PRESIDENCY UNIVERSITY
KOLKATA

04 Years Bachelor Programme under CHOICE BASED CREDIT SYSTEM for B. Sc. Honours with Research in Physics

(Total Credits: 194)

Effective from 2023-2024 Academic Session

Year	Semester	Category	Paper Code & Name	*Taught/ Sessional	Evaluation		Credits
					End Sem	IA	
1	I	Major Course (C)	PHYS101C01 Math. Physics-I	Taught	70	30	4 + 2
		Major Course (C)	PHYS102C02 Classical Mechanics	Taught	70	30	4 + 2
		Ability Enhancement Compulsory Course (AECC)	PHYS103AECC01 English Communication /MIL	Taught	50	--	4
		Minor Course (MC)	PHYS104MC01 Mechanics and Relativity	Taught	80	20	5 + 1
		Multidisciplinary Course (MDC)	PHYS105MDC01 Physics in Everyday Life	Taught	50	--	3
	1st Semester: Total Credit 25. Total Marks 400						
1	II	Major Course (C)	PHYS151C03 Waves and Optics	Taught	70	30	4 + 2
		Major Course (C)	PHYS152C04 Electricity and Magnetism	Taught	70	30	4 + 2
		Ability Enhancement Compulsory Course (AECC)	PHYS153AECC02 English Communication/MIL	Taught	50	--	4
		Minor Course (MC)	PHYS154MC02 General Properties of Matter	Taught	80	20	5 + 1

		Multidisciplinary Course (MDC)	PHYS155MDC02 Laboratory data analysis with Computer Programming	Taught	50	--	3
		Multidisciplinary Course (MDC)	PHYS156MDC03 Renewable Energy: Sources and Harvesting	Taught	50	--	3
	2nd Semester: Total Credit 28. Total Marks 450						
2	III	Major Course (C)	PHYS201C05 Math. Physics-II	Taught	70	30	4 + 2
		Major Course (C)	PHYS202C06 Thermal Physics	Taught	70	30	4 + 2
		Skill Enhancement Course (SEC) (Major)	PHYS203SEC01 Computer Programming (Statistical Inference)	Taught	100	--	4
		Value Added Course (VAC)	PHYS204VAC01 Environmental Science	Taught	50	--	3
		Minor Course (MC)	PHYS205MC03 Elements of Modern Physics	Taught	80	20	5 + 1
	3rd Semester: Total Credit 25. Total Marks 450						
	IV	Major Course (C)	PHYS251C07 Math. Physics-III	Taught	70	30	4 + 2
		Major Course (C)	PHYS252C08 Analog Systems and Applications	Taught	70	30	4 + 2
		Skill Enhancement Course (SEC) (Major)	PHYS253SEC02 Modern Analytical Instruments	Taught	100	--	5
		Value Added Course (VAC)	PHYS254VAC02 Computer simulation of electrical and electronic circuits	Taught	50	--	3
		Minor Course (MC)	PHYS255MC04 Radiological Physics	Taught	80	20	5 + 1
	4th Semester: Total Credit 26. Total Marks 450						

3	V	Major Course (C)	PHYS301C09 Digital Systems and Applications	Taught	70	30	4 + 2
		Major Course (C)	PHYS302C10 Quantum Mechanics and Applications	Taught	70	30	4 + 2
		Major Course (C)	PHYS303C11 Statistical Mechanics	Taught	70	30	4 + 2
		Summer Internship	PHYS341SI01	Sessional	100	--	4
	5th Semester: Total Credit 22. Total Marks 400						
	VI	Major Course (C)	PHYS351C12 Advanced Classical Mechanics-I	Taught	80	20	5+ 1
		Major Course (C)	PHYS352C13 Electromagnetic Theory	Taught	70	30	4 + 2
		Major Course (C)	PHYS353C14 Solid State Physics	Taught	70	30	4 + 2
		Major Course (Elective) (C)	PHYS354C15 A. Nuclear & Particle Physics B. Physics of Materials (Any one)	Taught	80	20	5 + 1
	6th Semester: Total Credit 24. Total Marks 400						
4	VII	Major Course (C)	PHYS401C16 Advanced Classical Mechanics-II	Taught	80	20	4
		Major Course (C)	PHYS402C17 Advanced Quantum Mechanics	Taught	80	20	4
		Major Course (C)	PHYS441C18 Laboratory-I	Sessional	100	--	4
		Major Course (C)	PHYS442C19 Project/ Dissertation	Sessional	100	--	4
		Minor Course (MC)	PHYS405MC05 Research Methodology	Taught	80	20	4
	7th Semester: Total Credit 20. Total Marks 500						

	VIII	Major Course (C)	PHYS451C20 Advanced Electromagnetism	Taught	80	20	4
		Major Course (C)	PHYS452C21 Advanced Statistical Mechanics	Taught	80	20	4
		Major Course (C)	PHYS491C22 Laboratory-II	Sessional	100	--	4
		Major Course (Elective) (C)	PHYS492C23 Project/ Dissertation	Sessional	200	--	8
		Minor Course (MC)	PHYS493MC06 Research and Publication Ethics	Sessional	50	--	4
	8th Semester: Total Credit 24. Total Marks 550						

Total Credits 194

Total Marks 3600

**Practical of 30 marks in 70+30 and Tutorial of 20 marks in 80+20 groups are sessional.*

04 Years Bachelor Programme under CHOICE BASED CREDIT SYSTEM for B. Sc. Honours in Physics (Total Credits: 194) Effective from 2023-2024 Academic Session

Semester I

PHYS101C01 (Major): Mathematical Physics I

Credit: 6 (Theory 4, Practical 2)

Theory (Contact Hours per Week 4)

***Ordinary Differential Equations* [12]:** First-Order homogeneous and non-homogeneous equations with variable coefficients. Superposition principle. Second-Order homogeneous and nonhomogeneous equations with constant and variable coefficients. Modelling Physics problems with ODE's.

***Functions of Several Variables* [6]:** Calculus of functions of more than one variable: Partial derivative, 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* [25]:** Vector Differentiation: Vector and scalar functions of fields, Derivatives, Curves, Arc length, Curvature. Gradient of a scalar field, Directional derivatives, Divergence of a vector field, Curl of a vector field. Vector integration: Line integral, Path independence of line integrals. Green's theorem in the Plane. Surfaces and Surface integrals, Triple integrals, Divergence theorem of Gauss, Stokes' theorem and their applications.

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

***Linear Vector Spaces and Matrix Eigenvalue Problems* [12]:** Real linear vector space: scalar product for real linear vector spaces. Linear independence of vectors. Basis for a vector space.

Dimension of vector space. Orthonormal basis. Linear Operators: Algebra of linear operators. Eigenvalues and Eigenvectors of Hermitian, unitary and normal operators. Similarity and unitary transformations. Matrix representations of vectors and of linear operators on a vector space.

Eigenvalues and Eigenvectors of matrices, characteristics (secular) equations. Transformation of basis in a vector space. Transformation between orthonormal bases. Diagonalization of matrices.

References:

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 University Press

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PHYS101C01 (Major): Mathematical Physics I

Practical (Contact Hours per Week 4)

Introduction and Overview:

Input/output devices, Computer architecture and organization, memory and 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.

PHYS102C02: Classical Mechanics

Credit: 6 (Theory 4, Practical 2)

Theory (Contact Hours per Week 4)

***Fundamentals of Dynamics* [6]:** Reference frames. Inertial frames; Galilean transformations; Galilean invariance. 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.

References:

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, R. Resnick, D. 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
9. University Physics. F.W Sears, M.W Zemansky, H.D Young 13/e, 1986, Addison Wesley
10. Physics for scientists and Engineers with Modern Phys., J.W. Jewett, R.A. Serway, 2010, Cengage Learning
11. Theoretical Mechanics, M.R. Spiegel, 2006, Tata McGraw Hill.
12. Introduction to Classical Mechanics, R. Takwale and P. Puranik, Tata McGraw-Hill, 1979

PHYS102C02: Classical Mechanics

Practical (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 as determination 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. 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.
5. Practical concepts on computer interfacing of simple experiments, such as simple and torsional pendulum experiments.
6. Learning by doing: observation and recording of the changes of time period with the length of string and other parameters.
7. Seminar/group discussion on types of error in measurement, error analysis, error minimizing etc.

