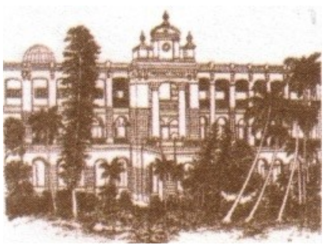
Structure and Detailed Syllabus
of the Undergraduate Course (B.Sc.) in Physics under CBCS
Department of Physics, Presidency University
(w.e.f. July, 2022)

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

Content

Topic	Page No.
A. Semester-wise Course Structure and Module Compositions	3
B. Detailed Syllabus and Suggested Reading List for respective Modules	5 - 35
PHYS01C1: Mathematical Physics-I	5
PHYS01C2: Mechanics	7
PHYS01GE1: Mechanics and Relativity	8
PHYS02C3: Electricity and Magnetism	9
PHYS02C4: Waves and Optics	12
PHYS02GE2: (Physics of Everyday Life)	14
PHYS03C5: Mathematical Physics-II	15
PHYS03C6: Thermal Physics	17
PHYS03C7: Analog Systems and Applications	19
PHYS03GE3: The Nuclear Age	22
PHYS03SEC1: Statistical and Computational Methods	23
PHYS04C8: Mathematical Physics-III	24
PHYS04C9: Elements of Modern Physics	26
PHYS04C10: Digital Systems and Applications	28
PHYS04GE4: Elements of Modern Physics	31
PHYS04SEC2: Modern Experimental and Theoretical Techniques	32
PHYS05C11: Quantum Mechanics and Applications	33
PHYS05C12: Statistical Mechanics	35
PHYS05DSE1 and PHYS05DSE2	37-39
PHYS06C13: Solid State Physics	41
PHYS0614: Electromagnetic Theory	43
PHYS06DSE3 and PHYS06DSE4	45-47

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	***DSE1.*** Advanced Mechanics (5+1), ***DSE2A.*** Nuclear Medicine (5+1) ***DSE2B***. Quantum Optics & Quantum Information (5+1)			
	Statistical Mechanics				
Sixth	Solid State Physics	***DSE3.*** Nuclear and Particle Physics (5+1) ***DSE4A.*** Physics of Materials (5+1) ***DSE4B.*** 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

Credit Allocation and Marks Distribution for the Undergraduate Course in Physics (Major) under CBCS
Department of Physics, Presidency University, Kolkata

Semester	Course Type	Paper Code	Course Name	Credits				Marks			
				Theory	Practical	Tutorial	Total	Theory	Practical	Tutorial	Total
First	Core Course	PHYS01C1	Mathematical Physics-I	4	2		6	70	30		100
First	Core Course	PHYS01C2	Mechanics	4	2		6	70	30		100
First	Generic Elective	PHYS01 GE1	Mechanics and Relativity (Credit 5+1, Marks 80+20)								100
First	Ability Enhancement Compulsory Course	PHYS01 AECC1	ENVS/ English Communication/MIL	4			4	100			100
Second	Core Course	PHYS02C3	Electricity and Magnetism	4	2		6	70	30		100
Second	Core Course	PHYS02C4	Waves and Optics	4	2		6	70	30		100
Second	Generic Elective	PHYS02 GE2	Physics of Everyday Life (Credit 5+1, Marks 80+20)								100
Second	Ability Enhancement Course	PHYS02 AECC2	ENVS/ English Communication/MIL	4			4	100			100
Third	Core Course	PHYS03C5	Mathematical Physics-II	4	2		6	70	30		100
Third	Core Course	PHYS03C6	Thermal Physics	4	2		6	70	30		100
Third	Core Course	PHYS03C7	Analog Systems and Applications	4	2		6	70	30		100
Third	Generic Elective	PHYS03 GE3	Any one of (i) Thermal Physics (Credit 4+2, Marks 70 +30) or (ii) Nuclear Age (Credit 5+1, Marks 80+20)								100
Third	Skill Enhancement Course	PHYS03 SEC1	Statistical and Computational Methods	4			4	100			100
Fourth	Core Course	PHYS04C8	Mathematical Physics-III	4	2		6	70	30		100
Fourth	Core Course	PHYS04C9	Elements of Modern Physics	4	2		6	70	30		100
Fourth	Core Course	PHYS04 C10	Digital Systems and Applications	4	2		6	70	30		100
Fourth	Generic Elective	PHYS04 GE4	Optics	5	1		6	80	20		100
Fourth	Skill Enhancement Course	PHYS04 SEC2	Modern Experimental & Theoretical Techniques	4			4	100			100
Fifth	Core Course	PHYS05 C11	Quantum Mechanics and Applications	4	2		6	70	30		100
Fifth	Core Course	PHYS05 C12	Statistical Mechanics	4	2		6	70	30		100

