**April, 2026**

# ELECTRICITY AND MAGNETISM

Time: 3 Hrs Full Marks: 100

*Answer all the questions.*
*The figures in the right hand margin indicate marks.*

**1. Answer all the following questions:** $(\mathbf{10x1 = 10})$

i. State Gauss's law in differential form.
ii. State the uniqueness theorem.
iii. If the potential difference across a capacitor is doubled then how does the capacitance change ?
iv. Define magnetic flux density.
v. A point charge is taken from a point A to a point B in an electric field. Does the work done by the electric field depend on the path of the charge? (yes/no)
vi. Why does a ferromagnetic material lose magnetism above Curie temperature?
vii. Give an example where the electric field $\boldsymbol{E}(\boldsymbol{r})$ is zero at a point but $\boldsymbol{\nabla}.\boldsymbol{E}$ is not zero there.
viii. Define bandwidth in an LCR circuit.
ix. State the maximum power transfer theorem.
x. The electric potential inside a conductor is __________. (fill in the blank)

**2. Answer all questions in 50 words each:** $(\mathbf{9x2 = 18})$

i. State Laplace's equation and explain its physical significance.
ii. The electric potential existing in space is $\boldsymbol{V(x,y,z) = A(xy + yz + zx)}$. (a) Write the dimensional formula of A. (b) Find the expression for the electric field.
iii. Explain the physical significance of Lenz's law.
iv. Three charges are situated at the corners of a square (side a), as shown in Fig. 2.1. How much work does it take to bring in another charge, +q, from far away and place it in the fourth corner?
v. Write a note on polarization vector $\vec{\mathbf{P}}$.
vi. What is power factor of an a.c. circuit ? Mention its physical significance.
vii. An series RLC circuit has $R = 150\Omega$, $L = 20mH$, $V = 20V$ and $\omega = 5000 rad/s$. Determine the value of the capacitance for which the current is maximum.
viii. Mention the dimensions and SI units of $\boldsymbol{\sigma_p} = \vec{\mathbf{P}}.\hat{\mathbf{n}}$ and $\boldsymbol{\rho_p} = -\vec{\nabla}.\vec{\boldsymbol{P}}$.
ix. What is meant by capacitive time constant ? Find its dimension

**3. Answer any eight of the following within 250 words each:** $(\mathbf{8x5 = 40})$

i. Prove that the electrostatic field is conservative. Hence derive the relation $\mathrm{E} = -\nabla \mathrm{V}$
ii. Derive the expression for the energy stored in a magnetic field.
iii. Explain the concepts of magnetization, magnetic intensity, and magnetic susceptibility. Derive the relation: $\boldsymbol{B} = \boldsymbol{\mu_0}(\boldsymbol{H} + \boldsymbol{M})$
iv. State and derive the integral form of Gauss's law for dielectric and hence express it in the differential form.
v. A thin, spherical shell of radius $\boldsymbol{R}$ carries a charge $\boldsymbol{Q}$ distributed uniformly over its surface. Find the potential due to this charge at a point inside the shell, at a distance $\boldsymbol{r}$ from the centre of the shell.

vi. The instantaneous values of voltage and current at the terminals of an ac circuit are given by $\boldsymbol{v(t) = V_0 cos\omega t}$ and $\boldsymbol{i(t) = I_0 \cos(\omega t - \theta)}$. Find average power absorbed by the circuit.

vii. Two infinitely large charge layers are uniformly spread parallel to each other, one along the plane $\boldsymbol{z = 0}$ and the other along the plane $\boldsymbol{z = z_0}$. As a result, the whole of the plane potential $\boldsymbol{z = 0}$ is at a constant potential $\boldsymbol{v = v_1}$ and the whole of the plane $\boldsymbol{z = z_0}$ is at a constant between the $\boldsymbol{v = v_2}$. There is no charge anywhere else. Find the potential in the region in between planes.

viii. Two semi-infinite grounded conducting planes meet at right angles. In the region between them, there is a point charge q, situated as shown in Fig. 3.1. Set up the image configuration, and calculate the the force on q.

ix. Write the differential form Maxwell's equations in free space and in a dielectric.

x. A closed loop carrying current $\boldsymbol{I}$ is placed in a uniform magnetic field $\vec{\boldsymbol{B}}$. Obtain an expression for the torque exerted on the loop.

