Program Name: B.Sc. (Physics)
Major in Physics

4 years Program following NEP Guidelines
Program Code: **PHY3403**

Offered by Department of Physics, School of Basic and Applied Sciences, Adamas University Duration: 4 Years

Academic Year: 2026-27

Course Structure

SCHOOL OF BASIC AND APPLIED SCIENCES									
UNDERGRADUATE COURSE STRUCTURE									
B.Sc. (Physics) (4-year Program)									
SEMESTER I									
Sl. No.	Type of Course	Code	Title of the Course	Contact Hours Per Week				Remarks	NCRF Credit Level
				L	T	P	C		
1	Major	PHY100	Mathematical Methods I	3	0	1	4	CC-1	4.5
2	Major	PHY101	Mechanics and Waves	3	0	1	4	CC-2	4.5
3	Minor	IKS101	Introduction to IKS				4		4.5
4	MDC		To be chosen from the given bucket				3		4.5
5	VAC		To be chosen from the given bucket				2		4.5
6	AEC		English Communication I	2	0	0	2		4.5
7	AEC		Foreign Language I	2	0	0	2		4.5
8	General Minor	GEN102	Principles and Applications of AI	2	0	0	2		4.5
Semester Credits							23		

SEMESTER II									
Sl. No.	Type of Course	Code	Title of the Course	Contact Hours Per Week				Remarks	NCRF Credit Level
				L	T	P	C		
1	Major	PHY102	Electromagnetic Theory I	3	0	1	4	CC-3	4.5
2	Major	PHY103	Thermal Physics	3	0	1	4	CC-4	4.5
3	Minor	GEN104	Basic Cyber Security and Internet of Things				4		4.5
4	MDC		To be chosen				3		4.5

			from the given bucket						
5	VAC		To be chosen from the given bucket				2		4.5
6	AEC		English Communication II	2	0	0	2		4.5
7	AEC		Foreign Language II	2	0	0	2		4.5
8	SEC		To be chosen from the given bucket				2		4.5
9	SEC		Soft Skills and Aptitude Courses				1		4.5
Semester Credits							24		

SEMESTER III									
Sl. No.	Type of Course	Code	Title of the Course	Contact Hours Per Week				Remarks	NCRF Credit Level
				L	T	P	C		
1	Major	PHY200	Mathematical Methods II	3	0	1	4	CC-5	5.0
2	Major	PHY201	Electronics I	3	0	1	4	CC-6	5.0
3	Major	PHY202	Electromagnetic Theory II	3	0	1	4	CC-7	5.0
4	Minor		To be chosen from the given bucket				4		5.0
5	MDC		To be chosen from the given bucket				3		5.0
6	VAC		To be chosen from the given bucket				2		5.0
7	SEC		To be chosen from the given bucket				2		5.0
8	SEC		Soft Skills and Aptitude Courses				1		5.0
Semester Credits							24		

SEMESTER IV									
Sl. No.	Type of Course	Code	Title of the Course	Contact Hours Per Week				Remarks	NCRF Credit Level
				L	T	P	C		
1	Major	PHY203	Quantum Mechanics	4	0	0	4	CC-8	5.0
2	Major	PHY204	Electronics II	3	0	1	4	CC-9	5.0
3	Major	PHY205	Analytical Mechanics and Special Theory of Relativity	4	0	0	4	CC-10	5.0
4	Minor		To be chosen from the given bucket				4		5.0
5	VAC		To be chosen from the given bucket				2		5.0
6	SEC		To be chosen from the given bucket				2		5.0
7	SEC		Soft Skills and Aptitude Courses				1		5.0
Semester Credits							21		

SEMESTER V									
Sl. No.	Type of Course	Code	Title of the Course	Contact Hours Per Week				Remarks	NCRF Credit Level
				L	T	P	C		
1	Major	PHY300	Statistical Mechanics	4	0	0	4	CC-11	5.5
2	Major	PHY301	Advanced Quantum Mechanics	4	0	0	4	CC-12	5.5
3	Major	PHY302	Advanced Physics Lab I	0	0	2	2	CC-13	5.5
4	Major	PHY303	Advanced Physics Lab II	0	0	2	2	CC-14	5.5
5	Minor		To be chosen from the given bucket				4		5.5
6	SEC		To be chosen from the given bucket				2		5.5
7	SEC		Soft Skills and				1		5.5

			Aptitude Courses						
8	INT	PHY340	Internship				2		5.5
Semester Credits							21		

SEMESTER VI									
Sl. No.	Type of Course	Code	Title of the Course	Contact Hours Per Week				Remarks	NCRF Credit Level
				L	T	P	C		
1	Major	PHY304	Numerical Methods and Simulations in Physics	1	0	3	4	CC-15	5.5
2	Major	PHY305	Solid State Physics	3	0	1	4	CC-16	5.5
3	Major	PHY306	Nuclear and Particle Physics	4	0	0	4	CC-17	5.5
4	Major	PHY307	Advanced Physics Lab III	0	0	2	2	CC-18	5.5
5	Minor		To be chosen from the given bucket				4		5.5
6	SEC		To be chosen from the given bucket				2		5.5
7	SEC		Soft Skills and Aptitude Courses				1		5.5
Semester Credits							21		
Total Credits of the Program after 3rd Year							134		

SEMESTER VII									
Sl. No.	Type of Course	Code	Title of the Course	Contact Hours Per Week				Remarks	NCRF Credit Level
				L	T	P	C		
1	Major	PHY400	Advanced Statistical Mechanics	4	0	0	4	CC-19	6.0
2	Major	PHY401 / PHY402 / PHY403 / PHY404 / PHY405 / PHY445	Introduction to Astronomy and Astrophysics/ Nanomaterials and Fabrication Technology/ Guided Wave Optics/ Properties of Solids I/ Physics for Medicine/ Solar Energy Materials and Photovoltaic Technology	4 3 3 4 4 3	0 0 0 0 0 0	0 1 1 0 0 1	4	CC-20	6.0
3	Major	PHY406 / PHY407 / PHY408 / PHY409 / PHY410 / PHY446	Introduction to Cosmology/ Nanoelectronics and Nanophotonics/ Nonlinear Optics and Bio-Photonics/ Introduction to Material Science/ Biomedical Instrumentation/ Electric Mobility and Energy Storage Technologies	4 3 4 3 3 3	0 0 0 0 0 0	0 1 0 1 1 1	4	CC-21	6.0
4	Major (For With Research)	PHY440 / MTH450	Research Methodology	0	0	4	4	CC-22 (With Research)	6.0

4A	Major (For Without Research)	PHY441	Machine Learning and Data Analytics	2	0	2	4	CC-22 (Without Research)	6.0
5	Minor		To be chosen from the given bucket				4		6.0
6	SEC		Soft Skills and Aptitude Courses				1		6.0
Semester Credits							21		

SEMESTER VIII									
Sl. No.	Type of Course	Code	Title of the Course	Contact Hours Per Week				Remarks	NCRF Credit Level
				L	T	P	C		
1	Major	PHY411 / PHY412 / PHY413 / PHY414 / PHY415 / PHY447	Computational Astrophysics/ Quantum Transport/ LASER and Optoelectronic Devices/ Properties of Solids II/ Medical Imaging and Image Processing/ Smart Renewable Energy Systems and Energy Harvesting	2 4 3 4 3 3	0 0 0 0 0 0	2 0 1 0 1 1	4	CC-23	6.0
2	Minor						4		6.0
3A	Major (For Without Research)	PHY442	X Ray Crystallography and related Techniques	4	0	0	4	CC-24 (Without Research)	6.0
3B	Major (For Without Research)	PHY443 / PHY444	Introduction to Vacuum Technology and its Applications / Solar Energy and its Applications	3	0	1	4	CC-25 (Without Research)	6.0
3C	Minor (For without						4		6.0

	Research)								
3	Dissertation (For With Research)						12	CC-24	6.0
Semester Credits							20		
Total Credits of the Program after 4th Year							175		

Minors to be offered by Department of Physics (4 credits each)

Minor Name –

1. From Mathematics to Mechanics
2. From Heat Waves to Light Waves
3. Electricity and Magnetism
4. Electromagnetic Theory
5. Quantum and Statistical Theory
6. Electronics and Quantum Optics
7. Physics of Solids and Smart Systems
8. Nuclear and Particle Physics

MDC to be offered by Department of Physics (3 credits each)

1. Basics of Geophysics
2. Introduction to Nuclear Engineering
3. Green Photonics

SEC to be offered by Department of Physics (2 credits each)

1. Introduction to Scientific Analysis and Documentation Skills
2. Instrumentation Skills
3. Radiation Safety Techniques
4. Object Oriented Programming in Python
5. Introduction to C++ Programming

VAC to be offered by Department of Physics (2 credits each)

1. Learning MATLAB
2. Computing with Mathematica
3. Object Oriented Programming in C++
4. Physics Simulation with COMSOL Multiphysic

Program Name: **B.Sc. (Physics)**

Major in Physics

4 years Program following NEP Guidelines

Program Code: **PHY3403**

Offered by Department of Physics, School of Basic and Applied Sciences, Adamas University

Duration: 4 Years

Academic Year: 2026-27

Syllabus

Semester I

Paper Name: Mathematical Methods I

Paper Code: PHY100
LTP: 3-0-1

Course Objectives:

1. To understand the mathematical principles and physical significance of ordinary and partial differential equations in modeling physical systems.
2. To explore vector calculus and matrix operations for solving complex problems in Physics, with applications in advanced topics.
3. To analyze Fourier series for representing periodic functions and their use in solving Physics-related problems.
4. To investigate special integrals, including Beta and Gamma functions, and their relevance in higher-level Physics contexts.
5. To develop programming skills in Python for solving numerical Physics problems and conducting simulations in laboratory settings.

Course Description

This course introduces key mathematical tools used in physics, including differential equations, vector calculus, linear algebra, Fourier series, and special integrals. Emphasis is placed on analytical methods and their applications in physical systems. The lab component covers error analysis, matrix operations, curve fitting, and basic scientific programming using Python, equipping students with essential computational skills for solving physics problems.

Course Outcome:

1. **CO1: Recall** fundamental mathematical concepts, formulas, and theorems used in calculus, linear algebra, and series expansions.
2. **CO2: Explain** the logical structure and theoretical basis of mathematical methods used in solving differential equations and vector problems.
3. **CO3: Apply** mathematical techniques to solve ordinary and partial differential equations, perform vector operations, and work with matrices and special functions.
4. **CO4: Analyze** mathematical problems by selecting appropriate methods, transforming equations, and identifying solution strategies.
5. **CO5: Evaluate** numerical methods to solve mathematical problems and interpret the obtained results.

6. **CO6: Develop and implement** computational tools to solve mathematical problems and visualize results using programming techniques.

Course Content:

Module I: Differential Equations *(10 Hours)*

Differential equations of first order, Linear Differential equation, Bernoulli's equation, Exact differential equation, integrating factor, second order differential equation, homogeneous and inhomogeneous equations, Complete solution = C.F + P.I. Different methods of finding Particular Integral. Wronskian and general solution. Statement of existence and Uniqueness Theorem for Initial Value Problems. Cauchy-Euler Equations, Legendre's equations, Method of variation of parameters, Method of undetermined coefficient.

Module II: Partial Differential Equations *(8 Hours)*

Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular, cylindrical and spherical symmetry. Wave equation and its solution for vibrational modes of a stretched string, rectangular and circular membranes.

Module III: Vectors *(10 Hours)*

Vector algebra: Scalar product and Vector product, Scalar triple product and their interpretation in terms of area and volume respectively. Scalar and Vector fields. Vector Calculus: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Del and Laplacian operators. Vector identities, Vector Integration, Ordinary Integrals of Vectors. Line, surface and volume integrals of Vector fields. Gauss' divergence theorem, Green's and Stokes Theorems and their applications.

Theory of Orthogonal Curvilinear Coordinates: Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems.

Linear Vector Space: Vectors in function space, Axiomatic definition, linear independence, bases, dimensionality, inner product, Gram-Schmidt orthogonalization, Operators, self-Adjoint and Unitary Operators, Transformation of Operators

Module IV: Matrices *(6 Hours)*

Definition, Various types of matrices, addition, subtraction and multiplication of matrices, Adjoint and Inverse of a matrix, Solution of simultaneous equations, Determination of Eigen Value and Eigen Vectors, Diagonalization of a real, symmetric matrix, Functions of a Matrix, Cayley-Hamilton's Theorem. commuting matrices with degenerate eigenvalues, Orthonormality of eigenvectors.

Module V: Fourier Series *(8 Hours)*

Periodic functions. Dirichlet's Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions. Complex representation of Fourier series. Expansion of functions with arbitrary period. Expansion of non-periodic functions over an interval. Even and odd functions and their Fourier expansions. Application. Summing of Infinite Series. Term-by-Term differentiation and integration of Fourier Series. Parseval Identity.

Module VI: Some Special Integrals *(3 Hours)*

Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions. Error Function (Probability Integral).

Module VII: Hands on Training

- **Introduction to Errors:** Systematic and Random Errors, Propagation of Errors, Standard and Probable Errors, Floating Point Numbers, Single and Double Precision Arithmetic, Underflow and Overflow

- **Introduction to Programming (Python):** Constants, Variable, Statement, Intrinsic functions, Conditional Execution, Functions, Iterations, Strings, Files, Lists, Introduction to Numpy, Scipy and Matplotlib, 2D graphs using both functions and data files

- **Matrix Operations:** Matrix addition, Matrix multiplication, Transpose of Matrix, Solution of Simultaneous Equations, Estimation of Eigen value and Eigen vector

- **Least Square Fitting Method:** Linear Least Square method, Nonlinear Least Square method – Exponential Form, Hyperbolic Form, Power Method

- **Sorting Method:** Selection Sort, Bubble Sort

Reference Books:

1. Mathematical Methods for Physicists, G.B.Arfken, H.J.Weber, F.E.Harris, 2013, 7thEdn., Elsevier.
2. Mathematical Methods in Physical Sciences, Mary L. Boas, 2006, 3rdEdn., Wiley.
3. Mathematical Physics, H K Dass, 2014, 6thEdn., S. Chand Publisher.
4. An introduction to Ordinary Differential Equations, E.A. Coddington, 2009, PHI learning.
5. Differential Equations, George F. Simmons, 2007, McGraw Hill.
6. Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.
7. Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.

Paper Name: Mechanics and Waves

Paper Code: PHY101
LTP: 3-0-1

Course Objectives:

1. To understand the dynamics of particles and systems, including central forces, collisions, and motion in non-inertial frames.
2. To explore gravitational principles and their application in analyzing central force motion, satellite orbits, and potential fields.
3. To analyze the rotational dynamics of rigid bodies, focusing on angular momentum, torque, and moments of inertia.
4. To investigate fluid dynamics, including the continuity equation and Bernoulli's principle, and their role in understanding fluid motion.
5. To develop practical skills for performing experiments on rigidity modulus, Young's modulus, viscosity, surface tension, and oscillations using laboratory techniques.

Course Description

This course provides a comprehensive foundation in classical mechanics, focusing on the dynamics of particles and rigid bodies, gravitational and central force motion, rotational dynamics, fluid mechanics, and oscillatory systems. It includes detailed study of inertial and non-inertial reference frames, conservation laws, and the mathematical formulation of motion. The laboratory component reinforces theoretical understanding through hands-on experiments related to elasticity, viscosity, oscillations, and wave phenomena, enhancing practical measurement and analysis skills essential to experimental physics.

Course Outcome:

1. **CO1: Recall** fundamental laws and principles governing particle motion, gravitation, fluid flow, and oscillatory behavior.

2. **CO2: Explain** the physical concepts and mathematical formulations underlying classical mechanics problems.

3. **CO3: Apply** theoretical principles to solve problems involving linear motion, rotation, central forces, and wave propagation.

4. **CO4: Analyze** mechanical systems by constructing physical models, identifying forces, and breaking down complex motion into solvable parts.

5. **CO5: Evaluate** the validity of solutions, compare theoretical predictions with known physical behavior, and assess the applicability of approximations in mechanics.

6. **CO6: Design and conduct** experiments to determine physical constants, verify theoretical laws, and interpret experimental data using appropriate techniques.

Course Content:

Module I: Fundamentals of Dynamics *(11 Hours)*

Velocity and Acceleration in Polar coordinates, Analysis of Central forces, Equation of motion of trajectory of a particle moving under central force, Elastic and inelastic collisions between particles. Centre of Mass. Determination of centre of mass for different geometrically symmetric objects, Principle of conservation of momentum. Impulse. Momentum of variable-mass system: Motion of rocket. Dynamics of a system of particles. Inertial and Non-inertial frames and fictitious forces. Uniformly rotating frame. Centrifugal force. Coriolis force and its applications.

Module II: Gravitation and Central Force Motion *(8 Hours)*

Gravitational potential, potential energy and field. Potential and field due to disc, spherical shell, solid sphere cylinder, conic etc. 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).

Module III: Rotational Dynamics of rigid bodies *(8 Hours)*

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. Calculation of moment of inertia for simple symmetric systems; Ellipsoid of inertia and inertia tensor; Setting up of principal axes in simple symmetric cases.

Module IV: Fluid Motion: *(8 Hours)*

Kinematics of Moving Fluids, Equation of Continuity, Euler's equation, Bernoulli's Theorem, Poiseuille's Equation for Flow of a Liquid through a Capillary Tube. Navier-Stokes equation and its applications.

Module V: Oscillations and Waves *(10 Hours)*

Simple Harmonic Oscillations. Differential equation of SHM and its solution. Damped oscillation, Forced oscillations, power dissipation and Quality Factor, Wave Motion, Concept of Progressive and Standing waves, energy transport.

Module VI: Hands on Training through Mechanics Lab Experiments: (Any 5 at least)

- Determination of Rigidity modulus by Dynamic method.
- Determination of Young's Modulus by Flexure method.
- Determination of coefficient of viscosity by Poiseuille's capillary flow method.
- Determination of Surface Tension of a given liquid by Jurin's Law.
- To determine the value of 'g' using Compound Pendulum.
- Determination of frequency of a tuning fork by using a Sonometer.
- To study Lissajous Figures along with Phase and Frequency determination.

Reference Books

1. An introduction to mechanics, D. Kleppner, R.J. Kolenkow, 1973, McGraw-Hill.
2. Introduction to Classical Mechanics, David Morin, Cambridge University Press
3. Classical Mechanics, Douglas Gregory, Cambridge University Press.
4. Mechanics, Berkeley Physics, vol.1, C.Kittel, W.Knight, et.al. 2007, Tata McGraw-Hill.
5. Physics, Resnick, Halliday and Walker 8/e. 2008, Wiley.
6. Theoretical Mechanics, M.R. Spiegel, 2006, Tata McGraw Hill.

Semester II

Paper Name: Electromagnetic Theory I

Paper Code: PHY102

LTP: 3-0-1

Course Objectives:

1. To understand the principles of electric fields, potentials, and energy, and apply Gauss's Law and Laplace's equation to electrostatic problems.
2. To explore the Method of Electrical Images and boundary value techniques for solving electrostatic problems in various coordinate systems.
3. To analyze the behavior of dielectric materials in electric fields and understand the energy storage in dielectric systems.
4. To evaluate DC circuits using network theorems, including Thevenin, Norton, and Maximum Power Transfer, for solving practical electrical problems.
5. To develop experimental skills in investigating magnetostatics and magnetic materials, focusing on current distributions and hysteresis losses.

Course Description

This course provides a foundational understanding of electrostatics, magnetostatics, and electromagnetic properties of materials. Topics include electric fields, potentials, dielectric behavior, boundary value problems, steady currents, and magnetic fields in matter. Emphasis is placed on applying mathematical techniques such as Gauss's law, Laplace's equation, and vector calculus to solve problems in classical electromagnetism. The laboratory component introduces basic circuit theorems, multimeter usage, hysteresis, and magnetic field measurement, reinforcing theoretical concepts through hands-on experimentation.

Course Outcome:

1. **CO1: Recall** fundamental laws and equations of electrostatics, magnetostatics, and current electricity.

2. **CO2: Explain** the physical meaning of electric and magnetic field concepts, material response, and circuit theorems.

3. **CO3: Apply** Maxwell's laws (in static form), Laplace's equation, and circuit theorems to solve standard problems in electromagnetism.

4. **CO4: Analyze** electric and magnetic field configurations and current distributions in various geometries and material media.

5. **CO5: Evaluate** electromagnetic systems using analytical methods and assess the influence of boundary conditions and material properties.

6. **CO6: Design and perform** basic electrical and magnetic experiments to verify theoretical laws and characterize materials or devices.

Course Content:

Module I: Electric field and Potential *(5 Hours)*

Electrostatic Field, Potential and Energy, Gauss' Law with applications, Laplace's and Poisson equations. The Uniqueness Theorem. Superposition theorem (statement only). Field potential and related properties of an electric dipole.

Module II*: Boundary Value Problems and Method of Electrical Images* *(7 Hours)*

Application of Laplace's equation in 1D, 2D and 3D for Cartesian, Spherical Polar and Cylindrical Polar coordinates. Method of Electrical Images and its application to: (1) Plane Infinite Sheet and (2) Sphere.

Module III*: Dielectric Properties and Electrostatic energy* *(8 Hours)*

Electric Field in matter. Concept of Polarization, Electrical Susceptibility and Dielectric Constant. Capacitor (parallel plate, spherical, cylindrical) filled with dielectric. Displacement vector D. Relations between E, P and D. Gauss' Law in dielectrics, Electrostatic energy of a charged sphere. Gauss' Law in presence of dielectrics, free charge and bound charge, Electrostatic energy density in presence of a dielectric.

Module IV: Steady current *(9 Hours)*

Ohm's law – Differential form, Kirchhoff's Law, Wheatstone bridge – its sensitivity (qualitative discussion only), Network Theorems: Ideal Constant-voltage and Constant-current Sources. Thevenin theorem, Norton theorem, Superposition theorem, Reciprocity theorem, Maximum Power Transfer theorem. Applications to dc circuits.T and π networks.

Module V: Magnetostatics *(8 Hours)*

Lorentz force and concept of magnetic field; Force and Torque on current element; Biot-Savart's law, magnetic vector potential; calculation of vector potential and magnetic induction in simple cases. $\vec{\nabla}\times\vec{B}=\mu_0\vec{J}$. Ampere's Law,

Module VI: Theory of Magnetism and Magnetic materials *(8 Hours)*

Free current and bound current; surface and volume density of current distribution; magnetisation; non-uniform magnetisation of matter; $\vec{\nabla} \times \vec{M} = J_b$; introduction of H; line integral of H in terms of free current; boundary conditions for B and H; hysteresis and energy loss in ferromagnetic material; magnetic circuit; energy stored in magnetic field.

Module VII: Hands on Training through Experiments:

- Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, (d) Capacitances and (e) Checking electrical fuses
- To measure the resistance per unit length of the wire of a bridge and to determine an unknown resistance by Carey Fosters bridge.
- To verify the Thevenin and Norton theorems.
- To verify the Superposition, and Maximum power transfer theorems.
- To draw the B-H curve of Fe using Solenoid & determine energy loss from Hysteresis curve.
- To study the nature of dependence of dipolar field of a short bar magnet on distance with the help of a deflection and Oscillation magnetometer and determine the horizontal component of the Earth's magnetic field.

Reference Books

1. Electricity and Magnetism, Rakshit and Chattopadhyay, New Age Publisher
2. Foundations of Electricity and Magnetism, B. Ghosh
3. Electricity and Magnetism, D. C. Tayal, S. Chand Publisher
4. Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education
5. Introduction to Electrodynamics, D.J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.
6. Feynman Lectures Vol.2, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education

Paper Name: Thermal Physics

Paper Code: PHY103

LTP: 3-0-1

Course Objectives:

1. To understand the Kinetic Theory of gases, including the Maxwell-Boltzmann distribution, mean free path, and transport phenomena in gases.
2. To explore the equation of state for real gases and analyze deviations from ideal gas behavior using Van der Waal's equation.
3. To evaluate the 1st and 2nd laws of thermodynamics, with a focus on assessing the efficiency of heat engines and refrigerators.
4. To investigate thermodynamic systems using Maxwell's relations and analyze phase transitions.
5. To develop experimental skills by conducting experiments related to thermal conductivity and the mechanical equivalent of heat.

Course Description

This course introduces the principles of kinetic theory, thermodynamics, and phase transitions. Students learn the statistical behavior of gases, real gas deviations, and the laws governing energy transfer and entropy. Advanced topics such as Maxwell's relations and phase transition equations are explored for deeper thermodynamic analysis. The laboratory component complements theory with hands-on experiments on thermal conductivity, thermoelectric effects, and temperature measurement techniques, reinforcing core concepts and experimental skills in thermal physics.

Course Outcome:

1. **CO1: Recall** the basic laws of thermodynamics, kinetic theory, and key thermodynamic functions.

2. **CO2: Explain** the behavior of ideal and real gases, energy transformations, and the nature of entropy and temperature.

3. **CO3: Apply** thermodynamic principles and equations to analyze heat engines, refrigerators, and phase transitions.

4. **CO4: Analyze** thermodynamic systems using Maxwell's relations, energy potentials, and transport phenomena in gases.

5. **CO5: Evaluate** thermodynamic processes by solving numerical problems and interpreting the physical significance of the results.

6. **CO6: Design and conduct** thermal experiments to measure physical parameters, calibrate instruments, and verify theoretical relationships.

Course Content:

Module I: Kinetic Theory of Gases *(12 Hours)*

Distribution of Velocities: Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Mean, RMS and Most Probable Speeds. Specific heat of Gases, Mean Free Path, Estimation of Mean Free Path. Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian Motion and its Significance.

Module II: Real Gases *(10 Hours)*

Behavior of Real Gases- Deviations from the Ideal Gas Equation, Van der Waal's Equation of State for Real gases. Joule-Thomson Effect for Real and van der Waal Gases

Module III: Laws of Thermodynamics *(14 Hours)*

Zeroth Law of Thermodynamics & Concept of Temperature, Concept of Work & Heat, State Functions, First Law of Thermodynamics and its differential form, Applications of First Law. 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, Concept of Entropy, Third Law of Thermodynamics. Unattainability of Absolute Zero.

Module IV: Maxwell's relations and Phase Transition *(8 Hours)*

Derivations and applications of Maxwell's Relations, Maxwell's Relations, First and second order Phase Transitions with examples, Clausius-Clapeyron Equation and Ehrenfest equations, Helmoltz Free energy and Gibb's Free energy

Module V: Hands on Training through Experiments (Any Five)

- To estimate the temperature of a torch bulb filament from resistance measurement and to verify Stefan's law
- Determination of Thermal Conductivity of a bad conductor of heat by Lee's and Charlton's method.
- To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT).
- Determination of thermoelectric power at a certain temperature of the given thermocouple.

- Determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
- Determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
- Calibrate a thermocouple to measure temperature in a specified range using (1) Null Method, (2) Direct measurement using Op-Amp difference amplifier and to determine Neutral Temperature.

Reference Books:

1. Thermal Physics, Roy and Gupta.
2. Heat and Thermodynamics, M.W. Zemansky, Richard Dittman, 1981, McGraw-Hill.
3. A Treatise on Heat, Meghnad Saha, and B.N.Srivastava, 1958, Indian Press
4. Thermal Physics, S. Garg, R. Bansal and Ghosh, 2nd Edition, 1993, Tata McGraw-Hill
5. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer
6. Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger. 1988, Narosa.
7. Concepts in Thermal Physics, S.J. Blundell and K.M. Blundell, 2nd Ed., 2012, OxfordUniversity Press

Semester III

Paper Name: Mathematical Methods II

Paper Code: PHY200

LTP: 3-0-1

Course Objectives:

1. To understand and apply Dirac Delta functions and their properties for solving physical problems and interpreting experimental results.
2. To explore the Frobenius method for solving differential equations and gain proficiency in using special functions such as Legendre, Bessel, Hermite, and Laguerre in physics applications.
3. To analyze physical experiments using probability and statistical methods for performing calculations and data interpretation.
4. To investigate physical systems by performing integral transforms (Fourier and Laplace) and solving differential equations both analytically and numerically.
5. To develop practical skills in executing numerical methods, including root finding, interpolation, differentiation, integration, and solving ordinary differential equations using algorithms and techniques.

Course Description

This course explores advanced mathematical techniques essential for solving problems in theoretical physics. Topics include special functions, series solutions of differential equations, probability distributions, integral transforms, and complex analysis. Emphasis is placed on the application of analytical methods such as the Frobenius method, Fourier and Laplace transforms, and Cauchy's theorems. The lab component introduces key numerical algorithms for root finding, interpolation, integration, and differential equations, offering practical tools for solving complex mathematical problems computationally.

Course Outcome:

1. **CO1: Recall** definitions, identities, and properties of special functions, probability distributions, integral transforms, and complex functions.

2. **CO2: Explain** the theoretical foundation and significance of methods such as the Frobenius method, Dirac delta function, and complex variable theory.

3. **CO3: Apply** mathematical tools such as special functions, transforms, and series expansions to solve analytical problems in physics.

4. **CO4: Analyze** mathematical structures and problem-solving strategies for differential equations, probability models, and integral transformations.

5. **CO5: Evaluate** analytical and semi-analytical methods for their applicability to physical systems, including solving numerically interpretable problems.

6. **CO6: Develop** numerical algorithms to solve mathematical problems using root-finding, interpolation, integration, and differential equation solvers.

Course Content:

Module I: Dirac Delta function and its properties *(5 Hours)*

Definition of Dirac delta function. Representation as limit of a Gaussian function and rectangular function. Properties of Dirac delta function.

Module II: Frobenius Method and Special Functions *(12 Hours)*

Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Legendre, Bessel, Hermite and Laguerre Differential Equations. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations. Expansion of function in a series of Legendre Polynomials. Bessel Functions of the First Kind: Generating Function, simple recurrence relations. Zeros of Bessel Functions and Orthogonality. Bessel function of 2nd kind, Generating functions, Spherical Bessel Functions, Legendre polynomials, Orthogonality, Physical interpretation of Generating functions, Associated Legendre's Equation, Spherical Harmonics, Hermite functions, Laguerre Functions.

Module III: Concept of Probability *(8 Hours)*

Basic concepts of probability distribution. Permutations and Combinations, Conditional Probability, Conditional Probability, Binomial distribution, Poisson's distributions, Multinomial distributions. Problems on probability calculation.

Module IV: Integral Transform *(9 Hours)*

Fourier and Laplace transform and their inverse transforms, Application of Laplace transform, Bromwich integral [use of partial fractions in calculating inverse Laplace transforms], Discrete Fourier Transform, Transform of derivative and integral of a function, Solution of differential equations using integral transforms.

