## DEPARTMENT OF PHYSICS
INDIAN INSTITUTE OF TECHNOLOGY, MADRAS

PH1020 Physics II

Tutorial 2 (29.1.2018)

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1. Consider a thick metallic spherical shell with inner and outer radii a and b, respectively, carrying a charge Q on it. A point charge q is fixed at the center of the shell. Calculate the charge on each surface of the shell, electric potential and field everywhere. Plot the variation of both the electric field and potential as a function of r, the distance from the center of the shell.

2. Show that the dipole moment of any arbitrary charge distribution $\rho(\vec{r'})$ depends on the choice of the origin. Determine the condition in which the dipole moment will be independent of the origin.

3. A dipole $\vec{p_1}$ is fixed at the origin and aligned along the x axis. Another dipole $\vec{p_2}$ is at the point $B(a, a)$ as shown in the figure.
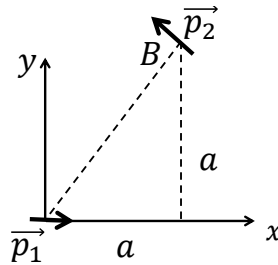
Find the orientation $\vec{p_2}$ will take if it is free to rotate in the xoy plane at B. After $\vec{p_2}$ has taken its equilibrium position, it is fixed in that position and $\vec{p_1}$ is allowed to rotate in the xoy plane at the origin. What orientation will $\vec{p_1}$ take? If $\vec{p_2}$ and $\vec{p_1}$ are both free to rotate in their places, what orientations will they take?

4. Consider the following distribution of three point charges: $2q$ at $(0, a, a)$; q at $(0, -a, a)$ and $-q$ at $(0, 0, -a)$.
   (a) Determine the dipole moment of this distribution and the dipole potential at $P(0, 0, z)$ where $z \gg a$.
   (b) Calculate the dipole field at $P(0, 0, z)$. Why is $\vec{E}_{dipole}(0, 0, z) \neq -\nabla_z V_{dipole}(0, 0, z)$?

5. A line charge on the z-axis extends from $z = -a$ to $z = +a$ and has linear charge density varying as

$$\lambda(z) = \begin{cases} \lambda_0 z^\alpha, & \text{when } 0 < z \leq a \\ -\lambda_0 |z|^\alpha, & \text{when } -a \leq z < 0 \end{cases}$$

where α is a positive constant and λ_0 is a positive constant of appropriate dimensions. Find the potential at any point (r, θ, ϕ) with $r > a$, up to the dipole term.