Four-year Undergraduate Programme

Subject: Physics
Semester: First
Course Name: Mathematical Physics and Mechanics
Existing Base Syllabus: HS Maths and Physics
Course Level: PHY101
Syllabus showing each unit against class number and marks

Unit no.	Unit content	No. of classes	Marks/Credit
Theory			
Part A: Mathematical Physics			
Unit I- Vector Calculus	Scalar and vector fields. Derivatives of vector functions (physical examples-velocity, centripetal acceleration of a point in circular motion). Directional derivative. Gradient of a scalar field (example of Newton's gravitational force as gradient of a scalar potential). Gradient as normal vector to a surface. Divergence and curl of a vector field- solenoidal and irrotational vector fields. Laplacian operator (physical problems –Laplacian of gravitational potential, divergence of central force). Vector identities. Vector integration- Line integral (physical example- work done by a force, path dependence/independence and concept of conservative force). Surface and volume integrals. Concept of vector flux. Gauss's divergence theorem and Stokes's theorem (statement only).	8	Credit - 1
Unit– II: Curvilinear coordinates	Introduction to curvilinear coordinates. Orthogonal curvilinear coordinates. Examples of spherical, cylindrical and plane polar coordinates. Line element- transformation from Cartesian to curvilinear coordinates (spherical and cylindrical). Gradient, divergence and curl in spherical and cylindrical coordinates.	5	
Unit-III: Dirac delta function	Definition and properties of Dirac delta function. Representation of delta function by Gaussian function, rectangular function and Laplacian of 1/r . 3-Dimensional delta function.	2	
Part B – Mechanics			

Unit 1- Reference frames	Inertial frames. Non-inertial frames and fictitious forces. Uniformly rotating frame. Laws of physics in rotating coordinate systems. Centrifugal force. Coriolis force and its applications.	4	Credit - 2
Unit –II: Gravitation and central force motion	Motion under central force. Two-body problem and its reduction to one body problem. Kepler's laws, Gravitational potential and fields due to spherical body. Gauss's law and Poisson's equation for gravitational field.	7	
Unit –III: Conservation laws	Dynamics of a system of particles. Centre of mass. Principle of conservation of momentum. Torque. Impulse. Elastic and inelastic collisions between particles. Centre of mass and laboratory frames.	4	
Unit–IV: Dynamics of rigid bodies	Rigid body motion. Rotational motion. Moment of inertia of rectangular lamina, disc, cylindrical and spherical bodies. Kinetic energy of rotation. Motion involving both translation and rotation.	6	
Unit–V: Work and energy	Work and kinetic energy theorem. Conservative and non-conservative forces. Potential energy. Force as gradient of potential energy. Work and potential energy. Work done by non-conservative forces.	3	
Unit –VI: Oscillations	Oscillation - differential equation of simple harmonic motion and its solution. Total energy of oscillation.	2	
Unit –VII: Properties of matter	Relation between elastic constants. Twisting torque on a cylinder or wire. Cantilever. Kinematics of moving fluids: Poiseuille's equation for flow of a liquid through a capillary tube.	4	
Laboratory			
	<u>At least four from the following:</u> 1. To study the motion of spring and calculate (a) spring constant and (b) rigidity modulus. 2. To determine the moment of inertia of a cylinder about two different axes of symmetry by torsional oscillation method.		Credit-1

	3. To determine coefficient of viscosity of water by capillary flow method (Poiseuille's method). 4. To determine the Young's modulus of the material of a wire by Searle's apparatus. 5. To determine the modulus of rigidity of a wire (static method). 6. To determine the value of g using bar pendulum. 7. To determine the value of g using Kater's pendulum. 8. To determine the height of a building using a sextant. 9. To determine g and velocity for a freely falling body using digital timing technique.		

Reading list

1. Essential Mathematical Methods for the Physical Sciences; K.F. Riley and M.P. Hobson, Cambridge University Press.
2. Advanced Engineering Mathematics; E. Kreyszic, John Wiley & Sons (New York).
3. Mathematical Methods for Physicists; G. B. Arfken, H. J. Weber and F.E. Harris, Elsevier.
4. Mathematical Physics-I, K. K Pathak and S. Parasher, Vishal Publication, Jalandhar (Delhi).
5. Theoretical Mechanics, M. R. Spiegel, Tata McGraw Hill.
6. Mechanics; D. S. Mathur, S. Chand & Company Limited.
7. An Introduction to Mechanics, D. Kleppner and R. J. Kolenkow, Tata McGraw-Hill.
8. Mechanics, Berkeley Physics, vol.1, C. Kittel, W. Knight, et.al., Tata McGraw-Hill.
9. Physics, R. Resnick, D. Halliday and J. Walker, John Wiley & Sons.
10. Analytical Mechanics, G. R. Fowles and G. L. Cassiday, Cengage Learning.

