# Electrodynamics-I, Problem set 2

Due date: Thursday, Oct. 15, 2011

*Please explain your reasoning clearly and show the steps in your calculations*

1. Show that:

   (a) The value of the electric field $\vec{E}$ inside a conductor vanishes when charges within it are in equilibrium (*i.e.*, there are no currents).

   (b) Any excess charge placed on a conductor must lie entirely on its surface.

   (c) A closed hollow conductor shields its interior from fields due to charges outside, but does not shield its exterior from the fields due to charges placed inside it.

   (d) The electric field at the surface of a conductor is normal to the surface and its tangential component along the surface vanishes. The normal component has a magnitude $4\pi\sigma$, where $\sigma$ is the surface charge density.

2. The time average potential of a neutral hydrogen atom is given by

$$\Phi(r) = q\,\frac{e^{-\alpha r}}{r}\left(1+\frac{\alpha r}{2}\right)$$

   where $q$ is the magnitude of the electronic charge and $\alpha$ is a constant. Find the distribution of charge (both continuous and discrete) which will give this potential and interpret your result physically.

3. (a) Consider the multipole moments of a charge distribution $\rho(r,\theta,\phi)$,

$$q_{lm} = \int r^2 dr \int \sin\theta d\theta \int d\phi \rho(r,\theta,\phi)\, r^l\, Y^*_{lm}(\theta,\phi)$$

   Show that for a *spherically symmetric* charge distribution, all moments beyond the monopole moment vanish (hence the higher moments quantify deviations from sphericity).

   (b) Write the components of a unit vector $\hat{n}$ in spherical polar coordinates and then express them in terms of spherical harmonics (*Hint: Only* $Y_{l=1,m}(\theta,\phi)$ *will contribute*).

   (c) Express the dipole moment $\vec{p}$ in rectangular coordinate system in terms of the dipole moment $q_{1,m}$ in spherical coordinates.

4. (a) Consider two point charges $+q$ and $-q$ with a separation $\vec{y}$, which is small but *finite* (this system forms a non-ideal dipole). Compute the first non-vanishing multipole moment beyond the dipole moment.

(b) Consider a system of two colinear but oppositely oriented dipoles $\vec{p}$ and $-\vec{p}$ placed a distance $\vec{y}$ appart. Find the dipole and quadrupole moments of this system.

(c) Find the interaction energy between two non-coincident dipoles with moments $\vec{p}_1$ and $\vec{p}_2$.