Fifth	Discipline Specific Elective (DSE) (Any Two)	DSE1	Advanced Mechanics (Credit 5+1, Marks 80+20)								100
		DSE2 (Any one of 2A & 2B)	DSE2A: Nuclear Medicine (Credit 5+1, Marks 80+20)								100
			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
				Total Credit			**148**	**Total Marks2600**			

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, 7th 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 π, 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 filed, 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 materialsin external electric field**,** Polarization, Force and torque on electric dipole in external electric filed, 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, Kirchhoff'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, λ, d etc.
3. Study of python program generating Fresnel diffraction pattern of a straight edge. Demonstration of changes of fringe pattern for variation of λ.
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 usingFresnel 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, DirichletConditions (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 LinearDifferential 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 ($J_o(x)$ 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, 7th 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.

6. A First Course in Partial Differential Equations, H. F. Weinberger, 1995, Dover

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 θ, cos θ, tan θ, 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, GibbsFree 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 Cp-Cv, 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 andStern's Experiment. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Lawof 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 bang 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 α and β, relations between α and β, brief Ideas on JFET and MOSFET

TransistorAmplifiers [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 lC'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 componentsand 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 $\delta_{ij} \wedge \varepsilon_{ijk}$. 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^{nd} order Differential Equations: Damped Harmonic Oscillator, Simple Electrical Circuits, Coupled differential equations of 1^{st} 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^{th} 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 θ, 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^{th} 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 systms, 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

---

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}Tc / ^{99}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. 3rd 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).

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 measurementprocess, 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-classicalstates of electromagnetic wave as tools for quantum measurement, Quantum non-demolitionmeasurements.

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]: MicroscopicPolarization. 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 Semiconductosr, 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 compund 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, planer 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 super conductors, 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.

Kittel C. Introduction to Solid State Physics, *8th Ed.*, John Wiley & Sons, Inc.

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

Department of Physics, Presidency University

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

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

**Not all electives will be offered every year)

PHYS-0701: Mathematical Methods (50 Lectures)

Complex Analysis [16]

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

Differential Equations [10]

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

Integral Transforms [8]

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

Group Theory [10]

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

Vector Spaces [6]

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

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

Preliminaries [10]

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

Rigid Body [12]

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

Canonical Transformation and Hamilton-Jacobi Theory [14]

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

Continuous Systems and Fields [10]

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

Nonlinear Dynamics and Classical Chaos [4]

Phase space dynamics, Stability analysis

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

Operator formalism in Quantum Mechanics [9]

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

Quantum angular momentum [14]

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

Approximate Methods in Quantum Mechanics [22]

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

Identical particles [5]

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

PHYS-0791: PG-Lab-I

The Following Experiments are part of the lab

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

PHYS-0792: PG-Lab-II

A] Experiments

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

B] Data Analyses and Statistical Techniques

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

PHYS-0801: Statistical Mechanics (50 Lectures)

Fundamentals of Statistical Mechanics [7]

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

Classical and Quantum Gas [25]

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

Phase transitions [18]

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

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

PHYS-0802: Classical Electrodynamics (50 lectures)

Basics
[16]

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

Relativistic Formulation of Electrodynamics
[14]

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

Radiation
[20]

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

PHYS-0803: Condensed Matter Physics (50 Lectures)

Electron States and Band Theory of Solids
[10]

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

Dynamics of Atoms in Crystals and Phonons
[10]

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

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

Dielectric and Optical Properties of Solids [6]

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

Magnetic Properties of Solids [10]

