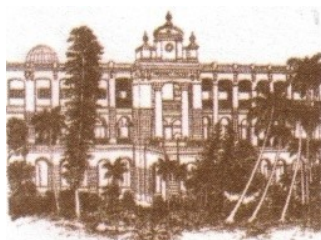


**Structure and Detailed Syllabus  
of the Undergraduate Course (B.Sc.) in Physics under CBCS  
Department of Physics, Presidency University  
(w.e.f. July, 2022)**



**PRESIDENCY UNIVERSITY**  
KOLKATA



**Department of Physics  
(Faculty of Natural and Mathematical Sciences)  
Presidency University  
Hindoo College (1817-1855), Presidency College (1855-2010)  
86/1, College Street, Kolkata - 700 073  
West Bengal, India**

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**Semester-wise Modules of the Undergraduate Course in Physics (Major) under CBCS**  
**Department of Physics, Presidency University, Kolkata**

Semester	Course Type				
	Core Course	Discipline Specific Elective	Generic Elective	Skill Enhancement Course	Ability Enhancement Compulsory Course
First	Mathematical Physics-I		Mechanics and Relativity		ENVS/ English Communications/MIL
	Mechanics				
Second	Electricity and Magnetism		Physics of Everyday Life		ENVS/ English Communications/MIL
	Waves and Optics				
Third	Mathematical Physics-II		The Nuclear Age	Statistical and Computational Methods	
	Thermal Physics				
	Analog Systems and Applications				
Fourth	Mathematical Physics-III		Elements of Modern Physics	Modern Experimental and Theoretical Techniques	
	Elements of Modern Physics				
	Digital Systems and Applications				
Fifth	Quantum Mechanics and Applications	<b>DSE1.</b> Advanced Mechanics (5+1), <b>DSE2A.</b> Nuclear Medicine (5+1) <b>DSE2B.</b> Quantum Optics & Quantum Information (5+1)			
	Statistical Mechanics				
Sixth	Solid State Physics	<b>DSE3.</b> Nuclear and Particle Physics (5+1) <b>DSE4A.</b> Physics of Materials (5+1) <b>DSE4B.</b> Supervised Project with Dissertation (6)			
	Electromagnetic Theory				

**Academic Session:** Each Semester shall contain at least 16 Teaching Weeks

**Odd Semesters:** Semesters One and Three - July to December

**Even Semesters:** Semesters Two and Four - January to June



Fifth	Discipline Specific Elective (DSE) (Any Two)	DSE1	Advanced Mechanics (Credit 5+1, Marks 80+20)							100
		DSE2 (Any one of 2A & 2B)	-----							100
			DSE2A: Nuclear Medicine (Credit 5+1, Marks 80+20) DSE2B: Quantum Optics and Quantum Information (Credit 5 + 1, Marks 80 + 20)							100
Sixth	Core Course	PHYS06 C13	Solid State Physics	4	2		6	70	30	100
Sixth	Core Course	PHYS06 C14	Electromagnetic Theory	4	2		6	70	30	100
Sixth	Discipline Specific Elective (DSE) (Any Two)	DSE3	Nuclear & Particle Physics (Credit 5+1, Marks 80+20)							100
		DSE4 Any one of 4A and 4B)	DSE4A: Physics of Materials (Credit 5+1, Marks 80+20)							100
			DSE4B: Supervised Project with Dissertation (Credit 6, Marks 100)							100
			<b>Total Credit</b>				<b>148</b>	<b>Total Marks2600</b>		

# First Semester

## Core Courses

### **PHYS01C1: MATHEMATICAL PHYSICS-I** **Credits: 6 (Theory-04, Practical-02)**

#### **Theory**

**Credit: 4**

**Contact Hours per Week: 4**

**Ordinary Differential Equations [10]:** First-Order homogeneous and nonhomogeneous equations with variable coefficients, Superposition principle, Second-Order homogeneous and nonhomogeneous equations with constant and variable coefficients, Second-Order homogeneous equations with variable coefficients, Modelling Physics problems with ODE's.

**Functions of Several Variables [6]:** Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Differentiation of composite functions. Implicit functions. Taylor series expansion of function of more than one variable. Maxima and minima. Applications to error analysis. Constrained Maximization using Lagrange Multipliers.

**Vector Calculus [24]:** Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Vector identities.

Vector Integration: Ordinary Integrals of Vectors. Multiple integrals, Jacobian. Notion of infinitesimal line, surface and volume elements. Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes's Theorems and their applications. Irrotational field.

**Orthogonal Curvilinear Coordinates [5]:** Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems.

**Matrices and Vector spaces [15]:** Linear vector spaces, basis for a space, basis transformation, linear transformations, dual space, representations of transformations by matrices, Norm and inner products. Special types of square matrix, Eigenvalues and eigenvectors, Change of basis and similarity transformation, Diagonalization of matrices.

#### **Reference Books:**

1. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 2013, 7<sup>th</sup> Edn., Elsevier.
2. Differential Equations, George F. Simmons, 2007, McGraw Hill.
3. Mathematical methods for Scientists and Engineers, D.A. Mc Quarrie, 2003, Viva Book
4. Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
5. Essential Mathematical Methods, K.F.Riley & M.P.Hobson, 2011, Cambridge Univ. Pres.

**Practical****Credit: 2****Contact Hours per Week: 4**

**Introduction and Overview:** Computer architecture and organization, memory and Input/output devices

**Basics of scientific computing:** Binary and decimal arithmetic, Floating point numbers, algorithms, Sequence, Selection and Repetition, single and double precision arithmetic, underflow & overflow- emphasize the importance of making equations in terms of dimensionless variables, Iterative methods

**Graphics and visualization with Python:** Introduction to plotting using Python (matplotlib). Scatter plots. Density plots. 3D graphics. Animation

**Introduction to programming in python:** Introduction to programming, constants, variables and data types, dynamical typing, operators and expressions, modules, I/O statements, iterables, compound statements, indentation in python, the if-elif-else block, for and while loops, nested compound statements, lists, tuples, dictionaries and strings, basic ideas of object oriented programming, random number generation, user-defined functions.

**Applications of Python Programming:** Sum and average of a list of numbers, sorting, binary search, finding prime numbers, area of a circle, volume of a sphere, value of  $\pi$ , sum of series, factorial, Fibonacci series.

**Introduction to Numerical computation using numpy and scipy:** Introduction to the python numpy module. Arrays in numpy, array operations, array item selection, slicing, shaping arrays. Basic linear algebra using the linalg submodule.

**Application of Numpy and Scipy:** Matrix multiplication, solution of transcendental equation, solution of a set of linear algebraic equation, determinant of a matrix, eigenvalue and eigenvector.



## **PHYS01C2: MECHANICS**

**Credits: 6 (Theory-04, Practical-02)**

### **Theory**

**Credit: 4**

**Contact Hours per Week: 4**

**Fundamentals of Dynamics [6]:** Reference frames. Inertial frames; Galilean transformations; Galilean invariance. Motion of a projectile in Uniform gravitational field Dynamics of a system of particles. Centre of Mass. Principle of conservation of momentum. Impulse. Momentum of variable- mass system: motion of rocket.

**Work and Energy [6]:** Work and Kinetic Energy Theorem. Conservative and non- conservative forces. Potential Energy. Qualitative study of one-dimensional motion from potential energy curves. Stable and unstable equilibrium. Elastic potential energy. Force as gradient of potential energy. Work & Potential energy. Work done by non-conservative forces. Law of conservation of Energy.

**Collisions [3]:** Elastic and inelastic collisions between particles. Centre of Mass and Laboratory frames.

**Rotation [6]:** Angular momentum of a particle and system of particles. Torque. Principle of conservation of angular momentum. Rotation about a fixed axis. Moment of Inertia. Calculation of moment of inertia for rectangular, cylindrical and spherical bodies. Kinetic energy of rotation. Motion involving both translation and rotation.

**Gravitation and Central Force Motion [10]:** Law of gravitation. Gravitational potential energy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere, Motion of a particle under a central force field. Two-body problem and its reduction to one-body problem and its solution. The energy equation and energy diagram. Kepler's Laws. Satellite in circular orbit and applications. Geosynchronous orbits. Weightlessness. Basic idea of global positioning system (GPS).

**Oscillations [6]:** Simple Harmonic Motion: - Kinetic energy, potential energy, total energy and their time-average values. Damped oscillation. Forced oscillations: Transient and steady states; Resonance, Applications.

**Non-Inertial Systems [8]:** Non-inertial frames and fictitious forces. Uniformly rotating frame. Laws of Physics in rotating coordinate systems. Centrifugal force. Coriolis force and its applications. Components of Velocity and Acceleration in Cylindrical and Spherical Coordinate Systems.

**Special Theory of Relativity [15]:** Michelson-Morley Experiment and its outcome. Postulates of Special Theory of Relativity. Lorentz Transformations. Simultaneity and order of events. Lorentz contraction. Time dilation. Relativistic transformation of velocity, frequency and wave number. Relativistic addition of velocities. Variation of mass with velocity. Massless Particles. Mass-energy Equivalence. Relativistic Doppler effect. Relativistic Kinematics. Transformation of Energy and Momentum.

## Reference Books:

1. An introduction to mechanics, D. Kleppner, R.J. Kolenkow, 1973, McGraw-Hill.
2. Mechanics, Berkeley Physics, vol.1, C.Kittel, W.Knight, et.al. 2007, Tata McGraw-Hill.
3. Physics, Resnick, Halliday and Walker 8/e. 2008, Wiley.
4. Analytical Mechanics, G.R. Fowles and G.L. Cassiday. 2005, Cengage Learning.
5. Feynman Lectures, Vol. I, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson Education
6. Introduction to Special Relativity, R. Resnick, 2005, John Wiley and Sons.
7. University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.

### Additional Books for Reference

8. Mechanics, D.S. Mathur, S. Chand and Company Limited, 2000
- University Physics. F.W Sears, M.W Zemansky, H.D Young 13/e, 1986, Addison Wesley
9. Physics for scientists and Engineers with Modern Phys., J.W. Jewett, R.A. Serway, 2010, Cengage Learning
  10. Theoretical Mechanics, M.R. Spiegel, 2006, Tata McGraw Hill.