Module V: Complex Variables *(12 Hours)*

Recapitulation of Complex numbers, triangular inequalities, Schwarz inequality. Function of a complex variable, single and multiple-valued function, limit and continuity, Differentiation, Cauchy-Riemann equations and their applications, Analytic and harmonic function, Complex integrals, Cauchy's theorem (elementary proof only), converse of Cauchy's theorem, Cauchy's Integral Formula and its corollaries, Series: Taylor and Laurent expansion, Classification of singularities, Branch point and branch cut, Cauchy's Residue theorem and evaluation of some typical real integrals using this theorem.

Module VI: Hands on Training

- **Root Finding for a Single Variable:** Bisection Method, Newton-Raphson Method
- **Interpolation:** Lagrange Interpolation, Newton Forward and Backward Interpolation
- **Numerical Differentiation and Integration:** Numerical Differentiation, Integration: Trapezoidal rule, Simpson's 1/3 method, Simpson's composite method, n-point Gaussian Quadrature method
- **Solution of Ordinary Differential Equation:** Solution of 1st order and 2nd ordinary differential equation – Euler algorithm, Runge Kutta algorithm (2nd Order and 4th Order)

Reference Books:

1. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 2013, 7th Edn., Elsevier.
2. An introduction to Ordinary Differential Equations, E.A. Coddington, 2009, PHI learning
3. Differential Equations, George F. Simmons, 2007, McGraw Hill.
4. Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.
5. Advanced Engineering Mathematics, D.G. Zill and W.S. Wright, 5 Ed., 2012, Jones and Bartlett Learning
6. Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
7. Mathematical Methods in Physical Sciences, Mary L. Boas, Wiley
8. Mathematical Methods for Physics and Engineering, K. F. Riley, M. P. Hobson, S. J. Bence, Cambridge University Press
9. Differential and Integral Calculus, N. Piskunov, Mir Publisher
10. Vector Analysis, Murry R. Spiegel, Schuam Series.
11. Mathematical Physics, H K Dass, S Chand Publisher
12. Differential Equations, S. L. Ross, Wiley

Paper Name: Electronics I

Paper Code: PHY201
LTP: 3-0-1

Course Objectives:

1. To understand the operation of PN junction diodes, including drift and diffusion processes, rectification, and their applications in voltage regulation using Zener, Schottky, and tunnel diodes.
2. To explore the behavior and characteristics of transistors (PNP, NPN) in different configurations (CB, CC, CE) and perform load line analysis to determine the Q-point.
3. To design and analyze transistor biasing circuits and amplifiers (CE, RC-coupled), focusing on their stability, efficiency, and frequency response using h-parameters and equivalent circuits.
4. To simplify and optimize logic circuits using Boolean algebra and Karnaugh maps, and apply digital logic gates in practical applications such as parity checking and binary addition.
5. To develop practical skills in constructing basic data processing circuits like multiplexers, demultiplexers, encoders, decoders, and arithmetic circuits to perform simple data manipulation tasks.

Course Description

This course introduces the fundamentals of semiconductor electronics, including the operation and applications of diodes, transistors, and digital logic circuits. Topics include rectifiers, amplifiers, switching behavior, biasing techniques, and digital logic simplification. Emphasis is placed on understanding device characteristics and circuit behavior in analog and digital systems. The laboratory component provides hands-on experience in designing and analyzing electronic circuits, enabling students to connect theoretical principles with practical applications in modern electronics.

Course Outcome:

1. **CO1: Recall** the basic principles of semiconductor devices, rectifiers, transistors, logic gates, and data processing circuits.

2. **CO2: Explain** the working principles of analog and digital components, including diode behavior, transistor configurations, amplifier models, and Boolean logic.

3. **CO3: Apply** circuit analysis techniques to design and evaluate analog and digital circuits using discrete components.

4. **CO4: Analyze** the performance of electronic circuits in terms of voltage/current relationships, frequency response, and logical operations.

5. **CO5: Evaluate** circuit behavior and design choices through numerical calculations and circuit simulations for both analog and digital systems.

6. **CO6: Design and implement** basic analog and digital circuits using diodes, transistors, and logic gates, and verify their behavior through experimental measurements.

Course Content:

Module I: Revisions of fundamentals *(10 Hours)*

Conduction mechanisms: Drift and Diffusion, Basics of PN junction, Derivation for Barrier Potential, Depletion region, Diode rectification: Half-wave, Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, Clipper and Clamper circuits. Application of diodes: Zener Diode and Voltage Regulation. Silicon Controlled rectifier (SCR, Thyristor), Schottky and Tunnel diode and Solar Cell.

Module II: Three terminal devices *(8 Hours)*

Transistor fundamentals: PNP and NPN Types and CB, CC and CE Configurations, Current gains α, β, g, and their Relations, Load Line analysis Q-point of Transistors. Transistor behaves as switch.

Module III: Amplifiers *(8 Hours)*

Transistor Biasing and Stabilization, Thermal runaway, Fixed Bias, Collector to base bias and Voltage Divider Bias, Cascaded amplifiers, Transistor as 2-port Network. H-parameter Equivalent Circuit. Analysis of a single-stage CE amplifier using Hybrid Model. Input and Output Impedance. Current, Voltage and Power Gains. Darlington pair, RC-coupled amplifier and its frequency response.

Module IV: Digital Electronics *(11 Hours)*

Fundamentals, Difference between Analogue and Digital electronics. Binary Numbers, Conversion: Decimal, Binary, Octal and Hexadecimal numbers. Logic gates: Basic and Universal Gates. XOR and XNOR Gates and application as Parity Checkers.

Boolean algebra: De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra. Idea of Minterms and Maxterms. Conversion of a Truth table into Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map.

Module V: Data Processing Circuits *(8 Hours)*

Data processing circuits: Basic idea of Multiplexers, De-multiplexers, Decoders, and Encoders. Arithmetic Circuits: Binary Addition. Binary Subtraction using 2's Complement. Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder/Subtractor.

Module VI: Hands on Training (Any Five):

- To Determine the V-I Characteristics of a Light Emitting Diode (LED) and calculate the Wavelength of the Emitted Light “OR” Determination of Planck’s Constant using LED.
- To study the V-I characteristics of a Zener diode and its use as voltage regulator.
- Designing of a Half Wave and Full Wave rectifier with and without filter.
- To study the characteristics of a Bipolar Junction Transistor in CE configuration.
- To design AND, OR and a switch (NOT gate) using a diode and transistor.
- To verify and design AND, OR, NOT and XOR gates using NAND gates. NAND and NOR gates as Universal Gates.

Optional:

- To study V-I characteristics of PN junction diode (Both Forwards and Reverse bias mode).
- Study of CRO & Measurement of Voltage Amplitude & Frequency.

Reference Books:

1. Digital Principles and Applications, A.P. Malvino, D.P.Leach and Saha, 7th Ed., 2011, Tata McGraw
2. Fundamentals of Digital Circuits, Anand Kumar, 2nd Edn, 2009, PHI Learning Pvt. Ltd.
3. Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.
4. Digital Systems: Principles & Applications, R.J.Tocci, N.S.Widmer, 2001, PHI Learning
5. Logic circuit design, Shimon P. Vingron, 2012, Springer.
6. Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning
7. Microprocessor Architecture Programming & applications with 8085, 2002, R.S. Goankar, Prentice Hall.
8. Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
9. Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.
10. Solid State Electronic Devices, B.G. Streetman & S.K. Banerjee, 6th Edn., 2009, PHI Learning4. *Digital Systems: Principles & Applications*, R.J.Tocci, N.S.Widmer, 2001, PHI Learning

Paper Name: Electromagnetic Theory II

Paper Code: PHY202

LTP: 3-0-1

Course Objectives:

1. To analyze the motion of charged particles in electric and magnetic fields, applying electromagnetism principles to solve related problems.
2. To apply Maxwell's equations to explain the propagation of electromagnetic waves in various media and interpret energy transfer using the Poynting theorem.
3. To understand and explain the phenomena of interference, diffraction, and polarization in optics, employing wave theory principles to address related problems.
4. To evaluate the properties of waveguides, including phase and group velocities, and discuss their implications for electromagnetic wave propagation.
5. To develop practical skills through experiments related to electromagnetic theory, optics, and quantum effects, such as measuring self-inductance, studying LCR circuits, and verifying fundamental atomic theories.

Course Description

This course provides a comprehensive introduction to the classical theory of electromagnetism and wave optics. Students explore the motion of charged particles in electric and magnetic fields, electromagnetic wave propagation through different media, and foundational concepts in interference, diffraction, and polarization. The course further introduces optical waveguides and guided modes. The hands-on laboratory component reinforces theoretical concepts through experiments in electromagnetism, optics, and atomic physics, cultivating a strong foundation in both physical understanding and experimental techniques.

Course Outcome:

1. **CO1: Recall** key concepts, equations, and laws related to electromagnetism, optics, and wave phenomena.

2. **CO2: Explain** the principles governing electromagnetic wave propagation, optical interference, diffraction, and polarization.

3. **CO3: Apply** Maxwell's equations, wave equations, and optical principles to solve analytical problems in classical electrodynamics and optics.

4. **CO4: Analyze** physical situations involving wave interactions, boundary conditions, field behavior, and optical system response.

5. **CO5: Evaluate** theoretical models and solve numerical problems to interpret experimental or physical outcomes in electromagnetism and optics.

6. **CO6: Design** and perform experiments related to electromagnetic phenomena and optics, analyze data, and validate theoretical predictions.

Course Content:

Module I: Motion of Charged Particles in Electro-magnetic field and Electromagnetic induction *(8 Hours)*

Motion of a charged particle in external Electric and Magnetic field (when velocity is perpendicular to the Magnetic field/not perpendicular to the magnetic field), Crossed Electric and Magnetic field. Basic principles of J. J. Thompson's Experiment. Faraday's and Lenz's law; motional e.m.f-simple problems; calculation of self and mutual inductance in simple cases; inductances in series and parallel; reciprocity theorem.

Module II: Maxwell Equations and EM Wave Propagation in Unbounded and Bounded Media *(12 Hours)*

Maxwell's equations. Gauge Transformations- Lorentz and Coulomb Gauge. Boundary Conditions at Interface between Different Media. Wave Equations. Poynting Theorem and Poynting Vector. Electromagnetic (EM) Energy Density, Plane EM waves through vacuum, isotropic dielectric medium, conducting medium. Fresnel's Formulae for perpendicular & parallel polarization cases, Brewster's law. Reflection & Transmission coefficients. Total internal reflection, evanescent waves. Metallic reflection (normal Incidence).

Module III: Optics *(14 Hours)*

Interference: Division of amplitude and wave front. Young's double slit experiment. Fresnel's Bi-prism, Interference in Thin Films: parallel and wedge-shaped films. Newton's Rings, Interferometer: Michelson Interferometer, Fabry-Perot interferometer.

Diffraction: Fraunhofer diffraction: Single slit. Circular aperture, Resolving Power of a telescope. Double slit. Multiple slits. Diffraction grating. Resolving power of grating. Fresnel Diffraction, Fresnel's Half-Period Zones for Plane Wave. Theory of a Zone Plate, Fresnel diffraction pattern of a straight edge, a slit and a wire.

Polarization: Description of Linear, Circular and Elliptical Polarization. Fresnel's Formula. Uniaxial and Biaxial Crystals. Nicol Prism. Circularly and Elliptically Polarized Light. Quarter-Wave and Half-Wave Plates. Babinet Compensator and its Uses. Analysis of Polarized Light, Fresnel's Theory of optical rotation. Calculation of angle of rotation. Experimental verification of Fresnel's theory. Specific rotation.

Module IV: Wave Guides *(8 Hours)*

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.

Module VI: Hands on Training (at least 8)

- 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.
- To study the response curve of a parallel LCR circuit and determine its (a) Anti-resonant frequency and (b) Quality factor Q.
- To determine the wavelength of H-alpha emission line of Hydrogen atom.
- To determine the value of e/m by J. J. Thompson method.
- To determine the wavelength and velocity of ultrasonic waves in a liquid (Kerosene Oil, Xylene, etc.) by studying the diffraction through ultrasonic grating.
- To determine the refractive Index of (1) glass and (2) a liquid by total internal reflection using a Gaussian eyepiece.
- To determine the specific rotation of sugar solution using Polarimeter.
- Adjustment of the Spectrometer for parallel rays by Schuster's method and to determine the wavelength of a monochromatic light by Newton's ring method

Reference Books

1. Electricity and Magnetism, Rakshit and Chattopadhyay, New Age Publisher
2. Foundations of Electricity and Magnetism, B. Ghosh
3. Electricity and Magnetism, D. C. Tayal, S. Chand Publisher
4. Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education
5. Introduction to Electrodynamics, D.J. Griffiths, 3rd Edn., 1998, Benjamin Cummings
6. Elements of Electromagnetics, M.N.O. Sadiku, 2001, Oxford University Press.
7. Introduction to Electromagnetic Theory, T.L. Chow, 2006, Jones & Bartlett Learning
8. Fundamentals of Electromagnetics, M.A.W. Miah, 1982, Tata McGraw Hill
9. Electromagnetic Fields & Waves, P.Lorrain&D.Corson, 1970, W.H.Freeman& Co.
10. Electromagnetics, J.A. Edminster, Schaum Series, 2006, Tata McGraw Hill.

Semester IV

Paper Name: Quantum Mechanics

Paper Code: PHY203

LTP: 4-0-0

Course Objectives:

1. To understand the phenomenon of blackbody radiation and its significance in the development of quantum theory.
2. To explore quantum states and wave functions, focusing on their probabilistic interpretations and the role of quantum operators in describing physical observables.
3. To apply Schrödinger's equation to solve one-dimensional quantum problems, including potential wells and harmonic oscillators.
4. To investigate the operator formulation of quantum mechanics and analyze the addition of angular momentum.
5. To solve three-dimensional quantum problems using Schrödinger's equation and explore their physical implications.

Course Description:

This course provides a foundational understanding of quantum mechanics, beginning with the limitations of classical theories and the development of quantum ideas. Emphasis is placed on the mathematical structure of quantum mechanics, including wave functions, operators, and the Schrödinger equation. Students will explore conceptual and computational approaches to quantum systems and develop the skills necessary to analyze and interpret quantum phenomena using both analytical and formal techniques.

Course Outcome:

1. **CO1: Recall** key concepts, principles, and mathematical tools used in quantum mechanics.
2. **CO2: Explain** the theoretical foundations and formalism of quantum mechanics using appropriate physical and mathematical language.
3. **CO3: Apply** quantum mechanical principles and equations to solve problems involving physical systems.
4. **CO4: Analyze** mathematical structures and physical interpretations of quantum systems using operator methods and formal frameworks.
5. **CO5: Evaluate** quantum mechanical solutions and models by solving problems and interpreting physical results.

Course Content:

Module I: Blackbody Radiation *(12 Hours)*

Classical Theory of Radiation: Blackbody Radiation. Kirchhoff's law. Stefan-Boltzmann law: Thermodynamic proof. Radiation Pressure. Wien's Displacement law. Wien's Distribution Law. Rayleigh-Jean's Law. Ultraviolet Catastrophe.

Quantum Theory of Radiation: Spectral Distribution of Black Body Radiation. Planck's Quantum Postulates. Planck's Quantum theory of Blackbody Radiation: Experimental Verification. Deduction of (1) Wien's Distribution Law, (2) Rayleigh-Jeans Law, (3) Stefan-Boltzmann Law, (4) Wien's Displacement law from Planck's law

Photoelectric Effect, Compton Effect, Pair Production, Matter wave, Wave-Particle duality, Uncertainty Principle, Localized Wave Packet, Motion of Wave packet

Module II: **Mathematical Foundation of Quantum Mechanics** *(15 Hours)*

Mathematical Foundation of Quantum Mechanics, Postulates of Quantum Mechanics, Schrodinger Equation, Operators and Observables, Introduction to bra-ket formulation, Representation of operators in discrete bases (Matrix representation), unitary transformations Equation of Continuity, Time evolution of system, Relation between Classical and Quantum Mechanics

Module III: One Dimensional Problems *(10 Hours)*

Application of Schrodinger equation in One dimension, Free Particle, Potential Step problem, Potential barrier, Infinite Square Well potential, Harmonic Potential, Delta Function potential.

Module IV: Angular Momentum *(12 Hours)*

Angular Momentum, Orbital and Spin angular momentum, Pauli Matrix, General Formalism of Angular momentum, Spherical harmonics, Matrix representation

Module V: Three Dimensional Problems *(10 Hours)*

Three-dimensional problems, Isotropic harmonic oscillator, Hydrogen atom problem

Reference Books:

1. Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.
2. Introduction to Modern Physics, Rich Meyer, Kennard, Coop, 2002, Tata McGraw Hill
3. Introduction to Quantum Mechanics, David J. Griffith, 2005, Pearson Education.
4. Physics for scientists and Engineers with Modern Physics, Jewett and Serway, 2010, Cengage Learning.

5. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, 2ed. 2006, Robert Eisberg,Robert Resnick
6. Quantum Mechanics, Leonard I. Schiff, 3rd Edn. 2010, Tata McGraw Hill.
7. Quantum Mechanics, G. Aruldhas, 2nd Edn. 2002, PHI Learning of India.
8. Quantum Mechanics, Bruce Cameron Reed, 2008, Jones and Bartlett Learning.
9. Quantum Mechanics: Foundations & Applications, Arno Bohm, 3rd Edn., 1993, Springer
10. Quantum Mechanics for Scientists & Engineers, D.A.B. Miller, 2008, Cambridge University

Paper Name: Electronics II

Paper Code: PHY204

LTP: 3-0-1

Course Objectives:

1. To understand the working principles and structures of Junction and Metal-Oxide Field Effect Transistors (MOSFETs) and explore their applications in electronic circuits.
2. To describe the characteristics and configurations of Operational Amplifiers (IC 741), including their use in inverting and non-inverting amplifiers, differentiators, and oscillators.
3. To classify different types of Integrated Circuits (ICs), considering the scale of integration and evaluating their advantages and limitations.
4. To analyze combinational and sequential logic circuits, employing components such as Flip-Flops, Shift Registers, and Counters in circuit design.
5. To apply knowledge of the 8085 Microprocessor, focusing on memory organization, instruction sets, and interfacing, for basic programming tasks and laboratory experiments.

Course Description:

This course introduces advanced concepts in analog and digital electronics, focusing on field-effect transistors, operational amplifiers, oscillators, and digital logic circuits. Students explore combinational and sequential logic design, integrated circuit technology, and the fundamental structure of microprocessor-based systems. The laboratory component emphasizes hands-on circuit implementation, analog and digital signal processing, and basic programming with the 8085 Microprocessor. The course equips students with the theoretical knowledge and practical skills necessary for modern electronic system design.

Course Outcome:

1. **CO1: Recall** fundamental concepts and components related to analog and digital circuits, different kind of signals, integrated systems, and microprocessors.

2. **CO2: Explain** the principles and working of analog amplifiers, oscillators, modulation fundamentals, logic circuits, and microprocessor architecture.

3. **CO3: Apply** theoretical knowledge to analyze and design basic analog and digital electronic circuits and basic circuit employed in communication electronics.

4. **CO4: Analyze** circuit performance, feedback behavior, amplitude and frequency modulation, timing sequences, and logical operations within electronic systems.

5. **CO5: Evaluate** circuit behavior and microprocessor programs by solving numerical problems and predicting output characteristics.

6. **CO6: Design and implement** analog and digital circuits and develop microprocessor- based solutions through hands-on experimentation

Course Content:

Module I: Four terminal device *(10 Hours)*

Field effect Transistors: Junction and Metal oxide field effect transistors, Structure and physical operation. Types of MOSFETs, Capacitance in MOS devices, Applications. Feedback in Amplifiers: Effects of Positive and Negative Feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise.

Module II: Op-AMPs (IC 741) *(10 Hours)*

Characteristics of an Ideal and Practical Op-Amp. Open-loop and Closed- loop Gain. Null offset approach, Frequency Response, CMRR, Application of Op-Amp: (1) Inverting and non-inverting amplifiers, (2) Adder, (3) Subtractor, (4) Differentiator, (5) Integrator, (6) Schmitt trigger etc., Sinusoidal Oscillators, Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator, Determination of Frequency. Oscillators: Wein-bridge, Hartley & Colpitts, Crystal oscillators

Module III: Communication Electronics *(10 Hours)*

Introduction to Communication Systems, Types of Signals and Systems, Modulation Fundamentals, Amplitude Modulation (AM), Frequency Modulation (FM), Demodulation Techniques, Transmission Media & Antennas, Introduction to Noise in Communication, Basic Electronic Components in Communication, Simple Communication Circuits & Applications

Module III: Integrated Circuits and VLSI Integrated Circuits (Qualitative treatment only) *(10 Hours)*

Active & Passive components. Discrete components. Wafer. Chip. Advantages and drawbacks of ICs. Scale ofintegration: SSI, MSI, LSI and VLSI (basic idea and definitions only). Classification of ICs. Examples of Linear and Digital ICs

Module IV: Combinational and Sequential Logic Gates Digital Electronics II *(10 Hours)*

Flip Flop: Sequential Circuits: SR, D, and JK Flip-Flops. Clocked (Level and Edge Triggered) Flip-Flops. Race-around conditions in JK Flip-Flop. M/S JK Flip Flop. Timers: IC 555: block diagram and applications: Multivibrator: Astable and Monostable, Shift registers: Serial-in-Serial-out, Serial-in-Parallel-out, Parallel- in-Serial-out and Parallel-in-Parallel-out Shift Registers (only up to 4 bits). Counters (4 bits): Ring Counter. Asynchronous counters, Decade Counter. Synchronous Counter.

Module V: Microprocessor Computer Organization, 8085 Microprocessor *(5 Hours)*

Input/output Devices. Data storage (idea of RAM and ROM).Computer memory. Memory organization & addressing. Memory Interfacing. Memory Map. Main features of 8085. Block diagram. Components. Pinout diagram. Buses. Registers. ALU. Memory. Stack memory. Timing & Control circuitry. Timing states.

Module VI: Hands on Training (Any 5):

- Study a Regulated Power Supply based load and line regulation characteristics.
- Half Subtractor, Full Subtractor, Adder-Subtractor using Full Adder ICs.
- To design and test the following circuits using an OPAMP
  - Inverting and Non-inverting amplifier
  - Differential amplifier.
  - Adder
  - Integrator
  - Differentiator.
- To design a Wien bridge oscillator for given frequency using an OPAMP.
- To design a digital to analog converter (DAC) of given specifications.
- To study the analog to digital convertor (ADC) IC.
- To build Flip-Flop (RS, Clocked RS, D-type and JK) circuits using NAND gates.
- Write the following programs using 8085 Microprocessor:
  - Addition and subtraction of numbers using direct addressing mode.
  - Addition and subtraction of numbers using indirect addressing mode.
  - Multiplication by repeated addition.
  - Division by repeated subtraction.

Reference Books:

1. Digital Principles and Applications, A. P. Malvino, D.P.Leach,7thEd., 2011, Tata McGraw
2. Fundamentals of Digital Circuits, Anand Kumar, 2nd Edn., 2009, PHI Learning Pvt. Ltd.
3. Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.
4. Digital Systems: Principles & Applications, R. J. Tocci, N. S. Widmer, 2001, PHI Learning
5. Logic circuit design, Shimon P. Vingron, 2012, Springer.

6. Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning.
7. Microprocessor Architecture Programming & applications with 8085, 2002, R.S. Goankar, Prentice Hall.
8. Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
9. Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.
10. Solid State Electronic Devices, B.G.Streetman&S.K.Banerjee, 6th Edn.,2009, PHI Learning
11. Electronic Devices & circuits, S. Salivahanan& N. S. Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill
12. OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall
13. Electronic circuits: Handbook of design & applications, U.Tietze, C.Schenk, 2008, Springer

Paper Name: Analytical Mechanics and Special Theory of Relativity

Paper Code: PHY205
LTP: 4-0-0

Course Objectives:

1. To understand the principles of Lagrangian mechanics and apply the Lagrange equations to analyze simple physical systems, including oscillators and pendulums.
2. To apply Hamilton's equations for solving mechanics problems related to conservative forces and electromagnetic fields.
3. To analyze small oscillations and continuous systems, identifying normal modes and frequencies in physical systems, such as coupled pendulums.
4. To interpret the fundamental concepts of the Special Theory of Relativity, focusing on time dilation, length contraction, and energy-momentum relations.
5. To solve problems in rigid body dynamics using advanced concepts, including Euler angles, rotational matrices, and the moment of inertia tensor.

Course Description:

This course explores the mathematical foundations and advanced formulations of classical mechanics. Students will learn the Lagrangian and Hamiltonian approaches, mechanics of small oscillations, and dynamics of rigid bodies. The course also introduces the principles of special relativity and applies advanced analytical methods to a variety of physical systems. Emphasis is placed on problem-solving, physical interpretation, and the structural elegance of classical theories in modern physics.

Course Outcome:

1. **CO1: Recall** the fundamental principles, mathematical tools, and classical formulations used in advanced mechanics.

2. **CO2: Explain** the concepts of variational methods, dynamical equations, small oscillations, relativistic transformations, and rigid body motion.

3. **CO3: Apply** analytical techniques such as Lagrangian and Hamiltonian formalisms to solve problems in classical and relativistic mechanics.

4. **CO4: Analyze** physical systems using coordinate transformations, stability criteria, and normal mode analysis.

5. **CO5: Evaluate** the results of classical mechanics problems through analytical calculations and interpret the physical significance of the solutions.

Course Content:

Module I: Variational Principles and Lagrangian Formulation *(12 Hours)*

Introduction to calculus of variations, few applications, Hamilton's Variational Principle, D' Alembert's principle, Lagrange's Equation of motion, Linear harmonic Oscillator, Few applications like simple pendulum, linear harmonic oscillator, isotropic oscillator, particle moving under a central force field, Atwood's machine, particle on a sphere, Compound pendulum. Invariance of Lagrange's equation under Galilean Transformation.

Module II: Hamiltonian Formulation *(12 Hours)*

Hamilton's equation of motion, Advantage of Hamiltonian approach, Applications of Hamilton's equation like simple pendulum, compound pendulum, Isotropic harmonic oscillator, Particle moving near the surface of earth, particle in a central force field. Hamiltonian for a charged particle in an electromagnetic field, Principle of least action, canonical transformation, Poisson's bracket.

Module III: Mechanics of small oscillations and continuous systems *(9 Hours)*

Stable and unstable Equilibrium, Formulation of the problem: Lagrange's equation of motion for small oscillations, Properties of T, V and ω, Normal co-ordinates and normal frequencies of vibration, Few applications- Parallel pendulum, Double pendulum, Triple pendulum, Transition from discrete to a continuous systems.

Module IV: Special Theory of Relativity *(12 Hours)*

Michelson-Morley Experiment, 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. Energy-Momentum Four Vector.

Module V: Rigid Body Motion *(11 Hours)*

Degrees of freedom, Orthogonal Transformations and properties of transformation matrices, Euler angles, Euler's Theorems on the motion of a rigid body, Finite and infinitesimal rotations, Moment of Inertia tensor, Principal axis of transformation, solution of rigid body problem using Euler equation of motion

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. Classical Electrodynamics, J.D. Jackson, 3rd Edn., 1998, Wiley.
4. The Classical Theory of Fields, L.D Landau, E.M Lifshitz, 4th Edn., 2003, Elsevier.
5. Introduction to Electrodynamics, D.J. Griffiths, 2012, Pearson Education.
6. Classical Mechanics: An introduction, Dieter Strauch, 2009, Springer.
7. Solved Problems in Classical Mechanics, O.L. Delange and J. Pierrus, 2010, Oxford Press

Semester V

Paper Name: Statistical Mechanics

Paper Code: PHY300

LTP: 4-0-0

Course Objectives:

1. To introduce the statistical foundations of thermodynamics, emphasizing microstates, macrostates, and the interpretation of entropy.
2. To familiarize students with the concepts of ensembles and the use of probability in describing systems in equilibrium.
3. To develop an understanding of classical statistics through the Maxwell-Boltzmann distribution and its relevance to ideal gas behavior.
4. To explore quantum statistical mechanics, with attention to the characteristics and applications of Bose-Einstein and Fermi-Dirac systems.
5. To apply statistical methods to analyze thermodynamic functions and physical phenomena such as specific heat, magnetic response, and quantum degeneracy.

Course Description:

This course introduces students to the foundational and advanced principles of statistical mechanics, which bridge the gap between microscopic particle behavior and macroscopic physical laws. Beginning with classical approaches and extending into quantum statistical models, the course develops an understanding of ensembles, probability distributions, and thermodynamic quantities. Key concepts such as entropy, phase space, and fluctuations are studied in depth, along with applications of Maxwell-Boltzmann, Bose-Einstein, and Fermi-Dirac statistics. Students will gain the ability to model real-world systems like gases, metals, and photon-based systems using theoretical tools rooted in statistical mechanics.

Course Outcome:

1. **CO1: Recall and define** the core concepts of statistical mechanics, including microstates, macrostates, phase space, entropy, and the fundamental postulates of classical and quantum statistics.

2. **CO2: Explain** the construction and significance of statistical ensembles—microcanonical and canonical—along with the derivation and meaning of thermodynamic quantities such as partition function, energy, and entropy.

3. **CO3: Apply** the Maxwell-Boltzmann distribution to calculate particle velocities and energy distributions in gases, and use the law of equipartition to interpret physical behavior in classical systems.

4. **CO4: Analyze** the principles and outcomes of quantum statistical distributions, such as Bose-Einstein and Fermi-Dirac, and their application to photon gas, electron gas, and phenomena like Bose-Einstein condensation.

5. **CO5: Evaluate** and Integrate theoretical tools from classical and quantum statistics to solve problems involving real systems, including Bose-Einstein condensation, Fermi energy calculations, and thermoelectric behavior.

Course Content:

Module I: Introduction *(8 hours)*

Objective of statistical mechanics, Macrostates and microstates, phase space and statistical ensembles, Ergodic hypothesis, postulate of equal a priori probability (PEAP) and equality of ensemble average and time average, Boltzmann's postulate of entropy, Counting the number of microstates in phase space, Liouville's Theorem (Derivation and description) Boltz H-theorem.

Module II: Ensembles *(10 hours)*

Microcanonical Ensemble*:* Description, Probability distribution function, Different properties, Thermal and Mechanical interaction, Equation of state, Entropy of a classical ideal gas, Gibb's paradox, spin 1/2 particles in an external magnetic field.

Canonical Ensemble*:* System in contact with a heat reservoir, expression of entropy, canonical partition function, Equation of State, Average energy, Magnetization of spin 1/2 particles in an external magnetic field. Helmholtz free energy, fluctuation of internal energy.

