Intermediate :
[10+2]

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Potential due to a dipole

[Continued ...]

Again, $\frac{1}{r_1} = \frac{1}{r}\left(1 - \frac{2a\cos\theta}{r}\right)^{-1/2}$

Expanding by Binomial Theorem and retaining terms upto the first order in a/r, we have

$$\frac{1}{r_1} \simeq \frac{1}{r}\left(1 + \frac{a}{r}\cos\theta\right) \quad \text{——— (6)}$$

Similarly $$\frac{1}{r_2} \simeq \frac{1}{r}\left(1 - \frac{a}{r}\cos\theta\right) \quad \text{——— (7)}$$

Putting these values of $\frac{1}{r_1}$ and $\frac{1}{r_2}$ in eqn (1) we have

$$V = \frac{q}{4\pi\epsilon_0} \cdot \frac{2a\cos\theta}{r^2} = \frac{2aq\cos\theta}{4\pi\epsilon_0 r^2}$$

$$= \frac{P\cos\theta}{4\pi\epsilon_0 r^2} \quad \ldots (8)$$

Where $q \times 2a$ is the magnitude of the dipole moment vector $\vec{P}$.

Now $P\cos\theta = \vec{P}.\hat{r}$, where $\hat{r}$ is a unit vector along the position vector $\vec{OP}$. The electric moment of the dipole is then given by

$$V = \frac{1}{4\pi\epsilon_0} \cdot \frac{\vec{P}.\hat{r}}{r^2} \quad \ldots (9)$$

from eqn (9), potential at the dipole axis ($\theta = 0, \pi$) is given by

$$V = \pm \frac{1}{4\pi\epsilon_0} \frac{P}{r^2} \quad \text{—(10)}$$

The potential in the equitorial plane ($\theta = \pi/2$) is zero.

Equipotential Surface. The locus of all points which have the same potential is called an equipotential surface.

For a point charge, the equipotential surfaces are family of concentric spheres. Similarly, for a spherical charge the equipotential surfaces are also concentric spheres due to symmetric considerations. For a uniform electric field, the equipotential surfaces are planes perpendicular to the field. In fact, the equipotential surfaces are always at right angles to the lines of electric force and to the direction of electric field $\vec{E}$. If the electric field $\vec{E}$ were not at right angles to the equipotential surface it would have a component lying in that surface. Then work would have to be done in moving a test charge from one point to the other on the equipotential surface

But no work is done to move a test charge between any two points on an equipotential surface because there is difference of potential.

Therefore, $\vec{E}$ is always at right angles to an equipotential surface and no work is done in moving a charge from one point to the other on an equipotential surface.

Two equipotential surfaces can not intersect. If they intersect the point of intersection will have the two values of potential which is ~~impossible~~. not possible.