## Practical

**Credit: 2**

**Contact Hours per Week: 4**

1. Hands-on experiments on frictionless movement using linear air track for (i)uniform motion and (ii) accelerated motion and verification of the laws of kinematics.
2. Add-on studies on the above, such asdetermination of conservation of linear momentum and energy and case study and group discussion on the same.
3. Experiments with torsional pendulum: determination of rigidity modulus of a material and measurement of the moment of inertia of an object of geometrical shape.
4. Seminar/group discussion on types of error in measurement, error analysis, error minimizing etc.
5. Determination of Young's modulus of the material of a metallic bar by the bending of a beam. Extended studies with
  - (i) plotting of load vs depression graph,
  - (ii) least square fitting of the plot
  - (iii) case studies with change of material and object dimension.
6. Practical concepts on computer interfacing of simple experiments, such as simple and torsional pendulum experiments.
7. Learning by doing: observation and recording ofthe changes of time period with the length of string and other parameters.

## Generic Elective Course **PHYS01GE1**

### **Mechanics and Relativity**

#### **Theory**

**Credit: 5**

**Contact Hours per Week: 5**

#### **1. Mathematical preliminaries [20]**

Scalar and vector fields. Gradient of a scalar field, and Divergence and Curl of a vector field in three dimensional cartesian coordinates. Line, surface and volume integrals. Divergence theorem and Stokes' theorem.

#### **2. Mechanics of a single particle [25]**

Inertial reference frame. Newton's laws of motion, Galilean transformation. Analytical solutions of the dynamical equation for special cases, Conservative forces and concept of potential, Linear momentum, Variable mass problem, Rocket motion, Simple harmonic oscillator with damping, Motion of a charged particle in crossed electric and magnetic field. Velocity and acceleration in plane polar coordinates, Motion under a central force, Conservation laws.

#### **3. Rotational motion [15]**

Torque, energy and angular momentum of rotating rigid bodies, Calculation of moments of inertia of simple symmetric objects, Parallel and perpendicular axis theorems, Solution of dynamical problems.

#### **4. Special Relativity [15]**

Frames of reference, Space-time diagrams, Postulates of special relativity, Lorentz transformation and its consequences, Relativistic dynamics.

# Second Semester

## Core Courses

### **PHYS02C3: ELECTRICITY AND MAGNETISM**

**Credits: 6 (Theory-04, Practicals-02)**

#### **Theory**

**Credit: 4**

**Contact Hours per Week: 4**

**Electrostatics [12]:** Electric field, Divergence and curl of electric field, Gauss's law and its applications, Electric potential, Electrostatic energy, Conductors in an electrostatic field, Multipole expansion, the uniqueness theorem, the method of image, Poisson and Laplace equation, Boundary value problems.

**Dielectrics [8]:** Dielectric materials in external electric field, Polarization, Force and torque on electric dipole in external electric field, Electric field of polarized materials, Electric field in dielectrics, Electrical Susceptibility and Dielectric Constant. Displacement vector **D**, Gauss' Law in dielectrics, Capacitors.

**Magnetostatics [16]:** Magnetic effect of steady current, Equation of continuity and steady current, Lorentz force and concept of magnetic induction, force on linear current element, Biot-Savart's law, Ampere's circuital law and its applications, Magnetic vector potential, calculation of vector potential and magnetic induction in simple cases, Magnetic dipole moment for rotating charge bodies, Gyro-magnetic ratio, Force & torque on a magnetic dipole.

**Magnetic Properties of Materials [8]:** Free current and bound current; surface and volume density of current distribution; magnetisation vector; non-uniform magnetisation of matter; Introduction of **H**; Magnetostatic boundary conditions. Magnetic scalar potential; Field due to uniformly magnetised sphere. Magnetic Susceptibility and permeability, Ferromagnetism, Hysteresis . Paramagnetism. Applications.

**Electromagnetic Induction [6]:** Faraday's and Lenz's law. Motional e.m.f.-simple problems. Calculation of self and mutual inductance in simple cases. Energy stored in magnetic field. Energy of a magnetic dipole.

**Circuits and Networks [10]:** AC Circuits, Kirchoff's laws for AC circuits, Complex Reactance and Impedance, Series LCR Circuit, Parallel LCR Circuit. Ideal Constant-voltage and Constant-current Sources, Thevenin theorem, Norton theorem, Superposition theorem, Reciprocity theorem, Maximum Power Transfer theorem. Applications to dc circuits.

#### **Practical**

**Credit: 2**

**Contact Hours per Week: 4**

1. To study the characteristics of a series RC Circuit.
2. To verify the Thevenin and Norton theorems.
3. To verify the Superposition, and Maximum power transfer theorems.

4. To determine self inductance of a coil by Anderson's bridge.
5. To study response curve of a Series LCR circuit and determine its (a) Resonant frequency, (b) Impedance at resonance, (c) Quality factor Q, and (d) Band width.
6. To study the response curve of a parallel LCR circuit and determine its (a) Anti-resonant frequency and (b) Quality factor Q.
7. To determine the mutual inductance of two coils.

**PHYS02C4: WAVES & OPTICS**  
**Credits: 6 (Theory-04, Practicals-02)**

**Theory**

**Credit: 4**

**Contact Hours per Week: 4**

**Basics of Waves [12]:** Linearity and Superposition Principle. Superposition of two collinear oscillations, Graphical and Analytical Methods. Lissajous Figures and their uses, Plane and Spherical Waves. Longitudinal and Transverse Waves. Plane Progressive (Travelling) Waves. Wave Equation. Particle and Wave Velocities. Differential Equation. Pressure of a Longitudinal Wave, Energy Transport, Intensity of Wave, Water Waves: Ripple and Gravity Waves.

Superposition of Harmonic Waves: Standing (Stationary) Waves in a String: Fixed and Free Ends. Analytical Treatment. Phase and Group Velocities. Changes with respect to Position and Time. Energy of Vibrating String. Transfer of Energy. Normal Modes of Stretched Strings. Plucked and Struck Strings. Melde's Experiment. Longitudinal Standing Waves and Normal Modes. Open and Closed Pipes.

**Geometrical Optics [14]:** Fermat's principle, Matrix method, Thick lens, Optical instruments, Aberration: spherical and chromatic

**Wave Optics [3]:** Electromagnetic nature of light. Definition and properties of wave front, Huygens Principle. Temporal and Spatial Coherence.

**Interference [10]:** Division of amplitude and wavefront. Young's double slit experiment. Lloyd's Mirror and Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger Fringes); Fringes of equal thickness (Fizeau Fringes). Newton's Rings: Measurement of wavelength and refractive index.

**Interferometer [5]:** Michelson Interferometer, formation of fringes, Determination of Wavelength, Wavelength Difference, Refractive Index, and Visibility of Fringes. Fabry-Perot interferometer. Applications.

**Diffraction [16]:** Fraunhofer diffraction: Single slit. Circular aperture, Resolving Power of a telescope. Double slit. Multiple slits. Diffraction grating. Resolving power of grating. Use of grating to produce monochromatic light.

Fresnel's Assumptions. Fresnel's Half-Period Zones for Plane Wave. Explanation of Rectilinear Propagation of Light. Theory of a Zone Plate: Multiple Foci of a Zone Plate. Fresnel's Integral and its applications, Fresnel diffraction pattern of a straight edge, a slit and a wire.

**Activities:**

1. Demonstration of Michelson and Fabry-Perot Interferometer.
2. Study of python program generating diffraction pattern of a grating. Demonstrate variation of fringe pattern with change in  $N$ ,  $\lambda$ ,  $d$  etc.
3. Study of python program generating Fresnel diffraction pattern of a straight edge. Demonstration of changes of fringe pattern for variation of  $\lambda$ .
4. Demonstration of XRD pattern for simple crystal structure.

**Practical**

**Credit: 2**

**Contact Hours per Week: 4**

1. Determination of the refractive index of a prism using a spectrometer for Sodium D-lines.
2. Interference by Newton's ring: To determine the radius of curvature of a plano-convex lens by using Newton's rings.
3. Diffraction by double slit: To study diffraction of light by using double slits and determination of unknown wavelengths.
4. Interference using Fresnel Biprism: To understand the use of Fresnel biprism to divide the wavefront of a monochromatic, coherent beam of light producing an interference pattern and measurement of wavelength
5. To Measure certain wavelengths of spectral lines of mercury vapour using diffraction grating

## Generic Elective Course **PHYS02GE2**

### **PHYSICS OF EVERYDAY LIFE (Interdisciplinary)**

**Credits: 6 (Theory-05, Tutorials-01)**

#### **Theory**

**Credit: 5**

**Contact Hours per Week: 5**

**Art of Estimation and Fermi Problems [20] :** The need for making approximations, Making quantitative estimates in real-life situations, introduction to a variety of Fermi problems in real life, Order of magnitude problems in different areas of physics, error estimation, significant digits, use of dimensional analysis to solve physics problems

**Understanding your Electric Bill [5]:** Basics of electricity and magnetism, Ohms law, power consumption, Joule heating, Energy Conservation and the use and generation of electricity, Saving electricity

**Your Car and your Refrigerator [15]:** The laws of thermodynamics, Microscopic and macroscopic view, Zeroth Law of Thermodynamics and Concept of Temperature, Concept of Work & Heat, Work Done during Isothermal and Adiabatic Processes, Reversible and Irreversible process with examples, Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot's Cycle, Carnot engine & efficiency. Refrigerator & coefficient of performance, 2nd Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence, Concept of Entropy and disorder, Petrol engine, Steam engine.

Group Discussion: Green energy

**How do Microwave ovens work [5]:** Electric and Magnetic fields, potentials, concept of electromagnetic waves, design of microwave ovens, precaution needed, basics of materials design, dc motors, induction ovens, Faraday's laws.

**The Physics of Digital Cameras [14]:** History of photography. Comparison of human eye and camera. Film photography. Color photographs. Charge coupled device (CCD). Operating principles of CCD camera. Color in CCD image. Filters. Bayer pattern. CCD vs film. Photo-electric effect. Wave and particle nature of light.

**The use of the Global Positioning System (GPS) [6]:** Navigation before GPS: position of astronomical objects in the sky. Operating principles of GPS. Atomic clocks. Gravitational time dilation. Accuracy and errors in GPS navigation.

**Mobile phone communication [10]:** Digital Electronics: Number systems: Decimal, binary. Conversion from decimal to binary and vice versa. How numbers are stored and manipulated in computers. Logic gates: OR, AND, NOT, XOR, NAND. Flip-flop circuit.

**Memory Devices:** History of memory devices: printing, recording of audio and video. Why binary number system is used for modern memory devices. Operating principles of compact disk, magnetic hard disk drive, solid state memory devices. MOSFET. Tunneling. Advantages and disadvantages of CD, magnetic disk, and solid state memory.

