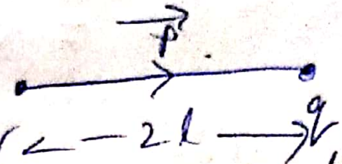
Electric dipole

An electric dipole is
* a pair of equal charge
* opposite point charges
* separated by a small distance

Electric dipole moment ($\vec{p}$):



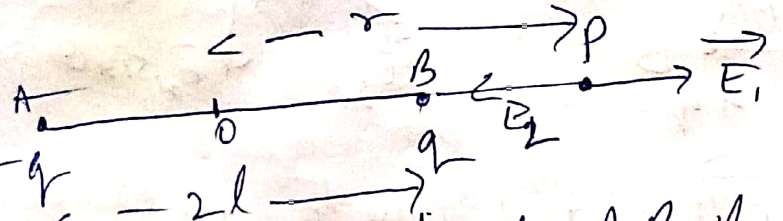
$\vec{p} = q(2\vec{l}) = q \times 2\vec{l}$

(direction of dipole moment is from negative to positive)

unit is Cm. Dimensional formula is [A T L]

e.g. HCl, H_2O.

Intensity of the Electric Field at a point on the AXIS of a dipole (AXIAL LINE) (END-ON-POSITION)



Let us consider dipole AB of length '2l'. P is any point at a distance r from the centre of dipole 'O'.

The electric field at P due to +q charge is

$$E_1 = \frac{1}{4\pi\epsilon_0}\frac{q}{(r-l)} \quad \text{—(1)} \quad \text{(along the dipole axis)}$$

The electric field at P due to −q charge is

$$E_2 = \frac{1}{4\pi\epsilon_0}\frac{q}{(r+l)} \quad \text{—(2)} \quad \text{(opposite to the dipole axis)}$$

Resultant Electric field is

$$E = E_1 - E_2 = \frac{1}{4\pi\epsilon_0} q\left[\frac{1}{(r-l)^2} - \frac{1}{(r+l)^2}\right]$$

$$= \frac{1}{4\pi\epsilon_0} q\left[\frac{(r+l)^2 - (r+l)^2}{r^2 - l^2}\right] = \frac{1}{4\pi\epsilon_0}\frac{2(q\cdot 2l)\cdot r}{r^2 - l^2}$$

$$E = \frac{1}{4\pi\epsilon_0}\frac{2pr}{(r^2 - l^2)}$$

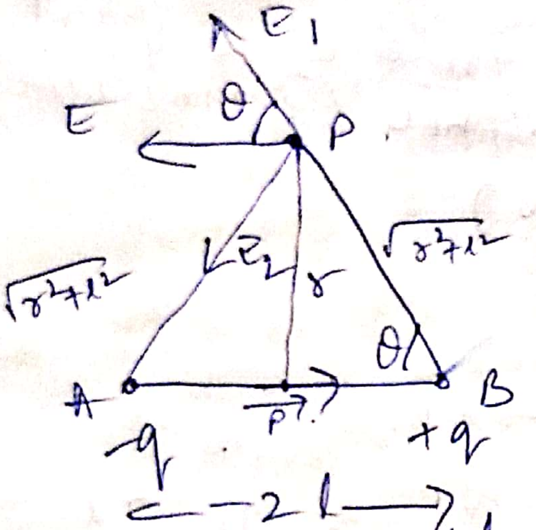
The direction of E is along the axis

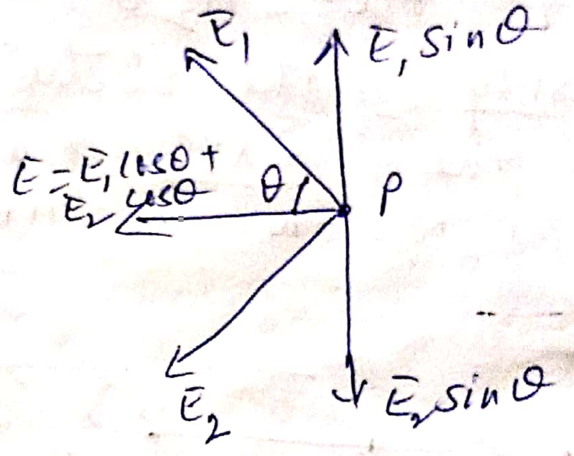
If $r >> l$ then

$$E = \frac{1}{4\pi\epsilon_0} \frac{2p}{r^3} \text{ newton/coulomb}$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{2\vec{p}}{r^3} \text{ newton/coulomb.}$$

Intensity of the Electric field at a point on the EQUATORIAL line of a dipole (BROAD SIDE ON POSITION)





The electric field at P due to +q charge is

$$E_1 = \frac{1}{4\pi\epsilon_0} \frac{q}{(r^2+l^2)} \quad \text{--- (1)}$$

The electric field at P due to '-q' charge is

$$E_2 = \frac{1}{4\pi\epsilon_0} \frac{q}{(r^2+l^2)} \quad \text{--- (2)}$$

$\therefore E_1 = E_2$

From the fig. the resultant electric field is $E = E_1\cos\theta + E_2\cos\theta$

$$= 2E_1\cos\theta$$

$$\cos\theta = \frac{l}{(r^2+l^2)^{1/2}}$$

$$\therefore E = 2 \cdot \frac{1}{4\pi\epsilon_0} \frac{q}{(r^2+l^2)} \frac{l}{(r^2+l^2)^{1/2}}$$

$$E = \frac{1}{4\pi\epsilon_0} \frac{P}{(r^2+l^2)^{3/2}}$$

The direction of electric field E is 'antiparallel' to the dipole axis

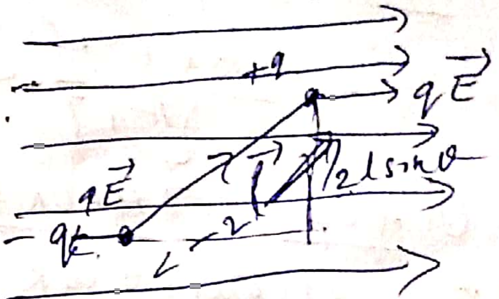
If $r >> l$. $E = \frac{1}{4\pi\epsilon_0} \frac{P}{r^3}$.

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{\vec{P}}{r^3} \text{ newton/coulomb}$$

$$\therefore \vec{E}_{axial} = -2\vec{E}_{equatorial}$$

TORQUE on a dipole in a UNIFORM Electric field

In Uniform electric field the net translatory force on dipole is ZERO. So there is no translatory motion.



Torque τ = (magnitude of force)(perpendicular distance)

$$\tau = qE(2l\sin\theta) = PE\sin\theta$$

$$\vec{\tau} = \vec{P} \times \vec{E} \text{ newton metre} \quad (P = q2l)$$

E = electric field.

Special cases

(1) If $\theta = 90°$ $\sin 90° = 1$

$$\tau_{max} = PE\sin 90° = PE$$

$$\tau_{max} = PE.$$

(2) If $\theta = 0°$, $\sin 0° = 0$

$$\tau = 0$$

(3) If $\theta = 180°$, $\sin 180° = 0$,

$$\tau = 0$$

Moment of an electric dipole is the torque acting on the dipole placed perpendicular to the direction of a uniform electric field of intensity 1 N/C