ANDHRA PRADESH STATE COUNCIL OF HIGHER EDUCATION

Model Syllabus for 4-Year UG Honours in B.Sc. (Physics) as Major in consonance with Curriculum framework w.e.f. AY 2025-26

COURSE STRUCTURE (for Semester I to VI)

Year	Semester	Course	Title of the Course	No. of Hrs /Week	No. of Credits
I	I	1	Introduction to Mathematical Physics	3	3
			Introduction to Mathematical Physics-Practical	2	1
		2	Mechanics and Properties of Matter	3	3
			Mechanics and Properties of Matter-Practical	2	1
	II	3	Waves and Optics	3	3
			Waves and Optics-Practical	2	1
		4	Heat and Thermodynamics	3	3
			Heat and Thermodynamics-Practical	2	1
II	III	5	Atomic, Molecular & Nuclear physics	3	3
			Atomic, Molecular & Nuclear physics-Practical	2	1
		6	Basic Electronics	3	3
			Basic Electronics-Practical	2	1
		7	Applied Optics	3	3
			Applied Optics-Practical	2	1
	IV	8	Electricity, Magnetism and Electromagnetic Theory	3	3
			Electricity, Magnetism and Electromagnetic Theory-Practical	2	1
		9	Analog Electronics	3	3
			Analog Electronics-Practical	2	1
		10	Advances in Physics	3	3
			Advances in Physics-Practical	2	1
III	V	11	Introduction to Solid State Physics	3	3
			Introduction to Solid State Physics-Practical	2	1

Year	Semester	Course	Title of the Course	No. of Hrs /Week	No. of Credits
		12 A	Electronic Instrumentation	3	3
			Electronic Instrumentation-Practical	2	1
		OR			
		12 B	Solar Energy and Applications	3	3
			Solar Energy and Applications-Practical	2	1
		OR			
		12 C	Fundamentals of Nano Science	3	3
			Fundamentals of Nano Science-Practical	2	1
		OR			
		12 D	Solar, Thermal and Photovoltaic Conversion	3	3
			Solar, Thermal and Photovoltaic Conversion-Practical	2	1
		OR			
		12 E	Fundamentals of Python and Numerical Methods	3	3
			Fundamentals of Python and Numerical Methods-Practical	2	1
		13 A	Electronic Devices and Circuits	3	3
			Electronic Devices and Circuits-Practical	2	1
		OR			
		13 B	Low Temperature Physics and Refrigeration	3	3
			Low Temperature Physics and Refrigeration-Practical	2	1
		OR			
		13 C	Synthesis of Nano Materials	3	3
			Synthesis of Nano Materials-Practical	2	1
		OR			
		13 D	Wind, Hydro, Ocean & Geo-thermal Energy	3	3
			Wind, Hydro, Ocean & Geo-thermal Energy-Practical	2	1
		OR			
		13 E	Computations in Mechanics, Waves and Oscillations	3	3
			Computations in Mechanics, Waves and Oscillations-Practical	2	1

Year	Semester	Course	Title of the Course	No. of Hrs /Week	No. of Credits
	VI	14 A	Analog and Digital Electronics	3	3
			Analog and Digital Electronics-Practical	2	1
		OR			
		14 B	Vacuum Technology	3	3
			Vacuum Technology-Practical	2	1
		OR			
		14 C	Characterization of Nano Materials	3	3
			Characterization of Nano Materials-Practical	2	1
		OR			
		14 D	Energy Storage and Conversion Systems	3	3
			Energy Storage and Conversion Systems-Practical	2	1
		OR			
		14 E	Computations in Optics, Heat and Thermodynamics	3	3
			Computations in Optics, Heat and Thermodynamics-Practical	2	1
		15 A	Electronic Communication Systems	3	3
			Electronic Communication Systems-Practical	2	1
		OR			
		15 B	Materials for Industrial Applications	3	3
			Materials for Industrial Applications-Practical	2	1
		OR			
		15 C	Applications of Nanomaterials	3	3
			Applications of Nanomaterials-Practical	2	1
		OR			
		15 D	Biomass and Hydrogen Energy	3	3
			Biomass and Hydrogen Energy-Practical	2	1
		OR			
		15 E	Computations in Electricity, Magnetism, Electromagnetic Theory and Modern Physics	3	3
			Computations in Electricity, Magnetism, Electromagnetic Theory and Modern Physics-Practical	2	1

Note: In the III Year (during the V and VI Semesters), students are required to select a pair of electives from one of the **FIVE** specified domains. **For example: if set 'A' is chosen, courses 12 to 15 to be chosen as 12 A, 13 A, 14 A and 15 A.** To ensure in-depth understanding and skill development in the chosen domain, students must continue with the same domain electives in both the V and VI Semesters.

SEMESTER-I

COURSE 1: INTRODUCTION TO MATHEMATICAL PHYSICS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE:

To equip students with foundational mathematical techniques—such as vector calculus, linear algebra, complex numbers, probability, and Fourier analysis—essential for understanding and solving problems in physics.

LEARNING OUTCOMES:

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

1. Apply concepts of vector differentiation and integration to analyze physical fields and prove integral theorems.
2. Use matrix operations and eigenvalue techniques to solve linear systems in physics.
3. Represent and manipulate complex numbers in various forms for solving AC circuit problems.
4. Interpret and apply basic probability concepts and distributions to model physical phenomena.
5. Analyze periodic signals using Fourier series and evaluate Fourier coefficients for common waveforms.

UNIT-I - VECTOR ANALYSIS (9. Hrs.)

Distinction between Ordinary and partial derivatives, Scalar and vector fields, gradient of a scalar field and its physical significance. Divergence and curl of a vector field with derivations and physical interpretation. Vector integration (line, surface and volume), Statement and proof of Gauss and Stokes theorems.

UNIT-II – LINEAR ALGEBRA (9. Hrs.)

Vector and Scalar quantities in Physics, Matrices and Operations: Types, Addition and Multiplication, Identity and Inverse, Determinant (2x2 and 3x3), Trace, Transpose, Eigenvalues and Eigen Vectors, Calculation of Eigen values using characteristic equations. System of Linear Equations: Solving 2-variable system using matrices, Simple examples from physics (Current, forces)

UNIT – III COMPLEX NUMBERS (9. Hrs.)

Basic Complex numbers: Real and imaginary parts, Conjugate of complex numbers, Modulus and argument (magnitude and phase), Polar and Exponential (Euler) form of complex numbers. Addition and subtraction of complex numbers, Multiplication and division of complex numbers. Phasor representation: representation of voltage and current as phasors, Derivation of Impedance of a series LCR circuit.

UNIT – IV PROBABILITY **(9. Hrs.)**

Probability Theory Basics, Sample space, events, conditional probability, and Bayes' theorem. Independence and mutual exclusivity. Random Variables and Probability Distributions, Concept of random variables (discrete and continuous). Common distributions and their applications: Binomial, Poisson, and Gaussian.

UNIT V FOURIER ANALYSIS **(9. Hrs.)**

Introduction to periodic functions: Concept of periodicity (waves, oscillations, AC current), Graphical understanding of Sine and Cosine functions, Need for Fourier analysis, Real world signals (heartbeat, electrical signal, musical tones), Fourier theorem ad evaluation of Fourier coefficients, Analysis of periodic wave functions – Square wave, saw tooth wave and triangular wave.

Reference books

1. Mathematical methods for physics sciences (3^{rd} edition) - Mary. L. Boas
2. First Chapter (Vector analysis) in Introduction to Electrodynamics (3^{rd} edition) – David. J. Griffiths
3. Mathematical Methods for Physicists: Arfken, Weber, 2005, Harris, Elsevier

Student Activities:

- Problem-solving sessions using real-life physics applications (e.g., using vector calculus in electromagnetism).

- Group projects on solving physical systems using matrix methods and linear algebra tools.

- Mini-lab activity on phasor diagrams and impedance using circuit simulation software (like LTspice or Tinkercad Circuits).

- Data collection and analysis task: Record physical measurements (e.g., decay times, counts) and apply statistical models (Poisson/Gaussian).

SEMESTER-I

COURSE 1: INTRODUCTION TO MATHEMATICAL PHYSICS

Practical	**Credits: 1**	**2 hrs/week**

COURSE OBJECTIVE:

To develop foundational computational and analytical skills through hands-on exercises that prepare students for understanding and solving problems in various realms of physics.

LEARNING OUTCOMES:

1. Graphing and Visualization:
   Students will be able to plot mathematical functions and visualize physical phenomena using Excel, Python, or MATLAB.
2. Vector and Matrix Computations:
   Students will perform operations on vectors and matrices and represent them both analytically and graphically.
3. Numerical Methods:
   Students will apply numerical techniques like Newton-Raphson, Bisection, and Euler's method to solve equations and differential equations.
4. Data Analysis and Fitting:
   Students will analyze experimental data using tools like least squares fitting and compute statistical quantities such as mean, standard deviation, and error.
5. Fourier and Complex Number Representation:
   Students will approximate functions using Fourier series and graphically represent complex numbers.

List of Practical

Minimum of 6 experiments to be conducted and recorded

1. Graphing standard functions: sin(x), cos(x), e^x, ln(x), x^2, $\sqrt{x}$ etc. using Excel/Python/Graph paper
2. Experimental determination and vector diagram verification of vector addition and scalar product using graphical methods.
3. Using MATLAB/Python to visualize vector fields and compute gradient, divergence, and curl.
4. Solve simple non-linear equations (e.g., x3−x−1=0) using graphical methods and bisection/newton-raphson method (Python or Excel).
5. Fit experimental data (e.g., Hooke's law) to a straight line using least squares method in Excel or Python.
6. Linear equation Solution and System of linear equation solution using MATLAB/OCTAVE
7. Fourier approximation of a square wave up to 5 terms using Python/MATLAB and plotting the result.

8. Numerical solution of dy/dx=x+y, given initial condition using Euler's method.
9. Single coin tossing and four coin tossing using MATLAB/OCTAVE and verification of statistical laws
10. Use Python/Excel to perform addition, multiplication, and finding inverse of 2x2 and 3x3 matrices.
11. Simulate and plot s-t, v-t graphs using s=ut+0.5gt2s = ut + 0.5gt^2 using Excel or Python.
12. Calculate mean, standard deviation, and percentage error for a given data set using Excel/Python/Manual calculations
13. Represent the given complex numbers on graph paper
14. Determine the Eigen Values of the given matrix using characteristic equation

SEMESTER-I

COURSE 2: MECHANICS AND PROPERTIES OF MATTER

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE:

To provide students with a foundational understanding of classical mechanics and the physical properties of matter, including particle dynamics, central forces, elasticity, fluid behavior, and the basic principles of special relativity.

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

1. Apply Newton's laws to variable mass systems and analyze particle collisions using conservation laws and scattering theory.
2. Describe motion under central forces and derive orbital dynamics including Kepler's laws and satellite motion.
3. Explain elastic behavior of materials using stress-strain relations, and analyze the bending of beams and torsional motion.
4. Interpret fluid dynamics concepts such as streamline flow, Bernoulli's principle, and viscosity with practical applications.
5. Understand the key postulates of special relativity and apply Lorentz transformations to problems involving time dilation, length contraction, and mass-energy equivalence.

UNIT-I MECHANICS OF PARTICLES (9 hrs.)

Newton's Laws of motion, motion of variable mass system, Equation of motion of a rocket. Conservation of energy and momentum, collisions in two and three dimensions, concept of impact parameter, scattering cross-section, Rutherford scattering-derivation

UNIT-II CENTRAL FORCES (9 hrs.)

Central forces, definition and examples, characteristics of central forces, conservative nature of central forces, conservative force as a negative gradient of potential energy, equations of motion under a central force, derivation of Kepler's laws, motion of satellites, Geo-stationary satellites

UNIT III: ELASTICITY AND BENDING OF BEAMS (9 hrs)

Stress and strain, Hooke's Law, Elastic moduli – Young's, bulk, and shear modulus, Poisson's ratio – Physical meaning, Bending of beams – Types, point and distributed load, Cantilever and uniform bending – Qualitative treatment, Torsional pendulum – working principle and uses.

UNIT IV: FLUID MECHANICS (9 hrs)

Fluids – Properties and classification, Streamline vs turbulent flow, Reynolds number, Bernoulli's theorem – Statement, simple derivation and applications (Venturimeter, airplane lift), Equation of continuity – Concept, Viscosity – Poiseuille's law (statement and qualitative explanation), Surface tension – Examples and qualitative ideas

UNIT V: SPECIAL THEORY OF RELATIVITY (9 hrs.)

Galilean relativity, absolute frames, Michelson-Morley experiment, negative result, postulates of special theory of relativity, Lorentz transformation, time dilation, length contraction, addition of velocities, mass-energy relation

REFERENCE BOOKS:

1. BSc Physics -Telugu Akademy, Hyderabad
2. Mechanics - D.S. Mathur, Sulthan Chand & Co, New Delhi
3. Mechanics - J.C. Upadhyaya, Ramprasad & Co., Agra
4. Properties of Matter - D.S. Mathur, S. Chand & Co, New Delhi ,11th Edn., 2000
5. Physics Vol. I - Resnick-Halliday-Krane ,Wiley, 2001
6. Properties of Matter – Brijlal & Subrmanyam, S. Chand & Co. 1982
7. Mechanics-EM Purcell, Mc Graw Hill
8. University Physics-FW Sears, MW Zemansky & HD Young, Narosa Publications, Delhi
9. College Physics-I. T. Bhima sankaram and G. Prasad. Himalaya Publishing House.
10. Mechanics, S. G. Venkata chalapathy, Margham Publication, 2003.
11. Fluid Mechanics – Frank M. White, McGraw Hill.
12. Textbook of Fluid Dynamics – M. D. Raisinghania, S. Chand & Co.

SEMESTER-I

COURSE 2: MECHANICS AND PROPERTIES OF MATTER

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE:

To develop practical skills in the use of laboratory equipment and experimental techniques for measuring properties of matter and analyzing mechanical systems.

LEARNING OUTCOMES:

1. **Demonstrate a practical understanding of classical mechanics** by performing experiments on momentum, collisions, and motion under force.
2. **Analyze physical systems involving elasticity, fluid flow, and torsion** through hands-on measurements and data interpretation.
3. **Apply fundamental physics principles** to explain satellite motion, scattering phenomena, and beam bending using experiments and simulations.
4. **Use scientific simulations and digital tools** to visualize and investigate abstract concepts such as rocket motion, central forces, and relativity.
5. **Develop experimental, observational, and analytical skills** including data recording, graph plotting, and error estimation in real and virtual environments.

Minimum of 6 experiments to be conducted and recorded

1. Young’s modulus by uniform bending
2. Young’s modulus by non-uniform bending
3. Rigidity modulus using torsional pendulum
4. Surface tension by capillary rise method
5. Flywheel – Determination of moment of inertia
6. Bifilar suspension – moment of inertia of a rectangular body
7. Radius of capillary tube by Hg thread method
8. Simulation of rocket motion using water rocket or computer simulation.
9. Verification of Kepler’s third law using orbit simulation.
10. Simulation-based study of Rutherford scattering.
11. Determination of modulus of rigidity using Maxwell’s needle.
12. Measurement of Poisson’s ratio of a rubber tube.
13. Verification of Bernoulli’s theorem using a horizontal tube setup.
14. Demonstration of lift on an airfoil using airflow setup.
15. Simulation of Michelson-Morley experiment.
16. Visualization of time dilation and length contraction using simulation.

STUDENT ACTIVITIES

Unit I: Mechanics of Particles

Activity: Collision Experiments

Students can set up simple collision experiments using marbles, carts, or other objects. They can measure the initial and final velocities, masses, and analyze the momentum conservation. By varying the conditions (e.g., masses, initial velocities), they can observe the effects on the collision outcomes.

Unit II: Central Forces

Activity: Pendulum Motion Students can investigate the motion of a simple pendulum by varying its length and measuring the time period. They can analyze the relationship between the period and the length, and discuss the concept of centripetal force and its role in circular motion.

Unit III: Elasticity and Bending of Beams

Activity: Beam Bending Experiment

Use rulers or meter sticks on supports to apply loads and measure deflection. This hands-on demo helps visualize how elasticity and loading affect real-world structures.

Unit IV: Lagrangian Mechanics

Activity: Apply Lagrangian mechanics to various physical systems

Unit V: Special Theory of Relativity

Activity: Time Measurement Students can perform a time measurement experiment using simple devices like water clocks or sand timers. They can compare the measured time between two events at different relative speeds and discuss the concept of time

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SEMESTER-II

COURSE 3: WAVES AND OPTICS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE:

The course aims to develop a foundational understanding of oscillatory motion, wave behavior in strings and bars, and optical phenomena like interference, diffraction, and polarization. Students will learn to mathematically analyze vibrations and light behavior through theoretical and experimental approaches.

LEARNING OUTCOMES:

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

1. Describe the basic characteristics of waves such as frequency, wavelength, amplitude, period, and speed and utilize mathematical relationships related to wave characteristics.
2. Distinguish between Longitudinal and Transverse waves.
3. Understand the phenomenon of interference of light and its formation in Thin films and Newton’s rings.
4. Distinguish between Fresnel’s diffraction and Fraunhoffer diffraction and observe the diffraction patterns in the case of single slit and the diffraction grating and to describe the construction and working of zone plate and make the comparison of zone plate with convex lens
5. Explain the various methods of production of plane, circularly and polarized light and their detection and the concept of optical activity.

UNIT-I: SIMPLE HARMONIC, DAMPED & FORCED OSCILLATIONS (9 Hrs.)

Simple Harmonic Oscillator: Solution of differential equation, and physical characteristics, Principle of superposition, Combination of two mutually perpendicular SHMs (1:1 and 1:2 frequencies), Lissajous figures. Damping, Damped Harmonic Oscillator: Solution of differential equation, Energy considerations, Logarithmic decrement, relaxation time, quality factor, Forced Oscillations: Solution of differential equation.

UNIT-II VIBRATING STRINGS AND BARS (9 Hrs.)

Transverse wave propagation along a stretched string, general solution of wave equation and its significance, modes of vibration of stretched string clamped at ends, overtones and harmonics. Energy transport and transverse impedance. Longitudinal vibrations in bars- wave equation and its general solution. Special cases (i) bar fixed at both ends (ii) bar fixed at the midpoint (iii) bar fixed at one end. Tuning fork.

UNIT-III: INTERFERENCE **(9 hrs)**

Principle of superposition – coherence Conditions for interference of light. Fresnel's biprism determination of wavelength of light, change of phase on reflection, Oblique incidence of a plane wave on a thin film due to reflected light (cosine law) –colors of thin films- Interference by a film with two non-parallel reflecting surfaces (Wedge shaped film). Determination of diameter of wire, Newton's rings in reflected light. Determination of wavelength of monochromatic light using Newton's rings.

UNIT-IV: DIFFRACTION **(9 hrs.)**

Introduction, distinction between Fresnel and Fraunhoffer diffraction, Fraunhoffer diffraction – Diffraction due to single slit, Fraunhofer diffraction pattern with N slits (diffraction grating), Resolving power of grating, Determination of wavelength of light in normal incidence using diffraction grating. Fresnel's half period zones-area of the half period zones-zone plate, Difference between interference and diffraction.

UNIT-V: POLARIZATION **(9 hrs.)**

Polarized light: methods of polarization by reflection, refraction, double refraction, Brewster's law, Mauls law, Nicol prism polarizer and analyzer, Quarter wave plate, Half wave plate, optical activity - Determination of specific rotation by Laurent's half shade Polarimeter. Idea of elliptical and circular polarization

REFERENCE BOOKS:

1. BSc Physics Vol.1, Telugu Academy, Hyderabad.
2. BSc Physics Vol.2, Telugu Akademy, Hyderabad
3. Fundamentals of Physics. Halliday/Resnick/Walker, Wiley India Edition 2007.
4. Waves & Oscillations. S. Badami, V. Balasubramanian and K.R. Reddy, Orient Longman.
5. College Physics-I. T. Bhimasankaram and G. Prasad. Himalaya Publishing House.
6. Optics – Ajoy Ghatak, Tata McGraw Hill
7. Fundamentals of Optics – Jenkins and White, McGraw Hill
8. Wave Optics and Vibrations – N. Subrahmanyam & Brijlal, S. Chand & Co.
9. Vibrations and Waves – H. J. Pain, Wiley

SEMESTER-II

COURSE 3: WAVES AND OPTICS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE:

The Course Objective for a practical course in electricity and magnetism may include to develop practical skills in handling electrical and electronic components, such as resistors, capacitors, inductors, transformers, and oscillators.

LEARNING OUTCOMES:

1. Determine fundamental mechanical quantities like acceleration due to gravity and spring constant using compound pendulum and spring-based experiments, applying principles of oscillatory motion.
2. Apply statistical methods to analyze experimental data, estimate errors, and understand the importance of precision in repeated time-period measurements using a simple pendulum.
3. Explore wave phenomena through sonometer experiments, verifying laws of vibrations in stretched strings, and understand the relationship between frequency, tension, and length.
4. Analyze interference patterns in Newton's rings and wedge method to determine lens curvature and wire thickness, demonstrating coherence and phase concepts in light.
5. Examine diffraction effects using grating and prisms to determine wavelength and dispersive power, and assess optical resolving capabilities of telescopes and gratings.
6. Investigate polarization phenomena through polarimetry and understand optical activity by determining specific rotation of optically active substances.

Minimum of 6 experiments to be conducted and recorded

1. Determination of 'g' by compound/bar pendulum
2. Simple pendulum normal distribution of errors-estimation of time period and the error of the mean by statistical analysis.
3. Solving equation of motion for DHO & FHO using MATLAB/OCTAVE/Python
4. Determination of the force constant of a spring by static and dynamic method.
5. Verification of laws of vibrations of stretched string –sonometer.
6. Determination of radius of curvature of a given convex lens-Newton's rings.
7. Resolving power of grating.
8. Study of optical rotation – polarimeter.
9. Fourier transform simulation of single slit diffraction
10. Fourier transform simulation of diffraction at circular,rectangular aperture,edge
11. Dispersive power of a prism.

12. Determination of wavelength of light using diffraction grating-normal incidence method.
13. Determination of wavelength of laser light using diffraction grating.
14. Resolving power of a telescope.
15. Refractive index of a liquid-hallow prism.
16. Determination of thickness of a thin wire by wedge method.

STUDENT ACTIVITIES

UNIT-I: SIMPLE HARMONIC, DAMPED & FORCED OSCILLATIONS

Activity: Measuring the period of a simple pendulum and verifying the relationship between the period and the length of the pendulum. Students can use a stopwatch and a ruler to measure the time for a fixed number of oscillations and calculate the period.

Activity: Measuring the damping coefficient of a mass-spring system and calculating the quality factor. Students can measure the amplitude of the system as it undergoes damped oscillations and use the logarithmic decrement formula to calculate the damping coefficient.

UNIT-II VIBRATING STRINGS AND BARS

Activity: Measuring the speed of sound in a metal rod and comparing it with the theoretical value. Students can use a microphone and an oscilloscope to measure the time delay between two reflections of a sound pulse in the rod. They can then use the formula for the speed of sound in a solid to calculate the speed and compare it with the theoretical value

UNIT-III: INTERFERENCE

Ask students to measure the diameter of the central bright spot and the diameter of the nth ring for different values of n, and then calculate the wavelength of light

UNIT-IV: DIFFRACTION

Build a simple diffraction grating using a piece of cardboard and some sewing needles. Ask students to measure the distance between the needles, count the number of lines per unit length, and then calculate the grating spacing and the wavelength of light.

UNIT-V: POLARIZATION

Ask students to measure the angle of rotation of the polarized light before and after passing through the sample, and then calculate the specific rotation of the sample.

SEMESTER-II

COURSE 4: HEAT AND THERMODYNAMICS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE:

The course on Heat and Thermodynamics aims to provide students with a fundamental understanding of the principles of heat and energy transfer and their applications in various fields

LEARNING OUTCOMES:

On successful completion of this course, the student will be able to:

1. Understand the basic aspects of kinetic theory of gases, Maxwell-Boltzmann distribution law, equipartition of energies, mean free path of molecular collisions and the transport phenomenon in ideal gases
2. Gain knowledge on the basic concepts of thermodynamics, the first and the second law of thermodynamics, the basic principles of refrigeration, the concept of entropy, the thermodynamic potentials and their physical interpretations. Understand the working of Carnot's ideal heat engine, Carnot cycle and its efficiency
3. Develop critical understanding of concept of Thermodynamic potentials, the formulation of Maxwell's equations and its applications.
4. Differentiate between principles and methods to produce low temperature, liquefy air, and understand the practical applications of substances at low temperatures.
5. Examine the nature of black body radiations and the basic theories.

UNIT-I: KINETIC THEORY OF GASES (9 hrs)

Kinetic Theory of gases- Introduction, Maxwell's law of distribution of molecular velocities, Lammert's toothed wheel method; Mean free path, Principle of equipartition of energy, Transport phenomenon in ideal gases: viscosity and Thermal conductivity.