PHYS104MC01 (Minor): Mechanics and Relativity

Credit: 6 (Theory 5, Tutorial 1)

Theory (Contact Hour per Week 6)

***Mathematical preliminaries* [20]:** Scalar and vector fields. Gradient of a scalar field, Divergence and Curl of a vector field in three dimensional Cartesian coordinates. Line, surface and volume integrals. Divergence theorem and Stokes' theorem.

***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.

***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.

***Special Relativity* [15]:** Frames of reference, Space-time diagrams, Postulates of special relativity, Lorentz transformation and its consequences, Relativistic dynamics.

References:

1. Vector Analysis, Murray M. Spiegel, McGraw-Hill, New York, 1959
2. Introduction to Classical Mechanics, R. Takwale and P. Puranik, Tata McGraw-Hill, 1979
3. Introduction to Electrodynamics, David Griffiths, Prentice Hall, 1999.
4. Introduction to Special Relativity, Robert Resnick, John Wiley & Sons, 1968
5. Mechanics, D. S. Mathur (revised by P. S. Hemne), S. Chand & Co., 2000
6. University Physics, Sears and Zemansky (revised and edited by H. D. Young and R. A. Freedman, Pearson Edn. India, 2008.

PHYS105MDC01 (Multidisciplinary): Physics in Everyday Life

Credits: 3 (Theory)

Contact Hours per Week 3

***The Art of Estimation* [10]:** The need for making approximations, Making quantitative estimates in real-life situations, introduction to a variety of problems, called the “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.

***Car and Refrigerator* [10]:** 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 and efficiency. Refrigerators, coefficient of performance, 2nd Law of Thermodynamics. Concept of Entropy and disorder, Petrol engine, Steam engine.

***Basic Electromagnetism* [10]:** Basics of electricity and magnetism, Ohms law, power consumption, Joule heating, Energy Conservation and the use and generation of electricity, Electric and Magnetic fields, potentials, concept of electromagnetic waves, working principle of microwave ovens, dc motors, induction ovens, Faraday’s laws – applications. Wireless routers.

***Optics in everyday life* [10]:** Eyes as optical instruments, Aberrations and Vision correction, Magnifying lens, Microscopes, Telescopes, CCDs, Fluroscent light, Lasers, Digital displays.

***Global Positioning System* (GPS) [5]:** 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.

References:

1. University Physics, F. W. Sears, M. Zemansky, R. A. Freedman, and H. D. Young, Pearson Education, India, 2008
2. Fundamentals of Physics, David Halliday, Robert Resnick, and J. Walker, John Wiley & Sons, 2008.
3. University Physics, Sears and Zemansky (revised and edited by H. D. Young and R. A. Freedman, Pearson Edn. India, 2008.
4. Introduction to GPS, Ahmed El-Rabbany, GNSS Technology and Application Series, Artec House Publications, 2006
5. For learning Fermi problems, a typical refence site can be - https://innovativeteachingideas.com/blog/an-excellent-collection-of-fermi-problems-for-your-class

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Semester II

PHYS151C03 (Major): Waves & Optics

Credits: 6 (Theory 4, Practical 2)

Theory (Contact Hours per Week 4)

***Basics of Waves* [9]:** Linearity and Superposition Principle. Superposition of two collinear oscillations, Graphical and Analytical Methods. Lissajous Figures and their uses, Plane and Spherical Wave Equation. Particle and Wave Velocities. Differential Equation. Pressure of a Longitudinal Wave, Energy Transport.

Superposition of Harmonic Waves: Standing (Stationary) Waves in a String: Fixed and Free Ends: analytical treatment. Phase and Group Velocities. Energy of Vibrating String. Normal Modes of Stretched Strings. Plucked and Struck Strings. Melde's Experiment.

***Geometrical Optics* [10]:** Fermat's principle, Matrix method in paraxial optics, Thick lens, Optical instruments, Aberration: spherical and chromatic aberrations.

***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* [13]:** 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.

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

***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, Polarizing beamsplitters and waveplates.

References:

1. Advanced Acoustics: D. P. Raychaudhuri, The New Book Stall, 1980
2. Optics: Miles V. Klein and Thomas E. Furtak, Wiley (2nd Edn.), 1986

3. Optics: Eugene Hecht, Pearson, 2017
4. Optics: Ajay Ghatak, McGraw-Hill, India, 2020
5. Optical Physics, A. Lipson, H. G. Lipson and H. Lipson, Cambridge University Press, 2011

PHYS151C03: Waves and Optics

Practical (Contact Hours per Week 4)

1. Determination of the refractive index of a prism using a spectrometer for Sodium D-lines.
2. Interference by Newton's ring: To determine the radius of curvature of a plano-convex lens by using Newton's rings.
3. Diffraction by double slit: To study diffraction of light by using double slits and determination of unknown wavelengths.
4. Interference using Fresnel Biprism: To understand the use of Fresnel biprism to divide the wavefront of a monochromatic, coherent beam of light producing an interference pattern and measurement of wavelength
5. Diffraction Grating Spectrometer: To get familiar with the use of diffraction grating spectrometer.
6. To Measure certain wavelengths of spectral lines of mercury vapour using diffraction grating.
7. Demonstration/Activities:
   a) Demonstration of Michelson and Fabry-Perot Interferometer.
   b) Study of python program generating diffraction pattern of a grating. Demonstrate variation of fringe pattern with change in N, λ, d etc.
   c) Study of python program generating Fresnel diffraction pattern of a straight edge. Demonstration of changes of fringe pattern for variation of λ.
   d) Demonstration of XRD pattern for simple crystal structure.

PHYS152C04 (Major): Electricity and Magnetism

Credits: 6 (Theory 4, Practical 2)

Theory (Contact Hours per Week 4)

***Electrostatics-I*: *The Fundamentals* [12]:** Electric field, Divergence and curl of an 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 images. Poisson and Laplace equations. Boundary value problems.

***Electrostatics-II*: Dielectrics [12]:** Dielectric materials in external electric field**.** Polarization. Force and torque on an electric dipole in an 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]:** Basic laws of magnetostatics in differential and integral form, Equation of continuity, Vector potential, gauge transformation, coulomb gauge, Poisson equation and its solution (derivation not required), Biot-Savart's law, Calculation of Vector potential & magnetic field : infinitely long thin current carrying wire, circular current loop, surface current flowing through a thin sheet, rotating spherical shell of radius R with uniform surface charge density. Magnetic fields of a localized current distribution (Multipole expansion), Magnetic moment: Current is confined to a plane; current distribution due to a no. of moving charge particles; Classical connection between angular momentum and magnetic moment; Gyromagnetic ratio. Dipole-dipole interaction energy, Force and torque on a magnetic dipole in an external magnetic field.

***Magnetic Properties of Materials* [10]:** Free current and bound current. Surface and volume densities of current distribution. Magnetisation vector. Introduction of **H**. Magnetostatic boundary conditions. Magnetic scalar potential. Field due to a uniformly magnetised sphere. Magnetic Susceptibility and permeability. Ferromagnetism, Paramagnetism.

***Electromagnetic Induction* [10]:** 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.

References:

1. Introduction to Electrodynamics: David Griffiths, Prentice Hall, 1999
2. Electricity and Magnetism, E. M. Purcell, Berkley Physics Course Vol. 2, 1984
3. Feynman Lectures on Physics Vol. 2, R. P. Feynman, R. B. Leighton and M. Sands, Pearson India, 2012
4. Electricity and Magnetism, W. N. Cottingham and D. A. Greenwood, Cambridge University Press, 1991

PHYS152C04: Electricity and Magnetism

Practical (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) Antiresonant frequency and (b) Quality factor Q.
7. To determine the mutual inductance of two coils by Absolute method.