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

Superconductivity [8]

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

Liquid Crystals [6]

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

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

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

Preparatory courses of writing computer programs

B] Numerical mathematical analysis [15]

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

C] Assigned problems in computer laboratory [25]

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

PHYS-0892: PG-Lab-IV

The Following Experiments are part of the lab

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

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

Scattering theory [20]

Laboratory and centre of mass frames, differential and total scattering cross-sections, scattering amplitude; Scattering by spherically symmetric potentials; Partial wave analysis and phase shifts; Ramsauer-Towwnsend effect; Scattering by a rigid sphere and square well; Regge poles, Coulomb scattering; Born approximation; Formal theory of scattering — Green's function in scattering theory; Lippman-Schwinger equation; Collisions of identical particles, applications

Relativistic Quantum Theory [30]

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

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

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

The Basic Hamiltonian in a Solid: Electronic and Ionic Parts. The Adiabatic Approximation, Single Particle Approximation of the Many Electron System: Single Product and Determinantal Wave Functions, Matrix Elements of one and two particle Operators. The Hatree Fock (HF)Theory. The HF Equation. Exchange Interaction and Exchange Hole, Koopmans Theorem. The Occupation Number Representation – The Many Electrons Hamiltonian in Occupation Number Representation,The HF Ground State Energy

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

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

Spin and Magnetic System [14]

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

Superconductivity Phenomena [10]

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

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

Astronomical Observations [16]

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

Stellar Astrophysics [18]

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

Galactic Astrophysics [10]

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

Extragalactic Astrophysics [6]

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

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

Interactions of Quasiparticles& Transport Phenomena in Solids[12]

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

Electronic Quasi particles in Solids [8]

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

Hall Effect and Higher – OrderQuasi particles.

Realistic Calculations in Solids[8]

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

Non-Crystalline Materials [10]

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

Nanoscale Physics [12]

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

PHYS-0903-B: General Relativity and Cosmology

(50 Lectures)

Foundations of General Relativity and Curved Spacetime [25]

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

Cosmology [25]

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

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

PHYS-0991: Project-I

Review of Literature/ Experimental Technique

PHYS-0992: Project-II

Formulation of Project Proposal

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

Interacting fields and Feynman Diagrams [8]

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

Elementary processes of quantum electrodynamics [8]

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

Radiative corrections [10]

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

Functional methods [14] Path integrals, functional quantizations, quantization of the electromagnetic field, symmetries in functional formalism ; Renormalization : systematics of renormalization, Spontaneous symmetry breaking.

Quantum Fields in curved spacetime [10]

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

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

Introduction to Nanostructured Materials [8]

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

Growth, fabrication and measurement techniques for nanostructures [12]

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

Electron transport in semiconductors and nanostructures [14]

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

Nanostructured ferromagnetism [6]

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

Self-assembly and catalysis [4]

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

Applications and future of nanomaterials [6]

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

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

Preliminaries
[7]
Brief overview of non-linearities in physics, One-dimensional phase space, Flows, Fixed points and stability, Bifurcations – perfect and imperfect and their classification.

Non-linear Dynamics
[28]
Two-dimensional phase space and phase portrait, Classification of fixed points and bifurcations in two-dimensions, Limit cycles, Closed orbits, Poincare-Bendixon theorem, Forced non-linear oscillators – van der Pol, Duffing, One-dimensional maps, Logistic map, period doubling,Lyapunov exponent, Lorenz map, Strange attractor, Chaos, Feigenbaum's theory, Interdisciplinary applications of non-linear dynamics.

Non-linear waves
[7]
Solitons, KdV equation, Solutions and symmetries.