UNIT-II: THERMODYNAMICS (9 hrs)

Introduction- Reversible and irreversible processes, Carnot's engine and its efficiency, Carnot's theorem, Thermodynamic scale of temperature, Second law of thermodynamics Entropy: Physical significance, Change in entropy in reversible and irreversible processes; Change of entropy when ice changes into steam. Temperature- Entropy (T-S) diagram and its uses.

UNIT-III: THERMODYNAMIC POTENTIALS AND MAXWELL'S EQUATIONS (9 hrs)

Thermodynamic Potentials-Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy and their significance, Derivation of Maxwell's thermodynamic relations from thermodynamic potentials, Clausius-Clayperon's equation, Joule-Kelvin coefficient for ideal and Van der Waals' gases.

UNIT-IV: LOW TEMPERATURE PHYSICS **(9 hrs)**

Methods for producing very low temperatures, Critical temperature, Inversion temperature, Joule Kelvin effect, Porous plug experiment, Joule expansion, Distinction between adiabatic and Joule Thomson expansion, Expression for Joule Thomson cooling, Production of low temperatures by adiabatic demagnetization (qualitative), Refrigeration – Vapour compression machine.

UNIT-V: QUANTUM THEORY OF RADIATION **(9 hrs)**

Black body, Ferry's black body, Spectral energy distribution of black body radiation, Wein's displacement law and Rayleigh- Jean's law (No derivations), Planck's law of black body radiation-Derivation, Deduction of Wein's law and Rayleigh- Jean's law from Planck's law, Solar constant and its determination using Angstrom pyro heliometer, Estimation of surface temperature of Sun.

REFERENCE BOOKS

1. BSc Physics, Vol.2, Telugu Akademy, Hyderabad
2. Thermodynamics, R.C. Srivastava, S.K. Saha & Abhay K. Jain, Eastern Economy Edition.
3. Unified Physics Vol.2, Optics & Thermodynamics, Jai Prakash Nath & Co. Ltd., Meerut
4. Fundamentals of Physics. Halliday/Resnick/Walker. C. Wiley India Edition, 2007
5. Heat and Thermodynamics - N BrijLal, P. Subrahmanyam, S. Chand & Co., 2012
6. Heat and Thermodynamics - MS Yadav, Anmol Publications Pvt. Ltd, 2000
7. University Physics, HD Young, MW Zemansky, FW Sears, Narosa Publishers, New Delhi

SEMESTER-II

COURSE 4: HEAT AND THERMODYNAMICS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE:

The objectives for practical's in Heat and Thermodynamics can vary depending on the specific course or program, but here are some general objectives that may apply, to develop practical skills in the use of laboratory equipment and experimental techniques for studying heat and thermodynamics.

LEARNING OUTCOMES:

1. Mastery of experimental techniques: Students should become proficient in using laboratory equipment and experimental techniques for studying heat and thermodynamics.
2. Application of theory to practice: Students should be able to apply theoretical concepts learned in lectures to real-world situations, and understand the limitations of theoretical models.
3. Accurate recording and analysis of data: Students should be able to accurately record and analyze experimental data, including understanding the significance of error analysis and statistical methods.
4. Critical thinking and problem solving: Students should be able to identify sources of error, troubleshoot experimental problems, and develop critical thinking skills in experimental design and analysis.
5. Understanding of physical principles: Students should develop an understanding of the physical principles governing heat and thermodynamics, including the laws of thermodynamics, heat transfer, and thermodynamic cycles.

Minimum of 6 experiments to be done and recorded

1. Specific heat of a liquid – Joule's calorimeter –Barton's radiation correction
2. Thermal conductivity of bad conductor - Lee's method
3. Thermal conductivity of rubber.
4. Measurement of Stefan's constant.
5. Specific heat of a liquid by applying Newton's law of cooling correction.
6. Heating efficiency of electrical kettle with varying voltages.
7. Thermo emf- thermo couple - Potentiometer
8. Thermal behavior of an electric bulb (filament/torch light bulb)
9. Study of variation of resistance with temperature - Thermistor.
10. Thermal expansion of solids using metal ball and a ring.

STUDENT ACTIVITIES

Unit I: Kinetic Theory of Gases

Activity: Speed Distribution Analysis

Students can conduct a simple experiment using gas molecules (e.g., small balls) in a container. They can measure the speeds of the molecules using a motion sensor or stopwatch and analyze the distribution of molecular velocities. They can compare the observed distribution with the expected Maxwell's law of distribution.

Unit II: Thermodynamics

Activity: Heat Engine Efficiency Calculation

Students can work in groups to design a simple heat engine (e.g., using a syringe and a small turbine). They can measure the temperature changes and calculate the efficiency of their engine. They can compare their calculated efficiency with the theoretical Carnot efficiency to understand the limitations of real heat engines.

Unit III: Thermodynamic Potentials and Maxwell's Equations

Activity: Thermodynamic Relations Verification

Students can solve numerical problems involving different thermodynamic potentials (internal energy, enthalpy, Helmholtz free energy, and Gibbs free energy) and verify the Maxwell's thermodynamic relations. They can compare the calculated values using different relations to ensure consistency.

Unit IV: Low Temperature Physics

Activity: Adiabatic Demagnetization Experiment

They can discuss the distinction between adiabatic and Joule-Thomson expansions.

Unit V: Quantum Theory of Radiation

Activity: Black Body Radiation Spectrum Analysis

They can estimate the surface temperature of the Sun using the solar constant and Angstrom pyro heliometer data.

SEMESTER-III

COURSE 5: ATOMIC, MOLECULAR AND NUCLEAR PHYSICS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE:

The course aims to introduce students to the principles of atomic structure, molecular spectroscopy, and fundamental nuclear physics. It covers key experimental methods and theoretical models, helping students understand how microscopic interactions lead to observable physical phenomena in atoms, molecules, and nuclei.

LEARNING OUTCOMES:

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

1. Understand the principles of atomic structure and spectroscopy.
2. Understand the principles of molecular spectroscopy.
3. Develop critical understanding of concept of Matter waves and Uncertainty principle.
4. Describe nuclear properties, binding energy, and nuclear models such as the liquid drop and shell model.
5. Explain the working of nuclear detectors and accelerators and classify elementary particles and their interactions.

UNIT-I: INTRODUCTION TO ATOMIC STRUCTURE AND SPECTROSCOPY (9 hrs.)

Introduction to Bohr's model of the hydrogen atom, Vector atom model and Quantum numbers associated with it, Stern and Gerlach experiment, Coupling Schemes (LS & JJ), Spectral terms and spectral notations, Selection rules, Zeeman effect, Experimental arrangement to study Zeeman effect and expression for Zeeman shift.

UNIT-II: MOLECULAR SPECTROSCOPY (9 hrs.)

Molecular rotational and vibrational spectra, electronic energy levels and electronic transitions, Raman effect, Characteristics of Raman effect, Experimental arrangement to study Raman effect, Quantum theory of Raman effect, Applications of Raman effect. Spectroscopic techniques: IR and UV-Visible.

UNIT-III: MATTER WAVES & UNCERTAINTY PRINCIPLE (9 hrs.)

Matter waves, de Broglie’s hypothesis, Properties of matter waves, Davisson and Germer’s experiment, Heisenberg’s uncertainty principle for position and momentum & energy and time, Illustration of uncertainty principle using diffraction of beam of electrons (Diffraction by a single slit) and photons (Gamma ray microscope).

UNIT-IV: INTRODUCTION TO NUCLEAR PHYSICS **(9 hrs)**

Nucleus: Properties of nucleus, Mass defect, Binding energy – binding energy curve; Nuclear forces: Characteristics of nuclear forces, Yukawa's meson theory; Nuclear Models- Liquid drop model- Semi empirical mass formula, Shell model, magic numbers.

UNIT-V: NUCLEAR DETECTORS AND NUCLEAR ACCELERATOR **(9 hrs)**

Nuclear detectors: Geiger- Muller counter, Cloud chamber (expansion type), Scintillation counter. Nuclear Accelerators: Cyclotron-construction, working and applications; Synchrocyclotron-construction, working and applications. Classification of elementary particles, Types of interactions- strong, electromagnetic and weak interactions;

REFERENCE BOOKS:

1. BSc Physics, Vol.4, Telugu Akademy, Hyderabad
2. Atomic Physics by J.B. Rajam; S. Chand & Co.,
3. Modern Physics by R. Murugeshan and Kiruthiga Siva Prasath. S. Chand & Co.
4. Concepts of Modern Physics by Arthur Beiser. Tata McGraw-Hill Edition.
5. Nuclear Physics, Irving Kaplan, Narosa Pub. (1998).
6. Nuclear Physics, Theory and experiment – P.R. Roy and B.P. Nigam, New Age Int.1997.
7. Atomic and Nuclear Physics (Vol.2), S.N. Ghoshal, S. Chand & Co. (1994).
8. Nuclear Physics, D.C. Tayal, Himalaya Pub. (1997).

SEMESTER-III

COURSE 5: ATOMIC, MOLECULAR AND NUCLEAR PHYSICS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE:

To develop practical skills and experimental understanding in atomic and nuclear physics, including spectral line measurements, particle detection, and verification of quantum and nuclear models.

LEARNING OUTCOMES:

1. Demonstrate a deep understanding of the principles and theories of modern physics through hands-on experimentation and data analysis.
2. Analyze and interpret experimental data using statistical methods and error analysis, drawing meaningful conclusions and relating them to theoretical concepts.
3. Design and conduct independent experiments or investigations related to modern physics, demonstrating the ability to plan, execute, and analyze experimental procedures and results.
4. Gain a solid understanding of fundamental concepts in nuclear physics.
5. Understand the principles and operation of laboratory equipment and instruments specific to nuclear physics experiments.
6. Develop proficiency in conducting experiments related to nuclear physics.

Minimum of 6 experiments to be done and recorded

1. e/m of an electron by Thomson method
2. Determination of Planck's constant using a photocell
3. Verification of inverse square law of light using photovoltaic cell
4. Determination of work function of the filament material using directly heated vacuum diode
5. GM counter – Determination of dead time
6. Study of characteristic curve of GM counter and estimation of its operating voltage
7. Estimation of efficiency for a gamma source using GM counter
8. Estimation of efficiency for a beta source using GM counter
9. Study of sodium doublet using a diffraction grating
10. IR or UV-Vis spectroscopy of samples using a portable spectrometer
11. Single slit diffraction of laser beam to illustrate uncertainty principle
12. Study of absorption of beta particles in aluminum sheets
13. Study of Compton scattering (demo or simulation)
14. Study of counting statistics using GM counter
15. Study of plateau region and dead time using a counting system

STUDENT ACTIVITIES

UNIT-I: Introduction to Atomic Structure and Spectroscopy

Spectroscopy Experiment

Divide the students into small groups and provide each group with a spectrometer or spectroscope, a light source, and different samples or elements for analysis.

Instruct the students to carefully observe the spectra produced by the samples using the spectrometer. Encourage them to note the presence of specific spectral lines or patterns.

Data Collection

Have the students record their observations in their lab notebooks or worksheets. They should note the wavelengths or colors of the observed spectral lines and any patterns they observe.

Analysis and Discussion: Guide a class discussion on the observed spectra and their significance. Discuss how the observed spectral lines correspond to specific energy transitions in the atoms. Ask students to compare the spectra of different samples or elements and identify any similarities or differences.

Discuss the concept of energy levels and how electrons transition between them, emitting or absorbing photons of specific wavelengths.

UNIT-II: Molecular Spectroscopy

Begin the activity with a brief introduction to molecular structure, discussing concepts such as chemical bonds, molecular geometry, and the importance of molecular structure in determining the properties and behavior of substances. Explain the principles of spectroscopy, focusing on vibrational and rotational spectra and how they relate to molecular vibrations and rotations.

UNIT-III: Matter waves & Uncertainty Principle

Begin the activity by introducing the concept of matter waves and the uncertainty principle. Discuss how the wave-particle duality of matter is a fundamental principle in quantum mechanics. Provide a brief overview of the historical development of the uncertainty principle and its implications for our understanding of the behavior of particles on a microscopic scale.

UNIT-IV: Introduction to Nuclear Physics

Provide students with a computer simulation or interactive app that allows them to explore radioactive decay processes. Ask students to observe and analyze the decay patterns of different isotopes, including the concept of half-life. Guide students to make connections between the simulation results and the fundamental principles of nuclear physics

UNIT-V: Nuclear Detectors and Nuclear Accelerators

Activity: Detector Comparison Chart – Students create a comparative table of detector types, operation principles, advantages, and use-cases.

SEMESTER-III

COURSE 6: BASIC ELECTRONICS

Theory | **Credits: 3** | **3 hrs/week**

COURSE OBJECTIVES

This course aims to introduce undergraduate physics students to the fundamental principles of electronics. It covers passive components, semiconductor physics, diode and transistor operation, DC power supplies, and the basics of digital logic. The goal is to build a solid foundation in circuit analysis and electronic devices for students with minimal prior background.

LEARNING OUTCOMES:

By the end of the course, students will be able to:

1. Identify and explain the function and types of resistors, capacitors, and inductors.
2. Understand the basic concepts of semiconductors and diode characteristics.
3. Analyze simple transistor circuits and their applications.
4. Describe the functioning of rectifiers, filters, and voltage regulators.
5. Perform basic binary arithmetic and construct simple digital logic circuits.

UNIT I: PASSIVE COMPONENTS AND CIRCUIT FUNDAMENTALS (9 hrs)

Resistors: Types (carbon, wire-wound, metal film), color coding, tolerance, power ratings - Capacitors: Types (ceramic, electrolytic, film), applications, charge/discharge behavior - Inductors: Basic structure and applications - Series and parallel combinations: Equivalent resistance/capacitance/inductance - Basic laws: Ohm's Law, Kirchhoff's Voltage and Current Laws (KVL, KCL) with simple applications

UNIT II: SEMICONDUCTOR PHYSICS AND DIODES (9 hrs)

Intrinsic vs extrinsic semiconductors - Doping, energy band diagrams, charge carriers - PN junction diode: Construction, working, forward/reverse biasing, I-V characteristics - Special diodes: Zener diode, LED, photodiode, solar cell – construction, characteristics and uses

UNIT III: TRANSISTORS AND THEIR OPERATION (9 hrs)

BJT: Structure, current components, working of NPN/PNP - Configurations: CB, CE, CC – input/output characteristics - Applications: Transistor as switch and amplifier (qualitative understanding)

UNIT IV: POWER SUPPLIES AND REGULATION (9 hrs)

Need for DC power supply: Block diagram - Rectifiers: Half-wave, full-wave, bridge with waveforms - Filter circuits: RC, LC, and π filters – working principle - Voltage regulation: Zener diode regulation, IC regulators (brief intro)

UNIT V: INTRODUCTION TO DIGITAL ELECTRONICS (9 hrs)

Analog vs Digital signals - Number systems: Binary, decimal, hexadecimal – conversions, binary arithmetic - Logic gates: AND, OR, NOT – symbols, truth tables, simple logic circuits , Universal gates (NAND, NOR) – brief introduction

Textbooks / References:

1. V.K. Mehta & Rohit Mehta – *Principles of Electronics*, S. Chand
2. R.S. Sedha – *A Textbook of Applied Electronics*, S. Chand
3. D. Chattopadhyay & P.C. Rakshit – *Electronics: Fundamental Concepts*, New Central
4. Malvino & Leach – *Digital Principles and Applications*, McGraw-Hill
5. A.K. Maini – *Digital Electronics*, Wiley India

Student Activities

1. **Component Hunt**
    - Task: Identify and collect physical samples of resistors, capacitors, diodes, and transistors from old circuit boards.
    - Outcome: Visual and tactile understanding of component shapes, labels, and ratings.
2. **Poster Presentation**
    - Topic examples: "Types of Diodes and Their Applications" or "Power Supply Block Diagram."
    - Outcome: Encourages concise technical communication and peer learning.
3. **Group Demonstration**
    - Task: Simulate or build a basic rectifier or transistor switch circuit using breadboard or simulation software.
    - Outcome: Team collaboration and hands-on understanding.
4. **Number System Puzzle or Quiz**
    - Task: Convert between binary, decimal, and hexadecimal; perform binary addition/subtraction.
    - Outcome: Reinforces digital electronics basics through gamified learning.
5. **Mini Project (Optional)**
    - Task: Build a simple LED flasher or night lamp circuit using transistors and passive components.
    - Outcome: Design thinking and real-world application.
6. **Circuit Debugging Challenge**
    - Task: Find and correct errors in a faulty circuit diagram provided by the teacher.
    - Outcome: Improves analytical and practical troubleshooting skills.
7. **Logic Gate Simulation**
    - Task: Use a free simulator (like Falstad, Tinkercad, or Logic.ly) to create logic circuits.
    - Outcome: Concept reinforcement through virtual labs.

SEMESTER-III

COURSE 6: BASIC ELECTRONICS

Practical	**Credits: 1**	**2 hrs/week**

COURSE OBJECTIVE:

To develop practical skills in handling basic electronic components and circuits by constructing, testing, and analyzing simple electronic systems such as rectifiers, filters, diode/transistor configurations, and digital logic gates using fundamental measurement tools.

Learning Outcomes

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

1. Measure and verify the behavior of passive components in circuits.
2. Construct and test diode and transistor-based circuits.
3. Analyze rectifier output and filter performance using basic instruments.
4. Build and verify logic gate circuits using ICs or trainer kits.
5. Practice circuit debugging, use of multimeters, and interpretation of waveforms using a CRO.

Minimum of 6 experiments to be done and recorded

Experiments (Practical List)

1. **Verification of Ohm's Law** using resistive networks (series and parallel combinations).
2. Series and Parallel Combination of Capacitors and Inductors
3. **Capacitor charging and discharging curves** using RC circuits and a stopwatch/multimeter.
4. **V-I characteristics of a PN junction diode** (forward and reverse bias)
5. Temperature Dependence of Resistance (Using Thermistor).
6. **Zener diode characteristics** and voltage regulation behavior.
7. **Study of LED and photodiode characteristics** under different light conditions.
8. **BJT transistor as a switch**: ON/OFF control of an LED.
9. **Construction of half-wave and full-wave rectifiers** and measurement of output voltage.
10. **Design and analysis of simple π-filtered power supply** circuits.
11. **Verification of logic gates (AND, OR, NOT, NAND, NOR)** using digital ICs or simulation.

SEMESTER-III

COURSE 7: APPLIED OPTICS

Theory	**Credits: 3**	**3 hrs/week**

COURSE OBJECTIVE:

This course aims to introduce students to the core principles of optics and the functioning of various optical instruments. The objective is to provide a clear understanding of ray optics, aberrations, lasers, optical fibers, holography, and their applications in modern optical systems such as microscopes and telescopes.

LEARNING OUTCOMES:

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

1. Understand the fundamentals of geometrical optics using ray matrices and apply them to complex lens systems.
2. Analyze and distinguish various types of optical aberrations and methods to minimize them.
3. Comprehend the basic principle of laser, the working of He-Ne laser and Ruby lasers and their applications in different fields.
4. Understand the basic principles of fibre optic communication and explore the field of Holography and Nonlinear optics and their applications.
5. Gain knowledge of various optical instruments including microscopes and telescopes, their types, and real-world applications

UNIT-I: GEOMETRICAL OPTICS (9 hrs.)

Ray optics assumptions, Fermat principle, Translation matrix, Reflection matrix, Refraction matrix, ABCD matrices system matrix, Thick lens formula, Thin lens formula, Ramsden eyepiece, Huygens eyepiece, Two lens formula - (i) separated by a distance and (ii) in contact.

UNIT-II: ABERRATIONS (9 hrs.)

Fresnel theory of Reflection and Refraction. Monochromatic aberrations, Spherical aberration, Methods of minimizing spherical aberration, Coma, Astigmatism and Curvature of field, Distortion; Chromatic aberration-the achromatic doublet; Achromatism for two lenses (i) in contact and (ii) separated by a distance.

UNIT-III: LASERS (9 hrs.)

Lasers: Introduction, Spontaneous emission, Stimulated emission, Population Inversion, Laser principle, Einstein coefficients, Types of lasers: He-Ne laser, Ruby laser, Semiconductor laser, Applications of laser.

UNIT-IV: OPTICAL FIBERS AND HOLOGRAPHY **(9 hrs.)**

Principle of Optical fibers, Acceptance angle, Acceptance cone, Numerical aperture, Types of optical fibers - Graded and Stepped index, Types Signal attenuation mechanisms in optical fibers, Applications of Optical fibers - Sensors, Imaging, Communication.

Holography: Basic principle of holography-Gabor hologram and its limitations, Applications of holography.

UNIT-V: APPLICATIONS OF OPTICAL INSTRUMENTS **(9 hrs.)**

Introductory ideas and applications of various microscopes *viz*., (i) Optical microscopes (Compound microscope, Confocal microscope) (ii) Electron microscopes – SEM, Introductory ideas and applications of various telescopes *viz*., (i) Optical telescopes (ii) Radio telescopes (iii) Solar telescopes (iv) Infrared telescope (v) Ultraviolet telescope

REFERENCE BOOKS:

1. BSc Physics, Vol.2, Telugu Akademy, Hyderabad.
2. Optics - principles and applications Kailash K. Sharma
3. An introduction to Lasers M N Avadhanulu
4. Lasers Tyagarajan Ghatak 2nd Ed.
5. Introduction to Fiber Optics Tyagarajan Ghatak
6. Principles of Laser material processing Elijah Kannatey Asibu
7. Quantum optics An introduction Mark Fox

SEMESTER-III

COURSE 7: APPLIED OPTICS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE:

To provide hands-on experience with optical components and instruments, and to reinforce theoretical concepts through practical applications involving lasers, optical fibers, microscopes, and ray optics techniques.

LEARNING OUTCOMES:

1. Understand and apply geometrical optics principles through practical experiments involving lens combinations, matrix methods, and measurement of focal lengths using systems like the two-lens setup.
2. Demonstrate hands-on understanding of monochromatic and chromatic aberrations by working with diffraction gratings and measuring resolving powers of optical components like gratings and telescopes.
3. Explore the operational principles and characteristics of lasers, including wavelength measurement using diffraction gratings and analysis of laser beam behavior through reflection and refraction experiments.
4. Operate and analyze optical fiber systems by determining the numerical aperture, acceptance angle, and exploring their applications in communication and light guiding.
5. Investigate holographic concepts by understanding the role of laser light in interference-based techniques and identifying the limitations of basic holographic setups.
6. Examine and interpret the working of various optical instruments such as microscopes and telescopes by studying resolution, power, and optical limitations through practical experiments and simulations.

Minimum of 6 experiments to be done and recorded

1. Wavelength of laser using Diffraction grating
2. Refractive index of liquid using Hollow prism
3. Resolving power of telescope
4. Resolving power of grating
5. Spectrometer: i-d curve
6. Laser Reflection grating using metal scale
7. Optical fiber - Numerical Aperture
8. Rabi Oscillations Octave program
9. Two lens system power pairs plot (Python/Octave)
10. Focal length and verification of matrix method for thick and thin lenses
11. Achromatic combination of two lenses – in contact and at a distance
12. Measurement of beam divergence and spot size of a laser
13. Verification of Malus' Law using a laser and polarizers
14. Study of diffraction pattern from circular aperture (Airy disk) – resolving limit
15. Young's double-slit experiment using laser – interference fringes and fringe width
16. Study of bending losses in optical fiber

STUDENT ACTIVITIES

Unit-I: Geometrical Optics

Activity: Lens Matrix Simulation and Eyepiece Comparison

Students can use Python or Octave to simulate the behavior of optical systems using ABCD matrices. They can plot system matrices for single and double-lens setups and analyze the effective focal length. Additionally, students may perform a comparative analysis between Ramsden and Huygens eyepieces using ray diagrams and matrix methods, presenting their findings through short presentations or lab reports

Unit-II: Aberrations

Ask students to observe and sketch the different images produced by the lens at different distances. Build a simple optical system with two lenses in contact and ask students to calculate the focal length and magnification of the system. Then, introduce a thin glass plate between the lenses to simulate the effects of chromatic aberration and ask students to observe and discuss the changes in the image produced.

Unit-III: Lasers

Activity: Laser Communication Demo – Group project to transmit voice using a laser beam and photodiode.

Unit-IV: Optical fibers and Holography

Demonstrate the principle of holography using a laser beam, a beam splitter, and a photographic plate. Ask students to record a hologram of a simple object and then reconstruct the image using a laser beam.

UNIT-V: Applications of Optical Instruments

Activity: Comparative Analysis of Optical and Electron Microscopes and Telescope Technologies Students will form groups to study various microscopes (compound, confocal, SEM) and telescopes (radio, solar, UV, IR). Each group will create a model or infographic that illustrates the working principles, resolution limits, and applications of these instruments. Presentations will focus on how optics is tailored to different wavelength regimes**.**

SEMESTER-IV

COURSE 8: ELECTRICITY, MAGNETISM AND ELECTROMAGNETIC THEORY

Theory	**Credits: 3**	**3 hrs/week**

COURSE OBJECTIVE:

The course on Electricity, Magnetism and Electromagnetic theory aims to provide students with a fundamental understanding of the principles of electricity, magnetism, and electromagnetic theory.