PHYS154MC02 (Minor): General Properties of Matter

Credits: 6 (Theory 5, Tutorial 1)

Contact Hours per week 6

***Elasticity and Elastic Behaviour of Materials* [15]:** Hooke's law, uniform strains, relations connecting the elastic constants. The torsion bar and shear waves, bending moment and the bent beam, buckling. Elastic materials: the tensor of strain, the tensor of elasticity, non-elastic behaviour. Calculation of elastic strain of materials.

***Flow of Dry Fluid* [15]:** Hydrostatic, the equation of hydrostatics, the equation of fluid motion, irrotational flow of fluid, vorticity. Steady flow-Bernoulli's theorem and its uses. Circulation, ideal fluid flow past a cylinder. Vortex lines.

***Flow of Wet Fluid and Viscosity* [15]:** Equation of continuity. Steady or streamline flow. Coefficient of viscosity. Viscous drag between two parallel plates, the shear stress in a viscous fluid. Motion of a fluid between two coaxial cylinders, rotation viscometer. Viscous flow, the Reynolds number, critical velocity, flow past a circular cylinder.

***Surface Tension and Surface Energy* [15]:** Brief review of molecular theory of surface tension. Relation between surface tension and surface energy. Angle of contact. Excess pressure over a curved liquid surface, Capillarity-rise of liquid in a capillary tube; Shape of liquid drops.

***Seminar presentation/Experimental Demonstration* [15]:** *(i)* Bending of Beams, *(ii)* Capillary rise of water and (*iii*) Measurement of Viscosity

Learning Outcome: Learner will be able to

- apply the knowledge in construction of beams, bridges etc.
- apply knowledge in understanding the flow of liquid and surface tension applied on the surface of liquid

References:

1. The Feynman Lectures on Physics Vol. 1: R. P. Feyman, R. B. Leighton and M. Sands, Pearson India, 2012

2. Properties of Matter, H. S. Starling, Mcmillan and Co., 1961
3. General Properties of Matter, C. J. Smith, Radha Publishing House, 2016
4. Classical mechanics and General Properties of Matter, S. N. Maiti and D. P. Raichaudhuri, New Age International Pvt. Ltd., 2006

PHYS155MDC02 (Multidisciplinary): Laboratory Data Analysis with Computer Programming

Credits: 3 (Theory)

Contact Hours per Week 3

***Learning Objectives*:** To make the students familiar with

1. The use of proper units and resolutions in measurement,
2. The types of error occurring in experiments in practical classes,
3. The essential concepts and methods of data and error analysis and
4. The use of computer programming in analysing data and errors.

***Idea of errors in experiments* [10]:** Proper use of units of measurement. Accuracy in measurement, decimal places and significant figures. Types of errors involved in experiments, personal error, instrumental error, statistical error. Theory of errors. Systematic and Random errors. Normal distribution of error. Estimation of errors. Errors in formula. Computational Error analysis.

***Scientific Concepts* [10]:** Drawing and deriving useful information from graphs. Choosing variables and units for plotting graphs. Plotting the data with error bars. Use of semilogarithmic graph. Surface plot. To find the histogram of experimental data. Linear and nonlinear regressions.

***Data Analysis and Simulation* [20]:** Statistical analysis with the given dataset and simulating the results with given formula and parameters for a certain experiment. Several such cases should be exercised. For instance:

Simple and compound pendulums:

1. Analysis of the distribution of time period with the given dataset
2. Analysis with a normal distribution, effective range of data
3. Simulation of time period with different lengths and other parameters

Modulus of Elasticity

1. Linear regression of the given load-depression data, calculations of Young's modulus and graph plotting
2. Calculating modulus of rigidity for different geometric parameters of the object

LCR Circuits

1. Solving differential equations numerically
2. Simulating results of charging and discharging and plotting graphs

3. Calculating parameters, such as time constant

The concerned teacher may adopt more such practical examples, such as

1. Simulation of radioactive decay,
2. Brownian motion and diffusion phenomena and
3. Estimating the hysteresis loss by calculating the area of the loop.

***Interactive Session* [5]:** Online demonstration of some experiments and simulations. Group discussions. Presentations. Outlining the basics of some classic experiments in physics.

References:

1. Alexander M. Mood, Franklin A. Graybill, Duane C. Boes, Introduction to the theory of statistics, McGraw-Hill (2013)
2. V. Rajaraman, Computer oriented numerical methods, Prentice-Hall India (2003).

PHYS156MDC03 (Multidisciplinary): Renewable Energy: Sources and Harvesting

Credits: 3 (Theory)

Contact Hours per Week 3

Learning Objectives

- To understand the energy scenario, environmental hazards and the need of renewable energy
- To comprehend society's present and future energy demands
- To explore the potential non-conventional energy sources and their utilizations

***Background Knowledge* [4]:** Fossil fuels, nuclear energy and their limitations. Need of renewable energy. Energy and sustainable development. Search for non-conventional energy sources, e.g. solar energy, wind energy, tidal energy, biochemical conversions and others. Environmental issues.

***Solar energy* [5]:** Estimation of solar radiation. Solar thermal systems, such as solar cooker, solar drier, solar water heater, solar distillation and greenhouses. Storage of solar thermal energy: solar pond.

Principle of solar photovoltaic cell. Solar electric power generation. Applications and limitations. Sun tracking systems.

***Wind Energy* [5]:** Fundamentals of wind energy. Similarity with and difference from windmill. Wind Turbines and related electrical machines. Wind energy conversion systems. Power electronic interfaces. Grid interconnection. Major problems associated with wind power.

***Hydro Energy* [4]:** Hydropower resources. Hydropower technologies. Environmental impact of hydropower sources.

***Ocean and Tidal Energy* [5]:** Ocean thermal energy conversion. Wave characteristics and statistics. Wave energy devices. Tidal Power: Tides and waves as energy suppliers. Tide characteristics and statistics. Tide energy technologies. Advantages and limitations.

***Geothermal Energy* [4]:** Geothermal resources. Geothermal heating. Geothermal power technologies.

***Biochemical Energy* [5]:** Biofuels. Biomass conversion technologies. Biomass gasification. Waste to energy conversion. Fuel cells: Classification and operating principles. Hydrogen energy: production, storage, applications, benefits and problems.

***Piezoelectric, Thermoelectric and Electromagnetic Energy harvesting* [5]:** Physics and characteristics of piezoelectric effect. Materials and theory for piezoelectricity. Piezoelectric parameters and modelling piezoelectric generators. Piezoelectric energy harvesting applications. Human power. Thermoelectric materials. Thermoelectric figure of merit and relationship with energy conversion efficiency. Thermoelectric generators. Electromagnetic induction. Electromagnetic transducers. Linear generators.

Seminar/ Group Discussion [4]

1. Non-conventional energy sources in Indian perspective.
2. India's geographic position and natural resources.
3. To discuss the environmental aspects of renewable energy resources.
4. Comparison of solar, wind, ocean and other energy potentials in Indian context.

Experimental Demonstrations [4]

1. Demonstration of solar energy and/or wind energy conversion using training modules.
2. Conversion of vibration to voltage using piezoelectric materials.
3. Conversion of thermal energy into voltage using thermoelectric modules.

References:

1. G. D. Rai, Non-conventional energy sources, Khanna Publishers, New Delhi, 1988
2. S. P. Sukhatme and J. K. Nayak, Solar energy, 4^{th} Ed. McGraw-Hill Education, New Delhi, 2017
3. A. Ghassemi (Ed) *I*ntroduction to Renewable Energy, CRC Press, US, 2011.

Semester – III

PHYS201C05 (Major): Mathematical Physics II

Credit: 6 (Theory 4, Practical 2)

Theory (Contact Hours per Week 4)

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

***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* [30]:** Singular points of second order linear differential equations and their importance. Frobenius method and its applications to differential equations. Legendre, Bessel, Hermite and Laguerre equations. Properties of Legendre Polynomials: Rodrigues formula, Generating function, orthogonality, simple recurrence relations. Expansion of function in a series of Legendre Polynomials. Bessel Functions of the first kind: Generating function, simple recurrence relations. Zeros of Bessel functions ($J_0(x)$ and$J_1(x)$) and orthogonality. Hermite polynomials. Application-based discussion on Legendre polynomials and potential theory.

