Nanoparticles: From theory to applications – G. Schmidt, Wiley Weinheim 2004.
3. V. Mitin, V. Kochelap, M. Stroscio, Introduction to Nanoelectronics, Cambridge University Press (2008).
4. Rainer Waser, Nanoelectronics and Information Technology: Advanced Electronic Materials and Novel Devices, Wiley-VCH (2003).
5. Edward L. Wolf, Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience, Wiley-VCH (2006).

Course Name: Physics of Renewable Energy Systems

Course Code: PHYS4105

Credits: 3+0+1 (4 credits)

Course Objectives: This course provides upper division science and engineering students to the underlying issues of energy demand, its link to human development, and a basic introduction to the physics of climate change and the Earth's carbon balance. An introduction to energy storage technologies is also provided and used to provide perspectives on electrochemical storage application to renewable grid integration and ground transportation.

Course Contents:

Unit – I

Solar Photovoltaics: P-N junction under illumination, Light generated current, I-V equation, Characteristics, Upper limits of cell parameters, losses in solar cells, equivalent circuit, effects of various parameters on efficiency, Solar cell design, Design for high I_{sc}, Anti-reflective coating (ARC), Design for high V_{oc} and fill factor, Analytical techniques; solar simulator, Quantum efficiency, Minority carrier lifetime and diffusion length measurement. Thin film solar cells: Advantages, materials, a-Si, CdTe, CIGS.

Unit – II

Sensitized and Polymer Photovoltaics: Dye sensitized solar cells, advantages and disadvantages, Quantum dot sensitized solar cells, Perovskite sensitized solar cells, Planar and bulk heterojunction polymer solar cells, Exciton generation and dissociation, Advantages, disadvantages and types of materials.

Unit – III

Batteries and Fuel cells: Primary batteries, Rechargeable batteries, Electrochemical energy storage: cell reaction, Laws, Parameters, thermodynamics parameters, kinetic parameters, Polarization, Heat effects, Types of batteries (Lead-acid, Ni/Cd, Ni/metal hybrid), charging methods and techniques, characteristic curves, Lithium batteries, chemistry and Physics of lithium batteries, anode and cathode materials, applications, Introduction to fuel cells.

Unit – IV

Supercapacitors: Similarities and differences between supercapacitors and batteries, Energetics, Double layer electrostatic capacitor, Pseudocapacitance, origin, kinetic theory, RuO_2 as a material for electrochemical capacitors, Regon plot, electrolyte factor, energy density and power density, Impedance of a pseudocapacitance, Technology development, various oxides as pseudocapacitors.

Unit – V

Newer Energy Materials: Carbon nano-tubes (CNTs) and multiwall carbon nanotubes (MWCNTs), graphene, graphene oxide, reduced graphene oxide and Polymer composites -classification, methods of production, properties, and its utility in making energy devices.

References:

1. Solar photovoltaics, Fundamentals, Technologies and Applications by Chetan Singh Solanki, PHI Learning Private Limited, Delhi.
2. Sie-Chin Tjong, Nanocrystalline Materials. Elsevier, 2014.
3. K. L. Chopra, Suhit Ranjan Das, Thin Film Solar Cells, Springer Science, 1983.
4. David Linden, Thomas B. Reddy, Handbook of batteries, 3rd Edition, Mcgraw Hill, 2002.
5. Polymer photovoltaics, a practical approach by Fredrik C. Krebs, Spie Press, Bellingham, Washington USA.
6. Organic Solar Cells, Theory, Experiment, and Device Simulation by Wolfgang Tress, Springer.
7. Dye Sensitized Solar Cells by K. Kalyansundaram, EPFL Press, A Swiss academic publisher distributed by CRC press.
8. Solar cells- Dye-sensitized Devices by Leonid A. Kosyachenko, Published by Intech, Janeza Trdine 9, 51000 Rijeka, Croatia.
9. Battery Technology Handbook by H. A. Kiehne , Marcel Dekker, Inc., New York, Basel.
10. Electrochemical Supercapacitors, Scientific fundamentals and Technological Applications by B. E. Conway, Kluwer Academic/Plenum Publishers, New York, Boston, Dordrencht, London, Moscow.

Course Name: Accelerator based Physics of Solids

Course Code: PHYS4106

Credits: 3+0+1 (4 credits)

Course Objectives: The course aims to expose students to different theoretical design and usage of various particle accelerators and its applications. Students will have the understanding of:

- various theoretical techniques to accelerate particles
- technical details of accelerator technology
- the latest accelerator available around the world

Course Contents:

Unit - I

Charged Particle Dynamics: Need of accelerated particles in Physics study; Production of ion beams (ion sources and accelerators); Interaction of radiation with matter; Particle motion in electric and magnetic fields, Beam transport system, Beam pulsing and bunching techniques, microbeams, Particle and ion sources, secondary beams, Measurement of beam parameters.

Unit - II

Radiofrequency Accelerators: Linear accelerators - Resonance acceleration and phase stability, electron and proton Linacs. Circular accelerators- Cyclotron, Frequency Modulated Synchrocyclotron, AVF Cyclotron, Alternating-gradient accelerators. **Electrostatic and Heavy Ion Accelerators:** Van de Graff voltage generator, Cockcroft-Walton voltage generator, insulating column, voltage measurement, Acceleration of heavy ions, Tandem electrostatic accelerator, Production of heavy negative ions, Pelletron and Tandetron, Cluster beams, Superconducting Heavy Ion Linear Accelerators.

Unit - III

Synchrotron Radiation Sources: Electromagnetic radiation from relativistic electron beams, Electron synchrotron, dipole magnet, multipole wiggler, non-coherent and coherent, Undulator, Characteristics of synchrotron radiation. **Radioactive ion Beams:** Production of Radioactive ion beams, Polarized beams, Protonsynchrotron, Colliding accelerators.

Unit – IV

Materials engineering using heavy ions: Ion implantation, ion beam assisted deposition (IBAD), ion beam mixing (IBM); Materials analysis using heavy ions – Rutherford backscattering spectroscopy (RBS), Elastic recoil detection analysis (ERDA); Ion induced nuclear reactions; Nuclear reaction analysis (NRA); Nuclear solid state physics - Microscopic magnetism using Perturbed angular distribution (PAD).

Unit – V

Use of accelerators for AMS and Ion-beam Analysis Techniques, Relativistic heavy ion accelerator, Large hadron collider, Stanford linear accelerator, J-Parc, FAIR facilities.