## Third Semester

Core Courses

**PHYS03C5: MATHEMATICAL PHYSICS-II**

**Credits: 6 (Theory-04, Practicals-02)**

**Theory**

**Credit: 4**

**Contact Hours per Week: 4**

**Fourier Series [15]:** Periodic functions, Orthogonal functions, Sturm-Liouville problem, Orthogonality of sine and cosine functions, Dirichlet Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Bessel inequality, Riemann-Lebesgue lemma. Expansion of functions with arbitrary period. Expansion of non-periodic functions over an interval. Even and odd functions and their Fourier expansions. Summing of Infinite Series. Term-by-Term differentiation and integration of Fourier Series. Parseval Identity. Complex representation of Fourier series Generalized Fourier Series and the Dirac Delta function and few examples of the use of Dirac delta function. Summation of Fourier series. The Gibbs phenomenon.

**Some Special Integrals [5]:** Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions.

**Frobenius Method and Special Functions [25]:** Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Legendre, Bessel, Hermite and Laguerre Differential Equations. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations. Expansion of function in a series of Legendre Polynomials. Bessel Functions of the First Kind: Generating Function, simple recurrence relations. Zeros of Bessel Functions ( $J_0(x)$  and  $J_1(x)$ ) and Orthogonality. Hermite polynomials. Application-based discussion on Legendre polynomials and potential theory, Bessel functions and the vibrating membrane, Hermite polynomials and the harmonic oscillator.

**Partial Differential Equations [15]:** Classification of partial differential equations (PDEs). Some examples of PDEs. Solution of PDEs with separation of variables and eigenfunctions. Boundary and initial conditions – vibration of a string. Laplace's equation and its solution in Cartesian, spherical polar with axially symmetric coordinate system and cylindrical polar with infinite cylinder coordinate system. Solution of 1-D and 2-D wave equations. Solution of heat conduction equation in 1-D. Applications of PDEs in real life problems.

**Reference Books:**

1. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 2013, 7<sup>th</sup> Edn., Elsevier.
2. Differential Equations, George F. Simmons, 2007, McGraw Hill.
3. Mathematical methods for Scientists and Engineers, D.A. Mc Quarrie, 2003, Viva Book
4. Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
5. Essential Mathematical Methods, K.F. Riley & M.P. Hobson, 2011, Cambridge Univ. Press.



**Practical**

**Credit: 2**

**Contact Hours per Week: 4**

**Interpolation:** Newton Gregory Forward and Backward difference formula, Error estimation of linear interpolation: Evaluation of trigonometric functions e.g.  $\sin \theta$ ,  $\cos \theta$ ,  $\tan \theta$ , etc.

**Numerical differentiation and Integration:** Forward and Backward difference formula and Integration by Trapezoidal and Simpson rules, Monte Carlo method, use of random numbers. Given Position with equidistant time data to calculate velocity and acceleration and vice versa. Find the area of B-H Hysteresis loop, Ohms law to calculate R, Hooke's law to calculate spring constant

**Solution of ODE:** First order Differential equations: Euler, modified Euler and Runge-Kutta second and fourth order methods. Second order differential equation. Fixed difference method, Numerical solution of differential equations:

1. Radioactive decay
2. Current in RC, LC, LRC circuits with DC source
3. Newton's law of cooling
4. Classical equations of motion

Numerical solution of second order differential equations:

- (i) Harmonic oscillator (no friction)
- (ii) Damped Harmonic oscillator
  - (a) Over damped solution
  - (b) Critical damped solution
  - (c) Oscillatory solution
- (iii) Forced Harmonic oscillator: Transient and Steady state solution

**Group discussion/ Extended studies:** ODE including applications in interdisciplinary areas, such as biological and chemical physics.

**PHYS03C6: THERMAL PHYSICS**  
**Credits: 6 (Theory-04, Practicals-02)**

**Theory**

**Credit: 4**

**Contact Hours per Week: 4**

**Zeroth and first law of Thermodynamics [7]:** Extensive and intensive Thermodynamic Variables, Thermodynamic Equilibrium, Zeroth Law of Thermodynamics & Concept of Temperature, Concept of Work & Heat, State Functions, Internal Energy, First Law of Thermodynamics and its applications: General Relation between specific heats at constant pressure and constant volume, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Co-efficient.

**Second law of Thermodynamics [8]:** Reversible and Irreversible process with examples, Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot's Cycle, Carnot engine & efficiency. Refrigerator & coefficient of performance, 2nd Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence, Carnot's Theorem. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale.

**Entropy [8] :** Concept of Entropy, Clausius Theorem. Clausius Inequality,

Entropy of a perfect gas. Principle of Increase of Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe. Temperature-Entropy diagrams for Carnot's Cycle, Mixing of entropy of two ideal gases. Third Law of Thermodynamics. Unattainability of Absolute Zero.

**Thermodynamic Potentials [7]:** Enthalpy, Helmholtz Free Energy, Gibbs Free Energy: Properties and Applications. Surface Films and Variation of Surface Tension with Temperature. Magnetic Work, Joule-Thompson porous plug experiment, Adiabatic demagnetization and cooling, First and second order Phase Transitions, Clausius-Clapeyron Equation and Ehrenfest criterion.

**Maxwell's Thermodynamic Relations [5]:** Derivations and applications of Maxwell's Relations such as  $C_p-C_v$ , TdS Equations, Joule-Kelvin coefficient for Ideal and Van der Waal Gases, Energy equations, Change of Temperature during Adiabatic Process.

**Kinetic theory of gases [8]:** Preliminaries: Basic postulates of kinetic theory, Pressure of an ideal gas, Maxwell-Boltzmann Law of Distribution of velocities and energy of an Ideal Gas and its Experimental Verification - Doppler Broadening of Spectral Lines and Stern's Experiment. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy and its applications, Specific heats of Gases.

**Molecular collisions [10]:** Mean Free Path, Collision Probability, Distribution of Mean Free Paths, Mean free path of ideal gases obeying Maxwell's velocity distribution, Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian Motion, Perrin's experiment, Random walk, applications of Brownian motion in diverse systems.

**Real gases [7]:** Behavior of Real Gases, Deviations from the Ideal Gas Equation. The Virial

equation. Andrew's Experiments on Carbon-dioxide Gas. Critical Constants. Continuity of Liquid and Gaseous State. Vapour and Gas. Boyle Temperature. Van der Waal's Equation of State for Real Gases. Values of Critical Constants. Law of Corresponding States. Survey of other equations of state for real gases.

**Practical**

**Credit: 2**

**Contact Hours per Week: 4**

1. To determine Mechanical Equivalent of Heat,  $J$ , by Callender and Barne's constant flow method.
2. To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
3. To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method.
4. To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT).
5. To study the variation of Thermo-Emf of a Thermocouple with Difference of Temperature of its Two Junctions.
6. To calibrate a thermocouple to measure temperature in a specified Range using Null Method.
7. Direct measurement of temperature using Op-Amp difference amplifier and to determine Neutral Temperature.

## **PHYS03C7: ANALOG SYSTEMS AND APPLICATIONS**

**Theory**

**Credit: 4**

**Contact Hours per Week: 4**

### **Semiconductor Fundamentals [6]**

Crystalline solids, semiconductors, electron and hole, intrinsic semiconductor, doping and n- and p-type semiconductors, direct and indirect band gap semiconductors, effective mass, Fermi level, energy band, distinction of metal, insulator and semiconductors, energy band diagrams, drift and diffusion of carriers, Einstein Relation, continuity equation, Hall Effect, resistivity and four-probe technique.

### **p-n Junction Diodes and Applications [7]**

Fabrication of p-n junction, barrier formation in p-n junction, barrier potential, forward and reverse biased diode, energy band diagrams, current flow mechanism in forward and reverse biased diodes, static and dynamic resistance, junction capacitances.

Diode rectifier, load line and  $Q$ -point, half-wave rectifier, centre-tapped and bridge full-wave rectifiers, calculation of average and rms current and voltage, voltage regulation, ripple factor and rectification efficiency, filters.

Zener Diode, Zener and avalanche breakdown, Zener diode as voltage regulator, Principle and structure of light-emitting diode (LED), photodiode and solar cell and metal-semiconductor contacts.

### **Applicability/ Employability of the above Topics [1]**

Diode clippers, clampers, voltage multipliers

### **Bipolar Junction transistor and Field-Effect Transistors [10]**

n-p-n and p-n-p transistors, characteristics of common-base (CB), common-emitter (CE) and common-collector (CC) configurations, active, cutoff and saturation regions, current gains  $\alpha$  and  $\beta$ , relations between  $\alpha$  and  $\beta$ , brief Ideas on JFET and MOSFET

### **Transistor Amplifiers [7]**

Load line and  $Q$ -point, transistor biasing and stabilization circuits, fixed bias, emitter-feedback bias, collector-feedback bias and voltage divider bias.

Two-port model and hybrid ( $h$ ) parameters, significance of  $h$  parameters, Thevenin and Norton equivalents of a transistor, transistor as two-port network, analysis of a single-stage CE amplifier using hybrid model, current and voltage gains, input and output impedance.

Need for power amplification, conditions for transistor power amplifier, distortions due to nonlinearity, classification of amplifiers: class A, B, AB and C amplifiers.

### **Coupled Amplifier [3]**

Transformer coupling, push-pull amplifiers, two stage RC-coupled amplifier and its frequency response. Frequency response of amplifier, cutoff frequencies.

### **Feedback in Amplifiers [4]**

Concept of feedback, effects of positive and negative feedback on input impedance, output impedance, gain, stability, distortion and noise.

### **Sinusoidal and Non-Sinusoidal Oscillators [4]**

Barkhausen criterion for self-sustained oscillations, Hartley oscillator, Colpitts oscillator, RC phase shift oscillator, multivibrators, crystal oscillator.

### **Operational Amplifier (Op-Amp) [2]**

Characteristics of an ideal and a practical op-amp, IC 741, open loop and closed-loop gain, frequency response, differential amplifier, common-mode rejection ratio (CMRR), offset current and voltage, slew rate.

### **Applicability[8]**

Inverting and non-inverting amplifiers, concept of virtual ground and virtual short, adder, differential amplifier, differentiator, integrator, active filters, logarithmic amplifier, comparator, zero-crossing detector and Schmitt trigger, Wein bridge oscillator.

### **Introduction to Cathode Ray Oscilloscope (CRO) [3]**

Block diagram of CRO, electron gun, deflection and focussing systems, time base, deflection sensitivity, applications of CRO: study of waveforms, measurement of voltage, current, frequency, and phase difference.