***Partial Differential Equations* [10]:** Classification of partial differential equations (PDEs). Solution of PDEs with separation of variables and eigenfunctions. 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 wave equations. Solution of heat conduction equation in 1-D.

References:

1. Mathematical Methods for Physicists, G.B. Arfken, H. J. Weber, F. E. Harris, 2013, 7th
2. Ed. Elsevier
3. Differential Equations, George F. Simmons, 2007, McGraw Hill
4. Mathematical methods for Scientists and Engineers, D.A. Mc Quarrie, 2003,Viva Book
5. Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India
6. Essential Mathematical Methods, K.F.Riley&M.P.Hobson, 2011, Cambridge Univ. Press
7. A First Course in Partial Differential Equations, H. F. Weinberger, 1995, Dover Publications

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PHYS201C05 (Major): Mathematical Physics II

Practical (Contact Hours per Week 4)

Interpolation: Newton Gregory Forward and Backward difference formula. Error estimation of linear interpolation and evaluation of trigonometric functions e.g. sinθ, cosθ, tanθ, etc.

Numerical differentiation and Integration: Forward and Backward difference formula and Integration by Trapezoidal, Simpson rules and 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, LCR circuits with DC source

3. Newton's law of cooling

4. Numerical solution of second order differential equations:

(i) Harmonic oscillator (no friction)

(ii) Damped harmonic oscillator (a) over damped solution (b) critically damped solution (c) oscillatory solution

(iii) Forced harmonic oscillator: Transient and steady state solution.

PHYS202C06 (Major): Thermal Physics

Credit: 6 (Theory 4, Practical 2)

Theory (Contact Hours per Week 4)

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

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

***Entropy* [8]:** Concept of Entropy, Clausius Theorem. Clausius Inequality, Entropy of a perfect gas. Principle of Increase of Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe. Temperature–Entropy diagrams for Carnot's Cycle, Mixing of entropy of two ideal gases. Third Law of Thermodynamics. Unattainability of Absolute Zero.

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

***Maxwell's Thermodynamic Relations* [5]:** Derivations and applications of Maxwell's Relations such as 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 and Stern's Experiment. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy and its applications, Specific heats of Gases.

***Molecular collisions* [10]:** Mean Free Path, Collision Probability, Distribution of Mean Free

Paths, Mean free path of ideal gases obeying Maxwell's velocity distribution, Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian motion, Perrin's experiment, Random walk, applications of Brownian motion in diverse systems.

***Real gases* [7]:** Behaviour 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.

References:

1. Heat and Thermodynamics, M. W. Zemansky and R. Dittman 1981, McGraw-Hill, 1981
2. A Treatise on Heat, M. Saha and B. N. Srivastava, Indian Press, 1969
3. Concepts in Thermal Physics, S. J. Blundell and K. M. Blundell, 2012, Oxford University Press, 2012
4. An Introduction to Thermal Physics, C. J. Adkins, Cambridge University Press, 1987

PHYS202C06 (Major): Thermal Physics

Practical (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.

PHYS203SEC01 (Skill Enhancement): Computer Programming (Statistical Inference)

Credit 4 (Theory)

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 Software* [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, Introduction to software: 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 distribution, Binomial, Poisson. Gaussian/Normal. Theory, PDF, CDF, Moments of a distribution.

***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.

References:

1. Guide to Scientific Computing in C++, Joe-Pitt Francis and J. Whiteley, Springer, 2012
2. Computational Physics with Worked Out Examples in FORTRAN and MATLAB, M. Bestehorn, 2012
3. The Mathematica Book, S. Wolfram, Wolfram Media Inc, 2003
4. Introduction to Computer Graphics, Darrell Hajek, 2018

PHYS204VAC01 (Value Added Course): Environmental Science

Credits 3 (Theory)

The unique curriculum to be followed by all the departments, will be prescribed by the University.

PHYS205MC03 (Minor): Elements of Modern Physics

Credit: 6 (Theory: 5, Tutorial: 1)

Contact Hours per Week 6

***Inception of Modern Physics* [5]:** *How did modern physics begin?* It is based on the two major breakthroughs of the twentieth century: relativity and quantum theory. The term modern physics means up-to-date physics. This term refers to the breakthrough that happened after Newton's laws, Maxwell's equations, and thermodynamics, these laws which are known as “classical” physics. The first five lectures should build a platform that makes a continuous transition from the high school knowledge to a deeper understanding at the undergraduate level.

***The Quantum Theory* [15]:** Blackbody Radiation: The experimental results leading to quantum concept. Quantum theory of Light. Photoelectric effect and Compton scattering. de Broglie wavelength and matter waves. Davisson-Germer experiment. Wave description of particles by wave packets. Two-Slit experiment with electrons. Quantum mechanical Probability.

Position measurement – The gamma ray microscope thought experiment. Heisenberg uncertainty principle Energy-time uncertainty principle - application to virtual particles and range of an interaction. Two slit interference experiment with photons, atoms and particles. The linear superposition principle. Bohr Atom and atomic spectra. Frank and Hertz experiment. Stern-Gerlach experiment.

***Wave Mechanics* [15]:** Schrodinger equation for non-relativistic particles; 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. Scattering and tunneling - Steps and barriers.

***The Structure of Atoms and Molecules* [10]:** Formation of molecules. Electron sharing. H_2 molecule and H_2^+ molecular ion – use of basic quantum mechanics to understand the bonding and stability. Spin-Orbit coupling. Idea of Spectroscopy.

***Special Relativity* [10]:** Definition of inertial frames and invariance of speed of light. Michelson-Morley experiment. Time dilation and Lorentz contraction. Events. Synchronization. Moving clocks. Doppler shift (red shift) and its implications. The Lorentz transformations. Momentum and relation to mass and energy as a relativistic effect.

***Nuclear and Particle Physics* [10]:** 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. The semi-empirical mass formula and binding energy. Radioactive decay, Alpha and beta decay, neutrino hypothesis, Fission - mass deficit, the nature of fragments in fission and the emission of neutrons. Fusion. Nuclear reactor: slow neutrons interacting with Uranium 235**.** Fusion and thermonuclear reactions driving stellar energy (brief qualitative discussions). Classification of particles. Big bang & stellar evolution (brief qualitative discussions).

***Experimental Methods* [10]:** Lasers. Einstein's A and B coefficients. Metastable states. Spontaneous and stimulated emissions. Optical Pumping and Population Inversion. Three-Level and Four-Level Lasers. Vacuum tube and Semiconductor Devices. Semiconductor laser. Light-emitting diode. Solar cell.

References:

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. Griffiths, 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. Feynman Lectures on Physics, Volume III, R. P. Feynman, R. B. Leighton and M. Sands, Narosa, New Delhi.

Semester IV

PHYS251C07 (Major): Mathematical Physics III

Credit: 6 (Theory 4, Practical 2)

Theory (Contact Hours per Week 4)

***Complex Analysis* [20]**: Function of a complex variable. Multivalued functions and Riemann surfaces. Complex differentiations: Analytic functions and singularities. Complex integrations: Cauchy integral theorem and integral formula. Harmonic functions in the plane. Taylor series and analytic continuation. Laurent series.

***Tensor Analysis* [20]:** Cartesian tensors: first and zero order cartesian tensors, second and higher order Cartesian tensors. Algebra of tensors: summation, multiplication, contraction, inner product. Isotropic tensors, improper rotation and pseudotensors, dual tensors. Moment of inertia tensor and stress tensor. Non-cartesian tensors, the metric tensors. General coordinate transformation and tensor transformation. Lorentz transformation, 4 vectors and electromagnetic field tensor. Covariant formulation of Maxwell's equations.

