PHY 103N: PHYSICS 2, (2007-2008, Semester -II) *(SAR/HW)*

Department of Physics, I.I.T. Kanpur

Assignment - 7 **Displacement current, Poynting theorem, Relativistic field transformations**

---

1. A parallel plate capacitor is immersed in sea water and driven by a sinusoidal voltage with frequency 4×10^8 Hz. Relative permittivity of sea water is 80 at this frequency, relative permeability is close to 1 and the resistivity is 0.23 Ωm. Find the ratio of the conduction current to the displacement current in the capacitor.

2. A parallel plate capacitor is made of two circular sheets of radius R with a separation of $d << R$. The capacitor is getting charged at a very slow rate with the charge $Q(t) = Q_o\{1 - \exp(-t/t_o)\}$.
   a) Plot the charge as a function of time.
   b) Determine and plot the displacement current as a function of time
   c) Determine the magnetic field in between the plates.
   What is the source of the magnetic field; when and where would the above analysis represent the true fields in between the plates?

3. A long straight conductor of conductivity carries a steady current I. Show that the energy dissipated by the Joule heating is replenished by the in flow of the energy. Connect this with the Poynting theorem.

4. Repeat the above calculation for a long solenoid of radius R encircled by a symmetrically placed conducting loop of radius $4R$. The Solenoid is carrying a weakly time dependent current $I(t)$.

5. An infinite sheet of charge with a constant surface charge density density σ (in the rest frame) is moving along the normal (to the surface) with a constant velocity $\vec{v} = v\hat{i}$. Determine the electric and magnetic fields everywhere by field transformations. Hence "verify" the solutions that you obtained for a similar problem directly.

6. A parallel plate capacitor is at rest in the lab frame S. The plates are tilted at an angle of 45^o from the x-axis. The charge density on the plates is $\pm\sigma_o$. Determine the following from the point of view of S'.
   a) What are the electric and magnetic fields ?
   b) Does the electric field continue to remain normal to the plates, if not, then determine that angle?

7. Using the Field transformations between frames S and S', explicitly verify that $E^2 - c^2B^2$ and $\vec{E} \cdot \vec{B}$ are Lorentz invariant.