Module III: Maxwell-Boltzmann statistics and Distribution law *(10 hours)*

Maxwell-Boltzmann Energy distribution function, Maxwell Boltzmann law of velocity distribution (most probable velocity, average velocity, RMS velocity), Limitations of M-B statistics, Law of Equipartition of Energy (with proof). Applications to Specific Heat and its Limitations, Elementary idea of quantum statistics.

Module IV: Introduction to Quantum Statistics *(25 hours)*

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

Fermi-Dirac Statistics: Fermi-Dirac Distribution Law, Thermodynamic functions of a Completely and strongly Degenerate Fermi Gas, Fermi Energy, Electron gas in a Metal, Specific Heat of Metals,

Reference Books:

1. Introductions to Statistical Mechanics, B.B.Laud
2. Statistical Physics (Allied Publishers), J. K. Bhattarjee:
3. Statistical Physics (Mc.Graw Hill), F.Reif:
4. Statistical Physics (Chapman and Hall/CRC), K.Hung:
5. Statistical Mechanics, R.K. Pathria

Paper Name: Advanced Quantum Mechanics

Paper Code: PHY301

LTP: 4-0-0

Course Objectives:

1. To describe the behavior of particles in three-dimensional potential problems, including the analysis of systems such as the hydrogen atom, harmonic oscillator, and the addition of angular momentum.
2. To apply time-independent perturbation theory for solving energy corrections in quantum systems, including relativistic mass corrections and the Zeeman effect.
3. To analyze the WKB approximation method and tunneling phenomena, applying these concepts to bound states and potential wells.
4. To explain time-dependent perturbation theory and utilize it for evaluating transition probabilities, including the adiabatic and sudden approximations.
5. To evaluate scattering cross-sections using the Born approximation and partial wave analysis to understand elastic scattering and particle interactions.

Course Description:

This course explores advanced topics in quantum mechanics with a focus on mathematical formalisms and approximation techniques used to solve complex quantum systems. Topics include three-dimensional potentials, angular momentum addition, perturbation theories (both time-independent and time-dependent), variational methods, and scattering theory. The course emphasizes physical insight and rigorous analytical skills required to study atomic systems, transitions, and quantum interactions in both bound and continuum states.

Course Outcome:

1. **CO1: Recall** key principles, mathematical tools, and approximation methods used in advanced quantum mechanics.

2. **CO2: Explain** advanced quantum mechanical concepts including perturbation theory, angular momentum, scattering, and transition probabilities.

3. **CO3: Apply** analytical techniques such as the variational method, WKB approximation, and perturbation theory to solve quantum mechanical problems.

4. **CO4: Analyze** quantum systems using formal tools such as angular momentum algebra, partial wave analysis, and operator methods.

5. **CO5: Evaluate** physical results obtained from approximation methods and scattering theory, and interpret their implications in quantum systems.

Course Content:

Module I: Three Dimensional Potential Problems and Angular Momentum *(14 Hours)*

Recapitulation of Hydrogen atom, 3-D problems in Cartesian co-ordinate; free particle, Box potential, Delta function potential, Harmonic Oscillator, 3-D problems in Spherical polar co-ordinate; free particle, square well potential, isotropic harmonic oscillator. Addition of angular momenta, Clebsch-Gordan co-efficient.

Module II: Approximation methods in quantum mechanics *(20 Hours)*

Time independent perturbation theory: (both non-degenerate and degenerate), First and Second order correction in energy Eigenvalues, and first order corrections in energy Eigen functions. Degenerate perturbation theory, application to one-electron system, Relativistic mass correction, Spin-orbit coupling (L-S and J-J coupling), Zeeman effect, Stark effect.

WKB Approximation: Quantization rule, General formalism, Bound states for potential wells with No rigid walls/ with One rigid wall/ with Two rigid walls, tunneling through a barrier, qualitative discussion of α decay.

Variational method: He atom as example; First order perturbation; Exchange degeneracy; Ritz principle for excited states for Helium atom.

Module III: Time dependent perturbation theory *(11 Hours)*

The pictures of Quantum Mechanics, Schrodinger picture, Heisenberg's picture and Interaction picture. Theoretical framework of time-dependent perturbation theory, Transition probability for a Constant perturbation and Harmonic perturbation, Fermi Golden rule, Adiabatic and Sudden approximations.

Module IV: Scattering Theory *(10 Hours)*

Scattering cross-section, lab frame and CM frame, Scattering amplitude and differential cross section, Green's function technique in scattering phenomena, Born approximation, Validity of Born Approximation, Partial Wave analysis for elastic scattering, scattering of identical particles.

Reference Books

1. Quantum Mechanics; L.I. Schiff:
2. Quantum Mechanics; NouredineZettili, John Wiley and Sons Ltd.
3. Quantum Mechanics; David J. Griffiths
4. Advanced Quantum Mechanics, J.J. Sakurai

5. Quantum Mechanics vol. 1 and 2; C. Cohen-Tannoudji, B. Dier, and F. Laloe:
6. Quantum Mechanics;E. Merzbacher
7. Quantum Mechanics, Vol. II; E. Merzbacher
8. Quantum Mechanics, Bransden and Joachain, Pearson Education.

Paper Name: Advanced Physics Lab I

Paper Code: PHY302
LTP: 0-0-2

Course Objectives:

1. To introduce experimental techniques in optics and optoelectronics using laser and fiber-optic systems.
2. To familiarize students with the operational behavior of key semiconductor and photonic devices.
3. To develop the ability to perform quantitative measurements and interpret I-V characteristics of non-linear devices like DIAC, SCR, and TRIAC.
4. To help students gain practical insight into polarization, interferometry, and optical losses in fibers.
5. To enhance problem-solving skills and critical thinking in designing and analyzing physics experiments.

Course Description:

This laboratory course provides hands-on training in advanced experimental physics, focusing on optical phenomena, optoelectronic devices, fiber optics, and nonlinear electronic components. Through experiments involving Michelson interferometry, polarization, optical fibers, and semiconductor devices such as DIAC, SCR, and TRIAC, students will gain both conceptual and practical understanding of key physical principles. The course emphasizes experimental accuracy, data interpretation, and the correlation of theoretical predictions with observed results.

Course Outcomes:

1. **CO1**: **Recall and define** fundamental concepts related to optical interference, optoelectronic device behavior, and nonlinear semiconductor characteristics.

2. **CO2**: **Explain** the working principles of photonic devices, interferometers, and optical fiber systems used in advanced laboratory experiments.

3. **CO3**: **Apply** experimental methods to determine refractive index, numerical aperture, and analyze I-V characteristics of photonic and semiconductor components.

4. **CO4**: **Analyze** experimental data to assess device performance, optical losses, and polarization behavior under varying experimental conditions.

5. **CO5**: **Evaluate** discrepancies between theoretical predictions and experimental outcomes, and justify experimental modifications to improve accuracy and reliability.

Course Content:

1. Determination of refractive index of a glass plate using Laser source based on Michelson interferometry technique.

2. Study characteristic of Optoelectronic devices.
    i) Study of response characteristic of a solar-cell using Laser light.
    ii) Study of V-I characteristic of LDR. Also study the response characteristic of LDR.
    iii) Study of V-I characteristic and response characteristic of a phototransistor.
    iv) To study the response characteristic of a photodiode.
    v) To study response characteristic of an opto-coupler.

3. To study polarization properties of light and verify the Malu's Law using Laser source.

4. Experiments using Optical Fiber:
    i) Determination of numerical aperture of an Optical fiber.
    ii) Study the bending and splice loss in an optical fiber.

5. Studies on I-V characteristics of a DIAC.

6. Studies on I-V Characteristics of SCR (Silicon controlled Rectifier).

7. Studies on Terminal and Gate characteristics of TRIAC.

8. Single slit, Double slit and Grating Spectra using LASER

References:

Internal laboratory manuals and experiment-specific handouts will be provided as primary reference materials.

Paper Name: Advanced Physics Lab II

Paper Code: PHY303
LTP: 0-0-2

Course Objectives:

1. To enable students to investigate key physical constants and validate classical and quantum theories through hands-on experiments.
2. To provide practical exposure to characterization techniques in semiconductors, including band gap, Hall effect, and magnetoresistance measurements.
3. To build understanding of experimental techniques used to verify foundational concepts like Bohr's model and Millikan's oil drop experiment.
4. To introduce students to the basics of digital logic circuits through flip-flop design using both logic gates and ICs.
5. To develop students' capabilities in handling laboratory equipment, data interpretation, and error analysis in physics experiments.

Course Description:

This advanced laboratory course provides in-depth experimental training in classical and modern physics, including quantum phenomena, solid-state physics, and digital electronics. Students will explore fundamental physical constants (such as Planck's constant, e/m ratio, and electron charge), semiconductor properties (band gap, Hall coefficient, magnetoresistance), and logic circuit behavior. The course is designed to develop experimental proficiency, enhance conceptual understanding, and build analytical skills through precise measurement, data analysis, and error evaluation.

Course Outcomes:

1. **CO1**: **Recall and define** essential concepts and physical constants related to quantum mechanics, electromagnetism, and semiconductor physics.

2. **CO2**: **Explain** the theoretical principles behind quantum experiments (e.g., Franck-Hertz, Millikan) and digital logic operations.

3. **CO3**: **Apply** measurement techniques to determine physical quantities like e/m ratio, Planck's constant, Hall coefficient, and band gap using laboratory instruments.

4. **CO4**: **Analyze** I-V characteristics, magnetoresistance behavior, and flip-flop timing diagrams to understand device performance and logical operations.

5. **CO5**: **Evaluate** experimental data with proper error estimation and validate the consistency between theoretical models and observed outcomes.

Course Content

1. Determine Plank's Constant using photo-cell with filters for different light wave length (λ). Also verify the inverse square law.

2. Determination of e/m of electrons by magnetic focusing method.

3. To determine the energy band gap of Ge crystal by Four Probe Method.

4. Study the variation of Magneto-resistance of *n-type*/*p-type* semiconductor material.

5. Verification of Bohr's atomic theory by Franck Hertz Experiment.

6. Determine the electron charge by Millikan's Oil drop method and hence determine the terminal velocity of the oil drop.

7. To build Flip-Flop (RS, Clocked RS, D-type and JK) circuits using NAND gates. To build JK Master-slave flip-flop using Flip-Flop ICs.

8. To find the fringe width of the interference pattern produced by Fresnel Biprism and to determine the wavelength of monochromatic source of light.

References:

Internal laboratory manuals and experiment-specific handouts will be provided as primary reference materials.

Paper Name: Internship

Paper Code: PHY340
LTP: 0-0-2

Course Objectives:

1. To apply theoretical knowledge of Physics in real-world settings through practical work in research laboratories, industries, or academic institutions, fostering hands-on experience in the field.
2. To develop problem-solving skills by tackling real-world challenges and projects within the internship environment, enhancing critical thinking and adaptability.
3. To evaluate the practical aspects of Physics concepts and their relevance to industrial and research contexts, bridging the gap between theory and application.
4. To communicate effectively with professionals and peers by presenting internship findings and insights in a structured manner, promoting clarity and engagement in discussions.
5. To reflect on the internship experience to identify areas of strength and improvement, and integrate this feedback into future career planning or academic pursuits, fostering continuous personal and professional development.

Course Description:

This internship provides a unique opportunity for students to apply theoretical knowledge in real-world settings, bridging the gap between classroom learning and practical experience. By working in research laboratories, industries, or academic institutions, students gain valuable hands-on experience, develop professional skills, and build a network of contacts in their field of interest. The internship is designed to enhance their understanding of Physics in practical applications, foster problem-solving skills, and significantly boost their employability. Through this immersive experience, students not only solidify their grasp of Physics concepts but also gain insights into potential career paths and the demands of the professional world, thereby improving their readiness for future career opportunities or higher studies. This practical exposure ensures that graduates are well-prepared and competitive in the job market.

Course Outcomes

1. **CO1: Interpret and explain** the structure, objectives, and operational practices of the host organization or research environment.

2. **CO2: Apply** theoretical knowledge and technical skills to execute tasks and solve practical problems in a professional setting.

3. **CO3: Analyze** work processes and challenges encountered during the internship to derive meaningful insights and solutions.

4. **CO4: Evaluate** the effectiveness of tools, techniques, or methodologies used during the internship, considering their limitations and applicability.

5. **CO6: Develop** a detailed report or presentation summarizing internship experiences, including innovative approaches, project outcomes, and lessons learned, while proposing future applications or solutions.

Semester VI

Paper Name: Numerical Methods and Simulation in Physics

Paper Code: PHY304
LTP: 1-0-3

Course Objectives:

1. To apply numerical methods such as the Bisection, Newton-Raphson, and Secant methods for solving transcendental equations in physical systems, including optics and potential wells.
2. To solve systems of linear equations using techniques like Gauss Elimination and Gauss-Seidel, applying these methods to practical problems such as electric circuits and coupled spring-mass systems.
3. To implement numerical solutions for first-order differential equations using the Euler and Runge-Kutta methods, modeling physical phenomena like radioactive decay and Newton's law of cooling.
4. To analyze second-order differential equations, particularly for harmonic oscillators, employing the Runge-Kutta method to address both damped and forced oscillatory systems.
5. To evaluate solutions to the Schrödinger equation using the Finite Difference Method and the Numerov algorithm, applying these techniques to quantum mechanical problems such as the hydrogen atom and screened Coulomb potentials.

Course Description:

This course introduces students to the practical application of numerical methods for solving a wide range of physics problems. It focuses on developing computational skills essential for modeling and simulating physical systems that are analytically intractable. Students will gain hands-on experience in solving transcendental and differential equations, implementing finite difference methods, and performing random simulations using appropriate programming tools. The lab work is reinforced with real-world physics problems from mechanics, quantum physics, statistical mechanics, and atomic systems. The course culminates in project-based assignments where students apply learned techniques to simulate complex phenomena such as orbital mechanics, molecular dynamics, and quantum tunneling.

Course Outcome:

1. **CO1: Explain** the theoretical foundations of numerical methods and their relevance to solving physical problems.

2. **CO2: Implement** standard numerical techniques to solve algebraic and differential equations arising in physics using programming tools.

3.

4. **CO3: Compare** the performance, stability, and accuracy of different numerical algorithms when applied to physical systems.

5. **CO4: Assess** the validity and limitations of simulation outcomes against expected physical behavior and experimental benchmarks.

6. **CO5: Design and execute** simulation-based mini-projects involving complex systems, demonstrating problem-solving and computational modelling skills.

Course Content:

1. Numerical solution of Transcendental equations by Bisection, Newton Raphson and Secant methods, Solution of linear and quadratic equation.

Problem:

- $I = I_0\left(\frac{\sin\alpha}{\alpha}\right)^2$ in optics.
- Particle in finite width potential well
- solving diffraction equation $\alpha = \tan\alpha$,

2. Solution of Linear system of equations by Gauss elimination method and Gauss-Seidal method.

Problem:

- Solution of mesh equations of electric circuits (3 meshes)
- Solution of coupled spring mass systems (3 masses).

3. First order differential equation, Euler, Modified Euler and Runge-Kutta second order method.

Problem:

- Solve equations for radioactive decay
- Newton's law of cooling,
- Classical equations of motion.

4. Second order differential equation solving by RK 4 method

Problem:

- Harmonic oscillator (no friction)
- Damped Harmonic oscillator, for 3 different cases such as- Over damped, Critical damped, Oscillatory
- Forced Harmonic oscillator
- Transient and Steady state solution.

5. Finite Difference method/ Numerov algorithm to solve 2nd order Differential Equation, Solution of Schrodinger Equation in 1D for different given potentials.

Problems:

- **Solve the s-wave Schrodinger equation** for the ground state and the first excited state of the hydrogen atom,

$$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2m}{\hbar^2}\left[V(r) - E\right] \text{, where } V(r) = -\frac{e}{r^2}$$

Here, m is the reduced mass of the electron. Obtain the energy Eigenvalues and plot the corresponding wave functions. Remember that the ground state energy of the hydrogen atom is ≈ -13.6 eV. Take e = 3.795 (eVÅ)$^{1/2}$, ħc = 1973 (eVÅ) and m = 0.511×106 eV/c^2.

- **Solve the s-wave radial Schrodinger equation** for an atom,

$$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2m}{\hbar^2}\left[V(r) - E\right]$$

where m is the reduced mass of the system (which can be chosen to be the mass of an electron), for the screened coulomb potential,

$$V(r) = -\frac{e^2}{r}e^{-r/a}$$

Find the energy (in eV) of the ground state of the atom to an accuracy of three significant digits. Also, plot the corresponding wave function. Take e = 3.795 (eVÅ)1/2, m = 0.511x106 eV/c2, and a = 3 Å, 5 Å, 7 Å. In these units ħc = 1973(eVÅ). The ground state energy is expected to be above -12 eV in all three cases.

- **Solve the s-wave radial Schrodinger equation** for a particle of mass m,

$$\frac{d^2y}{dr^2} = A(r)u(r), A(r) = \frac{2m}{\hbar^2}\left[V(r) - E\right],$$

for the anharmonic oscillator potential $V(r) = \frac{1}{2}kr^2 + \frac{1}{3}br^3$.

for the ground state energy (in MeV) of particle to an accuracy of three significant digits. Also, plot the corresponding wave function. Choose m = 940 MeV/c^2, k = 100MeV fm^{-2}, b = 0, 10, 30 MeV fm^{-3}. In these units, cħ = 197.3 MeV fm. The ground state energy is expected to lie between 90 and 110 MeV for all three cases.

6. Random Number generation and testing, Random number generation with given distribution

Problem:

- Coin tossing. Fit with binomial distribution.
- Random Walk: – In 1D and in 2D (Square grid) – Plot of r.m.s. value of end to end distance as a function of time step – fitting and finding of exponent

Projects and Assignments: (Any one)

- Simulation of Inverse Square Law of Gravitation and to check the stability of planetary orbits.
- Molecular Dynamics simulation using Lennard-Jones potential
- Electronic transmission through a nanostructure using Transfer Matrix method.
- Trace Map technique to analyze the eigen spectrum of a fractal lattice.

*Other problems might be given during class.

Paper Name: Solid State Physics

Paper Code: PHY305
LTP: 3-0-1

Course Objectives:

1. To explain the nature of interatomic forces and the various types of bonding in solids, including ionic, covalent, metallic, and intermolecular bonds.
2. To describe different crystal structures, the concept of Miller indices, Bragg's law, and lattice dynamics, including the role of phonons and their influence on the specific heat of solids.
3. To apply free electron theory and band theory to analyze the electrical and thermal properties of conductors, semiconductors, and insulators, including concepts like the Hall Effect and carrier mobility.
4. To analyze the magnetic properties of materials, explore superconductivity, and understand related phenomena such as the Meissner effect, hysteresis, and BCS theory.
5. To conduct hands-on experiments to measure properties such as the Hall coefficient, dielectric constant, and I-V characteristics of solar cells, while investigating tunneling effects in tunnel diodes.

Course Description:

This course offers a comprehensive overview of the fundamental physical principles governing solid materials. Topics include bonding in solids, crystal structure, lattice vibrations, electronic band theory, magnetic and dielectric properties, and superconductivity. The theoretical foundation is supplemented with hands-on laboratory experiments to reinforce key concepts and develop experimental skills relevant to solid-state physics and material science.

Course Outcomes:

1. **CO1: Recall** fundamental principles of bonding, crystal structures, and classification of solids based on electronic properties.

2. **CO2: Explain** lattice dynamics, phonon behavior, and specific heat models in solids along with basic transport mechanisms.

3. **CO3: Apply** theoretical models such as free electron theory, Kronig-Penney model, and Boltzmann transport to describe conduction and semiconducting behavior.

4. **CO4: Analyze** the origin and behavior of magnetic, dielectric, and superconducting properties in various material systems.

5. **CO5: Evaluate** material responses to external fields using theoretical frameworks and interpret key solid-state phenomena such as dispersion, polarization, and Hall effect.

6. **CO6: Design and perform** experiments to characterize electrical, optical, and thermal properties of solid materials using modern lab techniques.

Course Content:

Module I: Interatomic Forces and Bonding in Solids *(6 hours)*

Cohesive forces, Bonding in Solids, Ionic bonding, Covalent bonding, Metallic bonds, Intermolecular Bonds, Dipole, Hydrogen bonds.

Module II: Crystal Structure and Lattice Dynamics *(8 hours)*

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

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. T^3 law.

Module III: Free Electron Theory and elementary band theory *(10 hours)*

Free Electron Gas, Electrical and Thermal conductivity, Electronic Specific Heat, Sommerfeld's correction, Kronig Penny model. Formation of energy bands, Band Gap. Conductor, Semiconductor (P and N type) and insulator. Boltzman Transport Equation, Conductivity of Semiconductor, mobility, Hall Effect. Measurement of conductivity (4 probe method) & Hall coefficient.

Module IV: Magnetism and Superconductivity *(12 hours)*

Dia-, Para-, Ferri- and Ferromagnetic Materials. Classical Langevin Theory of dia and Paramagnetic Domains. 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.

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)

Module V: Dielectric Properties of Materials: *(8 hours)*

Polarization. Local Electric Field at an Atom. Depolarization Field. Electric Susceptibility. Polarizability. Clausius Mosotti Equation. Normal and Anomalous Dispersion. Ferroelectricity, Piezoelectricity, Complex Dielectric Constant. Optical Phenomena.

Module VI: Hands On Training:

- Determine the Hall coefficient of a semiconductor sample (*p type and n type*).
- Measure the Dielectric Constant of a dielectric Materials with frequency/temperature.
- Determine the I-V characteristics of a Solar Cell.
- Determine the temperature dependence of energy band-gap of a Ge semi-conductor.
- Determine the refractive index of a dielectric layer using Surface Plasmon resonance (SPR).
- Study the tunneling effect in tunnel diode using I-V characteristics

Reference Books:

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

Paper Name: Nuclear and Particle Physics

Paper Code: PHY306
LTP: 4-0-0

Course Objectives:

1. To explain the general properties of nuclei, including aspects such as mass, radii, binding energy, and the characteristics of nuclear forces.
2. To describe various nuclear models, including the liquid drop model, Bethe-Weizsäcker mass formula, Fermi gas model, and shell model, and their applications in nuclear physics.
3. To solve the Schrödinger equation for the ground and excited states of the deuteron, and to compare their potential energies in different configurations.
4. To analyze the different types of radioactive decay, including alpha, beta, and gamma decay, and to explore their specific features and implications in nuclear processes.
5. To conduct laboratory experiments related to beta particles, including studies on bremsstrahlung, G.M. counter characteristics, and to determine the range of beta particles and the plateau region of the counter.

Course Objectives:

This course explores the foundational aspects of nuclear and particle physics, introducing students to the internal structure of nuclei, their interactions, and the behavior of elementary particles. Topics include nuclear models, binding energy, radioactive decay processes, nuclear reactions, and the classification and interactions of subatomic particles. Emphasis is placed on theoretical frameworks, analytical problem-solving, and the physical interpretation of experimental findings relevant to nuclear and high-energy physics.

Course Outcomes:

1. **CO1: Recall** fundamental concepts, laws, and terminologies relevant to nuclear and particle physics
2. **CO2: Interpret** theoretical principles and physical meanings underlying nuclear and subatomic phenomena
3. **CO3: Use** appropriate physics principles to solve conceptual and numerical problems in nuclear and particle systems
4.

5. **CO4: Examine** physical situations and data to identify patterns, interactions, and governing laws in complex systems

6. **CO5: Assess** the validity and limitations of various theoretical models and experimental results in the context of modern physics

Course Content

Module I: General Properties of Nuclei *(8 hours)*

Constituents of Nucleus and their Intrinsic Properties, Quantitative Facts about Mass, Radii, Charge Density, Matter Density, Binding Energy, Angular Momentum, Parity, Magnetic Moment, Electric Moments, Nature of Nuclear Forces, Isospin, Nuclear Form Factor, Rutherford Scattering

Module II: Nuclear Structure *(10 hours)*

Liquid Drop Model of Nucleus, Bethe-Weizsäcker Mass Formula, Fermi Gas Model, Shell Model, Collective Model (features and predictions)

Module III: Deuteron Problems *(7 hours)*

Properties of deuteron, Schrödinger equation and its solution for ground state and excited state of deuteron. Comparison between potential energies of ground and excited states of deuteron

Module IV: Radioactive Decays *(10 hours)*

Law of radioactive decay, Radioactive Series, Application of Radioactive Isotopes, Detailed features of Alpha, Beta and Gamma Decay, Tunneling Theory of Alpha Decay, Neutrino Hypothesis, Fermi Theory of Beta Decay (qualitative), Fermi-Kurie plot, Selection Rule of Gamma Decay (Only Qualitative)

Module V: Nuclear Reactions *(10 hours)*

Types of Reactions, Conservation Laws, Kinematics of Reactions, Q-value, Reaction Rate, Reaction Cross Section, Concept of Compound and Direct Reaction, Resonance Reaction, Fission and fusion- mass deficit, relativity and generation of energy Nuclear Fission, Nuclear Astrophysics – Stellar Fusion

Module VI: Particle Physics *(14 hours)*

Classification of Elementary Particles, Basic Forces of Nature and their Characteristics, Characteristics of Coupling Constants, Basic Idea of Standard Model, Feynman Diagram of Basic Interactions, Properties of neutrinos, Characteristics of Strange particles, Quantum numbers, Quark model for Baryon and Mesons in Eightfold Scheme, Gellman-Nishijima Formula, Decay of Elementary Particles and Relevant Conservation laws

Reference Books:

1. Nuclear Physics; E. Fermi
2. Nuclear Physics; R. R. Roy, B. P. Nigam
3. Atomic and Nuclear Physics; S. N. Ghoshal
4. Introduction to High Energy Physics; D. H. Perkins
5. Introduction to Elementary Particles; D. J. Griffiths
6. Nuclear and Particle Physics; W. E. Burcham

Paper Name: Advanced Physics Lab III

Paper Code: PHY307
LTP: 4-0-0

Course Objectives:

1. To introduce students to advanced experiments in semiconductor physics, magnetism, and optoelectronic systems.
2. To develop experimental skills in measuring material and device properties using modern instrumentation.
3. To provide exposure to frequency response analysis of analog filters using both passive components and operational amplifiers.
4. To equip students with the ability to collect, analyze, and interpret experimental data for various physical systems.
5. To foster critical thinking and problem-solving abilities in the context of experimental setup design, error analysis, and data validation.

Course Description:

This advanced-level laboratory course offers hands-on training in modern experimental physics, spanning semiconductor characterization, optoelectronics, magnetism, spectroscopy, and analog signal processing. Students will learn to use advanced instruments such as hysteresis loop tracers, Michelson interferometers, ESR spectrometers, and temperature transducers. The course is designed to build core experimental skills, enhance conceptual understanding, and foster analytical thinking through real-world applications and electronic filter design.

Course Outcomes:

1. **CO1**: **Recall and define** the physical principles related to semiconductor behavior, magnetic properties, filter circuits, and optical phenomena.

2. **CO2**: **Explain** the working mechanisms of devices such as temperature transducers, photoresistors, and ESR setups, and the concepts behind their characterization techniques.

3. **CO3**: **Apply** experimental techniques to measure Hall coefficient, magnetic parameters, and optical wavelengths, and to construct analog filters.

4. **CO4**: **Analyze** I-V characteristics, frequency responses, and temperature-dependent behaviors to assess material/device performance.

5. **CO5**: **Evaluate** the accuracy of experimental results and interpret the data in light of theoretical models, identifying possible sources of error and limitations.

Course Content

1. Determine temperature dependence of Hall coefficient of n-type and p-type semiconductor material.

2. Study of Current Voltage characteristic of a *CdS*, a photo resistor as a function of Intensity using optical bench.

3. Determination of magnetic parameters (Coercive field, residual magnetization and saturation of magnetization) of a Ferromagnetic substance by using *Hysteresis Loop Tracer setup*

4. Determination of Lande-g factor by using Electron Spin Resonance Spectroscopy.

5. Determination of wavelength of a monochromatic source by using Michelson's Interferometer [Table top setup]

6. Study of characteristics of *Temperature Transducer*.(Thermocouple Sensors, IC Sensors)

7. Design and Study
   i. frequency response of Passive filters (a) High pass (b) Low pass (c) Notch filters. (d) Wide Band-pass Filter.
   ii. frequency response of 1st order Active filters (use OPAMP as active element) (a) High pass (b) Low pass (c) Band pass (d) Band reject (e) Narrow band pass filters etc.

References:

Internal laboratory manuals and experiment-specific handouts will be provided as primary reference materials.

Semester VII

Paper Name: Advanced Statistical Mechanics

Paper Code: PHY400

LTP: 4-0-0

Course Objectives:

1. To introduce the grand canonical ensemble and its applications to systems with variable particle number, including the role of chemical potential.
2. To explore the statistical treatment of interacting classical systems using cluster and virial expansions.
3. To develop a quantum statistical framework using the density matrix formalism for various ensembles.
4. To understand the statistical behavior of ideal quantum gases, focusing on Bose-Einstein condensation and Fermi gas thermodynamics.
5. To analyze phase transitions using mean field theory, Landau theory, and the renormalization group approach.

Course Description:

This course builds upon the foundational principles of statistical mechanics to explore more complex systems involving particle exchange, interactions, and quantum behavior. It introduces students to the grand canonical ensemble, statistical mechanics of real gases, density matrix formalism, and quantum statistical systems like ideal Bose and Fermi gases. The course also delves into phase transitions, mean field theory, and critical phenomena, offering analytical tools to study collective behaviors in physical systems. The theoretical foundation is complemented by applications to systems in condensed matter and high-energy physics.

Course Outcomes:

1. **CO1: Recall and define** key statistical mechanics concepts such as chemical potential, grand partition function, and entropy in systems allowing particle exchange.

2. **CO2: Explain** the statistical treatment of real gases using cluster and virial expansions and interpret the physical significance of virial coefficients in the equation of state.

3. **CO3: Apply** the density matrix formalism to various quantum systems and ensembles, and solve simple problems involving quantum states like particles in a box and electrons in magnetic fields.

4. **CO4: Analyze** the thermodynamic behavior of ideal quantum gases, and interpret Bose-Einstein condensation and the finite-temperature behavior of Fermi gases.

5. **CO5: Evaluate** models of phase transitions using mean field and Landau theory, and discuss critical phenomena using scaling laws and the renormalization group approach.

Course Content:

Module I: Grand Canonical Ensemble *(8 hours)*

System in contact with a particle reservoir, Chemical potential, Grand canonical partition function, fluctuation of particle number. Chemical potential of ideal gas.Entropy in terms of Grand partition function.