References:

1. Clarke D. R., Suresh S. and Ward I.M, Ion-solid interactions: fundamentals and applications, Cambridge Solid State Science Series, Cambridge University Press.
2. Richard Patrick, Methods of Experimental Physics: Atomic Physics, Accelerators (Vol. 17), Academic Press.
3. Griffiths D. J., Quantum Mechanics, Pearson Prentice Hall.
4. Avasthi, D.K. and Mehta, G.K., Swift Heavy Ions for Materials Engineering and Characterization, Springer.
5. Nastasi Michael Anthony, Mayer James W., Hirvonen James Karsten, Ion-solid interactions: fundamentals and applications, Cambridge University Press.
6. Mozumder A. and Hatano Y., Charged particle and photon interactions with matter: Chemical, physicochemical, and biological consequences with applications, CRC Press.
7. Wiedman, H.J., Particle Accelerator Physics, Vol. I and II, Springer Verlag, (1998).
8. Livingston, M.S., and Blewel, J.P., Particle Accelerators, McGraw-Hill Book Press,(1962).
9. Cerny, J., Nuclear Spectroscopy and Reactions Part-A, Academic Press (1974).
10. Lee, S.Y., Accelerator Physics, World Scientific, Singapore, (2004).

Course Name: Advanced Mathematical Physics

Course Code: PHYS4107

Credits: 3+0+1 (4 credits)

Course Objectives: The course will introduce to the students basic concepts of finite and infinite groups. Examples from various fields will be considered. Techniques for solving integral equations will be learnt. Introduction to Tensor analysis, Green functions and its construction will be studied.

Course Contents:

Unit - I

Finite discrete Group: Group Theory: Abstract groups: subgroups, classes, cosets, factor groups, normal subgroups, direct product of groups; Examples: cyclic, symmetric, matrix groups, regular n-gon. Mappings: homomorphism, isomorphism, automorphism. Representations: reducible and irreducible representation, unitary representations, Schur's lemma and orthogonality theorems, characters of representation, direct product of representations.

Unite - II

Continuous Group: Introduction to continuous groups: Lie groups, rotation and unitary groups. Applications: point groups, translation and space groups, representation of point groups; introduction to symmetry group of the Hamiltonian.

Unit - III

Integral Equations: Conversion of ordinary differential equations into integral equations, Fredholm and Volterra integral equations, separable kernels, Fredholm theory, eigen values and eigen functions.

Unit – IV

Tensor analysis: Tensor in three and/or four dimensions; rank of tensors; covariant and contravariant tensors; symmetric and antisymmetric tensors; metric tensors; Christoffels symbols; equation of a geodesic; Riemann-Christoffel tensor; simple applications.

Unit – V

Green function: Boundary Value Problems: boundary conditions: Dirichlet and Neumann; self-adjoint operators, Sturm-Liouville theory, Green's function, eigenfunction expansion.

References:

1. A.W. Joshi, Elements of Group Theory for Physicists (John Wiley, 1997).
2. M. A. Armstrong, Groups and Symmetry (Springer, 1988).
3. R. S. Kaushal & D. Parashar, Advanced Method of Mathematical Physics (Narosa, 2008).

4. M. Hamermesh, Group Theory and Its Applications to Physical Problems (Dover, 1989).
5. F. Albert Cotton, Chemical Applications of Group Theory (John Wiley, 1988).
6. G. Arfken, H. Weber, & F. Harris, Mathematical Methods for Physicists (Elsevier, 2012).
7. W. V. Lovitt, Linear Integral Equations (Dover, 2005).
8. A. J. Jerri, Introduction to Integral Equations with Applications (Wiley-Interscience, 1999).
9. Spiegel, M., Lipschutz, S., and Spellman, D., Vector Analysis, (Tata McGraw-Hill Education Private Limited, 2009).
10. Harper, C., Introduction to Mathematical Physics, (Prentice Hall, 2009).

Course Name: Advanced Solid State Physics

Course Code: PHYS4108

Credits: 3+0+1 (4 credits)

Course Objectives: The overall objective of the course is to give exposure and discussions on various topics which will include experimental aspects, enabling students to pursue higher studies both in theoretical as well as experimental condensed matter physics.

Course Contents:

Unit – I

Optical absorption: Free carrier absorption-optical transition between bands, direct and indirect, excitons, photoconductivity, general concepts, model of an ideal photoconductor, traps, space charge effects, crystal counters, experimental techniques, Transit time, Luminescence in crystal - excitation and emission, decay mechanism, Thallium activated alkali halides, model of luminescence in sulphide phosphors, electroluminescence.

Unit – II

Density of states, classification of solid into metals, semi-metals, semiconductors and insulators, Calculation of number of carries in intrinsic semiconductor, Fermi level, carrier concentration in impurity semiconductors, electronic degeneracy in semiconductors. Equation of motion of electrons in a band, Effective mass and concept of holes, Boltzmann Transport equation. contact potential, metal-semiconductor contact, Schottky boundary layer, injecting contacts, surface states.

Unit – III

Quantum wells and low dimensional systems: Electron confinement in –infinitely deep square well and square well of finite depth-confinement in two and one dimensional wellideas of quantum well structures, quantum dots and quantum wires-methods of preparation of nanomaterials: top down and bottom up approaches: wet chemical, self assembled vapour, phase condensation.

Unit – IV

Growth of single crystals - general ideas. Thin film preparation techniques: thermal and electron gun evaporation: dc and rf sputtering, amorphous solids: preparation techniques applications. Classification of liquid crystals, applications of liquid crystals, ceramic processing techniques, electrical and mechanical properties, composite materials.

References:

1. C. Kittel, Introduction to Solid State Physics.
2. A. J. Dekker, Solid State Physics.
3. R. H. Bube, Electronic Properties of Crystalline Solids.
4. G. Busch and H. Schade, Lectures on Solid State Physics.

5. A. Haug, Theoretical Solid State Physics.
6. T. H. Lynton, Superconductivity.
7. T. V. Ramakrishnan and C. N. R. Rao, Superconductivity Today.
8. N. W. Aschroft and N. D. Mermin, Solid State Physics.

Course Name: Plasma and Astrophysics

Course Code: PHYS4109

Credits: 3+0+1 (4 credits)

Course Objectives: The primary learning outcome for this course is for the students to learn the basic principles and main equations of plasma physics, at an introductory level, with emphasis on topics of broad applicability.

Course Contents:

Unit - I

Basic plasma concepts: Debye shielding, plasma frequency, plasma parameter; motion of charged particle in electromagnetic field; uniform E and B fields, gradient B drift, parallel acceleration and magnetic mirror effect.