**4. Answer any 4 of the following within 500 words each:** $\boldsymbol{(4x8 = 32)}$

i. A point charge $\mathbf{q}$ is placed near an infinite , grounded conducting plane. Use the method of images to find (a)field at any point above the plane, (b) surface charge density induced on the plane(c) electrostatic energy of the system (2+4+2)

ii. Discuss the characteristics features of a series RLC circuit in resonance. Obtain expressions for (a) current (b) resonant frequency (c) band width (2+2+2+2)

iii.(a) Deduce an expression for magnetic dipole moment of an electron revolving around a nucleus in a circular orbit. Use the expression to derive the relation between the magnetic moment of an electron moving in a circle and its related angular momentum. (3+2)

(b) A long straight wire of radius a carries uniformly distribute current I. Using ampere's circuital law , find the expressions for the magnetic field inside $(r < a)$ the conductor. (3)

iv. Discuss Weiss's domain theory for ferromagnetism. Describe the features of B-H curve for a ferromagnetic material. (4+4)

v. (a) In the network shown in fig-4.1 find the thevenin voltage, thevenin resistance through the 4$\boldsymbol{\Omega}$ resistor.

(b)In the network shown in fig-4.2, find the current through the load $R_L$ using superposition theorem.(4+4)

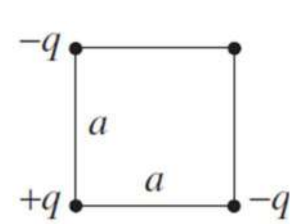

Fig-2.1

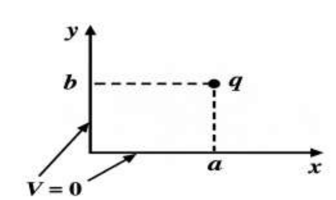

Fig-3.1

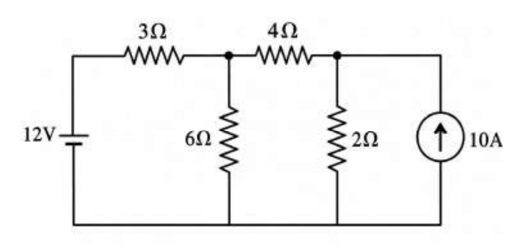

Fig-4.1

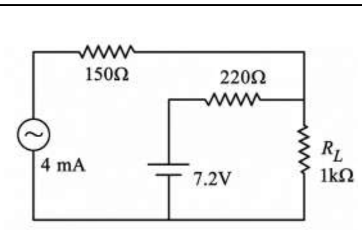

Fig-4.2

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+3 Sem-II (NEP)

**PHY-C-1P-IV(R&B) MAJ**

**APRIL, 2026**

# MATHEMATICAL PHYSICS-II

**Time: 3 Hrs** **Full Marks: 100**

*Answer all the questions.*

*The figures in the right hand margin indicate marks.*

## Part-I

**1. Answer all the following questions:** $(\mathbf{10X1=10})$

i. The value of $\int_{-1}^{+1} P_0(x)dx$ is

a. 0 b. x

c. 1 d. 2

ii. For Fourier representation of a function f(x), the function must be

a. an exponential functions b. a periodic and completely regular function

c. a periodic and piecewise regular function d. any arbitrary function

iii. The function f(x)=(sinx)$x^3$ in the range $-\pi < x < \pi$ is

a. an even function b. an odd function

c. may be even or odd function d. a numeric

iv. According to fourier expansion of $x^2$, the value of $\sum_{n=1}^{\infty} \frac{1}{n^2}$ is

a. $\frac{\pi^2}{3}$ b. $\frac{\pi^2}{4}$

c. $\frac{\pi^2}{6}$ d. $\frac{\pi^2}{12}$

v. A fourier series of a function f(x) contains only cosine terms if function f(x) is

a. an odd function of x b. an even function of x

c. an exponential function containing only real terms only d. it is not possible

vi. Laplace's equation may be used in the study of

a. steady state temperature in a region containing source of heat b. stady state temperature in a region containing no heat source

c. variable state temperature in a region with no heat source d. variable state temperature in a region containing heat source

vii. The partial differential equation is $\frac{\partial^2 u}{\partial t^2} - c^2 \frac{\partial^2 u}{\partial x^2} = 0$ is

a. wave equation b. heat equation

c. Laplace equation d. Helmholtz equation viii The value of $\Gamma(\frac{1}{2})$ is

a. 0 b. $\pi/2$

c. $\pi$ d. $\sqrt{\pi}$

ix The value of $erf(\infty)$ is

a. 0 b. $r$

c. $\infty$ d. $\pi/2$

x. The value of $P_n(1)$ is

a. 0 b. 1

c. -1 d. $-1^n$

### Part-II

**2. Answer all questions in 50 words each:** $(9X2 = 18)$

i. Develop $\mathbf{f(x) = 1}$ in Fourier series in the interval $(\mathbf{0, 2})$

