'समानो मन्त्रः समितिः समानी'

UNIVERSITY OF NORTH BENGAL

B.Sc. Honours 2nd Semester Examination, 2023

CC3-PHYSICS

ELECTRICITY AND MAGNETISM

Time Allotted: 2 Hours | Full Marks: 40

The figures in the margin indicate full marks.

GROUP-A

1. Answer any ***five*** questions from the following: 1×5 = 5

   (a) What is meant by coefficient of coupling in mutual induction?

   (b) What is displacement current?

   (c) Which property of a material determines its suitability for using it as the core of a transformer?

   (d) The magnetic vector potential at any point $\vec{r}$ in a magnetic field is given by $\vec{A} = r^2\hat{i}$. Calculate the magnetic field at that position.

   (e) Three point charges each having charge q are sitting at the three corners of a square of side a, the fourth corner being vacant. What will be the electric field at the point of intersection of the diagonals?

   (f) The electrostatic potential in free space is given by $\phi = 3x^2 + y^2 + 2z^2$, find the charge density in the region.

   (g) A cylindrical capacitor of 1 m length has inner and outer cylinder diameters 5.5 cm and 6 cm respectively, separated by bakelite (k = 4). Calculate the capacitance.

   (h) A dielectric sphere of radius 'a' has a polarization $\vec{P} = k\vec{r}$, where k is a constant, and the origin is at the centre of the sphere. Calculate the volume density of polarization charge.

GROUP-B

Answer any *three* questions from the following 5×3 = 15

2. (a) Define electrostatic potential. 1

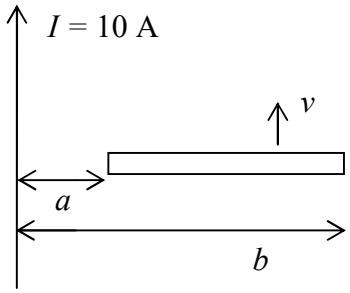
(b) A spherical distribution of charge consists of a uniform volume charge density ρ_1 from $r = 0$ to $r = \frac{a}{2}$, and a uniform volume charge density ρ_2 from $r = \frac{a}{2}$ to $r = a$. Show that the potential at the centre of the charge distribution ($r = 0$), is $\frac{a^2}{8\varepsilon_0}(\rho_1 + 3\rho_2)$. 4

3. (a) Establish the relation $\vec{D} = \varepsilon_0\vec{E} + \vec{P}$ in a dielectric medium. Symbols have their usual meaning. 2

(b) The inner sphere of radius '*a*' of a spherical capacitor is earthed while the outer spherical shell of inner radius '*b*' is charged to +*Q*. Find the capacitance of the system if the thickness of the outer spherical shell is '*t*'. 3

4. (a) State Lenz's law. 1

(b) A Cu-rod moves with a constant velocity of 2 m/s parallel to a long straight wire carrying a current of 10 A, the Cu-rod being oriented perpendicular to the long straight wire. Calculate the induced emf in the rod if the ends of the rod from the wire are at distances *a* = 8 cm and *b* = 32 cm. 4



5. A spherically symmetric charge distribution extending from $r = 0$ to $r = a$, has a volume charge density $\rho(r) = \rho_0(a/r)$, where ρ_0 is a constant. Outside $r = a$, there is no charge. Show that the energy of this charge distribution is $U = \frac{Q^2}{6\pi\varepsilon_0 a}$. 5

6. (a) Two long wires are placed parallel to each other at a distance '*d*', carrying currents *I* each in opposite directions. Derive an expression for the self-inductance per unit length of the combination. 3

(b) A closed circular coil has 200 turns of mean radius 25 cm. The resistance of the coil is 10 Ω. A uniform magnetic intensity of 100 Oe exists at right angle to the plane of the coil. Determine the electric charge passing through the coil when the latter is turned through 180°. 2

GROUP-C

Answer any *two* questions from the following 10×2 = 20

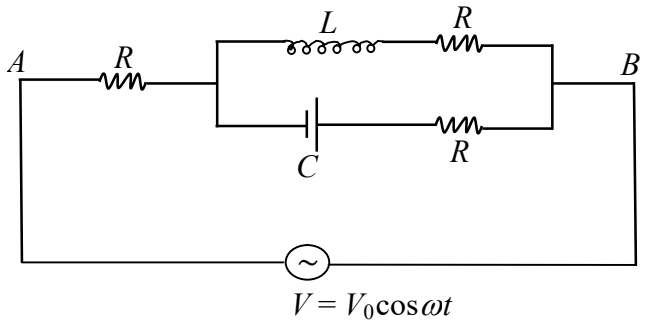
7. (a) Define electrical image. 1

   (b) Use the method of electrical image to find the surface density of induced charge on a grounded conducting sphere when a point charge is placed near but outside the sphere. 5

   (c) The space between $x = 0$ and $x = d$ is filled with a uniform charge of volume density ρ. The electric field at $x = d$ is zero. Calculate the potential difference between $x = 0$ and $x = d$, using Laplace's equation. 4

8. (a) Why is a parallel LCR circuit called a rejector circuit? 1

   (b) Show that the total impedance between the points A and B in the following circuit is $z = 3R$ with $L = \frac{\sqrt{3}R}{\omega}$ and $C = \frac{1}{\sqrt{3}\omega R}$, where ω is the angular frequency of the AC voltage applied. 3



   (c) Obtain an expression for the power factor of an AC circuit. Explain the term 'wattless' current. 2+1

   (d) A coil of resistance 10 Ω and inductance 0.1 H is connected in series with a capacitance of 150 μF across a 200 V, 50 Hz supply. Calculate the current, the power factor and the power consumed in the circuit. 3

9. (a) Apply Biot-Savart's law to calculate the magnetic field at a distance z from a coil having n turns, along the axis of the coil. The coil carries a current I. Hence find the field at the centre of the coil. 3+1

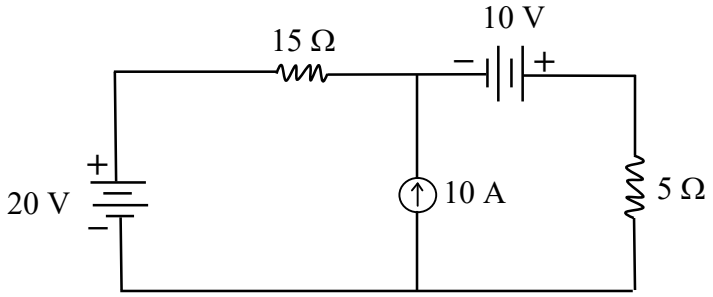
   (b) Derive Ampere's circuital law in terms of the magnetic intensity H. 2

   (c) Show that the field due to a dipole of moment $\vec{P}$ at a distance $\vec{r}$ is given by 4

$$\vec{E}(\vec{r}) = \frac{1}{4\pi\varepsilon_0}\left[\frac{3(\vec{p}\cdot\vec{r})\vec{r}}{r^5} - \frac{\vec{p}}{r^3}\right]$$

10.(a) State and explain superposition theorem. 2

(b) Find the voltage across the 15 Ω resistor using superposition theorem. 4



(c) Find the Thevenin equivalent circuit between the points *a* and *b* for the following network. Hence state the value of resistance to be connected at load between points *a* and *b* so that maximum power is transfered to the load. Also calculate the power. 4