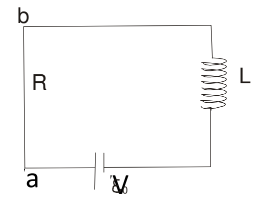
SB/HCV

PHY 103: General Physics 2 (2014 – 2015, Semester – I)

Department of Physics, Indian Institute of Technology - Kanpur

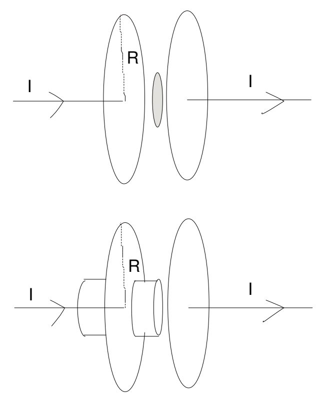
Assignment- 11

(ONLY the *ed questions will be DONE in the tutorial)

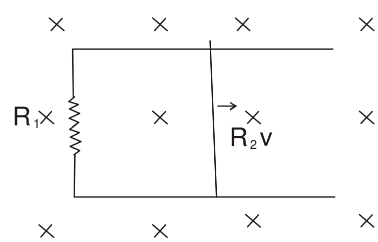


1 A cylindrical thin wire ab of length l, area of cross-section A and resistance R, is connected to a battery of emf V and an inductor of inductance L. The switch is put on at $t=0$. Find the magnitude of $\nabla\times\mathbf{B}$ at a point inside the wire as a function of time.

2 A positive charge q is moving along the positive x-axis with a velocity $v << c$. Determine the displacement current density J_d at a point (i) $x=x_0$ on the x-axis, (ii) $y=y_0$ on the y axis, when the charge q is at the origin.



3*. Long straight wires carry a constant current I in the z-direction to a parallel plate capacitor having circular plates. Take the center of the capacitor as the origin. Each plate has a radius R which is much larger than the separation between the plates and the wires connect to the centers of the plates. Assume that the surface charge is uniform over the surface of the plates at any given time, being zero at t=0. (a) What is the displacement current in the space between the plates? Outside the plates? (b) Consider a circle of radius s (<R), in the plane z = 0 (upper part of the figure). Get the magnetic field at the periphery of this circle from the Ampere-Maxwell equation $\oint \vec{B}\cdot d\vec{l} = \mu_0\int(\vec{J}+\varepsilon_0\frac{\partial\vec{E}}{\partial t})\cdot d\vec{a}$ using this circle as the closed curve and the flat circular area enclosed by it as the surface area bounded by it. (c) Now consider an open cylindrical surface, as shown in the lower part of the figure, with the circle of radius r as the periphery. Explicitly evaluate the right side of the Ampere-Maxwell equation on this surface and see that it is the same as that calculated in part (b). Neglect any fringing effect.



4. The figure shows two thick metallic rails in a perpendicular constant magnetic field B. The rails are joined by a resistant R_1 at the left end. Another wire of resistance R_2 slides on the rails with a velocity v as shown. Find the electric field inside the sliding wire.

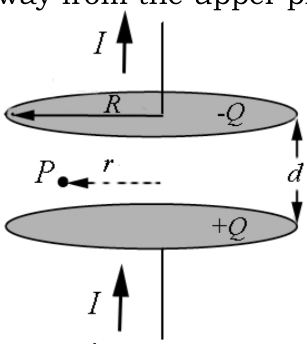
5. The E, B fields in a region varies as follows.

$$\mathbf{B}(\mathbf{r},t)=0\ ,\ \mathbf{E}(\mathbf{r},t)=\frac{K}{r^2}\hat{r}\ \text{if}\ r<vt\ ,=0\ \text{if}\ r>vt\,.$$

(a) Find the charge density everywhere. (b) Find the displacement current density everywhere

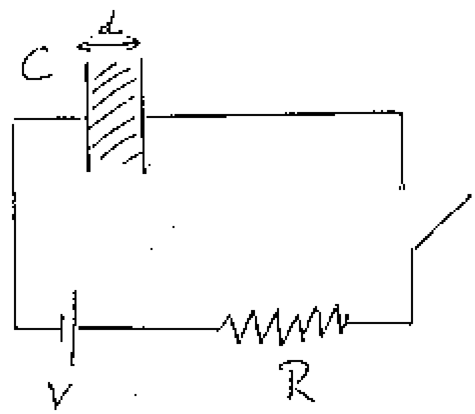
(c) Find the current density everywhere

6. A parallel-plate capacitor consists of two circular plates, each with radius R, separated by a distance d. A steady current I is flowing towards the lower plate and away from the upper plate, charging the plates.