***Fourier Transform* [20]:** Square integrable functions. Inverse Fourier transform. Representation of Dirac delta function as a Fourier Integral. Fourier transform of derivatives, Parseval's theorem. Convolution theorem. Cosine and Sine transforms. Three dimensional Fourier transforms with examples. Adjoint of an integral operator, Unitarity of Fourier transform. Application of Fourier transforms to differential equations: One dimensional wave, diffusion and heat flow equations.

References:

1. Tensor Calculus, David C Kay, 2011, McGraw Hill
2. Differential Equations, George F. Simmons, 2007, McGraw Hill.
3. Mathematical methods for Scientists and Engineers, D.A. Mc Quarrie, 2003, Viva Book
4. Introduction to Mathematical Physics, Charlie Harper, 1978 Prentice Hall India
5. Essential Mathematical Methods, K.F.Riley&M.P.Hobson, 2011, Cambridge Univ Press.
6. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 2013, 7th Edn., Elsevier.
7. Mathematical Physics: The Basics, S.D. Joglekar, Universities Press, India (2006)

PHYS251C07: Mathematical Physics III

Practical (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.

PHYS252C08 (Major): Analog Systems and Applications

Credits: 6 (Theory 4, Practical 2)

Theory (Contact Hours per Week 4)

***Semiconductor Fundamentals* [4]:** 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* [10]:** 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. Diode clippers, clampers, voltage multipliers.

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.

***Bipolar Junction transistor* (*BJT*) *and Field-Effect Transistors* (*FETs*) [8]:** 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, Early effect, brief Ideas on JFET and MOSFET

***Transistor Amplifiers* [12]:** Transistor biasing and stabilization, load line and *Q*-point, fixed bias, emitter-feedback bias, collector-feedback bias and voltage divider bias. BJT small-signal voltage amplifier: CE, CC and CB amplifiers.

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.

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: direct coupling, transformer coupling, two stage RC-coupled amplifier and its frequency response, cutoff frequencies, push-pull amplifiers.

***Feedback Amplifiers and Oscillators* [8]:** Concept of feedback and types of feedback, effects of negative feedback on input impedance, output impedance, gain, stability, distortion and noise.

Sinusoidal and non-sinusoidal oscillators, positive feedback, Barkhausen criterion for self-sustained oscillations, Hartley oscillator, Colpitts oscillator, phase-shift oscillator, Wien bridge oscillator, multivibrators, crystal oscillator.

***Operational Amplifier* (*Op-Amp*) *and Applications* [10]:** 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.

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.

***Introduction to Cathode Ray Oscilloscope* (*CRO*) [2]:** 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. Brief idea on digital storage oscilloscope.

***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 ICs.

***Interactive Session* [4]:** Seminar/group discussion on the learning outcome, scientific and analytical reasoning, critical thinking on the applicability/employability of the above topics.

References:

1. Boylestad R. L. and Nashelsky L., *Electronic Devices and Circuit Theory*, Pearson.
2. Malvino A. P. and Bates D. J., *Electronic Principles*, McGraw-Hill Education.
3. Raychaudhuri Barun, Electronics: Analog and Digital, Cambridge University Press.
4. Cathey J. J., *Schaum's Outline of* Theory and Problems of Electronic Devices and Circuits, McGraw-Hill.
5. Helfrick A. D. and Cooper W. D., *Modern Electronic Instrumentation and Measurement Techniques*, PHI.

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.

PHYS252C08: Analog Systems and Applications

Practical (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. Bipolar Junction Transistor (BJT)

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

Scientific Analysis: Determination of current gain and hybrid parameters

5. 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

6. Astable Multivibrator

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

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

7. Op-Amp-1

Experiments:

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

(b) 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.

8. Op-Amp-2

Experiment:

(a) To design adder in inverting mode.

(b) To design a differential amplifier.

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

9. Op-Amp-3

Experiment:

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

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

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

10. 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.

11. 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.

12. Team Work/Group Discussion

For example, on the comparative features of diode, LED and Zener diode or attempting some novel application of op-amp, such as waveform generator.

PHYS253SEC02 (Major): Modern Analytical Instruments

Credit 5 (Theory)

Contact Hours per Week 5

***Fundamentals* [5]:** Analytical approach in science and technology. Qualitative and quantitative. Importance of sample/data collection, measuring system and calibration, error analysis, validation

***Colorimetry and Spectrophotometry* [10]:** Absorption and scattering in a medium. Beer-Lambert law, Colorimeters, UV-Vis-NIR spectrophotometers, Principles of diffraction, monochromator and beam splitting, single and double beam instruments, Sources and detectors. Working principle of Fourier Transform Infrared (FTIR) spectroscopy and its applications. Flame emission photometers.

***Gas Analyzers and Pollution Monitoring Instruments* [8]:** Types of gas analyzers: Oxygen, NO_2 and H_2S types, IR analyzers, thermal conductivity analyzers, analysis based on ionization of gases. Air pollution due to carbon monoxide, hydrocarbons, nitrogen oxides, sulphur dioxide estimation. Dust and smoke measurements.

***Chemical and Electrochemical Analysis* [7]:** Principle of pH measurement, types of glass electrodes, hydrogen electrodes, reference electrodes, selective ion electrodes, ammonia electrodes, biosensors, dissolved oxygen analyzer – Sodium analyzer – Silicon analyzer. Liquid and gas chromatography.

***Radio Chemical and Magnetic Resonance Techniques* [5]:** Nuclear radiations and detectors, GM counter, Proportional counter, Solid state detectors, Gamma cameras. Absorption meters, Detectors. Nuclear Magnetic Resonance (NMR) – Basic principles and instrumentation, NMR spectrometer – Applications, particularly in medical science.

***Mass Spectrometry* [4]:** Working principle, Ion generation, mass separation and detection, spectral interpretation. Applications.

***X-Ray Diffraction and X-Ray Fluorescence Spectroscopy* [10]:** Theory and method of X-Ray Diffraction, analysis of the structure of materials. Determination of the size of the particles. X-ray fluorescence as an atomic spectral property, qualitative and quantitative information on the elemental composition of all types of samples. Instrumentation and technique.

***Atomic and Molecular Spectroscopy* [7]:** Atomic absorption spectroscopy: Sources and detectors, Fluorescence, Phosphorescence, Luminescence. Vibration spectroscopy, Raman Spectroscopy- a non-destructive chemical analysis tool that offers quantitative knowledge on chemical structure, phase and polymorphism, crystallinity, and molecular interactions.

***Optical and Electron Microscopy* [10]:** Basics of digital imaging. Optical imaging microscope. Interaction of electron with matter. Scanning Electron Microscopy (SEM), imaging technique, study of surface micrograph and microstructure analysis. EDAX analysis for the determination of chemical composition of materials. Field Emission Scanning Electron Microscopy (FESEM). Transmission Electron Microscope (TEM): dark and bright field imaging. Analysis of lattice fringes with High resolution transmission electron microscopy (HRTEM). Scanning tunneling microscopy (STM). Electron diffraction patterns for single crystal, polycrystal and amorphous materials.

Thermoanalytical Instrumentations [7]: Thermogravimetric analysis: Determination of purity and composition of materials, drying and ignition temperatures of materials and knowing the stability temperatures of compounds. Derivative thermogravimetry.

Differential Thermal Analysis: determination of the temperatures of transitions, reactions and melting points of substances.

Seminar/ Group Discussion [2]: Interactive conversation with students of different majors, interdisciplinary applications.

References:

1. R. S. Khandpur, *Handbook of Analytical Instruments*, Tata McGraw Hill publishing Co. Ltd., 2003.
2. H. H. Willard, L. L. Merritt, J. A. Dean, F. A. Settle, *Instrumental methods of analysis*, CBS publishing & distribution, 1995.
3. J. W. Robinson, E. M. S. Frame and G. M. Frame II, Undergraduate Instrumental Analysis, 6th Ed. Marcel Dekker, NY, 2005.