Unit - II

Waves in plasma, electron and ion plasma waves, their dispersion relations and properties, fundamental equations of magneto-hydrodynamics (MHD), the MHD approximation, hydromagnetic waves, plasma confinement schemes, plasma in space.

Unit - III

Introduction to the interstellar medium: Neutral and ionized gas, gaseous nebulae, HII regions, supernova remnants, photo-dissociation regions, different phases of the interstellar medium: cold neutral medium, warm neutral and ionized medium, hot medium, diffuse clouds, dense clouds.

Unit - IV

Radiative processes: Radiative transfer, emission and absorption coefficients, emission and absorption lines, the role of thermal and free electrons.

References:

1. Bellan, P. M., Fundamentals of Plasma Physics, 1st edition (Cambridge University Press, 2008).
2. Chen, F. F., Introduction to Plasma Physics and Controlled Fusion, 2nd edition, Vol. 1, (Springer, 1984).
3. Tielens, A. G. G. M., Physics and chemistry of the interstellar medium, (Cambridge University Press, 2010).
4. Dyson, J. E. and Williams, D. A., The Physics of the interstellar medium, 2nd edition (Taylor and Francis, 1997).
5. van der Hulst, J. M., The interstellar medium in galaxies, 1st edition (Astrophysics and Space Science Library, Springer; 2001).
6. Krishan, V., Astrophysical Plasmas and Fluids, 1st edition (Springer, 1999).
7. Spitzer, L., Physical Processes in the interstellar medium, (Wiley-VCH, 1998).
8. Draine, B. T., Physics of the Interstellar and Intergalactic Medium, (Princeton University Press, 2010).

9. Shu, F., The Physical Universe, (University Science Books, 1982).
10. Abhyankar, K. D., Astrophysics: Stars and Galaxies, (Sangam Books Ltd, 2002).

Course Name: Ultrafast Spectroscopy

Course Code: PHYS4110

Credits: 3+0+1 (4 credits)

Course Objectives: This course is intended on non-linear and ultrafast optics with application to ultrafast spectroscopy. In this course students will be enabled to learn laser basics and Maxwell's equation. Generation and characterization of ultrashort laser pulses and its application in different fields of modern spectroscopy will be discussed.

Course Contents:

Unit - I

Laser Basics: Introduction to nonlinear Optics; Review of Maxwell Equation; 2-Level Atoms: Einstein Relation & Optical Bloch Equations; Dispersion, Absorption, Gain; Single Mode Laser and Q-Switching.

Unit - II

Pulse Generation: Active & Passive Mode-Locking; Mode-Locking with Saturable Absorbers; Kerr-Lens Mode-Locking; Nonlinear Pulse Propagation Pulse Compression, Characterization and Conversion.

Unit - III

Pulse Compression & Shaping: Autocorrelation; FROG and SPIDER; Self-Phase Modulation (SPM) and Solitons; White Light Generation; Optical Parametric Amplification (OPA & NOPA); THz Generation, High Harmonic Generation, Attosecond Pulses and X-ray generation.

Unit - IV

Spectroscopic Methods: Pump-Probe Methods, Four-Wave Mixing and other third-order techniques, Time- resolved Electron Spectroscopy, Ultrafast Microscopy, Time-Resolved Electron Diffraction and Seeded Free-Electron Lasers.

References:

1. J.-C. Diehls, W. Rudolf , Ultrashort Laser Pulse Phenomena, Elsevier, 2006.
2. Wolfgang Demtroder, Laser Spectroscopy: Basic Concepts and Instrumentation, Springer, 1996.
3. Orazio, Svelto, Principles of Lasers, Springer, 2010.

Semester-IV
Elective Courses

Course Name: Materials Science-II

Course Code: PHYS4111

Credits: 3+0+1 (4 credits)

Course Objectives: The main goal of this subject is to provide basic understanding of fabrication and characterization of nano structured materials by different analytical methods. More importantly, the students will have enriched knowledge on the properties of materials at the nanoscale and implementing it for various applications.

Course Contents:

Unit - I

Growth: Synthesis of metal, semiconductor, carbon and bio nanomaterials. Grains and grain boundaries, distribution of grain sizes, pores, strains. Thin film preparation methods by thermal evaporation, sputtering and pulsed laser deposition methods. Gas phase synthesis of nanopowders, chemical and colloidal methods, mechanical milling, dispersion in solid-doped glasses and sol gel method; Functionalization of nanoparticles.

Unit - II

Chemical Methods: Metal nanocrystals by reduction, Solvothermal synthesis, Photochemical synthesis, Nanocrystals of semiconductors and other materials by arrested precipitation,Thermolysis routes, Sonochemical routes, Liquid-liquid interface, Hybrid methods, Solvated metal atom dispersion, Post-synthetic size-selective processing. Sol gel, Micelles and microemulsions, Cluster compounds.

Unit - III

Characterization using Spectroscopic techniques: Ultraviolet-Visible-Infrared, Fourier Transform Infrared Spectroscopy. Raman. X-ray Photoelectron Spectroscopy (XPS), XAS and EXAFS. Photoluminescence, Fluorescence, Phosphorescence, Electroluminescence, Photoconductivity, Auger spectroscopy, Energy Dispersive X-ray Spectroscopy, Wavelength Dispersive X-ray Spectroscopy, Electron Energy Loss Spectroscopy, Scanning tunneling spectroscopy, Differential Thermal analysis (DTA) - Differential Scanning Calorimetry (DSC) – Thermo-gravimetric analysis (TGA); Chemical characterizations-Raman spectroscopy. **Magnetic measurement technique:** Magneto-resistance, Vibrating Sample Magnetometer (VSM), Superconducting Quantum Interference Device (SQUID), Magneto-Optical Kerr Effect.

Unit - IV

Properties: Chemical-reactivity, Mechanical properties at nanoscale; Mechanical superplasticity. Magnetism at nanoscale; Magnetic and electron transport- GMR and Optical linear and nonlinear.

Unit - V

Applications of nanomaterials: Electronics and Electromagnetics-ceramic capacitors and magnetic recording Optics-nanophosphors and photonic crystals Mechanics-Biology and environment. Nanomaterial Devices: Quantum dot heterostructure lasers, all optical switching and optical data storage.