### **Integrated Circuit (IC) [2]**

Active & passive components, discrete components, wafer, chip, advantages and limitations of ICs, scale of integration: SSI, MSI, LSI and VLSI (basic idea and definitions only), classification of ICs, examples of linear and digital IC's.

### **Seminar/Interactive Session [3]**

### **Reference Books:**

1. Boylestad R. L. and Nashelsky L., *Electronic Devices and Circuit Theory*, Pearson.
2. Raychaudhuri Barun, *Electronics: Analog and Digital*, Cambridge University Press.
3. Cathey J. J., *Schaum's Outline of Theory and Problems of Electronic Devices and Circuits*, McGraw-Hill.
4. Helfrick A. D. and Cooper W. D., *Modern Electronic Instrumentation and Measurement Techniques*, PHI.
5. Malvino A. P. and Bates D. J., *Electronic Principles*, McGraw-Hill Education.
6. Millman J. and Halkias C. C., *Integrated Electronics: Analog and Digital Circuits and Systems*, McGraw-Hill, Inc.
7. Streetman B. G. and Banerjee S.K., *Solid State Electronic Devices*, PHI.
8. Gayakwad R. A., *Op-Amps and Linear Integrated Circuits*, Pearson.

### **Practical**

**Credit: 2**

**Contact Hours per Week: 4**

**At least eight of the following list of experiments**

#### **1. p-n Junction Diode**

Experiment: To record the forward and reverse current-voltage data and to draw the forward current-voltage characteristic curve

Scientific Analysis: Determination of dynamic resistance, static resistance and cut-in voltage

## **2. Light-Emitting Diode (LED)**

Experiment: To record the forward and reverse current-voltage data and to draw the forward current-voltage characteristic curve

Scientific Analysis: Determination of dynamic resistance and cut-in voltage

## **3. Zener Diode**

Experiment: To record the forward and reverse current-voltage data and to draw the forward and reverse characteristics. The calculation of current-limiting resistance is included.

Extended Studies: To determine the breakdown voltage and to conduct the load regulation characteristics.

## **4. Team Work/Group Discussion** on the comparative features of diode, LED and Zener diode

## **5. Bipolar Junction Transistor (BJT)**

Experiment: Output current-voltage characteristics in common-emitter (CE) configuration

Scientific Analysis: Determination of current gain and hybrid parameters

## **6. BJT Amplifier**

Experiment: Biasing the transistor and to design a CE amplifier of given gain

Extended Studies: To study the linearity and the frequency response of the voltage gain

## **7. Astable Multivibrator**

Experiment: To design the multivibrator using BJT, capacitors and resistors

Case Study: To observe the changes in the waveform with circuit components and to determine its frequency

## **8. Op-Amp-1**

Experiments:

(i) To design an inverting amplifier and to study its dc amplification.

(ii) To design a non-inverting amplifier and to study its dc amplification.

Scientific Analysis: To investigate the voltage gain and linearity of the amplifiers and the ac response.

## **9. Op-Amp-2**

Experiment:

(i) To design adder in inverting and/or noninverting mode

(ii) To design a differential amplifier

Case Study: Verification of the circuit performance with different voltage levels.

## **10. Op-Amp-3**

Experiment:

(i) To investigate the use of op-amp as integrator

(ii) To investigate the use of op-amp as differentiator

Case Study: Verification of the circuit performance with different voltage waveforms.

## **11. Op-Amp-4**

Experiment: To study the op-amp comparator with zero-crossing detector.

Extended Study: To fabricate op-amp Schmitt trigger and to study its performance.

## **12. Wien Bridge Oscillator**

Experiment: To design the oscillator and to study the waveform for more than one C-R combination.

Extended Study: To investigate the properties of the lead-lag network, such as the change of output phase with frequency.

## Generic Elective Course **PHYS03GE3**

### **THE NUCLEAR AGE**

**Credits: 6 (Theory-05, Tutorials-01)**

**Theory**

**Credit: 5**

**Contact Hours per Week: 5**

**Preliminaries [8]:** Origin of Quantum Mechanics: Blackbody spectrum, photoelectric effect. Basic quantum phenomena- discrete energy levels, tunnelling, Atoms and their constituents, Concept of a wavefunction. Origin of natural radioactivity, Radioactive decay processes – half-life and mean-life, Discovery of the nucleus, Elementary aspects of nuclear physics, Binding energy, Energy release in nuclear processes, Alpha, beta, gamma emission.

**Nuclear Fission and Nuclear Reactors [22]:** Overview of nuclear reactions, Kinematics of nuclear reaction, Reaction cross-sections, Neutron reactions in different energy regimes, Cross-sections in the resonance region and the continuous region, Discovery of nuclear fission, Products of nuclear fission and their mass distribution, Energetics, Decay of fission fragments, Chain reaction, Criticality and the multiplication factor, Role of moderators, Nuclear reactors, Classification of reactors and their components, Conversion ratio and production of plutonium in thermal reactors, Fast breeder reactors, Nuclear reactor safety, Calculation of electricity generation cost by nuclear fission based technology Introduction to risk management, Characterisation of nuclear fuel cycle – uranium enrichment, fuel fabrication and reprocessing, Introduction to radioactive waste management, Deep geologic waste disposal and its alternatives,. Generating energy from nuclear waste.

**Nuclear Weapons [10]:** Uncontrolled chain reaction, nuclear fusion, Introduction to fission and fusion based nuclear weapons, Biological effects of radiation injury, physical and chemical damage. radiation doses, Types of effects – deterministic and stochastic, Effects of low radiation doses, Concentration of radionuclides in the environment, Radiation measurement tools, Dosimetry, absorbed dose and its calculation. Prescribed safe radiation standards.

**History of the Quantum Revolution [5]:** Contributions by Planck, Einstein, Bohr, Pauli, Heisenberg, Schrodinger, Born, Oppenheimer; Wave mechanics vs Matrix mechanics, Brief mention of the timelines and parallel development in different geographical locations such as Goetingen, Zurich, Copenhagen etc.

**The beginning of nuclear physics [10]:** History of natural and artificial radioactivity, The Curie family, Rutherford at Montreal and Manchester, Bethe, History of discovery of nuclear fission, Hahn, Strassmann, Meitner; Herbert Anderson at Columbia University, Bohr-Wheeler collaboration.

**The Manhattan Project [15]:** Capsule history of World War II, The Allies and the Axis, Pearl Harbor, Fermi and the Chicago Atomic Pile, Brief elucidation of the history of launching the

Manhattan Project, Einstein's peace initiatives, Immigration of important German scientists of Jewish origin to the United States, Szilard and Teller, Relevant American wartime industry, Los Alamos, Robert Oppenheimer and General Leslie Groves, Technical challenges in building the first atomic bomb, Dropping of the Allied Atomic *Fission* bomb in Japan.

**The Nazi Atomic Bomb [5]:** Brief discussion of the Nazi wartime effort in building the atomic bomb under the leadership of Heisenberg, Analysis of the reasons behind failure of the Nazi effort.

## **Skill Enhancement Course**

### **PHYS03SEC1: STATISTICAL AND COMPUTATIONAL METHODS**

**Credit: 4**

**Contact Hours per Week: 4**

**Computer Programming (Fortran/C/C++) [16]:** Basic programming concepts. Constants, variables and arrays. Control Statements. Input/Output facilities. Operators and expressions. Loops. Nested loops. Function. Subroutine, Libraries. Use of random numbers.

**Introduction to Softwares [14]:** Basic 2D and 3D graph plotting - plotting functions and data files, fitting data using gnuplot's fit function, polar and parametric plots, modifying the appearance of graphs, Surface and contour plots, exporting plots as eps, pdf, png, jpg files, Intro to softwares : XMAXIMA /OCTAVE/ MATLAB/ MATHEMATICA/ Origin Word processing in word and latex.

**Propagation and reporting of uncertainties [5]:** Characterisation of uncertainties present in various basic instruments in the lab. Effect of uncertainties in the final result.

**Probability Distributions [10]:** Probability theory, PDF, CDF, Moments of a distribution, Binomial, Poisson. Gaussian/Normal.

**Classification of experimental uncertainties [4]:** Instrumental, random, and systematic uncertainties in various experiments in labs. Concept of different moments: mean, standard deviation. Standard deviation on the mean.

**Least-Square Fit [4]:** Straight line. Polynomial. Arbitrary function. Uncertainties from fit.

**Goodness of Fit [7]:** Confidence intervals. Chi-squared test. Degrees of freedom. Reduced Chi-square. Correlation and covariance. F test. Monte-Carlo test.



## Fourth Semester

Core Courses

**PHYS04C8: MATHEMATICAL PHYSICS-III**

**Credits: 6 (Theory-04, Practicals-02)**

**Theory**

**Credit: 4**

**Contact Hours per Week: 4**

**Complex Analysis [20]:** Complex Numbers. Functions of Complex Variables. Analyticity and Cauchy-Riemann Conditions. Examples of analytic functions. Singular functions: poles and branch points, order of singularity, branch cuts. Integration of a function of a complex variable. Cauchy's Inequality. Cauchy's Integral formula. Simply and multiply connected region. Laurent and Taylor's expansion. Residues and Residue Theorem. Application in solving Definite Integrals., Complex series and its convergence.

**Tensor Analysis [15]:** Cartesian tensors: first and zero order Cartesian tensors, second and higher order Cartesian tensors. Algebra of tensors: summation, multiplication, contraction, inner product, the quotient law. The tensors  $\delta_{ij}$  and  $\epsilon_{ijk}$ . Isotropic tensors, improper rotation and pseudo-tensors, dual tensors. Non-Cartesian tensors, the metric tensors. General coordinate transformation and tensors. Applications (e.g., electromagnetic field tensors, stress-strain tensors, moment of inertia tensors).

**Integrals Transforms [25]:** Fourier Integral theorem. Fourier Transform. Examples. Representation of Dirac delta function as a Fourier Integral. Fourier transform of derivatives, Inverse Fourier transform, Parseval's theorem. Convolution theorem. Three dimensional Fourier transforms with examples. Application of Fourier Transforms to differential equations: One dimensional Wave, Diffusion and Heat Flow Equations.

Laplace Transform (LT) of Elementary functions. Properties of LTs: Change of Scale Theorem, Shifting Theorem. LTs of Derivatives and Integrals, Derivatives and Integrals of LTs. LT of Unit Step function, Dirac Delta function, Periodic Functions. Convolution Theorem. Inverse LT. Application of Laplace Transforms to 2<sup>nd</sup> order Differential Equations: Damped Harmonic Oscillator, Simple Electrical Circuits, Coupled differential equations of 1<sup>st</sup> order. Solution of heat flow along infinite bar using Laplace transform.