LEARNING OUTCOMES:

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

1. Understand the Gauss law and its application to obtain electric field in different cases and formulate the relationship between electric displacement vector, electric polarization, Susceptibility, Permittivity and Dielectric constant.
2. To learn the methods used to solve problems using loop analysis, Nodal analysis, Thvenin's theorem, Norton's theorem, and the Superposition theorem
3. Distinguish between the magnetic effect of electric current and electromagnetic induction and apply the related laws in appropriate circumstances.
4. Understand Biot and Savart's law and Ampere's circuital law to describe and explain the generation of magnetic fields by electrical currents.
5. Develop an understanding on the unification of electric, and magnetic fields and Maxwell's equations governing electromagnetic waves.
6. Phenomenon of resonance in LCR AC-circuits, sharpness of resonance, Q- factor, Power factor and the comparative study of series and parallel resonant circuits

UNIT-I: ELECTROSTATICS AND DIELECTRICS **(9 hrs)**

Gauss's law - Statement and its proof, Electric field intensity due to uniformly charged solid sphere, Electrical potential–Equipotential surfaces, Potential due to a uniformly charged sphere. Dielectrics-Polar and Non-polar dielectrics - Effect of electric field on dielectrics, Dielectric strength, Electric displacement D, electric polarization Relation between D, E and P, Dielectric constant and electric susceptibility.

UNIT-II: CURRENT ELECTRICITY **(9 hrs)**

Electrical conduction - drift velocity-current density, equation of continuity, ohms law and limitations, Kirchhoff's Law's, Branch current method, Nodal Analysis, Star to Delta & Delta to Star conversions. Superposition Theorem, Thevenin's Theorem, Norton's Theorem, Maximum power transfer theorem.

UNIT-III: MAGNETOSTATICS AND ELECTROMAGNETIC INDUCTION (9 hrs)

Magneto statics: Biot-Savart's law and its applications: (i) long straight wire and (ii) circular loop, Hall Effect, determination of Hall coefficient and applications, magnetic charge, concept of vector potential.

Electromagnetic Induction: Faraday's laws of electromagnetic induction, Lenz's law, Self-induction and Mutual induction, Self- inductance of a long solenoid, Magnetic Energy density, mutual inductance of a pair of coils, coefficient of Coupling.

UNIT-IV ELECTROMAGNETIC WAVES-MAXWELL'S EQUATIONS (9 hrs)

Maxwell's equations: integral and differential forms (No derivation), Continuity equation, Concept of displacement current. Plane electromagnetic wave equation, Hertz experiment - Transverse nature of electromagnetic waves, Electromagnetic wave equation in conducting media, Skin depth, Poynting theorem-Pointing vector, Wave equations for E & B, Maxwell's equations in matter.

UNIT-V VARYING AND ALTERNATING CURRENTS (9 hrs)

Growth and decay of currents in LR, CR, LCR circuits-Critical damping, alternating current - A.C. fundamentals, and A.C through pure R, L and C, Relation between current and voltage in LR and CR circuits, Phasor and Vector diagrams, LCR series and parallel resonant circuit, Q - factor, Power in ac circuits, Power factor.

REFERENCE BOOKS:

1. BSc Physics, Vol.3, Telugu Akademy, Hyderabad.
2. Electricity and Magnetism, D.N. Vasudeva. S. Chand & Co.
3. Electricity, Magnetism with Electronics, K.K. Tewari, R. Chand & Co.,
4. "Electricity and Magnetism" by Brijlal and Subramanyam Ratan Prakashan Mandir, 1966
5. "Electricity and Magnetism: Fundamentals, Theory, and Applications" by Murugeshan, Kiruthiga Siva prasath, and M. Saravanapandian
6. "Electricity and Magnetism: Theory and Applications" by Ajoy Ghatak and Lokanathan
7. Electricity and Magnetism: Problems and Solutions" by Ashok Kumar and Rajesh Kumar
8. Electricity and Magnetism, R.Murugeshan, S. Chand & Co.

SEMESTER-IV

COURSE 8: ELECTRICITY, MAGNETISM AND ELECTROMAGNETIC THEORY

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE:

The Course Objective for a practical course in electricity and magnetism may include to develop practical skills in handling electrical and electronic components, such as resistors, capacitors, inductors, transformers, and oscillators.

LEARNING OUTCOMES:

1. Demonstrate a thorough understanding of the fundamental concepts and principles of electricity and magnetism.
2. Apply the laws and principles of electricity and magnetism to analyze and solve electrical and magnetic problems.
3. Design, construct, and test electrical circuits using various components and measuring instruments.
4. Measure and analyze electrical quantities such as voltage, current, resistance, capacitance, and inductance using appropriate instruments.
5. Apply the principles of electromagnetism to understand and analyze the behavior of magnetic fields and their interactions with electric currents

Minimum of 6 experiments to be done and recorded

1. LCR circuit series resonance, Q factor.
2. LCR circuit parallel resonance, Q factor.
3. Determination of AC-frequency –Sonometer.
4. Verification of Kirchhoff’s laws and Maximum Power Transfer theorem.
5. Field along the axis of a circular coil carrying current-Stewart & Gee’s apparatus.
6. Charging and discharging of CR circuit-Determination of time constant
7. A.C Impedance and Power factor
8. Determination of specific resistance of wire by using Carey Foster’s bridge.
9. Study of electric field and equipotential lines using conducting paper/Solution
10. Measurement of inductance using bridge method (Maxwell’s or Anderson's bridge)
11. Demonstration of electromagnetic shielding (Faraday cage effect)
12. Study of skin effect using high-frequency AC and measuring resistance variation
13. Simulation of electromagnetic wave propagation using MATLAB/Python
14. Poynting vector direction demonstration using polarizers and wave sources (conceptual demo)
15. Q factor and resonance frequency using CRO in LCR circuits (with variable frequency AC generator)

STUDENT ACTIVITIES

UNIT-I Electrostatics and Dielectrics

Conduct a simulation to visualize equipotential surfaces for a given charge distribution.

Conduct a group discussion on the significance of electric field lines and how they can be used to predict the motion of charged particles in electric fields.

UNIT-II Current electricity

Conduct a Wheatstone bridge experiment in class and discuss the balancing condition and sensitivity. Conduct a group activity where students are divided into groups and assigned a different circuit analysis method (nodal analysis, mesh analysis, superposition theorem, etc.) and asked to present their findings to the class.

UNIT-III Magneto statics and Electromagnetic Induction

Conduct a demonstration to show the Hall Effect and measure the Hall coefficient of a given material. Conduct a group activity where students are divided into groups, and assigned a different application of Faraday's law (electromagnetic induction, transformers, etc.) and asked to present their findings to the class.

UNIT-IV Electromagnetic waves

Conduct a group activity where students are asked to research the history of the development of Maxwell's equations and present their findings to the class.

Conduct a simulation to visualize the propagation of electromagnetic waves in different media (vacuum, air, water, etc.) and discuss the differences in the behaviour of waves in different media.

UNIT-V Varying and alternating currents

Conduct a demonstration to show the resonance in an LCR circuit and measure the Q-factor.

Conduct a group activity where students are divided into groups and assigned a different power factor correction method (capacitor banks, synchronous condensers, etc.) and asked to present their findings to the class.

SEMESTER-IV

COURSE 9: ANALOG ELECTRONICS

Theory	Credits: 3	3 hrs/week

COURSE OBJECTIVE:

To build on the understanding of transistor and op-amp-based analog circuits, enabling students to analyze and design amplifiers, oscillators, and basic analog signal processing systems for real-world applications.

LEARNING OUTCOMES:

By the end of the theory course, the student will be able to:

1. Analyze the design and performance of BJT amplifier circuits and multistage configurations.
2. Distinguish between different classes of power amplifiers and understand feedback principles.
3. Understand the internal operation and characteristics of operational amplifiers.
4. Design practical op-amp-based analog circuits for mathematical operations and signal conditioning.
5. Explain the principles of sinusoidal oscillator circuits and their applications.

UNIT I: BJT AMPLIFIERS (9 hrs)

Review of transistor operation in CE configuration - Load line analysis, biasing concepts (fixed bias, voltage divider bias) - CE amplifier: Circuit, gain, input/output impedance - Frequency response, bandwidth - Multistage amplifiers and emitter follower (voltage follower)

UNIT II: POWER AND FEEDBACK AMPLIFIERS (9 hrs)

Classification of amplifiers: Class A, B, AB, C - Class A and Class B power amplifiers – working and efficiency - Push-pull amplifier – circuit and waveforms - Negative feedback: Types (voltage/current series/shunt), effect on gain, bandwidth, stability

UNIT III: OPERATIONAL AMPLIFIERS – BASICS (9 hrs)

Characteristics of ideal and practical op-amp - Parameters: CMRR, slew rate, input offset voltage, bias current - Pin configuration and block diagram of IC 741 - Open loop and closed loop configuration

UNIT IV: APPLICATIONS OF OP-AMPS (9 hrs)

Inverting and non-inverting amplifiers – gain derivation and characteristics - Adder, subtractor circuits - Integrator and differentiator – design and applications - Comparators and zero-crossing detectors

UNIT V: OSCILLATOR CIRCUITS (9 hrs)

Conditions for oscillations: Barkhausen criterion - RC oscillators: Phase shift oscillator, Wein bridge oscillator – circuit, working - LC oscillators: Hartley, Colpitts – basic theory and circuits - Crystal oscillator: Construction and applications

Textbooks / References:

1. Robert L. Boylestad – *Electronic Devices and Circuit Theory*, Pearson
2. Ramakant A. Gayakwad – *Op-Amps and Linear Integrated Circuits*, PHI
3. D. Roy Choudhury – *Linear Integrated Circuits*, New Age International
4. A.P. Malvino – *Electronic Principles*, Tata McGraw-Hill
5. Millman & Halkias – *Integrated Electronics*, McGraw-Hill

Student Activities List

1. **Waveform analysis**: Record and interpret CRO traces from amplifier and oscillator outputs.
2. **Op-amp datasheet exploration**: Interpret specifications of IC 741 or similar.
3. **Mini project**: Build a tone generator or audio amplifier circuit.
4. **Simulation task**: Simulate CE amplifier or op-amp circuit using free tools like Falstad or Multisim Live.
5. **Classroom quiz**: Identify amplifier classes and feedback types based on circuit conditions.
6. **Group circuit-building challenge**: Design a multistage amplifier with given constraints.
7. **Poster presentation**: On "Power Amplifier Classes: Differences and Applications."
8. **Function generator use**: Demonstrate square, triangle, and sine wave outputs and measure frequency.
9. **Lab oral viva**: Justify component selection in op-amp applications.
10. **Oscillator comparison chart**: Create a chart comparing Hartley, Colpitts, and Wein bridge oscillators.

SEMESTER-IV

COURSE 9: ANALOG ELECTRONICS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE:

To provide hands-on experience in constructing and analyzing analog circuits involving BJTs, operational amplifiers, and oscillator configurations using commonly available components and instruments.

LEARNING OUTCOMES:

By the end of the lab course, the student will be able to:

1. Design and analyze various transistor amplifier circuits.
2. Measure amplifier parameters such as voltage gain, bandwidth, and input/output impedance.
3. Implement analog signal processing circuits using op-amps.
4. Test sinusoidal oscillator circuits and identify working conditions.
5. Utilize function generators, power supplies, and CROs for analog circuit testing..

Minimum of 6 experiments to be done and recorded

1. **CE amplifier design and performance:** Measure voltage gain and bandwidth.
2. **Transistor biasing circuits**: Fixed bias and voltage divider bias—measurement of Q-point.
3. **Class-B push-pull amplifier**: Construction and efficiency estimation.
4. **Negative feedback amplifier**: Study gain variation with and without feedback.
5. **Study of IC 741 op-amp parameters**: Offset voltage, bias current, and CMRR.
6. **Op-amp inverting and non-inverting amplifiers**: Gain and phase comparison.
7. **Op-amp adder and subtractor circuits**: Build and verify output equations.
8. **Op-amp integrator and differentiator**: Observe and sketch output waveforms.
9. **Wein bridge oscillator using op-amp or transistor**: Frequency and waveform measurement.
10. **Phase-shift oscillator** using RC networks and op-amp.

SEMESTER-IV

COURSE 10: ADVANCES IN PHYSICS

Theory **Credits: 3** **3 hrs/week**

Course Objectives

1. To introduce students to fundamental concepts of quantum mechanics, classical mechanics, and the evolution of computing with emphasis on quantum computing principles.
2. To expose students to emerging areas in physics, including nanotechnology and renewable energy, and their practical applications in modern technology and sustainable development.

Learning Outcomes

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

1. Apply basic quantum mechanics concepts including the Schrödinger equation, quantum postulates, and Pauli matrices to simple physical systems.
2. Formulate and solve mechanical problems using Lagrangian and Hamiltonian formulations of classical mechanics.
3. Trace the historical and technological evolution of computers, and explain the significance of quantum algorithms and the concept of quantum supremacy.
4. Identify and describe types of nanomaterials and discuss their unique properties and applications in science and technology.
5. Compare various renewable energy sources and explain principles of energy generation, storage, and integration into modern power grids.

UNIT-I CONCEPTS OF QUANTUM MECHANICS **(9 hrs.)**

Photoelectric effect, Compton Effect, Schrodinger's wave Equation time dependent, Time independent, Postulates of Quantum mechanics, Properties of wave function, Expectation values. One-dimensional problems - Particle in a box. Pauli spin matrices.

UNIT-II LAGRANGIAN MECHANICS **(9 hrs.)**

Conservation laws, Constraints, Generalized coordinates and velocities, Virtual displacement, virtual work, D'Alambert Principle, Lagranges equation of motion, Application-Simple pendulum, Atwood machine. Principle of least action, Hamiltonian equation of motion, Legendre transformation.

UNIT III EVOLUTION OF COMPUTERS **(9 hrs.)**

Computers: Mechanical to electronic evolution, Generations of computers: Vacuum tubes, transistors, ICs, microprocessors, Moore's Law and classical computing limitations, Need for a new paradigm: Introduction to quantum concepts, Key contributions from Feynman, Deutsch, and others, Overview of Shor's and Grover's algorithms, Concept and implications of quantum supremacy

UNIT IV: FUNDAMENTALS OF NANOTECHNOLOGY (9 hrs.)

Introduction to Nanoscience and Nanotechnology, Definition, historical development, and importance. Volume to Surface ratio, quantum effects, Types of Nanomaterials: Nanoparticles, nanowires, nanotubes, quantum dots. Applications of Nanotechnology: In electronics, medicine, energy, and environment

UNIT V: RENEWABLE ENERGY (9 hrs.)

Conventional and Non-conventional energy sources. Renewable energy and its resources
Solar energy - Generation, energy storage. Grid Integration and Smart Grids
Green energies - Wind energy, Biomass energy, Tidal energy and green energy, Fuel cells

Books and References

1. **Quantum Mechanics: Concepts and Applications –** Nouredine Zettili
2. **Principles of Quantum Mechanics** – R. Shankar
3. **A Textbook of Quantum Mechanics** – P.M. Mathews and K. Venkatesan *(Indian Author)*
4. **Classical Mechanics** – H. Goldstein, C. Poole, and J. Safko
5. **Introduction to Classical Mechanics** – R.G. Takwale and P.S. Puranik *(Indian Author)*
6. **Classical Mechanics** – J.C. Upadhyaya *(Indian Author)*
7. **Computer Organization and Architecture** – William Stallings
8. **Quantum Computation and Quantum Information** – Michael A. Nielsen and Isaac L. Chuang
9. **Fundamentals of Computers** – V. Rajaraman *(Indian Author)*
10. **Quantum Mechanics and Path Integrals** – Richard P. Feynman and A.R. Hibbs
11. **Introduction to Nanotechnology** – Charles P. Poole Jr. and Frank J. Owens
12. **Nanoscience and Nanotechnology** – M.A. Shah and Tokeer Ahmad *(Indian Author)*
13. **Renewable Energy Resources –** John Twidell and Tony Weir
14. **Non-Conventional Energy Sources –** G.D. Rai *(Indian Author)*
15. **Solar Energy: Principles of Thermal Collection and Storage** – S.P. Sukhatme and J.K. Nayak *(Indian Author)*

Student Activities

1. **Solve numerical problems** on particle in a box, harmonic oscillator, and quantum statistics to reinforce conceptual understanding.
2. **Create a comparison chart** of industrial materials highlighting their properties and specific applications across different industries.
3. **Prepare a poster or presentation** on types of nanomaterials and their real-life applications in healthcare, electronics, or energy.
4. **Demonstrate or simulate** the working of basic sensors and use a CRO or signal generator to observe and analyze waveforms.
5. **Build a working model** or give a seminar on a renewable energy system (e.g., mini solar panel setup or wind turbine model).

SEMESTER-IV

COURSE 10: ADVANCES IN PHYSICS

Practical **Credits: 1** **1 hrs/week**

Course Objective:

To provide students with hands-on experience and demonstrations of fundamental and emerging concepts in modern physics through physical and simulated experiments, focusing on quantum phenomena, material properties, energy technologies, and basic nanoscience.

Learning Outcomes

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

1. **Demonstrate understanding of quantum and thermal physics principles** through experiments such as photoelectric effect and Boltzmann constant determination.
2. **Analyze electrical and magnetic properties** of materials using real measurements (resistivity, magnetization, LDR, etc.).
3. **Explore basic properties of nanomaterials and their synthesis** through simple laboratory techniques like green synthesis of nanoparticles.
4. **Develop awareness of renewable energy technologies** and compare efficiencies of energy devices like solar panels, LEDs, and fuel cells.
5. **Apply instrumentation skills** in using sensors, CROs, and circuit components for measuring physical parameters.
6. **Interpret results from simulated experiments** and link theoretical physics models with practical outcomes (e.g., Maxwell-Boltzmann distribution, particle in a box).
7. **Enhance scientific inquiry and experimental reporting skills** through observations, data analysis, and interpretation.

A minimum of 6 experiments to be performed and recorded

1. Photoelectric Effect using UV LED and LDR
   - Demonstrates threshold frequency and energy quantization.
2. Determination of Boltzmann Constant from Diode Characteristics
   - Uses current–voltage relation of a diode.
3. Simple Pendulum – Time Period vs. Lagrangian Prediction
   - Validates theoretical dynamics.
4. Atwood Machine – Verification of Newton's Laws
   - Demonstrates conservation of energy and force analysis.
5. LCR Circuit and Impedance Measurement
   - Explores phase relations and resonance in AC circuits..
6. Synthesis of Iron Oxide Nanoparticles (Green Method)
   - Simple and safe wet-chemical synthesis using plant extracts.
7. Surface Area to Volume Ratio Demonstration Using Sugar Cubes/Sponge
   - Explains nanoscale effects visually.

8. Wind Energy Demonstration (Fan + Mini Turbine Setup)
    - Demonstrates wind-to-electricity conversion.
9. Hydrogen Generation via Electrolysis and Fuel Cell Demonstration
    - Produces H_2 and shows voltage from a fuel cell.
10. Efficiency Comparison Between LED and Incandescent Bulbs
    - Measures power consumption and light output.
11. Solar Panel Efficiency under Different Light and Load Conditions
    - Demonstrates photovoltaic energy conversion and optimization.
12. Battery/Fuel Cell Voltage Measurement with Varying Load
    - Observes how output voltage changes with load resistance.

💻 Simulation-Based or Digital Experiments

13. 1D Particle in a Box – Simulation using PhET/Python
    - Visualizes quantum confinement and energy levels.
14. Rutherford Scattering Simulation
    - Models scattering patterns and cross-section concepts.
15. Spin-½ System and Pauli Matrices – Qiskit or QuTiP
    - Simulates spin operators and quantum states.
16. Visualization of Kepler's Laws and Satellite Orbits
    - Models elliptical motion and geostationary conditions.
17. Lagrangian and Hamiltonian Simulation (e.g., Double Pendulum)
    - Explores classical mechanics through dynamic systems..
18. Basic Quantum Circuit Simulation using IBM Quantum Lab (Qiskit)
    - Visualizes gates, superposition, and basic algorithms.

SEMESTER-V

COURSE 11: INTRODUCTION TO SOLID STATE PHYSICS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE:

This course aims to introduce students to the fundamental principles of solid-state physics, including crystal structures, bonding, electrical and magnetic properties, and superconductivity. Emphasis will be given to theoretical understanding and experimental applications in real-world materials.

LEARNING OUTCOMES:

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

1. Understand the structure and classification of solids and determine crystal structures using lattice parameters and Miller indices.
2. Apply Bragg's Law and diffraction techniques to determine crystal structure and analyze reciprocal lattices.
3. Gain insight into dielectric behaviour of materials including polarization, dielectric constant, and dispersion relations.
4. Differentiate between magnetic materials and understand magnetic susceptibility, hysteresis, and energy loss.
5. Explore the phenomenon of superconductivity, its theoretical background, and practical applications.

UNIT I: CRYSTAL STRUCTURE AND BONDING (9 hrs)

Types of solids: Crystalline and amorphous, Unit cell, lattice, basis – 1D, 2D, and 3D lattices, Bravais lattices (3D) and seven crystal systems, Miller indices – Planes and directions in crystals, Common crystal structures: Simple cubic, BCC, FCC packing fraction and coordination number. Types of bonding in solids: Ionic, covalent, metallic, molecular, and van-der Waals

UNIT II: X-RAY DIFFRACTION AND CRYSTAL STRUCTURE DETERMINATION

(9 hrs)

X-ray generation and properties (brief review), Bragg's Law – Derivation and physical meaning Laue's method and powder diffraction method (qualitative), Applications in structure determination, Reciprocal lattice – Concept and construction (2D and 3D)

UNIT III: DIELECTRIC PROPERTIES OF SOLIDS **(9 hrs)**

Polarization. Local Electric Field at an Atom. Depolarization Field. Electric Susceptibility. Polarizability. Clausius-Mosotti Equation. Classical Theory of Electric Polarizability. Cauchy and Sellmeier relations. Complex Dielectric Constant.

UNIT IV: MAGNETISM IN SOLIDS **(9 hrs)**

Dia, Para, Ferri and Ferromagnetic Materials. Classical Langevin Theory of Dia and Paramagnetism. Curie’s law, Weiss’s Theory of Ferromagnetism and Ferromagnetic Domains. Discussion of B-H Curve. Hysteresis and Energy Loss. Soft, Hard magnetic materials and their application.

UNIT V: SUPERCONDUCTIVITY **(9 hrs)**

Introduction to Superconductivity, Experimental results-critical temperature, critical magnetic field, Meissner effect, London’s Equation and Penetration Depth, Isotope effect, Type I and Type II superconductors, BCS theory, High T_C Superconductors. Applications of superconductors

REFERENCE BOOKS:

1. BSc Physics, Vol.4, Telugu Akademy, Hyderabad.

2. Introduction to Solid State Physics – Charles Kittel

3. Solid State Physics – S.O. Pillai, New Age International

4. Solid State Physics – R.L. Singhal, Kedarnath Ramnath

5. Solid State Physics – P.K. Palanisamy, Scitech Publications

6. Elements of Solid-State Physics – J.P. Srivastava

7. Fundamentals of Solid-State Physics – B.S. Saxena, R.C. Gupta, P.N. Saxena

8. Solid State Physics: Structure and Properties of Materials – M.A. Wahab

SEMESTER-V

COURSE 11: INTRODUCTION TO SOLID STATE PHYSICS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE:

To provide hands-on experience and simulations that enable students to visualize and experimentally verify the structural, dielectric, magnetic, and superconducting properties of solids using modern tools and techniques. This practical component helps reinforce theoretical concepts from the Solid-State Physics syllabus through real and virtual lab investigations

LEARNING OUTCOMES:

On successful completion of this practical course, students will be able to:

1. Determine the crystal structure of solids using powder diffraction data and verify Bragg's Law using simulation tools.
2. Visualize and analyze common crystal structures such as SC, BCC, FCC, and HCP using software tools like VESTA.
3. Identify Miller indices of crystallographic planes and directions in a cubic crystal system using hands-on models.
4. Measure and interpret the dielectric constant and understand dispersion behavior through Cauchy and Sellmeier relations.
5. Investigate magnetic properties including magnetic susceptibility and hysteresis behavior in ferromagnetic materials.
6. Demonstrate and understand the key experimental observations related to superconductivity, including the Meissner effect and critical parameters.

Minimum of 6 experiments to be done and recorded

1. **Determination of Crystal Structure Using Powder XRD Data**
   Analyze diffraction peaks to identify crystal system and lattice constants.
2. **Verification of Bragg's Law using Simulation**
   Simulate diffraction pattern and verify the Bragg condition $n\lambda=2d\sin\theta$
3. **Visualization of Crystal Structures (SC, BCC, FCC, HCP) using VESTA Software**
   Explore unit cell geometry and atomic positions.
4. **Indexing of Planes and Directions in a Cubic Crystal using Models**
   Understand Miller indices with 3D models or interactive tools.
5. **Calculation of Packing Fraction for Cubic Structures using Models or Spreadsheet**
   Compute atomic packing efficiency for SC, BCC, FCC structures.
6. **3D Paper Models or Software-based Visualization of Miller Indices**
   Use CrystalMaker, VESTA, or handmade cutouts for hkl planes.
7. **Manual Calculation of d-Spacings and 2θ Values for NaCl or KCl Crystals**
   Apply Bragg's law calculations using data tables or Excel.
8. **Measurement of Dielectric Constant of Solid Materials**
   Use parallel plate capacitors with different dielectrics and an LCR meter.