References:

1. Nanostructured Materials and Nano technology by H. S. Nalwa (Ed.) (Academic Press, 2002).
2. Nanomaterial and Nanochemistry by C. Brechignac, P. Houdy and M. Lahmani (Springer, 2006).
3. Characterization of Nanophase Materials by Z. L. Wang (Ed.) (Wiley-VCH, 2000).
4. Semiconductor Nanocrystal Quantum Dots by A. L. Rogach (Ed.) (Springer Wien NY, 2008).
5. Introduction to Nanotechnology by C. P. Poole Jr. & F. J. Owens (Wiley-Interscience, 2003).
6. Carbon Nanotubes by S. Reich, C. Thomsen & J. Maultzsch, (Wiley-VCH, 2004).

Course Name: Condensed Matter Physics-II

Course Code: PHYS4112

Credits: 3+0+1 (4 credits)

Course Objectives: This course intends to provide knowledge of emerging topics in condensed matter physics. In addition, this course aims to provide a general introduction to theoretical and experimental aspects of advanced topics.

Course Contents:

Unit – I

Transport Properties: Linearised Boltzmann transport equation, Electrical conductivity, Relaxation time, Impurity scattering, Ideal resistance, Carrier mobility, General transport coefficient; Thermal conductivity, Thermoelectric effects, Lattice conduction, Phonon drag, Hall effect and magnetoresistance.

Unit – II

Superconductivity: Electron-electron interaction and screening, electron-phonon-electron interaction and Cooper pairs, Salient features of BCS theory, Superconducting ground state, Quasi particle and energy gap, High T_c superconductors; Charge transfer model of Cuprates, Defect ordering.

Unit – III

Magnetic Resonance: General theory of magnetic resonance and Bloch equations, Electron paramagnetic resonance (EPR): Method of observation, Structure of resonance lines and their uses; Nuclear magnetic resonance (NMR): Salient theory and method of observation, Structure of resonance lines and their uses.

Unit – IV

Mossbauer Effect: Difficulties in observing resonance flourescence of nuclear system, Recoil energy, Natural and dipole broadenings, Classical and quantum theories of Mossbauer effect, experimental method and principal uses of Mossbauer effect.

Unit - V

Liquid crystals: Liquid Crystals, Structural peculiarities and applications, Thermotropic liquid crystals; Classification, Phases and phase transitions; anisotropic materials; symmetry aspects; optics; electro-optics of liquid crystals; ferro-, and antiferroelectric liquid crystals; examples of liquid crystals in nanoscience, photonics and microwave electronics, display devices.

References:

1. Principle of theory of solid by J.M. Ziman (Cambridge University Press, London).
2. Theoretical Solid State Physics Vol. I and Vol. II by W. Jones and N.H. March (John Wiley and Sons, London).
3. Quantum Theory of Solid by C. Kittel (John Wiley and Sons, London).
4. Quantum Theory of Solids by R.E. Peirls (Oxford University Press, London).
5. Mossbauer Effect and its Application by V. G. Bhinde.

6. Principles of Magnetic Resonance by C.P. Slichter (Horper and Row, NewYork).
7. Pierre-Gilles de Gennes, “The physics of liquid crystals”, Oxford Science Publications.
8. Peter J. Wojtowicz, E. Priestly, Ping Sheng, “Introduction to Liquid Crystals”, Springer.

Course Name: Soft Matter Physics

Course Code: PHYS4113

Credits: 3+0+1 (4 credits)

Course Objectives: This course aims to provide physics based approach to study the structure and assembly of a variety materials including liquid crystals, polymers, colloidal systems and surfactants including biological examples.

Course Contents:

Unit - I

Introduction: Characteristics of soft condensed matter, States of matter and phase transition, review of statistical mechanics relevant to the study of soft materials, soft materials in industry, nature and biology. **Forces and Energy scales:** Atomic and molecular forces, van der Waals forces, casimir forces, hard core repulsion, shapes of molecules, entropy.

Unit - II

Capillarity and wetting: Surface and interfacial tension, dynamics of wetting, viscosity capillary rise and meniscus, shapes of droplets – solid substrates and liquid substrates, droplet spreading dynamics, Wetting of films and fibres and dewetting.

Unit - III

Colloids: Interparticle interactions, particle packing and frustration, phase diagram of hard spheres, thermodynamics of colloidal system, dynamics of small particles – diffusion equation, The Langevin equation and viscosity, aggregation, rheology. Applications in inks, food colloids, sedimentation and flotation, Simple methods of preparation of colloidal particles.

Unit -IV

Polymers: The ideal chain structure, statistical mechanics of chain structure, polymer solution and melts, fractals in polymers – disorder and scale invariance, random aggregation, diffusion limited aggregation (DLC) and DLCA, glass transition, amorphous and crystalline polymers, block polymers. Applications rubbers, plastics, biopolymers like proteins, DNA, viscoelastic fluids and synthetic materials Simple experimental methods of preparation of some of the polymers.

Unit - V

Liquid crystals: Classification, Nematic liquid crystals order, singularity, elasticity, display application, lamellar properties, Cholesterics, Lamellar systems – structures and properties, chiral systems, Smectics and Columnar systems – structures and properties, phase transitions, preparation of liquid crystals and application to liquid crystal displays.

Unit - VI

Amphiphiles: Miscellar shape and phase behavior, giant miscelles, fluid membranes, bilayers and vesicles, microemulsions, Langmuir Monolayers, self-assembly. Applications; soaps and detergents, thin films, foams and biological cells.

References:

1. Soft Condensed Matter, Richard A.L. Jones, Oxford University Press (2002).
2. Structured Fluids: Polymers, Colloids, Surfactants, Thomas A. Witten, Oxford UniversityPress (2004).
3. Scaling concepts in Polymers, P.G. De Gennes, Cornell University Press (1979).
4. Principles of condensed matter, Sections 1, 2 and 6, P M Chaikin, T C Lubensky (2000).
5. Soft Matter Physics: An Introduction, Maurice Kleman, Oleg D Laverntovich, J. Firedel, Springer, 2000.

Course Name: Nanomagnetism and Spintronics

Course Code: PHYS4114

Credits: 3+0+1 (4 credits)

Course Objectives: The main goal of this course is to introduce about the magnetism and charge transport at the nanoscale. New frontiers in magnetic nanomaterials will also be discussed. Spin-electronics (spintronics) has emerged as a new discipline that aims at producing, manipulating and detecting spin-polarized currents, that is, a new discipline that handles the current depending on the electron spin.

Course Contents:

Unit - I

Magnetism basics and nanomagnetism: Magnetic quantities and units, magnetism of free atoms and ions, Hund's rules and the Landé factor, localized electron magnetism in solids, itinerant electron magnetism in metals, band theory of magnetism, indirect exchange interaction, magnetic anisotropy, magnetization and magnetic materials, domains, magnetic energies (magnetostatic energy, magnetocrystalline energy, magnetostrictive energy), domain walls, demagnetizing field, magnetization process.

