Electric dipole:

i) Two equal and opposite charges separated by a constant distance is called electric dipole. $\vec{P} = q.2\vec{l}$.

ii) **Dipole moment** $(\vec{P})$

Dipole moment is the product of one of the charges and distance between the charges. It is a vector directed from negative charge towards the positive charge along the line joining the two charges.

iii) The torque acting on an electric dipole placed in a uniform electric field is given by the relation $\vec{\tau} = \vec{P} \times \vec{E}$ i.e., $\tau = PE\sin\theta$, where θ is the angle between $\vec{P}$ and $\vec{E}$.

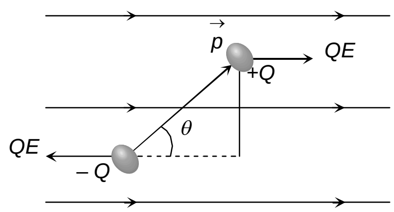
Dipole in an external electric field :

When a dipole is kept in an uniform electric field. The net force experienced by the dipole is zero as shown in fig.

The net torque experienced by the dipole is

$$\tau = pE\sin\theta$$

$$\vec{\tau} = \vec{p} \times \vec{E}$$



Hence due to torque so produced, dipole align itself in the direction of electric field. This is the position of stable equilibrium of dipole.

iv) The electric intensity(E) on the axial line at a distance 'd' from the centre of an electric dipole is $E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2Pd}{(d^2 - l^2)^2}$ and on equatorial line, the electric intensity (E) = $\frac{1}{4\pi\varepsilon_0} \cdot \frac{P}{(d^2 + l^2)^{3/2}}$.

v) For a short dipole i.e., if $l^2 << d^2$, then the electric intensity on axial line is given by $E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2P}{d^3}$.

vi) For a short dipole i.e., if $l^2 << d^2$, then the electric intensity on equatorial line is given by

$E = \frac{1}{4\pi\varepsilon_0} \cdot \frac{P}{d^3}$.

.vii) Electric intensity at any point on the bisector parallel to the bisector is zero.

Electric field due to a dipole (In Polar Co-ordinates)

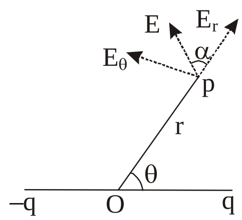
(i) There are two components of electric field at any point

(a) E_r - in the direction of $\vec{r}$

(b) E_θ - in the direction perpendicular to $\vec{r}$

$$E_r = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2P\cos\theta}{r^3}$$

$$E_\theta = \frac{1}{4\pi\varepsilon_0} \cdot \left(\frac{P\sin\theta}{r^3}\right)$$



(ii) Resultant

$$E = \sqrt{E_r^2 + E_\theta^2} = \frac{P}{4\pi\varepsilon_0 r^3}\sqrt{1+3\cos^2\theta}$$

(iii) Angle between the resultant $\vec{E}$ and $\vec{E}_r$ is given by, $\alpha = \tan^{-1}\left(\frac{E_\theta}{E_r}\right) = \tan^{-1}\left(\frac{1}{2}\tan\theta\right)$

(iv) If $\theta = 0$, i.e point is on the axis -

$$E_{axis} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2P}{r^3}$$

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(v) If $\theta = 90^o$, i.e. point is on the line bisecting the dipole perpendicularly

$$E_{equator} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{P}{r^3}$$

(vi) So, $E_{axis} = 2E_{equator}$ (for same r)

(vii) $$E_{axis} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2Pr}{(r^2 - \ell^2)^2}$$

$$E_{equator} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{P}{(r^2 + \ell^2)^{3/2}}$$

where $P = q.(2l)$

l-Separation between the two charges.