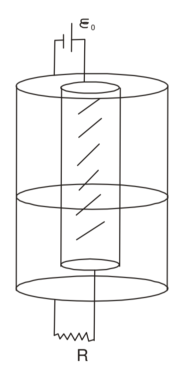
(a) What is the direction and magnitude of the electric field **E** between the plates? You may neglect any fringing fields due to edge effects.
(b) What is the magnetic field **B** at a point P located between the plates at radius r <R .
(c) What is the direction and magnitude of the Poynting vector **S** at a distance r from the center of the capacitor.
(d) By integrating **S** over an appropriate surface, find the power that flows into the volume of the capacitor up to r <R and compare with energy stored in the capacitor.

7. A parallel plate capacitor consists of two circular metal plates of radius a, separated by a distance d. The insulating material between the plates has a dielectric permittivity $\varepsilon = \varepsilon_0$. At time t = 0 we close the switch. As a function of time, and ignoring edge effects, compute the following quantities for all spatial points within the dielectric material: (a) the electric field, (b) the magnetic field, (c) the Poynting vector, (d) total energy stored in the capacitor as t --> ∞ by integrating S over appropriate surface and time.

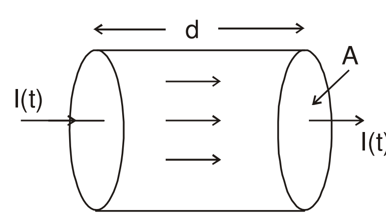


8. A very long solenoid of radius a, with n turns per unit length, carries a current I. A circular ring of much larger radius b and having a resistance R, is placed coaxially with the solenoid. The current in the solenoid is gradually increased and this induces a current in the ring. (a) Find the induced electric field just outside the solenoid; (b) Find the magnetic field just outside the solenoid, produced by the current in the ring (c) Find the power loss in the ring. (d) Find the Poynting vector just outside the solenoid and from this the total every flowing away from the solenoid. Compare with the answer in part (c).

9*. A long cylindrical wire of radius a is surrounded by a coaxial cylindrical tube of radius b. Assume the two to have negligible resistances. They are connected to a battery of emf ε_0 at one and to a resistor of resistance R at the other end. (a) Find the surface charge density appearing on the inner wire. (b) What is the electric field in the space between the two, i.e. $a < s < b$? (c) Find the magnetic field in the regions $a < s < b$. (d) Find the Poynting vector **S** in the region $a < s < b$. (e) Consider a cross-section, $a < s < b$ in the space between the two conductors. How much energy flows through this area per unit time?



10. Suppose a cylindrical conductor of length d and area of cross-section A is connected to two thin wires at the end faces as shown in figure. Suppose the wires carry current I



which varies with time. Also suppose the electric field in the conductor is maintained by charges Q and $-Q$ appearing at the end faces.

(a) Show that $\varepsilon_0 \rho \dfrac{dI_1}{dt} + I_1 = I$ where I_1 is the conduction current in the conductor.

(b) Show that the first term in the above represents displacement current through a cross section of the conductor.

11. Consider a cylindrical wire of radius R which carries a current I distributed uniformly over its cross-section. Consider the volume element $d\tau = s ds d\phi dz$ of the wire.
(a) Calculate $\mathbf{E} \cdot \mathbf{J} d\tau$ and check that it is equal to $I^2 r$ where I is the current through the element and r is its resistance.
(b) Calculate the Poynting vector $\mathbf{S}$.
(c) Show that the rate of energy deposited in the volume element, obtained using $\mathbf{S} \cdot \mathbf{da}$ at appropriate surfaces, is save as the thermal energy developed in the element.