PHY 552: Electromagnetic Theory - 1, (2011-12, Semester -I)

Department of Physics, I.I.T. Kanpur

Assignment – 2 (Solving for electrostatic fields and potentials)

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1. Consider a surface comprising a dipole layer with a dipole moment density of $\vec{p}(\vec{r})$. Find the conditions relating the electrostatic potentials on either side of the surface. Can you solve for the potential associated with a uniform, flat, and infinitely large dipole layer?

2. Consider the potential of a neutral hydrogen atom given by

$$\phi(\vec{r}) = \frac{q}{4\pi\varepsilon_0} \frac{e^{-\alpha r}}{r} \left(1 + \frac{\alpha r}{2}\right).$$

   Find the distribution of the charge that gives rise to this potential and discuss your result physically.

3. Discuss the issue of charge screening and stability of a colloid composed of spherical nanoparticles of silica or polystyrene. Try to understand how pH affects the stability.

4. A charge q is uniformly distributed on a straight line of length $2c$. Calculate the electrostatic potential everywhere. You may find it convenient to choose the origin to be at the centre of the rod. Discuss the equipotential surfaces associated with this charge distribution. (Hint: you may find it easy to use the elliptic coordinates here). Using this result obtain the capacitance of a conducting ellipsoid of revolution with with major axis $2a$ and minor axes $2b$.

5. Obtain the charge distribution that forms on the surface of a planar conductor when a charge q is placed at a distance z from the surface. Find the work done to remove the charge to infinity from its initial location.

6. Obtain the force between a charge q kept at a distance $z > a$ from a conducting sphere of radius a if,
   (a) The sphere were uncharged and isolated; (b) If the sphere was isolated, but carrying a charge Q; and (c) If the sphere were kept at a constant potential V.
   Make a plot of the force for all the above cases with the distance z and analyze various cases for positive and negative Q and V. In each case, find the work required to be done to move the charge from z to infinity. For the case of (c), calculate the charge distribution induced on the sphere when $V = 0$ and plot it for various z.

7. Using the field due to a uniformly charged sphere with charge density ρ and considering two overlapping spheres with equal but opposite charge distributions, obtain the surface charge distribution for a conducting sphere placed within a uniform electric field. Now using this charge distribution, obtain the electric fields everywhere.

8. Obtain the capacitance per unit length for a typical co-axial cable used by you in your experiments. (If you do not know the spatial dimensions, go to the lab., cut a cable and measure). Similarly, calculate the capacitance per unit length of two straight long conductors, assumed cylindrical with radius a, and placed a distance r_0 away from each other. This is the case of a bus bar. In both the above cases, the capacitance would affect the data transfer rate. Pay some thought and try to understand this issue.