**Reference Books:**

1. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 2013, 7<sup>th</sup> Edn., Elsevier.
2. Differential Equations, George F. Simmons, 2007, McGraw Hill.
3. Mathematical methods for Scientists and Engineers, D.A. Mc Quarrie, 2003, Viva Book

4. Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
5. Essential Mathematical Methods, K.F.Riley & M.P.Hobson, 2011, Cambridge Univ Press.

### **Practical**

**Credit: 2**

**Contact Hours per Week: 4**

**Solution of Algebraic and Transcendental Equations:** Bisection method, Newton Raphson and Secant methods, Solution of linear and quadratic equation.

**Solution of Linear System of Equations:** Gauss elimination method and Gauss Seidal method. Diagonalization of matrices, Inverse of a matrix, Eigen vectors, eigen value problems , Solution of mesh equations of electric circuits (3 meshes), Solution of coupled spring mass systems (3 masses)

**Generation of Special functions using User defined functions:** Generating and plotting Legendre Polynomials Generating and plotting Bessel function, Evaluation of trigonometric functions e.g.  $\sin \theta$ , Given Bessel's function at N points find its value at an intermediate point.

**Fourier Series and Fourier Transform:** Fourier analysis: Sawtooth function, half wave function, summation of Fourier series, discrete Fourier transform, aliasing, fast Fourier transform

### **PHYS04C9: ELEMENTS OF MODERN PHYSICS**

**Credits: 6 (Theory-04, Practicals-02)**

#### **Theory**

**Credit: 4**

**Contact Hours per Week: 4**

**Quantum Theory [20]:** Planck's quantum, Planck's constant and light as a collection of photons; Blackbody Radiation: Quantum theory of Light; Photo-electric effect and Compton scattering. De Broglie wavelength and matter waves; Davisson-Germer experiment. Wave description of particles by wave packets. Group and Phase velocities and relation between them. Two-Slit experiment with electrons. Probability. Wave amplitude and wave functions.

Position measurement- gamma ray microscope thought experiment; Wave-particle duality, Heisenberg uncertainty principle (Uncertainty relations involving Canonical pair of variables): Energy-time uncertainty principle- application to virtual particles and range of an interaction, Two slit interference experiment with photons, atoms and particles; linear superposition principle as a consequence; Matter waves and wave amplitude; Bohr Atom, Atomic spectra: Frank Hertz experiment.

**Wave Mechanics [17]:** Schrodinger equation for non-relativistic particles; Momentum and Energy operators; stationary states; physical interpretation of a wave function, probabilities and normalization; Probability and probability current densities in one dimension, Scattering and

bound states for a general potential. One dimensional problems: particle in a box, Quantum dot, Scattering and tunneling - Steps and barriers.

**Nuclear Model [15]:** Size and structure of atomic nucleus and its relation with atomic weight; Impossibility of an electron being in the nucleus as a consequence of the uncertainty principle. Nature of nuclear force, NZ graph, Liquid Drop model: semi-empirical mass formula and binding energy, Nuclear Shell Model and magic numbers, Radioactive decay, Alpha and beta decay, neutrino hypothesis, Fission and fusion- mass deficit, relativity and generation of energy; Fission - nature of fragments and emission of neutrons. Nuclear reactor: slow neutrons interacting with Uranium 235, Fusion and thermonuclear reactions driving stellar energy (brief qualitative discussions).

**Lasers [8]:** Einstein's A and B coefficients. Metastable states. Spontaneous and stimulated emissions. Optical Pumping and Population Inversion. Three-Level and Four-Level Lasers. Ruby Laser and He-Ne Laser.

**Reference Books:**

1. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, 2ed Paperback – 2006 by Robert Eisberg and Robert Resnick, Wiley student edition
2. Introduction to Quantum Mechanics, D.J. Griffith, 2nd Ed. 2005, Pearson Education
3. Concepts of Modern Physics (SIE) 6th Edition (English, Paperback, Arthur Beiser, Shobit Mahajan), 2009, McGraw Hill Education (India) Private Limited
4. University Physics Plus Modern Physics Plus Mastering Physics with eText -- Access Card Package, 13th Edition, Hugh D. Young and Roger A. Freedman, 2012, Pearson.

**Practical**

**Credit: 2**

**Contact Hours per Week: 4**

1. Photo-electric effect: photo current versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light
2. Animation of simple solution of Schrodinger equation.
3. Solving Schrodinger equation and evaluating the time evolution of probability waves
4. Analysis of Planck's law for Black Body radiation and Wein's Law
5. Animation of laser properties
6. Measurement of Planck's constant using black body radiation and photo-detector
7. To determine the wavelength of H-alpha emission line of Hydrogen atom.
8. To show the tunneling effect in tunnel diode using I-V characteristics.
9. To determine (1) wavelength and (2) angular spread of He-Ne laser using plane diffraction grating
10. To verify discrete atomic level using the Frank-Hertz experiment

## **PHYS04C10: DIGITAL SYSTEMS AND APPLICATIONS**

**Credits: 6 (Theory-04, Practicals-02)**

### **Theory**

**Credit: 4**

**Contact Hours per Week: 4**

### **Digital Principles [4]**

Analog and digital systems, number systems and conversions: binary numbers, decimal to binary and binary to decimal conversions, octal and hexadecimal numbers, binary coded decimal, binary arithmetic, 1's complement and 2's complement, signed binary numbers.

### **Boolean Algebra [4]**

Boolean laws, OR, AND and NOT operations, De Morgan's theorems, simplification of logic circuit using Boolean algebra, sum-of-products (SOP) and product-of-sums (POS), idea of minterms and maxterms, conversion of a truth table into equivalent logic circuit by SOP and POS method, Karnaugh Map.

### **Combinational Logic Circuits**

**Basics [6]:** Boolean algebra and digital electronics, positive and negative logic, logic gates, AND, OR and NOT gates, NAND and NOR gates as universal gates, bubbled gates, exclusive-OR gate, logic families: diode-transistor logic, TTL and MOS logic (brief introduction only)

**Arithmetic and Logic Circuits [5]:** half adder, full adder, half and full subtractors, adder-subtractor, digital comparators

**Data processing circuits [4]:** multiplexers, demultiplexers, decoders, encoders, parity checker and generator

### **Sequential Logic Circuits**

**Clock and timer [4]:** clock parameters, propagation delay, IC 555 block diagram, working principle and applications as astable and/or monostable multivibrator.

**Flip-flops [6]:** RS flip-flops constructed with NAND gate and NOR gate, D flip-flop and JK flip-flop, the use of clock, racing, edge triggering, pulse triggering, master-slave flip-flop, preset and clear operations.

**Shift Register [4]:** serial-in-serial-out, serial-in-parallel-out, parallel-in-serial-out and parallel-in-parallel-out shifting operations, applications of shift register

**Counter [4]:** asynchronous counter, synchronous counter, decade counter, applications of counter

**D/A and A/D Conversions [4]:** Weighted resistor D/A converter, R-2R ladder D/A converter, accuracy and resolution, A/D Conversion (introductory)

**Computer Organization [3]:** Input/output devices, data storage, idea of read-only memory (ROM) and random access memory (RAM), computer memories, memory organization and addressing, memory interfacing, memory map.

**Intel 8085 Microprocessor Architecture and Programming [8]:** Main features of 8085, block diagram, registers, stack memory, timing states, instruction cycle, opcode.

Classifications of 8085 instructions, 1-byte, 2-byte 3-byte instructions, composing simple 8085 programs.

### **Seminar/ Participatory Pedagogies [4]**

#### **Reference Books:**

1. Digital Principles and Applications, A.P. Malvino, D.P. Leach and G. Saha, 8th Edn. McGraw-Hill Education.
2. Electronics: digital and Analog, Barun Raychaudhuri, Cambridge University Press.
3. Digital Systems: Principles & Applications, R.J. Tocci, N.S. Widmer, 10th Edn. Pearson
4. Integrated Electronics: Analog and Digital Circuits and Systems, J. Millman and C.C.
5. Halkias, 2nd Edn. 2017, McGraw Hill Education.
6. Schaum's Outline of Theory and Problems of Digital Principles, R. L. Tokheim, 3rd Edn.
7. McGraw-Hill.
8. Microprocessor Architecture, Programming and Applications with the 8085, R.S. Gaonkar, 5<sup>th</sup> Edn. Penram (India).

#### **Practical**

**Credit: 2**

**Contact Hours per Week: 4**

At least eight of the following

##### **1. Designing logic gates**

Experiment: Realizing AND and OR gates with diodes and resistors and NOT gate with transistor and resistors.

Scientific and analytical reasoning: Determining logic levels, understanding the range of voltage supply and the use of analog devices into digital circuits.

##### **2. Designing logic circuits**

Experiment: Construction of AND, OR, NOT and XOR gates using NAND gates.

Extended Studies:

- (i) Realizing combinational logic system for a specified truth table
- (ii) Fabricating logic circuits using ICs for simple Boolean expressions
- (iii) Minimizing a given logic circuit.

##### **3. Arithmetic and Logic operations-I**

Experiment: To fabricate Half Adder and Full Adder circuits for single bit addition using NAND gates.

Extended Studies: To fabricate Half Subtractor and Full Subtractor circuits for single bit.

##### **4. Arithmetic and Logic operations-II**

Experiment: To build 1-bit comparator for equality and inequality of two bits.

Extended Studies: Realizing Adder-Subtractor using Full Adder IC.

##### **5. Multivibrators**

Experiment: To fabricate an astable multivibrator of given specifications using 555 Timer IC and to study the waveform.

Group Discussion: Designing a monostable multivibrator of given specifications using 555 Timer IC.

### **6. Flip-flop-I**

Experiment: To build RS and D-type Flip-Flop circuits using NAND gates.

Scientific and analytical reasoning: To understand the use of clock pulse, the latch and memory properties of flip-flop.

### **7. Flip-flop-II**

Experiment: To build JK Flip-Flop circuits using NAND gates.

Team Work/ Group Discussion: To compare the features of RS and JK flip-flops.

### **8. Counter**

Experiment: Fabrication of 4-bit Counter using Flip-Flop ICs and to study its timing diagram.

Scientific Analysis: To understand the role of each flip-flop in the circuit, LSB and MSB, frequency division by counter outputs.

### **9. Shift Register**

Fabrication of 4-bit Shift Registers (serial and parallel) using Flip-Flop ICs and to study their performances.