Graduate Attributes

i. Course Objective

This course introduces mathematical physics and mechanics. The basic objectives of the course are

- *to introduce essential primary concepts in mathematical physics such as calculus of vectors, curvilinear coordinates and Dirac delta function which are required for developing insight of the theories of physics,*
- *to introduce the concepts of dynamics of particles, energy, oscillation and basic properties of matter which will equip students with the tools required for applying the concepts of physics in practical problems and*
- *to train the students with concept visualisation through some laboratory practices.*

ii. Learning outcome

On successful completion of the course, students will be able to understand the calculus of vectors and concept of curved spaces which play central roles in developing insight of the theories of physics. They will learn the powerful method of computation through Dirac delta function which often appears in complex problems of physics. Students will be able to understand and apply the concepts of dynamics of particles, energy, oscillation and basic properties of matter in various problems of physics, technology and engineering. They will be trained in concept realisation through laboratory practices.

Theory Credit: 03 (Three)

Practical Credit: 01 (One)

No. of Required Classes: 45

No. of Contact Classes: 45

No. of Non-Contact Classes:

Particulars of Course Designer (Name, Institution, email id):

1) **Dr. Sanjeev Kalita**, Gauhati University, sanjeev@gauhati.ac.in
2) **Dr. Krishna Kingkar Pathak,** Arya Vidyapeeth College, kkingkar@gmail.com
3) **Dr. Samrat Dey,** Pragjyotish College, samratdgr8@gmail.com

Subject: Physics
Semester: Two
Course Name: Mathematical Physics & Electricity and Magnetism
Existing Base Syllabus: HS Maths and Physics
Course Level: PHY151
Syllabus showing each unit against class number and marks

Unit no.	Unit content	No. of classes	Marks/Credit
Theory			
Part A: Mathematical Physics (Theory)			
Unit 1- Differential equations	First and second order ordinary differential equations (ODE). Homogeneous and inhomogeneous differential equations. Solutions of first order ODE – integrating factors (physical examples – radioactive decay, Newton's law of cooling, particle falling under gravity through a resistive medium). Concept of initial/boundary conditions. Solutions of second order ODE with constant coefficients - complementary function and particular integral (physical examples- simple harmonic oscillation, forced vibration). Wronskian- definition and its use to check linear independence of 2nd order homogeneous linear differential equation. Partial differential equations (PDE) (physical examples – wave equation, diffusion equation, Laplace and Poisson equation – introduction only). Exact and inexact differentials. Concept of variable separation in a PDE.	10	Credit - 1
Unit– II: Matrices	Properties of matrices. Determinant and rank. Transpose and complex conjugate of matrices. Hermitian and anti-Hermitian matrices. Unitary and orthogonal matrices. Representation of linear homogeneous and inhomogeneous equations through matrix equation. Inverse of a matrix. Eigen values and eigen-vectors. Cayley-Hamilton Theorem (statement only), Diagonalization of simple matrices.	5	
Part B – Electricity and Magnetism (Theory)			
Unit I: Electric field	Electrostatic field, electric flux. Gauss's law. Application of Gauss's law to charge distributions with planar, spherical and	13	Credit - 2

and electric potential	cylindrical symmetries. Conservative nature of electrostatic field. Electrostatic potential. Electrostatic energy of a system of charges. Electrostatic boundary conditions. Laplace's and Poisson's equations. Uniqueness theorem. Application of Laplace's equation involving planar, spherical and cylindrical symmetries. Potential and electric field of a dipole. Force and torque on a dipole. Capacitance of a system of charged conductors. Parallel plate capacitor. Capacitance on an isolated conductor.		
Unit –II: Dielectric properties of matter	Electric field in matter. Polarisation, polarisation charges. Electrical susceptibility and dielectric constant. Capacitor (parallel plate, spherical and cylindrical) filled with dielectric. Displacement vector, $\vec{D}$. Relation between $\vec{E}$, $\vec{P}$ and $\vec{D}$. Gauss's law in dielectrics.	4	
Unit –III: Magnetic field	Magnetic force on a point charge, definition and properties of magnetic field $\vec{B}$. Curl and divergence. Vector potential, $\vec{A}$. Magnetic scaler potential. Magnetic force on (i) a current carrying wire and (ii) between two elements. Torque on a current loop in a uniform magnetic field. Biot-Savart's law and its simple application: straight wire and circular loop. Current loop as a magnetic dipole and its dipole moment (analogy with electric dipole). Ampere's circuital law and its application to (i) solenoid and (ii) torus.	6	
Unit–IV: Magnetic properties of matter	Magnetization vector, $\vec{M}$. Magnetic intensity, $\vec{H}$. Magnetic susceptibility and permeability. Relation between $\vec{B}$, $\vec{H}$ and $\vec{M}$. Ferromagnetism. B-H curve and hysteresis.	2	
Unit–V: Electrical circuits	AC circuits: Kirchhoff's laws for AC circuits. Complex reactance and inductance. Series LCR circuits and parallel LCR circuits: (i) phasor diagram, (ii) resonance, (iii) power dissipation, (iv) quality factor, and (v) band width. Ideal constant-voltage and constant-current sources. Thevenin theorem and Norton theorem (only statements and solving of related problems).	5	
Laboratory			
	<u>At least four from the following:</u>		Credit-1

