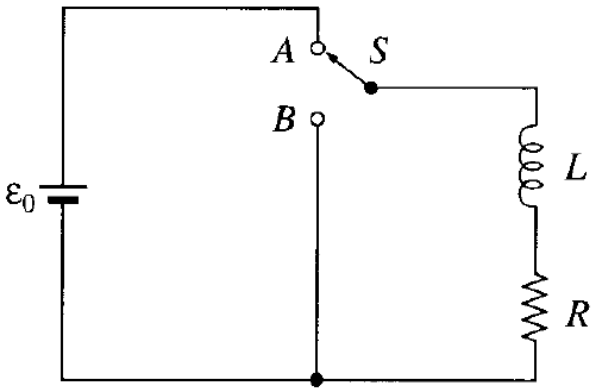
Department of Physics, IIT Kanpur

Semester-1, 2016-17

PHY103 Problem Set # 10 Date: October 04, 2016 [RCB/Krishnacharya]

1. Consider the circuit shown below which has been connected to the battery through the switch S for long. Now at time t=0 suddenly the switch is thrown, bypassing the battery.
   (a) What is the current at any subsequent time?
   (b) What is the total energy delivered to the resistor?
   (c) Show that this is equal to the energy originally stored in the inductor.



2. Consider a parallel plate capacitor with each plate of radius a and a constant current I flows to charge the plates. Assume that the current flows out over the plates in such a way that the surface charge is uniform, at any given time, and is zero at t = 0. Gap between the plates w << a.
   (a) Find the electric field between the plates, as a function of time.
   (b) Find the displacement current through a circle of radius s in the plane midway between the plates. Using the circle as your Amperian loop and the flat surface that span it, find the magnetic field at distance s from the axis.
   (c) Repeat (b) , but this time use a cylindrical surface that extends to the left through the plate and extend outside the capacitor.

3. The electric field produced by an alternating current $I = I_0 \cos(\omega t)$ that flows down a straight wire, and returns along a coaxial conducting tube of radius a is given as;
   $\mathbf{E}(s,t) = (\mu_0 I_0 \omega/2\pi) \sin(\omega t) \ln(a/s)\hat{\boldsymbol{z}}$
   (a) Find displacement current density J_d
   (b) Integrate it to get total displacement current I_d
   (c) Compare I_d and I. What is their ratio? If the outer cylinder is say 2 mm in diameter, how high the frequency have to be for I_d to be 1% of I?

4. Suppose

$$\mathbf{E}(\mathbf{r},t) = -\frac{1}{4\pi\epsilon_0}\frac{q}{r^2}\theta(vt-r)\hat{\mathbf{r}};\quad \mathbf{B}(\mathbf{r},t) = 0$$

Show that these fields satisfy all of Maxwell's equations, and determine ρ and J. Describe the physical situation that gives rise to these fields.

5. Sea water at frequency $\upsilon = 4 \times 10^{8}$ Hz has permittivity $\varepsilon = 81\ \varepsilon_0$, permeability $\mu = \mu_0$ and resistivity $\rho = 0.23\ \Omega$.m. What is the ratio of conduction current to displacement current?