### **10. Microprocessor 8085 programming and related studies**

(i) At least the following programs are to be done.

- (a) Addition and subtraction of numbers using direct addressing mode
- (b) Addition and subtraction of numbers using indirect addressing mode
- (c) Multiplication by repeated addition.
- (d) Division by repeated subtraction.
- (e) Handling of 16-bit Numbers.
- (f) Use of CALL and RETURN Instruction.
- (g) Block data handling, sorting and rearrangement of numbers.

(ii) Lab Demonstrations/ Participatory Pedagogies

- (a) Other programs of microprocessor, such as parity check, use of interrupts etc.
- (b) Demonstration of microcontroller, such as Arduino.

## Generic Elective Course

### **PHYS04GE4: OPTICS**

**Credits: 6 (Theory-05, Practical-01)**

**Contact Hours per Week: 5**

#### **Geometrical Optics [20]**

**Fermat's principle** and its application to plane and curved surfaces, Matrix method in paraxial optics and its applications, Seidel and chromatic aberrations – elementary discussions.

Optical systems: eye glasses, eyepieces, compound microscope, telescope

#### **Physical Optics**

##### **Waves and Interference of Light [15]**

Superposition of waves, Huygen's principle, Young's experiment, coherence, interference by division of wavefront and division of amplitude, Newton's ring, oil film.

##### **Diffraction of Light [15]**

Fresnel and Fraunhofer diffraction, Huygen-Fresnel theory, zone plate, different apertures, Fraunhofer diffraction due to a single slit, double slit, transmission grating, resolving power of optical systems, spectrometers, applications.

##### **Polarization of Light [10]**

Unpolarized and partially polarized light, state of polarization, polarization by reflection and scattering, Brewster's angle, polaroid and Malus' law, optical anisotropy, wave equation in anisotropic media, birefringence, o- and e- rays, double refraction, wave plates, optical activity, applications.

##### **Interferograms and Holography [10]**

Interferograms, testing optical surfaces, generating holograms and holographic wavefront reconstruction, applications.

## Skill Enhancement Course

### **PHYS04SEC2: MODERN EXPERIMENTAL AND THEORETICAL TECHNIQUES**

**Credit: 4**

**Contact Hours per Week: 4**

**Introduction to state-of-the-art research topics [20]:** Research seminar, Colloquium and student journal club on topics in particle physics, Particle physics, Condensed Matter Systems, Atomic and Molecular physics, Non-linear physics, Cold-atom systems, Statistical physics, Atmospheric physics, Fluid dynamics, Material science, History and philosophy of science, Sociology of physics and other interdisciplinary topics.

**Modern Experimental Techniques [30]:** Experimental methods in materials science and engineering: characterization of material structures (using spectroscopy, microscopy and diffraction techniques), Material properties (Mechanical, Thermal, Electrical, Electrochemical, etc.) and Material processes (Phase transformations, Reactions). Laboratory demonstrations on different kinds of materials (e.g., metals, ceramics, polymers, carbons, semiconductors and composites). Different state of the art telescopes

**Research Lab Visits [10]:** Visit of local research labs and demonstration of facilities



# Fifth Semester

## Core Courses

### PHYS05C11: QUANTUM MECHANICS AND APPLICATIONS

Credits: 6 (Theory-04, Practicals-02)

#### Theory

Credit: 4

Contact Hours per Week: 4

**Schrodinger equation [6]:** Time dependent Schrodinger equation and dynamical evolution of a quantum state; Properties of Wave Function. Interpretation of Wave Function Probability and probability current densities in three dimensions; Conditions for Physical Acceptability of Wave Functions, Hamiltonian, stationary states and energy eigenvalues; expansion of an arbitrary wavefunction as a linear combination of energy eigenfunctions

General solution of the time dependent Schrodinger equation in terms of linear combinations of stationary states; Application to spread of Gaussian wave-packet for a free particle in one dimension; wave packets, Fourier transforms and momentum space wavefunction; Position-momentum uncertainty principle.

**General discussion of bound states in an arbitrary potential [6]:** continuity of wave function, boundary condition and emergence of discrete energy levels; application to one-dimensional problem-square well potential; Quantum mechanics of simple harmonic oscillator-energy levels and energy eigenfunctions using Frobenius method; Hermite polynomials; ground state, zero point energy & uncertainty principle, operator method for quantization of the harmonic oscillator

**Quantum theory of hydrogen-like atoms[9]:** time independent Schrodinger equation in spherical polar coordinates; separation of variables for second order partial differential equation; angular momentum operator & quantum numbers; Radial wavefunctions from Frobenius method; shapes of the probability densities for ground & first excited states; Orbital angular momentum quantum numbers  $l$  and  $m$ ; s, p, d,.. shells, introduction to spin

**Formalism [10]:** Linear Vector Spaces and linear operators, Hilbert space, Eigen functions of a Hermitian Operator, Uncertainty Principle, Dirac Notation, Heisenberg equation of motion, Symmetries in Quantum Mechanics

**Atoms in Electric & Magnetic Fields [14]:** Electron angular momentum. Space quantization. Electron Spin and Spin Angular Momentum. Larmor's Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Electron Magnetic Moment and Magnetic Energy, Gyromagnetic Ratio and Bohr Magneton. Normal and Anomalous Zeeman Effect. Paschen Back and Stark Effect.

**Many electron atoms[15]:** Pauli's Exclusion Principle. Symmetric & Antisymmetric Wave Functions. Periodic table. Fine structure. Spin orbit coupling. Spectral Notations for Atomic States. Total angular momentum. Vector Model. Spin-orbit coupling in atoms- L-S and J-J couplings. Hund's Rule. Term symbols. Spectra of Hydrogen and Alkali Atoms (Na etc), Molecular spectra, Raman effect, Modern applications

**Reference Books:**

1. A Text book of Quantum Mechanics, P.M.Mathews and K.Venkatesan, 2nd Ed., 2010, McGraw Hill
2. Quantum Mechanics, Robert Eisberg and Robert Resnick, 2nd Edn., 2002, Wiley.
3. Quantum Mechanics, Leonard I. Schiff, 3rd Edn. 2010, Tata McGraw Hill.
4. Quantum Mechanics, Eugen Merzbacher, 2004, John Wiley and Sons, Inc.
5. Introduction to Quantum Mechanics, D.J. Griffiths, 2nd Ed. 2005, Pearson Education
6. Concepts of Modern Physics (SIE) 6th Edition (English, Paperback, Arthur Beiser, Shobit Mahajan), 2009, McGraw Hill Education (India) Private Limited

**Practical****Credit: 2****Contact Hours per Week: 4**

1. Solve the Schrodinger equation for the ground state and the first excited state of the hydrogen atom
2. Solve the radial Schrodinger equation for an atom for the screened coulomb potential
3. Solve the radial Schrodinger equation for a particle of mass in an anharmonic oscillator potential
4. Solve Schrodinger equation for vibrational spectra of hydrogen
5. Simulate the Stern Gerlach experiment for spin half particles
6. Simulate a two state quantum system and study its properties (e.g., spin half systems)
7. Interactive Tutorial on Foundations of Quantum Mechanics

## **PHYS05C12: STATISTICAL MECHANICS**

**Credits: 6 (Theory-04, Practicals-02)**

### **Theory**

**Credit: 4**

**Contact Hours per Week: 4**

**Classical Statistics [18]:** Macrostate & Microstate, Elementary Concept of Ensemble: micro-canonical, canonical, grand canonical. Phase Space, Entropy and Thermodynamic Probability, Maxwell-Boltzmann Distribution Law, Partition Function, Thermodynamic Functions of an Ideal Gas, Classical Entropy Expression, Gibbs Paradox & resolution, Sackur Tetrode equation, Law of Equipartition of Energy (with proof) – Applications to Specific Heat and its Limitations, Thermodynamic Functions of a Two-Level System, Negative Temperature., Introduction to nonequilibrium phenomena, Purcell 's experiment, Langevin dynamics.

**Quantum Theory of Radiation [9]:** Spectral Distribution of Black Body Radiation, Planck's Quantum Postulates. Planck's Law of Blackbody Radiation: Experimental Verification. Deduction of (1) Wien's Distribution Law, Rayleigh-Jeans Law, (3)Stefan-Boltzmann Law, (4) Wien's Displacement law from Planck's law. Applications.

**Bose-Einstein Statistics [12]:** B-E distribution law, Thermodynamic functions of a strongly Degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description), Radiation as a photon gas and Thermodynamic functions of photon gas, Bose derivation of Planck's law.

**Fermi-Dirac Statistics [15]:** Fermi-Dirac Distribution Law, Thermodynamic functions of a strongly Degenerate Fermi Gas, Fermi Energy, Electron gas in a Metal, Specific Heat of Metals, Thermoionic emission & Richardson equation, Pauli spin paramagnetism.

### **Reference Books:**

1. Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2 nd Ed., 1996, Oxford University Press.
2. Statistical Physics, Berkeley Physics Course, F. Reif, 2008, Tata McGraw-Hill
3. Statistical and Thermal Physics, S. Lokanathan and R.S. Gambhir. 1991, Prentice Hall
4. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.
5. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer
6. An Introduction to Statistical Mechanics & Thermodynamics, R.H. Swendsen, 2012, Oxford Univ. Press
7. An Introduction to Thermal Physics. Daniel V. Schroeder. 422 pp. Addison–Wesley, Reading, Massachusetts,. 2000

**Practical****Credit: 2****Contact Hours per Week: 4**

1. Study of Specific Heat of Solids in different approximations and physical regimes.
3. Numerical study of Maxwell-Boltzmann, Fermi-Dirac and Bose-Einstein distribution functions
4. Numerical estimates of metallic specific heat
5. Numerical studies of the Partition function and its properties
6. Verification of Stirling approximation for large numbers
7. Simulating Spin systems
8. Numerical study of the ortho-para states of hydrogen
9. Numerical analysis of Bose gas confined in a harmonic trap

**PHYS05DSE1: Discipline Specific Electives(Any two of the three)****(i) ADVANCED MECHANICS****Credits: 6 (Theory-05, Tutorials-01)****Theory****Credit: 5****Contact Hours per Week: 5**

**Rigid Body Dynamics [15]:** Demonstration of gyroscopic motion, Rotation about a fixed axis, Moment of inertia tensor, Products of inertia, Principal axis, Precession of top due to weak torque (formal derivation of gyroscopic motion), Euler's equation and its solution for symmetric rigid bodies.