	1. Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, (d) Capacitances, and (e) Checking electrical fuses. 2. To study the characteristics of a series RC circuit. 3. To determine an unknown Low Resistance using Potentiometer. 4. To determine an unknown Low Resistance using Carey Foster's Bridge. 5. To compare capacitances using De' Sauty's bridge. 6. Measurement of field strength $\vec{B}$ and its variation in a solenoid (determine $\frac{dB}{dx}$). 7. To verify the Thevenin and Norton Theorems. 8. To verify the superposition and maximum power transfer theorems. 9. To determine the self-inductance of a coil by Anderson's bridge. 10. To study the response curve of a Series LCR circuit and determine its (a) Resonant frequency, (b) Impedance at resonance, (c) Quality factor Q, and (d) Band width. 11. To study the response curve of a parallel LCR circuit and determine its (a) Anti-resonant frequency and (b) Quality factor Q. 12. Measurement of charge and current sensitivity and CDR of Ballistic Galvanometer. 13. Determine a high resistance by leakage method using Ballistic Galvanometer. 14. To determine the self-inductance of a coil by Rayleigh's method.		

	15. To determine the mutual inductance of two coils by the Absolute method.		

Reading list

[1] Essential Mathematical Methods for the Physical Sciences; K. F. Riley and M. P. Hobson, Cambridge University Press.
[2] Advanced Engineering Mathematics; E. Kreyszic, John Wiley & Sons (New York)
[3] Mathematical Methods for Physicists; G. B. Arfken, H. J. Weber and F.E. Harris, Elsevier
[4] Mathematical Physics, H. K. Dass and Dr. Rama Verma, S. Chand Publication.
[5] Mathematical Physics-I; Krishna K. Pathak and Sangeeta Prasher, Vishal Publishing Co, Jalalandhar (Delhi).
[6] Introduction to Electrodynamics, D. J. Griffiths.
[7] Electricity and Magnetism [With electromagnetic theory and special theory of relativity], D. Chattopadhyay and P. C. Rakshit, 2013, New Central Book Agency (P) Limited.
[8] Electricity, Magnetism and Electromagnetic Theory, S. Mahajan and S. R. Choudhury, 2012, Tata Mcgraw.
[9] Schaum's outline of Theory and Problems of Electromagnetics, J. A. Edminister.
[10] Electromagnetics, B. B. Laud, New Age International Publishers.
[11] Feynman Lectures Vol. 2, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education.
[12] Electricity and Magnetism, Edward M. Purcell, 1986, McGraw-Hill Education.
[13] Elements of Electromagnetics, M. N. O. Sadiku, 2008. Pearson Education.
[14] Electricity and Magnetism, J. W. Fewkes and J. Yarwood, Vol. I, 1991, Oxford Univ. Press.

Graduate Attributes

i. Course Objective

- *To introduce the methods of solving differential equations.*
- *To introduce various concepts of matrix algebra.*
- *Electric field from vector calculus point of view and use of potential formulation to solve electrostatic problems.*
- *Magnetic fields of current carrying conductors, torus, solenoids etc. Study magnetic properties of matter.*
- *Study and analysis of AC circuits like LCR, and use of network theorems in electrical circuits.*

ii. Learning outcome

After the successful completion of the course, students will be able to understand methods of solving various differential equations appearing in physics. It will give an idea of how to study evolution of a physical system. Through matrix algebra students will be able to compute various matrix operations which are required for solving physical problems. They will be able to understand electric field and magnetic fields in matter, dielectric properties of matter, magnetic properties of matter, application of Kirchhoff's law in different circuits, and application of network theorem in different circuits. The students will also get accustomed to using multimeters and potentiometers, and they will be able to determine some of the important physical quantities related to electricity and magnetism for a better understanding of the topic.

Theory Credit: 03 (Three)

Practical Credit: 01 (One)

No. of Required Classes: 45

No. of Contact Classes: 45

No. of Non-Contact Classes:

Particulars of Course Designer (Name, Institution, email id):

1. **Dr. Manos P. C. Kalita**, Gauhati University, mpckalita@gauhati.ac.in
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