Unit - II

Magnetism in small structures: Single domain particles, superparamagnetism, blocking temperature, magnetic ultrathin films, magnetic surface and interface anisotropies.

Unit - III

Introduction to spin electronics, Giant Magnetoresistance (GMR): Mechanism of GMR, spin dependent scattering of electrons, interlayer exchange coupling (RKKY coupling), exchange biasing, spin valves, quantum tunneling, tunnelling magnetoresistance (TMR), magnetic oxides and phase transformations: colossal magnetoresistance (CMR), magnetic semiconductors, multiferroics.

Unit - IV

Magnetic data storage: Magnetic recording overview, recording medium, particulate recording media, thin film recording materials, longitudinal versus perpendicular recording, write heads, read heads, magnetic random access memory (MRAM), outlook and fundamental limits to recording, patterned media.

Unit - V

Nanobiomagnetism: Materials for biomagnetism, targeting, functionalization of magnetic nanoparticles, magnetic separation, manipulation of magnetic particles in fluids magnetic tweezers, drug and gene delivery, magnetic resonance imaging, hyperthermia, magnetic biosensors, biological assay system, lab on-a-chip concept.

References:

1. 1.Modern magnetic materials, Robert C. O'Handley, John Wiley & Sons Inc., 2000.
2. Introduction to Magnetic Materials, Cullity and Graham, John Wiley & Sons Inc., 2009.

3. Introduction to Magnetism and Magnetic Materials, D. Jiles, Chapman and Hall pub., 1991.
4. Fundamentals of Magnetism, Mathias Getzlaff, Springer, 2008.
5. Spin Electronics, M. Ziese and M.Thornton (Eds.), Springer, 2001.
6. Advanced Magnetic Nanostructures, Sellmyer and Skomski (Eds.), Springer, 2006.

Course Name: Fibre Optics and Applications

Course Code: PHYS4115

Credits: 3+0+1 (4 credits)

Course Objectives: The course is designed to give an overview of optical fibre communication devices and systems including optical fibre transmission link, fibre modes configuration and structures and to understand the different kinds of losses, signal distortion etc.

Course Contents:

Unit – I

Science of Fibre Optics: Introduction and importance of fibre optics technology, Wave propagation in Planar and cylindrical waveguides, optical fibre types; design and basic characteristics; Ray analysis of optical fibre, numerical aperture, Electromagnetic (modal) analysis of step-index multimode fibres, Hybrid and linearly polarized modes, Single mode fibre, Power confinement and mode cutoff, Mode field diameter, Graded index fibre, WKB analysis, Fibre optic communication system: Concepts of WDM, DWDM; Repeaters and optical amplifiers optimum profile.

Unit – II

Experimental techniques: Fibre fabrication and characterization, Splices, Connectors and fibre cable, Loss mechanism in optical fibre, Pulse propagation, Dispersion and chirping in single-mode fibres, Dispersion compensation mechanism, Dispersion-tailored and dispersion compensating fibres, Fibre birefringence and polarization mode dispersion, Fibre bandwidth, Fibre optic sensors.

Unit – III

Non-linear Effects in Optical Fibre: Stimulated Raman scattering, stimulated Brillouin scattering, self phase modulation, Cross phase modulation, Optical solutions.

Unit – IV

Fibre based Devices: Erbium doped fibre amplifiers and lasers, Fibre Bragg gratings, Optical fibre sensors, Intensity modulated sensors, Phase modulated sensors, Spectrally modulated sensors, Optical temperature sensor, Mach-Zehnder interferometer, Photonic crystal fibres.

References:

1. A.K. Ghatak and K. Thyagrajan, Introduction to Fibre Optics, Cambridge University Press, 1998.
2. G.P. Agarwal, Fibre Optic Communication Systems, John Wiley Sons, 1997.
3. John A. Buck, Fundamentals of Optical Fibres, Wiley Interscience, 2004.

Course Name: Molecular Spectroscopy

Course Code: PHYS4116

Credits: 3+0+1 (4 credits)

Course Objectives: To teach the students the nature of molecular spectra (rotational, vibrational, electronic and Raman) of polyatomic molecules (including diatomic) classified on the basis of their topological symmetry using group theoretical approach.

Course Contents:

Unit – I

Group Theory: Symmetry elements and symmetry operations, Point group and their representation, Mathematical group, Matrix representation, Orthogonality theorem (statements and interpretation only), Reducible and irreducible representations, Direct product group.

Unit – II

Electronic Spectra: Electronic energy and total energy, vibration structure of electronic transitions, progressions and sequences, rotational structure of electronic bands, band head formation and band origin. Intensity distribution in vibrational structure, Frank-Condon principle and its quantum mechanical formulation, intensity alternation in rotational lines.

Units – III

Rotation and Vibration Spectra: IR and Raman spectra of rigid rotator and harmonic oscillator, IR and Raman spectra of non-rigid rotator, anharmonic oscillator and vibrating rotator, Intensities in rotation - vibration spectra, Isotope effects in rotation and vibration spectra.

Unit – IV

Vibrational and Raman Spectra: Normal modes, symmetry characterization of electronic states and vibrational modes of polyatomic molecules, character tables (C_{2v}, D_{3h} and D_{6h}) and their applications to selection rules of IR and Raman spectra, application to H_2O and CO_2 molecules.

References:

1. Molecular Spectra and Molecular Structure by G. Herzberg (Dover Publication).
2. Fundamentals of Spectroscopy by C.N. Banwell and E.M. McCash (Tata-McGrawHill).
3. Introduction to Molecular Spectroscopy by G.M. Barrow (McGraw-Hill).
4. Modern Spectroscopy by M.J. Hollas (Wiley Inter Science).
5. Elements of Group theory for Physicists by A.W. Joshi (Wiley Eastern).
6. Chemical Applications of Group Theory by F.A. Cotton (Wiley Eastern).

Course Name: Superfluidity and Applied Superconductivity

Course Code: PHYS4117

Credits: 3+0+1 (4 credits)

Course Objectives: This course intends to provide knowledge of Superconductivity, Superfluidity & Critical Phenomena in terms of theoretical aspects.

Course Contents:

Unit - I

Hartee-Fock approximation (HFA), Exchange energy of electron gas in HFA, Shortcomings of HFA, Screening in an electron gas, Thomas Fermi approximation.