Module II: Statistical Mechanics for Interacting Systems *(8 hours)*

Equation of state of real gas, Cluster expansion for a classical gas, Virial expansion of the equation of state, Evaluation of the virial coefficients,

Module III: Quantum statistical mechanics *(10 hours)*

Density Matrix, Quantum Liouville's theorem, Density matrices for micro canonical, canonical and grand canonical systems, Simple examples of density matrices, one electron in a magnetic field, particle in a box, Identical particles, B-E and F-D distributions.

Module IV: Statistical Behaviour of Ideal Quantum Gases *(16 hours)*

(i) *Ideal Bose Systems:* Thermodynamic behaviour of an ideal Bose Gas, Equation of state, Bose-Einstein Condensation.

(ii) *Ideal Fermi System*: Equation of state of ideal Fermi gas; Fermi gas at finite *T*.

Module V: Phase Transition and Mean Field Theory *(10 hours)*

Ising model: partition function for one dimensional case; Chemical equilibrium and Saha ionisation formula. Phase transitions: first order and continuous, critical exponents and scaling relations. Calculation of exponents from Mean Field Theory and Landau's theory, upper critical dimension. Renormalisation Group.

Reference Books:

1. Introductions to Statistical Mechanics; B. B. Laud
2. Statistical Physics (Allied Publishers); J. K. Bhattarjee
3. Statistical Physics (Mc.Graw Hill); F.Reif:
4. Statistical Physics (Chapman and Hall/CRC); K.Hung
5. Statistical Mechanics; R.K. Pathria

Paper Type: CC (Advanced Specialization)

Track: Astronomy and Astrophysics

Paper Name: Introduction to Astronomy and Astrophysics

Paper Code: PHY401
LTP: 4-0-0

Course Objectives:

1. To define the fundamental concepts of differential geometry and tensor calculus that are essential for understanding General Relativity.
2. To explain the principles of General Relativity, focusing on Einstein's field equations and the equivalence principle as foundational concepts.
3. To analyze the Schwarzschild solution and describe the properties of black holes, including their event horizons and singularities.
4. To apply the Friedmann-Robertson-Walker metric to various cosmological models and discuss the implications of cosmic microwave background radiation in the context of these models.
5. To conduct experiments and evaluate observations related to General Relativity, such as the detection of gravitational waves and the study of black hole phenomena.

Course Description:

This course provides a comprehensive overview of key principles and techniques in astronomy and astrophysics, ranging from astronomical scales and positional astronomy to the physical processes governing stellar structure, solar dynamics, and the evolution of stars. Students will explore celestial coordinate systems, telescopic instrumentation, radiation mechanisms, and nuclear processes in stars. Emphasis will also be placed on the formation and dynamics of stars, solar and galactic systems, and the physical conditions of the interstellar medium.

Course Outcome:

1. **CO1: Explain** fundamental astronomical observables and coordinate systems.
2. **CO2: Apply** observational and instrumental techniques (telescopes, detectors, spectroscopy) to infer stellar and galactic properties such as mass, temperature, and luminosity.

3. **CO3: Analyze** the physical processes governing the Sun and solar system, including radiative transfer, thermodynamic equilibrium, and solar activity.

4. **CO4: Evaluate** stellar structure, evolution, and formation mechanisms using principles such as hydrostatic equilibrium, energy transport.

5. **CO5: Interpret** the physics of compact objects, including white dwarfs, neutron stars, black holes.

Course Content:

Module I: Basic Concepts of Astronomical Observables *(10 hours)*

Gravitation in Astrophysics, Broad idea about planets, stars, galaxy and cosmolgy, Astronomical Distance (AU, light year, parsec, megaparsec), Mass scale of celestial bodies, Luminosity of stars, Radiant Flux and Luminosity, Stellar Radii, Stellar Temperature, Celestial Sphere, Astronomical Coordinate Systems, Equatorial System, Diurnal Motion of the Stars, Various time scales (Measurement of Time, Sidereal Time, Apparent Solar Time, Mean Solar Time).

Module II: Astronomical Observation Techniques *(10 hours)*

Basic Optical Definitions for Astronomy, Types of Reflecting Telescopes, Space Telescopes, Basics of X-ray/Gamma-ray astronomy, Spectroscopic (Continuous, Emission, and Absorption Spectra) observation of Stellar parameters (Mass, Radius and Temperature), HR diagram, Main sequence stars.

Module III: Astrophysics of the Sun and the Solar System *(8 hours)*

Solar Parameters, Solar Photosphere, Solar Atmosphere, Chromosphere. Corona, Solar Activity, Basics of Solar Magneto-hydrodynamics, Origin of the Solar System, The Nebular Model, Tidal Forces and Planetary Rings, Stellar spectra and classification Structure

Module 4: Fundamentals of Stellar Astrophysics *(10 hours)*

Hydrostatic Equilibrium of a Star, Virial Theorem, Sources of Stellar Energy, Modes of Energy Transport, Simple Stellar Model, Polytropic Stellar Model, Formation of Protostar, Jeans criterion, Fragmentation of collapsing clouds, From protostar to Pre-Main Sequence, Hayashi Line, Supernovae, Stellar Pulsation, Basic Idea about: White dwarfs, Neutron stars, Pulsars, Black holes, Close binary systems.

Module 5: (Ultra)-Compact objects *(12 hours)*

Basic Familiarity with Compact Stars, Equation of State and Degenerate Gas of Fermions, Theory of White Dwarf, Chandrasekhar Limit, Neutron Star and Landau–Oppenheimer–Volkoff Estimation of the Neutron Star parameters.

Reference Books:

1. Modern Astrophysics; B.W. Carroll & D.A. Ostlie
2. Astrophysics for Physicist; Arnab Rai Choudhuri
3. Introductory Astronomy and Astrophysics; M. Zeilik and S.A. Gregory
4. Theoretical Astrophysics (Volume 2); T. Padmanabhan
5. Fundamental of Astronomy; H. Karttunen
6. An introduction to Astrophysics; by BaidyanathBasu

Paper Name: Introduction to Cosmology

Paper Code: PHY406
LTP: 4-0-0

Course Objectives:

1. To describe the different types of galaxies and their morphological classifications, including spiral, elliptical, and irregular galaxies.
2. To explain the principles of relativity, encompassing both special and general relativity, and to discuss their implications on the nature of spacetime.
3. To analyze cosmological models, including the Robertson-Walker metric, and to explore various geometries of the universe.
4. To apply the concepts of physical cosmology to understand the thermal history of the universe and the significance of cosmic microwave background radiation in cosmological studies.
5. To evaluate observational data related to galaxies, cosmology, and relativity, and to discuss current research findings and theoretical models in these fields.

Course Description:

This course provides a theoretical foundation in the study of galaxies, the framework of general relativity, and the evolution and structure of the universe. Topics include galaxy morphology, active galaxies, relativistic phenomena in strong gravitational fields, cosmological models, and the early universe. Emphasis is placed on understanding physical principles and mathematical formulations that describe the large-scale structure and dynamics of the cosmos.

Course Outcome:

1. **CO1: Explain** the foundations of Special and General Relativity, including spacetime structure, curvature, and Einstein's field equations..
2. **CO2: Apply** relativistic concepts to physical phenomena such as gravitational redshift, lensing, orbital motion, and gravitational radiation.
3. **CO3: Analyze** standard cosmological models using the Robertson–Walker metric, Hubble's law, and Friedmann dynamics for different universe geometries.
4. **CO4: Evaluate** observational cosmology tools and data, including distance measures, cosmic microwave background anisotropies, and supernova-based expansion evidence.
5. **CO5: Interpret** the thermal and structural evolution of the universe.

Course Content:

Module I: Overview of Relativity *(16 hours)*

Principles of Relativity: Overview of Special Relativity, Spacetime interval and Lorentz metric four vectors, Introduction to General Relativity (GR), Notions of curvature, Einstein Field Equation and Gravitation as a manifestation of the curvature of spacetime, Schwarzschild Solution of the Einstein Equation, Gravitational redshift and clock corrections, Orbits in strong gravity, light bending and gravitational lensing, Hydrostatic equilibrium in GR, Gravitational radiation

Module II: Cosmological Models *(14 hours)*

Universe at large scales, Homogeneity and isotropy, Distance ladder, Newtonian cosmology, Expansion and redshift, Cosmological Principle, Hubble's law, Robertson-Walker metric, Observable quantities – luminosity and angular diameter distances, Horizon distance, Dynamics of Friedman- Robertson-Walker models, Discussion of closed, open and flat Universes

Module III: Physical Cosmology ~~and Early Universe~~ *(14 hours)*

Cosmic Distance Ladder, Hubble's Law (Distance- Velocity Relation, Thermal History of the Universe, Distribution functions in the early Universe – relativistic and nonrelativistic limits, Cosmic microwave background radiation (CMB), Anisotropies in CMB, Accelerating universe and type-Ia supernovae, Evolving vs. Steady State Universe

Reference Books:

1. An Introduction to Modern Cosmology; Andrew Liddle
2. Gravitation and Cosmology; S. Wienberg
3. Spacetime and Geometry; Sean Carrol
4. Introduction to Cosmology; Matts Roos
5. Introduction to Cosmology; Barbara Ryden

Paper Type: CC (Advanced Specialization)

Track: Nanoscience

Paper Name: Nanomaterials and Fabrication Technology

Paper Code: PHY402
L T P – 3-0-1

Course Objectives:

1. To define the classifications of nanostructures, including one-dimensional (1D), two-dimensional (2D), and three-dimensional (3D) nanostructures, while explaining the principles of quantum confinement and its significance in nanotechnology.
2. To describe various synthesis methods for nanomaterials, differentiating between top-down and bottom-up approaches, and elaborating on specific techniques such as ball milling and chemical vapor deposition.
3. To analyze the size-dependent properties of nanomaterials, including changes in their chemical, optical, thermal, electrical, magnetic, and mechanical characteristics as a function of size.
4. To apply diverse characterization techniques to evaluate the properties of nanomaterials, including but not limited to electron microscopy, X-ray characterization, and UV-VIS spectroscopy.
5. To conduct hands-on experiments for synthesizing and characterizing nanomaterials, such as metal thin films and nanoparticles, while evaluating the impact of size reduction on their physical and chemical properties.

Course Description:

This course offers an integrated understanding of nanomaterials, encompassing their classification, synthesis methods, size-dependent properties, and characterization techniques. Theoretical modules focus on the physical principles that govern nanoscale behavior and advanced methods of material fabrication and analysis. Complementing this, practical sessions engage students in hands-on synthesis and investigation of nanostructures using various experimental techniques. The course is designed to provide a comprehensive foundation for students aiming to pursue research or applications in nanoscience and nanotechnology.

Course Outcome:

1. **CO1: Define** key terminologies and outline fundamental concepts related to nanomaterial classification, synthesis, and nanoscale phenomena.

2. **CO2: Describe** the influence of size reduction on physical properties and explain the principles governing the behavior of nanomaterials.

3. **CO3: Use** appropriate theoretical frameworks to **illustrate** how synthesis methods and processing parameters affect the structure and function of nanomaterials.

4. **CO4: Compare** various synthesis and characterization techniques and **differentiate** their applicability for studying different types of nanostructures.

5. **CO5: Assess** the suitability and limitations of models, tools, and methods used in understanding and investigating nanoscale systems.

6. **CO6: Design and conduct** basic experiments on the synthesis and characterization of nanomaterials and interpret the experimental data to evaluate their properties

Course Content:

Module I: Introduction to Nanomaterials *(10 hours)*

Historical development, Classification of Nanostructures: 1D, 2D and 3D nanostructures (nanodots, thin films, nanowires and nanorods), Classification as per composition, Nanoscale forces, Bulk to Surface transition, Size effect: quantum confinement.

Module II: Nanomaterial Synthesis *(20 hours)*

Top down and Bottom up approach, Mechanical route synthesis: Ball milling. Vacuum deposition techniques: Physical vapor deposition (Thermal Evaporator, E-beam evaporator, sputtering (magnetron)-DC, RF), Pulsed LASER deposition, Atomic Layer Deposition, Hydrothermal/solvo-thermal synthesis of nanomaterials, Chemical vapor deposition synthesis: Plasma Enhanced Chemical Vapor Deposition. Precipitative synthesis: Hydrothermal/solvothermal methods, Sol-gel methods, Electro-chemical method: Electro-deposition technique, solution-growth based chemical synthesis: Fundamentals of nucleation and growth.

Module III: Properties of Nanomaterials *(7 hours)*

Size dependence of properties-Chemical Optical, Thermal, Electrical, Magnetic and Mechanical properties of nanomaterials.

Module IV: Nanomaterial characterization techniques *(10 hours)*

Limitation of optical microscopy and introduction to electron microscopy. Scanning and Transmission Electron Microscopy. Prospect of Scanning Probe Microscopies: Atomic Force, scanning tunneling microscopy, Fundamentals of X-ray characterization.

UV-VIS and IR spectroscopic techniques Mechanical characterization of nanophase Materials: Nano-indentation Technique.

Module V: Hands on Training:

- Deposition of metal thin films on glass substrate by thermal evaporation techniques.
- Synthesis of oxide semiconductor nanoparticles and study its band gap.
- Chemical synthesis of ferrite nanoparticles (Hydrothermal/ Sol Gel route)
- Study of microstructure of nanomaterials with optical microscopy.
- Synthesis of thin films by spin coating method.

  (Or)

- Effect of size reduction on the properties of nanomaterials

Reference Books:

1. Materials Science, M.S.Vijaya, G.Rangarajan, Tata McGraw-Hill publishing company Ltd., New Dehli, 2014.
2. Encyclopedia of Nanoscience and Nanotechnology; 25-Volume Set, H. S. Nalwa American Scientific Publishers, USA, 2005.
3. Encyclopedia of Materials Characterization, C. Richard Brundle, C. A. Evans, Jr., S. Wilson, Butterworth-Heinemann, Braille edition, 1992.
4. Introduction to Nanoscience and Nanotechnology, K. K. Chattopadhyay and A. N. Banerjee Prentice Hall India, 2009.

Paper Name: Nanoelectronics and Nanophotonics

Paper Code: PHY407

L T P – 3-0-1

Course Objectives:

1. To describe the fundamental concepts and materials in nanoelectronics, including the transport mechanisms of electrons in low-dimensional structures and the principles of nanolithography for device fabrication.
2. To explain the operation and limitations of nanoscale MOSFETs and other nanoelectronic devices, focusing on quantum effects and their applications in molecular electronics and MEMS/NEMS systems.
3. To analyze the theoretical foundations of nanophotonics, including macroscopic electrodynamics, wave equations, and the behavior of evanescent fields in nanoscale environments.
4. To apply principles of nanophotonics to practical applications such as confocal microscopy, near-field optical microscopy, and surface plasmon resonance, utilizing simulation tools and experimental techniques for demonstration.
5. To conduct simulations and experiments on nanophotonic devices, including single-electron transistors, photonic crystals, and surface plasmonic devices, in order to investigate their functionalities and real-world applications.

Course Description:

This course introduces the principles and applications of nanoelectronics and nanophotonics. It covers the behavior of electrons in low-dimensional systems, the design and limitations of nanoscale devices, and theoretical foundations of light–matter interactions at the nanoscale. Students will also explore applications of nanophotonics in microscopy, imaging, and quantum optical systems. A hands-on component introduces computational simulations for modeling nanoelectronic and nanophotonic devices using modern software tools, equipping students with essential analytical and technical skills.

Course Outcome:

1. **CO1: Define** fundamental principles of nanoelectronics and nanophotonics, and identify materials and structural configurations used in nanoscale systems.

2. **CO2: Explain** quantum transport phenomena and electromagnetic field behavior in low-dimensional and nanostructured systems.

3. **CO3: Apply** relevant theoretical models to calculate physical parameters and predict behavior of nanoelectronic and nanophotonic devices.

4. **CO4: Analyze** the influence of size effects, boundary conditions, and material properties on the performance of nanoscale systems.

5. **CO5: Evaluate** the operational principles and design constraints of nano-devices and photonic components in terms of physical limitations and application requirements.

6. **CO6: Develop and simulate** nanoelectronic or nanophotonic systems using computational tools, and interpret simulation outcomes to assess device behavior.

Course Content:

Module I: Basics of Nanoelectronics *(12 hours)*

Introduction to Nanoelectronics, Moore's law, Materials for Nanoelectronics: Semiconductors, Carbon nanomaterials and nanotubes, Transport of electrons in low-dimensional structures – Electrons in quantum wells, Electrons in quantum wires and Electrons in quantum dots. Crystal growth and Nanolithography, molecular electronics, Micro-electromechanical and Nano-electromechanical system

Module II: Nanoelectronic devices: Basics and applications *(9 hours)*

Nanoscale MOSFETs- Challenges in miniaturization, quantum effects, thin oxides, random dopant fluctuations, tunnelling and subthreshold currents, power density, hot electron effects, fundamental limits of MOS operations, GaN based High Electron Mobility Field Effect Transistors, MOSFET to Single-electron-transfer devices, Coulomb Blockade, Resonant-tunneling diodes, Nanoelectronics for molecular biology: next generation DNA sequencing

Module III: Theoretical Foundations of Nanophotonics *(12 hours)*

Macroscopic electrodynamics, wave equations, time harmonic fields, Dyadic Green's function, Evanescent fields. Propagation and focusing of optical fields – field operators, paraxial approximation of optical fields, polarized electric and magnetic fields, focusing of fields, point spread function.

Module IV: Applications of Nanophotonics *(10 hours)*

Principles of confocal microscopy, near field optical microscopy, scanning near –field optical microscopy, Nanoscale optical microscopy – far field illumination and detection, near field illumination and far-field detection, far field illumination and near field detection, energy transfer microscopy. Near –field optical probes- dielectric probes- conical, tapered, tetrahedral, Aperture probes. Probe –sample distance control. Light emission and optical interactions in nanoscale environments- multipole expansion, radiating electric dipole, spontaneous decay, delocalized excitations, Quantum emitters, dipole emission near planar interfaces, Light in periodic structures: Photonic crystals and resonators, Surface Plasmon. Metamaterials

Module V: Hands on Training

- Computational simulation of single electron transistor using MATLAB.
- Determine Numerical Aperture (NA) of a single mode optical fiber using scanning and visual method.
- Simulation on Finite Element Method (FEM) based surface plasmonic devices
- Modelling of Photonics crystal-based devices for various applications (Sensor/ Optical fiber laser etc.)

Reference Books:

1. Lessons from Nanoelectronics: A New Perspective on Transport (Lessons from Nanoscience: a Lecture Notes Series);S. Datta, World Scientific, 2012
2. Introduction to Nanoelectronics: Science, Nanotechnology, Engineering, and Applications; V. Mitin, V. Kochelap, and M. Stroscio, Cambridge University Press, 200
3. Introduction to nanotechnology; C. P. Poole and F. J. Owens, John Wiley & Sons, 2003.
4. Principles of Nano-optics; L Novotny and B Hecht, Cambridge University Press, 2006.
5. Introduction to Nanophotonics; S V Gaponenko, Cambridge University Press, 2010.
6. Principles of nanophotonics; MotoichiOhtsu, , CRC Press, 2008

Track: Optoelectronics and Photonics: Principles and Practices

Paper Name: Guided Wave Optics

Paper Code: PHY403
LTP: 3-0-1

Course Objectives:

1. To describe the fundamental concepts and materials in nanoelectronics, including the transport mechanisms of electrons in low-dimensional structures and the principles of nanolithography for device fabrication.
2. To explain the operation and limitations of nanoscale MOSFETs and other nanoelectronic devices, focusing on quantum effects and their applications in molecular electronics and MEMS/NEMS systems.
3. To analyze the theoretical foundations of nanophotonics, including macroscopic electrodynamics, wave equations, and the behavior of evanescent fields in nanoscale environments.
4. To apply principles of nanophotonics to practical applications such as confocal microscopy, near-field optical microscopy, and surface plasmon resonance, utilizing simulation tools and experimental techniques for demonstration.
5. To conduct simulations and experiments on nanophotonic devices, including single-electron transistors, photonic crystals, and surface plasmonic devices, in order to investigate their functionalities and real-world applications.

Course Description:

This course provides an in-depth understanding of the theoretical foundations and practical implementations of optical fiber communication and sensing systems. It covers wave propagation in optical waveguides, dispersion and nonlinear effects, amplifier technologies, fiber communication architectures, and fiber optic sensors. Students will also gain hands-on experience through simulation and modeling of optical networks and photonic sensors. The course bridges concepts from electromagnetic theory, photonics, and communication engineering to prepare students for advanced research and development in fiber optic technology.

Course Outcome:

1. **CO1**: **List** fundamental concepts and **define** key parameters related to wave propagation, optical fibers, and sensor systems.

2. **CO2**: **Explain** the principles of mode behavior, dispersion, nonlinear effects, and signal transmission in fiber-based systems.

3. **CO3**: **Use** appropriate theoretical models to **calculate** optical parameters and predict performance of communication and sensing networks.

4. **CO4**: **Analyze** the influence of fiber geometry, materials, and multiplexing strategies on the efficiency and functionality of optical systems.

5. **CO5**: **Evaluate** different optical network architectures and sensing mechanisms based on their performance characteristics and application demands.

6. **CO6**: **Design** and **simulate** fiber optic systems or sensors using computational tools, and **interpret** the outcomes for optimization and application

Course Content

Module I: Electromagnetic Modes and Waveguides *(14 hours)*

Electromagnetic Modes in Planar waveguides and Cylindrical Waveguides, Basic characteristic of Optical Fiber Waveguides – Ray theory- Acceptance angle, Numerical aperture, skew rays, V-Parameters, Power Distribution and Confinement Factor, Goos-Haenchen shift, cutoff wavelength, attenuation, bending loss, mode field diameter birefringence measurements, OTDR, Index profile, effect of material dispersion of optical fibers, Step index and Graded index Fibers- Single Mode and Multimode fibers, Photonic Crystal Fibers, other specialty optical fibers

Module II: Single Mode Fibres and Limitations *(12 hours)*

Dispersion in single mode fibers, limitations, Fiber losses attenuation coefficient, Nonlinear optical effects-SRS, SBS, SPM, modal birefringence and polarization maintaining fibers, Coupled mode theory and applications

Optical Fiber Amplifiers- Optical amplification, Erbium doped Fiber Amplifier, Fiber Raman Amplifier, Wide band amplifiers, Optical integrated circuits.

Time Division Multiplexing, Frequency Division Multiplexing (FDM), Dense Wavelength Division Multiplexing (DWDM), Coarse Wavelength Division Multiplexing (CWDM)Passive Components, Multiplexers and Demultiplexers, Active components, Topologies and Architectures

Module III: Optical Fibre Communication *(15 hours)*

Optical Fiber Communications- Essential components of Fiber Communication System, Types of Topologies, Types of Networks, Submarine cables, Open system interconnection (OSI), System Architectures, Line coding in Optical Links, Error control or Correction.

Performance of Passive Linear Optical Networks, Performance of Star Optical Network, SONET and SDH, Metro and Long-Haul optical Networks, Nonlinear effect, Dispersion, Solitons.

Optical Fiber Sensors- Essential components of Fiber Optic Sensor (OFS), Fiber optics cables and connectors, Splicer, Classification of OFS, res, Applications of FOSs.

Various OFS fabrication/ modeling techniques, Real application of Conventional and specialty optical fiber based sensor

Module IV: List of Experiments:

- Determine Numerical Aperture (NA) of a single mode optical fiber using visual method.
- Study of optical fiber-based pressure/turbidity/displacement sensor
- Design of Optical fiber communication network
    - i) Integration of Optical Network with Radio Access Network
    - ii) Multi-Tenant oriented Optical Network Virtualization and Slicing
    - iii) Inter or Intra Data Center Connection in Edge Computing
    - iv) Energy-Aware Communication in Optical Network
    - v) Improved Design and Optimization of Optical Network
    - vi) Photonic Integrated Circuits Manipulation in Optical Networks

- Determine the peak power and beam divergence of Laser beam.

Reference Books:

1. Guided Wave Optics and Photonic Devices; Shyamal Bhadra and AjoyGhatak, CRC Press, 1st edition, 2013.
2. Fundamentals of Guided-Wave Optoelectronic Devices; William S. C. Chang, Cambridge University Press, 2011.
3. Fiber Optic Communication; Joseph C Palais, Pearson Prentice Hall, 2013
4. Optical Fiber Communications: Principles and Practice; J M Senior, Pearson 2011
5. Fundamentals of Optical Fiber Sensors; Zujie Fang, Ken Chin, Ronghui Qu, Haiwen Cai, Kai Chang, , Wiley, ISBN: 978-0-470-57540-6, 2012
6. Fiber Optic Sensors: An Introduction for Engineers and Scientists; Eric Udd, William B. Spillman Jr., Wiley, ISBN: 9781118014080
7. Introduction to Fiber Optics, Ghatak and Thyagarajan, Cambridge University Press (2009)

Paper Name: Nonlinear Optics and Bio-Photonics

Paper Code: PHY408

L T P – 4-0-0

Course Objectives:

1. To explain the principles of nonlinear optical susceptibility and their significance in optical interactions, including processes such as second harmonic generation and phase matching.
2. To apply quantum mechanical theories, including Schrödinger equation and density matrix methods, for the calculation of nonlinear optical susceptibility in various materials.
3. To analyze parametric processes such as third-order nonlinear optics and Kerr-type nonlinearities, with a focus on four-wave mixing and optical breakdown phenomena.
4. To evaluate the effects of light-tissue interactions in biological systems, utilizing imaging techniques such as fluorescence microscopy and confocal microscopy for practical applications.
5. To demonstrate and refine experimental techniques for studying optical solitons and nonlinear effects in ultrafast and intense field optics.

Course Description:

This course provides a rigorous theoretical foundation in nonlinear optics, exploring wave-based and quantum mechanical treatments of optical interactions. It delves into harmonic generation, parametric processes, Kerr nonlinearities, and ultrafast optical phenomena. The course also introduces the fundamental principles governing light–tissue and light–cell interactions, with applications in advanced optical imaging and microscopy. Designed as a theory-intensive course, it equips students with the conceptual and analytical tools necessary to understand and evaluate complex optical effects in materials and biological systems.

Course Outcome:

1. **CO1: Define** key terms, phenomena, and nonlinear optical processes, and recall theoretical constructs used in describing light–matter interactions.
2. **CO2: Explain** the physical and quantum mechanical principles underlying second- and third-order nonlinear effects, harmonic generation, and light scattering.
3. **CO3: Apply** theoretical models to derive equations governing nonlinear susceptibilities and interaction dynamics in optical media.
4. **CO4: Analyze** the dependence of nonlinear optical processes on parameters such as phase matching, field intensity, and material properties.

5. **CO5: Evaluate** the applicability and limitations of nonlinear optical models and imaging techniques in interpreting complex light–matter and light–biological system interactions.

Course Content:

Module I: Nonlinear Optics *(10 hours)*

Nonlinear optical susceptibility, wave equation description of nonlinear optical interactions – Sum frequency generation, Difference frequency generation, Second Harmonic generation, Phase matching condition, Optical parametric Oscillators

Module II: Quantum Mechanical theory of Nonlinear Optics *(12 hours)*

Quantum mechanical theory of nonlinear optical susceptibility- Schrodinger equation calculation, density matrix calculation.

Spontaneous light scattering and acousto-optic, Stimulated Brillouin Scattering, Stimulated Rayleigh Scattering, Stimulated Raman Scattering

Module III: Harmonic generation and Kerr type *(12 hours)*

Second harmonic generation, parametric processes, 3rd order nonlinear optics, Kerr type nonlinearities, 4-wave mixing, self-focusing collapse, optical breakdown, two beam coupling, electro optics and photorefractive effects, optically induced damage and multiphoton absorption

Ultrafast and intense field nonlinear optics and optical solitons.

Module IV: Light-tissue and Cell interactions *(10 hours)*

Light-tissue and biological cell interactions and light induced effects in biological systems.
Basic principles of optical imaging and spectroscopy systems. Principles of standard optical microscopy/fluorescence microscopy/endoscopy and instrumentation. Confocal microscopy: Principles and Instrumentation and Applications. Two-Photon and Multi-photon Microscopy.

Reference Books:

1. Nonlinear optics, second Edition, Robert W Boyd, Academic Press (2003).
2. Photonics-Optical Electronics in Modern communications, A Yariv and P Yeh, Sixth edition, Oxford University Press (2007).
3. The Principles of nonlinear Optics, Y R Shen, Wiley-Interscience, 1991.
4. Handbook of Nonlinear Optics, R L Sutherland, Marcel Dekker, 1996.
5. Biomedical Photonics Handbook by Tuan Vo-Dinh, CRC Press, 2003.
6. Introduction to Biophotonics by P.N. Prosad, John-Wiley 2003.

Paper Type: CC (Advanced Specialization)

Track: Condensed Matter Physics

Paper Name: Properties of Solids I

Paper Code: PHY404
LTP: 3-0-1

Course Objectives:

1. To explain the dielectric function in solids and its importance, focusing on concepts such as dielectric losses, Kramer's-Kronig relations, and exciton-polaritons, providing a foundation for understanding electronic interactions in materials.
2. To analyze the electronic properties of materials using theoretical models like the Nearly Free Electron Model and Tight Binding Model, with emphasis on effective mass, excitons, and quantum confinement in low-dimensional systems.
3. To examine transport properties in bulk and mesoscopic systems, focusing on electrical and thermal conductivity, quantized conduction, and the Landauer-Buttiker formulation, to understand how materials behave at different scales.
4. To compare the effects of temperature on various properties, including Fermi gases, band bending, heterojunctions, and two-dimensional electron gases, helping students grasp how low-dimensional systems respond to temperature variations.
5. To apply theoretical models to explore advanced phenomena such as the Quantum Hall Effect, Spin Hall Effect, persistent current, and conduction fluctuations, deepening understanding of mesoscopic and quantum systems.

Course Description:

This course offers a theoretical exploration of the dielectric, optical, electronic, and transport properties of solids, focusing on both classical and quantum models. It covers dielectric response functions, interband transitions, polaritons, electronic structure models including quantum confinement, and mesoscopic transport phenomena. Through mathematical formulation and physical interpretation, students will develop a deep understanding of the mechanisms governing the behavior of electrons and phonons in condensed matter systems, with particular attention to low-dimensional systems and modern quantum transport theories.

Course Outcome:

1. **CO1: Define** essential terms, physical constants, and theoretical models relevant to dielectric, electronic, and transport phenomena in solids.

2. **CO2: Explain** the physical mechanisms governing polarization, optical absorption, band structure formation, and carrier transport in both bulk and confined systems.

3. **CO3: Apply** theoretical models to derive and solve equations describing material responses such as dielectric function, density of states, and conductivity.

4. **CO4: Analyze** the influence of quantum confinement, dimensionality, and disorder on the electrical and optical behavior of solids.