ii. Locate and classify the singular points of the differential equation

$$\mathbf{x^3(x-1)y'' - 2(x-1)y' + 3xy = 0} \quad \text{where } \mathbf{y'} = \frac{\mathbf{dy}}{\mathbf{dx}} \text{ and } \mathbf{y''} = \frac{\mathbf{d^2y}}{\mathbf{dx^2}}.$$

iii. Show that $\mathbf{H_1(x) = 2xH_0(x)}$ for Hermite polynomial**.**

iv. Express $\boldsymbol{15x^2 - 9x}$ in terms of Legendre polynomials.

v. Show that $\mathbf{H_n(-x) = (-1)^n H_n(x)}$

vi. Explain Dirichlet's conditions for the function f(x) which can be expanded into a Fourier series.

vii. Express $\mathbf{8x^2 + 4x - 4}$ in terms of Hermite polynomials.

viii. How will you change the function f(x) from interval $(\boldsymbol{-\pi, \pi})$ to $(\boldsymbol{-l, +l})$ in fourier series?

ix. Define error function.

### Part-III

**3. Answer any eight of the following within 250 words each:** $(8X5 = 40)$

i. Expand in a Fourier series,

$$\boldsymbol{f(x) = -1, \; (-\pi \le x \le 0)}$$
$$\boldsymbol{= +1 \quad (0 \le x \le \pi)}$$

ii. Explain how one can check whether a given point is an ordinary point, regular singular point and essential singular point of a given homogeneous, linear, second order differential equation.

iii. Obtain the power series solution of the differential equation $\frac{\mathbf{d^2y}}{\mathbf{dx^2}} + \boldsymbol{x}\frac{\mathbf{dy}}{\mathbf{dx}} + \mathbf{y = 0}$

iv. Find the relation between beta and gamma functions.

v. Show that $\int_0^{\pi/2} \boldsymbol{\sin^2\varphi \cos^2\varphi \, d\varphi} = \frac{\pi}{6}$

vi. Evaluate $\int_0^2 \sqrt{\boldsymbol{x(2-x)}}\, \boldsymbol{dx}$ .

vii. Evaluate $\int_{-1}^{+1} \boldsymbol{xP_{n-1}(x)P_n(x)} \; \boldsymbol{dx}$

viii. Solve $\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2}$ if $\boldsymbol{u(x,0) = sin\ \pi x}$

ix. Show that the Legendre polynomial $P_n(x)$ may be derived in the following differential form

$$\boldsymbol{P_n(x) = \frac{1}{2^n n!}\frac{d^n}{dx^n}(x^2-1)^n}$$

x. Derive recurrence relation for Hermite polynomial

$$\boldsymbol{2nH_{n-1} = H_n'(x)}$$

## Part-IV

**4. Answer any 4 of the following within 500 words each:** $(\boldsymbol{4X8 = 32})$

i. Obtain the orthonormality condition for legendre polynomials i.e. $\int_{-1}^{+1} \boldsymbol{P_m(x)P_n(x)dx = 0}, if\ m \neq n$

ii. Obtain the polynomial solutions of the differential equation

$\boldsymbol{\frac{d^2y}{dx^2} - 2x\frac{dy}{dx} + 2ny = 0}$ for integral values of $\boldsymbol{n}$ .

iii. Find a series of sine and cosine of multiple of x which will represent f(x)in the interval$(-\pi, +\pi)$ where

$\boldsymbol{f(x) = 0;\ -\pi < x < 0}$

$= \frac{\pi x}{4}; \boldsymbol{0} < x < \pi$ and hence deduce that $\frac{\pi^2}{8} = \boldsymbol{1} + \frac{1}{3^2} + \frac{1}{5^2} + \cdots$ **6+2**

iv. a. Show that $\boldsymbol{\Gamma m\, \Gamma(1-m) = \frac{\pi}{sin\pi}}$

**b.** Evaluate $\int_0^1 \frac{dx}{1-x^n}$

v. Solve the wave equation $\frac{\partial^2 u}{\partial x^2} = \frac{1}{c^2}\frac{\partial^2 y}{\partial t^2}$ for a stretched string fixed by rigid supports at the ends $x = 0\ and\ x = l$ if at t=0, $\frac{\partial y}{\partial t} = 0$ and $y(x,t) = y_0(x)$.