Unit - II

Isotope effect, BCS model of superconductivity, Bogoliubov-Vallatin transformation, solution of BCS gap equation, energy gap as a function of temperature. Applications of electron band structure results to calculate electron-phonon coupling constant McMillan's formula, GLAG theory – recent theories on high T_c materials, Coherence length, expression for critical temperature T_c, critical field H_c, critical current J_c – heavy fermion superconductivity.

Unit - III

Ginzburg-Landau theory of type II superconductors. Hc_1 and Hc_2. High T_c superconductors: properties of the normal and superconducting states, introduction to possible theories.

Unit - IV

Superfluidity of liquid ^3He, Phases of superfluid ^3He, Singlet and triplet state pairing, Landau's theory of phase transitions, Critical exponents, Ginzburg Criterion, Critical dimensionality, Examples of different types of transition: solids-liquid, liquid-gas, magnetic transitions, Ferroelectric-paraelectric, superconducting transition, glass transitions.

Unit - V

Kadonoff's scaling hypothesis, The renormalization group, renormalization group for the Ising chain, Fixed points, Calculation of fixed point for the 2D Ising model on the triangular lattice.

References:

1. D.R. Tilley and Tilley, Superfluidity and Superconductivity. Adam Hilger, 1986.
2. H.S. Kowk and D.T. Shaw (Eds.), Superconductivity and its Applications. Elsevier SciencePublishing, 1988.
3. M.Tinkham, Introduction to Superconductivity, CBS Publishers & Distributors, New Delhi, 2008.
4. S. Blundell, Superconductivity: A Very Short Introduction. Oxford University Press, 2009.
5. J. R. Schrieffer, Theory of Superconductivity, Levant Books, 2009.

Course Name: Applied Physics

Course Code: PHYS4118

Credits: 3+0+1 (4 credits)

Course Objectives: This course intends to impart knowledge of conceptual physics and its applications relevant to various streams of engineering and technology. More specifically, the student will be able to understand the properties of materials being used in various applications including transducers, sensors and detectors, cryogenics and energy harvesting, energy storage and conversion devices.

Course Contents:

Unit - I

Transducers: Fundamentals of transducer, classifications and general characterises; displacement transducers, strain gauges, pressure and force transducers, torque transducers, flow transducers, transducers for biomedical applications. Microelectromechanical systems (MEMS); microfabrication and micromachining, advanced lithography techniques, diffusion & ion implantation, and high aspect ratio processes.

Unit - II

Sensors: Resistive, capacitive, inductive, electromagnetic, thermoelectric, piezoelectric, piezoresistive, photosensitive and electrochemical sensors; Toxic gas monitoring; thermal conductivity analysers, colorimetric determination, sorption type dosimeters; non-dispersive infrared and ultraviolet sensors; flame ionisation detectors; semiconductor sensors. Lasers for optical communication system – Applications of optical fibre - Fibre optic communications.

Unit - III

Vacuum Techniques: Basics, viscous and molecular flow, Conduction, Pumping speed, throughput etc., Displacement and containment pumping, Design of technique of high vacuum and ultra-high vacuum pumping system, Vacuum valves, Flanges and itscomponents, Vacuum chamber material, Out gassing of material, Measurement of low pressure, calibration of vacuum gauges, General principle of mass flow measurement and control.

Unit - IV

Cryogenics: Basic cryogenics science, Cryostat design properties of material at low temperature, head load etc.

Unit - V

Alternate Energy Storage and Harvesting: Electrochemical energy storage devices - EMF,reversible and irreversible cells, free energy, thermodynamic calculation of the capacity of a battery, calculations of energy and power density of cells. Types of batteries, factors affecting battery capacity, voltage and current level; types of discharge: Applications of lithium ion batteries in electronic devices, and electric vehicle. Supercapacitors and fuel cells: basics of fuel cells, types of fuel cells and technology development. Solid and polymer electrolyte and solid oxide fuel cells. Basics of solar energy; brief history of solar energy utilization; various approaches of utilizing solar energy. Formation of solar cell and its equation; fill factor and maximum power; silicon solar cell; tandem solar cell; dye sensitized solar cell; organic solar cell.

References:

1. H. N. Norton, Handbook of Transducers, Prentice Hall, (1989).
2. N. Maluf, An introduction to Microelectromechanical Systems Engineering.
3. J. W. Gardner, Microsensors: Principles and Applications, John Wiley, (1994).
4. L. R. Ristic, Sensor Technology and Devices, Artech House publishers, (1994).
5. Roth, Vacuum Technology, Elsevier (1990).
6. G. K. White, Experimental Techniques in Low Temperature Physics, Clarendon (1993).
7. Nelson, The Physics of Solar Cells, Imperial College Press, 2003.
8. B. G. Streetman and S. Banerjee, Solid State Electronic Device, 6th edition, Prentice Hall, (2006).

Course Name: Advanced Quantum Mechanics

Course Code: PHYS4119

Credits: 3+0+1 (4 credits)

Course Objectives: To impart knowledge of advanced quantum mechanics for solving relevant physical problems.

Course Contents:

Unit - I

Concepts of fields, Lagrangian dynamics of Classical fields, Derivation of the Euler-Lagrange equation from Hamilton's variational principle, Lagrangians and equations of motion of fundamental fields, Noether's theorem, Invariances, Conserved currents and charges, Energy-momentum tensors and energy of fields.

Unit - II

Canonical quantization and particle interpretation of the real Klein-Gordon field, Fock space of bosons, Energy of the real Klein Gordon field, Normal ordering, Introduction of antiparticle, Charge of quantum complex Klein-Gordon field, Canonical quantization and energy of the Dirac field, Anti-commutators, Pauli principle, Equal time anti-commutator between the Dirac field and the canonically conjugate momentum field.

Unit - III

Coulomb gauge quantization and energy of the Electromagnetic field, A comparison between non-covariant and covariant quantization of the electromagnetic field, Features of covariant quantizations: Derivation of equal-time commutators between the components of fields and canonically conjugate momentum fields, (Derivation of energy operator not needed) special properties of time-like photons, Gupta-Bleuler formalism.

Unit - IV

Basic ideas of the path integral formalism in quantum mechanics and quantum field theory, Interacting fields (mainly electromagnetic interaction), Lagrangian and equations of motion of a system of interacting electrons and photons, Covariant perturbation theory, Derivation of the s-matrix operator, Time-ordering, Application to Compton scattering, Wick's theorem (statement only).