5. **CO5: Evaluate** the suitability of classical and quantum models in describing observed phenomena across dielectric, electronic, and transport regimes.

Course Content:

Module I: Dielectric and Optical properties of solids *(20 hours)*

The dielectric function: the dielectric function for a harmonic oscillator, dielectric losses of electrons, Kramer's-Kronig relations; Real and imaginary parts of dielectric functions, Interband transition, direct and indirect transition; Absorption in insulators, Ferroelectricity, Soft Modes, Polaritons, Phonon-Polaritons, Lyddane-Sachs-Teller relation, Exciton-Polaritons.

Module II: Electronic properties *(15 hours)*

Recapitulations of Nearly Free Model and Tight Binding Model, effective mass, excitons, Metals and Fermi gas, Fermi Gas at $T = 0$, Fermi Gas at finite temperature, Band Bending and Hetero-junctions, Quantum confinement, Density of States in Quantum-Confined systems, Super lattices, Disorder in quantum confined systems, The Two-Dimensional electron gas.

Module III: Transport properties *(20 hours)*

Recapitulation of transport properties in bulk and B-E equation, Electrical and Thermal conductivity, Origin of resistivity, Introduction to mesoscopic systems, idea of length scales, Characteristic features of low-dimensional systems: Conduction quantization, Conduction fluctuation, persistent current etc. Formulation to study electron transport phenomena: Landauer-Buttiker formulation (Qualitative discussions only). Landau band and Quantum Hall effect, Spin Hall Effect (Qualitative discussions only).

Reference Books

1. Optical Properties of Solids; Mark Fox, Oxford Master series
2. Solid State Physics: An Introduction to Theory and Experiments; H. Ibach and H. Luth:
3. Solid State Physics: Essential Concepts; avid W. Snoke.
4. Principles of the Theory of Solids; J.M. Ziman:
5. Electronic Transport in Mesoscopic systems; Supriyo Datta, Cambridge Universuty Press

6. Quantum Transport: Atom to Transistor; Supriyo Datta, Cambridge Universuty Press
7. Lessons from Nanoelectronics; Supriyo Datta

Paper Name: Material Science

Paper Code: PHY409

L T P – 3-0-1

Course Objectives:

1. To describe the structure and bonding in various materials, including crystalline, amorphous, and advanced materials such as metals, semiconductors, ceramics, and polymers, establishing a foundational understanding of their material properties.
2. To explain the significance of phase diagrams, phase transformations, and the properties of alloys, focusing on binary and ternary systems, to provide insights into material behavior during phase changes.
3. To analyze the electronic properties and structures of different carbon-based materials, such as graphene, diamond, fullerenes, and carbon nanotubes, emphasizing their unique characteristics and potential applications.
4. To examine the role of defects in solids, including dislocations and color centers, and assess their impact on the mechanical, electrical, and optical properties of materials.
5. To conduct hands-on experiments on semiconductor materials, such as band-gap determination, Hall effect, and magneto-resistance measurements, and analyze experimental results to reinforce theoretical concepts.

Course Description:

This course provides a comprehensive understanding of the structural, bonding, electronic, and defect properties of crystalline and amorphous solids, including advanced carbon and composite materials. It introduces key concepts such as phase diagrams, solid solutions, and the classification of defects. The course also includes a practical component where students conduct experiments related to the electrical and magnetic behavior of semiconductors. Together, the theoretical and experimental modules offer students foundational knowledge essential for materials science, nanotechnology, and electronic device applications.

Course Outcome:

1. **CO1: List and define** key concepts related to crystal structures, bonding types, and classes of solid-state materials.

2. **CO2: Explain** the principles governing phase behavior, carbon allotropes, and the formation of structural defects in materials.

3. **CO3: Apply** theoretical models to illustrate phase diagrams, defect structures, and electronic behavior in solids.

4. **CO4: Analyze** the interdependence of bonding, crystal geometry, and microstructural defects on the macroscopic properties of materials.

5. **CO5: Assess** the theoretical implications and limitations of structural imperfections and phase compositions in determining material performance and reliability.

6. **CO6: Conduct** semiconductor-based experiments and interpret the resulting data to extract key physical parameters such as bandgap, Hall coefficient, and photoconductivity.

Course Content:

Module I: Recapitulations of Structure & bonding in solids *(12 hours)*

Crystalline and amorphous materials. Crystal structure of solids, Bravais lattice, Symmetry operation. Introduction to space group and point group. Single crystals, polycrystalline and nano-crystalline solids. Interatomic forces and types of bonding (Ionic Bonds, Covalent Bonds, Metallic Bonds, Hydrogen Bonds and Vander Waal's Bonds). Introduction to metallic materials and semiconductor materials, Properties of Dielectric material, Properties of ceramics & polymers, fundamentals of magnetic materials. Advanced materials: Composite materials, Smart materials, solar energy materials, Optoelectronic materials).

Module II: Solid solutions and Alloys *(8 hours)*

Phase diagrams: Gibb's phase rule, Single component systems, Eutectic phase diagram, lever rule. Study of phase diagrams, phase transformation Nucleation kinetics and growth. Introduction to Haussler alloy: binary and Ternary

Module III: Different form of Carbon Materials *(12 hours)*

Graphene, Diamond and fullerenes, Carbon Nano Tube (Density of States, Elementary electronic properties and band structure), Single wall and multiwall carbon nanotube.

Module IV: Study of Defects in Solids *(9 hours)*

Idea of closed packed structure, lattice constant/cell volume, Imperfection in solids, Different dimension of defects: linear defects, Planar defects, Volume defects, Formation of colourcentres.

Dislocations: Burger vectors, Dislocation densities, Slip, A brief discussion on hardness of materials/alloys.

Module V: Hands on Trainings:

- Determine energy band-gap a semiconductor by measuring temperature dependence of reverse saturation current of a junction diode

- Find the Curie temperature of BaTiO3 by studying temperature dependent dielectric constant.
- Thin film deposition of Al and XRD studies by thermal evaporation method.
- Thin film synthesis of ZnO by spin coating unit and characterization by UV-vis spectroscopy and crystallinity by XRD.
- Thin film synthesis of polymer and characterization of molecular vibration by FTIR spectroscopy.

Reference Books:

1. Introduction to Solid State Physics; C. Kittel, Wiley Eastern Ltd, 2005.
2. Materials Science and Engineering: A First Course; V. Raghavan, Prentice Hall, 2006
3. Solid State Physics; A.J. Dekker, Macmillan & Co, 2000.
4. Essentials of Solid-State Physics; S. P. Kuila, New Central Book Agency, 2013.

Paper Type: CC (Advanced Specialization)

Track: Biomedical Instrumentation

Paper Name: Physics for Medicine

Paper Code: PHY405

LTP: 4-0-0

Course Objectives:

1. To describe the organization and structural differences between prokaryotic and eukaryotic cells, and to understand the composition of tissues in the human body.
2. To explain how light interacts with biological tissues, including key phenomena such as absorption, scattering, and the optical properties of skin layers and blood.
3. To analyze the dynamics of biomolecules, including diffusion, osmosis, and surface tension, and their relevance to biological processes.
4. To evaluate thermodynamic principles in living systems, with a focus on energy conservation, entropy, and Gibbs free energy in biological contexts.
5. To apply the principles of biomechanics and the electrical properties of tissues to investigate human body movement and neuron excitability.

Course Description:

This course introduces the theoretical principles that govern the physical and physiological behavior of living systems. It covers cellular and tissue structure, light-tissue interactions, transport and thermodynamic processes in biological environments, biomechanics, and the electrical behavior of excitable membranes. Through a multidisciplinary framework, students develop a conceptual understanding of how physical laws apply to biological systems, forming a foundation for further studies in biophysics, medical physics, and physiology.

Course Outcome:

1. **CO1**: **Identify** and **define** the fundamental structural and functional elements of cells, tissues, and biological systems relevant to biophysical study.

2. **CO2**: **Explain** the physical principles behind light–tissue interaction, transport phenomena, and the electrical properties of biological membranes.

3. **CO3**: **Apply** theoretical models and physical laws to **calculate** and **interpret** biophysical parameters such as osmotic pressure, diffusion rates, and free energy changes.

4. **CO4**: **Analyze** the behavior of biological systems under mechanical, optical, and electrical stimuli using appropriate theoretical frameworks.

5. **CO5**: **Evaluate** the applicability and limitations of biophysical models in describing complex biological processes such as human motion, membrane conductivity, and coupled chemical reactions.

Course Content:

Module I: Cell and Tissue *(10 hours)*

Cell Organization Cell as the basic structural unit, Origin & organization of Prokaryotic and Eukaryotic cell, Cell size & shape, Fine structure of Prokaryotic & Eukaryotic cell organization (Bacteria, Cyanobacteria, plant & Animal cell), Internal architecture of cells, Connection between cell & its environment, Extracellular Matrix, Kinetics of cell growth, Structure and type of tissues in human body.

Module II: Tissue Optics *(12 hours)*

Light-matter interaction: absorption, scattering, reflection, refraction, luminescence, interference, polarization; their physical models and mechanisms. Specific features of living tissues from the point of optics. Relations of scattering and absorption in tissues -different interaction of lasers with tissues – Thickness and optical properties of appropriate skin layers - Skin pigments (melanin, bilirubin, carotene, hemoglobin) and their spectra - Composition of blood. Spectral properties of erythrocytes, thrombocytes and blood plasma - Differences between oxygenated and deoxygenated hemoglobin absorption spectra.

Module III: Dynamics of biomolecules *(8 hours)*

Biological importance of Diffusion, Laws of diffusion, Active transport, Facilitated diffusion, Osmosis, Osmotic pressure, Osmoregulation, Viscosity and biological importance, Surface tension, Factors influencing surface tension.

Module IV: Thermodynamics of living systems *(7 hours)*

Conservation of energy in living systems, Entropy and Life, Gibbs and Standard free energy, Equilibrium constant, Coupled reactions.

Module V: Statics and kinematics of the body *(10 hours)*

Forces, moments, angular momentum, Rigid Body Mechanics, Musculoskeletal Anatomy, Basic Statics and Joint Mechanics (elbow, shoulder, spine, hip, knee, ankle), Basic Dynamics to Human Motion: Review of linear and angular kinematics; Kinetic equations of motion; Work & energy methods; Momentum methods; Examples in biomechanics; Modern kinematic measurement techniques; Applications of human motion analysis

Module VI: Electrical properties of excitable membranes *(7 hours)*

Basic electricity and electric circuits; Neurons as conductors of electricity; Equivalent circuit representation; Electrical properties of excitable membranes: Membrane conductance, linear and nonlinear membrane, ionic conductance, current-voltage relations; Ion movement in excitable cells: Physical laws, Nernst-Planck Equation.

Reference Books:

1. Physics of the Human Body, Herman, I.P. (2007), Springer. ISBN: 978-3540296034
2. Physics of the Body, Cameron, J. R., Skofronick, J. G. and Grant, R. M. (1999), , Medical Physics Publishing, 2nd Ed., ISBN: 978-0944838914
3. Physics in Biology and Medicine; Davidovits, P., (2008), , 3rd Edition, Elsevier/Academic Press, ISBN: 978-0123694119.

Paper Name: Biomedical Instrumentation

Paper Code: PHY410
LTP: 3-0-1

Course Objectives:

1. To describe the sources of biomedical signals and the essential design constraints associated with medical instrumentation systems.
2. To explain the working principles and applications of diagnostic instruments such as oximeters, spirometers, and blood pressure measurement systems in healthcare.
3. To illustrate the need for therapeutic instruments, including pacemakers, defibrillators, and ventilators, and explain their operational mechanisms.
4. To analyze the principles behind cutting-edge biomedical technologies, such as wearable sensors, AI-driven healthcare solutions, and telemedicine applications.
5. To conduct experiments using biomedical instruments like ECG machines, pulse oximeters, and spirometers, and develop skills in measuring and calibrating health parameters.

Course Description:

This course introduces the theoretical foundation and practical applications of biomedical instrumentation. It covers signal sources, diagnostic and therapeutic equipment, patient safety, and ethical concerns in medical device development. Students will learn the operating principles of instruments such as ECG, EEG, spirometers, pacemakers, and wearable sensors. The laboratory component provides hands-on experience in operating and calibrating biomedical devices, preparing students for careers in healthcare technology and clinical engineering.

Course Outcome:

1. **CO1**: **Recall** the sources of biomedical signals and **list** the core components and types of biomedical instrumentation systems.

2. **CO2**: **Explain** the principles of operation, signal pathways, and physiological relevance of diagnostic and therapeutic biomedical devices.

3. **CO3**: **Use** theoretical frameworks to **demonstrate** how biomedical instruments interact with human physiological signals in clinical contexts.

4. **CO4**: **Distinguish** among different biomedical systems and **analyze** how signal artifacts, system constraints, and patient variability affect instrument performance.

5. **CO5**: **Justify** the selection and theoretical design of biomedical instruments by assessing their functional principles, limitations, and clinical suitability.

6. **CO6**: **Set up**, **operate**, and **evaluate** basic biomedical instruments in a laboratory environment and **interpret** measurement results for accuracy and reliability.

Course Content:

Module I: Introduction to Biomedical Signals and Instrumentation *(12 hours)*

Sources of biomedical signals, basic medical instrumentation system, PC based medical instruments, General constraints in design of medical instrumentation systems, origin of bioelectric signals, Electrocardiogram (ECG) -block diagram, ECG leads, effects of artifacts, multi-channel, ECG machine, Phonocardiograph-origin of heart sounds, microphones and amplifiers for PCG, Electroencephalogram (EEG) - block diagram, computerized analysis of EEG, Electromyogram (EMG), Myoelectric control, Voluntary control of myoelectric signals, use of myoelectric signal for control - signal processing and recording, biofeedback instrumentation. Medical device regulations and standards, Risk management and patient safety, Ethical considerations in biomedical instrumentation research and development.

Module II: Diagnostic Instruments *(12 hours)*

Oximetry- In-vitro and in-vivo, ear oximetry, pulse oximetry, skin reflectance oximeters, intravascular oximeter. Blood flowmeter types and their principle, Pulmonary function measurement measurements-respiratory volumes and capacities, compliance and related pressures, dynamic respiratory parameters, basic spirometer, ultrasonic spirometer, pneumotacometer, Blood Pressure Measurement - Non-invasive and invasive techniques, Arterial blood pressure waveform analysis, Blood pressure monitoring systems

Module III: Therapeutic Instruments *(10 hours)*

Need for cardiac pacemaker, external pacemaker, implantable pacemakers-types, ventricular synchronous demand pacemaker, programmable pacemaker, power sources for implantable pacemakers. Need for defibrillator, DC defibrillator, automatic external defibrillator, implantable defibrillators, Principle of surgical diathermy and surgical diathermy machine, Anesthesia-Need for anesthesia, delivery of anesthesia, anesthesia machine, Ventilator – types, controlling parameters, working principle.

Module IV: Emerging Trends in Biomedical Instrumentation *(8 hours)*

Clinical laboratory instrumentation, Blood cell counter and associated hematology system, Endoscopic diagnosis and foreign body removal, blood gas analyzers, Wearable sensors and mobile health technologies, Telemedicine and remote patient monitoring, Artificial intelligence in healthcare, Safety and Ethical Considerations.

Module V: Hands On Training:

- Experiments and calibration with ECG machine.
- Experiments with Pulse-oximeter machine.
- Experiments with Audiometer
- Experiment and calibration of Sphygmomanometer.
- Experiments with glucometer.
- Experiments for measuring pulmonary functions with spirometer.

Reference Books:

1. Hand book of Biomedical Instrumentation; Khandpur R.S., TMH, 2003.
2. Biomedical Digital Signal Processing; Tompkins,.
3. Biomedical Instrumentation and Measurements; Leslie Cromwell, Fred J. Weibell, Pub: Erich A. Pfeiffer.
4. Introduction to biomedical engineering; Enderle, John, and Joseph Bronzino, eds.. Academic press, 2012.

Paper Type: CC (Advanced Specialization)

Track: Physics of Renewable Energy and Smart Energy Systems

Paper Name: Solar Energy Materials and Photovoltaic Technology
Course Code: PHY445
Credits: 4
L–T–P: 3–0–1

Course Objectives

1. To introduce the fundamental concepts of solar energy and its role in sustainable energy systems.
2. To understand the physics and materials used in photovoltaic devices.
3. To study different solar cell technologies including thin-film and nanostructured materials.
4. To develop knowledge of photovoltaic system design and performance evaluation.
5. To expose students to industrial applications and emerging technologies in the solar energy sector.

Course Outcomes

After successful completion of the course, students will be able to:

CO1: Explain the principles of solar radiation and solar energy conversion processes.

CO2: Understand the semiconductor physics underlying photovoltaic devices and the photovoltaic effect.

CO3: Compare different photovoltaic materials and solar cell technologies including silicon, thin-film, and emerging nanostructured solar cells.

CO4: Analyze the performance of solar photovoltaic systems and evaluate important efficiency parameters.

CO5: Design basic solar photovoltaic systems for small-scale applications and demonstrate practical skills in measuring solar cell characteristics.

Course Content

Unit I: Solar Energy Fundamentals

Global energy scenario and renewable energy resources, Solar potential and solar energy utilization, Solar radiation, solar constant, and solar spectrum, Interaction of light with matter and absorption in semiconductors

Unit II: Photovoltaic Materials and Devices

Basics of semiconductor physics for solar cells, p–n junction and photovoltaic effect, Silicon solar cells (monocrystalline, polycrystalline, amorphous), Thin-film solar cells (CdTe, CIGS), Emerging photovoltaic materials: perovskite and nanostructured solar cells

Unit III: Solar PV System Design

Solar module structure and efficiency parameters, Solar thermal collectors and hybrid solar systems, Photovoltaic system components (inverter, charge controller, batteries), Grid-connected and off-grid photovoltaic systems

Unit IV: Industrial Applications and Emerging Trends

Large-scale solar power plants and solar parks, Solar energy development in India and government policies, Solar rooftop systems and decentralized energy systems, Emerging technologies in the solar industry and future prospects

Practical / Laboratory (1 Credit)

1. Measurement of I–V characteristics of a solar cell.
2. Determination of solar panel output power under different conditions (solar panel output changes with light illuminance, dust, shading, and temperature).
3. Study a simple MPPT concept using basic control or simulation.
4. Compare different types of solar panels using data.
5. Compare different solar cells (mono-Si, poly-Si, thin film)
6. Measure variation of voltage (Voc) and current (Isc) change with temperature.
7. Outdoor testing of solar cell using real sunlight and a pyranometer.
8. Build a simple solar cell model (one-diode model) using Python or MATLAB.
9. Mini project: Design and analysis of a small solar power system for household or laboratory use.

Reference Books

1. **S. P. Sukhatme and J. K. Nayak**, *Solar Energy: Principles of Thermal Collection and Storage*, Tata McGraw Hill.
2. **Martin A. Green**, *Solar Cells: Operating Principles, Technology and System Applications*, Prentice Hall.
3. **Chetan Singh Solanki**, *Solar Photovoltaics: Fundamentals, Technologies and Applications*, PHI Learning.

4.
5. **Jenny Nelson**, *The Physics of Solar Cells*, Imperial College Press.
6. **Dieter K. Schroder**, *Semiconductor Material and Device Characterization*, Wiley.

Paper Name: Electric Mobility and Energy Storage Technologies
Course Code: PHY446
Credits: 4
L–T–P: 3–0–1

Course Objectives

1. To introduce the fundamental concepts of energy storage systems used in modern energy applications.
2. To understand the working principles and technologies of different battery systems.
3. To study the architecture and operation of electric vehicles and their components.
4. To explore hydrogen energy technologies and fuel cells as future energy solutions.
5. To develop practical understanding of energy storage devices and electric mobility systems.

Course Outcomes (COs)

After successful completion of the course, students will be able to:

CO1: Explain the basic principles and classifications of different energy storage systems.

CO2: Understand the working mechanisms and characteristics of various battery technologies and battery management systems.

CO3: Analyze the structure and operation of electric vehicles including motors, power electronics, and regenerative braking systems.

CO4: Evaluate hydrogen production methods, fuel cell technologies, and their role in future energy systems.

CO5: Demonstrate practical understanding of energy storage devices and electric mobility systems through laboratory experiments and simple system modeling.

Course Content

Unit I: Fundamentals of Energy Storage

Energy demand and role of energy storage in modern energy systems, Energy density, power density, and efficiency of storage systems, Classification of energy storage technologies, Mechanical, thermal, and electrochemical energy storage systems

Unit II: Battery Technologies

Fundamentals of electrochemical energy storage, Lead-acid batteries and their applications, Lithium-ion and solid-state battery technologies, Battery charging–discharging mechanisms and degradation processes, Battery Management Systems (BMS) and safety considerations

Unit III: Electric Vehicles

Overview and development of electric mobility, Architecture and components of electric vehicles, Electric motors used in EVs, Power electronics and control systems, Regenerative braking and energy efficiency in EVs

Unit IV: Hydrogen and Future Energy Systems

Hydrogen as a clean energy carrier, Hydrogen production methods (electrolysis, reforming, etc.), Fuel cells: principles and types (PEMFC, SOFC), Hydrogen economy and future prospects, EV charging infrastructure and smart charging technologies

Practical / Laboratory (1 Credit)

1. Study of charging and discharging characteristics of rechargeable batteries.
2. Compare battery vs supercapacitor performance.
3. Observe battery performance reduces over cycles. Measure internal resistance in a simple way.
4. Study basic BMS logic: overcharge, safety, balancing.
5. Mini project: - Estimate EV range and charging challenges.

   Advanced Lab

6. Study battery performance at different charge/discharge speeds (C-rate).
7. Perform battery + supercapacitor combined test to understand load sharing.
8. Measure motor efficiency across full torque and speed range.
9. Implement a basic cell balancing logic using Arduino or Python.
10. Build an energy model based on real driving data (GPS, elevation, speed).

Reference Books

1. **Iqbal Husain**, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press.
2. **Mehrdad Ehsani, Yimin Gao, and Ali Emadi**, *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles*, CRC Press.
3. **David Linden and Thomas B. Reddy**, *Handbook of Batteries*, McGraw-Hill.
4. **Bent Sørensen**, *Hydrogen and Fuel Cells: Emerging Technologies and Applications*, Academic Press.
5. **A. R. Jha**, *Energy Storage Systems*, Academic Press.

Compulsory Courses (CC With Research)

Paper Name: Research Methodology

Paper Code: PHY440
L T P – 3-0-1

Course Objectives:

1. To understand the nature and scope of scientific research in Physics.
2. To identify appropriate research designs and data collection strategies.
3. To apply statistical tools for data analysis and uncertainty estimation.
4. To develop clear and effective scientific communication skills.
5. To recognize and uphold ethical standards and responsible conduct in research.
6. To carry out a mini-research project and present results using scientific formats.

Course Description:

This course introduces students to the foundational concepts and practices of research methodology in physics. It covers both theoretical aspects—including research design, data analysis, scientific communication, and ethical conduct—and practical elements involving the execution of a research project. Emphasis is placed on developing critical thinking, statistical reasoning, and scientific writing skills essential for academic and professional research. The course prepares students to carry out responsible, well-structured, and impactful research in the physical sciences.

Course Outcome:

1. **CO1**: **Identify** key concepts of scientific research, research types, and ethical responsibilities relevant to the practice of physics research.

2. **CO2**: **Explain** the principles of research design, hypothesis formulation, and data collection methods used in quantitative and qualitative physics research.

3. **CO3**: **Apply** appropriate statistical tools and error analysis techniques to organize, analyze, and interpret experimental or observational data in physics.

4. **CO4**: **Analyze** the structure and content of scientific documents and research papers to improve the quality and clarity of scientific communication.

5. **CO5**: **Evaluate** research plans, ethical decisions, and data integrity based on established standards of responsible conduct in scientific research.

6. **CO6**: **Develop** and **carry out** a small-scale research project, and **present** the findings through appropriate scientific formats such as reports or presentations.

Course Content:

Module I: Introduction to Research Methodology

Understanding the nature and significance of research, difference between quantitative and qualitative research, identifying research objectives and formulating research questions, exploring ethical considerations and responsible conduct of research

Module II: Research Design and Data Collection

Understanding different research designs (experimental, observational, survey, etc.) in physics, formulating hypotheses and defining research variables, selecting appropriate data collection methods and instrumentation, ensuring validity, reliability, and accuracy of data collection

Module III: Data Analysis and Interpretation

Introduction to statistical analysis techniques for physics research, using statistical software for data analysis and visualization, interpreting and drawing conclusions from research data, understanding error analysis and uncertainty estimation

Module IV: Research Communication and Scientific Writing

Structuring and organizing research papers and reports, enhancing scientific writing skills for research articles and proposals, preparing effective research presentations (oral and poster), developing communication skills for scientific conferences and collaborations

Module V: Ethics, Responsible Conduct, and Research Project

Understanding ethical considerations and regulations in physics research, discussing responsible conduct of research and authorship guidelines, applying ethical principles in data management and protection of human subjects, implementing research project and presenting research findings

Reference Books:

1. Research Methodology: A Step-by-Step Guide for Beginners, Ranjit Kumar
2. Research Design: Qualitative, Quantitative, and Mixed Methods Approaches; John W. Creswell and J. David Creswell
3. Writing for Science, Robert Goldbort
4. Ethics in Research: Continuum Research Methods, Margaret Adolphus

5. Research Methods in Physics and Astrophysics, Hale Bradt

Compulsory Courses (CC Without Research)

Paper Name: Machine Learning and Data Analytics

Paper Code: PHY441
L-T-P: 1-0-3

Course Objectives:

1. To understand the theoretical foundations and evolution of machine learning algorithms.
2. To apply supervised and unsupervised learning models to real-world datasets.
3. To use statistical and probabilistic methods for data analysis and model evaluation.
4. To perform feature engineering, data transformation, and dimensionality reduction.
5. To gain proficiency in Python-based tools (Pandas, Scikit-Learn, PyTorch) for implementing machine learning workflows.
6. To conduct practical experiments in model development, performance evaluation, and data interpretation using modern programming environments.

Course Description:

This hybrid course introduces foundational and advanced concepts in machine learning and data analytics. It covers supervised and unsupervised learning techniques, neural networks, statistical analysis, and essential tools in Python such as Pandas and Scikit-Learn. Students will learn theoretical underpinnings and apply them through practical coding exercises in regression, clustering, classification, and data preprocessing. The course balances conceptual rigor with hands-on problem-solving to prepare students for real-world data science applications.

Course Outcomes

1. **CO1: Identify** key concepts and terminology in machine learning, statistical learning, and data analytics.

2. **CO2: Explain** the principles of supervised and unsupervised learning, neural networks, and their application contexts.

3. **CO3: Apply** data preprocessing techniques, statistical measures, and learning algorithms to solve classification and regression problems.

4. **CO4: Analyze** the performance of machine learning models using appropriate evaluation metrics and validation strategies.

5. **CO5: Evaluate** the suitability and effectiveness of different models and data analysis approaches for specific learning tasks and datasets.

6. **CO6: Develop and execute** end-to-end machine learning pipelines using Python-based tools, and interpret the results for meaningful decision-making**.**

Course Content

Module I: Foundations of Machine Learning and Data Analytics *(5 hours)*

Evolution and types of Machine Learning techniques, Components of a machine learning framework: information vs. data, Overview of supervised and unsupervised learning, Basics of Python programming for data analysis, Introduction to Pandas: Series, DataFrames, importing and exploring datasets, Use of Jupyter Notebook for interactive data analysis

Module II: Data Preprocessing and Feature Engineering *(6 hours)*

Data preprocessing: handling missing data, outliers, categorical variables; Data scaling, normalization, and standardization, Feature selection and filtering techniques, Feature creation and transformation, Principal Component Analysis (PCA) for dimensionality reduction

Module III: Supervised and Unsupervised Learning Techniques *(12 hours)*

Supervised Learning: Linear and Non-linear Regression, Logistic Regression, Decision Trees, Support Vector Machines (SVMs)

Unsupervised Learning: K-Means Clustering, Hierarchical Clustering (Agglomerative, Divisive), Dendrograms and linkage methods

Module IV: Advanced Learning Techniques and Evaluation *(10 hours)*

Neural Networks: Basics of Artificial Neural Networks, Perceptron and Backpropagation, Introduction to PyTorch

Model Evaluation and Validation: Training, validation, testing; Cross-validation techniques, learning curves; Overfitting and underfitting; Evaluation metrics for classification: Accuracy, Precision, Recall, F1 Score; Evaluation metrics for regression: MAE, MSE, RMSE, R^2

Module V: Statistical Tools for Data Analysis *(8 hours)*

Descriptive statistics and exploratory data analysis, Probability theory and distributions, Confidence intervals and hypothesis testing, Goodness-of-fit tests, Outlier detection

Module VI: Hands On Training

- Python programming using Pandas and NumPy
- Data visualization using Pandas and Matplotlib
- Implementation of machine learning models using Scikit-Learn
- Neural Network model building using PyTorch
- Dimensionality reduction using PCA
- Clustering using K-Means and hierarchical methods
- Model validation, cross-validation, and performance interpretation

Reference Books:

1. Machine Learning Algorithms; by G. Bonaccorso
2. Hands-on Machine Learning with Python; by A. Pajankar, A. Joshi
3. Machine Learning using Python; M. Pradhan, U. D. Kumar
4. Hands-On Data Preprocessing in Python; by R. Jafari
5. Machine Learning with PyTorch and Scikit-Learn; S. Raschka, Y. Liu, V. Mirjalili

Semester VIII

Paper Type: CC (Advanced Specialization)

Track: Astronomy and Astrophysics

Paper Name: *Computational Astrophysics*

Paper Code: PHY411
LTP: 2-0-2

Course Objectives:

1. To understand the basic ideas and importance of computation in solving astrophysical problems.
2. To explain simple numerical techniques like integration and solving differential equations.
3. To learn basic programming (Python or C) for solving problems in astrophysics.
4. To apply computer programs to simulate planetary motion and star structure.

Course Description:

This discipline-specific elective course introduces undergraduate Physics students to the powerful role of computation in solving and visualizing astrophysical problems. Covering topics from celestial mechanics to stellar and galactic modelling, the course blends core concepts in physics with essential numerical techniques and programming skills. Students will learn to implement simulations using Python (or C) and apply methods such as numerical integration, differential equation solving, and root-finding to explore orbital dynamics, stellar structures, and cosmological expansion. The course is complemented by hands-on simulation-based lab work, empowering students to model realistic astrophysical systems and interpret computational results. Designed for aspiring physicists and computational scientists, this course builds a strong foundation for research and higher study in astrophysics, computational physics, and data-driven science.

Course Outcomes:

1. **CO1**: **Describe** the role of computation in astrophysics and the basic structure of programming languages such as Python or C, including the use of variables, loops, and arrays.

