BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI (RAJ)

SEMESTER I 2023 - 2024

Electromagnetic Theory I (PHY F212): COMPRE - PART B

Date : 6 Dec 2023 **Open Book** **Marks: 60** **Duration max: 90 min**

All the parts should be answered together. All bold face characters represents vectors.

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1. Two homogeneous cylindrical dielectric regions have dielectric constants $\varepsilon_1 = 5$ (Inner region, $s < 10$ cm) and $\varepsilon_2 = 3$ (Outer region, $s > 10$ cm), respectively. The electric displacement at the interface of outer region is given as $\mathbf{D}_2 = 12\mathbf{s} - 6\boldsymbol{\phi} + 9\mathbf{k}$ C/m^2, where s, ϕ and k are unit vectors in cylindrical coordinate system.

   (a) Find the electric displacement of inner region $\mathbf{D}_1$ at $s = 10$ cm.

   (b) Also find the deviation of electric field $\mathbf{E}$ (angle in degree) at the interface.

   (c) If some free charge is added to the dielectric and it shows a surface charge density $\sigma_f = 10$ C/m^2 at the interface, find the new value of $\mathbf{D}_1$ at $s = 10$ cm. **[6+4+3 = 13M]**

2. A long straight wire of radius $3a$ (along Z-axis) has a circular hole of radius a parallel to its own axis but displaced from the center by a distance a along X-axis. If a current I flows in the wire and is uniformly distributed across the conductor, find the magnetic field $\mathbf{B}$ within and outside the conductor using Cartesian unit vectors $\hat{\mathbf{x}}$, $\hat{\mathbf{y}}$, and $\hat{\mathbf{z}}$. **[17M]**

3. An infinite straight wire carries a current I is placed to the left of a rectangular loop of wire with width w and length l as shown in Fig 1. The total resistance of the loop is R.

   (a) Determine the magnetic flux through the rectangular loop due to the current I.

   (b) If the loop moves to the right with a velocity v, what is the induced emf in the loop and the direction of the induced current?

   (c) What is the magnetic force on the loop? In what direction?

   (d) If the loop starts out at $s = d$ with a speed v_0 (to the right) at $t = 0$ and slides freely, what is its speed as a function of distance s? **[4+4+4+4 = 16M]**

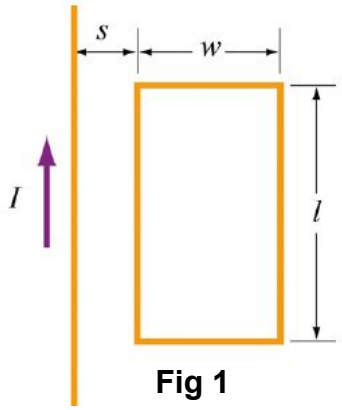

Fig 1

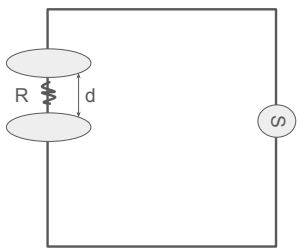

Fig 2

4. A parallel-plate capacitor has circular plates of area A separated by a distance d. A thin straight wire of length d lies along the axis of the capacitor and connects the two plates as shown in Fig 2. This wire has a resistance R. The exterior terminals of the plates are connected to a source of alternating emf with a voltage $V(t) = V_0 \sin(\omega t)$.

   (a) What is the displacement current through the capacitor ?

   (b) What is the current in the thin wire? What is the current arriving at the outside terminals of the capacitor ?

   (c) What is the magnetic field between the capacitor plates at a distance s from the axis ? Assume that s is less than the radius of the plates. **[5+5+4 = 14M]**