Electric Dipole.

classmate

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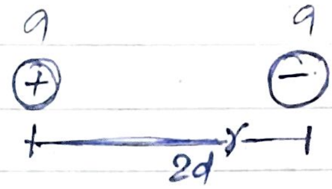
(i) combination of two charges +q and -q separated by small distance 2d constitutes an electric dipole.



This system of charges is called **dipole**

The line joining the two charges is called the dipole axis.

Electric dipole moment

* it is denoted by $\vec{p}$, and it is vector quantity.
* SI units —— Cm

$$p = 2qd$$

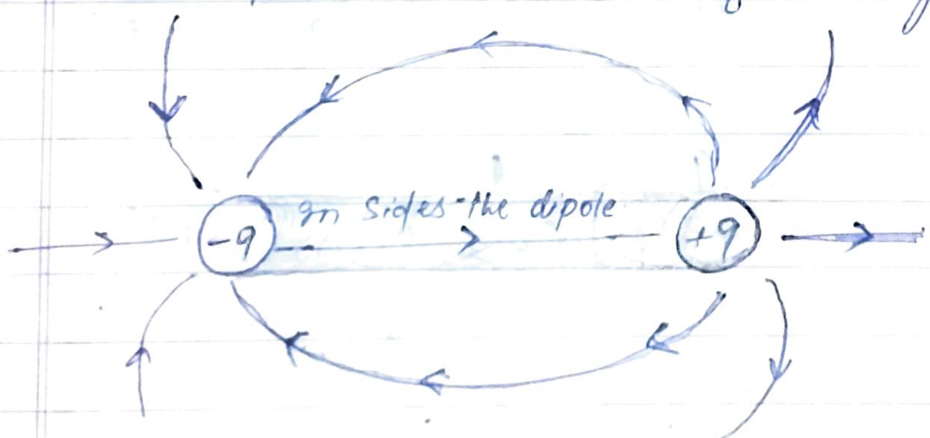
→ The dipole moment is a vector directed ~~toward~~ from the negative to +ve along the dipole axis.

~~* Electric potential due to Dipole,~~

~~* Electric field due to dipole,~~

electric field produced by a dipole is called a dipole field.

1. Two equal charges -q and +q separated by a small distance is called an electric dipole.
2. The dipole moment = One of the charge × distance bet^n charge

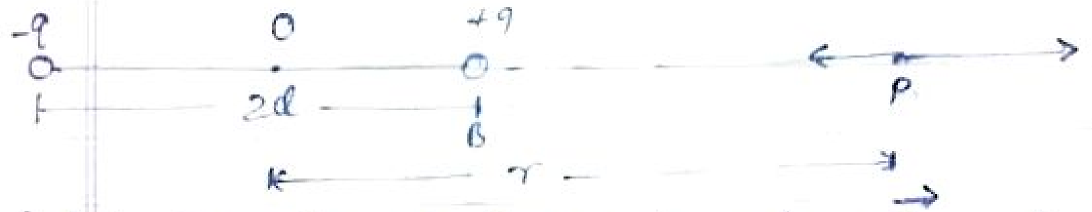


3. SI units of dipole moment is Cm
4. An ideal dipole consists of two very very large charges +q and -q separated by a very very small distance

Electric intensity at a point Due to an electric Dipole

Case 01 At a point on the axis of the dipole

Consider an electric dipole consisting of two equal but opposite charges $-q$ and $+q$ separated by a vector distance $2l$



electric intensity at P due to $-q$ $= \vec{E}_A = \frac{1}{4\pi\epsilon_0}\frac{q}{(r+d)^2}$

directed along PD.

electric intensity at P due to $+q$ $= \vec{E}_B = \frac{1}{4\pi\epsilon_0}\frac{q}{(r-d)^2}$

Resultant of electric field.