2. **CO2**: **Explain** key numerical techniques such as differentiation, integration, root-finding, and their relevance in solving astrophysical problems.

3. **CO3**: **Apply** Newtonian gravity and numerical methods to simulate and visualize celestial orbits, escape velocities, and other orbital parameters.

4. **CO4**: **Analyze** simple models of stellar structure by numerically solving equations for hydrostatic equilibrium and energy transport.

5. **CO5**: **Interpret** galactic rotation curves and Hubble's law through simulations, and relate these to fundamental concepts such as dark matter and cosmic expansion.

6. **CO6**: **Construct** computational models for a variety of astrophysical systems, integrate multiple numerical tools, and generate plots for scientific interpretation and communication.

Course Content

Module I: Introduction to Computational Astrophysics *(8 Hours)*

Use of computation in astronomy; Introduction to programming (Python or C); Basics of variables, loops, arrays, plotting tools (e.g., Matplotlib).

Module II: Numerical Methods *(10 Hours)*

Numerical differentiation and integration (Trapezoidal and Simpson's Rule); Euler's method for solving differential equations; Root finding (Bisection method).

Module III: Celestial Mechanics *(10 Hours)*

Newton's law of gravitation; Two-body problem; Simulating orbits (Earth-Sun system); Escape velocity; Orbit shapes and plotting.

Module IV: Stellar Modelling *(10 Hours)*

Introduction to stellar structure; Hydrostatic equilibrium; Energy transport basics; Simple models of temperature and pressure inside stars.

Module V: Galactic and Cosmological Simulations *(10 Hours)*

Rotation curves of galaxies; Simple idea of dark matter; Hubble's law and redshift; Simulating galaxy motion and expanding universe.

Module VI: Hands On Training (Simulation-Based Laboratory Work):

- Earth-Sun Orbit Simulation: Write a program to simulate Earth's orbit using Newtonian gravity and plot the result.
- Numerical Integration and Differentiation: Calculate integrals and derivatives for known functions and compare with exact values.
- Stellar Temperature Profile: Model and plot the change of temperature with radius in a simple star using numerical methods.
- Galaxy Rotation Curves: Plot a sample galaxy's rotation curve and compare it with the expected theoretical curve.
- Hubble Expansion Plot: Simulate redshift vs. distance and draw the Hubble diagram using basic data.

Reference of Books:

1. Paul Hellings, *Astrophysics With a PC: An Introduction to Computational Astrophysics*, Willmann-Bell, 1st English Edition, 1994.
2. Jamie Flux, *Computational Physics - Astrophysics: All in One Handbook with Python*, Independently published, 2025
3. Zeljko Ivezic et. al., *Statistics, Data Mining and Machine Learning in Astronomy*, 2019.
4. Qingkai Kong et. al., *Python Programming and Numerical Methods: A Guide for Engineers and Scientists*, 1sr Edition, 2020.
5. Online Resources – astropy.org, scipy.org, matplotlib.org

Paper Type: CC (Advanced Specialization)

Track: Nanoscience

Paper Name: Quantum Transport

Paper Code: PHY412
LTP: 4-0-0

Course Objectives:

1. To understand the characteristic length scales and properties of 2D Electron Gas, Quantum Wires, and Quantum Dots, facilitating a foundation for further exploration of low-dimensional systems.
2. To apply the tight-binding model to various systems, including Graphene, Graphene nanoribbons, and Fractal Geometries, in order to calculate energy dispersion and eigenstates, enhancing computational skills in solid-state physics.
3. To analyze transport mechanisms using the Landauer-Büttiker formalism, and compute transmission probabilities via different methods such as the Transfer Matrix and Green's Function, fostering a deeper understanding of quantum transport phenomena.
4. To evaluate quantum transport in closed systems by studying quantum interference effects, the Aharonov-Bohm effect, and persistent current phenomena, linking theoretical concepts to experimental observations.
5. To investigate electronic localization in quasi-crystals and disordered lattices, and apply models like the Aubry-Andre-Harper to study energy eigenstates in quasi-periodic systems, thereby exploring the implications of disorder in quantum mechanics.

Course Description:

This course provides a theoretical foundation for understanding quantum transport phenomena and electronic behavior in low-dimensional and disordered systems. It begins with the concept of quantum confinement and mesoscopic length scales, followed by the application of tight-binding models to various geometries including graphene and fractal lattices. The course introduces quantum transport through the Landauer-Büttiker formalism and explores computational techniques like Green’s functions and transfer matrices. Students also study quantum interference, persistent currents, and localization effects in quasi-periodic systems such as Fibonacci and Thue-Morse lattices.

Course Outcomes:

1. **CO1: Recall** the fundamental concepts of quantum confinement, tight-binding theory, and localization in low-dimensional systems.

2. **CO2: Explain** the principles underlying mesoscopic observables, band structures, and quantum transport in nano-structured systems.

3. **CO3: Apply** theoretical models such as tight-binding formalism and Landauer-Büttiker framework to analyze transport properties of quantum systems.

4. **CO4: Analyze** the influence of geometry, dimensionality, and disorder on the transport behavior and energy spectra of electronic systems.

5. **CO5: Evaluate** quantum interference effects, localization phenomena, and transport signatures in periodic, disordered, and quasi-periodic systems using appropriate theoretical tools.

Course Content:

Module I: Introduction to Length Scales *(12 hours)*

Introduction to the Characteristic Length scales, Mesoscopic observables in nanostructures, Nano-structures and Nano-devices, Quantum confinement, 2D Electron Gas and its properties, Lateral confinement in Quantum Wires and Quantum Dots.

Module II: Tight Binding Theory *(12 hours)*

Tight Binding Model in discrete Wannier basis. Energy dispersion relation and Eigenstates calculations in various linear systems like 1D ordered chain, alternating chain, Ladder network, 2D square lattice, Graphene, Graphene nano-ribbons (Zigzag and Armchair edge), Kagome Lattice, Lieb Lattice, Fractal Geometries etc.

Module III: Transport Mechanism *(12 hours)*

Conductance from Transmission, Landauer-Büttiker formalism for open system transport for Two-terminal and Multi-terminal quantum systems, Landauer formula. Calculation of Transmission probability by (i) Wave-guide Theory, (ii) Transfer-Matrix Method, (iii) Green's Function Technique. S matrix and T matrix, Fisher-Lee relation.

Module IV: Quantum Transport *(12 hours)*

Quantum Transport in Closed systems, Quantum Interference, Aharonov-Bohm Effect, Persistent Current Phenomena, Drude Weight, Magnetic susceptibility, Calculation of persistent current by (i) Derivative Method, (ii) Green's function Technique.

Module V: Idea of Localization and Quasi crystals *(12 hours)*

Electronic Localization, Inverse Participation Ratio, Lyapunov Exponent, Shanon entropy, Electronic localization in Random disordered lattice, Quasi-crystals, Aubry-Andre-Harper Model. Study of energy Eigenstates in various Quasi-periodic systems like Fibonacci lattice (Golden Mean sequence, Silver mean, copper mean etc.), Thue-Morse lattice, Period Doubling chain etc.

Reference Books:

1. Lessons from Nanoscience: A Lecture Note Series; Supriyo Dutta, World Scientific (2012).
2. Quantum Transport- Atom to Transistor; Supriyo Dutta, Cambridge University Press (2005).
3. Introduction to Nanoelectronics; V. Mitin, V. Kochelap, M. Stroscio,Cambridge University Press (2008).
4. Nanoelectronics and Information Technology: Advanced Electronic Materials and Novel Device; Rainer Waser, Wiley-VCH (2003).
5. Nanoelectronics and Nanosystems; Karl Goser, Peter Glosekotter, Jan Dienstuhl,Springer (2004).
6. Introduction to Nanoelectronics: Science, Nanotechnology, Engineering &Applications; Vladimir. V. Mitin.

Paper Type: CC (Advanced Specialization)

Track: Optoelectronics and Photonics: Principles and Practices

Paper Name: LASER and Optoelectronic Devices

Paper Code: PHY413
LTP: 3-0-1

Course Objectives:

1. To explain the fundamental principles of laser action, including atomic energy levels, mechanisms behind laser radiation, and advanced concepts like Q-switching, mode locking, and population inversion.
2. To describe and differentiate between various types of laser systems, such as continuous wave (CW) lasers, pulsed lasers, and semiconductor lasers, and to discuss their industrial and scientific applications, as well as safety protocols for laser handling.
3. To analyze the application of lasers across diverse fields, including communications, material processing, and biomedical technologies, with a focus on understanding their practical uses.
4. To evaluate the working principles of photovoltaic cells and optical detectors, including performance metrics and noise characteristics, enhancing students' knowledge of photodetector systems.
5. To conduct experiments that assess the characteristics of laser beams, optoelectronic devices, and the behavior of photodetectors and solar cells, thereby reinforcing the theoretical knowledge through hands-on learning.

Course Description:

This course explores the quantum theory of laser operation and a wide range of applications in communication, materials processing, metrology, defense, and biomedicine. It covers fundamental concepts such as population inversion, radiative transitions, line broadening, and the design of various laser systems. Applications of lasers in storage and manufacturing, as well as principles of photovoltaic devices and photodetectors, are integrated into the theoretical component. A complementary practical component introduces hands-on experimentation with laser beams and optoelectronic devices.

Course Outcome:

1. **CO1: Recall** the quantum principles of laser operation, types of lasers, and key components of a laser system.

2. **CO2: Describe** the working mechanisms and physical parameters of CW, pulsed, and semiconductor lasers, as well as their applications.

3. **CO3: Apply** theoretical models to explain laser-material interactions, optical detection principles, and photovoltaic performance.

4. **CO4: Analyze** the suitability and efficiency of lasers for various applications in industry, communication, metrology, and biomedical systems.

5. **CO5: Evaluate** the performance of photonic devices such as optical receivers, amplifiers, and detectors using relevant physical criteria and theoretical models.

6. **CO6: Perform** laser and optoelectronic device experiments, and interpret the resulting data to determine beam characteristics and device response parameters.

Course Content:

Module I: Quantum Theory of Laser Radiation *(15 hours)*

Quantum Theory of Atomic Energy Levels, Radiative and Nonradiative decay of excited state atoms, Emission Broadening and linewidth, Radiation and Thermal equilibrium, properties of laser radiation, and laser safety; Principle of Laser action and basic Laser components, Population Inversion, Einstein's A and B coefficients, Optical Resonator: Quality Factor, Q-switching, Mode locking

CW lasers systems: Ruby-, Nd:YAG- and Nd:Glass lasers, DPSS lasers, fiber lasers, gas lasers,
Pulsed lasers: ns, ps, and fs lasers, excimer, dye, X-ray and free-electron lasers;
Semiconductor lasers: DH, QW, QCL, VCSEL, DFB and DBR lasers; Quantum-well Lasers

Module II: Application of Lasers in Storage and Communication *(15 hours)*

Application of lasers in data storage, communication and information technology; Principle of holography; Laser applications in optical metrology; Surface profile and dimensional measurements; Laser Applications in material processing and manufacturing; 3D-printing, marking, drilling, cutting, welding, hardening and manufacturing; Laser Doppler velocimetry, LIDAR, laser spectroscopy, LIF, LIBS, Bio-medical applications of lasers, Laser tweezers and applications, laser applications in defence.

Module III: Photovoltaics and applications *(10 hours)*

Principle of Photovoltaic Cell, Basic Model of Solar cell, Dye-Sensitized Cells, Application of Photovoltaic Cell. Principle of Photonic detection. Optical Receiver, Principles of Semiconductor photodetectors, Performance parameters of Photodetectors, noise of photodetectors, Types of optical detectors, Receiver analysis, BER of an Ideal Optical Receiver
Optical Amplifiers: Semiconductor optical Amplifiers, Fiber Raman Amplifier (FRA), Application, Optical Switches (MEMS, MOMS etc.)

Module IV: Project **[15 Hours]**

Project 1

Modelling of Photonic sensor using Finite Element Method

OR

Project 2

Simulation on thin film coated optical fiber-based surface plasmon resonance (SPR) refractive index sensor

Reference Books:

1. Laser Fundamentals; W.T. Silfvast, Second Edition, Cambridge University Press, 2004
2. Principles of Lasers; O. Svelto, Fourth edition, Springer, 1998
3. Photonics: Optical Electronics in Modern Communications; A. Yariv and P. Yeh, Sixth Edition, Oxford University Press, 2007
4. Semiconductor Optoelectronic devices; Pallab Bhattacharya, Prentice Hall of India, 1995
5. Semiconductor Optoelectronics; Jasprit Singh, Tata Mc Graw Hill, 1995
6. Optoelectronics - an Introduction; Wilson and Hawkes, Prentice Hall, 1998

Paper Type: CC (Advanced Specialization)

Track: Condensed Matter Physics

Paper Name: Properties of Solids II

Paper Code: PHY414
LTP: 4-0-0

Course Objectives:

1. To introduce the quantum mechanical treatment of many-electron systems using second quantization formalism.
2. To describe the fundamental concepts of magnetic systems, including spin-spin interactions, magnons, and spontaneous magnetization, establishing a foundational understanding of magnetism in materials.
3. To explain the thermodynamics of magnons and spin-waves, particularly in ferri- and antiferromagnetic materials, and explore the Ising model for magnetic systems.
4. To analyze the phenomena of superconductivity, focusing on key concepts such as Cooper pairing, the BCS wave function, and the Meissner effect, to develop an in-depth understanding of superconducting materials.
5. To evaluate the Josephson effect and investigate novel high-temperature superconductors using the Ginzburg-Landau theory and Bogoliubov transformation, applying advanced theoretical models to real-world materials and To explore the significance of topological phases of matter, including topological insulators, superconductors.

Course Description:

This course introduces the theoretical framework for understanding of many-electron systems spin dynamics, magnetic ordering, and superconductivity in condensed matter systems. It covers spin waves, magnons, exchange interactions, and models like Ising and Stoner theories. The course then explores quantum theory of superconductivity, BCS theory, magnetic response, and Josephson effects. An advanced component introduces the fundamentals of topological phases, including topological insulators and superconductors, their symmetry classifications, and topological invariants such as Chern number and Zak phase. The course emphasizes analytical understanding and mathematical modeling of quantum phases in low-temperature physics.

Course Outcome:

1. **CO1: Recall** foundational concepts such as exchange interactions, spin-wave excitations, and quasiparticle formulations in magnetic and superconducting systems.
2. **CO2: Explain** and **Describe** quantum many-body methods and the physical principles behind magnetic ordering, superconducting behavior, and the emergence of collective excitations in quantum systems.
3. **CO3: Apply** theoretical models like the Ising model, BCS theory, and Ginzburg-Landau equations to examine spin, magnetic, and superconducting properties.
4. **CO4: Analyze** spin interactions, symmetry breaking, and excitation spectra to understand phenomena like Meissner effect, magnon thermodynamics, and Josephson junction behavior.
5. **CO5: Evaluate** theoretical predictions and physical significance of topological invariants (e.g., Zak phase, Chern number) and their relation to edge states and quantum phases in matter.

Course Outcome:

Module I: Fundamentals of many-electron systems and Second quantization *(8 hours)*

Schrodinger equation for a many-electron system, Matrix elements of non-interacting and interacting parts. Creation and annihilation operator, occupation no representation, (anti)-commutation relations, Vacuum state

Module II: Spin and Magnetic Systems *(25 hours)*

Origin of the exchange interaction, Spin-waves in ferromagnets, magnons, Spontaneous magnetization, thermodynamics of magnons, Spin-waves in lattices with a basis, ferri- and Antiferromagnetism, Measurement of magnon spectrum, Stoner's criterion for metallic ferromagnets, The Ising Model, Domain and Domain walls, Spin-spin Interactions, Spin flip and Spin dephasing.

Module III: Superconductivity *(22 hours)*

Superconductors, Constructing Bosons from Fermions, Cooper pairing, BCS wave-functions, Excitation spectrum of a superconductor, Magnetic effects of a superconductor, Bogoliubov transformation notion of quasiparticles, Ginzburg-Landau theory and London equation, Meissner effect, Type-II superconductors characteristic length, Josephson effect, Novel High Temperature" superconductors, Josephson Junctions, Metal-Superconductor junction, Andreev Reflection.

For Project:

Topological Phases of Matter

Significance of Topological phases, Topological insulator and topological superconductor. SSH Hamiltonian, Winding number and edge states, Symmetries: time-reversal, Particle-hole and Chiral symmetries, Chern no and Zak phase. TI in higher dimension and Chern insulators.

Reference Books

1. Magnetism in Condensed Matter (Oxford Master Series in Condensed Matter Physics) – Stephen Blundell
2. Introduction to Superconductivity: v. 1 (Dover Books on Physics)- Michael Tinkham
3. Introduction to topological Phases in Condensed Matter; Adolfo G. Grushin

Paper Type: CC (Advanced Specialization)

Track: Biomedical Instrumentation

Paper Name: Medical Imaging and Image Processing

Paper Code: PHY415
LTP: 3-0-1

Course Objectives:

1. To describe the fundamental principles behind various medical imaging modalities, including X-rays, CT scans, MRI, and ultrasound, and their diagnostic applications.

2. To explain the technical aspects of image formation, sampling, and quantization in medical imaging, with a focus on the 2D-DFT and other image transforms.

3. To analyze techniques for enhancing, filtering, and restoring medical images to improve quality and assist in accurate diagnosis.

4. To evaluate modern image processing techniques, including edge detection, segmentation, and classification, using neural networks and statistical methods.

5. To design and conduct experiments involving AI-driven medical imaging systems, with consideration for ethical and regulatory standards.

Course Description:

This hybrid course integrates the physical principles of medical imaging modalities with digital image processing and analysis techniques. Students will explore the physics of diagnostic imaging technologies such as X-ray, CT, PET, MRI, ultrasound, and optical imaging, followed by a theoretical foundation in image acquisition, enhancement, restoration, and classification. Emphasis is placed on computational tools, perception-based image evaluation, and AI-driven imaging innovations. Hands-on training in digital image processing using programming environments provides students with practical skills for clinical and research applications.

Course Outcome:

1. **CO1**: **Identify** fundamental imaging principles and physical mechanisms involved in modalities such as X-ray, MRI, CT, PET, and ultrasound.

2. **CO2**: **Describe** image formation models, perception systems, quantization, and transformation techniques used in medical imaging.

3. **CO3**: **Apply** theoretical models and mathematical tools for image enhancement, restoration, and feature extraction in medical image analysis.

4. **CO4**: **Analyze** different image classification, segmentation, and filtering techniques in terms of diagnostic quality, noise behavior, and spatial features.

5. **CO5**: **Evaluate** the role of advanced techniques such as AI and computational pathology in modern medical imaging, considering ethical and regulatory challenges.

6. **CO6**: **Write** and **execute** programs for medical image processing tasks including enhancement, filtering, segmentation, and edge detection using appropriate computational tools.

Course Content:

Module I: Medical Imaging Modalities *(12 hours)*

Physics of diagnostic radiology – Production of X-rays - diagnostic X-ray tube and its electrical circuits- X-ray tube rating - X-ray film, properties and Processing -Intensifying screens - Factors affecting radiographic imaging. Principle and Theory of computer tomography (CT) scanning, spiral CT scanning and (positron emission tomography) PET scan, Gamma camera. Physics of MRI and its application in the field of diagnostics. Physics of ultrasound imaging, probes and modes of scanning, uses in diagnosis, Image quality description and patient risk, Theory and applications of optical, thermography imaging.

Module II: Image Fundamentals *(8 hours)*

Image Perception, MTF of the visual system, image fidelity criteria, image model, image sampling and quantization – 2 dimensional sampling theory, image quantization, optimum mean square quantizer, image transforms- 2 D – DFT and other transforms.

Module III: Image processing, analysis and classification *(12 hours)*

Image enhancement –point operation, histogram modelling, spatial operation, transforms operations. Image restoration- image degradation model, inverse and wiener filtering. Image analysis- spatial feature extraction, edge detection, image segmentation classification technique-statistical methods, neural network approaches.

Module IV: Emerging Trends and Challenges *(8 hours)*

AI-driven medical imaging, Computational pathology, Image-guided interventions, Ethical considerations and regulatory aspects in medical imaging

Module V: Hands On Training

1. Programs for image gray-level transform.
2. Program to show histogram equalization effect for an image.
3. Programs for image filtering in spatial domain.
4. Programs for image filtering in frequency domain.
5. Program for image segmentation.
6. Programs for image edge detection.

Reference Books:

1. Richard P. Feynman, Robert B. Leighton, Matthew Sands: Feynman lectures on physics, Vol 2 & 3 Narosa Pub., 1986.
2. Medical imaging systems; Albert Macovski:, Prentice-Hall, Englewood Cliffs, 1983.
3. Medical Imaging Physics; W.R.Hendee&E.R. Ritenour, ,3rdedition, Mosbey year Book,Inc.,1992.
4. Digital Image Processing; R.C.Gonzalez and R.E. Woods, , Second Edition, Pearson Education, 2018.
5. Fundamentals of Digital Image Processing; Anil Kumar Jain, , Prentice Hall of India, 1989.

Paper Type: CC (Advanced Specialization)

Track: Physics of Renewable Energy and Smart Energy Systems

Course Name: Smart Renewable Energy Systems and Energy Harvesting
Course Code: PHY447
Credits: 4
L–T–P: 3–0–1

Course Objectives

1. To introduce various renewable energy technologies and their role in sustainable energy generation.
2. To understand the principles of energy harvesting from different ambient sources.
3. To study modern smart grid technologies and energy management systems.
4. To explore nanomaterials and emerging technologies used in advanced energy devices.
5. To develop practical knowledge of renewable energy monitoring and small-scale energy harvesting systems.

Course Outcomes (COs)

After successful completion of the course, students will be able to:

CO1: Explain the working principles and applications of major renewable energy technologies.

CO2: Understand the mechanisms of energy harvesting from thermal, mechanical, and electromagnetic sources.

CO3: Analyze the operation of smart grids, distributed generation, and microgrid systems.

CO4: Evaluate the role of nanomaterials and hybrid renewable systems in modern energy technologies.

CO5: Demonstrate practical understanding of renewable energy monitoring and small-scale energy harvesting devices.

Course Content

Unit I: Renewable Energy Technologies

Overview of renewable energy resources, Wind energy systems and Betz limit, Hydro and tidal energy conversion systems, Biomass energy and geothermal energy technologies

Unit II: Energy Harvesting Technologies

Fundamentals of energy harvesting, Thermoelectric energy conversion and Seebeck effect, Piezoelectric energy harvesting and vibration-based generators, Electromagnetic micro-generators and small-scale energy devices, Pyroelectric energy harvesting and Triboelectric energy harvesting.

Unit III: Smart Grid and Energy Management

Introduction to smart grid technologies, Distributed energy generation and microgrids, Integration of renewable energy with energy storage systems, IoT-based energy monitoring and control systems

Unit IV: Emerging Technologies

Nanomaterials for energy harvesting and energy devices, Hybrid renewable energy systems, Smart energy management and energy optimization, Future trends in renewable energy technologies

Practical / Laboratory (1 Credit)

1. Study piezoelectric output with different vibration conditions
2. Thermoelectric output vs temperature difference.
3. Wind energy output vs blade angle (basic understanding).
4. Study on simple IoT-based energy monitoring idea.
5. Mini project: Design of a smart renewable energy monitoring/energy harvesting system

Advanced Lab

6. Improve piezoelectric output by changing mass and beam length.
7. Perform matched load test in thermoelectric generator.
8. Use QBLADE software with real wind data instead of small fan experiments.
9. Build a simple IoT energy monitoring system (NodeMCU + sensor + dashboard).
10. Mini project: Create a self-powered wireless sensor with energy limits.

Reference Books

1. **G. D. Rai**, Non-Conventional Energy Sources, Khanna Publishers.
2. **Shashank Priya and Daniel J. Inman**, Energy Harvesting Technologies, Springer.
3. **Godfrey Boyle**, Renewable Energy: Power for a Sustainable Future, Oxford University Press.
4. **Bent Sørensen**, Renewable Energy: Physics, Engineering, Environmental Impacts, Academic Press.
5. **A. K. Gupta and S. K. Sharma**, Energy Harvesting and Storage Devices, CRC Press.

Compulsory Courses (CC Without Research)

Paper Name: X Ray Crystallography and related Techniques

Paper Code: PHY442
LTP: 4-0-0

Course Objectives:

1. To **u**nderstand the crystal structures, symmetry, unit cells, and lattice systems, crystal growth and sample preparation for diffraction studies.
2. To realize the principles of X-ray Generation and Diffraction**,** the detectors characteristics.
3. To differentiate the single crystal and powder X-ray diffraction experiments.
4. To perform the structural Analysis using diffraction data, e.g. miller indices, lattice constant, stress-strain analysis in a crystal structure.
5. To understand the crystallographic databases (e.g., CCDC, ICSD).

Course description:

Provides an introduction to the principles and applications of X-ray crystallography, a powerful technique for determining the atomic structure of materials. Students will explore the theoretical foundations of X-ray diffraction, symmetry and space groups, data collection, structure solution, and refinement methods. Course will cover other structural characterization techniques i.e. neutron diffraction, electron diffraction, small-angle X-ray scattering (SAXS), etc.The integration of these techniques in materials science, chemistry, biology, and pharmacology will also be discussed here.

Course Outcome:

1. **CO1**: **Recall** the fundamental concepts of crystal structures, crystal systems, and crystal defects.

2. **CO2: Explain** the principles of X-ray diffraction methods, including Bragg's law and diffraction intensity calculations, and describe the functioning of spectrometers and diffractometer.

3. **CO3: Utilize** X-ray diffraction techniques like powder diffraction and Debye-Scherrer methods for determining crystal structures and lattice parameters.

4. **CO4: Analyze** the quality and orientation of single crystals and polycrystalline aggregates.

5. **CO5: Assess** the accuracy and reliability of data from electron and neutron diffraction methods for structural analysis, including interpreting crystal strain and magnetic structures. Critically evaluate research literature involving crystallography.

Course Content:

Module I: Introduction Structure of materials and Defects *(8 Hrs)*

Crystal structure: lattices, unit cell, Definition of the crystal lattice and unit cell, Lattices, lattice parameters, and symmetry, Conventional and primitive lattices: 14 Bravais lattices, Crystal structure of the elements, Miller indices and crystal planes, Closed-packed metals-cubic and hexagonal packed structure, Crystal structure, e.g. Diamond and Zinc-blend structure and other compounds. Crystal defects: point defects, dislocations and stacking faults.

Module II: X-ray Generation and Interaction with Matter *(8 Hrs)*

Production of X-rays: X-ray tubes and synchrotron radiation, Properties of X-rays**,** Interaction of X-rays with matter (absorption, scattering)**,** Bragg's Law and Laue equations, Diffraction geometry: Rotating Crystal method, and powder Method, Diffraction Intensity: scattering by an electron, scattering from atoms, scattering by a unit cell; structure factor function. Structure-factor calculations; Application to powder method, Multiplicity factor, Lorentz factor, Absorption factor, Temperature factor, Intensities of powder pattern lines, Intensity calculations, Measurement of x-ray intensity.

Module III: X-ray Diffraction Techniques *(9 Hrs)*

Single crystal X-ray diffraction (SCXRD), Sample mounting, data collection, indexing, Structure solution and refinement, Powder X-ray diffraction (PXRD): Instrumentation and sample preparation, Phase identification and Rietveld refinement using FullProf software, Structure Determination and Refinement: The phase problem and solutions, Fourier transforms and electron density maps, Structure factor calculations, Least-squares refinement, Crystallographic parameters (R-factors, B-factors, etc.)

Module IV: Application of X-rays *(5 Hrs)*

Orientation and Quality of Single Crystals, The back-reflection Laue method. Transmission Laue method and Diffractometer method. Structure of Polycrystalline Aggregates, Crystal Size: Grain size, Particle size and calculation of lattice strain, Crystal Quality, Depth of X-ray penetration.

Module V: Electron and Neutron Diffraction *(10 Hrs)*

Low energy electron diffraction technique of structure analysis. Methods of neutron diffraction: data collection, structure analysis and refinement. Use of polarised neutron beams for structure analysis. Refinement of crystal structures. Diffraction at small angles/interpretation of larger structures. Working examples of Structure Determination of self-assembled structures, polymers etc. by diffraction. Determination of magnetic structure by neutron diffraction.

Reference Books:

1. Crystal Structure Analysis: A Primer – Jenny P. Glusker & Kenneth N. Trueblood, Wiley.
2. *Contemporary Crystallography*; M. J. Buerger, McGraw Hill, l970.
3. *X-ray Structure*; G. H. Stout and L. H. Jenson, Mcmillan, l968.
4. *Structure Analysis by Small Angle X-ray and Neutron Scattering*; L. A. Feigin and D. I. Svergun, Springer, 2013.
5. *X-ray Structure Determination: A Practical Guide – George H. Stout & Lyle H. Jensen*

Paper Name: Introduction to Vacuum Technology and Its Application

Paper Code: PHY443
LTP: 3-0-1

Course Objectives:

1. To understand basic concepts of vacuum technology, including gas laws and rarefied gas theory.
2. To learn the types and working principles of vacuum pumps (mechanical, diffusion, turbo-molecular, cryogenic, getter).
3. To gain knowledge of vacuum measurement techniques and appropriate gauge selection.
4. To analyze methods for producing and maintaining low temperatures techniques like the Joule-Thomson effect, adiabatic demagnetization, and dilution refrigeration, to comprehend their importance in vacuum technology.
5. To apply cleanroom standards and vacuum practices in scientific and industrial settings.

Course Description:

Fundamental principles of vacuum science and technology, with a focus on the generation, measurement, and maintenance of vacuum environments. Students will learn about different vacuum regimes (low, medium, high, and ultra-high vacuum), types of vacuum pumps, pressure measurement techniques, leak detection methods, and system design considerations. Applications of vacuum technology in various scientific and industrial contexts will be discussed. Emphasis will be placed on both theoretical understanding and practical problem-solving.

Course Outcomes (COs):

1. **CO1**: **Recall** fundamental concepts of the kinetic theory of gases, vacuum terminology, and the basic principles of gas flow at low pressure.

2. **CO2: Explain** the working principles of various vacuum pumps and pressure measurement techniques, distinguishing between their applications and limitations.

3. **CO3**: **Apply** appropriate vacuum technologies to achieve specific pressure levels and maintain controlled environments for experimental or industrial processes.

4. **CO4**: **Analyze** the characteristics of low-temperature production and measurement techniques, and assess the suitability of different thermometers for specific applications.

5. **CO5**: **Evaluate** the design and operational standards of clean room technology, emphasizing quality control and the efficiency of filtration systems.

