U.G. 3rd Semester Examination-2024

PHYSICS

[MAJOR]

Course Code : PHS-MAJ-T-03

(Electricity and Magnetism)

[NEP-2020]

Full Marks : 40 Time : $2\frac{1}{2}$ Hours

The figures in the right-hand margin indicate marks.

Candidates are required to give their answers in their own words as far as practicable.

Symbols have their usual meaning.

GROUP-A

1. Answer any **five** questions: $2\times5=10$

a) Determine the electric field due to potential

$$\phi(r)=\left(\frac{A}{r}\right)e^{-\lambda r}$$

b) Verify that for a charged spherical conductor of radius a,

$$\epsilon_0\int E^2 dv=\frac{Q^2}{4\pi\epsilon_0 a}$$

c) Find the general solution to Laplace's equation in spherical coordinates, for the case where the potential, V depends on r only.

d) What is meant by polarization in dielectric? Define dielectric constant.

e) Explain the concept of a magnetic dipole.

f) What is an eddy current? State one of its applications.

g) Write the time constant of an RL circuit and explain its significance.

h) What is the role of damping in a ballistic galvanometer? Explain with an example.

GROUP-B

2. Answer any **two** questions: $5\times2=10$

a) Obtain the expression for the energy density in an electrostatic field. Consider a charged sphere of radius R. The electric field at any inside point is $\vec{E} = Ar^3\hat{r}$ (where A is constant). Find the volume charge density and also the total charge within the sphere. $2+3$

b) Define electric dipole moment. Write the expression of potential energy of a dipole with dipole moment $\bar{p}$ placed in an external electric field $\bar{E}$. Hence show that the force on the dipole due to the electric field is given by $\bar{F} = (\bar{p}.\bar{\nabla})\bar{E}$. 1+1+3

c) State Biot-Savart law. Starting from Biot-Savart law derive Ampere's Circuital law. 1+4

d) What are self-inductance and mutual-inductance? Show that the equivalent inductance of two coils of self-inductances L_1, L_2 and Mutual inductance M connected in parallel is :

$$L_{eq} = \frac{L_1 L_2 - M^2}{L_1 + L_1 \pm 2M}$$ 2+3

GROUP-C

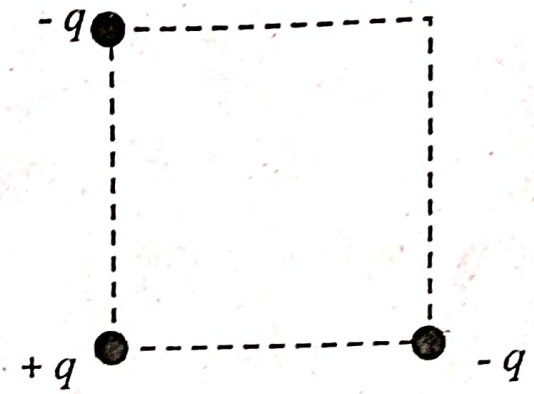
Answer any **two** questions: 10×2=20

3. a) Consider a point charge at the origin. Starting from the equation:

$$\bar{E} = \frac{1}{4\pi \epsilon_0} \frac{q}{r^2} \hat{r}$$

Show that $\bar{\nabla} \times \bar{E} = 0$.

b) Three charges are situated at the corners of a square (side a) as shown in the figure below. How much work does it take to bring another charge, $+q$, from far away and place it in the fourth corner?



c) Suppose a charge Q is distributed within a sphere of radius R in such a way that the charge density $\rho(r)$ at a distance r from the centre of the sphere is

$$\rho(r) = \begin{cases} K(R-r) & \text{for } 0 < r < R \\ 0 & \text{for } r \geq R \end{cases}$$

i) Determine constant K in terms of Q and R.

ii) Calculate the electric field at any point inside the sphere.

iii) Find the value of r for which the field is maximum.

iv) What is the value of this maximum field?

2+3+(1+2+1+1)

4. a) Derive the expression for the capacitance of a parallel plate capacitor filled with a dielectric material of permittivity ϵ.

b) An electric dipole formed by two equal and opposite charges each of magnitude 1 μC separated by a distance of 1 m is placed in a uniform electric field of strength 10^5 V/m such that the axis of the dipole is parallel to the field. Calculate the amount of work to be done to rotate the dipole end to end i.e. by an angle 180°.

c) A dielectric sphere of radius a carries a (frozen-in) polarization $\overline{P} = k\overline{r}$, where k is a constant and r is the distance from the centre. Use Gauss theorem in dielectrics to find the electric field inside ($r < a$) and outside ($r > a$) the sphere.

3+3+4

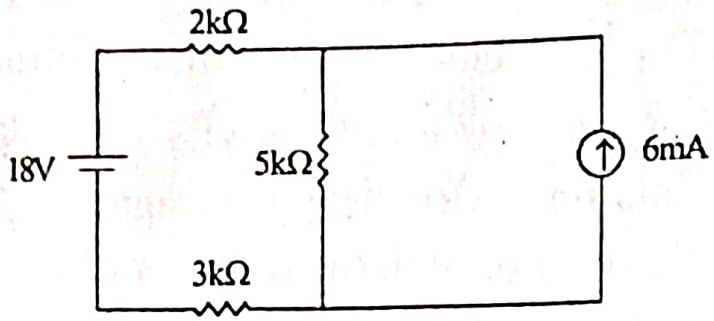
5. a) Calculate the torque on a current loop with area A and carrying current I in a uniform magnetic field B.

b) Derive the equation of continuity. What does it signify?

c) Show that at the boundary of two magnetic media the normal component of $\overline{B}$ is continuous while the tangential component of $\overline{H}$ is discontinuous by an amount equal to free surface current density.

2+(2+1)+5

6. a) Consider the circuit below. Using the principle of superposition find the potential drop across the 5kΩ resistor.



b) Consider a parallel L-C combination in series with a resistance R. Calculate the expression for output voltage across L-C combination for sinusoidal input.

c) Explain the transient behaviour of an RC circuit during charging and discharging. Illustrate with appropriate diagrams and equations.

d) A series RC circuit consists of C = 1 μF, R=100 Ω, and a 24 V battery. Calculate the time taken for the charge to reach 63.2 of its final value. 3+3+2+2