# PH108 : Electricity & Magnetism : Problem Set 10

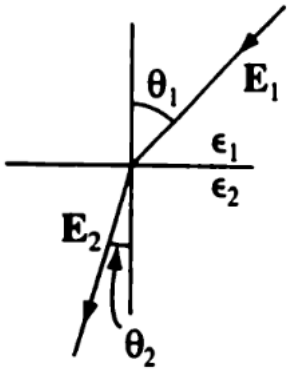
Only * problems are to be solved in the tut session

1. A cylinder of radius $a$ and length $2L$ is placed with its axis along $\hat{z}$ and its center at the origin. It has an uniform frozen electric polarisation $\vec{P} = P_0\hat{z}$. It is set rotating with angular velocity $\omega$ about the direction of polarisation. Calculate the magnetic field $\vec{B}$ at a point on the $\hat{z}$ axis.

2. A sphere of linear dielectric material has embedded in it a uniform free charge density $\rho$. Find the potential at the center of the sphere (relative to infinity), if its radius is $R$ and the dielectric constant is $\epsilon_r$.

3. * An uncharged conducting sphere of radius $a$ is coated with a thick insulating shell (dielectric constant $\epsilon_r$) out to radius $b$ . This object is now placed in an otherwise uniform electric field $E_0$. Find the electric field in the insulator.

4. * Two dielectrics having permittivity $\epsilon_1$ and $\epsilon_2$ have an interface which has no free charges. The electric field in medium 1 makes an angle 1 with perpendicular of interface while, the field in medium 2 makes an angle 2. Find the Relationship between two angles.




5. Consider an infinite cylindrical region with its axis along $\hat{z}$ and radius $R$. Consider another parallel cylinder running along $\hat{z}$ of radius $a$ with axis at a distance $b$ from the larger cylinder. Assume that $b$ is small enough that the smaller cylinder is a 'cavity' in the larger. Suppose that a magnetic field $\mathbf{B}(t) = B_0 t\hat{z}$ exists everywhere inside the larger cylinder except for the cavity. Find the Electric field induced inside the cavity.

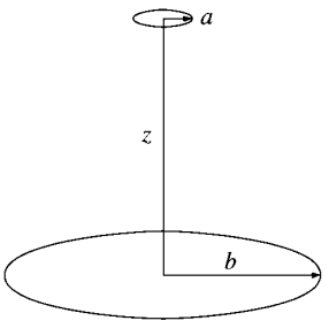
6. * A charge $Q$ is distributed uniformly on a non-conducting ring of radius $R$ and mass $M$. The ring is dropped from rest from a height $h$ and falls to the ground through a non-uniform magnetic field $\mathbf{B(r)}$. The plane of the ring remains horizontal during its fall.

   (a) Explain qualitatively why the ring rotates as it falls.

   (b) Use Faraday's flux rule to show that the velocity of the center of mass of the ring when it hits the ground is

$$v_{CM} = \sqrt{2gh - \frac{Q^2R^2}{4M^2}\left[B_z(0) - B_z(h)\right]^2}$$

7. * Two circular loops of wire share the same axis but are displaced vertically by a distance, z. The wire of radius a is considerably smaller than the wire of radius b.




(a) The larger loop (of radius b) carries a current I. What is the magnetic flux through the smaller loop due to the larger? (Hint: The field of the large loop may be considered constant in the region of the smaller loop.)

(b) If the same current I now flows in the smaller loop, then what is the magnetic flux through the larger loop? (Hint: The field of the smaller loop may be treated as a dipole.)

(c) What is the mutual inductance of this system? Show that $M_{12}$=$M_{21}$

8. A rectangular capacitor with side lengths a and b has separation s, with s much smaller than a and b. It is partially filled with a dielectric with dielectric constant $\kappa$. The overlap distance is x. The capacitor is isolated and has constant charge Q

   (a) What is the energy stored in the system? (Treat the capacitor like two capacitors in parallel.)

   (b) What is the force on the dielectric? Does this force pull the dielectric into the capacitor or push it out?