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NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

Department of Physics

PH1003E Electricity and Magnetism

Endsemester Examination - Winter 2024-25

Time: 3 Hours | Maximum Marks: 50

Answer All Questions

1. Answer the following questions briefly. (1×10=10 Marks)

   (a) Justify why the static electric field can be represented as the gradient of a scalar potential.

   (b) When a linear dielectric material is inserted into the space between the parallel plates of a capacitor, the capacitance may increase, decrease or remain the same. True or False? Justify.

   (c) The charges in a perfect conductor rearrange to make the electric field inside it .....

   (d) The vector potential that determines the magnetic field is not unique. Justify.

   (e) The potential due to a magnetic dipole falls of as $1/r^n$, where $n = \ldots$

   (f) Two circular loops are placed with center at the same point and on perpendicular planes. Their mutual inductance is zero. True or False? Justify.

   (g) The currents induced in a loop by changing magnetic flux generate magnetic fields that (opposes/strengthens) the change.

   (h) In a long straight cylindrical wire, a constant current is flowing. The direction of the Poynting vector is (parallel/anti-parallel/towards the axis/away from the axis)

   (i) In magnetostatics, the divergence of **H** is zero when .....

   (j) Any current carrying system will always have a non-zero self inductance. True or False? Justify.

2. A sphere of radius R, whose volume had been charged with a constant density ρ, is split with a very narrow, planar gap passing through its center. Calculate the force of mutual repulsion of the resulting two hemispheres. The volume element in spherical coordinates is given by $dV = r^2 \sin\theta dr d\theta d\phi$. (4 marks)

3. A long cylindrical shell of inner radius 2 m and outer radius 4 m has a uniform charge density ρ C/m^3. Find the electric field $\vec{E}$ using the Gauss law in all regions. (4 Marks)

4. Calculate the electrostatic energy U of a spherical shell of inner radius R_1 and outer radius R_2, with a charge Q uniformly distributed through its volume. (4 marks)

5. A magnetic material of cylindrical shape, having radius a and permeability $\mu > \mu_0$, is placed coaxially inside a cylindrical solenoid carrying a current I and having a radius b and n turns per unit length. The remaining volume inside the solenoid is filled with air. Assuming that both the solenoid and cylinder are infinitely long and the magnetic material is linear,

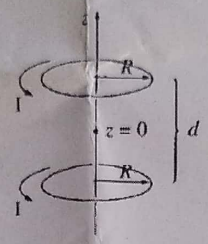
   (a) calculate $\vec{H}$, $\vec{B}$ and $\vec{M}$ inside the solenoid. Plot H, B and M as a function of the radial distance from the axis.

   (b) calculate the bound volume and bound surface current density. (3+1=4 Marks)

6. A coaxial cable consists of a long cylindrical copper wire of radius r_1 surrounded by a cylindrical shell of inner radius r_2 and outer radius r_3. The wire and the shell carry equal and opposite currents I uniformly distributed over their volumes. Find the magnetic fields in each of the regions $r < r_1$, $r_1 < r < r_2$, $r_2 < r < r_3$ and $r > r_3$. (4 Marks)

7. (a) Find the magnetic field B as a function of z, and show that $\frac{\partial B}{\partial z}$ is zero at the point midway ($z = 0$) between arrangement of two circular current loops, known as a Helmholtz coil (Shown in Figure below).

   (b) Determine d such that $\frac{\partial^2 B}{\partial z^2} = 0$ at the midpoint. (3+1=4 Marks)



8. A circular loop of radius a having N turns is placed in a uniform magnetic field $\vec{B}$ which is perpendicular to the plane of the circular loop. Find the emf induced in the loop, if the loop is rotated with a uniform angular velocity ω about

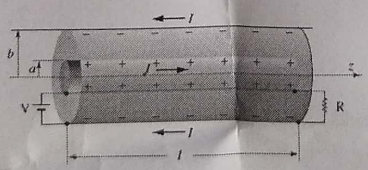
   (a) an axis passing through the center and perpendicular to the plane of the loop.

   (b) an axis along the diameter. (1+3=4 Marks)

9. A parallel plate capacitor with circular plates of radius R and vacuum between the plates, is being charged. Obtain the induced magnetic field in terms of the electric field $\vec{E}$ between the plates, for a distance $s < R$ and $s \geq R$, where s is the radial distance from the axis of the capacitor. Assume that the electric field does not fringe over the edge of the capacitor plates. (4 Marks)

10. A long coaxial cable consists of an inner solid conducting cylinder of radius a, carrying a uniform current I, and an outer thin conducting shell, of radius b, carrying an identical current in the opposite direction to that of the inner conductor. The conductor in addition is charged positive with a uniform charge density per unit length λ, while the shell is charged negative, with the same charge density. Calculate the electric field, magnetic field and the Poynting vector for the system.

(4 Marks)



11. In free space the electric field of a plane electromagnetic wave is given by

$$\vec{E} = 50\cos(\omega t - kz)\hat{x} \ \text{V/m}.$$

   (a) Find out the magnetic field $\vec{B}$.

   (b) Find the average power crossing a circular area of radius 2.5 m in the plane z=constant.

(1+3=4 Marks)