6. **CO6**: **Design** a vacuum system or clean room setup tailored to a specific industrial or research application, integrating vacuum pumps, measurement tools, and temperature control techniques.

Course Content:

Module I: Recapitulation of Kinetic Theory of Gases and Introduction to Vacuum Technology *(6 Hours)*

Physical states of matter; General gas laws; Motion of molecules in rarefied gases; Pressure and mean free path; Transport phenomena in viscous and molecular regimes; Thermal diffusion and energy transport; Gas flow at low pressures; Rarefied gas theory; Basic vacuum terms, definitions, and units; Overview of physico-chemical phenomena relevant to vacuum (adsorption, desorption, outgassing, surface contamination).

Module II: Production of Vacuum and Vacuum Pumps *(6 Hours)*

Vacuum ranges and measuring units; Pumping speed and pump-down time; Classification of vacuum pumps: Mechanical pumps (rotary, piston), Momentum transfer pumps (diffusion, turbo-molecular), Entrapment pumps (cryogenic, getter pumps including ion and sputter ion pumps); Operational principles and typical applications.

Module III: Vacuum Measurements *(6 Hours)*

Measurement of low to ultra-high pressures; Overview of vacuum gauges: McLeod manometer, thermal conductivity gauges (Pirani, thermocouple); Ionization gauges (hot and cold cathode); Gauge calibration, accuracy, and limitations; Gauge selection based on vacuum range and application.

Module IV: Production and Measurement of Low Temperature *(6 Hours)*

Principles and methods of achieving low temperatures: Joule–Thomson effect, regenerative cooling, evaporative cooling, adiabatic demagnetization, dilution refrigeration; Use of vacuum in cryogenics; Liquefaction of air and gases; Temperature measurement: gas thermometers and corrections, secondary thermometers (resistance, thermocouple, vapor pressure, magnetic); Temperature below 1 K.

Module V: Cryogens and Clean Room Technology *(7 Hours)*

Liquid and Solid Cryogens:
Properties and behavior of liquid helium (He-4 and He-3), lambda point, superfluidity, compressibility factor, viscosity, thermal conductivity, and sound velocity in cryogenic fluids.

Clean Room Technology:
Clean room classifications and standards; Design principles; High-efficiency particulate air (HEPA) filtration; Cleanroom practices and disciplines; Quality control; Scientific and industrial applications (e.g., semiconductor fabrication, space instrumentation, material science labs).

Module VI: List of Experiments *(10 Hours)*

1. Study of Vacuum System Components: Identify and understand the function of rotary pumps, diffusion pumps, gauges, valves, and seals.
2. Leak Detection in a Vacuum System: Use simple techniques (soap bubble method, pressure rise method) to detect and locate leaks.
3. Calibration of Vacuum Gauges: Compare readings from Pirani, Penning (cold cathode).
4. Evacuation Curve of a Vacuum System: Record pressure as a function of time during system evacuation and plot the curve.
5. Thin Film Deposition by Thermal Evaporation: Deposit a metal film (e.g., aluminum) in a vacuum chamber and study film thickness and uniformity.
6. To simulate pressure variation during vacuum chamber evacuation and compare with experimental data.

Reference Books:

1. Experimental Techniques in Low Temperature Physics; White G. K., Philip M.
2. Vacuum Science and Engineering; V. Atta
3. Vacuum Technology; Harris N. S.
4. Vacuum Technology; Roth A
5. Fundamentals of Vacuum Technology; W. Umrath

Paper Name: Solar Energy and Its Application

Paper Code: PHY444
LTP: 3-0-1

Course Objectives:

1. To understand the fundamentals of solar energy and solar radiation measurement instruments.
2. To explore solar energy conversion technologies.
3. To analyze Solar Thermal applications and study Photovoltaic (PV) Technology.
4. To design and evaluate solar energy systems.
5. To develop practical and analytical Skills.

Course Description:

A detailed overview of solar energy as a sustainable and renewable resource. It covers the fundamental principles of solar radiation, solar thermal systems, and solar cell technology. Students will learn about solar energy collection, conversion, storage, and utilization, with a focus on both residential and industrial applications.

Course Outcome:

1. **CO1: Recall and describe** the fundamental concepts of solar radiation, solar constants, and instruments used for measuring solar irradiance.
2. **CO2: Analyze** various solar energy conversion technologies, including thermal and photovoltaic systems.
3. **CO3: Demonstrate** the working principles and practical uses of solar photovoltaic systems for energy conversion and specific applications such as lighting and water pumping.
4. **CO4: Design** basic solar thermal systems for water heating, cooking, and drying applications.
5. **CO5: Evaluate** the performance and components of photovoltaic (PV) systems for standalone and grid-connected setups**.**
6. **CO6: Demonstrate** practical skills in handling, installing, or simulating solar energy devices and systems, considering efficiency and sustainability.

Course Content:

Module I: Solar Radiation *(7 Hours)*

Introduction to renewable energy sources, Importance and potential of Solar energy, Solar radiation at the earth's surface: Extraterrestrial and terrestrial radiation, Solar radiation components: beam, diffuse, and global radiation, Solar radiation on tilted surfaces, Solar radiation data and estimation methods/instruments (Pyranometer, Pyrheliometer), Air mass and atmospheric effects on Solar radiation.

Module II: Solar Thermal Systems *(8 Hours)*

Principle of conversion of solar radiation into heat, Collectors used for solar thermal conversion: Solar collectors: Flat plate collectors and Concentrating collectors (parabolic trough, Fresnel, dish, central receiver, Solar Thermal Power Plant, Solar cookers, Solar hot water systems, Solar dryers, Solar Distillation, Solar greenhouses.

Module III: Solar Photovoltaic Systems *(8 Hours)*

Basics of semiconductor physics and photovoltaic effect, Conversion of Solar energy into Electricity – Photovoltaic (PV) effect, Fabrication of Solar cell, solar cells generation: mono-crystalline, poly-crystalline, thin-film, PV modules, arrays, and Panel configurations, storage systems: batteries, charge controllers, inverters. Grid-connected vs standalone systems, Maximum Power Point Tracking (MPPT).

Module IV: Design and Analysis of Solar Systems *(7 Hours)*

Design methodology for solar thermal and PV systems, Estimation of solar availability and load matching, Performance analysis and efficiency calculations, Case studies on domestic and industrial solar applications.

Module V: Hands On Training *(10 Hours)*

1. The electrical and optical properties of various photo-detectors.
2. Solar cell characteristics study using simulation software (PC1D or AMPS 1D).
3. Connect solar panels in series and parallel to optimize the solar power.
4. Construct an illuminated house using Solar PV panel.
5. I-V characteristic of solar cell and calculate efficiency of the solar cell.

Reference Books:

1. Solar Energy: Fundamentals and Applications; H Garg and J Prakash, McGraw Hill Education, 2017.

2. Energy- Fundamentals, design, modeling & applications; G.N. Tiwari, Solar, Narosa Pub., 2005.
3. Solar Energy-Principles of thermal energy collection & storage; S.P. Sukhatme,, Tata McGraw Hill Publishers, 1999.
4. Solar Photovoltaics- Fundamentals, technologies and applications; Chetan Singh Solanki, PHI Learning Pvt. Ltd., 2015.
5. Solar Photovoltaic Basics; S. White, Taylor & Francis, 2018

Compulsory Courses (With Research)

Paper Name: Dissertation

Paper Code: PHY499

LTP: 0-0-12

Course Objectives:

1. To identify a relevant research topic and formulate research questions and objectives based on a comprehensive literature review, establishing a strong foundation for the research project.
2. To collect and analyze data using appropriate experimental, theoretical, or computational methods and tools, ensuring rigorous and systematic investigation of the research problem.
3. To compose a structured dissertation that includes the introduction, methods, results, discussion, and conclusion, adhering to academic writing standards for clarity and coherence.
4. To present research findings through an oral presentation, utilizing visual aids effectively and demonstrating the ability to defend the research methodology and results against critical questioning.
5. To review and revise the dissertation based on feedback and peer review, ensuring clarity, accuracy, and adherence to academic standards for successful completion of the research project.

Course Description

The Dissertation paper is a culminating academic experience for students in the B.Sc. Physics program, designed to provide an opportunity for independent, in-depth research on a topic of choice within the field of physics. Under the guidance of a faculty advisor, students will identify a research question, conduct a comprehensive literature review, design and perform experiments or simulations, analyze data, and present their findings in a written dissertation and oral presentation.

Course Outcomes

1. **CO1: Demonstrate** a clear understanding of the research problem, relevant literature, and the theoretical framework underlying the study.

2. **CO2: Apply** appropriate research methodologies, tools, and techniques to investigate the identified problem.

3. **CO3: Aanalyze** data, experimental results, or simulations to draw meaningful inferences and identify patterns or discrepancies.

4. **CO4: Evaluate** the validity, reliability, and significance of research findings in the context of existing knowledge.

5. **CO5: Design and develop** an original research report or dissertation that contributes new insights or innovative approaches to the chosen field of study.

Multi-Disciplinary Courses

Offered by Department of Physics, School of Basic and Applied Sciences, Adamas University

Academic Year: 2026-27

Paper Name: Basics of Geophysics

Paper Code: PHY182

LTP: 3-0-0

Course Objective:

1. To introduce the principles and significance of geophysics, including Earth's structure, geomagnetism, and mathematical tools for geophysical analysis.
2. To familiarize students with geophysical exploration methods such as gravity, magnetic, electrical, and electromagnetic techniques.
3. To develop an understanding of seismic methods, including wave propagation, reflection, refraction, and seismic tomography.
4. To provide knowledge about earthquake seismology, including causes, faulting, seismicity, and applications for earthquake prediction and engineering problems.
5. To enable students to apply geophysical techniques for the interpretation of Earth's physical properties and subsurface exploration.

Course Description:

This course provides an in-depth understanding of geophysics, including Earth's structure, exploration methods, seismic techniques, and earthquake seismology. Topics range from geomagnetism and mathematical tools to seismic tomography and fault plane solutions. The course emphasizes the application of geophysical methods for subsurface exploration and earthquake prediction, with a focus on the seismicity and tectonics of India.

Course Outcome:

1. **CO1: Recall and describe** key concepts of geophysics, including Earth’s structure, geophysical techniques, and relevant mathematical tools.

2. **CO2: Explain** the working principles of geophysical exploration methods and the physical behavior of seismic and electromagnetic waves.

3. **CO3: Apply** mathematical techniques such as vector analysis, matrices, and differential equations to solve problems in geophysical contexts.

4. **CO4: Analyze** geophysical data and wave phenomena to interpret subsurface features, tectonic activity, and geological structures.

5. **CO5: Evaluate** the effectiveness and limitations of various geophysical and seismological methods for earth exploration and seismic hazard assessment**.**

Course Content:

Module I: Introduction to Geophysics and Mathematical Methods *(12 hours)*

Introduction to geophysics and its significance, Overview of geophysical methods and techniques, Earth's structure and composition, Geomagnetism, elements of earth's magnetism, Rock and mineral magnetism

Elements of vector analysis, Matrices, Eigen values and Eigen vectors and their applications in geophysics. Linear ordinary differential equations of first and second order. Partial differential equations (Laplace, wave and heat equations in two and three dimensions).

Module II: Geophysical Exploration Methods *(11 hours)*

Gravity and Magnetic Methods: Gravitational field and its measurement, Gravity anomalies and interpretation, Magnetic field and its measurement, Magnetic anomalies and interpretation

Electrical and Electromagnetic Methods: Introduction to electrical and electromagnetic methods, Electrical resistivity methods, Induced polarization and self-potential methods, Electromagnetic methods (EM)

Geophysical Well Logging: Principles and applications of well logging, Gamma ray, resistivity, and porosity logs, Interpretation of well logs

Module III: Seismic Methods *(10 hours)*

Introduction to seismic waves, Seismic wave propagation and velocity, Seismic reflection and refraction methods, Interpretation of seismic data

Seismic waves: types and their propagation characteristics, absorption, attenuation and dispersion. Seismic ray theory for spherically and horizontally stratified earth, basic principles of Seismic Tomography and receiver function analysis.

Module IV: Earthquake Seismology *(10 hours)*

Seismology, Plate tectonics, earthquakes and their causes, focal depth, epicenter, great Indian earthquakes, Intensity and Magnitude scales, Energy of earthquakes, foreshocks, aftershocks, Elastic rebound theory, Types and Nature of faulting, Fault plane solutions, Seismicity and Seismotectonics of India, Frequency-Magnitude relation (b-values). Bulk and rigidity modulus, Lame’s Parameter, Earthquake prediction; dilatancy theory, short-, medium- and long- term predictions, Seismic microzonations, Applications for engineering problems

Reference Books:

1. *Introduction to Geophysics* - Philip Kearey, Keith A. Klepeis, and Michael Brooks.
2. *Solid Earth Geophysics: An Introduction to Geophysics* - C.M.R. Fowler.
3. *Exploration Seismology* - R.E. Sheriff and L.P. Geldart.
4. *Applied Geophysics* - W.M. Telford, L.P. Geldart, and R.E. Sheriff.
5. *Geophysics: Principles and Concepts* - Michael A. Ellis and Barbara J. Singer.
6. *Geophysics: A Very Short Introduction* - William Lowrie.
7. *Introduction to Geophysical Prospecting* - Dobrin, M.B. and Savit, C.H..
8. *Exploration Geophysics* - Robinson, E.S. and Coruh, C. Basic.

Paper Name: Introduction to Nuclear Engineering
Paper Code: PHY183
LTP: 3-0-0

Course Objective:

1. To provide foundational knowledge of nuclear physics, including nuclear structure, forces, reactions, and fission and fusion processes.
2. To introduce the principles and techniques of radiation interaction, detection, and measurement, including various detector designs.
3. To familiarize students with nuclear reactor systems, fuel management, and the layout and operation of nuclear power plants.
4. To explore nuclear reactor safety principles, radiation protection standards, and radioactive waste management techniques.
5. To provide an understanding of accelerators, their classifications, and applications, as well as their global facilities.
6. To encourage students to investigate the societal applications of nuclear technology in fields like medicine, agriculture, industry, and archaeology.

Course Description:

This course covers the basics of nuclear physics, radiation detection, nuclear reactors, and accelerator technologies. Topics include nuclear reactions, reactor components, radiation safety, and waste management. Students will also learn about accelerator classifications and explore societal applications of nuclear technology. Practical insights are provided through projects focusing on medical, agricultural, and industrial applications of nuclear technologies.

Course Outcome:

1. **CO1: Recall** core concepts of nuclear physics, radiation, reactors, waste management, and accelerators.

2. **CO2: Demonstrate** an understanding of fundamental nuclear processes, detection principles, reactor operations, safety standards, and accelerator technologies.

3. **CO3: Apply** theoretical knowledge to solve conceptual problems in nuclear science.

4. **CO4: Analyze** the design, function, and interrelations of nuclear systems**.**

5. **CO5: Assess** the benefits, limitations, and safety considerations of nuclear technologies using theoretical criteria.

Course Content:

Module I: Basic Concepts of Nuclear Physics *(14 hours)*

Structure of the nucleus, Nuclear masses and binding energies, Nuclear forces, Nuclear models, Radioactivity and the laws of radioactive transformations - Spectra, energetic, systematic, Nuclear reactions, Q-value equation and its solution, Cross-sections and reaction rates, Neutron induced reactions, Introduction to Nuclear Fission and Fusion reaction

Module II: Radiation Interaction and Detection *(7 hours)*

Radiation sources, Basic principles of radiation detection, Design aspects of Gas Detectors / Scintillation detectors / Semiconductor detectors and their characteristics, Neutron sources and Neutron detection techniques, Basic electronic circuits and electronic equipment used in nuclear radiation.

Module III: Introduction to Nuclear Reactors and Nuclear Power Plant System *(8 hours)*

Basic principle, Reactor components and their characteristics, Classification and Nomenclature of Reactors - Research, production, and power reactors, Reactor fuel requirements – Idea of Fissionable and Fissile material, Uranium enrichment, Introduction to Fast reactor systems and Breeder reactor, Introduction to Fusion Reactors, Basic considerations in nuclear plant design and general layout, In-core fuel management and fuel management strategies - Burn up studies of nuclear fuels, Open and Close Cycle operation of Nuclear Power plants, Components of nuclear power cost, Future trends in nuclear power cost

Module IV: Nuclear Reactor Safety and Radioactive Waste Management *(7 hours)*

Radiation units, Standards of radiation protection, Calculation of exposure and dose, Principles, working and selection of Health Physics Instruments for personal dosimetry and environmental surveillance, Materials for shielding and their properties and technology involved, General background to nuclear reactor safety, its aims and importance, Release of radioactive materials within the containment and to the environment, Accident containment, Risk assessment for nuclear power plants.

Build-up and decay of radioactive nuclides, Nuclear waste, High level liquid waste and its characterization, Commercial high level liquid waste management, Low and medium level wastes and their treatment, Special wastes of tritium, krypton and iodine isotopes, Considerations of ultimate disposal of nuclear wastes: Transport containers/Waste storage facilities and shielded cells, Assessment of long-term safety, Fuel Reprocessing Facility

Module V: Accelerators *(5 hours)*

Introduction to Accelerators; Classification of Accelerators -- Cyclotron, Betatron, Linear Accelerators. Brief Descriptions of a few important Global Accelerator facilities.

Note:

1. Students will be given projects in the following topics: “Social Applications of Nuclear Technology in various field: Medical / Agriculture, Industry / Archeology

Reference Books:

1. Introduction to Nuclear Reactor Theory; John R. Lamarsh.
2. Nuclear Energy, An introduction to the concepts, systems, and Applications of Nuclear Processes; by R. L. Murray
3. Nuclear Power Plant Instrumentation and Control Systems for Safety and Security; M. Yastrebenetsky and V. Kharchenko
4. Management of Radioactive Wastes; G. A. Mawsor

Paper Name: Green Photonics
Paper Code: PHY184
LTP: 3-0-0

Course Objective:

1. To introduce the fundamentals of photonics and green photonics, focusing on sustainable lighting and energy technologies.
2. To provide an understanding of the physics, device structures, and efficiency factors of inorganic and organic LEDs and OLEDs.
3. To explore the design and development of LED and OLED-based illumination systems for diverse applications, including general lighting and displays.
4. To study sunlight harvesting technologies, including solar concentrators and advanced optical designs for daylight saving and illumination engineering.
5. To examine solar photovoltaic technologies, their principles, and applications in sustainable energy generation.

Course Description:

This course provides a comprehensive understanding of photonics and its applications in green technologies. Topics include solid-state lighting using LEDs and OLEDs, light out-coupling techniques, sunlight harvesting systems, and solar photovoltaics. The course emphasizes the design and development of energy-efficient lighting and sustainable energy solutions.

Course Outcome:

1. **CO1: Recall** fundamental concepts of photonics, radiation-matter interaction, solid-state lighting, and solar energy technologies.

2. **CO2: Explain** the working principles of LEDs, OLEDs, light-coupling systems, and photovoltaic devices

3. **CO3: Apply** theoretical knowledge to analyze lighting and solar energy systems for efficiency and performance.

4. **CO4: Analyze** optical design techniques, material properties, and device architectures for photonic and green energy applications.

5. **CO5: Evaluate** the suitability and sustainability of photonic technologies in energy-efficient and environmentally friendly applications.

Course Content:

Module I: Fundamentals of Photonics and Solid-State Lighting Technologies *(12 hours)*

Introduction to Photonics and need for green photonics, Interaction of radiation with materials Overview of solid-state lighting technologies and their advantages.

Inorganic and Organic LEDs: Fundamentals, device physics, diode structures and operating principles, electric drive circuits, internal, external and power Efficiency.

Module II: Design and Applications of LED and OLED-Based Illumination Systems *(10 hours)*

Design and development of light out-coupling techniques. Photometry and colorimetry of LEDs and OLEDs. Free-form optics and design of LEDs and OLEDs based illumination systems: General lighting, traffic lights, automotive, streat & flood lighting, and backlights for displays.

Module III: Daylight Harvesting and Non-Imaging Optical Systems *(11 hours)*

Sunlight Harvesting Technologies, Non-imaging Solar Concentrators and illuminators: Parabolic and Fresnel lens, Diffractive, Micro optics and Free-form optics for lighting and illumination engineering of day light saving, light guiding devices and diffuse lighting materials and devices.

Module IV: Solar Photovoltaic Technologies and Concentrator Systems *(9 hours)*

Solar photovoltaics: Inorganic, Organic and Polymeric solar cells: Principles, Technology and Applications. Role of solar concentrators.

References:

1. Light-emitting diodes - Schubert, E. Fred, Cambridge Univ. Press, 2003.
2. Handbook of luminescence, display materials, and devices - Nalwa Hari Singh, American Scientific Publishers, Vol I, II and III 2003.
3. Introduction to Solid State Lighting - Zakauskas, A., Shur, M., Gaska, R.
4. High Collection Nonimaging Optics - W.T. Welford and R. Winston, Academic Press Inc., pp. 53-273 (1989).
5. Nonimaging Optics - R. Winston, J.C. Minano and P. Benitez, Elsevier Academic Press, pp. 1-217, (2005).

SKILL ENHANCEMENT COURSES

Offered by Department of Physics, School of Basic and Applied Sciences, Adamas University

Academic Year: 2026-27

Paper Name: Introduction to C/C++ Programming
Paper Code: SEC
LTP: 0-0-2

Course Objectives:

1. To introduce the fundamental concepts of programming languages, focusing on C/C++ as the foundation for computational problem-solving.
2. To develop a strong understanding of data types, arrays, vectors, and their applications in programming.
3. To enable students to effectively utilize control structures, functions, and parameter passing to write modular programs.
4. To familiarize students with pointers and dynamic memory allocation techniques for efficient memory management.
5. To provide practical skills in file handling for reading, writing, and manipulating data files in C/C++.

Course Description:

This course introduces the fundamental concepts of programming using C/C++. It covers data types, arrays, vectors, control structures, functions, pointers, and file input/output operations. Students will develop problem-solving skills by writing, compiling, and debugging C/C++ programs. Emphasis is placed on creating efficient and modular code, dynamic memory allocation, and file handling for practical applications.

Course Outcome:

1. **CO1: Recall** basic programming concepts and syntax related to C/C++ language, data types, and control structures.

2. **CO2: Demonstrate** understanding of arrays, pointers, functions, and file operations in C/C++.

3. **CO3: Apply** programming logic using loops, conditional statements, and functions to implement problem-solving algorithms.

4. **CO4: Analyze** program structure and debug errors in C/C++ code for correctness and efficiency.

5. **CO5: Develop** functional C/C++ programs using dynamic memory allocation, modular programming, and file handling.

Course Content:

Module I: Introduction to C/C++

Programming Language – Machine Language, Assembly Language, High-Level Language, Interpreted vs. Compiled, Compiling C/C++ Program

Module II: Fundamentals Data Types, Array and Vectors

Variables, Arithmetic, Input and Output, Strings, Common Array Algorithm, Arrays and Functions, Multi-Dimensional Arrays, Vectors

Module III: Flow of Control and Functions

If Statement, Logical and Relational Operators, While Statement, Loop using For Statement, Switch Statement, Nested Branches, Nested Loops, Implementing Functions, Parameter Passing, Return Values, Functions Without Return Values

Module IV: Pointers

Defining and Using Pointers, Arrays and Pointers, Dynamic Memory Allocation

Module V: File Input and Output

Redirecting Console Output to File, Writing to File, Reading from File

References:

1. *Brief C++*; C. Horstmann
2. *Guide to Scientific Computing in C++*; J. Pitt-Francis, J. Whiteley
3. *Introduction to Computational Modeling Using C and Open-Source Tools*; J. M. Garrido

Paper Name: Introduction to Scientific Analysis and Documentation Skills

Paper Code: SEC122

LTP: 1-0-1

Course Objectives:

1. To introduce the basics of operating systems, with a focus on Linux and fundamental commands.
2. To familiarize students with scientific word processing using LaTeX for professional documentation and publication.
3. To develop skills in data visualization and graphical analysis using tools like Gnuplot for interpreting computational data.
4. To provide practical knowledge of Microsoft Excel for data analysis, visualization, and efficient spreadsheet management.

Course Description:

This course covers the fundamentals of operating systems, scientific word processing, data visualization, and spreadsheet applications. Students will learn Linux basics, LaTeX for professional documentation, Gnuplot for graphical analysis, and Microsoft Excel for data management and visualization. The course emphasizes practical skills and tools essential for computational and data-driven problem-solving.

Course Outcomes:

1. **CO1: Recall** fundamental concepts of operating systems, open-source tools, documentation platforms, and data analysis environments.

2. **CO2: Explain** the purpose and basic functionalities of Linux commands, LaTeX, Gnuplot, and Excel for scientific computing.

3. **CO3: Apply** scientific tools and software to perform word processing, data plotting, and spreadsheet operations.

4. **CO4: Analyze** the structure and formatting of technical documents and the visual representation of data using Gnuplot and Excel.

5. **CO5: Evaluate** the suitability and effectiveness of different open-source tools for document preparation, visualization, and computation.

6. **CO6: Design and develop** well-formatted documents, data visualizations, and analysis sheets using LaTeX, Gnuplot, and Excel tools.

Course Content:

Module I: Introduction to Operating System

Basics of Operating System, Introduction to Open Source and Linux, Fundamental Linux Commands

Module II: Scientific Word Processing

Introduction to LaTeX, Document classes, Compiling LaTeX file, LaTeX tags for creating different environments, Defining LaTeX commands and environments, Changing type and style, Fonts, Symbols from other languages, Formulae and Equation, Figures and other Floating Bodies, Tabular Environment, Generating Table of Contents, Bibliography and Citation, List making Environments

Module III: Visualization

Introduction to graphical analysis and its limitation, Importance of Visualization of Computational Data, Introduction to Gnuplot, Basic Gnuplot Commands: Simple Plots, Plotting Data from a File, Saving and Exporting, Multiple Data Sets per File, Physics with Gnuplot

Module IV: Microsoft Excel and Its Uses

A look into Excel Platform, Arithmetic Operations, Data Validation and Filters, Group, Ungroup and Subtotal, Functions and Formulas, Charts, Pivot Tables and Offset Functions, Data Analysis, Formatting, Editing and Printing Worksheets, Plotting

References:

1. The Complete Reference – Linux; R. Peterson
2. A Guide to LATEX and Electronic Publishing; H. Kopka, P. W. Daly
3. Gnuplot in Action, Understanding Data with Graphs; P. K. Janert
4. Step by Step – Microsoft Excel 2010; C. D. Frye

Paper Name: Instrumentation Skills
Paper Code: SEC124
LTP: 1-0-1

Course Objective:

1. To provide an understanding of the principles and specifications of electrical measurement instruments, including accuracy, precision, and resolution.
2. To introduce the working principles and applications of Cathode Ray Oscilloscopes (CRO) and Digital Storage Oscilloscopes (DSO).
3. To explore the fundamentals and applications of digital instruments, focusing on ADCs and DACs.
4. To develop hands-on skills in using electrical measurement instruments for practical applications in electronics and signal processing.
5. To enable students to simulate, design, and implement circuits using tools like NI Multisim, Expeyes kits, and Arduino UNO.

Course Description:

This course provides a comprehensive overview of instruments used for electrical measurements, including multimeters, CROs, DSOs, and digital instruments. Topics include measurement principles, ADC and DAC systems, and their applications. Laboratory exercises emphasize practical skills in circuit design, signal measurement, and conversion techniques, using tools like NI Multisim and Arduino UNO.

Course Outcome:

1. **CO1: Recall** key principles and terminology related to electrical measurements, CROs, and digital instrumentation.

2. **CO2: Explain** the construction, operation, and characteristics of measurement instruments including multimeters, CROs, and ADC/DAC systems.

3. **CO3: Apply** theoretical knowledge to interpret specifications and perform calculations related to analog and digital measurement systems.

4. **CO4: Analyze** the functioning and performance of electronic instruments and measurement circuits for accuracy and reliability.

5. **CO5: Evaluate** the advantages, limitations, and applications of analog and digital measurement instruments in practical scenarios.

6. **CO6: Design and implement** measurement circuits and perform hands-on experiments using simulation tools and hardware platforms like NI Multisim, Expeyes, and Arduino.

Course Content:

Module I: Instruments for Electrical Measurement

Basic of Measurement: Instruments accuracy, precision, sensitivity, resolution range etc. Digital Multimeter: Principles of measurement of dc voltage and dc current, ac voltage, ac current and resistance, capacitance values and others. Specifications of a multimeter and their significance.

Module II: Cathode Ray Oscilloscope

Block diagram of basic CRO. Construction of CRT, Electron gun, electrostatic focusing and acceleration, brief discussion on screen phosphor, visual persistence & chemical composition. Time base operation, synchronization. Front panel controls. Specifications of a CRO and their significance. Use of CRO for the measurement of voltage (dc and ac frequency, time period. Special features of dual trace, introduction to digital oscilloscope, Uses of function generator and measurement through the CRO like frequency measurement by Lissajous pattern, Digital Storage oscilloscope (DSO) block diagram and measurement technique.

Module III: Digital Instruments

Introduction to digital instruments, Advantages of Digital instruments over Analog instruments, Block diagram, principle of operation, Accuracy of digital instruments, Need of ADC, ADC types like Flash, Counter, SAR and Dual-Slope, ADC Specifications, ADC Numerical, Need of DAC, DAC types like Weighted-Resistor and R-2R ladder, DAC Specifications, Its applications in digital instruments like Digital Multimeter, Digital Kilo Watt Hour meter, Digital Clamp meter.

List of Experiments (Hands on Training)

- Design of different circuits using NI Multisim software.
- Measurement of voltage, Frequency and phase using CRO.
- Study and implementation of Amplitude and frequency modulation using Expeyes junior kit.
- Study and implementation of Analog to digital conversion.
- Study and implementation of Digital to Analog conversion.
- Blinking of LED using Arduino UNO.

References:

1. Electrical and Electronics Measurements and Instruments; A. K. Sawhney, Dhanpat Rai & Co.
2. Electronic Instrumentation and Measurement Techniques; W. D. Cooper & A. D. Helfrick, PHI, 4th e/d, 1987.
3. Electronic Instrumentation and Measurements; David Bell, Prentice Hall, 2e/d, 2013.
4. Electronic Instruments and Instrumentation Technology; M. M. S. Anand, PHI, 2004.

Paper Name: Radiation Safety Techniques

Paper Code: SEC125

LTP: 2-0-0

Course Objectives:

1. To provide foundational knowledge of atomic and nuclear physics, including nuclear reactions, radioactive decay, and radiation types.
2. To introduce the principles and operation of radiation detection and monitoring devices, such as gas detectors, scintillation detectors, and dosimeters.
3. To familiarize students with radiation quantities, units, and the biological effects of ionizing radiation.
4. To explore the principles and standards of radiation protection, including ALARA, shielding, and waste management practices.
5. To develop hands-on skills in radiation measurement, monitoring, and dose distribution through laboratory experiments.