PHYS254VAC02 (Value-Added Course): Computer Simulation of Electronic circuits

Credits 3

Contact Hours per Week 3

***Learning Objectives*:**

This value-added add-on course covers experimental topics partly similar to the practical of CBCS UG Sem 4 Analog Systems and Applications (PHYS252C08) and UG Sem 5 Digital Systems and Applications (PHYS301C09). Instead of fabricating the actual electronic circuit in the laboratory, it generates a computer simulation of the same with freely downloadable software, such as LTspice.

***Significance of Computer Simulation* [3]**

The teaching-learning methodology should communicate the key ideas that the circuit simulation is a preparatory process that can eliminate or replace expensive and impractical circuit components. The simulation models can be altered easily to understand the effects of modifications and to identify the limitations of a circuit system. The voltage and current values for every circuit point can be traced easily. It helps the student self-learning and provides a cost effective and time-saving method to test a circuit performance before it is actually constructed. General emphasis should be laid on:

a. Selection of circuit components and specification of the values during the process of circuit assembling
b. The study of the changes of the output conditions, the plotted data and the analysed results
c. Sharing of views, calculations and determinations with the teacher and the classmates, preferably in group discussion or seminar presentation.

***Simulations with p-n Junction Devices* [4]**

a. To study the forward and reverse current-voltage characteristics of a p-n junction diode.
b. To determine the dynamic resistance, static resistance and cut-in voltage.
c. To study the forward and reverse current-voltage characteristics of a Zener diode.
d. To determine the current limiting resistance, breakdown voltage and to conduct the load regulation characteristics.

***Simulations with Bipolar Junction Transistor* (*BJT*) [4]**

a. To draw the output current-voltage characteristics in common-emitter (CE) configuration.
b. To determine the current gain and the hybrid parameters.
c. Biasing the BJT and designing a CE amplifier of given gain.
d. To study the linearity and the frequency response of the amplifier.

***Simulations with Operational Amplifier* (*Op-Amp*) [8]**

a. To design an inverting amplifier and/or non-inverting amplifier and to study the following properties of the circuit: (i) dc amplification, (ii) voltage gain, (iii) linearity and (iv) ac response.
b. To design adder in inverting and/or noninverting mode and to study the output characteristics for both dc and ac inputs.
c. To design a differential amplifier and to study the circuit performance with different voltage levels.
d. To investigate the use of op-amp as integrator and differentiator and verification of the circuit performance with different voltage waveforms.
e. To study the op-amp comparator with zero-crossing detector.
f. To fabricate op-amp Schmitt trigger and to study its performance.

***Simulations with Basic Digital Circuits* [5]**

a. Constructing AND and OR gates with diodes and resistors and NOT gate with transistor and resistors. Understanding the logic levels, the range of voltage supply and the use of analog devices into digital circuits.
b. Construction of AND, OR, NOT and XOR gates using NAND and/or NOR gates. Understanding the concept of Universal Gate
c. Practice with combinational logic circuits for specified truth tables and minimizing logic circuits.

***Simulations for Combinational Logic operations* [5]**

a. To construct Half Adder and Full Adder circuits for single bit addition using NAND gates.
b. To build 1-bit comparator for equality and inequality of two bits.
c. Understanding controlled inversion and applying the same for realizing adder-subtractor.

***Simulations for Sequential Logic Operations* [8]**

a. To build RS and D-type Flip-Flop circuits using NAND gates. To understand the use of clock pulse, the latch and memory properties of flip-flop.
b. To build JK Flip-Flop circuits using NAND gates.
c. Fabrication of 2-bit Counter using Flip-Flops and to study its timing diagram. To understand the role of LSB and MSB and frequency division by counter outputs.
d. Fabrication of 2-bit Shift Registers using Flip-Flops and to study their performances.

***Simulations for Device Applications* [4]**

a. To design an astable multivibrator either using BJT, capacitors and resistors or using IC555 and to observe the changes in the waveform and frequency with circuit components.
b. To design Wein bridge oscillator with op-amp, to study the waveform and to investigate the properties of the lead-lag network.

***Brief Ideas on Microprocessor and Microcontroller* [4]**

Simulations of 8085 simple programs, such as register and memory handling, addressing modes, arithmetic and logical operations, number sorting

Simulation of Arduino programs for generating a voltage to drive an LED, accepting analog input voltage etc.

Learning Outcome

The software-based circuit simulation can predict the expected results before building an actual circuit. The student is expected to fabricate similar circuit systems on their own and probe the different parts of those systems for different input conditions for developing better analytic skill. The familiar circuit theories may be verified in this connection. They are expected to be able to evaluate how different circuit components and parameters can influence the output conditions.

References:

1. Boylestad R. L. and Nashelsky L., *Electronic Devices and Circuit Theory*, Pearson.
2. Malvino A. P. and Bates D. J., *Electronic Principles*, McGraw-Hill Education.
3. Raychaudhuri B., Electronics: Analog and Digital, Cambridge University Press.
4. Leach D.P., Malvino A.P., and Saha G., Digital Principles and Applications, 8th Edn. McGraw-Hill Education.

5. Tocci R. J., Widmer N. S. and Moss G. L., Digital Systems: Principles & Applications, 10^{th} Ed. Pearson.

PHYS255MC04 (Minor): Radiological Physics

Credits: 6 (Theory 5, Tutorial 1)

Contact Hours per Week 6

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* [32]:** 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.

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

***Radiation effect and measurements* [15]:** 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 & amp; 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.

References:

1. Nuclear Physics, Principles and Applications by J. S. Lilly (John Wiley & Sons, Inc. 2002).
2. Radiation Detection and Measurement by G. F. Knoll (John Wiley & Sons, Inc. 3 rd 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).

Semester V

PHYS301C09 (Major): Digital Systems and Applications

Credits: 6 (Theory 4, Practical 2)

Theory (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* [5]:** 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, changing counter modulus, 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: flash-type and counter-type.

***Basics of computer architecture and programming* [10]**: Microprocessor, input/output devices, data storage, idea of read-only memory (ROM) and random access memory (RAM), memory organization and addressing, memory interfacing, memory map.

Microprocessor registers, timing and control, instruction cycle, opcode, machine and assembly language, types of instructions, addressing modes, input-output and interrupt, program control, pipelining, embedded input-output systems, microcontroller.

Seminar/ Interactive Pedagogies [4]: Interpretation of don't care conditions in Karnaugh map, demonstration of the equivalence of SOP and POS forms, and to highlight that the Boolean simplification is not unique.

Scientific and Analytical Reasoning: critical thinking on topics, multi-disciplinary and interdisciplinary applications of digital systems.

References:

1. Digital Principles and Applications, D.P. Leach, A.P. Malvino and G. Saha, 8th Edn. McGraw-Hill Education.
2. Digital Systems: Principles & Applications, R.J. Tocci, N.S. Widmer and G. L. Moss, 10^{th} Ed. Pearson.
3. Electronics: Analog and Digital, Barun Raychaudhuri, Cambridge University Press.
4. Integrated Electronics: Analog and Digital Circuits and Systems, J. Millman and C.C. Halkias, 2nd Edn. 2017, McGraw Hill Education.
5. Schaum's Outline of Theory and Problems of Digital Principles, R. L. Tokheim, 3rd Edn. McGraw-Hill.
6. Harris D. M. and Harris S. L., *Digital Design and Computer Architecture*, Morgan Kaufmann, Elsevier, USA, 2013.

PHYS301C09 (Major): Digital Systems and Applications

Practical (Contact Hours per Week 4)

At least eight of the following list of experiments.

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:

a. Realizing combinational logic system for a specified truth table
b. Fabricating logic circuits using ICs for simple Boolean expressions
c. 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. Multiplexer/ Demultiplexer

Experiment: To design a 4-to-1 multiplexer or to design an 1-to-4 demultiplexer using basic gates.

Extended Studies:

a. To convert the circuit as a decoder.
b. To discuss the outcome of increasing the number of inputs and outputs.

7. 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

8. 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

9. 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.

10. Shift Register

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

11. Lab Demonstrations/ Participatory Pedagogies

(i) To build up and execute microprocessor programs, may be using 8085 as a learning tool. The following tasks are mentioned as examples.