$$\vec{E} = \vec{E}_B - \vec{E}_A$$

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

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

$$= \frac{q}{4\pi\epsilon_0}\left\{\frac{r^2+d^2+2rd-r^2-d^2+2rd}{(r^2-d^2)^2}\right\}$$

$$= \frac{q}{4\pi\epsilon_0}\frac{4rd}{(r^2-d^2)^2}$$

The values of $r^2 >> d^2$ the $d^2 \approx 0$

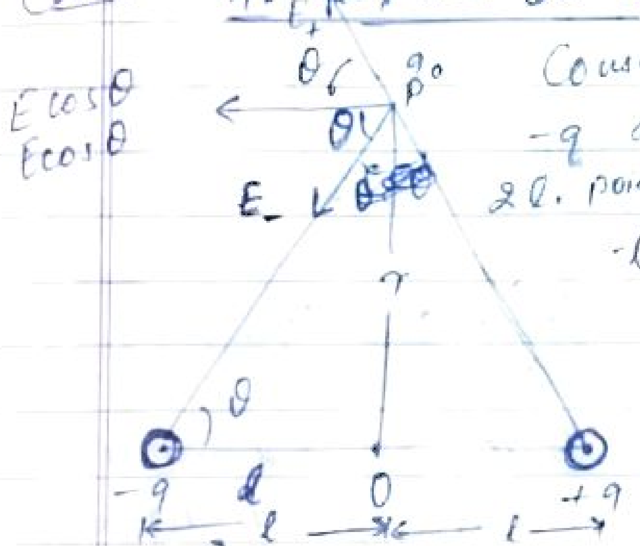
$$\frac{1}{4\pi\epsilon_0} \frac{4 r l}{r^4}$$

$$= \frac{1}{4\pi\epsilon_0} \frac{2 \cdot 2ql}{r^3}$$

$$\boxed{\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{2P}{r^3}}$$ $\vec{E}$ is directed along PC.

$$\left(\vec{E}_{axial} = \frac{1}{4\pi\epsilon_0} \frac{2\vec{P}}{r^3}\right)$$ along the direction of the dipole moment $\vec{P}$

Case II — At the point on the equatorial line.



Consider an electric dipole of charge −q and +q placed at distance 2l. point P at distance q_0 from the the centre of dipole.

$(\vec{E}_+)$ it is electric field at the point P due to +ve charge.

$$\vec{E}_+ = \frac{1}{4\pi\epsilon_0} \frac{q}{(\sqrt{r^2+l^2})^2}$$

$\vec{E}_-$ is the electric field at the point P due to −ve charge.

$$\vec{E}_- = \frac{1}{4\pi\epsilon_0} \frac{q}{(\sqrt{r^2+l^2})^2}$$

In ΔPQO

$$\cos\theta = \frac{l}{\sqrt{r^2+l^2}}$$

$$\vec{E}_R = 2\vec{E}\cos\theta$$

$$= 2\frac{1}{4\pi\epsilon_0} \frac{q}{r^2+l^2} \times \frac{l}{\sqrt{r^2+l^2}}$$

