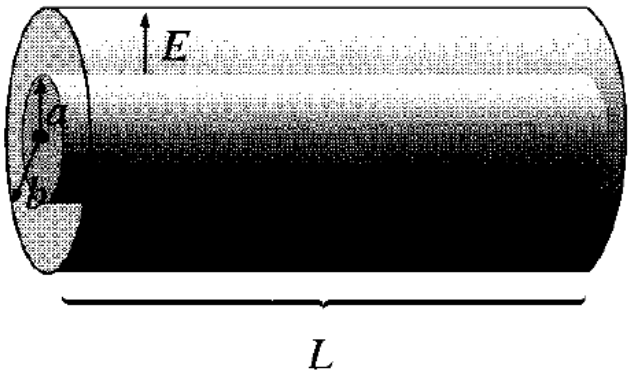
Department of Physics, IIT Kanpur

Semester-1, 2016-17

PHY103 Problem Set # 9 Date: September 28, 2016 [RCB/Krishnacharya]

1. Two long cylinders (radii a and b) are separated by material of conductivity $\sigma(s) = k/s$ (where k is a constant), if they are maintained at a potential difference V, find the resistance between the cylinders.



2. (a) Two metal objects are embedded in weakly conducting material of conductivity σ, show that the resistance between them is related to the capacitance of the arrangement by $R = \varepsilon_0/\sigma C$
   (b) Suppose you connect a battery between 1 and 2 and charge them up to a potential difference V_0. If you then disconnect the battery, the charge will gradually leak off. Show that $V(t) = V_0 e^{(-t/\tau)}$ and find the time constant τ, in terms of ε_0 and σ.

3. A metal bar of mass m slides frictionlessly on two parallel conducting rails a distance l apart. A resistor R is connected across the rails and a uniform magnetic field **B**, pointing into the page, fills the entire region.
   (a) If the bar moves to the right at speed v, what is the current in the resistor? In what direction does it flow?
   (b) What is the magnetic force on the bar? In what direction?
   (c) If the bar starts out with speed v_0 at time t = 0, and is left to slide, what is the speed at a later time t?
   (d) The initial kinetic energy of the bar, of course, $mv_0^2/2$. Check that the energy delivered to the resistor is exactly $mv_0^2/2$

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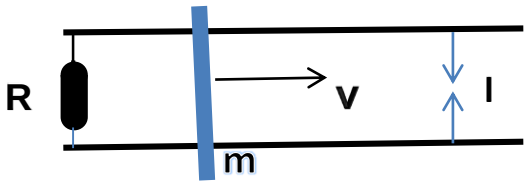
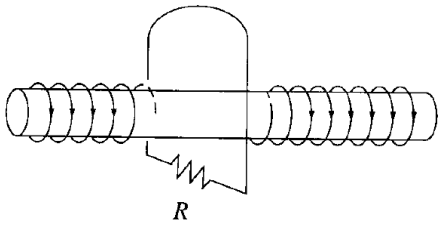


4. An alternating current $I = I_0 \cos(\omega t)$ flows down a long straight wire, and returns along a coaxial conducting tube of radius a.
   (a) In what direction does the induced emf point (radial, circumferential or longitudinal)
   (b) Assume that the field goes to zero as s tend to infinity, find **E**(s,t).

5. A long solenoid of radius a, carrying n turns per unit length, is looped by a wire of with resistance R, as shown in the figure below.
   (a) If the current in the solenoid is increasing at a constant rate ($dI/dt = k$), what current flow in the loop, and which way (left or right) does it pass through the resistor?
   (b) If the current I in the solenoid is constant but the solenoid is pulled out of the loop and reinserted in the opposite direction, what total charge passes through the resistor?



6. A small loop of wire (radius a) lies at a distance z above the centre of the large loop (radius b), as shown in the figure below. The planes of two loops are parallel, and perpendicular to the common axis.
   (a) Suppose current I flows in the big loop. Find the flux through the little loop (the little loop is so small that the field of big loop over the small loop is constant)
   (b) Suppose current I flows in the little loop. Find the flux through the big loop (the little loop may be treated as a magnetic dipole).
   (c) Find the mutual inductance and confirm that $M_{12} = M_{21}$.