9. **Measurement of Capacitance of a Parallel Plate Capacitor with Various Dielectrics**
   Explore effect of dielectric materials on capacitance.
10. **Simulation of Dispersion Curves using Cauchy and Sellmeier Relations**
    Model wavelength dependence of refractive index using Python or Excel.
11. **Simulation of Complex Dielectric Function (ε' and ε") vs Frequency**
    Use computational tools to analyze dielectric response.
12. **Measurement of Magnetic Susceptibility using Quincke's Method**
    Determine susceptibility using liquid column displacement.
13. **Measurement of Magnetic Susceptibility using Gouy's Method**
    Use a balance and a magnet to measure force on a sample.
14. **Study of B-H Curve and Hysteresis Loop of a Ferromagnetic Material**
    Plot magnetization versus magnetic field and observe hysteresis.
15. **Visualization of Ferromagnetic Domains (Using MOKE Images or Simulation)**
    View domain patterns and switching behavior under field.
16. **Demonstration of Meissner Effect and Superconductivity (Real or Simulated)**
    Show magnetic levitation or expulsion in superconductors.
17. **Simulation of London Penetration Depth vs Temperature**
    Model how superconducting properties change near Tc.
18. **Virtual Lab: Superconductivity & Meissner Effect (Amrita/PhET/MIT)**
    Explore superconducting concepts via interactive platforms.
19. **Measurement of Dielectric Constant of Solids using Low-cost Setups**
    Combine affordable dielectrics, LCR meters, and manual measurements.
20. **Simulation of Bragg Diffraction with Adjustable Wavelength and Lattice Spacing**
    Hands-on interaction with diffraction geometry and conditions.

SEMESTER-V

COURSE 12 A: ELECTRONIC INSTRUMENTATION

Theory	**Credits: 3**	**3 hrs/week**

COURSE OBJECTIVE:

To introduce fundamental measurement principles, sensor technologies, signal conditioning, and electronic measurement tools. This course prepares students to operate, analyze, and troubleshoot basic instrumentation systems in physics and electronics laboratories.

LEARNING OUTCOMES:

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

1. Describe the basic characteristics of a measurement system and types of errors.
2. Classify and explain working principles of various sensors and transducers.
3. Design and analyze signal conditioning circuits using op-amps and filters.
4. Explain the operation of ADCs, DACs, and various display systems.
5. Use CRO/DSOs and signal generators to measure and analyze waveforms.

UNIT I: BASICS OF MEASUREMENTS (9 hrs)

Measurement system: block diagram - Characteristics: Accuracy, precision, sensitivity, resolution, repeatability - Errors: Systematic, random, gross – causes and minimization - Standards of measurements: Primary, secondary, working standards

UNIT II: SENSORS AND TRANSDUCERS (9 hrs)

Classification: Active vs passive, analog vs digital - Temperature sensors: Thermistor, RTD, thermocouple - Displacement sensors: LVDT, capacitive and resistive types - Strain gauge and piezoelectric transducers – principle and applications

UNIT III: SIGNAL CONDITIONING (9 hrs)

Operational amplifier as signal conditioning element - Instrumentation amplifiers – basic configuration and applications - Bridge circuits: Wheatstone, Kelvin bridge – measurement of resistance - RC filters – low pass, high pass, band pass and band stop

UNIT IV: CONVERTERS AND DISPLAYS (9 hrs)

ADC: Successive approximation, flash ADC – block diagrams and timing - DAC: Weighted resistor and R-2R ladder type - Digital displays: Seven-segment, dot matrix, LCD - Display drivers and interfacing concepts

UNIT V: SIGNAL OBSERVATION TOOLS (9 hrs)

Cathode Ray Oscilloscope (CRO): Block diagram, CRT, vertical and horizontal deflection - Time base generator and triggering - Use of CRO in amplitude, frequency, and phase measurement - Function generators, signal generators – applications

Textbooks / References:

1. H.S. Kalsi – *Electronic Instrumentation*, Tata McGraw-Hill
2. A.K. Sawhney – *Electrical and Electronic Measurements and Instrumentation*, Dhanpat Rai
3. J. Helfrick & W.D. Cooper – *Modern Electronic Instrumentation and Measurement Techniques*, PHI
4. Albert D. Helfrick – *Instrument Transducers*, PHI
5. B.C. Nakra & K.K. Chaudhry – *Instrumentation, Measurement and Analysis*, McGraw-Hill

Student Activities for Electronic Instrumentation

1. **Sensor showcase**: Bring a working/defunct sensor from household gadgets and explain its type and function.
2. **Mini poster/chart**: "How an LVDT Works" or "ADC vs DAC in Real Devices."
3. **CRO Skill Check**: Identify parts of a CRO and demonstrate triggering.
4. **Circuit Simulation Task**: Simulate filters or ADC circuits using free tools (Falstad, Proteus).
5. **Viva Drill**: Identify sensor types from specifications or photos.
6. **Hands-on Signal Generator**: Explore all waveform settings and applications.
7. **Build a Basic Digital Thermometer (Group Project)** using thermistor + op-amp.
8. **Quiz**: Based on bridge circuits, filtering ranges, and oscilloscope measurements.
9. **Function Generator Demo**: Connect to CRO, vary frequency, and record waveform changes.
10. **Sensor Datasheet Reading**: Interpret ratings, sensitivity, and output formats.

SEMESTER-V

COURSE 12 A: ELECTRONIC INSTRUMENTATION

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE:

To provide practical experience in using sensors, bridges, filters, and waveform measuring tools essential for real-time signal acquisition and processing in electronics and physics labs.

LEARNING OUTCOMES:

1. Operate and test temperature, displacement, and strain sensors.
2. Measure resistance using bridge circuits with calibration.
3. Construct and evaluate signal conditioning circuits such as filters and amplifiers.
4. Use CROs and function generators for time- and frequency-domain measurements.
5. Understand and implement ADC/DAC conversion and digital display interfaces.

Minimum of 6 experiments to be done and recorded

1. **Study of Thermistor or RTD characteristics:** Resistance vs temperature.
2. **Displacement measurement using LVDT**: Calibration and sensitivity analysis.
3. **Wheatstone bridge and Kelvin bridge**: Resistance measurement and balancing.
4. **Strain gauge measurement**: Bridge configuration and deformation sensitivity.
5. **RC filter circuits:** Design and test low-pass, high-pass, and band-pass filters.
6. **Instrumentation amplifier using op-amp**: Gain measurement and noise rejection.
7. **Analog to Digital Converter (ADC)**: Using a basic ADC chip or simulation.
8. **Digital to Analog Converter (DAC)**: Design using weighted resistor or R-2R ladder.
9. **Seven-segment display interfacing**: Display digits using BCD counter or logic circuit.
10. **Cathode Ray Oscilloscope (CRO)**: Frequency and amplitude measurement of waveforms

SEMESTER-V

COURSE 12 B: SOLAR ENERGY AND ITS APPLICATIONS

Theory | **Credits: 3** | **3 hrs/week**

COURSE OBJECTIVE:

The objective of the course on Solar Energy and Its Applications is to provide students with a comprehensive understanding of solar energy technologies, their principles, and their applications. The course aims to develop students' knowledge and skills in harnessing solar energy for various purposes, including electricity generation, heating, and cooling**.**

LEARNING OUTCOMES:

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

1. Understand Sun structure, forms of energy coming from the Sun and its measurement.
2. Acquire a critical knowledge on the working of thermal and photovoltaic collectors.
3. Demonstrate skills related to callus culture through hands on experience
4. Understand testing procedures and fault analysis of thermal collectors and PV modules.
5. Comprehend applications of thermal collectors and PV modules

UNIT - I: BASIC CONCEPTS OF SOLAR ENERGY (9hrs.)

Spectral distribution of solar radiation, Solar constant , zenith angle and Air-Mass, standard time, local apparent time, equation of time, direct, diffuse and total radiations. Pyrheliometer - working principle, direct radiation measurement, Pyranometer-working Principle, diffuse radiation measurement, Distinction between the two meters.

UNIT - II: SOLAR THERMAL COLLECTORS (9hrs.)

Solar Thermal Collectors-Introduction, Types of Thermal collectors, Flat plate collector – liquid heating type, Energy balance equation and efficiency, Evacuated tube collector,collector overall heat loss coefficient, Definitions of collector efficiency factor, collector heat-removal factor and collector flow factor, Testing of flat-plate collector, solar water heating system, natural and forced circulation types.Concentrating collectors, Solar cookers, Solar dryers, Solar desalinators.

UNIT - III: FUNDAMENTALS OF SOLAR CELLS (9hrs.)

Semiconductor interface, Types, homo junction, hetero junction and Schottky barrier, advantages and drawbacks, Photovoltaic cell, equivalent circuit, output parameters, conversion efficiency, quantum efficiency, Measurement of I-V characteristics, series and shunt resistance, their effect on efficiency, Effect of light intensity, inclination and temperature on efficiency

UNIT -IV: TYPES OF SOLARCELLS AND MODULES (9hrs.)

Types of solar cells, Crystalline silicon solar cells, I-V characteristics, poly-Si cells, Amorphous silicon cells, Thin film solar cells-CdTe/CdS and CuInGaSe2/CdS cell configurations, structures, advantages and limitations, Multi junction cells – Double and triple junction cells. Module fabrication steps, Modules in series and parallel, Bypass and blocking diode

UNIT – V: SOLAR PHOTOVOLTAIC SYSTEMS (9hrs.)

Energy storage in PV systems, Energy storage modes, electrochemical storage, Batteries, Primary and secondary, Solid-state battery, Molten solvent battery, lead acid battery and dry batteries, Mechanical storage – Flywheel, Electrical storage –Super capacitor

References:

1. Solar Energy Utilization by G. D. Rai, Khanna Publishers
2. Solar Energy- Fundamentals, design, modelling and applications by G.N. Tiwari, Narosa Publications, 2005.
3. Solar Energy-Principles of thermal energy collection & storage by S.P. Sukhatme, TataMc-Graw Hill Publishers, 1999.
4. Science and Technology of Photovoltaics, P. Jayarama Reddy, CRC Press (Taylor & Francis Group), Leiden &BS Publications, Hyderabad, 2009.
5. Solar Photovoltaics- Fundamentals, technologies and applications, Chetan Singh Solanki, PHI Learning Pvt. Ltd.,
6. Web sources suggested by the teacher concerned and the college librarian including reading material.
   (a) https://courses.edx.org/c4x/DelftX/ET.3034TU/asset/solar_energy_v1.1.pdf
   (b) https://www.sku.ac.ir/Datafiles/BookLibrary/45/John%20A.%20Duffie, %20William%2 0A.%20Beckman(auth.)-Solar%20Engineering%20of%20Thermal%20Processes,%20Fourth%20Edition%20(20 13).pdf

SEMESTER-V

COURSE 12 B: SOLAR ENERGY AND ITS APPLICATIONS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE:

The objective of the practical course on Solar Energy and Its Applications is to provide students with hands- on experience and practical skills in working with solar energy systems, performing measurements and analysis, and implementing solar energy projects. The course aims to develop students' proficiency in solar energy system installation, maintenance, performance analysis, and practical application.

LEARNING OUTCOMES:

On successful completion of this practical course, studentshall be able to:

1. List out and identify various components of solar thermal collectors and systems, solar photovoltaic modules and systems.
2. Learn the procedures for measurement of direct, global and diffuse solar radiation, I -V characteristics and efficiency analysis of solar cells and modules.
3. Demonstrate skills acquired in evaluating the performance of solar cell / module in connecting them appropriately to get required power output.
4. Acquire skills in identification and elimination of the damaged panels without affectingthe output power in a module / array.
5. Perform procedures and techniques related to general maintenance of solar thermal and photovoltaic modules.

Practical (Laboratory) Syllabus:

Minimum of 6 experiments to be done and recorded

1. Measurement of direct radiation using pyrheliometer.
2. Measurement of global and diffuse radiation using pyranometer.
3. Evaluation of performance of a flat plate collector
4. Evaluation of solar cell / module efficiency by studying the I – V measurements.
5. Determination of series and shunt resistance of a solar cell / module.
6. Determination of efficiency of two solar cells / modules connected in series.
7. Determination of efficiency of two solar cells / modules connected in parallel.
8. Study the effect of input intensity on the performance of solar cell / module.
9. Study the influence of cell / module temperature on the efficiency.
10. Study the effect of cell / module inclination on the efficiency.

Lab References:

1.Solar Photo voltaic- Alab training manual, C.S. Solanki et al., Foundation Books Publishers, 2012.

2. Laboratory Manual on Solar thermal experiments, HP Garg, TC Kandpal, Narosa Publishing House 2000.
3. Web sources suggested by the teacher concerned. https://renewablelab.niu.edu/experiments/solarPanel Development of simple solar hot water collector: https://www.youtube.com/watch?v=WP8H5IOTwYU https://www.instructables.com/Solar-Water-Heater-From-Scratch/

Suggested Co-Curricular Activities

1. Training of students by related industrial/ technical experts using guest lectures/ invited talks.
2. Assignments (including technical assignments like identifying components of a solar hot water and solar photovoltaic systems and their handling, operational techniques and maintenance procedures with safety and security)
3. Seminars, Group discussions, Quiz, Debates etc. on related topics.
4. Preparation of videos on thermal and photovoltaic systems and technical procedures.
5. Collection of brochures/figures/photos related to products and applications of solar energy and organizing them in a systematic way in a file.
6. Making a (i) solar panel (ii) solar light (iii) solar cooker (iv) solar oven (v) sola inverter at Home.
7. Visits to nearby solar thermal system as well as solar photovoltaic power stations, firms, research organizations etc.

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SEMESTER-V

COURSE 12 C: FUNDAMENTALS OF NANOSCIENCE

Theory	Credits: 3	3 hrs/week

COURSE OBJECTIVE:

The objective of this course is to introduce undergraduate students to the fundamental principles of nanoscience and nanotechnology, focusing on the unique properties of materials at the nanoscale and their widespread applications. The course aims to build conceptual understanding of size-dependent behavior, types of nanomaterials, characterization tools, and real-life applications, while also addressing ethical and societal considerations.

LEARNING OUTCOMES:

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

1. **Define nanoscience and nanotechnology** and explain the significance of nanoscale dimensions and surface-to-volume ratio in determining material behavior.
2. **Describe how physical and chemical properties change at the nanoscale**, including quantum effects, optical and thermal properties, and compare them with bulk material properties.
3. **Classify various types of nanomaterials** based on their dimensions (0D to 3D), composition, and synthesis, and understand the influence of size and shape on their functionality.
4. **Identify common tools used in nanoscience**, such as electron microscopes and light-based techniques, and explain their role and limitations in characterizing nanoscale materials.
5. **Recognize the applications of nanotechnology in everyday life**, including consumer products, packaging, environment, and healthcare, while reflecting on ethical and safety issues related to nanoscience.

UNIT I: INTRODUCTION TO NANOSCIENCE (9 hours)

What is nanoscience and nanotechnology?, The nanoscale: Understanding size and dimensions, Importance of surface-to-volume ratio, Historical milestones in nanotechnology, Everyday examples of nanotechnology

UNIT II: PROPERTIES AT THE NANOSCALE (9 hours)

Size-dependent properties (color, melting point), Quantum effects and quantum confinement, Mechanical and thermal properties of nanomaterials, Electrical and optical behavior at nanoscale, Comparison with bulk materials

UNIT III: TYPES OF NANOMATERIALS **(9 hours)**

Zero-dimensional (nanoparticles), 1D (nanowires), 2D (graphene), 3D (nanocomposites), Common nanomaterials: Metals, oxides, carbon-based, Natural vs. synthetic nanomaterials, Role of shape and size in applications, Introduction to hybrid materials

UNIT IV: TOOLS FOR NANOSCIENCE **(9 hours)**

Basic idea of microscopes (SEM, TEM, AFM)**,** Simple spectroscopy (UV-Vis, color changes)**,** Measuring particle size (light scattering)**,** Importance of imaging at nanoscale**,** Limitations of nanoscale measurements

UNIT V: NANOSCIENCE IN DAILY LIFE **(9 hours)**

Nanotechnology in consumer products (e.g., sunscreen, clothing), Nanotechnology in food and packaging, Environmental benefits of nanotechnology, Safety and ethical concerns, Future potential of nanoscience

Reference books

1. Concise Concepts of Nanoscience and Nanomaterials by Narendra Kumar Sunitha Kumbhat

2. An Introduction to Nanoscience and nanotechnology by Alain Nouailhat

3. Nanotechnology: Principles and Practices" by Sulabha K. Kulkarni

4. Introduction to Nanoscience" by S.M. Lindsay

Suggested Student Activities:

1. Presentation/Poster: Key milestones and Nobel Prizes in nanoscience.
2. Simulation Activity: Demonstrate size-dependent properties using available virtual labs or videos (e.g., melting point variation).
3. Virtual tour/video review: TEM/SEM working principles or nanoscale imaging.
4. Material Research Project: Find and present current nanomaterials used in industries (e.g., carbon nanotubes, quantum dots).
   Debate or discussion: Ethics and risks of nanotechnology in consumer products or healthcare.

SEMESTER-V

COURSE 12 C: FUNDAMENTALS OF NANOSCIENCE

Practical	**Credits: 1**	**2 hrs/week**

COURSE OBJECTIVE:

The objective of this practical course is to introduce students to basic experimental techniques in nanoscience using simple, low-cost, and visually engaging methods. Through hands-on activities, students will explore the synthesis, observation, and characterization of nanoparticles and nanomaterials. The course emphasizes conceptual understanding, safety, observation skills, and the connection between nanoscale phenomena and real-world applications.

LEARNING OUTCOMES:

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

1. **Synthesize and observe nanoparticles** using chemical and green synthesis methods and identify visual indicators such as color changes due to size-dependent optical effects.
2. **Demonstrate basic techniques** for preparing nanoparticle suspensions and thin films, and explore nanoparticle interaction with light, including scattering and fluorescence.
3. **Compare particle sizes** using mechanical grinding and visualize differences through simple tools or software-based image analysis.
4. **Analyze basic physical properties** of nanomaterials such as settling behavior and surface tension using simple measurement techniques.
5. **Relate experimental results** to nanoscale behavior and interpret the significance of observed changes in color, texture, or optical response.
6. **Use digital tools** (e.g., ImageJ) to simulate nanoscale imaging and understand the role of characterization in nanoscience research.
7. **Follow safe and responsible laboratory practices** while handling nanoparticle materials and conducting experiments.

A minimum of 6 of the following experiments to be recorded

1. Color Change in Silver Nanoparticles
   Synthesize silver nanoparticles using silver nitrate and sodium citrate; observe color change.

   Equipment: Beakers, hot plate, stirrer.

2. Green Synthesis with Plant Extract
   Use leaf extract (e.g., mint) to make silver nanoparticles; note color shift.

   Equipment: Beakers, hot plate, filter paper.

3. Grinding for Nanoparticle Size Reduction
   Use a mortar and pestle to grind charcoal or chalk; compare sizes.

Equipment: Mortar, pestle, sieves.

4. Observing Light Scattering with Nanoparticles
   Shine a laser pointer through a nanoparticle solution to observe scattering.

   Equipment: Laser pointer, glass vial, nanoparticle solution.

5. Making a Nanoparticle Suspension
   Disperse zinc oxide (ZnO) powder in water and observe settling behavior.

   Equipment: Beakers, stirrer, ZnO powder.

6. Simple Thin Film Preparation: Drop-cast a nanoparticle solution (e.g., ZnO) on a glass slide to form a thin film. Equipment: Glass slides, pipette, nanoparticle solution.
7. UV Light Interaction with Nanoparticles: Expose ZnO nanoparticles to UV light and observe fluorescence. Equipment: UV lamp, ZnO nanoparticles, dark room.
8. Surface Tension of Nano fluids
   Measure surface tension of a nanoparticle-water mix using the drop-count method.

   Equipment: Pipette, beaker, balance.

9. Paper-Based Nanoparticle Coating
   Coat filter paper with silver nanoparticles and observe color or texture changes.

   Equipment: Filter paper, nanoparticle solution, brush.

10. Simulating Nanoscale Imaging
    Use free software (e.g., ImageJ) to analyze nanoparticle images from online sources.

    Equipment: Computer with software.

SEMESTER-V

COURSE 12 D: SOLAR, THERMAL AND PHOTOVOLTAIC CONVERSION

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE

To provide students with a comprehensive understanding of solar energy fundamentals, solar radiation principles, thermal and photovoltaic energy conversion systems, and their practical applications, while equipping them with the knowledge to analyze system performance and explore sustainable solar-based solutions for real-world energy needs.

LEARNING OUTCOMES

Upon successful completion, students will be able to:

1. Describe the solar radiation parameters and use instruments to measure solar radiation.
2. Differentiate between flat plate and concentrating collectors based on design and performance.
3. Explain various solar thermal systems like water heating, cooking, and greenhouses.
4. Analyze the structure, working, and efficiency of different types of solar cells.
5. Design small PV systems and assess the challenges in solar energy applications and maintenance.

UNIT-I: SOLAR RADIATION (9 hours)

Structure of Sun, Spectral distribution of solar radiation, Solar constant, Concept of declination, hour angle, inclination angle, zenith angle, azimuth angle, tilt angle, angle of incidence, Measurement of solar radiation using pyranometer and pyrheliometer, Estimation of direct and diffused radiation

UNIT-II: FLAT PLATE AND CONCENTRATING COLLECTORS (9 hours)

Solar collectors – classification,Flat plate collectors: construction, working, energy balance equation, efficiency, factors affecting performance, Advantages, disadvantages and applications

Concentrating collectors: classification, design, performance analysis, Comparison between flat plate and concentrating collectors, Paraboloidal dish collector

UNIT-III: SOLAR THERMAL APPLICATIONS (9 hours)

Solar hot water system (SHWS): natural and forced circulation types, Space heating: active and passive methods, Space cooling concepts, Solar cookers: box type, paraboloidal dish type, advanced cookers, Solar furnace, greenhouse

UNIT-IV: SOLAR PHOTOVOLTAIC CELL FABRICATION (9 hours)

Photovoltaic effect, Fabrication and characteristics of solar cells, Equivalent circuit, energy losses, and efficiency, Classification of solar cells, Production of single crystal silicon: Czokralski (CZ) and Float Zone (FZ) methods, Thin film solar cells: CdTe/CdS, Multi-junction solar cells.

UNIT-V: SOLAR PHOTOVOLTAIC MODULES AND APPLICATIONS (9 hours)

PV module formation: series and parallel connection of cells, Mismatch issues, use of bypass and blocking diodes, Design and fabrication of PV modules, Current, voltage and power characteristics of PV module Stand-alone PV system Grid-connected and hybrid PV systems, Installation, operation, and maintenance

Reference Books

1. *Solar Energy Utilization* – G.D. Rai, Khanna Publishers
2. *Non-Conventional Energy Resources* – B.H. Khan, McGraw Hill
3. *Non-Conventional Energy Sources and Utilization* – R.K. Rajput, S. Chand
4. *Solar Photovoltaics: Fundamentals, Technologies and Applications* – Chetan Singh Solanki, PHI
5. *Science and Technology of Photovoltaics* – P. Jayarama Reddy, BS Publications
6. *Solar Energy: Principles of Thermal Collection and Storage*, Sukhatme, S. P., & Nayak, J. K. Tata McGraw-Hill.
7. *Solar Photovoltaics: Fundamentals, Technologies and Applications*, Chetan Singh Solanki PHI Learning Pvt. Ltd.
8. *Principles of Solar Engineering*, D. Yogi Goswami & Frank Kreith CRC Press.
9. *Solar Energy: Fundamentals and Applications*, H.P. Garg & J. Prakash – Tata McGraw-Hill.
10. *Photovoltaic Systems Engineering*, Messenger, R., & Ventre, J. – CRC Press.

SEMESTER-V

COURSE 12 D: SOLAR, THERMAL AND PHOTOVOLTAIC CONVERSION

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE

To provide hands-on experience in the measurement, analysis, and evaluation of solar thermal and photovoltaic systems, enabling students to understand their real-world performance and operation.

LEARNING OUTCOMES

1. Measure and interpret solar radiation using appropriate instruments.
2. Analyze the efficiency and performance of solar collectors and PV panels.
3. Examine the electrical characteristics of solar photovoltaic modules under different conditions.
4. Assess the impact of installation parameters such as tilt angle, shading, and wiring configuration.
5. Demonstrate understanding of solar tracking, diode protection, and energy losses in PV systems.

