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 (3rd edition) - Mary. L. Boas
2. First Chapter (Vector analysis) in Introduction to Electrodynamics (3rd 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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