Quantum Chaos
[8]
Quantum billiards, Random matrices – symmetries, universality classes, Gaussian ensembles, Spectral correlation

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

Atomic and Molecular Physics
[20]
Fine structure of spectral lines; Selection rules; Lamb shift. Hyperfine interaction and isotope shift; Hyperfine splitting of spectral lines; selection rules, Many electron atoms: Equivalent and nonequivalent electrons; Energy levels and spectra; Hunds rule; Lande interval rule; Alkali spectra, Born- Oppenheimer approximation, Electronic states of diatomic molecules, Approximation methods for the calculation of electronic Wave function, The LCAO approach, States for hydrogen molecular ion, Coulomb, Exchange and Overlap integral, Symmetries of electronic wave functions; Shapes of molecular orbital and bond Term symbol for simple molecules.
Rotation and Vibration of Molecules: Solution of nuclear equation; Molecular rotation: Non-rigid rotator, Centrifugal distortion, Symmetric top molecules, Molecular vibrations: Harmonic oscillator and the anharmonic oscillator approximation, Morse potential.Spectra of Diatomic Molecules:Transition matrix elements, Vibration-rotation spectra: Pure vibrational transitions, Pure rotational transitions, Vibration-rotation transitions, Electronic transitions: Structure, Franck-Condon principle, Rotational structure of electronic transitions, Fortrat diagram, Dissociation energy of molecules, Continuous spectra, Raman transitions and Raman spectra, Group theory approach

Nuclear Physics [18]

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

Elementary Particle Physics [12]

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

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

1. Carrier Transport Phenomena (10)

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

2. Fabrication Techniques (8)

Bulk and epitaxial crystal growth techniques: Growth of single crystals by Czochralski and Bridgman techniques, purification by float-zone process, epitaxial growth, vapour phase epitaxy, metal organic chemical vapor deposition, molecular beam epitaxy, thermal diffusion and ion implantation processes for doping,
Thin Films: conductivity and other properties of thin films, thermal oxidation, dielectric deposition, polysilicon deposition, metallization, lithographic techniques, integrated devices.

3. Characterization techniques (10)

X-ray diffraction and crystallography, small angle X- ray scattering (SAXS), particle size determination, surface structure, thermal effects on diffraction patterns,
Microscopy: Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM), Field Ion Microscopy (FIM), Scanning Tunneling Electron Microscopy (STEM).
Spectroscopy: Infrared and Raman spectroscopy, Photoluminescence, Photoemission and X-ray spectroscopy. Magnetic Resonance

4. Microwave Devices (8)

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

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

PHYS-1091A: Condensed Matter Physics Lab

The Following Experiments are part of the lab

1. Determination of Space Group and Crystal Structure of a Single Crystal Material by Laue Diffraction Method.
2. Determination of Crystal Structure and Lattice Parameters of a Polycrystalline Material by Powder Diffraction (Debye Scherrer) Method.
3. Determination of Hall Effect &Magnetoresistance of Polycrystalline Bismuth Sample at RT.
4. Determination of Magnetic Susceptibility of Paramagnetic Salts by Guoy Balance Method.
5. Determination of AC Conductivity and Dielectric Constants of Composites Materials by LCR Bridge.
6. Study of Dielectric Constants of Ferroelectric Crystals at Elevated Temperatures and determine the Curie Temperature.
7. Study of F Centers of Xray Irradiated Alkali Halides (KCl&KBr) Samples.
8. Study of the Nature of Band Gap and Determination of Optical Constants (n, k) of Semiconductor (Crystalline and Amorphous) Thin Films using UV-VIS (Dual and Single beam) Spectrophotometer.
9. FTIR Study of Si Based Oxide/ Carbon Nano Composites.
10. Study of the variation of Hall Coefficient of a given extrinsic semiconductor as a function of temperature using Temperature dependence Hall – effect setup.
11.Study of the electrical properties of given thin films of different materials (metal, insulator and semiconductor) using Four – Probe Setup.
12. Measurement of electrical resistivity of superconductors at low temperature.

(Students will do 6-8 experiments among these)

PHYS-1091B: Astrophysics Lab

Data Analysis Projects

1. Determining parameters of Extra-Solar planets.

2. Main sequence fitting of a star cluster.

3. Statistics of the Cosmic Microwave Background

4. Galaxy Spectral Fitting

Experimental Projects

1. Solar Limb Darkening

2. Characterizing radio antennae.

3. Characterization of Charged Coupled Device

4. Faraday Rotation

PHYS-1092: Project-III

Report and Viva 1

PHYS-1093: Project-IV

Presentation 2 and Viva 2

PHYS-1094: Project-V

Supervisor's Assessment and Presentation 3