Minimum of 6 experiments to be done and recorded

Practicals List

1. Measurement of direct solar radiation using pyrheliometer/pyranometer
2. Measurement of efficiency of a solar flat plate collector
3. Performance testing of a solar cooker unit
4. Study of solar cell characteristics
5. Effect of tilt angle on efficiency of a solar photovoltaic panel
6. Study on solar photovoltaic panels in series/parallel combination
7. I-V and P-V characterization of a solar PV module under varying illumination
8. Estimation of shadowing and mismatch losses in PV modules
9. Study of bypass and blocking diodes in a PV module
10. Solar tracking vs. fixed mounting performance (simulation or demo)
11. Thermal analysis of a solar water heater using temperature sensors
12. Performance comparison of box-type and paraboloidal solar cookers

SEMESTER-V

COURSE 12 E: FUNDAMENTALS OF PYTHON AND NUMERICAL METHODS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE:

The primary objective of this course is to equip students with the fundamental knowledge and practical skills in Python programming, focusing on its application in scientific computing and data analysis. Students will learn to leverage Python's powerful libraries for numerical operations, data manipulation, visualization, and solving common scientific and engineering problems using numerical methods.

LEARNING OUTCOMES:

1. Students will master Python fundamentals including data structures and control flow.
2. Students will proficiently use NumPy, Pandas, and Matplotlib for scientific computing and data visualization.
3. Students will be able to create diverse plots for experimental data and perform curve fitting.
4. Students will also apply essential numerical methods like integration and solving ordinary differential equations.
5. Student will develop Python codes to implement these numerical techniques for problem-solving.

UNIT-I: PYTHON FUNDAMENTALS (9 hrs)

Introduction to Python programming language, variables, data types (integers, floats, strings, booleans), Operators (arithmetic, comparison, logical), Input/Output functions, Basic data structures: Lists, Tuples, Dictionaries and control flow: Conditional statements (if, elif, else), Loops (for, while), Break and continue statements (conditionals and loops), Functions: Defining and calling functions, Arguments, return values, Local and global variables

UNIT-II: PYTHON MODULES FOR SCIENTIFIC COMPUTING (9 hrs)

NumPy and its components, Pandas DataFrames and its components, Matplotlib and its components, SciPy and its components, SymPy and its components, Jupyter Notebook, Seaborn for statistical plots.

UNIT-III: DATA VISUALIZATION (9 hrs)

Data importing and exporting, types of plots: line, scatter, histograms, contour, writing of program to plot experimental physics data (at least 3 data sets covering different experiments), customization of plots: labels, titles, legends, axes limits, colors, markers, line styles, curve fitting using SciPy

UNIT-IV: NUMERICAL METHODS **(9 hrs)**

Basic statistics: mean, median, standard deviation, Numerical integration methods: Riemann sums, the trapezoidal rule, and Simpson's 1/3 rule, Solving ordinary differential equations (ODEs) using Euler and Runge-Kutta (2^{nd} and 4^{th} order) methods.

UNIT-V: PYTHON CODES FOR NUMERICAL METHODS **(9 hrs)**

Developing codes for solving simple problems using Euler and Runge-Kutta methods employing scipy.integrate.solve_ivp. Developing codes for solving simple problems using Riemann sums, the trapezoidal rule, and Simpson's rule employing scipy.integrate.quad.

REFERENCE BOOKS:

1. "Python Crash Course: A Hands-On, Project-Based Introduction to Programming" by Eric Matthes
2. "A Primer on Scientific Programming with Python" by Hans Petter Langtangen
3. "Python for Data Analysis" by Wes McKinney
4. "Numerical Python: Scientific Computing and Data Science Applications with NumPy, SciPy and Matplotlib" by Robert Johansson
5. "Numerical Methods in Engineering with Python" by Jaan Kiusalaas
6. "Python Programming And Numerical Methods: A Guide For Engineers And Scientists" by Qingkai Kong, Tim Miller, and Steven L. Brunton
7. "Python Data Science Handbook: Essential Tools for Working with Data" by Jake VanderPlas

STUDENT ACTIVITIES:

UNIT-I: Python Fundamentals

Students will engage in basic programming challenges to practice control flow and data structure manipulation, and participate in "Fix the Bug" exercises to enhance debugging skills.

UNIT-II: Python Modules for Scientific Computing

Activities focus on performing NumPy array operations and Pandas DataFrame manipulations, alongside exploring Jupyter Notebooks to reproduce scientific plots.

UNIT-III: Data Visualization

Students will complete experimental data plotting assignments and undertake curve fitting mini-projects using SciPy to visualize and analyze data.

UNIT-IV: Numerical Methods

Activities include manual calculation comparisons with code for integration and ODEs, and an analysis of different numerical methods to assess accuracy and efficiency.

UNIT-V: Python Codes for Numerical Methods

Students will develop Python codes for numerical methods, including simulating physical systems with ODEs and calculating complex integrals using scipy.integrate functions.

SEMESTER-V

COURSE 12 E: FUNDAMENTALS OF PYTHON AND NUMERICAL METHODS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE:

This course aims to introduce students to fundamental Python programming concepts, including data types, control flow, data structures, and basic functions. It also provides an initial exposure to numerical computing with NumPy and data visualization using Matplotlib.

LEARNING OUTCOMES:

1. **Apply Python Fundamentals:** Students will be able to write basic Python programs using variables, input/output, conditional statements, and loops.
2. **Manipulate Data Structures:** Students will demonstrate proficiency in creating and utilizing Python lists, tuples, and dictionaries for data organization and retrieval.
3. **Perform Numerical Operations:** Students will be able to create and manipulate NumPy arrays, including performing basic matrix operations.
4. **Visualize Data:** Students will be able to generate and customize fundamental plots like line plots and histograms using Matplotlib.
5. **Develop Reusable Code:** Students will be able to define and call functions to encapsulate common tasks and improve code organization.

Minimum of 6 experiments to be conducted and recorded

1. Write a program to calculate the area and perimeter of a rectangle, taking length and width as input.
2. Create a program that determines if a given year is a leap year (divisible by 4, but not by 100 unless also divisible by 400)
3. Create a list of 5 student names and their corresponding scores (e.g., [('Alice', 85), ('Bob', 92), ...]). Store this data in a list of tuples or a list of lists.
4. Write a function calculate_average(scores_list) that takes a list of marks from university exam results and returns their subject wise average.
5. Create a dictionary student_grades where keys are student names and values are their scores. Write a function get_grade(student_name, grade_dict) that returns the score for a given student.
6. Create a 2D NumPy array B (3x3 matrix) filled with ones.
7. Create two 2x2 NumPy matrices, M1 and M2, and perform matrix multiplication (@ operator or np.dot()).
8. Generate a simple line plot of y=x2 for x ranging from -5 to 5
9. Plot two functions on the same graph (e.g., sin(x) and cos(x)) and add a legend
10. Generate 1000 random numbers from a normal distribution and create a histogram to visualize their distribution.

SEMESTER-V

COURSE 13 A: ELECTRONIC DEVICES AND CIRCUITS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE:

To provide students with a comprehensive understanding of semiconductor devices and their applications in biasing, amplification, regulation, and waveform generation. This course enables students to construct and analyze functional analog electronic circuits.

LEARNING OUTCOMES:

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

1. Understand the principles and techniques of transistor biasing and stabilization.
2. Explain the construction and characteristics of JFETs and MOSFETs.
3. Analyze the performance of rectifiers and filter circuits.
4. Design voltage regulators using discrete components and ICs.
5. Construct multivibrator circuits and understand waveform generation mechanisms.

UNIT I: BJT BIASING AND STABILIZATION (9 hrs)

Need for biasing, operating point (Q-point) - Load line analysis – DC and AC load lines - Biasing methods: Fixed bias, collector-to-base bias, voltage divider bias - Stability factors and thermal runaway

UNIT II: FIELD EFFECT TRANSISTORS (FETs) (9 hrs)

JFET: Construction, working, transfer characteristics - MOSFET: Enhancement and depletion mode – characteristics - Comparison of JFET and MOSFET - Applications of FETs as amplifiers and switches

UNIT III: RECTIFIERS AND FILTERS (9 hrs)

Review of diode characteristics - Rectifiers: Half-wave, full-wave (center tapped and bridge) with waveforms - Filter circuits: Capacitor filter, LC filter, π filter – working and output analysis - Ripple factor and its reduction

UNIT IV: VOLTAGE REGULATION (9 hrs)

Zener diode voltage regulator: Series and shunt regulators - Transistor series regulator – concept and design - IC voltage regulators: 78xx and 79xx series – features and applications - Concept of line and load regulation

UNIT V: MULTIVIBRATORS AND WAVEFORM GENERATORS (9 hrs)

Astable, monostable, and bistable multivibrators using BJTs – circuit diagrams and waveforms - Schmitt trigger – working and applications - Applications of multivibrators in timing and waveform shaping

Textbooks / References:

1. Millman & Halkias – *Electronic Devices and Circuits*, McGraw-Hill
2. S. Salivahanan – *Electronic Devices and Circuits*, McGraw-Hill
3. Boylestad & Nashelsky – *Electronic Devices and Circuit Theory*, Pearson
4. Thomas L. Floyd – *Electronic Devices*, Pearson
5. R.L. Gupta – *Electronics Devices and Circuits*, Katson Books

SEMESTER-V

COURSE 13 A: ELECTRONIC DEVICES AND CIRCUITS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE:

To develop practical skills in handling active semiconductor devices and constructing analog circuits such as bias networks, rectifiers, regulators, and waveform generators using transistors and diodes.

LEARNING OUTCOMES:

1. Design and test transistor biasing circuits for proper Q-point selection.
2. Analyze rectifier outputs and evaluate ripple factor with and without filters.
3. Build and test FET amplifiers and compare with BJT circuits.
4. Construct and test voltage regulators using Zener diodes and regulator ICs.
5. Observe multivibrator waveforms and determine timing characteristics.

Minimum of 6 experiments to be done and recorded

1. **Fixed bias and voltage divider bias circuits:** Plot DC load line and measure operating point.
2. **DC characteristics of JFET**: Plot transfer and drain characteristics.
3. **Half-wave and full-wave rectifier circuits**: Observe waveforms and measure output voltage.
4. **Bridge rectifier with capacitor filter**: Measure ripple factor and compare with theory.
5. **π filter performance in rectifier circuit**: Compare ripple reduction.
6. **Zener diode voltage regulator:** Analyze voltage regulation under load conditions.
7. **Transistor series voltage regulator**: Build and test regulated output.
8. **IC 7805 and 7812 voltage regulators**: Study line and load regulation.
9. **Astable and monostable multivibrator using BJT**: Observe output waveform using CRO.
10. **Schmitt trigger circuit using BJT**: Understand hysteresis behavior and switching.

SEMESTER-V

COURSE 13 B: LOW TEMPERATURE PHYSICS & REFRIGERATION

Theory | **Credits: 3** | **3 hrs/week**

COURSE OBJECTIVE:

The objective of the course on Low Temperature Physics & Refrigeration is to provide students with a comprehensive understanding of the fundamental principles, concepts, and applications of low-temperature physics and refrigeration systems. The course aims to develop students' theoretical knowledge and practical skills in working with low temperatures, understanding cryogenic phenomena, and operating refrigeration systems.

LEARNING OUTCOMES:

Students after successful completion of the course will be able to

1. Identify various methods and techniques used to produce low temperatures in the Laboratory.
2. Acquire a critical knowledge on refrigeration and air conditioning.
3. Demonstrate skills of Refrigerators through hands on experience and learns about refrigeration components and their accessories.
4. Understand the classification, properties of refrigerants and their effects on environment.
5. Comprehend the applications of Low Temperature Physics and refrigeration.

UNIT-I PRODUCTION OF LOW TEMPERATURE (9 hrs.)

Production of low temperatures-Introduction, Freezing mixtures, Joule-Thomson effect, Regenerative cooling, Different methods of liquefaction of gases, liquefaction of air, Production of liquid hydrogen and nitrogen, Adiabatic demagnetization, Properties of materials at low temperatures

UNIT-II MEASUREMENT OF LOW TEMPERATURE (9 hrs.)

Gas thermometer and its correction and calibration, Secondary thermometers, resistance thermometers, thermocouples, Vapour pressure thermometers, Magnetic thermometers, Advantages and drawbacks of each type of thermometer.

UNIT-III PRINCIPLES OF REFRIGERATION (9 hrs.)

Introduction to Refrigeration- Natural and artificial refrigeration , Stages of refrigeration, Types of refrigeration - Vapor compression and vapor absorption refrigeration systems, Refrigeration cycle and explanation with a block diagram, Introductory ideas on air- conditioning.

Refrigerants-Introduction, Ideal refrigerant, Properties of refrigerant, Classification of refrigerants, commonly used refrigerants, Eco-friendly refrigerants

UNIT-IV COMPONENTS OF REFRIGERATOR (9 hrs.)

Refrigerator and its working, Block diagram, Coefficient of Performance (COP), Tons of refrigeration (TR) and Energy Efficiency Ratio (EER), Refrigerator components: Types of compressors, evaporators, condensers, and their functional aspects, defrosting in a refrigerator, Refrigerant leakage and detection

UNIT-V APPLICATIONS OF LOW TEMPERATURE & REFRIGERATION (9 hrs.)

Applications of Low temperatures: Preservation of biological material, Food freezing, liquid nitrogen and liquid hydrogen in medical field, Superconducting magnets in MRI- Tissue ablation (cryosurgery) - Cryogenic rocket propulsion system.

Applications of refrigeration: Domestic refrigerators, Water coolers, Cold storages, Ice plants, Food preservation methods, Chemical and Process industries, Cold treatment of metals, Construction field, Desalination of water, Data centers.

References

1. Heat and Thermodynamics by Brij Lal &N.Subramanyam, S.Chand Publishers.
2. Thermal Physics by S C Garg, R M Bansal & C K Ghosh, McGrawHill Education, India
3. Heat and Thermodynamics by M MZemansky,McGrawHill Education (India).
4. Low-Temperature Physics by Christian E. & Siegfried H., Springer.
5. Thermal Engineering by S. Singh, S.Pati, Ch:18 Introduction to Refrigeration.
6. The Physics Hyper Text Book. Refrigerators.https://physics.info/refrigerators/
7. Refrigeration and Air Conditioning by Manohar Prasad, New age international (P) limited, New Delhi
8. A course in Refrigeration and Air Conditioning by S.C. Arora and S. Domkundwar, Dhanpatrai and sons, Delhi

SEMESTER-V

COURSE 13 B: LOW TEMPERATURE PHYSICS & REFRIGERATION

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE:

The objective of the practical course on Low Temperature Physics & Refrigeration is to provide students with hands-on experience and practical skills in working with low temperatures, operating refrigeration systems, and conducting experiments in the field of low temperature physics. The course aims to develop students' proficiency in handling cryogenic equipment, performing temperature measurements, and conducting experiments at low temperatures.

LEARNING OUTCOMES:

On completion of practical course, student shall be able to

1. List out, identify and handle equipment used in refrigeration and low temperature lab.
2. Learn the procedures of preparation of Freezing Mixtures.
3. Demonstrate skills on developing various Freezing mixtures and materials and their applications in agriculture, medicine and day to day life.
4. Acquire skills in observing and measuring various methodologies of very low temperatures
5. Perform some techniques related to Refrigeration and Freezing in daily life.

Minimum of 6 experiments to be done and recorded

1. Measure the temperatures below Melting point of Ice using a thermometer available in the Lab.
2. Make a freezing mixture by adding different salts viz., Sodium chloride, Potassium Hydrate (KOH), Calcium chloride to ice in different proportions and observe the temperature changes.
3. Study the operation of a refrigerator and understand the working of different parts.
4. Study the properties of refrigerants like chlorofluorocarbons-hydrochlorofluoro-carbons and record the lowest temperatures obtained.
5. Consider a simple faulty refrigerator and try to troubleshoot the simple problems by understanding its working
6. Understand the practical problem of filling the Freon Gas into the Refrigerator.
7. Get the Liquid Nitrogen or Liquid Helium from nearby Veterinary Hospital and measure their temperatures using chromel-alumel thermocouple or mercury thermometer and observe their physical properties like colour, smell etc and precautions to be taken for their safe handling.
8. Preparation of freeze drying food with Dry ice and liquid nitrogen
9. Preparation of freeze drying food with liquid nitrogen

STUDENT ACTIVITIES

Co-Curricular Activities:

(a) Mandatory:(*Training of students by teacher in field related skills: (lab:10 + field: 05*)

1. **For Teacher**: Training of students by the teacher in the in the laboratory/field for a total of not less than 15 hours on the techniques/skills of Low Temperature Production, methods used and applications of Low temperatures and refrigeration in day to day life and other applications in medicine and industry.
2. **For Student**: Student shall (individually) visit (i) a small ice plant or a cold storage plant

   (ii) Air Conditioner (AC) repair shop or (iii) Refrigerator repair shop to understand the construction, working principle and the trouble shooting of these devices after interacting with the technicians. **Or** Student shall observe the various thermodynamic processes taking place while working with the refrigerator and observe the leak detection in refrigeration system by different methods, air removal and charging of a refrigeration unit and testing of a refrigeration system to find out the Refrigerating capacity/Ton of refrigeration (TR) and the Power input. **Or** Student shall identify the refrigerant cylinder by color coding and standing pressure. **Or** Student shall visit the freezer aisle of a supermarket and observes the bags of different frozen fruits. Student shall write the observations and submit a hand- written Fieldwork/Projectwork not exceeding 10 pages in the given format to the teacher.

3. Max marks for Fieldwork/Project work: 05.
4. Suggested Format for Fieldwork/Project work: *Title page*, *student details, index page*, *details of place visited, observations, findings and acknowledgements*.
5. Unit tests (IE).

(b) <u>Suggested Co-Curricular Activities</u>

1. Training of students by related Factory, industrial experts.
2. Assignments (including technical assignments like identifying tools in Refrigerators, Freezers and their handling, operational techniques with safety and security)
3. Seminars, Group discussions, Quiz, Debates etc. (on related topics).
4. Preparation of videos on tools and techniques in Low Temperatures and applications.
5. Collection of material/figures/photos related to substances used in Freezing Mixtures, their Properties and availability etc., writing and organizing them in a systematic wayin a file.
6. Visits to Ice plants and labs in universities, research organizations, private firms, etc.
7. Making your own mini refrigerator at home
8. Build your own water cooler with the materials available at home.
9. Making hand launched liquid nitrogen rockets

10. Experiments with Liquid nitrogen and strawberry/ banana/ lemon/ onion/ mushroom/egg etc. (*To be tried under professional supervision only*).
11. Invited lectures and presentations on related topics by field/industrial experts
12. Identification of different Ozone-depleting substances (ODS) that damage the ozone layer in the upper atmosphere.
13. Demonstration to illustrate the greenhouse effect and the role of carbon dioxide as a greenhouse gas using plastic water bottles, flood light lamp, beakers and temperature sensors and observe the temperature changes.

https://edu.rsc.org/experiments/modelling-the-greenhouse-effect/1543.article
https://sealevel.jpl.nasa.gov/files/archive/activities/ts1hiac1.pdf

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SEMESTER-V

COURSE 13 C: SYNTHESIS OF NANOMATERIALS

Theory	**Credits: 3**	**3 hrs/week**

COURSE OBJECTIVE:

The objective of this course is to introduce students to the fundamental concepts and practical methods used in the synthesis of nanomaterials. Students will explore various synthesis routes—physical, chemical, and green—and learn the importance of controlling size, shape, and stability of nanoparticles. Emphasis will be placed on safe laboratory practices, low-cost techniques, and the basic chemistry behind the preparation of nanomaterials suitable for undergraduate-level understanding.

LEARNING OUTCOMES:

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

1. **Differentiate between top-down and bottom-up approaches** to nanomaterial synthesis and explain the importance of controlling particle size and morphology.
2. **Describe common physical synthesis techniques** such as grinding, milling, and evaporation, and evaluate their advantages and limitations in laboratory-scale applications.
3. **Apply basic chemical synthesis methods** such as chemical reduction, sol-gel, and precipitation to produce nanoparticles, and understand the roles of pH and temperature in synthesis.
4. **Perform green synthesis of nanoparticles** using natural extracts, identify the function of plant-based reducing agents, and discuss the environmental benefits and challenges of eco-friendly methods.
5. **Understand strategies to stabilize nanoparticles**, including the use of surfactants and coatings, and assess how storage conditions and solution environments affect nanoparticle stability.

UNIT I: BASICS OF SYNTHESIS (9 hours)

What is nanomaterial synthesis?, Top-down vs. bottom-up approaches,Importance of controlling size and shape, Safety in nanomaterial preparation, Common chemicals used in synthesis

UNIT II: PHYSICAL METHODS (9 hours)

Grinding and milling for nanoparticles, Evaporation and deposition basics, Simple mechanical methods for nanofibers, Advantages of physical methods, Low-cost physical synthesis techniques

UNIT III: CHEMICAL METHODS **(9 hours)**

Chemical reduction for metal nanoparticles, Precipitation for oxide nanoparticles, Sol-gel method basics, Role of pH and temperature, Simple chemical reactions for synthesis

UNIT IV: GREEN SYNTHESIS **(9 hours)**

Using plant extracts for nanoparticles, Role of natural reducing agents, Eco-friendly synthesis benefits, Examples: Silver and gold nanoparticles, Challenges in green methods

UNIT V: STABILIZING NANOMATERIALS **(9 hours)**

Preventing nanoparticle clumping, Using surfactants and coatings, Storage of nanomaterials, Testing stability in solutions, Practical tips for lab synthesis

Reference books

1. Concise Concepts of Nanoscience and Nanomaterials by Narendra Kumar Sunitha Kumbhat
2. An Introduction to Nanoscience and nanotechnology by Alain Nouailhat
3. Nanotechnology: Principles and Practices" by Sulabha K. Kulkarni – great for Indian UG level.
4. Introduction to Nanoscience" by S.M. Lindsay – clear and modern.

Student Activities:

1. Lab demo/video assignment: Synthesis of nanoparticles using sol-gel or chemical reduction method.
2. Compare and contrast chart: Physical vs. chemical vs. biological synthesis methods.
3. Prepare a flowchart: Steps in a specific synthesis technique (e.g., CVD, ball milling).
4. Literature survey: Review a journal article on a novel synthesis technique.
5. Safety audit task: Identify hazards and precautions in a nano lab

SEMESTER-V

COURSE 13 C: SYNTHESIS OF NANOMATERIALS

Practical	**Credits: 1**	**2 hrs/week**

COURSE OBJECTIVE:

The objective of this laboratory course is to introduce students to the synthesis and handling of nanomaterials through simple, cost-effective, and educational experiments. Students will gain hands-on experience in chemical, physical, and green synthesis methods and learn basic techniques for nanoparticle stabilization and thin film preparation, fostering foundational lab skills in nanoscience.

LEARNING OUTCOMES:

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

1. **Synthesize nanoparticles** using various methods including chemical reduction, precipitation, sol-gel, and eco-friendly green synthesis.
2. **Demonstrate physical techniques** such as manual grinding and soot collection to produce and handle nanomaterials.
3. **Apply stabilization strategies** using surfactants or additives and assess nanoparticle dispersion and aggregation behavior.
4. **Perform basic characterization-related observations**, such as color change, settling, or film formation, to infer nanoparticle size and stability.
5. **Fabricate simple nanomaterial films** using drop-casting techniques and understand their relevance in real-world applications.
6. **Follow proper laboratory practices** for the safe handling, preparation, and disposal of nanomaterial samples.

A minimum of 6 of the following to be recorded

1. Silver Nanoparticle Synthesis: Make silver nanoparticles using silver nitrate and glucose. Equipment: Beakers, hot plate, stirrer.
2. Zinc Oxide Nanoparticle Synthesis: Prepare ZnO nanoparticles using zinc acetate and sodium hydroxide. Equipment: Beakers, hot plate, oven.
3. Green Synthesis with Tea Extract: Use black tea extract to synthesize silver nanoparticles; observe color change. Equipment: Beakers, hot plate, filter paper.
4. Manual Grinding for Nanoparticles: Grind iron oxide powder with a mortar and pestle; compare particle sizes. Equipment: Mortar, pestle, sieves.
5. Precipitation of Copper Nanoparticles: Synthesize copper nanoparticles using copper sulfate and ascorbic acid. Equipment: Beakers, stirrer, hot plate.
6. Stabilizing Nanoparticles with Soap : Add soap to a nanoparticle solution and observe dispersion. Equipment: Beakers, soap solution, stirrer.

7. Making Carbon Nanoparticles from Soot: Collect candle soot and disperse in water to form a nanoparticle suspension. Equipment: Candle, beaker, ultrasonic bath (optional).
8. Simple Sol-Gel Synthesis: Prepare silica nanoparticles using a sol-gel method with sodium silicate. Equipment: Beakers, stirrer, drying oven.
9. Testing Nanoparticle Stability: Add salt to a nanoparticle solution and observe settling or clumping. Equipment: Beakers, salts, stirrer.
10. Drop-Casting Nanomaterial Films Create a thin film of ZnO nanoparticles on a glass slide by drop casting. Equipment: Glass slides, pipette, nanoparticle solution.