(a) Addition and subtraction of numbers using direct and indirect addressing mode

(b) Multiplication by repeated addition and division by repeated subtraction.

(c) Enhancing the number of bits used in a program, such as handling 16-bit numbers with 8-bit microprocessor.

(d) Block data handling, sorting and rearrangement of numbers.

(ii) Demonstration of microcontroller operations, such as with Arduino.

PHYS302C10 (Major): Quantum Mechanics and Applications

Credits: 6 (Theory 4, Practical 2)

Theory (Contact Hours per Week 4)

***Schrodinger equation* [12]:** Time dependent Schrodinger equation and dynamical evolution of a quantum state. Wave function and its normalization. Probability and probability current densities. 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 representation of wavefunctions. The uncertainty principle.

General discussion of bound states in an arbitrary potential **[8]**: Continuity of wave function, boundary condition and emergence of discrete energy levels, application to one-dimensional problems - square well potential, as an example. Linear harmonic oscillator - energy levels and energy eigenfunctions (use of raising and lowering operators to determine the energy levels). Hermite polynomials; ground state, zero point energy & uncertainty principle.

Quantum theory of the hydrogen atom **[10]:** 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 and first excited states. Orbital angular momentum quantum numbers *l* and *m*; *s, p, d*,.. shells.

Algebraic Formalism

(*a*) ***Linear vector space*** **[4]:** Basis sets and dimensionality; Orthonormal basis sets:Gram-Schimidt orthonormalization,Expansion of an arbitrary vector;Basis-independence of the inner product. Cauchy-Schwarz and triangle inequality. Schrodinger equation in Dirac notation; Solution of the two-state systems like Ammonia Maser.

(*b*) ***Infinite-dimensional vector spaces*** **[2]**: The space l 2 of square-summable sequences; space L 2 of square-integrable functions; Continuous basis. Position and momentum space wave functions of a particle. Hilbert space; subspaces.

(*c*) ***Linear operators on a vector space*** **[2]**: Linear operators, norm and bounded operators.

Symmetric , hermitian and self-adjoint operators.The derivative operator in L 2 . Eigen values and non-normalizable eigenstates of   and momentum operator.

(*d*) ***The formalism of quantum mechanics*** **[6]**: State of a system, Observables; Commutators; Quantum correspondence principle. Postulates of Quantum mechanics, Expectation value, Commutator Relations and Uncertainty principle, Complete sets of commuting observables; Maximally informative states. Ehrenfest t heorem, Schrodinger and Heisenberg pictures, Symmetry principles and conservation laws.

Atoms in Electric & Magnetic Fields **[8]:** Space quantization of angular momentum. 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. Stark Effect.

Many electron atoms **[8]:** Pauli's Exclusion Principle. Symmetric & Antisymmetric Wave Functions. Fine structure. Spin orbit coupling. Spectral Notations for Atomic States. Total angular momentum. Spin-orbit coupling in atoms- L-S and J-J couplings. Hund's Rule.

References:

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.

PHYS302C10: Quantum Mechanics and Applications

Practical (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

PHYS303C11 (Major): Statistical Mechanics

Credits: 6 (Theory 4, Practical 2)

Theory (Contact Hours per Week 4)

***Classical Statistics* [22]:** Inadequacies of classical thermodynamics, Macrostate & Microstate, Elementary Concept of Ensemble: micro-canonical, canonical, grand canonical. Phase Space, Entropy and Thermodynamic Probability, Gibbs Distribution, 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-Levels System, Negative Temperature., Purcell 's experiment, Langevin dynamics.

***Phase transitions* [8]:** Introduction to magnetic phase transition, Liquid-gas phase transition, Equation of state of non-ideal classical gas, Van-der-Waals theory of liquid-gas phase transition, critical exponents, universality.

***Bose-Einstein Statistics* [14]:** Black-Body radiation, 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. Low temperature specific heat of solids, Debye law.

***Fermi-Dirac Statistics* [16]:** 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: 2nd 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

PHYS303C11 (Major): Statistical Mechanics

Practical (Contact Hours per Week 4)

1. Study of Specific Heat of Solids in different approximations and physical regimes.
2. Numerical study of Maxwell-Boltzmann, Fermi-Dirac and Bose-Einstein distribution functions.
3. Numerical estimates of metallic specific heat.
4. Video demonstration of BEC.
5. Numerical studies of the Partition function and its properties.
6. Verification of Stirling approximation for large numbers8. Simulating Spin systems.
7. Numerical study of the ortho-para states of hydrogen.
8. Numerical analysis of Bose gas confined in a harmonic trap.

PHYS341SI01: Summer Internship

Semester VI

PHYS351C12 (Major): Advanced Classical Mechanics-I

Credits: 6 (Theory 5, Tutorial 1)

Contact Hours per Week 6

***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* [25]:** Variational Principle and 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 and weakly coupled pendulum, Normal coordinates and modes.

***Fluid Mechanics* [16]:** 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. Elasticity, L. D. Landau and E. M. Lifshitz, 1976, Pergamon.
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

PHYS352C13 (Major): Electromagnetic Theory

Credits: 6 (Theory-4, Practicals-2)

Theory (Contact Hours per Week 4)

***Maxwell Equations and Related Discussion* [8]**: Review of Maxwell's equations. 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.

***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.

***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)

***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 (Definitions Only).

***Electrodynamics and Special Relativity* [15]:** Relativity Pre-Einstein, Inconsistency with electromagnetic theory, Velocity Addition and Lorentz Transformations, Relativistic Energy momentum, Four vectors and transformation properties, Simple applications to particle decay and elastic collision, Aberration, Doppler effect: examples in modern research, Incompleteness of special relativity, Non-inertial reference frame and the equivalence principle.

References:

1. Introduction to Electrodynamics, D.J. Griffiths, 3rd Ed., Prentice Hall, 1999
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

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PHYS352C13 (Major): Electromagnetic Theory

Practical (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. Polarization by Reflection: Introduction to the method of producing linearly polarized light and testing the electromagnetic theory of reaction of polarized light from a dielectric surface, as expressed in Fresnel's equations.
4. Study of Magnetic Hysteresis: To study the phenomena of magnetic hysteresis and determination of ferromagnetic constants.

PHYS353C14 (Major): Solid State Physics

Credits: 6 (Theory 4, Practical 2)

Theory (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 Structure Factor.

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

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

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

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

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

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

References:

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. Elementary Solid State Physics: Principles and Applications, M. Ali Omar, Pearson
4. Solid State Physics, A. J. Dekker, Macmillan
5. Perspectives of Modern Physics, Arthur Beiser, McGraw-Hill

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PHYS353C14 (major): Solid State Physics

Practical (Contact Hours per Week 4)

1. Determination of resistivity and band gap of a semiconductor by four probe method.
2. Determination of the concentration of majority carriers of a semiconductor using Hall effect.
3. Measurement of susceptibility of paramagnetic salt.

4. To measure the resistivity of GE semiconductor.
5. To measure hysteresis loop of Ferroelectric crystal.
6. Experiment on lattice dynamics (diatomic molecule).

PHYS354C15 (Elective): Physics of Materials

Credits: 6 (Theory 5, Tutorial 1)

Contact Hours per Week 6

***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, computer programming to generate and analyse theoretical results.

References:

1. Richard J.D. Tilley, Understanding Solids: The Science of Materials, 2nd edition, Wiley, UK, 2013.
2. Kittel C. Introduction to Solid State Physics, 8th Ed., John Wiley & Sons, Inc.
3. Blakemore J. S. Solid State Physics, 2nd Ed. Cambridge University Press.

PHYS354C15 (Elective): Nuclear & Particle Physics

Credits: 6 (Theory 5, Tutorial 1)

Contact Hours per Week 6

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

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.

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 processes

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.