Unit - V

Enumeration of terms of s-matrix element and corresponding Feynman diagrams, Statement of Feynman rules of graphs in quantum electrodynamics, Vacuum polarization diagram in Hydrogen atom, Charge renormalization and Lamb shift, (Detailed derivations of integrals not needed), Drawing of diagrams and statement of anomalous magnetic moment of electron.

References:

1. Relativistic Quantum Fields - J. D. Bjorken and S. D. Drell, McGraw-Hill Book Company (1965).

2. Quantum Field Theory - Lewis H Ryder, Cambridge University Press (1985).
3. Quantum Field Theory - Claude Itzyksen and Jean-Bernard Zuber, McGraw Book Co. (1985).
4. Quantum Field Theory in a nutshell - A. Zee, Princeton University Press (2003).
5. A First Book of Quantum Field Theory – A. Lahiri and P. B. Pal, Narosa Publishing House (2001).

Course Name: Numerical Techniques

Course Code: PHYS4120

Credits: 3+0+1 (4 credits)

Course Objectives: This course is intended to provide an insight into the advanced numerical methods, like Interpolation, Solution of Linear Equations, Monte Carlo Methods, Curve-Fitting techniques etc. This will also allow students to develop computing algorithms and programs (in C/C++) for various numerical techniques.

Course Contents:

Unit - I

Error analysis: Round-off and truncation errors, Elements of Numerical Integration, Error estimates of Trapezoidal rule, Simpson midpoint and 3/8 rules, Composite Numerical Integration. Gaussian Quadrature using interpolating polynomials, special polynomials like Legendre polynomials etc. **Multisimensional integrals:** Two and three dimensional integration. **Interpolation:** Introduction, Polynomial interpolation; Lagrange Interpolatiion polynomial; Cubic Spline Interpolation.

Unit - II

Solution of Linear Algebraic Equations: Introduction, Augmented Matrix, Gaussian elimination with Backward substitution, Pivoting strategies – partial and complete, Gauss-Jordan Elimination Method, Operation Counts, Tridiagonal Systems of Linear Equations, Inverse of a matrix, LU Decomposition.

Unit - III

Numerical Methods: Numerical Differentiation, Partial differential equations – elliptic equations; boundary conditions; Finite Difference method; Forward and Backward difference methods, Few examples: Heat equations, Wave equations; Introduction to Finite Element method.

Unit - IV

Monte Carlo Methods: Introduction; Random Numbers – Uniform and other random deviates, Generation of Random Numbers, Random walk problem in 1, 2, 3 and n-dimensions, Simulation: Introduction, Few examples: Coin toss and dice throws, Radioactive Decay Chain, Two-Level Spin System, Ising Model, Scattering - Toy model; Law of Large Number and Central Limit Theorem; Random number generation using arbitrary distributions – inverse transform method and acceptancerejection method, generating discrete distributions, Monte Carlo Integration Methods.

Unit - V

Curve fitting methods: Modeling of Data, Maximum Likelihood Estimator; Pearson chi-square; Least Squares method – both without and with errors in dependent variable; Parameter estimations and errors; General Linear Least Squares.

References:

1. Numerical Recipes 3rd Edition: The Art of Scientific Computing (2007) by William H. Press, Saul A. Teukolsky, William T. Vetterling , Brian P. Flannery.
2. Numerical Analysis 10th Edition (2016) by Richard L. Burden, J. Douglas Faires, Annette M. Burden, Cengage Learning, USA.
3. Data Reduction and Error Analysis for the Physical Sciences 3rd Edition (2003) by Philip Bevington and D. Keith Robinson, McGraw Hill Education.
4. Monte Carlo Simulation in Statistical Physics An Introduction 5th Edition (2010) by Binder, Kurt, Heermann, Dieter, Springer.

Course Name: Dissertation I
Course Code: PHYS4198
Credits: 0+4+0 (4 credits)

Course Name: Dissertation II
Course Code: PHYS4199
Credits: 0+8+0 (8 credits)

Open Elective Courses (Offered to Other Departments)

Course Name: Vacuum Science and Thin Film Technology

Course Code: PHYS4201

Credits: 3+0+1 (4 credits)

Course Objectives: The course is designed to develop an insight into materials science of thin film formation and to recognize the importance and need for vacuum science in thin film deposition methods. The course will help the students to identify emerging applications using thin film based devices, its pros and cons, fabrication and usage.

Course Contents:

Unit - I

Basics of Vacuum Science: creation of vacuum: rotary, diffusion, getter ion, turbo molecular, and cryo pumps, measurement of vacuum: Penning, Pirani, ionization gauges, B-A gauge. Designing a typical vacuum system, vacuum leak detection: helium leak detector, residual gas analyzer.

Unit - II

Methods of producing thin films: PVD, CVD, sputtering, epitaxial films, film thickness measurement growth of thin films.

Unit - III

Mechanical properties: adhesion and stress measurements, electrical properties, resistivity variation, Hall Effect,

Unit - IV

Optical properties: reflection, refraction, ellipsometry, reflecting and anti reflecting films.

Unit - V

Thin film analysis (with applications of techniques in solving research problems): ion beam sputtering, selective surfaces, depth profiling, Study of inter diffusion in thin films using XPS, AES, SIMS and RBS. Diffraction studies on thin films using LEED. Thin film morphological studies by SEM, STM and AFM.

References:

1. Handbook of Thin Film Technology: Maissel and Glange (McGraw Hill).
2. Vacuum Technology: A. Roth (North Holland).
3. Fundamentals of Vacuum Techniques: Pipko, Pliskosky et al. (Mir Publishers).
4. Thin Films: K.L. Chopra.
5. Ultra High Vacuum Technology: D.K. Awasthi.
6. Thin Film Solar Cells: S.R. Das and S.P. Singh.

Course Name: Laser Physics

Course Code: PHYS4202

Credits: 3+0+1 (4 credits)

Course Objectives: The course is designed to

- Develop knowledge in the basics of lasers.
- Enhance comprehension in the principles of lasers.
- Explore the control of laser properties.
- Familiarize with the diverse applications of lasers.

Course Contents:

Unit - I

Interaction of radiation with matter: Introduction to electromagnetic radiation, wavelength, wave number, frequency, interaction oflight with atoms and molecules, absorption, emission, kinetics of optical absorption, stimulated and spontaneous emission, intensity of spectral lines, line broadening mechanism.

Unit - II

Basic principles of laser: Principle of lasers, population inversion, conditions of lasing action, characteristics of a laser coherence, monochromaticity, divergence, intensity, Einstein's coefficients, laser pumping, two and three level laser systems.