SEMESTER-V

COURSE 13 D: WIND, HYDRO, OCEAN AND GEOTHERMAL ENERGIES

Theory **Credits: 3** **3 hrs/week**

Course Objective

The objective of this course is to provide students with a comprehensive understanding of various non-conventional renewable energy systems including wind, small hydro, ocean thermal, tidal, and geothermal sources. It aims to familiarize students with the principles of energy conversion, system components, design considerations, site selection, and applications of each system. The course also emphasizes the status, potential, and challenges of these energy sources in the Indian context, promoting sustainable and environment-friendly power generation methods.

Learning Outcomes

1. Understanding of wind resources, principles of wind conversion technologies, ocean energy sources and geothermal resources.
2. Ability to understand production and application of wind, hydro, ocean and geothermal energy
3. Grid-connected & off-grid applications of wind energy, OTEC systems and thermoelectric power generation.
4. Model preparation of wind turbine and analysis of environmental impact of ocean and geothermal energy.
5. Understanding the design and functioning of wind turbines, tidal and geothermal energy systems.

UNIT-I: WIND GENERATION AND MEASUREMENT (9 hours)

Meteorology of wind, Global wind distribution, Wind speed variation with height and statistics, Principles of wind energy conversion, Types and characteristics of Wind Energy Conversion, Systems (WECS), Wind measurement methods: Eolian features, anemometers, balloon measurements

UNIT-II: WIND ENERGY APPLICATIONS (9 hours)

Wind turbine design: horizontal vs vertical axis, Simulation of turbine characteristics, Wind pumps: design, performance, testing, Economics and environmental impacts of wind energy, Wind energy status in India

UNIT-III: SMALL HYDROPOWER SYSTEMS (9 hours)

Overview of micro, mini and small hydro systems, Elements of pumps and turbines, Site selection, speed and voltage regulation, Load management and tariff issues, Hybrid wind-hydro standalone systems, Small hydro potential in India

UNIT-IV: OCEAN THERMAL AND TIDAL ENERGIES (9 hours)

Ocean Thermal Energy Conversion (OTEC): working, site selection, Tidal energy: origin, types, technologies, Merits, limitations, and applications, Basics of wave motion and power

UNIT-V: GEOTHERMAL ENERGY (9 hours)

Earth's internal structure and geothermal gradients, Geothermal resource classification and extraction, Exploration and development, Applications and limitations, Geothermal energy scenario in India

Reference Books

1. *Non-Conventional Energy Sources* – G.D. Rai, Khanna Publishers
2. *Non-Conventional Energy Resources* – B.H. Khan, McGraw Hill
3. *Non-Conventional Energy Sources and Utilization* – R.K. Rajput, S. Chand Publishers

SEMESTER-V

COURSE 13 D: WIND, HYDRO, OCEAN AND GEOTHERMAL ENERGIES

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE

The objective of this laboratory course is to experimentally explore the working principles and performance characteristics of various renewable energy systems, including wind, hydro, tidal, ocean thermal, and geothermal sources. The practical sessions aim to provide hands-on experience in measuring, analyzing, and understanding energy conversion processes and system efficiencies using models, instruments, and simulations.

LEARNING OUTCOMES

By the end of the lab course, students will be able to:

1. **Measure and analyze wind speed and turbine characteristics** using anemometers and wind turbine models.
2. **Compare the performance** of different wind turbine designs, including blade variations and rotor orientation.
3. **Demonstrate energy generation principles** from wave, tidal, and ocean thermal systems through physical models or simulations.
4. **Evaluate the efficiency** of micro-hydro systems and understand the effect of flow and turbine type.
5. **Estimate geothermal gradients** and understand the process of geothermal energy extraction using simplified data sets.
6. **Interpret the effects of environmental factors** such as wave motion, blade design, and turbine speed on renewable energy output.
7. **Appreciate the practical challenges** and limitations of implementing renewable systems in real-world scenarios.

Practical

1. Estimation of wind speed using anemometer
2. Study of wind characteristics
3. Determination of wind generator characteristics
4. Effect of number and size of blades on power output
5. Comparison of vertical and horizontal wind turbine rotors
6. Effect of wave amplitude and frequency on energy output
7. Demonstration of wind turbine model and voltage output measurement
8. Efficiency test of a small water turbine (hydro setup)
9. Simulation/demonstration of OTEC system
10. Geothermal gradient estimation using simulated data
11. Model demonstration of a tidal barrage system

SEMESTER-V

COURSE 13 E: COMPUTATIONS IN MECHANICS, WAVES AND OSCILLATIONS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE:

This course aims to equip students with the skills to design and implement physics simulations using Object-Oriented Programming in Python. Students will apply computational methods to model and analyze various physical phenomena, from kinematics to waves.

LEARNING OUTCOMES:

1. Students will be able to design, implement, and utilize Python classes and objects to model physical entities and build structured simulation frameworks.
2. Students will master vector operations using NumPy, calculate kinematic quantities, and plot motion graphs for systems like projectile motion.
3. Simulate Central Force Systems: Students will compute central forces and angular momentum, and simulate and visualize different types of orbits, including planetary motion.
4. Students will set up and solve differential equations for various oscillatory systems (e.g., mass-spring, pendulum, damped oscillations) and visualize their time evolution.
5. Students will be able to simulate wave propagation, interference, and standing waves, and apply Fourier analysis to decompose and interpret complex wave forms.

UNIT-I: OBJECT-ORIENTED PROGRAMMING AND SIMULATIONS (9 hrs)

Object-Oriented Programming (OOP) for Simulations: Classes, objects, attributes, methods, encapsulation, Designing Simulation Components: Creating classes for physical entities (e.g., Particle, Vector, Force), Building a Simulation Framework: Structuring code for managing multiple interacting objects and evolving the system state.

UNIT-II: KINEMATICS (9 hrs)

Creating and manipulating 1D and 2D vectors as NumPy arrays, Vector addition, subtraction, scalar multiplication, Dot product and cross product for physical quantities (e.g., work, torque - introduced as vector operations), Calculation of displacement, velocity, and acceleration using kinematic relations, Plotting position-time, velocity-time, and acceleration-time graphs, Projectile motion analysis (without air resistance): calculating range, maximum height, time of flight, Kinetic energy of translation and rotation (introduction), Gravitational potential energy (mgh) and Elastic potential energy (1/2 kx^2).

UNIT-III: CENTRAL FORCES (9 hrs)

Calculation of gravitational force, plotting gravitational force as a function of distance, calculation of angular momentum using NumPy's cross product, calculation of total energy in a central force field, Simulating elliptical, parabolic, and hyperbolic orbits, visualizing variation of time period as a function of semi major axis, visualizing law of areas.

UNIT-IV: OSCILLATIONS (9 hrs)

Plotting of sine and cosine functions, Setting up differential equations for mass-spring system and simple pendulum (small angle approximation) as a system of first-order ODEs, Plotting displacement, velocity, and acceleration as functions of time, Combination of two mutually perpendicular SHMs (1:1 and 1:2 frequencies), Lissajous figures, Setting up ODEs for underdamped, critically damped, and overdamped oscillations, Simulating and plotting the time evolution for each damping regime.

UNIT-V: WAVES (9 hrs)

Mathematical representation of 1D transverse and longitudinal waves, Animating wave propagation, Wave speed, wavelength, frequency relationships, Simulating constructive and destructive interference patterns, Visualizing standing waves (formed by two oppositely traveling waves), Fourier analysis: Concept of decomposing complex signals into sine and cosine components, Visualization of complex waves (Square, Saw tooth and Triangular waves) by varying number of sine and cosine waves, Perform Fast Fourier Transform on simulated wave data using scipy.fft.fft and fftfreq, Interpreting frequency spectra.

REFERENCE BOOKS:

1. "Computational Physics" by Nicholas J. Giordano and Hisao Nakanishi
2. "A First Course in Computational Physics" by Paul L. DeVries and Jian-Ke Shang
3. "Python for Data Analysis" by Wes McKinney
4. "Python Data Science Handbook: Essential Tools for Working with Data" by Jake VanderPlas
5. "Principles of Physics" by Halliday, Resnick, and Walker (for general physics background on Kinematics, Central Forces, Oscillations, Waves)
6. "Classical Dynamics of Particles and Systems" by Stephen T. Thornton and Jerry B. Marion (for more advanced mechanics concepts in Kinematics and Central Forces)
7. "Vibrations and Waves" by A.P. French (for in-depth coverage of oscillations and waves)
8. "Numerical Methods in Engineering with Python" by Jaan Kiusalaas (for practical implementation of ODE solvers)
9. "Object-OrientOriented Programming in Python: A Guide to the Fundamentals of Object-Oriented Programming (OOP) for Developers and Aspiring Programmers" by Michael Urban (for a focused OOP reference)

STUDENT ACTIVITIES:

UNIT-I: Object-Oriented Programming and Simulations

- Activity 1: Design and implement core OOP components like Particle, Vector, and Force classes, including attributes, methods, and encapsulation for physical entities.
- Activity 2: Develop a basic Simulation framework that uses these classes to manage multiple interacting objects and evolve the system state over time steps.

UNIT-II: Kinematics

- Activity 1: Perform vector operations (addition, subtraction, dot, cross products) using NumPy, applying them to calculate physical quantities like work and torque.
- Activity 2: Simulate and plot position-time, velocity-time, and acceleration-time graphs for projectile motion, calculating range, maximum height, and time of flight, and include calculations for kinetic and potential energies.

UNIT-III: Central forces

- Activity 1: Calculate and plot gravitational force as a function of distance, and compute angular momentum using NumPy's cross product.
- Activity 2: Simulate and visualize elliptical, parabolic, and hyperbolic orbits in a central force field, demonstrating the variation of time period with the semi-major axis and the law of areas.

UNIT-IV: Oscillations

- Activity 1: Set up and solve differential equations for mass-spring systems and simple pendulums (small angle approximation) as systems of first-order ODEs, plotting their displacement, velocity, and acceleration over time.
- Activity 2: Simulate and visualize Lissajous figures from combining two mutually perpendicular SHMs, and set up ODEs for and simulate the time evolution of underdamped, critically damped, and overdamped oscillations.

UNIT-V: Waves

- Activity 1: Mathematically represent and animate 1D transverse and longitudinal wave propagation, illustrating wave speed, wavelength, and frequency relationships, as well as simulating constructive and destructive interference and standing waves.
- Activity 2: Apply Fourier analysis by visualizing the decomposition of complex waves (Square, Saw tooth, Triangular) into sine and cosine components, and perform Fast Fourier Transform (FFT) on simulated wave data using scipy.fft to interpret frequency spectra.

SEMESTER-V

COURSE 13 E: COMPUTATIONS IN MECHANICS, WAVES AND OSCILLATIONS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE:

This course aims to equip students with the practical skills to design, implement, and visualize physics simulations using Python's Object-Oriented Programming capabilities and scientific libraries. Students will apply computational methods to model and analyze various physical phenomena from mechanics to wave theory.

LEARNING OUTCOMES:

1. Students will be able to design and implement Python classes for physical entities and construct simulation frameworks to evolve system states.
2. Students will master vector operations using NumPy and simulate projectile motion, analyzing trajectories and energy.
3. Students will be able to calculate and visualize gravitational forces and simulate basic orbital mechanics.
4. Students will animate 1D wave propagation and demonstrate constructive and destructive interference patterns.
5. Students will synthesize complex waveforms by summing sine and cosine components, visualizing the approximation process.

Minimum 6 experiments to be conducted and recorded

1. Define a Particle class with initial attributes for position (2D or 3D vector, e.g., a NumPy array), velocity, acceleration, and mass.
2. Design a Simulation class that holds a list of Particle objects
3. Simulate 2-3 particles moving under constant acceleration (e.g., gravity), and store their trajectories.
4. Represent 2D force and displacement vectors as NumPy arrays.
5. Calculate the work done by a constant force moving an object along a given displacement using the dot product.
6. Simulate the trajectory of a projectile launched at a given initial velocity & angle and Plot the projectile's path (Y vs. X)
7. Write a function to calculate the gravitational force vector between two masses given their positions & masses and Plot the magnitude of gravitational force as a function of distance.
8. Write a function to generate the displacement y(x, t) for a 1D transverse wave and Create an animation that shows the wave propagating along the x-axis over time
9. Superimposition of two separate 1D waves to show: Constructive interference (in-phase) and Destructive interference (out-of-phase).

10. Synthesize a square wave by summing a finite number of sine (and cosine for triangular/sawtooth) components. Visualize how adding more terms approximates the original wave.
11. Synthesize a sawtooth wave by summing a finite number of sine (and cosine for triangular/sawtooth) components. Visualize how adding more terms approximates the original wave.
12. Synthesize a triangular wave by summing a finite number of sine (and cosine for triangular/sawtooth) components. Visualize how adding more terms approximates the original wave.

SEMESTER-VI

COURSE 14 A: ANALOG AND DIGITAL ELECTRONICS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE:

To develop a unified understanding of analog signal processing using operational amplifiers and the principles of digital logic design, enabling students to analyze and implement both analog and digital circuits in real-life applications.

LEARNING OUTCOMES:

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

1. Design and analyze advanced op-amp circuits such as log amplifiers, detectors, and waveform generators.
2. Apply Boolean algebra to simplify digital expressions and construct logic circuits.
3. Implement practical combinational circuits including adders, encoders, and multiplexers.
4. Understand the operation of flip-flops, counters, and shift registers.
5. Differentiate between logic families and apply memory devices in simple digital systems.

UNIT I: ADVANCED OP-AMP APPLICATIONS **(9 hrs)**

Log and antilog amplifiers – circuit design and working - Peak detector and sample-and-hold circuits - Schmitt trigger – hysteresis and switching characteristics - Timer IC 555 – internal block diagram, astable and monostable operation

UNIT II: BOOLEAN ALGEBRA AND LOGIC SIMPLIFICATION **(9 hrs)**

Basic laws and theorems of Boolean algebra - DeMorgan's theorems – statement and verification - Logic gates: Symbols, truth tables, logic expressions - SOP and POS forms, simplification using Boolean laws

UNIT III: COMBINATIONAL LOGIC CIRCUITS **(9 hrs)**

Half adder and full adder – circuit, truth table, logic diagrams - Multiplexers, demultiplexers – working principles and applications - Encoders and decoders – design and uses - Implementation of Boolean expressions using multiplexers

UNIT IV: SEQUENTIAL CIRCUITS AND FLIP-FLOPS **(9 hrs)**

Latches and flip-flops: SR, JK, D, T – truth tables and characteristic equations - Edge-triggered and level-triggered flip-flops - Counters: Asynchronous and synchronous – binary and mod-N counters - Shift registers – SIPO, PISO, ring and Johnson counters

UNIT V: MEMORY DEVICES AND LOGIC FAMILIES **(9 hrs)**

Classification of memories: ROM, RAM, PROM, EPROM – working principles - TTL and CMOS logic families – characteristics, comparison - Noise margin, fan-in, fan-out - Interfacing TTL with CMOS and vice versa

Textbooks / References:

1. R.P. Jain – *Modern Digital Electronics*, McGraw-Hill.
2. Operational Amplifiers and Linear ICs, David A. Bell, 3rd Edition, 2011
3. D. Roy Choudhury & Shail Jain – *Linear Integrated Circuits*, New Age
4. Morris Mano – *Digital Logic and Computer Design*, Pearson
5. Thomas L. Floyd – *Digital Fundamentals*, Pearson
6. M.M. Mano & Ciletti – *Digital Design*, Pearson

Student Activities for Analog and Digital Electronics

1. **Logic gate truth table race**: Time-based group challenge for filling truth tables.
2. **Build your own digital lock** using basic gates or flip-flops.
3. **Mini project**: Design a basic traffic light controller using counters and logic gates.
4. **Boolean expression challenge**: Simplify and implement using NAND/NOR only.
5. **IC datasheet analysis**: Read and present features of IC 7400, 74138, or 555 timer.
6. **Schmitt trigger behavior demonstration** with varying input voltages.
7. **Poster presentation**: “TTL vs CMOS Logic Families.”
8. **Simulation**: Use Logic.ly, Tinkercad, or Falstad to simulate logic circuits.
9. **Classroom quiz**: Rapid-fire on memory types and logic circuit features.
10. **Sequential logic clock design**: Create a timing circuit using flip-flops and counters.

SEMESTER-VI

COURSE 14 A: ANALOG AND DIGITAL ELECTRONICS

Practical	**Credits: 1**	**2 hrs/week**

COURSE OBJECTIVE:

To provide hands-on experience in designing analog and digital circuits using op-amps, logic gates, and digital ICs, allowing students to observe, test, and troubleshoot various signal processing and logic control systems

LEARNING OUTCOMES:

1. Construct and analyze analog op-amp circuits like log amplifiers and Schmitt triggers.
2. Simplify Boolean expressions and implement them using logic gates.
3. Design and verify the behavior of adders, multiplexers, and encoders.
4. Build sequential circuits using flip-flops and observe timing behaviors.
5. Interface digital ICs from different logic families and use memory components.

Minimum of 6 experiments to be done and recorded

1. **Logarithmic and antilogarithmic amplifiers** using op-amps.
2. **Peak detector and sample-and-hold circuit**: Observe input/output waveforms.
3. **Astable and monostable multivibrator** using IC 555 timer.
4. **Schmitt trigger circuit** using op-amp or digital IC.
5. **Verification of Boolean laws and DeMorgan’s theorems** using logic gates.
6. **Design and implementation of half-adder and full-adder** using basic gates or ICs.
7. **Multiplexer and demultiplexer circuits** using 74153, 74138, etc.
8. **Flip-flop circuits (SR, JK, D)**: Setup using ICs and verify truth tables.
9. **Ripple counter and mod-N counter implementation**.
10. **Shift register using 7495 or equivalent**: Observe sequence and modes.

SEMESTER-VI

COURSE 14 B: VACUUM TECHNOLOGY

Theory **Credits: 3** **3 hrs/week**

Course Objective:

The primary objective of this course is to provide a comprehensive understanding of the principles, design, operation, and applications of vacuum systems across different pressure regimes. The course aims to equip students with foundational knowledge of gas behavior in vacuum, pumping mechanisms, measurement techniques, leak detection methods, and the wide-ranging industrial and scientific uses of vacuum technology. Emphasis is placed on both theoretical aspects and practical considerations in selecting and operating vacuum systems for research and industrial environments.

Learning outcomes

1. **Understand** the fundamental principles of vacuum, vacuum ranges, gas laws, and characteristics of low to medium vacuum systems and pumps.
2. **Explain** the design, operation, and limitations of high and ultra-high vacuum systems including advanced pumps and materials used.
3. **Identify and compare** various vacuum pressure measurement methods and select appropriate gauges based on vacuum levels and system requirements.
4. **Apply** leak detection techniques to diagnose, troubleshoot, and maintain the integrity of vacuum systems.
5. **Explore and analyze** diverse industrial, scientific, and emerging applications of vacuum technology across multiple domains including thin films, space, and semiconductor processing.

UNIT I: INTRODUCTION AND LOW TO MEDIUM VACUUM SYSTEMS (9 hours)

Introduction to Vacuum: History, Definition of vacuum and vacuum ranges (low, medium, high, ultra-high), Gas laws (Ideal gas law, mean free path, Knudsen number), Surface phenomena in vacuum; Gas Flow in Vacuum Systems, Low to Medium Vacuum Pumps: Mechanical pumps: Rotary vane, Diaphragm pumps, Scroll pumps, Liquid ring pumps, Working principles, characteristics, merits & limitations, Back streaming and oil contamination

UNIT II: HIGH AND ULTRA-HIGH VACUUM SYSTEMS (9 hours)

High Vacuum Pumps: Diffusion pumps: Operation, oil backstreaming, traps, Turbomolecular pumps: Design, speed, limitations; Ultra-high Vacuum Pumps: Ion pumps: Sputter-ion, getter-ion, Titanium sublimation pumps, Cryopumps and sorption pumps; Pumping System Design: Pump combinations (e.g., rotary + diffusion pump), Pumping station layout and material selection, Vibration isolation, cleanliness, and bake-out

UNIT III: VACUUM MEASUREMENT SYSTEMS **(9 hours)**

Basic Concepts: Importance of pressure measurement, Units: Torr, Pascal, mbar; Gauges for Low and Medium Vacuum: Bourdon gauge, McLeod gauge, Thermocouple and Pirani gauges; Gauges for High and Ultra-High Vacuum: Ionization gauges (Hot cathode and cold cathode), Bayard-Alpert gauge; Calibration and Gauge Selection: Accuracy, sensitivity, limitations, Gauge calibration methods

UNIT IV: LEAK DETECTION TECHNIQUES **(9 hours)**

Importance of Leak Detection: Effects of leaks on vacuum quality and stability; Common Leak Types: Real and virtual leaks, Permeation and desorption; Leak Detection Methods: Pressure rise method, Halogen leak detector, Helium mass spectrometer leak detection (MSLD), Ultrasonic and bubble test techniques; Leak Testing Setup: Sensitivity, resolution, and quantitative leak rate analysis, Troubleshooting leak problems in vacuum systems

UNIT V: APPLICATIONS OF VACUUM TECHNOLOGY **(9 hours)**

Industrial Applications: Vacuum coating (PVD, CVD, sputtering, evaporation), Vacuum metallurgy and degassing, Electron beam welding; Scientific Applications: Particle accelerators, Scanning Electron Microscopy (SEM), TEM, Surface science and thin film research; Semiconductor and Space Applications: Vacuum in semiconductor fabrication (etching, lithography), Vacuum insulation and thermal shielding in space tech; Emerging and Miscellaneous Applications: Food packaging, Vacuum drying, freeze drying, Vacuum tube devices, lighting technology

Recommended Textbooks & References

1. Vacuum Science and Technology by V.V. Rao, T.B. Ghosh, and K.L. Chopra – Allied Publishers
2. Vacuum Technology by A. Roth – North-Holland (Elsevier)
3. Handbook of Vacuum Technology by Karl Jousten – Wiley-VCH
4. NPTEL Course:
   Vacuum Technology and Process Applications – Prof. V. Vasudeva Rao, IIT Kharagpur
   View Course

5. Manufacturers' Manuals & Videos:
   Pfeiffer, Edwards, and Agilent vacuum systems (operation, leak detection, maintenance)

6. Online Simulations and Virtual Labs:
   nanohub.org

   vlabs.iitb.ac.in – Virtual Experiments on Pumps and Pressure Gauges

SEMESTER-VI

COURSE 14 B: VACUUM TECHNOLOGY

Practical **Credits: 1** **2 hrs/week**

Course Objective:

To impart practical knowledge of vacuum generation, measurement, and leak detection techniques essential for thin film deposition, material processing, and analytical instrumentation.

Learning Outcomes: After completing this course, students will be able to:

1. Understand and operate vacuum pumps and pressure gauges.
2. Measure vacuum levels using appropriate sensors and methods.
3. Identify flow regimes and evaluate pump-down characteristics.
4. Detect and interpret common vacuum system leaks and conductance limitations.
5. Maintain and troubleshoot basic vacuum systems safely.

Minimum of 6 experiments to be done and recorded

Experiment 1: Demonstration of Vacuum using a Bell Jar and Rotary Pump

- Objective: To demonstrate creation of low vacuum using a bell jar and observe pressure reduction.
- Apparatus: Bell jar, rotary vane pump, vacuum gauge, rubber seal.
- Procedure: Evacuate air from the bell jar and observe physical changes (e.g., bursting balloon, water boiling at room temperature).
- Concepts: Low vacuum creation, pressure vs. boiling point, pressure gauge reading.

Experiment 2: Calibration of a Pirani Gauge

- Objective: To calibrate a Pirani gauge using known pressures.
- Apparatus: Pirani gauge, vacuum system with pressure control, reference gauge.
- Procedure: Record gauge readings at known pressures and plot calibration curve.
- Concepts: Gauge sensitivity, thermal conductivity-based pressure sensing.

Experiment 3: Estimation of Pumping Speed of a Rotary Pump

- Objective: To measure the pumping speed of a rotary pump.
- Apparatus: Rotary pump, vacuum chamber, vacuum gauge, stopwatch.
- Procedure: Record pressure vs. time and use gas law relations to estimate speed.
- Concepts: Pumping speed, pressure decay analysis.

Experiment 4: Measurement of Pressure Using McLeod Gauge

- Objective: To measure low pressure using a McLeod gauge.
- Apparatus: McLeod gauge, vacuum pump.
- Procedure: Compress a known gas volume and read pressure.
- Concepts: Boyle’s law, precision pressure measurement.

Experiment 5: Leak Detection using Bubble Method

- Objective: To detect leaks in a vacuum system using soap solution.
- Apparatus: Vacuum tubing system, pump, soap solution.
- Procedure: Apply soap to joints and observe bubbles while evacuating.
- Concepts: Leak identification, pressure loss due to leaks.

Experiment 6: Observation of Mean Free Path Effects

- Objective: To demonstrate changes in mean free path at low pressures.
- Apparatus: Small gas discharge tube, variable pressure chamber.
- Procedure: Observe discharge glow as pressure decreases.
- Concepts: Mean free path, gas discharge, low-pressure physics.