**Lagrangian and Hamiltonian Formalism [18]:** Variational Principle in Mathematics, Principle of least action, Virtual displacement, D'Alembert's principle, Principle of virtual work, Generalised coordinates, Constraints and degrees of freedom, Lagrange's equations of motion for conservative holonomic systems, Generalised momentum, Cyclic coordinates, Application to simple cases, Construction of Hamiltonian using Legendre transformation, Hamilton's equations of motion and its application to simple cases, Relation between Hamiltonian and total mechanical energy in various cases, Noether's theorem: Symmetries and conservation principle.

**Small Oscillations [7]:** Secular equation for small oscillations and its solution: Double pendulum, Weakly coupled pendulum, Normal coordinates and modes.

**Fluid Mechanics [23]:** The equation of continuity, Euler's equation for ideal fluids, Hydrostatics, Bernoulli's theorem, Potential flow, Incompressible fluids, Newtonian fluids, Navier-Stokes equation and its applications. Poiseuille's formula, Couette flow, Turbulent flow

and Reynold's number, Modern Applications

**Elasticity [12]:** Stress and Strain tensors, Hooke's law, Isotropic solids and their conditions for equilibrium, Energy of deformation, Propagation of waves in an elastic medium.

### **Reference Books:**

1. Classical Mechanics, H.Goldstein, C.P. Poole, J.L. Safko, 3rd Edn. 2002, Pearson Education.
2. Mechanics, L. D. Landau and E. M. Lifshitz, 1976, Pergamon.
3. The Classical Theory of Fields, L.D Landau, E.M Lifshitz, 4th Edn., 2003, Elsevier.
4. Classical Mechanics, P.S. Joag, N.C. Rana, 1st Edn., McGraw Hall.
5. Classical Mechanics, R. Douglas Gregory, 2015, Cambridge University Press.
6. Classical Mechanics: An introduction, Dieter Strauch, 2009, Springer.
7. Solved Problems in classical Mechanics, O.L. Delange and J. Pierrus, 2010, Oxford Press

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### **DSE2A: Nuclear Medicine**

**Credits: 6 (Theory : 5, Tutorial : 1)**

#### **Why Nuclear Medicine[3]**

Frontiers in Nuclear physics; Application of the Nuclear physics techniques in different branch; Present status of cancer treatment and usefulness of Nuclear Medicine.

#### **Radiation Physics[20]**

Mechanism of radioactive decay; Effective half lives; Alpha, Beta and gamma emission and electron capture; Interaction with matter; Energy loss of radionuclide in matter; Neutron production, detection; Neutron energy loss in medium; Radiation damage due to neutron; Decay scheme and energy level diagrams; Radionuclide hazards; Internal exposure – contamination control; External exposure – shielding, distance, time; safe handling of radioactive sources; Filters and its use in the image processing; 3 D construction, Fusion imaging principal of DICOM, image transfer PACK technology.

#### **Radionuclide production and Application [30]**

Production of radio nuclide by reactors, cyclotrons and other particle accelerators; Man-made sources of radiation; Medical cyclotron; Use of radionuclide generators; Parent – Daughter relationship of radionuclide generator systems ( $^{99m}\text{Tc}$  /  $^{99}\text{Mo}$ ) including solvent extraction; Radionuclide used in therapy. Trace element analysis.

Gas filled detectors, Scintillation detectors, and General systems for the scintillation detector. Liquid Scintillation detectors. Semi-conductor detectors; Gamma camera – both single and dual head; Position emission tomography scanner (both simple and hybrid); Beta counter principals and operation. Projection Imaging with internal and external radiation; computed Tomography; Magnetic Resource Imaging Principles, Radiation therapy: proton and heavy ion therapy. Present advancement and opportunity.

### **Radiation effect and measurements [14]**

Biological effects of Radiation; Radiation injury, physical and chemical damage; normal and abnormal human exposure to radiation – maximum permissible levels; Dosimetry: absorbed dose, calculation of absorbed dose; Dosimetry of individuals: absorbed dose from diagnostic & therapeutic nuclear survey; Radiation measurement – monitoring; Personal monitoring: TLD's film; Contamination monitoring; Survey instruments, wipe tests.

### **Radiation safety and protection [8]**

Accidents and emergencies: Management of radiation accidents, Radiation protection in different nuclear isotope therapy procedures – protection of workers, patient relatives; Loss of radioactive sources. Quality assurance in Nuclear Medicine.

### **Reference**

1. Nuclear Physics, Principles and Applications by J. S. Lilly (John Wiley & Sons, Inc. 2002).
  2. Radiation Detection and Measurement by G. F. Knoll (John Wiley & Sons, Inc. 3<sup>rd</sup> Ed. 2000).
  3. Physics & Engineering of Radiation Detection by S. N. Ahmed (Academic Press 2007).
  4. Techniques for Nuclear and Particle Physics Experiments by W. R. Leo (Springer-Verlag 1987).
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## **DSE2B. QUANTUM OPTICS AND QUANTUM INFORMATION**

**Credits: 6 (Theory: 5, Tutorials : 1)**

### **Theory**

**Credit: 5**

**Contact Hours per Week: 5**

### **Quantum Optics[35]:**

**E.M Field Quantization:** Quantization of a single mode field, Quantum fluctuations of a single mode field, Quadrature operators for a single mode field, Multimode fields, Thermal fields, Vacuum fluctuations and zero point energy. Coherent States: Eigen states of the annihilation operator and minimum uncertainty states, Displaced vacuum states, Wave packets and time evolution, Generation of coherent states, Fock state representation of coherent state, Properties of coherent states: Minimum uncertainty state, completeness relation, Non orthogonality and over completeness,

**Coherent state as basis:** Non diagonal and diagonal coherent state basis representation of operator.

**Density operators and phase space probability distributions:** Pure state and mixed state, Glauber-Sudarshan P function, Phase space quasi-probability, Anti diagonal method to find P-function of a field, Optical equivalence theorem, Husimi-Kano Q function, Wigner W function, Characteristic function, Classical & non classical states.

**Quantum Coherence functions:** Classical coherence functions, Quantum Coherence functions, Young's interference, Higher-order coherence functions.

**Beam splitters and interferometers:** Experiments with single photon, Quantum mechanics of beam splitters, Interferometry with a single photon & coherent states of light.

**Squeezed States of light:** Quadrature squeezing, Quantum nature of squeezed state, Unitary squeeze operator, Action of the squeeze operator on any state, Ideal squeezed states, Photon

statistics, Generation and detection of quadrature squeezed light, amplitude squeezed states, photon anti bunching and sub-poissonian statistics, Schrodinger cat states, Two-mode squeezed vacuum states, higher order squeezing, Broadband squeezed light, Interferometry with squeezed states for the detection of gravity waves.

**Decoherence:** Quantum system interacting with environment, Generation of coherent states from decoherence.

**Emission and absorption of radiation by atoms:** Interaction of an atom with a classical and quantized field, The Rabi model, Jaynes-Cummings model, dressed states, Density operator approach to deal with mixed states.

**Quantum Measurement[15]:** The interpretation of quantum mechanics and the measurement process, The probabilistic interpretation and collapse of the wave function, Decoherence parameter, Density matrix description of the measurement process, Measurement theories -von Neumann-Wigner approach, Neutron interferometry and quantum Zeno effect, Non-classical states of electromagnetic wave as tools for quantum measurement, Quantum non-demolition measurements.

**Quantum Information [25]:** Classical information, Shannon entropy, Entangled states, Bloch sphere, von Neumann entropy, Applications of entanglement to quantum information processing, Einstein-Podolsky-Rosen paradox, Bell's inequality, Greenberger-Horne-Zeilinger equality, Optical test of local realistic theories, Quantum teleportation, Quantum cryptography.

**Reference Books:**

1. Quantum Optics – G. S. Agarwal, Cambridge University Press.
2. Fundamentals of Quantum Optics and Quantum Information – P. Lambropoulos and D. Petrosyan, Springer.

## Sixth Semester

### Core Courses

#### **PHYS06C13: SOLID STATE PHYSICS**

**Credits: 6 (Theory-04, Practicals-02)**

#### **Theory**

**Credit: 4**

**Contact Hours per Week: 4**

**Crystal Structure [12]:** Amorphous and Crystalline Materials. Lattice Translation Vectors. Lattice with a Basis – Central and Non-Central Elements. Unit Cell. Miller Indices. Reciprocal Lattice. Types of Lattices. Brillouin Zones. Diffraction of X-rays by Crystals. Bragg's Law. Atomic and Geometrical Factor.

**Elementary Lattice Dynamics [10]:** Lattice Vibrations and Phonons: Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids. Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids. Discussion: Thermal resistance of phonon gas.

**Magnetic Properties of Matter [8]:** Magnetic Susceptibility. Dia-, Para-, Ferri- and Ferromagnetic Materials. Classical Langevin Theory of dia- and Paramagnetic materials. Quantum Mechanical Treatment of Paramagnetism. Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains. Discussion of B-H Curve, Hysteresis and Energy Loss.

**Dielectric Properties of Materials [8]:** Microscopic Polarization. Local Electric Field at an Atom. Electric Susceptibility. Polarizability. Clausius Mosotti Equation. Classical Theory of Electric Polarizability. Frequency dependence of dielectric constant. Langevin-Debye equation. Complex Dielectric Constant.

**Ferroelectric Properties of Materials [6]:** Structural phase transition, Classification of crystals, Piezoelectric effect, Pyroelectric effect, Ferroelectric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop.

**Elementary band theory [10]:** Bloch's theorem, Energy bands in solids, Band filling, Brillouin zones, Effective mass. Kronig Penny model. Band gap. Conductor, semiconductor and insulator. Conductivity of Semiconductors, mobility, Hall Effect. Measurement of conductivity & Hall coefficient. Discussion: Direct and indirect band gaps of a semiconductor and quantum efficiency of light emission.