References:

1. Introductory Nuclear Physics by Kenneth S. Krane (John Wiley & Sons).
2. Theory of Nuclear Structure by M. K. Pal (Affiliated East-West Press).
3. Introduction to Nuclear Reactions by G. R. Satchler (Oxford University Press).
4. Nuclear Reaction and Nuclear Structure by P. E. Hodgson (Clarendon Press).
5. Nuclear Physics, Principles and Applications by J. S. Lilly (John Wiley & Sons, Inc.).
6. Techniques for Nuclear and Particle Physics Experiments by W. R. Leo (Springer Science & Business Media).
7. Introduction to High energy physics by D. H. Perkins (4th edn. C.U.P. (2000)).
8. Elementary particles by D. Griffiths, 2nd edn. Wiley, (2008).

Semester VII

PHYS401C16 (Major): Advanced Classical Mechanics – II

Credits 4 (Theory), Contact Hours per Week 4

***Preliminaries* [10]:** Variational principle and Lagrange's equations of motion – simple applications, Lagrangian for mechanical systems with dissipation and for systems subject to nonholonomic constraints, Hamiltonian formulation, Small Oscillations.

***Rigid Body* [14]:** Kinematics, Euler angles, Infinitesimal rotation, Symmetry group of rotation, Motion of heavy symmetrical top with one point fixed, other applications.

***Canonical Transformation and Hamilton-Jacobi Theory* [18]:** Generating function, Poisson bracket, Canonical invariants, Hamilton-Jacobi theory, Action angle variables, Kepler problem.

***Continuous Systems and Fields* [10]:** Lagrangian and Hamiltonian formulation for continuous systems, Symmetry and conservation principles – Noether's Theorem, Classical field theory.

***Nonlinear Dynamics and Classical Chaos* [8]:** Phase space dynamics, Stability analysis, Lyapunov exponent, Bifurcation, examples.

References:

1. Classical Mechanics, H.Goldstein, C.P. Poole, J.L. Safko, 3rd Edn. 2002, Pearson Education
2. Introduction to Classical Mechanics: David J. Morin, Cambridge University Press.
3. Classical Mechanics - John R. Taylor, University Science Books.
4. Classical Mechanics - H. C. Corben, Dover Books on Physics.
5. Classical Mechanics - R. Douglas Gregory, Cambridge University Press.
6. Mechanics – Arnold Sommerfeld, Academic Press.

PHYS402C17 (Major): Advanced Quantum Mechanics

Credits 4 (Theory), Contact Hours per Week 4

***Axiomatic Formulation of Quantum Mechanics* [10]:** State vectors and linear operators in Hilbert space, Dual space, Dirac notation, Matrix representations, Compatible observables, Schrödinger and Heisenberg pictures.

***Symmetries* [8]:** Conservation laws and the degeneracy associated with symmetry. Continuous symmetries – space and time translations, Rotations, Discrete symmetries – parity and time reversal.

***Angular Momentum* [12]:** Angular momentum algebra, Orbital angular momentum and spin. Addition of two angular momenta, Clebsch-Gordon coefficients, irreducible spherical tensor operators, Wigner-Eckart theorem.

***Approximate methods* [30]**

A. Time-independent perturbation theory: Non-degenerate and degenerate systems.

Applications – corrections to Hydrogen atom spectra due to relativistic electrons, spin-orbit coupling, Zeeman effect, Stark effect.

B. Variational method and its applications (to Helium, for example). WKB method:

Construction of wave function, correction formula, Applications: quantum tunnelling through a barrier, e.g. in radioactive alpha particle decay. Tunnelling probability.

C. Time dependent perturbation theory: Intensity of spectral lines and transition probability, selection rule, constant and harmonic perturbations – Fermi's Golden Rule, approximations, Rabi oscillations.

D. The Adiabatic Theorem and Adiabatic Approximation, Geometric Phase and the Aharonov-Bohm effect.

References:

1. Modern Quantum Mechanics (3^{rd} Ed.): J. J. Sakurai and J. J. Napolitano, Pearson
2. Elements of Quantum mechanics: B. Dutta-Roy, New Age International Publishers
3. Introduction to Quantum Mechanics: David J Griffiths, Pearson
4. Introduction to Quantum Mechanics: B. H. Bransden and C. J. Joachain, Pearson.

PHYS441C18 (Major) Laboratory-I

Credits 4 (Practical), Contact Hours per Week 6

The Following Experiments are part of the lab:

1. Determination of the Lande 'g' factor of DPPH using electron spin resonance spectrometer
2. Performance of high pass and low pass filters
3. Experiment with Michelson's Interferometer
4. Determination of the saturation magnetization of ferromagnetic substance using hysteresis loop tracer
5. To study the characteristics of optical fibre

PHYS442C19 : Project / Dissertation

Credits 4, Contact Hours per Week 4

PHYS405MC05 (Minor): Research Methodology

Credits 4 (Theory), Contact Hours per Week 4

Semester VIII

PHYS451C20 (Major): Advanced Electromagnetism

Credits 4 (Theory), Contact Hours per Week 4

***Basics* [15]:** Maxwell's equations for electrostatics and magnetostatics: Solutions of boundary value problems in electrostatics using Green's functions. Multipole expansions.

***EM waves* [5]:** EM waves, propagation in inhomegenous media, transversality, gauge fixing and degrees of freedom; polarization including partial polarization, Stokes parameters.

***Relativistic Formulation of Electrodynamics* [15]:** Covariant Lagrangian formalism of point charges, Relativistic kinematics. Vacuum Maxwell equations for potentials and their symmetries; origin of special relativity and Lorentz invariance; Relativistic Doppler effect. Electromagnetic stress tensor, relativistic energy and momentum,

***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.

***Advanced Topics* [5]:** Electromagnetic duality, Magnetic monopoles, Dirac Quantisation condition, Local gauge invariance and abelian field theory, Brief introduction to Yang-Mills theory

References:

1. Classical Theory of Electricity and Magnetism: A. K. Raychaudhuri, Springer
2. Introduction to Electrodynamics: D. J. Griffiths, PHI
3. Classical Theory of Fields: L. D. Landau and E. M. Lifshitz, Pergamon
4. Classical Electrodynamics: J. D. Jackson, Wiley
5. Lectures on Electromagnetism: David Tong, University of Cambridge (Freely available on internet).
6. Classical Electrodynamics: W. Greiner, Springer

PHYS452C21 (Major): Advanced Statistical Mechanics

Credits: 4 (Theory), Contact Hours per Week 4

***Applications of Gibbs Distribution* [15]:** Ising model in one dimension, Calculation of partition function by transfer matrix method, Calculation of free energy, Long range ferromagnetic order, Peierls argument, Long-range interactions.

***Ferromagnetic Phase Transitions* [15]:** Mean field theories, Bragg-Williams theory, Landau theory, Bethe-Peierls theory, determination of critical exponents, Widom-Kadanoff scaling hypothesis, Griffiths and Rushbrooke equalities, Universality.

***Cluster Integral and Mayer-Ursell Expansion* [11]:** Cluster Integrals, Calculations in simple cases, Virial expansion, Derivation of Mayer-Ursell equation of state, applications.

***Brownian Motion* [10]:** Einstein-Smoluchowski theory, Langevin theory, Approach to equilibrium, Fokker-Planck equation, irreversible phenomena, Onsager relations.

***Fluctuations* [9]:** Thermodynamic fluctuations, Spatial correlations in a fluid, Spectral analysis of fluctuations, Wiener-Khintchine theorem.

Reference Books:

1. Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2 nd Ed., 1996, Oxford University Press.
2. Equilibrium Statistical Physics, M. Plischke and B. Bergersen, Prentice -Hall International Editions
3. Statistical Mechanics, Kerson Huang, Wiley-India editions.
4. Phase transition and critical phenomena, A. Aharony, Vol-6, Ed. C. Domb and M. S. Green, Academic press, New York.
5. Introduction to phase transition and critical phenomena, H E Stanley, Clarendon Press, Oxford.

PHYS491C22 (Major): Laboratory-II

Credit: 4 (Practical), Contact Hours per Week 6

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.

PHYS492C23 : Project / Dissertation

PHYS493MC06 : Research and Publication Ethics