Unit-III

Types of lasers: Solid state lasers, the ruby laser, Nd:YAG Laser, semiconductor lasers, features of semiconductor lasers, diode lasers, gas laser: He-Ne laser, CO_2 laser, liquid lasers: dye lasers and chemical lasers.

Unit-IV

Control of laser properties and production: Laser pumping, resonators, vibrational modes of resonators, number of modes/unit-volume, open resonators, control resonators, Q factor, losses in the cavity, threshold condition, quantum yield, mode locking (active and passive).

Unit - V

Applications of lasers: Ether drift and absolute rotation of the earth-laser isotope separation, laser range finder- laserin pollution detection, holography- optical communication, optical fiber.

References:

1. B.B. Laud, Lasers and Nonlinear Optics, 3rdEd, New Age Int. Pub. 2011.
2. K. Thyagarajan, and A.K. Ghatak, Lasers Theory and Applications, 2nd Ed, Plenum Press, 1986.
3. A.K. Ghatak and K. Thyagarajan, Optical electronics, Cambridge University Press, 1989.
4. Seigman, Lasers, 3rd Ed., Oxford Univ. Press, 1986.

5. Maitland and Dunn, Laser Physics, N.H. Amsterdam, 1969.
6. J. Hecht, The laser guidebook, 1986.
7. O. Seelto, Principles of Laser, 5th Ed., Springer Publication, 2010.

Course Name: Energy Storage and Devices

Course Code: PHYS4203

Credits: 3+0+1 (4 credits)

Course Objectives: The course aims to understand the basic concepts of energy storage, different types of energy storage devices and their applications.

Course Contents:

Unit - I

Basic concepts and energy storage: Definition and units of energy, power, conservation of energy, second law of thermodynamics, renewable energy resources, energy storage - need of energy storage; different modes of energy storage. capacitors, electrochemical storage, electrical and magnetic storage, chemical energy storage, hydrogen for energy storage.

Unit - II

Electrochemical energy storage systems: Electrochemical energy storage systems batteries: primary, secondary, lithium, solid-state and molten solvent batteries; lead acid batteries; nickel cadmium batteries; advanced batteries, Role of carbon nano-tubes in electrodes.

Unit – III

Magnetic and electric energy storage systems: Magnetic and electric energy storage systems superconducting magnet energy storage (SMES) systems; capacitor and batteries: comparison and application; super capacitor: electrochemical double layer capacitor (EDLC), principle of working, structure, performance and application, role of activated carbon and carbon nano-tube.

Unit - IV

Fuel cell basics and storage: Basics, difference between batteries and fuel cells, fuel cell history, components of fuel cells, principle of working of fuel cell, advantages and disadvantages of fuel cell power plant, fuel cell types: alkaline fuel cell, polymer electrolyte fuel cell, phosphoricacid fuel cell, molten carbonate fuel cell, solid oxide fuel cell, problems with fuel cells, applications of fuel cells.

Unit-V

Hydrogen production and storage methods: Production- from fossil fuels, electrolysis, thermal decomposition, photochemical, photocatalytic, hybrid; Storage: Metal hydrides, metallic alloy hydrides, carbon nano-tubes; sea as the source of deuterium.

References:

1. R.A. Huggins, Energy Storage, 1st Ed., Springer, 2010.
2. J.-M. Tarascon, and Patrice Simon, Electrochemical Energy Storage, 1st Ed., Wiley, 2015.
3. F. Díaz-González, A. Sumper and O. Gomis-Bellmunt, Energy storage in powersystems, 1st Ed., Wiley, 2016.

4. Srinivasan, Fuel Cells from Fundamentals to Applications, 1st Ed., Springer, 2006.
5. A. Basile, A. Iulianelli, Advances in Hydrogen Production, 1st Ed., Storage andDistribution, Woodhead Publishing, 2014.
6. Sie-Chin Tjong, Nanocrystalline Materials, Elsevier, 2014.
7. K.L. Chopra, SuhitRanjan Das, Thin Film Solar Cells, Springer Science, 1983.
8. David Linden, Thomas B. Reddy, Handbook of batteries, 3rd Edition, Mcgraw Hill, 2002.

Course Name: Introduction to Nanotechnology

Course Code: PHYS4204

Credits: 3+0+1 (4 credits)

Course Objectives: The course aims to

- Impart the basic knowledge on nanoscience and nanotechnology.
- Develop understanding on the exotic properties of nanostructured materials.
- Introduce various techniques available for the processing of nanostructured materials.
- Emphasize the importance and development of nanotechnology in various fields

Course Contents:

Unit - I

Introduction to nanoscience: History and importance of nanotechnology, opportunity at the nanoscale, length and time scale in structures, difference between bulk and nanoscale materials and their significance, properties at nanoscale, optical, electronic, magnetic and chemical.

Unit - II

Nanostructures and dimensions: Classification of nanostructures: zero, one, two and three dimensional nanostructures, size dependency in nanostructures, quantum size effects in nanostructures, chemistry of tailored nano shapes, quantum dots, nanowells, nanoribbons and nanowires.

Unit – III

Synthesis of nanomaterials: Top down and bottom up approach, method of nanomaterials preparation, wet chemical routes of synthesis: reduction, sol-gel, hydrothermal, sonochemical synthesis, physical routes, physical vapor deposition (PVD), chemical vapor deposition (CVD), laser ablation, sputtering.

Unit - IV

Characterization of nanomaterials: X-ray Diffraction (XRD), Scanning electron microscope (SEM), Transmission electron microscope (TEM), Scanning probe microscope (SPM), ***Magnetic Characterization:*** Vibrating sample magnetometer, thermal analysis; TGA, UV-Vis absorption spectroscopy, IR and Raman spectroscopy.

Unit - V

Applications of nanomaterials: Nanotechnology in energy systems, textiles, food and health care, agriculture, automotive industry, solar technology, pharmaceutical and drugs, nanoelectronics, nanosensors and devices.

References:

1. T. Pradeep, Nano: The Essentials, 1st Ed., McGraw Hill, 2007.
2. Chattopadhyay, Banerjee, Introduction to Nanoscience and Nanotechnology, PHI, 2009.

3. C. Binns, Introduction to Nanoscience and Nanotechnology, Vol. 14, John Wiley & Sons, 2010.
4. P.C. Poole Jr, and F.J. Owens, Introduction to Nanotechnology, John Wiley & Sons, 2003.
5. R. Kelsall, I.W. Hamley, and M. Geoghegan, Nanoscale Science and Technology, John Wiley & Sons, 2005.