Experiment 7: Vacuum Distillation or Water Boiling at Low Pressure

- Objective: To show that water boils at lower temperatures under vacuum.
- Apparatus: Bell jar, beaker with water, vacuum pump.
- Procedure: Evacuate bell jar and observe boiling of water at room temp.
- Concepts: Vapor pressure, pressure-temperature relation.

Experiment 8: Determination of Outgassing Rate

- Objective: To measure the rate of pressure rise due to outgassing.
- Apparatus: Sealed vacuum chamber, pressure gauge.
- Procedure: Pump down chamber, isolate, and record pressure rise over time.
- Concepts: Outgassing, gas desorption from surfaces.

Experiment 9: Study of Pressure Rise with and without Cold Trap

- Objective: To compare pressure stability with/without cold trap.
- Apparatus: Cold trap (liquid nitrogen), vacuum line, gauge.
- Procedure: Monitor pressure over time in both configurations.
- Concepts: Vapor capture, pressure maintenance, oil backstreaming control.

Experiment 10: Simple Thin Film Deposition by Thermal Evaporation in Vacuum

- Objective: To deposit a thin metal film using a basic thermal evaporator setup.
- Apparatus: Evaporation chamber, resistive heater (tungsten filament), metal wire (e.g., Al), glass substrate.
- Procedure: Evacuate chamber, heat metal to evaporation, observe film on glass.
- Concepts: Vacuum coating, deposition, evaporation rate.

SEMESTER-VI

COURSE 14 C: CHARACTERIZATION OF NANOMATERIALS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE

To introduce students to the fundamental principles and practical applications of nanomaterial characterization techniques, enabling them to understand and analyze key structural, optical, surface, electrical, and magnetic properties using both experimental methods and digital tools, while appreciating the role of characterization in linking nanoscale features to material behavior and functionality.

LEARNING OUTCOMES

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

1. **Explain** the need for nanomaterial characterization and the differences between bulk and nanoscale properties.
2. **Describe** the basic principles and applications of optical, structural, surface, electrical, and magnetic characterization techniques.
3. **Interpret** experimental data from techniques such as UV-Vis spectroscopy, XRD, SEM, and DLS for analyzing nanoparticle properties.
4. **Apply** software tools like ImageJ and Origin to analyze images, spectra, and patterns related to nanomaterial properties.
5. **Recognize** the limitations and challenges in nanoscale measurement and data interpretation.

UNIT I: NEED OF CHARACTERIZATION (9 hours)

Need for characterization: structure–property relationships in nanomaterials, Key parameters: particle size, shape, distribution, crystallinity, and surface area, Differences between bulk and nanoscale behavior, Role of characterization in synthesis validation and application suitability

Classification of techniques: microscopic, spectroscopic, surface, and property-based, Introduction to qualitative vs. quantitative methods, Overview of limitations and challenges in nanoscale measurement

UNIT II: OPTICAL CHARACTERIZATION TECHNIQUES (9 hours)

Visual cues: color change due to nanoparticle size (e.g., silver/gold nanoparticles), UV-Visible Spectroscopy: absorption peak shifts and size estimation, Fluorescence Spectroscopy: emission behavior of quantum dots, ZnO nanoparticles, Dynamic Light Scattering (DLS): principle and interpretation of size distribution, Tyndall Effect and Light Scattering: basic demonstrations

Cost-effective classroom/lab setups for basic optical analysis

UNIT III: STRUCTURAL AND SURFACE ANALYSIS TECHNIQUES (9 hours)

X-ray Diffraction (XRD): basic principles, Bragg's law, and crystallite size estimation using Scherrer's formula, Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM): image interpretation, magnification limits (conceptual level)

Atomic Force Microscopy (AFM): surface topography and roughness (introductory idea)

Brunauer–Emmett–Teller (BET) Method: surface area measurement (overview)

Particle size estimation using mechanical sieving and limitations

UNIT IV: ELECTRICAL AND MAGNETIC PROPERTIES (9 hours)

Electrical conductivity in nanomaterials: size effects and measurement basics, Four-Point Probe Method: concept and application in resistivity measurement, I-V Characteristics of nanomaterials (introductory level), Magnetic properties: basic concepts of paramagnetism, superparamagnetism in nanoparticles, Use of Vibrating Sample Magnetometer (VSM): basic working

UNIT V: DIGITAL TOOLS AND SOFTWARE FOR ANALYSIS (9 hours)

ImageJ: measuring particle size, area, and shape from microscope images, Origin/Excel: plotting UV-Vis spectra, XRD patterns, and thermal curves, Simulated datasets for spectrum analysis (UV-Vis, XRD, Fluorescence), Basics of software-based pattern fitting and peak identification

Online repositories for open-access nanomaterial datasets, Introduction to nanomaterial databases and visualization tools (e.g., NanoHUB simulations)

Reference books

1. Concise Concepts of Nanoscience and Nanomaterials by Narendra Kumar Sunitha Kumbhat

2. An Introduction to Nanoscience and nanotechnology by Alain Nouailhat

3. Characterization of Nanostructures by Klaus D. Sattler

4. Materials Characterization by Yang Leng

SEMESTER-VI

COURSE 14 C: CHARACTERIZATION OF NANOMATERIALS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE:

The objective of this laboratory course is to provide hands-on experience with simple, cost-effective experimental techniques for characterizing the properties of nanomaterials. Through a series of guided experiments, students will explore optical, electrical, magnetic, thermal, and surface characteristics of nanoparticles using basic lab tools and freely available software.

LEARNING OUTCOMES:

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

1. **Identify and interpret optical characteristics** of nanoparticles through color changes, light scattering, and UV fluorescence.
2. **Test basic electrical and magnetic properties** of nanomaterials using simple instruments like multimeters and magnets.
3. **Perform particle size analysis** using sieve methods and image processing software (e.g., ImageJ).
4. **Conduct surface property experiments** such as dye adsorption to understand surface area effects in nanomaterials.
5. **Analyze simulated X-ray diffraction patterns** using free tools (e.g., VESTA) to understand the crystal structure of nanoparticles.
6. **Observe thermal behavior of nanomaterials** through heating experiments and interpret physical changes like color and mass.
7. **Utilize digital tools** to analyze microscope images and spectra, enabling deeper insight into nanoparticle morphology and behavior.
8. **Practice safe laboratory procedures** while working with nanomaterials and associated equipment.

A minimum of 6 experiments of the following to be recorded

1. Color Analysis of Nanoparticles
   Compare colors of different nanoparticle solutions (e.g., Ag, Au) visually.

   Equipment: Beakers, nanoparticle solutions.

2. Light Scattering with a Laser Pointer
   Use a laser pointer to observe scattering in a nanoparticle solution.

   Equipment: Laser pointer, glass vial, nanoparticle solution.

3. UV Lamp Fluorescence Test
   Expose ZnO nanoparticles to UV light and observe glowing effect.

Equipment: UV lamp, ZnO nanoparticles.

4. Simple Conductivity Test
   Measure conductivity of a nanoparticle film using a multimeter.

   Equipment: Multimeter, glass slide with nanoparticle film.

5. Magnetic Property Test
   Test magnetic behavior of iron oxide nanoparticles using a magnet.

   Equipment: Magnet, Fe3O4 nanoparticles, beaker.

6. Sieve Analysis for Particle Size
   Use sieves to estimate size of ground nanoparticles (e.g., charcoal).

   Equipment: Sieves, mortar, pestle.

7. Dye Adsorption for Surface Area
   Adsorb a dye (e.g., methylene blue) on ZnO nanoparticles to estimate surface area.

   Equipment: Beakers, dye, UV-Vis spectrophotometer (optional).

8. Simulating XRD Patterns
   Use free software (e.g., VESTA) to simulate X-ray diffraction of nanomaterials.

   Equipment: Computer with software.

9. Thermal Test of Nanoparticles Heat ZnO nanoparticles in an oven and observe color or weight change. Equipment: Oven, balance, ZnO nanoparticles.
10. Image Analysis with Software Use ImageJ to analyze provided nanoparticle images for size and shape. Equipment: Computer with software.

SEMESTER-VI

COURSE 14 D: ENERGY STORAGE AND CONVERSION SYSTEMS

Theory	Credits: 3	3 hrs/week

COURSE OBJECTIVE

The objective of this course is to introduce students to the principles, classifications, and applications of various energy storage systems and direct energy conversion technologies. It aims to provide foundational knowledge on mechanical, electrochemical, thermal, and magnetic energy storage, along with direct conversion devices like thermoelectric, thermionic, MHD generators, and fuel cells. The course emphasizes the role of these technologies in modern and sustainable energy systems.

LEARNING OUTCOMES

By the end of this course, students will be able to:

1. Understand the need for energy storage and differentiate between various storage technologies including mechanical, chemical, thermal, and electrical.
2. Explain the working principles and applications of different battery systems such as lead-acid, Ni-Cd, and lithium-ion batteries.
3. Describe the construction, operation, and comparison of capacitors, supercapacitors, and SMES, and their relevance in high-power energy applications.
4. Analyze the functioning and performance of direct energy conversion devices such as thermoelectric, thermionic, and magneto hydro dynamic generators.
5. Comprehend the design, classification, and efficiency of fuel cells, and identify suitable applications and limitations of various fuel cell types.

UNIT-I: ENERGY STORAGE (9 hours)

Importance of energy storage, Flywheel, electrical and magnetic storage, Capacitors, electromagnets, Thermo-chemical, photochemical, biochemical, and electrochemical storage, Fossil and synthetic fuels, hydrogen as storage.

UNIT-II: BATTERIES (9 hours)

Battery classification: primary vs secondary, MnO_2 batteries, lead-acid, Ni-Cd, lithium-ion, Battery applications

UNIT-III: SUPER CAPACITORS AND SMES (9 hours)

Superconducting Magnet Energy Storage (SMES), Concept and types of supercapacitors: EDLCs, pseudocapacitors, hybrids, Differences between capacitors, supercapacitors, and batteries

UNIT-IV: DIRECT ENERGY CONVERSION DEVICES (9 hours)

Thermoelectric generators: Seebeck effect, efficiency, Thermionic generators: construction, efficiency, Magneto Hydro Dynamic (MHD) generators: working and performance

UNIT-V: FUEL CELLS (9 hours)

Fuel cell concept and classification, Alkaline, phosphoric acid, PEM, molten carbonate, solid oxide fuel cells, Efficiency and characteristics, Applications and limitations

Reference Books

1. *Fundamentals of Energy Storage* – J. Jensen, B. Sorensen
2. *Electrochemical Power Sources* – P. Peregrines
3. *Supercapacitors: Materials, Systems, and Applications* – F. Beguin & E. Frackowiak
4. *Non-Conventional Energy Sources and Utilization* – R.K. Rajput
5. *Non-Conventional Energy Resources* – B.H. Khan

SEMESTER-VI

COURSE 14 D: ENERGY STORAGE AND CONVERSION SYSTEMS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE

To provide students with practical exposure to various energy storage technologies, fuel cell operations, and direct energy conversion systems, enabling hands-on understanding of their characteristics, efficiency, and real-world applications.

LEARNING OUTCOMES

By the end of the practical course, students will be able to:

1. Analyze charge–discharge behavior of batteries (lead-acid, lithium-ion, Ni-Cd) and capacitors through real-time measurements.
2. Evaluate fuel cell performance under varying load and temperature conditions using voltage–current characteristics.
3. Construct and test simple electrochemical systems, such as primary batteries and thermoelectric modules.
4. Demonstrate and interpret the Seebeck effect using thermocouple and Peltier modules.
5. Simulate or observe direct energy conversion devices, such as MHD generators, and understand their potential in renewable energy systems.

A minimum of 6 experiments to be performed and recorded

Practical list

1. Charge-discharge characteristics of storage batteries
2. Charging/discharging behavior of capacitors
3. Charging of Ni-Cd battery using solar PV
4. Performance estimation of a fuel cell
5. Temperature dependence of fuel cell efficiency
6. Voltage-current characteristics of fuel cells
7. Construction and testing of a simple lemon battery (primary battery demo)
8. Determination of internal resistance and efficiency of a lead-acid battery
9. Study of charging characteristics of a lithium-ion battery
10. Observation of Seebeck effect using thermocouple setup
11. Testing of a thermoelectric module (TEC1 – Peltier/Seebeck module)
12. Simulation or model demonstration of a Magneto Hydro Dynamic (MHD) generator

SEMESTER-VI

COURSE 14 E: COMPUTATIONS IN OPTICS, HEAT AND THERMODYNAMICS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE:

This course aims to equip students with computational skills to model, analyze, and visualize fundamental concepts in optics, thermodynamics, and quantum theory. Students will learn to implement and simulate key physical phenomena using programming techniques.

LEARNING OUTCOMES:

1. Students will be able to computationally apply Snell's Law, trace ray paths, and define optical components as objects to analyze image formation and lens systems.
2. Students will be able to simulate and visualize interference patterns, calculate maxima/minima positions, and plot intensity distributions for various wave experiments.
3. Students will be able to write functions to determine maxima/minima for single-slit and grating diffraction, visualize spectra, and calculate grating resolving power.
4. Students will be able to compute and visualize Maxwell's velocity distribution, plot P-V and T-S diagrams, and calculate thermodynamic efficiencies and potentials.
5. Students will be able to computationally model and graphically compare spectral distributions from Wien's, Rayleigh-Jeans, and Planck's laws, and calculate energy density using the Stefan-Boltzmann law.

UNIT-I: RAY OPTICS (9 hrs)

Write functions to calculate the refracted angle using Snell's Law and the reflected angle, Visualize ray paths and image formation graphically, write functions to calculate resultant focal length of two lenses separated by a distance, Defining lenses and mirrors as objects with properties (focal length, curvature, position).

UNIT-II: ABERRATIONS AND INTERFERENCE (9 hrs)

Visualization of chromatic aberration, Computer positions of maxima, minima and fringe width in Young’s double-slit experiment, Plot the intensity distribution for Young's double-slit experiment, Create a 2D heatmap or contour plot of the interference pattern produced by two point sources, visualization of Newton’s rings.

UNIT-III: DIFFRACTION (9 hrs)

Write functions to compute positions of maxima and minima in Fraunhoffer diffraction due to single slit and diffraction grating. Visualize the spectrum of white light using diffraction grating, calculation of resolving power of grating, write function to calculate wavelength of light using diffraction grating.

UNIT-IV: THERMODYNAMICS **(9 hrs)**

Calculation and visualization of Maxwell's distribution of molecular velocities, Write functions to graphically represent P-V diagrams and T-S diagrams, Write function to compute efficiency of Carnot engine, Write function to calculate Thomson's cooling, write function to calculate thermodynamic potentials (Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy).

UNIT-V: QUANTUM THEORY OF RADIATION **(9 hrs)**

Write functions to calculate spectral distributions using Wien's displacement law, Rayleigh-Jeans law, Planck's quantum theory, Graphical comparison of Wien's displacement law, Rayleigh-Jeans law, Planck's quantum theory of radiation, calculation of energy density Stephan-Boltzmann law as a function of temperature.

REFERENCE BOOKS:

1. "Computational Physics" by Nicholas J. Giordano and Hisao Nakanishi
2. "A First Course in Computational Physics" by Paul L. DeVries and Jian-Ke Shang
3. "Python for Data Analysis" by Wes McKinney
4. "Optics" by Eugene Hecht
5. "Computational Photonics: An Introduction with MATLAB/Python" by Marek S. Wartak
6. "Thermodynamics and an Introduction to Thermostatistics" by Herbert B. Callen
7. "Thermal Physics" by Ralph Baierlein
8. "Thermal Physics" by Daniel V. Schroeder
9. "Concepts of Modern Physics" by Arthur Beiser
10. "Quantum Mechanics: Concepts and Applications" by Nouredine Zettili
11. "Python Data Science Handbook: Essential Tools for Working with Data" by Jake VanderPlas

STUDENT ACTIVITIES

UNIT-I: Ray Optics

- Activity 1: Write functions to calculate refracted and reflected angles using Snell's Law, then visualize light ray paths and image formation through lenses and mirrors graphically.
- Activity 2: Define lenses and mirrors as objects with properties like focal length and curvature, then write functions to calculate the resultant focal length of multiple lenses.

UNIT-II: Aberrations and Interference

- Activity 1: Visualize chromatic aberration and write functions to compute positions of maxima, minima, and fringe width for Young's double-slit experiment, then plot the intensity distribution.
- Activity 2: Create 2D heatmaps or contour plots of interference patterns from two point sources, and visualize Newton's rings.

UNIT-III: Diffraction

- Activity 1: Write functions to compute and visualize the positions of maxima and minima for Fraunhofer diffraction from single slits and diffraction gratings, including the visualization of white light spectra.
- Activity 2: Implement functions to calculate the resolving power of a grating and determine the wavelength of light using diffraction grating principles.

UNIT-IV: Thermodynamics

- Activity 1: Calculate and visualize Maxwell's distribution of molecular velocities, and write functions to graphically represent P-V and T-S diagrams for thermodynamic processes.
- Activity 2: Write functions to compute the efficiency of a Carnot engine, calculate Thomson's cooling, and determine various thermodynamic potentials (Internal Energy, Enthalpy, Helmholtz Free Energy, Gibbs Free Energy).

UNIT-V: Quantum Theory of Radiation

- Activity 1: Write functions to calculate and graphically compare the spectral distributions from Wien's displacement law, Rayleigh-Jeans law, and Planck's quantum theory.
- Activity 2: Calculate and visualize the total energy density as a function of temperature using the Stefan-Boltzmann law.

SEMESTER-VI

COURSE 14 E: COMPUTATIONS IN OPTICS, HEAT AND THERMODYNAMICS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE:

This course aims to develop students' ability to computationally model and visualize fundamental phenomena in optics, thermodynamics, and quantum radiation theory. Students will implement core physics principles through programming to analyze and interpret physical systems.

LEARNING OUTCOMES:

1. Model Ray Optics Systems: Students will be able to write functions to apply Snell's Law and calculate reflection, and compute equivalent focal lengths for multi-lens systems.
2. Analyze and Visualize Interference Patterns: Students will be able to calculate intensity distributions for Young's double-slit experiment and generate 2D plots of interference patterns.
3. Compute and Plot Diffraction Phenomena: Students will be able to write functions to determine intensity and angles for single-slit diffraction and diffraction gratings.
4. Simulate and Graph Thermodynamic Processes: Students will be able to visualize Maxwell's velocity distributions and plot P-V diagrams for thermodynamic cycles like the Carnot cycle.
5. Compare Quantum Radiation Laws: Students will be able to computationally implement and graphically compare Wien's, Rayleigh-Jeans, and Planck's laws for spectral radiance.

Minimum of 6 experiments to be conducted and recorded

1. Write a function snell_law(n1, n2, theta_i) to calculate the refracted angle
2. Write a function reflect_angle(theta_i) to calculate the reflected angle.
3. Write a function calculate_resultant_focal_length(lens1, lens2, separation) that computes the equivalent focal length for two thin lenses separated by a distance d.
4. Write a function to calculate the intensity at a point on a screen for Young's double-slit setup, given wavelength, slit separation, and screen distance.
5. Generate a 2D heatmap or contour plot of the interference pattern, clearly showing regions of high and low intensity.
6. Write a function to calculate the intensity for single-slit diffraction given slit width, wavelength, and angle.
7. Write a function to calculate the diffraction angles for different orders (m) and wavelengths passing through a grating.
8. Plot the distribution for different temperatures (e.g., 300K, 600K) and for different gases (e.g., Hydrogen, Oxygen) on the same graph, observing the shift in peak velocity.
9. Plot the P-V diagram for a complete Carnot cycle (two isothermal and two adiabatic processes).
10. Write functions to calculate the spectral radiance (or energy density) as a function of wavelength for Wien's, Rayleigh-Jeans, and Planck's laws.

SEMESTER-VI

COURSE 15 A: ELECTRONIC COMMUNICATION SYSTEMS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE

To provide students with a comprehensive understanding of the principles, techniques, and components used in electronic communication systems, including analog and digital modulation, antennas, wave propagation, and modern communication technologies such as fiber optics, microwaves, and satellite communication.

LEARNING OUTCOMES

After successful completion, students will be able to:

1. Describe types and characteristics of antennas and propagation mechanisms.
2. Explain and differentiate AM, FM, and pulse modulation techniques.
3. Analyze transmitter and receiver block diagrams for analog and digital systems.
4. Design and simulate basic modulator and detector circuits.
5. Apply communication principles in optical, satellite, and digital transmission systems.

UNIT-I ANTENNAS AND WAVE PROPAGATION (9hrs)

Antenna - Effective resistance - Efficiency - Directive gain - Bandwidth, Beam width and polarization - Dipole - Folded dipole - Arrays - Yagi - Uda - Helical - Discone - Parabolic - Dish Antennas - Ground wave, sky wave and space ware propagation - Skip distance - Maximum usable frequency.

UNIT-II AMPLITUDE MODULATION (9hrs)

Modulation - Needs for Modulation - Types of Modulation - Amplitude Modulation Generation and detections circuits - Balanced Modulator - DSB/SC and SSB Modulation - VSB modulation. Block diagram of AM Radio transmitter and super heterodyne Receiver.

UNIT-III FREQUENCY MODULATION (9hrs)

Frequency Modulation - Definition - Derivation of Modulated wave - Generation of FM - Varactor diode and Reactance tube Modulators, Detectors - Balanced slope detector, Foster Seeley discriminator, and ratio detector, Block diagram of FM transmitter and receiver.

UNIT-IV PULSE MODULATION (9hrs)

Pulse Modulation - Sampling theorem - PAM, PWM, PCM - quantizing, sampling, coding, decoding, quantization error, delta modulation and adaptive delta modulation.

UNIT-V DIGITAL COMMUNICATION (9hrs)

Multiplexing - FDM, TDM, CDMA - ASK, FSK, PSK

Advantages of Digital Communication, Introduction to Microwave, Fiber optic, Satellite Communications

Text Books

1. Electronic Communication Systems - *George Kennedy*, McGraw Hill Book Company, 4/e, 2005.
2. Communication Engineering - *T.G. Palanivelu*, Anuradha Publicatons, 1/e, 2002.
3. Communication System - *Roddy & Coolen*, 4/e, Pearson Education, 2005.
4. Principles of Communication Engineering - *Anok Singh*, 4/e, Sathyaprakasam Publications, 2004.
5. Electronic Communication Systems *Wayne Tomasi*, 4/e, Pearson Education, 2004.

Student Activities

1. **Model Making:** Build simple antennas (dipole, Yagi) using rods or wires.
2. **Circuit Assembly:** Construct AM or FM transmitters using breadboard and discrete components.
3. **Simulations:** Use Python/Matlab/Scilab for visualizing AM/FM/PCM waveforms.
4. **Poster Presentation:** Compare analog and digital modulation in communication history.
5. **Mini Project:** Design a simple radio receiver or a simulated digital communication system.
6. **Group Assignment:** Trace signal path in an FM radio or DTH system with block diagrams.

SEMESTER-VI

COURSE 15 A: ELECTRONIC COMMUNICATION SYSTEMS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE

To provide practical experience in various analog and digital modulation techniques and their applications in communication systems.

LEARNING OUTCOMES:

By completing the lab, students will be able to:

1. Design and construct basic analog and digital modulation/demodulation circuits.
2. Use simulation tools to generate and analyze modulated waveforms.
3. Compare performance of various modulation schemes.
4. Understand block-level implementation of communication systems.
5. Relate antenna performance to theoretical parameters.

Minimum of 6 experiments to be done and recorded

1. **Amplitude Modulation (AM) and Demodulation**
2. **Frequency Modulation (FM) and Demodulation**
3. **Simulation of AM and FM Signals** ***(using Python/Scilab/Matlab)***
4. **Pulse Amplitude Modulation (PAM): Generation and Detection**
5. **Pulse Width Modulation (PWM): Generation and Detection**
6. **Pulse Code Modulation (PCM): Generation, Sampling, and Reconstruction**
7. **Delta Modulation and Adaptive Delta Modulation**
8. **Amplitude Shift Keying (ASK): Generation and Detection**
9. **Frequency Shift Keying (FSK): Generation and Detection**
10. **Phase Shift Keying (PSK): Generation and Detection**
11. **Observation of Antenna Radiation Patterns** ***(Dipole and Yagi – Simulation or Demonstration)***
12. **Construction and Testing of a Simple AM or FM Radio Receiver**

SEMESTER-VI

COURSE 15 B: MATERIALS FOR INDUSTRIAL APPLICATIONS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVES

To provide an overview of materials used in industrial applications, their classification, properties, and methods of fabrication and characterization, enabling students to relate material science concepts to practical engineering systems.

LEARNING OUTCOMES

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

1. **Classify engineering materials** (metals, ceramics, polymers, composites) and describe their atomic structures, bonding types, and physical properties including mechanical, electrical, thermal, magnetic, and optical behavior.
2. **Analyze the structure and properties of metals and alloys**, interpret phase diagrams (e.g., iron–carbon), explain heat treatment processes, and understand corrosion mechanisms and preventive methods.
3. **Describe the structure, processing, and applications of ceramics and polymers**, and compare their mechanical and thermal characteristics for industrial use.
4. **Differentiate types of composite and smart materials**, understand their fabrication methods, and evaluate their applications in advanced technologies such as aerospace, biomedical, and automotive sectors.
5. **Apply principles of material selection** using performance criteria, cost, and availability; utilize Ashby charts and databases at a basic level; and evaluate real-world case studies involving material choices for specific applications.