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

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

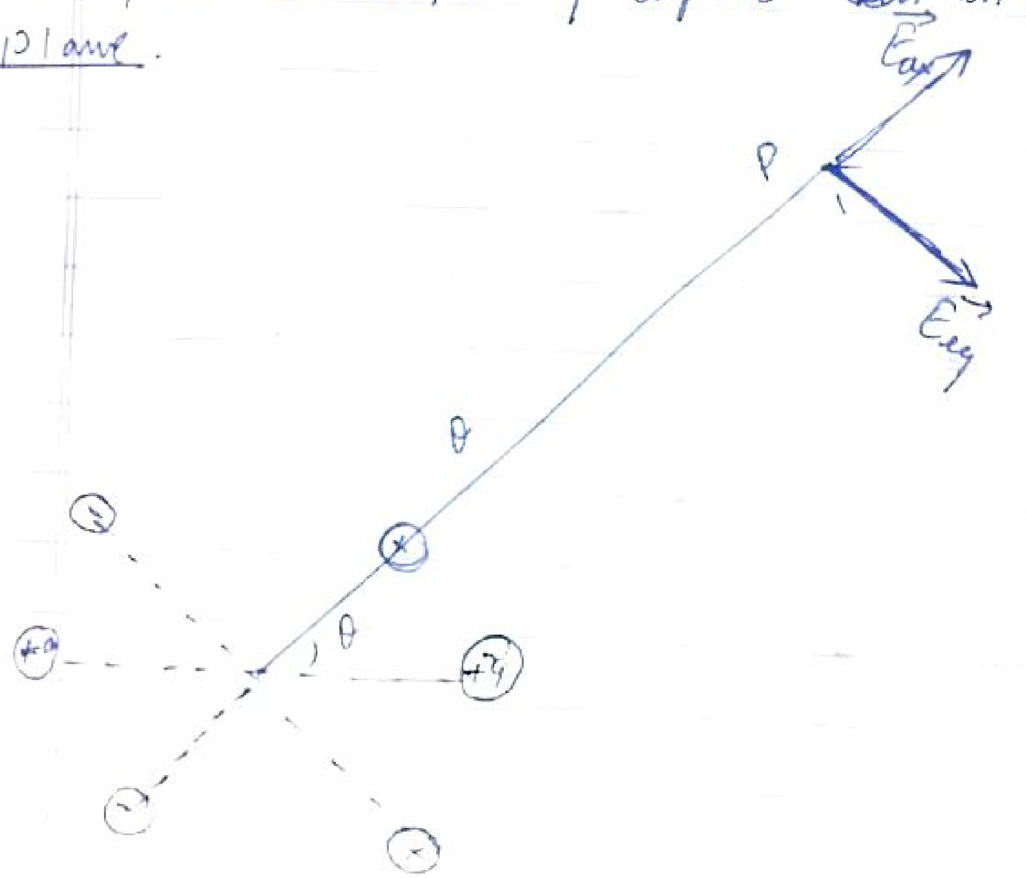
$r >> l$ so that $l^2 \simeq 0$

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{p}{r^{2 \times 3/2}}$$

$$\boxed{\vec{E}_{eq} = \frac{1}{4\pi\epsilon_0} \frac{\vec{p}}{r^3}}$$

Case 3. At any point in the plane of the electric dipole

Let an electric dipole of charge $+q$ and $-q$ placed at distance $2d$. if any point p at distance r from the centre of dipole ~~then~~ in same plane.



dipole moment $\vec{P}$ make angle θ with

Then comp. of dipole along is

$\rightarrow \vec{P} \cos\theta$

and $\perp$ to the $\vec{r}$ is $\vec{P}\sin\theta$.

point $\vec{P}$ on axis of dipole comp. $P\cos\theta$

Then

$$\vec{E}_{axis} = \frac{1}{4\pi\epsilon_0}\frac{2\vec{P}\cos\theta}{r^3}$$

point P on the eq. line of dipole comp $P\sin\theta$.

$$\vec{E}_{eq} = \frac{1}{4\pi\epsilon_0}\frac{P\sin\theta}{r^3}$$

Resultant

$$\vec{E}_R = \sqrt{(E_{ax.})^2 + (E_{eq})^2}$$

$$= \sqrt{\left(\frac{1}{4\pi\epsilon_0}\frac{2p\cos\theta}{r^3}\right)^2 + \left(\frac{1}{4\pi\epsilon_0}\frac{P\sin\theta}{r^3}\right)^2}$$

$$= \sqrt{\left(\frac{P}{4\pi\epsilon_0 r^3}\right)^2 (4\cos^2\theta + \sin^2\theta)}$$

$$= \frac{P}{4\pi\epsilon_0 r^3}\sqrt{4\cos^2\theta + \sin^2\theta}$$

$$\boxed{\vec{E}_R = \frac{1}{4\pi\epsilon_0}\frac{P}{r^3}\sqrt{3\cos^2\theta + 1}}$$