Course Description:

This course explores the fundamental concepts of atomic and nuclear physics, including radiation types, nuclear reactions, and decay processes. It provides practical insights into radiation detection devices and monitoring techniques. Students will also learn about radiation safety management, biological effects, and standards for radiation protection. Laboratory sessions emphasize hands-on experience in using G.M. counters, TLD readers, and dose distribution measurements.

Course Outcomes:

1. **CO1: Recall** fundamental concepts of atomic and nuclear structure, types of radiation, decay laws, and radiation units.

2. **CO2: Explain** the principles of nuclear reactions, radiation interactions, detection mechanisms, and radiation protection standards.

3. **CO3: Apply** theoretical knowledge to interpret radioactive decay data, identify suitable detectors, and assess radiation exposure.

4. **CO4: Analyze** the design and function of radiation detection systems and evaluate biological and environmental effects of ionizing radiation.

5. **CO5: Evaluate** radiation safety protocols, regulatory principles, and control measures for radiological protection in various settings.

Course Content:

Module 1: Basics of Atomic and Nuclear Physics

Basic concept of atomic structure; X rays characteristic and production; concept of bremsstrahlung and auger electron, The composition of nucleus and its properties, law of radioactive decay, Mean life and half life, basic concept of alpha, beta and gamma decay, concept of cross section and kinematics of nuclear reactions, types of nuclear reaction, Fusion, fission. Types of Radiation: Alpha, Beta, Gamma and Neutron and their sources, sealed and unsealed sources

Module 2: Radiation detection and monitoring devices

Radiation Quantities and Units: Basic idea of different units of activity, KERMA, exposure, absorbed dose, equivalent dose, effective dose. Radiation detection: Basic concept and working principle of gas detectors (Ionization Chambers and Geiger Muller Counter), Scintillation Detectors (Inorganic and Organic Scintillators), Solid States Detectors and Neutron Detectors, Thermo luminescent Dosimetry.

Module 3: Radiation protection and safety management

Biological effects of ionizing radiation, Operational limits and basics of radiation hazards evaluation and control: radiation protection standards, International Commission on Radiological Protection (ICRP) principles, ALARA (As Low As Reasonably Achievable) concept Time, distance, and shielding principles Protective measures for workers and the public Occupational radiation exposure limits, Nuclear waste and disposal management.

List of Laboratory Experiments (Hands on Demonstration)

1. Measurement of current-voltage characteristics of a G.M. counter using beta and gamma source and determination of plateau and resolving time of the counter

2. Calibration of TL phosphor &TLD reader and its use in dose distribution measurements

References:

1. Nuclear and Particle Physics; W. E. Burcham and M. Jobes, Harlow Longman Group, 1995.
2. Radiation detection and measurement; G. F. Knoll, 4th Edition, Wiley Publications, 2010.
3. Thermoluminescence dosimetry; A. F. Mcknlay, Bristol, Adam Hilger (Medical Physics Hand book 5)

4. Fundamental Physics of Radiology; W .J. Meredith and J.B. Massey, John Wright and Sons,UK, 1989.
5. An Introduction to Radiation Protection; A. Martin and S. A. Harbisor, John Willey & Sons,Inc. New York, 1981.

Paper Name: Object Oriented Programming in Python

Paper Code: SEC

LTP: 0-0-2

Course Objective:

1. Reinforce understanding of Python fundamentals, including data types, operators, control flows, and functions.
2. Develop skills to use Python libraries (e.g., NumPy, SciPy, and Pandas) and advanced programming concepts like recursion and vectorization.
3. Introduce object-oriented programming concepts such as classes, objects, inheritance, and polymorphism in Python.
4. Equip students with tools and techniques for data analysis, manipulation, and visualization using Python.
5. Provide a foundation in creating animations and integrating visual elements for scientific and educational purposes.

Course Description:

This course covers Python programming, emphasizing its versatility and applications in scientific computing and data science. Students will start with Python basics and progress to advanced concepts, including object-oriented programming, data manipulation, and animation. The course prepares students to solve real-world problems by leveraging Python's libraries and features for structured coding, data analysis, and visualization.

Course Outcome:

1. **CO1: Demonstrate** understanding of Python programming structures, modules, object-oriented principles, and data manipulation tools.

2. **CO2: Apply** Python programming skills to perform structured coding tasks, including data processing, statistical operations, and visualization.

3. **CO3: Analyze** Python scripts for logic, modularity, and performance across various domains like data science and animation.

4. **CO4: Evaluate** the effectiveness and efficiency of Python programs in handling real-world data and producing meaningful outputs.

5. **CO5: Develop** Python applications integrating data science libraries and animation tools

to solve problems and visualize dynamic results.

Course Content:

Module I: Recapitulation of Basic Python

Data Types, Operators, Flow Controls, Functions, List

Module II: Python Modules and Advanced Coding Concepts

Numpy, Sympy, Scipy, Random, Statistics, Namespace and Scopes, Tuples, Dictionaries, Sets, Vectorization, Recursion

Module III: Object Oriented Python

Classes, objects, encapsulation, polymorphism, inheritance, function overloading

Module IV: Python for Data Science

Uploading, streaming and sampling data streams, structured and unstructured data access, Use of NumPy and Pandas for data selection, filtering, visualization and other manipulations

Module V: Animation

Animating a Sequence of Images, Animating Functions, Combining Videos with Animated Functions

Reference Books:

1. Introduction to Python Programming; Gowrishankar S., Veena A.
2. Scientific Computing with Python; C. Führer, O. Verdier, J. Erik Solem
3. Introduction to Python for Science and Engineering; D. J. Pine
4. Python for Engineers and Scientists – Concepts and Applications; R. Nayak, N. Gupta

Value Added Courses

Offered by Department of Physics, School of Basic and Applied Sciences, Adamas University

Academic Year: 2026-27

Paper Name: Learning MATLAB
Paper Code: VAC110
LTP: 1-0-1

Course Objectives:

1. Equip students with foundational knowledge of MATLAB, focusing on its environment and toolboxes.
2. Develop computational skills for handling matrices, vectors, and linear algebraic operations in MATLAB.
3. Teach structured programming and algorithm development using MATLAB scripts and functions.
4. Enable students to create and manage data visualizations, including 2D and 3D plots, to present complex datasets effectively.
5. Foster problem-solving skills through the integration of logical operations, conditional statements, and iterative structures in MATLAB.

Course Description:

This course introduces the fundamentals of MATLAB, a powerful computational tool widely used in Physics and Engineering. Students will explore MATLAB's environment, perform matrix and vector operations, and learn to write scripts and functions. Emphasis is placed on algorithm development, data visualization, and file management techniques. By the end of the course, students will acquire the skills necessary to tackle Physics and engineering problems using MATLAB.

Course Outcome:

1. **CO1: Recall** fundamental concepts of the MATLAB environment, syntax, variables, and mathematical functions.

2. **CO2: Demonstrate** understanding of MATLAB data structures, matrix operations, and control flow constructs.

3. **CO3: Apply** MATLAB programming skills to solve problems involving matrices, algorithms, and repetitive computations.

4. **CO4: Analyze** MATLAB scripts for structure, logic, and efficiency in performing numerical and algorithmic tasks.

5. **CO5: Develop and execute** MATLAB programs for data visualization, file handling, and

custom function creation.

Course Content:

Module I: MATLAB basics

The MATLAB environment, Basic computer programming, Variables and constants, operators and simple calculations, Formulas and functions, MATLAB toolboxes

Module II: Matrices and vectors

Matrix and linear algebra review, Vectors and matrices in MATLAB, Matrix operations and functions in MATLAB

Module III: Computer programming

Algorithms and structures, MATLAB scripts and functions (m-files), Conditional Statements- Logical Operators, Conditional Statements- if, else, and elseif, Conditional Structures- Switch, Repetition Structure- For Loops, Repetition Structure: While Loops

Module IV: Graphics with MATLAB

Files and File Management – Import/Export, Basic 2D, 3D plots, Graphic handling

Reference Books:

1. A Guide to MATLAB - for Beginners and Experienced Users; Brian R. Hunt, Ronald L. Lipsman, Jonathan M. Rosenberg.
2. Essentials of MATLAB Programming; Stephen J. Chapman.
3. MATLAB Demystified; David McMahon.
4. MATLAB® for Engineers; Holly Moore.
5. Engineering computation with MATLAB; David M. Smith.

Paper Name: Computing with Mathematica
Paper Code: VAC
LTP: 0-0-2

Course Objective:

1. Introduce students to Mathematica as a computational and symbolic algebra tool.
2. Develop skills for handling lists, matrices, and algebraic manipulations using Mathematica.
3. Teach students to compute derivatives, integrals, limits, and solve differential equations with Mathematica.
4. Enable students to create and customize 2D, 3D, parametric, and polar plots, along with animations for visualization.
5. Guide students to apply Mathematica for solving practical problems in Physics and writing simple codes.

Course Description:

This course introduces Mathematica, a versatile computational tool, to aid in symbolic algebra, numerical computation, and data visualization. Students will explore the use of Mathematica for solving equations, performing algebraic and calculus operations, and generating complex plots. Applications in Physics include coding solutions for problems such as harmonic oscillations and visualizing forced vibration solutions.

Course Outcome:

1. **CO1: Demonstrate** understanding of Mathematica's syntax, functional structure, and computational capabilities for symbolic and numeric tasks.

2. **CO2: Apply** Mathematica tools to perform algebraic operations, solve equations, compute calculus problems, and manipulate data structures.

3. **CO3: Analyze** the logic, flow, and efficiency of Mathematica code used in mathematical modeling and visualization.

4. **CO4: Evaluate** the accuracy, clarity, and suitability of Mathematica outputs in solving mathematical and physical problems.

5. **CO5: Design and implement** Mathematica programs to simulate and visualize real-world scenarios and generate custom computational tools.

Course Content:

Module I: Introduction to Mathematica and Basic Syntax

Getting started with Mathematica, input and output, brackets and braces, Exact and approximate numbers, Built-in functions, Defining functions and inequalities

Module II: Lists, Matrices, and Algebraic Operations

List and Matrices, Generating list, Functions Involving Lists, Displaying Tables and Matrices, Algebraic manipulation, solving equations

Module III: Calculus and Linear Algebra with Mathematica

Computing limits, derivatives, integrals, expanding series, solving differential equations, linear algebra

Module IV: 2D and 3D Visualization Techniques

Basic Plots, Plot Options, Parametric Plots, Basic 3D plots, 3D Plot options, Parametric 3D, plots, Polar plots, Using animations

Module V: Applications and Problem Solving Using Mathematica

Application of Mathematica for writing simple codes like Fibonacci sequence generation, Matrix generation of arbitrary dimension, Solving Simple Harmonic and Damped Harmonic oscillation problem, Visualizing the forced vibration solution etc.

Reference Books:

1. An Elementary Introduction to the Wolfram Language; Stephen Wolfram
2. The Mathematica Book; Stephen Wolfram
3. Mathematica for Physics; Robert L. Zimmerman
4. Mathematica for Scientists and Engineers; Martha L. Abell and James P. Braselton

Paper Name: Object Oriented Programming in C++
Paper Code: VAC
LTP: 0-0-2

Course Objective:

1. Reinforce understanding of fundamental C++ concepts, including data types, operators, control structures, and pointers.
2. Develop skills in working with structures, enumerations, and their interaction with functions and pointers.
3. Introduce object-oriented programming concepts such as objects, classes, constructors, and operator overloading.
4. Provide a comprehensive understanding of inheritance, polymorphism, and abstraction in C++ programming.
5. Teach efficient memory management techniques using pointers, dynamic memory allocation, and debugging.

Course Description:

This course provides an in-depth understanding of C++ programming, emphasizing both procedural and object-oriented paradigms. Students will explore foundational topics like data types, control structures, and arrays, progressing to advanced concepts such as objects, classes, inheritance, polymorphism, and memory management. The course is designed to equip students with skills to write efficient and modular code for complex applications.

Course Outcome:

1. **CO1: Demonstrate** understanding of advanced C++ features including classes, objects, structures, inheritance, and polymorphism.

2. **CO2: Apply** object-oriented programming concepts to solve problems using functions, classes, pointers, and memory management.

3. **CO3: Analyze** C++ code to trace execution flow, identify logical errors, and optimize program structure and performance.

4. **CO4: Evaluate** the effectiveness, reusability, and safety of C++ programs through modular design and dynamic memory handling.

5. **CO5: Design and implement** efficient C++ programs using object-oriented principles, operator overloading, and memory management techniques.

Course Content:

Module I: Recapitulation of Basic C++

Data Types, Operators, Flow Controls, Functions, Arrays, Pointers

Module II: C++ Structures

Structures and Functions, Pointers to Structure, C++ Enumeration

Module III: C++ Object and Class

Object and Class, Constructors, Objects and Functions, Operators Overloading

Module IV: C++ Inheritance, Polymorphism and Abstraction

Inheritance Access Control, C++ Function Overriding, Inheritance Types, Polymorphism, Data Abstraction

Module V: Pointer and Memory Management

New and Delete, Pointers to Objects, Debugging Pointers

Reference Books:

1. Brief C++; C. Horstmann
2. Guide to Scientific Computing in C++; J. Pitt-Francis, J. Whiteley
3. Introduction to Computational Modeling Using C and Open-Source Tools; J. M. Garrido

Paper Name: Physics Simulation with COMSOL Multiphysics
Paper Code: VAC111
LTP: 0-0-2

Course Objective:

1. Introduce the necessity and fundamentals of Multiphysics modeling for engineering design and analysis.
2. Provide an overview of the Finite Element Method (FEM) and its role in solving complex physical problems.
3. Teach students how to model electrical circuits using COMSOL, focusing on resistor-capacitor and inductor-resistor configurations.
4. Enable students to model heat transfer problems, including solid-liquid interfaces and cooling mechanisms.
5. Explore bioheat transfer modeling for biomedical applications, such as microwave cancer therapy.
6. Introduce wave optics modeling for analyzing optical responses and electromagnetic heating in advanced applications.

Course Description:

This course introduces Multiphysics modeling using COMSOL, emphasizing its importance in engineering design and analysis. Students will learn about the Finite Element Method and develop models in electrical circuits, heat transfer, bioheat, and wave optics. Applications include bioheat transfer in cancer therapy, electromagnetic heating, and optical responses in plasmonic structures.

Course Outcome:

1. **CO1: Demonstrate** understanding of multiphysics modeling principles and finite element method concepts used in COMSOL simulations.

2. **CO2: Apply** COMSOL Multiphysics to simulate real-world problems involving electrical, thermal, and optical systems.

3. **CO3: Analyze** simulation results to interpret the behavior of coupled physical systems and evaluate model accuracy.

4. **CO4: Evaluate** the impact of material properties, boundary conditions, and meshing strategies on simulation outcomes.

5. **CO5: Design and implement** multiphysics simulation models to solve interdisciplinary engineering and biomedical problems.

Course Content

Module I: Introduction

Necessity of the Multiphysics Modeling for engineering design and analysis, Guidelines for COMSOL Multiphysics modelers, Simple model setup overview

Module II: Summary of Finite Method

Introduction to Finite Element Method, basic working principles, its merit and demerit

Module III: Electrical Circuit Modeling

Guidelines for electrical circuit modelling, resistor-capacitor series circuit model, inductor-resistor series circuit model, series resistor parallel-inductor-capacitor model

Module IV: Heat Transfer Modeling

Heat transfer in solid and liquid interface, Laminar Flow, Modeling of electric chip heating and air cooling with heat sink

Module V: Bioheat Models

Bioheat modelling considerations, bioheat transfer models, 2D axisymmetric microwave cancer therapy model

Module VI: Wave Optics Module

Introduction to Frequency and Time Domain, Optical response of dielectric and conductors, Plasmonic structures, Approximated interaction between optical pulses and metallic structures, Electromagnetic heating

Note: 1. Unit1 and Unit2 are mandatory
2. Students can choose two units between Unit3 – Unit 6

Reference Books:

1. COMSOL For Engineer; M. Tabatabain.
2. MultiPhysics Modeling using COMSOL® 5 and Matlab; R. W. Pryor.

Principles and Applications of AI (Code: GEN102)

Credits: 2

Total Duration: 30 Hours

Target Group: STEM Students

Industry Collaboration: Intel (Joint Curriculum)

- CO1: Demonstrate understanding of AI concepts, lifecycle, and applications in STEM domains.
- CO2: Import, clean, preprocess and visualization of structured datasets.
- CO3: Build and evaluate basic predictive models using python and machine learning.
- CO4: Apply fundamental concepts of neural networks and deep learning techniques for intelligent system development.
- CO5: Utilize computer vision techniques to analyze visual data and solve real-world complex problems.

Syllabus

Module 1: Introduction to AI and AI Lifecycle 3 Hours

- What is Artificial Intelligence, Machine Learning, and Deep Learning
- Use cases in STEM domains
- AI Lifecycle: Data → Model → Deployment → Feedback

Module 2: Data Import, Cleaning & Preprocessing 6 Hours

- Loading data from CSV, Excel, and APIs
- Handling missing values, outliers, normalization
- Data encoding and feature selection basics
- Data Visualization basics using Graphs and Charts

Module 3: AI for Statistical Data & Predictive Modelling /Rule Based AI

5 Hours

- Overview of statistical AI applications
- Linear Regression and Logistic Regression
- Introduction to Decision Trees and Random Forests
- Performance metrics: accuracy, precision, recall, confusion matrix
- Rule based AI: Definition, Feature, Basic Structure, Advantage, Limitation, Application

Module 4: Introduction to Computer Vision and Neural Network 7Hours

- Introduction to computer vision and Introduction to neural networks
- Digital image, Pixels and image resolution, Color models (RGB and Grayscale) , Basic image operations : Resize , Crop, Rotate , Brightness adjustment
- Introduction to image filtering
- Biological neuron vs artificial neuron
- Structure of a neural network : Input layer, hidden layer, output layer
- Activation functions :ReLU , Sigmoid

Concept of training and learning

Module 5: Introduction to Python 6 Hours

- Variables and constants, Inut and output statements, Data types : Integer, Float String, Boolean
- Type conversion
- Operators : Arithmetic, Relational , Logical , Assignment
- Conditional statements :if , if-else , nested if Looping statements: for loop , while loop
- Strings: String operations, String slicing, Common string methods
- Lists: Creating lists ,List operations ,List methods ,Nested lists
- Tuples: Tuple creation and operations ,Difference between lists and tuples
- Dictionaries: Key-value pairs , Dictionary operations and methods

** For Advance Learner: Introduction to functions : Function definition and calling , Parameters and return values Built-in functions : Recursive functions (basic idea), Break and continue statement

Module 6: Hands-On Mini Projecusing AI tools 3 Hours

- Google Teachable Machine : No-code AI applications
- Google Colab : Learning machine learning
- Google Antigravity
- TensorFlowplayground
- Streamlit: AI web applications
- Keras: Beginner neural network projects

Course Outcomes \ Program Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	2			2	1	1			1		2
CO2	3	2		1	3					2	1	2
CO3	3	3	2	2	3	1				2	1	2

CO4	2	2	2	1	3	1			2	3	2	3
CO5	2	2	3	2	3	2			3	2	3	3

Reference Books

1. AI for Everyone; Author: Saptarshi Goswami, Publisher: Pearson Education; AI assisted programming Author: Tom TaulliPublisher: O'Reilly

2. Artificial Intelligence: Made Simple; Author: H. S. Behera Publisher: BPB Publications

3. Artificial Intelligence Simplified Author: Amit Konar Publisher: New Age International

4. Python Machine Learning: Machine Learning and Deep Learning with Python, scikit-learn, and Tensor Flow; Author: Sebastian Raschka& Vahid Mirjalili Publisher: Packt Publishing Edition: 3rd Edition (or latest)

Paper Name: Introduction to IKS **Paper Code:** (XXX)
Credit: 4
LTP: 4–0–0

Course Objectives:

1. To introduce the fundamental concepts and sources of Indian Knowledge Systems.
2. To explore scientific and technological developments in ancient India.
3. To examine architectural, engineering, and ecological knowledge systems.
4. To analyze philosophical traditions contributing to scientific thought.
5. To relate traditional knowledge systems with modern scientific advancements.

Course Description:

This course provides a comprehensive overview of Indian Knowledge Systems with emphasis on scientific, technological, and intellectual developments of ancient India. It includes foundational texts, mathematical and astronomical advancements, metallurgical excellence, architectural achievements, and traditional medical knowledge. The course also highlights ecological sustainability and philosophical reasoning while establishing connections with modern science and innovation.

Course Outcomes:

CO1 Explain the historical development, fundamental concepts, educational traditions, and philosophical foundations of Indian Knowledge Systems, including major schools of Indian thought.

CO2 Describe the contributions of ancient India in polity, economy, mathematics, astronomy, Ayurveda, and other scientific disciplines, with reference to classical texts and scholars.

CO3 Interpret the principles of traditional Indian engineering, metallurgy, materials science, architecture, urban planning, and technological innovations developed in ancient India.

CO4 Analyze indigenous ecological knowledge, environmental ethics, water management systems, and sustainable agricultural practices in the context of present-day sustainability challenges.

CO5 Evaluate the significance and contemporary relevance of Indian Knowledge Systems in modern education, scientific research, innovation, technology development, and societal well-being.

Course Content:

Module I Foundations of Indian Knowledge Systems: Philosophy and Scientific Thoughts [14 lecture hours]

a. Introduction to Indian Knowledge Systems with historical evolution. Ancient Indian Literature and Scriptures (*Vedas, Vedanga, Puranas*, the maha-kavya— Ramayana and Mahabharata).
b. Oral traditions in Ancient Indian Education- Preservation of culture, tradition and Dharma through education*: Guru-Shishya Parampara*, Gurukulas, Six philosophical Schools-*Samkhya, Yoga, Nyaya, Vaisheshika, Purva-Mimamsa, Advaita (Uttara-Mimamsa)*
c. Indian philosophy: Concept of Pancha-bhuta. Conscious Awakening through Mindfulness, Breath Control, Meditation, Philosophical debates-Buddhism and Jainism- The role of ancient Indian Universities- *Nalanda* and *Takshashila.*

Module II Ancient Indian polity and economy [6 lecture hours]

a. Introduction to Ancient Indian Political and Economic System. The notion of Bharartavarsha as a Chakravarti-Kshetra and important attributes of Chakravartin.
b. Concept of Kingship: Duties and Responsibilities of a king in ancient India.
c. Ancient Indian economy- taxation, Savings and Expenditure

Module III Mathematics, Astronomy, Ayurveda and Life Sciences in Ancient India [12 lecture hours]

a. The development of mathematical and astronomical knowledge in ancient India, evolution of the number system, decimal representation, and the concept of zero and infinity. Contributions of Aryabhata, Brahmagupta, and Bhaskara II..
b. Early astronomical concepts and Astronomical Instruments (*Yantras*)
Application of Physics and Chemistry
c. The fundamental concepts of Ayurveda as a holistic system of medicine. Ayurvedic view of cause of deceases.
d. References to classical texts such as Surya Siddhanta, *Charaka Samhita*
and *Sushruta Samhita.*

Module IV Metallurgy, Materials, architecture and Civil Engineering [14 lecture hours]

a. The advancements in metallurgy and materials science in ancient India, traditional metallurgical practices and early innovations in materials : the Iron Pillar of Delhi-example of advanced materials engineering.
b. Nanomaterials and nanotechnology in ancient India.

c. The architecture and civil engineering in ancient India-Temple architecture- *Nagara* and *Dravida* styles
d. Urban planning concepts- the cities of Harappa and Mohenjo-Daro, drainage systems and spatial organization. Ancient cities of Indus -Saraswati region. Cave and monolithic architecture.

Module V Environmental Ecology and Agricultural Sustainability [8 lecture hours]

a. Traditional ecological knowledge and sustainable practices, biodiversity preservation. Ancient Indian water harvesting techniques. The concept of Pancha-bhuta and its relation to environmental balance.
b. Sustainable agricultural practices and their relevance in the context of present-day environmental challenges.

Module VI Modern Relevance of IKS [6 lecture hours]

a. Relevance of IKS in contemporary contexts. Ancient, traditional practices such as textile weaving, pottery, and shipbuilding as examples of applied knowledge systems.
b. The role of Indian Knowledge Systems in modern research, innovation, contemporary education and scientific development.

References-

1.Acarya P.K, *Indian Architecture*, Munshiram Manoharlal Publishers, New Delhi (1996)

2.Bag, A K, *Mathematics in Ancient and Medieval India*, Chaukhamba Orientalia, New Delhi, 1979

3.Banerjee, P*, Public Administration in Ancient India,* Macmillan, London, 1916

4.Chatterjee, Satishchandra, *An Introduction to Indian Philosophy*, Rupa & Co. Calcutta

5. Kapoor, kapil, Singh, Avadesh, *Indian Knowledge Systems* Vol. 1-2, D.K print World Ltd, New Delhi 2021

6. Debiprasad Chattopadhyaya, Science in Ancient India

7. Dharampal, Indian Science and Technology in the Eighteenth Century

8. A.L. Basham, The Wonder That Was India

Course Code	Basic Cyber Security and Internet of Things (IoT)		L	T	P	C
Pre-requisite	Basic Computer Applications and Internet		4	0	0	4
Co-requisite	None	Contact Hours: 60				

Course Objectives:

- To introduce students to the concepts of cyberspace, cyber security, and digital technologies used in everyday life.
- To develop awareness regarding cyber threats, cybercrime, and safe digital practices.
- To familiarize students with cyber ethics, privacy concerns, and basic cyber laws.
- To introduce the fundamentals, architecture, and applications of the Internet of Things (IoT).
- To understand security, privacy, and ethical concerns in smart connected environments.

Course Outcomes (COs):

On completion of this course, the student will be able to:

- **CO1**. Understand the concepts of cyberspace, digital assets, and cyber security fundamentals.
- **CO2**. Identify common cyber threats, cybercrimes, and appropriate preventive measures for safe digital usage.
- **CO3**. Demonstrate awareness regarding cyber ethics, responsible digital citizenship, privacy, and cyber laws.
- **CO4**. Explain the architecture, components, communication technologies, and working principles of IoT systems.
- **CO5**. Identify real-world applications of IoT across different sectors and smart environments.
- **CO6**. Understand security, privacy, and ethical concerns associated with IoT-enabled systems and emerging digital technologies.

Course Description:

The rapid expansion of digital technologies has transformed communication, education, healthcare, commerce, entertainment, and governance. Alongside these advancements, cyber threats and privacy concerns have emerged as critical challenges for individuals and organizations. Simultaneously, the Internet of Things (IoT) has enabled interconnected smart devices and intelligent systems that are reshaping modern lifestyles and industries.
This course introduces undergraduate students from all disciplines to the fundamentals of cyber security and IoT in a simple and learner-friendly manner. The course emphasizes cyber awareness, safe digital practices, responsible use of technology, ethical and legal aspects of cyberspace, and the principles and applications of IoT. Students will explore smart devices, sensors, communication technologies, and real-life applications of IoT in homes, healthcare, transportation, agriculture, and smart cities. The course is designed to develop informed, digitally aware, and responsible citizens capable of safely navigating an increasingly connected world..

Course Content:

Unit I: Digital World and Cyber Security Foundations	12 Lecture Hours
Digital Society and Emerging Technologies, Cyberspace, Digital Identity, Digital Footprints Data, Information, and Digital Assets, Fundamentals and Need for Cyber Security, CIA Principles	

(Confidentiality, Integrity, Availability), Common Cyber Threats and Cyber Risks, Cyber Awareness and Safe Digital Behaviour	
Unit II: Cyber Threats, Cybercrime and Safe Practices	**12 Lecture Hours**
Malware: Virus, Worm, Trojan, Spyware, Ransomware, Phishing, Smishing, Vishing, Online Fraud and Scams, Password Security and Multi-Factor Authentication (MFA), Social Engineering Attacks and Identity Theft, Social Media Security and Privacy Settings, Email, Mobile Device and Public Wi-Fi Safety, Safe Online Shopping and Digital Payment Security (UPI Safety), Cyber Hygiene and Best Practices	
Unit III: Cyber Ethics, Privacy and Cyber Laws	**12 Lecture Hours**
Cyber Ethics and Responsible Technology Use, Digital Citizenship and Online Behaviour, Privacy, Personal Data Protection and Digital Rights, Intellectual Property Rights (IPR), Copyright and Plagiarism, Information Technology Act, 2000 (Basic Overview), Cybercrime Reporting Mechanisms in India, Ethical Use of Artificial Intelligence Tools, Misinformation, Fake News and Deepfakes	
Unit IV: Fundamentals of Internet of Things (IoT)	**12 Lecture Hours**
Introduction and Evolution of IoT, Smart Devices, Sensors and Actuators, IoT Ecosystem and Architecture (Basic Concepts), Data Collection, Communication and Connectivity, IoT Communication Technologies: Wi-Fi, Bluetooth, RFID, NFC Cloud and Edge Computing in IoT (Basic Concepts), Benefits and Challenges of IoT	
Unit-V: IoT Applications, Security and Future Trends	**12 Lecture Hours**
Smart Homes and Smart Cities, Smart Healthcare and Wearables, Smart Agriculture and Transportation, Industrial IoT (Basic Concepts), Environmental Monitoring Systems IoT Security Risks and Privacy Issues, Safe Practices for Smart Devices, Artificial Intelligence and IoT (AIoT): Future Trends: Digital Twins, Industry 5.0, Sustainable Smart Technologies	
Suggested Practical/Activity (Optional for NEP Minor Course)	
1. Phishing email identification 2. Cybercrime case analysis 3. Social media privacy audit 4. Digital footprint assessment 5. IoT device survey at home/campus 6. Awareness poster/video creation 7. Group presentation on Smart City/Healthcare/Agriculture 8. Mini project/report on cyber safety or IoT impact	
Textbooks: 1. Nina Godbole and Sunit Belapure, Cyber Security: Understanding Cyber Crimes, Computer Forensics and Legal Perspectives, Wiley India. 2. Arshdeep Bahga & Vijay Madisetti, Internet of Things: A Hands-on Approach, Universities Press. 3. Charles J. Brooks et al., Cyber Security Essentials.	
Reference Books: 1. Michael Miller, The Internet of Things. 2. Rajkumar Buyya and Amir Vahid Dastjerdi, Internet of Things: Principles and Paradigms. 3. William Stallings, Cryptography and Network Security, Pearson. 4. Pethuru Raj and Anupama Raman, The Internet of Things: Enabling Technologies, Platforms and Use Cases.	