UNIT I: FUNDAMENTALS OF ENGINEERING MATERIALS (9 Hours)

Classification: Metals, Ceramics, Polymers, Composites, Atomic structure and bonding in solids, Crystalline vs. amorphous solids; defects in crystals, Mechanical properties: Stress-strain, toughness, hardness, ductility, Electrical, thermal, magnetic, and optical properties overview

UNIT II: METALS AND ALLOYS (9 Hours)

Ferrous metals: Types of steel, cast iron – uses in industry, Non-ferrous metals: Aluminum, copper, titanium – applications, Phase diagrams (Iron-Carbon), alloying principles, Heat treatment: Annealing, quenching, tempering, Corrosion mechanisms and prevention (coatings, plating)

UNIT III: CERAMICS AND POLYMERS **(9 Hours)**

Ceramics: Structure, properties, manufacturing (sintering, vitrification), Applications: Refractories, abrasives, dielectrics, Polymers: Thermoplastics vs. thermosets, Examples: Nylon, PVC, PTFE, Bakelite, Polycarbonate, Mechanical and thermal behavior of polymers

UNIT IV: COMPOSITES AND SMART MATERIALS **(9 Hours)**

Types of composites: Fiber-reinforced, metal/ceramic matrix, Fabrication techniques: Hand lay-up, pultrusion, resin transfer molding, Applications: Aerospace, automotive, biomedical, construction, Smart materials: Shape memory alloys, piezoelectric, magnetostrictive materials

UNIT V: MATERIALS SELECTION AND CASE STUDIES **(9 Hours)**

Criteria for material selection: Performance, cost, durability, availability, Ashby charts and material databases (introductory level), Case studies: Automotive components, Power plant materials, Packaging (metal, plastic, bio-degradable), Biomedical materials (implants, prosthetics)

Text Books & References

1. *Materials Science and Engineering* – William D. Callister
2. *Introduction to Materials Science for Engineers* – James F. Shackelford
3. *Engineering Materials: Properties and Selection* – Kenneth G. Budinski
4. NPTEL Courses on Materials Science
5. TTTI Modules on Material Selection in Industry

Suggested Student Activities:

1. Material Identification Task: Classify given samples (metals, ceramics, polymers, composites) based on their observable properties.
2. Case Study: Analyze material choice in a common product (e.g., engine block, prosthetic implant, or smartphone casing).
3. Simple hardness or tensile strength demo: Use school-level setups or virtual tools.
4. Poster/Presentation: Emerging materials in aerospace or biomedical industries.
5. Factory or lab visit report: Interaction with an industrial process involving materials (e.g., foundry, welding unit, polymer lab).

SEMESTER-VI

COURSE 15 B: MATERIALS FOR INDUSTRIAL APPLICATIONS

Practical **Credits: 1** **2 hrs/week**

Course Objective:

The objective of this practical course is to provide hands-on experience in testing and analyzing the mechanical, thermal, electrical, and structural properties of various engineering materials. Students will develop experimental skills relevant to industrial applications, including characterization of metals, polymers, composites, and smart materials. The course aims to bridge theoretical knowledge with real-world materials behavior and processing techniques.

Learning Outcomes:

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

1. Perform tensile and hardness tests to evaluate the mechanical properties of materials.
2. Analyze the effect of heat treatment on the hardness of steel and interpret microstructural changes using optical microscopy.
3. Measure and compare electrical resistivity and thermal conductivity of different materials.
4. Conduct corrosion testing and understand the degradation behavior of metals in corrosive environments.
5. Fabricate simple composite samples and perform basic testing on polymer materials.
6. Demonstrate the shape memory effect in NiTi alloys and understand its significance in advanced materials.
7. Apply safe laboratory practices and document experimental results with scientific accuracy

Minimum of 6 experiments to be done and recorded

List of Practical

1. Stress-strain analysis (tensile test)
2. Hardness testing (Rockwell, Brinell)
3. Heat treatment and hardness variation in steel
4. Microstructure observation using optical microscopy
5. Electrical resistivity of metals and semiconductors
6. Thermal conductivity comparison of materials
7. Simple polymer mechanical testing
8. Composite fabrication using hand lay-up method
9. Corrosion testing in saline solution
10. Demonstration of shape memory effect in NiTi alloy

SEMESTER-VI

COURSE 15 C: APPLICATIONS OF NANOMATERIALS

Theory **Credits: 3** **3 hrs/week**

COURSE OBJECTIVE

To introduce students to the diverse and interdisciplinary applications of nanotechnology across key sectors such as electronics, energy, healthcare, environment, and consumer goods, while fostering an understanding of its societal impact, ethical considerations, and future directions.

Learning Outcomes

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

1. **Explain** how nanomaterials are used in modern electronics, including displays, sensors, and flexible devices.
2. **Describe** the role of nanotechnology in enhancing energy generation, storage, and efficiency through advanced materials.
3. **Discuss** biomedical applications of nanotechnology, including drug delivery, diagnostics, and antimicrobial coatings.
4. **Analyze** how nanotechnology contributes to environmental sustainability through purification, sensing, and green innovations.
5. **Evaluate** the societal, ethical, and economic implications of nanotechnology, and recognize its global trends and challenges.

UNIT I: NANOTECHNOLOGY IN ELECTRONICS *(9 hours)*

Role of nanomaterials in display technologies (e.g., OLED, quantum dots), Nanoscale materials in sensors and transistors, Carbon-based conductive materials: Graphene, CNTs, and their electrical properties, Introduction to flexible and printable electronics using nanomaterials

Emerging trends in nanoelectronics: miniaturization and performance enhancement

UNIT II: NANOTECHNOLOGY IN ENERGY *(9 hours)*

Application of nanomaterials in photovoltaic cells (e.g., TiO_2, perovskite nanoparticles), Nanostructured electrodes in lithium-ion and solid-state batteries, Role of nanomaterials in supercapacitors and hydrogen storage, Thermo-reflective and energy-efficient nanocoatings, Nanotechnology for renewable and clean energy systems

UNIT III: NANOTECHNOLOGY IN HEALTH *(9 hours)*

Targeted drug delivery using liposomes, dendrimers, and polymeric nanoparticles, Use of gold and silver nanoparticles in diagnostics and biosensors, Antibacterial and antiviral nanocoatings for medical devices, Toxicological aspects and biocompatibility of nanomaterials, Examples of nanomedicine in commercial healthcare products

UNIT IV: NANOTECHNOLOGY FOR ENVIRONMENT ***(9 hours)***

Nanomaterials for water purification: adsorption, photocatalysis, and filtration, Air filtration and pollutant breakdown using nanocatalysts, Use of nanosensors for detecting environmental contaminants, Waste treatment and recycling aided by nanomaterials, Principles and examples of green nanotechnology

UNIT V: NANOTECHNOLOGY IN SOCIETY ***(9 hours)***

Everyday nanotech products: textiles, cosmetics, food packaging, Economic impact and affordability of nanotechnology-based goods, Ethical, legal, and safety issues in nanotechnology development, Promoting public awareness and responsible nanotechnology education, Global trends, policies, and future directions in nanotechnology

Reference books

1. Concise Concepts of Nanoscience and Nanomaterials by Narendra Kumar Sunitha Kumbhat

2. An Introduction to Nanoscience and nanotechnology by Alain Nouailhat

3. **Introduction to Nanotechnology** – Charles P. Poole Jr. and Frank J. Owens

4. **Nanotechnology: Principles and Practices**– Sulabha K. Kulkarni

5. **Nanotechnology for Beginners**– Nan Yao and Zhong Lin Wang

SEMESTER-VI

COURSE 15 C: APPLICATIONS OF NANOMATERIALS

Practical	**Credits: 1**	**2 hrs/week**

COURSE OBJECTIVE

To provide students with hands-on experience in applying nanotechnology to real-world problems in energy, environment, healthcare, and electronics. The experiments aim to demonstrate basic concepts of nanomaterials and their functional properties using simple, low-cost setups.

LEARNING OUTCOMES:

At the end of this course, students will be able to:

1. **Demonstrate basic fabrication and testing techniques** for nanomaterial-based devices and coatings.
2. **Perform simple experiments** to understand energy harvesting, antibacterial activity, and environmental cleanup using nanomaterials.
3. **Test and analyze functional properties** such as conductivity, UV protection, and sensing behavior of nanoparticle-coated surfaces.
4. **Develop simple prototypes** such as filters, sensors, or coatings using nanocomposites.
5. **Interpret experimental results** and relate them to scientific principles in nanotechnology.

A minimum of 6 experiments of the following to be recorded

1. Simple Solar Cell Model
   Make a basic solar cell using TiO2 nanoparticles and fruit juice dye.

   Equipment: Glass slides, TiO2, multimeter, fruit juice.

2. Dye Removal with Nanoparticles
   Use ZnO nanoparticles to remove dye from water under sunlight.

   Equipment: Beakers, ZnO, dye, sunlight.

3. Antibacterial Test of Silver Nanoparticles Test silver nanoparticles on a paper disc against bacterial growth (e.g., on agar). Equipment: Agar plates, silver nanoparticles, incubator.
4. Nanoparticle-Coated Fabric Coat cotton fabric with ZnO nanoparticles and test water repellency. Equipment: Cotton, ZnO nanoparticles, beaker.
5. Simple Nanosensor Model
   Use silver nanoparticles on paper to detect ammonia (color change).

   Equipment: Paper, ammonia solution, nanoparticles.

6. Conductive Nanoparticle Film
   Create a carbon nanoparticle film and test its conductivity with a multimeter.

   Equipment: Multimeter, glass slide, carbon nanoparticles.

7. Nanoparticle Water Filter
   Make a filter with nanoparticle-coated paper and test dye removal.

   Equipment: Filter paper, nanoparticles, dye solution.

8. Battery Model with Nanomaterials
   Build a simple battery using carbon nanoparticles as an electrode.

   Equipment: Multimeter, carbon, zinc, electrolyte.

9. UV-Protective Coating
   Coat a paper with ZnO nanoparticles and test UV blocking with a UV lamp.

   Equipment: UV lamp, ZnO, paper.

10. Nanocomposite Preparation Mix ZnO nanoparticles with glue to make a nanocomposite and test its strength. Equipment: Glue, ZnO, mold, balance.
    Implementation Notes

SEMESTER-VI

COURSE 15 D: BIOMASS AND HYDROGEN ENERGIES

Theory	Credits: 3	3 hrs/week

COURSE OBJECTIVE

This course aims to introduce students to the fundamental principles and technologies involved in the generation and utilization of bioenergy and hydrogen energy. It covers biomass resources, biogas production, gasification, biofuels, and hydrogen as alternative energy carriers. The course emphasizes the role of these renewable sources in achieving sustainable and eco-friendly energy solutions.

LEARNING OUTCOMES

By the end of this course, students will be able to:

1. Identify various biomass resources and explain their conversion routes such as thermochemical, biochemical, and physical methods.
2. Understand the design, operation, and efficiency of different biogas plant models and recognize the factors affecting gas production.
3. Explain the gasification process and distinguish it from combustion and pyrolysis, including its application in waste-to-energy conversion.
4. Classify biofuels and describe their sources, production methods, advantages over fossil fuels, and their current status in India.
5. Understand the significance of hydrogen as a clean fuel, its production and storage techniques, and its applications in energy systems.

UNIT-I: BIOMASS RESOURCES (9 hours)

Definition and sources, Photosynthesis, Biomass conversion: physical, incineration, thermochemical, biochemical, Biomass properties and applications

UNIT-II: BIOGAS PRODUCTION (9 hours)

Biogas plants and components, Floating drum, Janatha, and Deenabandhu models, Factors affecting biogas generation, Applications and troubleshooting

UNIT-III: GASIFICATION AND WASTE-TO-ENERGY (9 Hours)

Definition and need for gasification, Comparison with combustion and pyrolysis, Advantages of gasification for biomass utilization, Fixed Bed Gasifiers (Updraft and downdraft configurations, Working principle, structure, and temperature zones), Waste-to-Energy Technologies: Urban Solid Waste: Segregation, drying, shredding for fuel, Liquid Waste: Anaerobic digestion, biogas production

UNIT-IV: BIOFUELS **(9 Hours)**

What are biofuels? Classification: first, second, and third-generation biofuels, Benefits over fossil fuel, Ethanol as a Biofuel: Raw materials, Production methods: fermentation and distillation (basic process); Biodiesel: Sources: vegetable oils, animal fats, waste cooking oil, Transesterification Process (basic) Properties of biodiesel; Producer Gas Composition Properties and calorific value, E85 Fuel, Biofuel Scenario in India

UNIT-V: HYDROGEN ENERGY **(9 Hours)**

Introduction to Hydrogen Energy Why hydrogen? Role in clean energy Physical and chemical properties of hydrogen, Advantages and Disadvantages, Hydrogen Production Techniques: Electrolysis of Water, Thermochemical water splitting (concept only), Hydrogen Storage Methods: Compressed Gas Cylinders, Liquid Hydrogen Tanks, Solid-State Storage (Hydrides); Applications of Hydrogen Energy: Fuel cells (brief mention), Hydrogen as fuel for vehicles and industry

Reference Books

1. *Bio Energy Technology* – David Boyles
2. *Non-Conventional Energy Sources* – G.D. Rai
3. *Non-Conventional Energy Resources* – B.H. Khan
4. *Biogas Technology – A Practical Handbook* – K.C. Khandelwal & S.S. Mahdi

SEMESTER-VI

COURSE 15 D: BIOMASS AND HYDROGEN ENERGIES

Practical	**Credits: 1**	**2 hrs/week**

COURSE OBJECTIVE

To provide hands-on experience and practical understanding of biomass properties, biogas and biofuel production, gasification systems, and hydrogen energy technologies. This lab enables students to correlate theoretical concepts with real-world renewable energy applications.

LEARNING OUTCOMES

By the end of the practical course, students will be able to:

1. **Determine key physical properties** of biomass such as calorific value, moisture content, and bulk density.
2. **Demonstrate the working principles** of biogas plants and fixed bed gasifiers using models or simulations.
3. **Analyze the effect of feedstock characteristics** on biogas yield through experiments or data-based simulations.
4. **Prepare biodiesel from vegetable oil** using basic chemical processes and assess its physical properties like flash point.
5. **Understand the principles of hydrogen production** through electrolysis and evaluate its energy density using simple demonstrations.

A minimum of 6 experiments to be performed and recorded

Practical

1. Determination of Calorific Value of Biomass Samples
2. Measurement of Moisture Content and Bulk Density of Biomass
3. Demonstration of a Mini Biogas Plant (Floating Drum or Deenabandhu Model)
4. Effect of Feedstock Type on Biogas Yield (Data/Simulation-Based)
5. Model Demonstration of a Fixed Bed Gasifier (Updraft/Downdraft)
6. Segregation and Calorific Estimation of Urban Waste Samples
7. Preparation of Biodiesel from Vegetable Oil (Basic Transesterification Process)
8. Determination of Flash Point of Ethanol and Biodiesel
9. Hydrogen Production by Electrolysis of Water
10. Demonstration or Simulation of Hydrogen Balloon for Energy Density Concept

SEMESTER-VI

COURSE 15 E: COMPUTATIONS IN ELECTRICITY, MAGNETISM, ELECTROMAGNETIC THEORY AND MODERN PHYSICS

Theory	**Credits: 3**	**3 hrs/week**

COURSE OBJECTIVE:

This course aims to computationally model and visualize fundamental concepts in electricity, magnetism, electromagnetic theory, spectroscopy, and quantum mechanics. Students will develop programming skills to solve complex physics problems and interpret their results graphically.

LEARNING OUTCOMES:

1. Students will be able to calculate and visualize electric and magnetic field lines, and analyze the behavior of currents in AC/DC circuits.
2. Students will compute Lorentz force, self/mutual inductance, and analyze electromagnetic wave properties including reflection and transmission at interfaces.
3. Students will be able to calculate atomic properties, determine spectral terms using different coupling schemes, and analyze Raman spectra.
4. Students will compute de Broglie wavelengths, uncertainty principle limits, and visualize atomic orbitals and quantum well wave functions.
5. Students will be able to numerically determine eigenvalues and visualize wave functions for basic quantum systems like the 1D infinite potential well.

UNIT-I: ELECTRICITY, VARYING AND ALTERNATING CURRENTS (9hrs)

Calculation of intensity of electric field due to uniformly charged solid sphere and spherical shell, visualization of electric field lines due to point charge, Write function to express relationship between D, E and P, Calculation of potential due to a uniformly charged solid sphere, Representations of Growth and decay of currents in LR, CR, LCR circuits, representation of variation of impedance in LCR series and parallel resonant

UNIT-II: MAGNETISM (9hrs)

Visualization of magnetic field lines, Calculation of magnetic field induction due to (i) long straight wire, (ii) circular loop and (iii) solenoid, visualization of field as a function of distance, Write function to compute Hall coefficient and carrier concentration.

UNIT-III: ELECTROMAGNETIC THEORY (9hrs)

Calculation of Lorentz Force on a point charge, Calculation of Self- inductance of a long solenoid, Magnetic Energy density, Mutual inductance of a pair of coils, Coefficient of Coupling, Calculation of Visualization of Electric and Magnetic components of electromagnetic waves, Calculate the reflection and transmission coefficients for an EM wave incident normally on an interface between two dielectric media.

UNIT-IV: SPECTROSCOPY (9hrs)

Calculation for radius, energy and wave number of Bohr's atomic model, visualization of Bohr's atomic structure, write function to calculate quantum number associated with vector atom model, write function to calculate spectral terms in L-S coupling and j-j coupling, Calculation of Raman Shift, position of stokes lines and anti-stokes lines.

UNIT-V: MATTER WAVES AND QUANTUM MECHANICS (9hrs)

Calculation of de Broglie wavelength and visualization of variation of wavelength with mass and velocity, calculation of uncertainty in Heisenberg uncertainty principle, visualization of atomic orbitals (s, p and d), computation of eigen values of an eigen value equation, visualization of wave functions and energy levels of 1-D infinite potential well.

REFERENCE BOOKS:

1. "A First Course in Computational Physics" by Paul L. DeVries and Jian-Ke Shang
2. "Python for Data Analysis" by Wes McKinney
3. "Python Data Science Handbook: Essential Tools for Working with Data" by Jake VanderPlas
4. Computational Electromagnetics with MATLAB" by Matthew N.O. Sadiku (While MATLAB focused, the numerical methods and principles are highly relevant and transferable to Python)
5. NumPy: https://numpy.org/doc/stable/user/index.html (Essential for vector operations, arrays)
6. Matplotlib: https://matplotlib.org/stable/users/index.html (For all plotting and visualization)
7. SciPy: https://docs.scipy.org/doc/scipy/reference/ (For numerical integration, ODE solvers, FFT)
8. Pandas: https://pandas.pydata.org/pandas-docs/stable/user_guide/index.html (If you include data handling in experiments beyond basic arrays)
9. Jupyter Notebook Documentation: https://jupyter-notebook.readthedocs.io/en/stable/ (For learning to use the interactive environment)
10. Python Official Documentation: https://docs.python.org/3/ (General Python language reference)
11. ComPADRE Physics Education Resources: https://www.compadre.org/physics/ (A vast collection of physics education resources, including computational tools and simulations. Search for topics related to E&M, Quantum, etc.)
12. Online Courses (e.g., Coursera, edX, MIT OpenCourseware):
13. Many universities offer free or audit options for computational physics, electromagnetism, and quantum mechanics courses that often provide lecture notes, problem sets, and sometimes even Python code examples. Searching for "computational electromagnetism" or "computational quantum mechanics" on these platforms can yield good supplementary material.

14. "The Feynman Lectures on Physics" (Online Edition): https://www.feynmanlectures.caltech.edu/ (Volume II covers Electromagnetism. While not computational, it provides profound conceptual understanding.)

STUDENT ACTIVITIES:

UNIT-I: Electricity, Varying and Alternating Currents

- Activity 1: Write functions to calculate and visualize electric field lines for point charges, and intensity of electric fields for uniformly charged solid spheres and spherical shells.
- Activity 2: Develop simulations to represent the growth and decay of currents in LR, CR, and LCR circuits, and visualize the variation of impedance in LCR series and parallel resonance.

UNIT-II: Magnetism

- Activity 1: Visualize magnetic field lines for various current configurations (long straight wire, circular loop, solenoid) and plot field strength as a function of distance.
- Activity 2: Write functions to compute the Hall coefficient and carrier concentration from simulated or given experimental data, demonstrating their relationship.

UNIT-III: Electromagnetic Theory

- Activity 1: Write functions to calculate the Lorentz force on a point charge and determine self-inductance of a solenoid, magnetic energy density, and mutual inductance/coefficient of coupling for coils.
- Activity 2: Visualize the electric and magnetic components of electromagnetic waves in 2D or 3D, and calculate reflection and transmission coefficients for EM waves incident normally on dielectric interfaces.

UNIT-IV: Spectroscopy

- Activity 1: Calculate and visualize the radius, energy, and wave number for Bohr's atomic model, and write functions to determine quantum numbers for the vector atom model.
- Activity 2: Write functions to calculate spectral terms in L-S and j-j coupling schemes, and compute Raman shift, positions of Stokes and anti-Stokes lines for given molecular parameters.

UNIT-V: Matter waves and quantum mechanics

- Activity 1: Calculate de Broglie wavelength and visualize its variation with mass and velocity, and compute the uncertainty in position/momentum according to Heisenberg's principle.
- Activity 2: Visualize the spatial distribution of atomic orbitals (s, p, and d), and computationally determine eigenvalues and visualize wave functions and energy levels for a 1-D infinite potential well.

SEMESTER-VI

COURSE 15 E: COMPUTATIONS IN ELECTRICITY, MAGNETISM, ELECTROMAGNETIC THEORY AND MODERN PHYSICS

Practical **Credits: 1** **2 hrs/week**

COURSE OBJECTIVE

This course aims to develop students' computational skills to model, simulate, and visualize fundamental concepts across classical electromagnetism, atomic physics, and quantum mechanics. Students will learn to apply numerical methods and programming to solve complex physical problems.

LEARNING OUTCOMES:

1. Students will be able to calculate and visualize electric fields and simulate the transient behavior of RC and LR circuits.
2. Students will compute and plot magnetic fields from various current configurations and simulate the Lorentz force on moving charges in electromagnetic fields.
3. Students will calculate and visualize reflection and transmission coefficients for EM waves at interfaces.
4. Students will be able to calculate and visualize properties of the Bohr atom and determine wavenumber positions for Raman spectroscopy.
5. Students will compute de Broglie wavelengths, demonstrate the Heisenberg Uncertainty Principle, visualize atomic orbitals, and model wave functions/energy levels for basic quantum systems.

Minimum 6 experiments to be conducted and recorded

1. Write a function to calculate the electric field vector E at a given point due to a point charge at the origin.
2. Use this function to compute and visualize the electric field lines for a single positive point charge in 2D.
3. For an RC circuit, simulate the charging of a capacitor and the decay of current when discharging. Plot current vs. time and voltage across capacitor vs. time.
4. For an LR circuit, simulate the growth of current when a switch is closed and its decay when the voltage source is removed. Plot current vs. time.
5. Write a function to calculate the magnetic field magnitude due to a long straight current-carrying wire as a function of perpendicular distance. Plot the field's dependence.
6. Write a function to calculate the magnetic field magnitude along the axis of a circular current loop. Plot the field's dependence on axial distance.
7. Simulate the 3D trajectory of a charged particle (given initial position, velocity, charge, mass) using numerical integration of its equations of motion.
8. Write functions to calculate the reflection coefficient (R) and transmission coefficient (T) for normal incidence of an EM wave from medium 1 to medium 2.

9. Plot R and T as functions of the ratio of refractive indices (n_2/n_1).
10. Write functions to calculate the orbital radius (rn), energy (En), and wavenumber for transitions ($1/\lambda$) for the hydrogen atom.
11. Visualize the first few Bohr orbits (e.g., n=1,2,3,4) as concentric circles.
12. Write a function to calculate the wavenumber positions of Stokes and anti-Stokes lines given the excitation wavenumber and molecular vibrational wavenumbers.
13. Write a function to calculate the de Broglie wavelength for objects of varying mass and velocity (e.g., a thrown ball vs. an electron). Visualize the extreme differences in scale.
14. Given an uncertainty in position (Δx), calculate the minimum uncertainty in momentum (Δp) and vice-versa. Plot the relationship between Δx and Δp.
15. Use 3D plotting to visualize the isosurfaces of the probability density for a selected s, p, and d orbital.
16. Write functions to calculate the energy eigenvalues En and normalized wave functions ψ_n (x) for the first few quantum states (n=1,2,3,4) in a 1D infinite potential well of given width.
17. Plot each wave function $\psi_n(x)$ and its corresponding probability density $|\psi_n(x)|^2$.