PHY 103: General Physics 2 (2014 – 2015, Semester – I)

Department of Physics

Indian Institute of Technology - Kanpur

Assignment-4

Note: The questions marked with circles are to be solved by the students as Home Work. These will not be solved in the tutorials. The students are encouraged to clear any doubts on these questions during the office hours of tutors.

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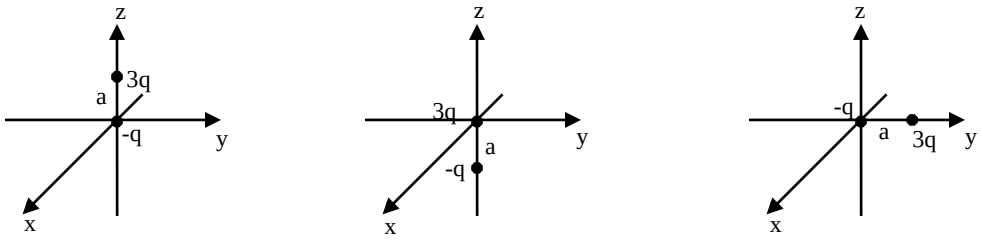
1. A point dipole p is situated at the origin, pointing in the z direction.
   (a) What is the force on a point charge q at (a, 0, 0) (Cartesian coordinates)?
   (b) What is the force on q at (0, 0, a)?
   (c) How much work does it take to move q from (a, 0, 0) to (0, 0, a)?

2. Two point charges $3q$ and $-q$, are separated by a distance a. For each of the arrangements shown below, find (i) the monopole moment, (ii) the dipole moment, and the approximate potential (in spherical coordinates) at large r (include both monopole and dipole contributions).



(a) (b) (c)

3. A sphere of radius R, centered at the origin, carries a charge density

$$\rho(r,\theta) = k\frac{R}{r^2}(R-2r)\sin\theta\,,$$

where k is a constant, and r, θ are the usual spherical coordinates. Find the approximate potential for points on the z axis, far from the sphere (Use multipole expansion).

4. A small dipole of size d is kept at a distance r from the center of an uncharged conducting sphere of radius a (d<<a, d<<r). Estimate for both parallel and perpendicular orientations of the dipole the, (a) induced dipole moments on the conducting sphere taking the center of the sphere as the origin (b) the interaction energy of the dipole and the sphere, and (c) the force between the dipole and the conducting sphere.

5. Prove that the electric field at any point $\vec{r}$ due to a dipole with moment $\vec{p}$ placed at the origin is

$$\vec{E} = \frac{1}{4\pi\varepsilon_o}\left[\frac{3(\vec{p}.\hat{r})\hat{r} - \vec{p}}{r^3}\right]$$

If another dipole with dipole moment $\vec{p}_1$ is brought a distance $\vec{r}$ apart from the above dipole. Show that the interaction energy of the two dipoles is

$$U = \frac{1}{4\pi\varepsilon_o}\left[\frac{(\vec{p}.\vec{p}_1) - 3(\vec{p}.\hat{r})(\vec{p}_1.\hat{r})}{r^3}\right]$$