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**APRIL,2026**

# MECHANICS

**Time: 3 Hrs** **Full Marks: 100**

*Answer all the questions.*

*The figures in the right hand margin indicate marks.*

## Part-I

1. **Answer all the following questions:** $(10x1 = 10)$

i. A molecule consists of two atoms, each of mass  separated by a distance a. The moment of inertia(MI) of the molecule about its center of mass is

a. $2ma^2$ b. $ma^2$

c. $\frac{1}{2}ma^2$ d. $\frac{1}{4}ma^2$

ii. The MI of a solid sphere of mass m and radius R about an axis tangential to the surface of the sphere is

a. $\frac{4}{5}MR^2$ b. $MR^2$

c. $\frac{6}{5}MR^2$ d. $\frac{7}{5}MR^2$

iii. In damped oscillation, the amplitude

a. Increases continuously b. Remains constant

c. Decreases exponentially d. Becomes infinite

iv. Resonance occurs when

a. Driving frequency equals natural frequency b. Driving frequency is zero

c. Natural frequency is zero d. Damping becomes infinite

v. The SI unit of surface tension is

a. N b. N/m

c. $N/m^2$ d. Joule

vi. The gravitational field inside a hollow spherical shell is

a. Maximum b. Infinite

c. Zero d. Constant

vii. For a central force, the conserved quantity is

a. Linear momentum b. Angular momentum

c. Velocity d. Acceleration

viii According to Einstein's Special Theory of Relativity, the speed of light in vacuum

a. Depends on observer b. Depends on source

c. Is constant for all inertial observers d. Depends on wavelength ix Time dilation implies that a moving clock

a. Runs faster

b. Runs slower

c. Stops

d. Oscillates

x. The rotational kinetic energy of a rigid body is

a. $\frac{1}{2}mv^2$

b. $I\omega$

c. $\frac{1}{2}I\omega^2$

d. $I\omega^2$

**Part-II**

**2. Answer all questions in 50 words each:** $(9x2 = 18)$

i. State and explain the Parallel Axis Theorem.

ii. What is resonance? State the condition for resonance.

iii. Explain what is meant by mass-energy equivalence ?

iv. What is surface tension? Explain its molecular origin.

v. Discuss the nature of gravitational force.

vi. Show graphically the variation of potential and field against distance from the centre of a thin spherical shell.

vii. State Kepler's Laws of Planetary motion.

viii. Show that the expression $\mathbf{x^2+y^2+z^2-c^2t^2}$ is not invariant under the Galilean transformation.

ix. State the postulates of the special theory of relativity.

**Part-III**

**3. Answer any eight of the following within 250 words each:** $(8x5 = 40)$

i. Calculate the MI of a thin rod having mass M and length L about an axis perpendicular to its length and passing through the centre.

ii. Differentiate between underdamped, critically damped and overdamped motions.

iii. At what distance from thr centre of the earth does the gravitational acceleration acceleration has $\frac{1}{3}rd$ the value that it has on the earth surface.

iv. Obtain an expression for the rotational kinetic energy of a rigid body. How does it provide an analogy between MI and mass.

v. Two masses $m_1$ and $m_2$ are joined by weightless rod of length r. Calculate the moment of inertia of the system about an axis passing through the CM and perpendicular to the rod.

vi. What is meant by quality factor(Q) of a damped harmonic oscillator ? Deduce an expression for Q of a weakly damped harmonic oscillator.

vii. Show that Kepler's second law of planetary motion is a direct consequence of the conservation of angular momentum under central forces.

viii. Derive relativistic velocity addition formulae using L-T equations.

ix. Deduce Lorentz transformation equations.

x. In special theory of relativity express total energy of a particle in terms of its momentum.

## Part-IV

**4. Answer any 4 of the following within 500 words each:** $(4x8 = 32)$

i. Calculate the MI of a uniform ring of radius R and mass M about (a) an axis passing through its centre and perpendicular to its plane, (b) a diameter , (c) an axis lying in its plane at a distance R/2 from the centre.

ii. What is a damped harmonic oscillator ? Establish its equation of motion and obtain the solution.

iii. What is meant by a central force ? A particle is moving in a central force field. Obtain the differential equation of the orbit of the particle.

iv. Write notes on (a) Simultaneity in relativity (b) Length contraction (c) time dilation

v. Derive the formula $\mathbf{m} = \frac{\mathbf{m_0}}{\left(1-\mathbf{v^2}/\mathbf{c^2}\right)^{1/2}}$ where the symbols have their usual meaning.

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