**Superconductivity [6]:** Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors, London's Equation and Penetration Depth. Isotope effect. Idea of BCS theory (No derivation)

**Reference Books:**



1. Introduction to Solid State Physics, Charles Kittel, 8th Edition, 2004, Wiley India Pvt. Ltd.
2. Elements of Solid State Physics, J.P. Srivastava, 2nd Edition, 2006, Prentice-Hall of India
3. Introduction to Solids, Leonid V. Azaroff, 2004, Tata Mc-Graw Hill
4. Solid State Physics, N.W. Ashcroft and N.D. Mermin, 1976, Cengage Learning
5. Solid-state Physics, H. Ibach and H. Luth, 2009, Springer
6. Elementary Solid State Physics, 1/e M. Ali Omar, 1999, Pearson India
7. Solid State Physics, M.A. Wahab, 2011, Narosa Publications

### **Practical**

**Credit: 2**

**Contact Hours per Week: 4**

1. Determination of resistivity and band gap of semiconductor by four probe method.
  2. Determination of Hall coefficient and the concentration of majority carriers of a semiconductor (Ge) using Hall effect.
  3. Measurement of susceptibility of paramagnetic salt and determination of effective number of Bohr magneton for the paramagnetic ions.
  4. To measure hysteresis loop (P-E) of Ferroelectric crystal and find the coercive field.
  5. Determination of dispersion curve and frequency gap of the diatomic lattice using transmission network.
- Discussion on possible collaboration with entrepreneurs about commercialisation.

## **PHYS06C14: ELECTROMAGNETIC THEORY**

**Credits: 6 (Theory-04, Practicals-02)**

### **Theory**

**Credit: 4**

**Contact Hours per Week: 4**

**Maxwell Equations [8]:** Displacement Current. Vector and Scalar Potentials. Gauge Transformations: Lorentz and Coulomb Gauge. Boundary Conditions at Interface between Different Media. Wave Equations. Plane Waves in Dielectric Media. Poynting Theorem and Poynting Vector. Electromagnetic (EM) Energy Density. Physical Concept of Electromagnetic Field Energy Density, Momentum Density and Angular Momentum Density, Experimental realization.

**EM Wave Propagation in Unbounded Media [9]:** Plane EM waves through vacuum and isotropic dielectric medium, Transverse nature of plane EM waves, Refractive index and Dielectric constant, Wave impedance. Propagation through conducting media, Relaxation time, skin depth. Wave propagation through dilute plasma, Electrical conductivity of ionized gases, plasma frequency, Refractive index, Skin depth, Application to propagation through ionosphere, Qualitative discussion on turbulence in magnetically confined plasma, Plasma frequency of alkali metal.

**EM Wave in Bounded Media [8]:** Boundary conditions at a plane interface between two media. Reflection & Refraction of plane waves at plane interface between two dielectric media- Laws of Reflection & Refraction. Fresnel's Formulae for perpendicular & parallel polarization cases, Brewster's law. Reflection & Transmission coefficients. Total internal reflection, evanescent waves. Metallic reflection (normal Incidence), Demonstration through numerical simulation.

**Polarization of Electromagnetic Waves [12]:** Description of Linear, Circular and Elliptical Polarization. Propagation of E.M. Waves in Anisotropic Media. Symmetric Nature of Dielectric Tensor. Fresnel's Formula. Uniaxial and Biaxial Crystals. Light Propagation in Uniaxial Crystal. Double Refraction. Polarization by Double Refraction. Nicol Prism. Ordinary & extraordinary refractive indices. Production & detection of Plane, Circularly and Elliptically Polarized Light. Phase Retardation Plates: Quarter-Wave and Half-Wave Plates. Babinet Compensator and its Uses. Analysis of Polarized Light

Rotatory Polarization: Optical Rotation. Biot's Laws for Rotatory Polarization. Fresnel's Theory of optical rotation. Calculation of angle of rotation. Experimental verification of Fresnel's theory. Specific rotation. Laurent's half-shade polarimeter

**Wave Guides [8]:** Planar optical wave guides. Planar dielectric wave guide. Condition of continuity at interface. Phase shift on total reflection. Eigenvalue equations. Phase and group velocity of guided waves. Field energy and Power transmission, Optical Fibres:- Numerical

Aperture. Step and Graded Indices. Co-axial transmission line, TE waves in rectangular wave guide.

**Electrodynamics and Special Relativity [15]:** Concept of metric, Minkowski spacetime and diagrams, Lorentz transformation, Lightcone and intervals, Length contraction and time dilation, Four vectors and transformation properties, Equivalence of mass-energy, particle decay and collision, four momentum identities, Plane Wave, Doppler effect, Aberration, Incompleteness of special relativity, Non-inertial reference frame and the equivalence principle.

### **Reference Books:**

1. Introduction to Electrodynamics, D.J. Griffiths, 3rd Ed., 1998, Benjamin Cummings.
2. Elements of Electromagnetics, M.N.O. Sadiku, 2001, Oxford University Press.
3. Introduction to Electromagnetic Theory, T.L. Chow, 2006, Jones & Bartlett Learning
4. Fundamentals of Electromagnetics, M.A.W. Miah, 1982, Tata McGraw Hill
5. Electromagnetic field Theory, R.S. Kshetrimayun, 2012, Cengage Learning
6. Electromagnetic Field Theory for Engineers & Physicists, G. Lehner, 2010, Springer
7. Electromagnetic Fields & Waves, P.Lorrain & D.Corson, 1970, W.H.Freeman & Co.
8. Electromagnetics, J.A. Edminster, Schaum Series, 2006, Tata McGraw Hill.
9. Electromagnetic field theory fundamentals, B. Guru and H. Hiziroglu, 2004, Cambridge University Press

### **Practical**

**Credit: 2**

**Contact Hours per Week: 4**

1. Verification of Cauchy's relation by plotting a dispersion curve using a Prism Spectrometer
2. Study of Optical Activity with Polarimeter: To calibrate a polarimeter and determine the specific rotation of an optically active substance
3. Study of Magnetic Hysteresis: To study the phenomena of magnetic hysteresis and determination of ferromagnetic constants.
4. Verification of Brewster's law and finding of the Brewster's angle.
5. Study of polarization of light by reflection and determination of the angle of polarization.

## PHYS06DSE: Discipline Specific Elective

*(Any two of the following three)*

### DSE3. NUCLEAR AND PARTICLE PHYSICS

**Credits: 6 (Theory-05, Tutorials-01)**

#### **Theory**

**Credit: 5**

**Contact Hours per Week: 5**

**Nuclear properties and models [14]:** Properties of nuclei – size, shape, charge distribution, mass defect, binding energy, spin, electric and magnetic moment, parity. Nature of the nuclear force. Form of nucleon-nucleon potential, charge independence and charge symmetry of nuclear forces. Deuteron problem. Nuclear stability – liquid drop model and semi-empirical mass formula. Evidence for nuclear shell structure, single particle shell model, magic numbers, Fermi gas model, concept of mean field, Nuclear deformation, Rotation and vibration.

**Unstable nuclei [10]:** Alpha decay, Geiger-Nuttal law, Straggling of range. Beta decay: Kurie plot, neutrino hypothesis, selection rules. Gamma decay: selection rule, spectroscopy, isomeric states, internal conversion, Mossbauer effect. Angular distributions, correlation measurements.

**Nuclear reaction and Nuclear Astrophysics [16]:** Conservation principles, Q value and threshold, Classification of nuclear reactions. Bohr's postulate of compound nucleus formation, Ghosal's experiment. Fission -energy and mass distribution of fragments, Bohr-Wheeler theory of fission. Chain reactions. Nuclear reactors. Fusion – explanation from liquid drop model. Primordial nucleosynthesis, Stellar nucleosynthesis. Heavy element production, r- and s- and p-processes, Helium problem.

**Accelerators and Detectors [12]:** Interaction of particles and radiation with matter. Bethe-Block formula, Cerenkov detector, Ionisation chamber and GM counter, Scintillation detectors, Semiconductor detectors. Basic principle of calorimetry for detection of highly energetic particles. Basic acceleration mechanisms and introduction to particle accelerators: cyclotron, linear accelerator, storage rings.

**Particle Physics [23]:** Four fundamental interactions. Quantum numbers – spin, isospin, strangeness, parity, hypercharge. Conservation laws. Particle classification – hadron and lepton. Quark model of hadron – baryon and meson. Gell-Mann plot. Elementary discussion of key experiments that led to the current understanding of unified electro-weak interaction and strong interaction. Standard Model. Elementary exposition of diagrammatic techniques (without actual calculation) used to evaluate cross-sections of production processes and decay rates. Introduction to physics beyond the Standard Model.

## DSE4A. PHYSICS OF MATERIALS

**Credits: 6 (Theory-05, Tutorials-01)**

### **Theory**

**Credit: 5**

**Contact Hours per Week: 5**

**Macrostructures and Microstructures [6]:** chemical bonding, ionic, covalent and metallic bonding, crystalline and non-crystalline solids, nanoparticles and nanostructures, point defects, linear, planar and volume defects.

**Crystallography and Crystal Structures [10]:** lattice, crystal planes, Miller indices, crystal geometry and reciprocal lattice, determination of crystal structure by x-ray diffraction, Bragg and Laue diffraction, electron diffraction, neutron diffraction, some typical crystal structures.

**Classes of Materials [20]:** metals, ceramics, polymers and composites, distinctions in bonding, structures and properties.

Insulating solids: dielectrics, piezoelectric and ferroelectric materials.

Magnetic solids: dia, para and ferromagnetic materials.

Electronic conductivity in solids: metal, semiconductor, conducting polymer.

Nanostructures and Nanomaterials: quantum confinement of electrons, quantum well, wire and dot, preparation and characterization of nanomaterials, carbon nanotubes and fullerenes, magnetism on the nanoscale, modulation doping and electron mobility.

Non-crystalline and glassy materials: structure, thermodynamics, glass transition and related models, amorphous semiconductors, electrical, optical and magnetic properties.

Soft Condensed Matter: liquid crystal, optical properties and applications, polymers, effect of temperature, mechanical and electrical properties.

**Energy Bands in solids [10]:** Band structure and classification of metal, insulator and semiconductor. Effective mass, cyclotron resonance, concept of hole and exciton, determination of energy bands, photoemission.

**Magnetic Properties [10]:** magnetic susceptibility, ferrites. Ferrofluids, magnetic resonance, superconductivity, zero resistance, Meissner effect, critical field, electrodynamics of superconductors, transition temperature, High TC superconductors.

**Optical Properties [6]:** luminescence, reflection from thin film, optical properties of nanoparticles.

**Thermal Properties [8]:** heat capacity, Einstein and Debye, thermal conductivity, electrical and thermal conductivity in metals, measuring thermal conductivity, thermoelectric effects, thermoelectric materials and devices.

### **Seminar/Interactive Session [5]**

Critical thinking and discussion on the learning outcome of the above topics

### **Reference Books**

Richard J.D. Tilley, Understanding Solids: The Science of Materials, 2nd edition, Wiley, UK, 2013.

**DSE4B. SUPERVISED PROJECT WITH DISSERTATION:** Directed Study, Supervised theoretical or experimental work etc.