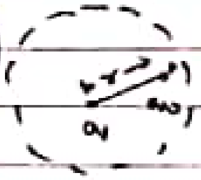
* Electrostatic field → It may be defined as a 3-Dimensional region surrounding a static charge in which any other charge enters experiences an electric force (either attracting or repulsive).

At a point inside the electric field due to source charge (q), the strength of electric field or the electric field intensity ($\vec{E}$) is mathematically equal to the coloumb force experienced by a test charge (q_0) placed at that point.

Source charge – q (either +ve or -ve)
test charge
→ very small
→ always +ve



At P

coloumb force, $F = \frac{k \cdot q \cdot q_0}{r^2}$

$\therefore q_0 \longrightarrow F$, at p

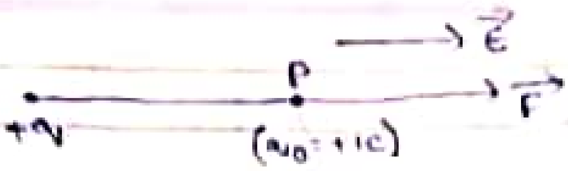
$\therefore +1C = \frac{F}{q_0} = E_p$

$$\therefore \boxed{\vec{E} = \lim_{q_0 \to 0} \frac{\vec{F}}{q_0}}$$

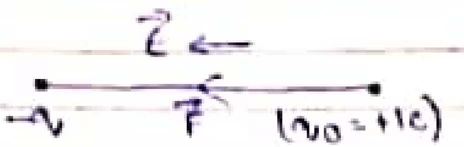
SI unit is NC^{-1} or Vm^{-1}

$\therefore$ Electric field at a point (r) due to the point source charge (q) is

$$\boxed{E = \frac{kq}{r^2}}$$



Radially outward



NOTE Electric force experienced by a charge (E) placed at a point P of a know E-field $(E_P \neq 0)$

$$\boxed{F = qE}$$

If $q > 0$

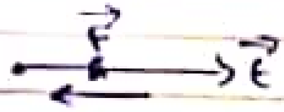
$$\boxed{\vec{F} = +q\vec{E}}$$

$ma = qE$

$a = \frac{qE}{m} = \text{const} \neq 0$

If $q < 0$

$$\boxed{\vec{F} = -q\vec{E}}$$



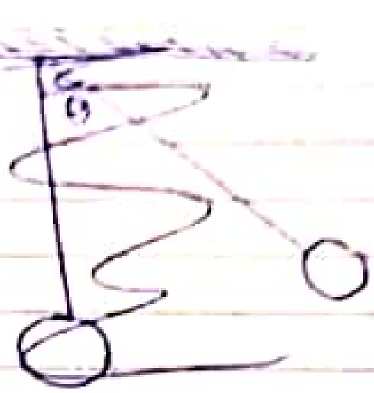
$ma = qE$

$a = \frac{qE}{m} = \text{const} \neq 0$

1Q The mass of a bob of a simple pendulum is 20g carrying +ve charge of magnitude μC. A horizontal electric field $\vec{E} = (10\, N/C)\hat{i}$ is applied calculate the angle by which the simple pendulum displaces from verticle position in equilibrium $(g = 10\, ms^{-2})$.

mass of bob = 2og $= 20\times10^{-3}$
$= 2\times10^{-2}$ kg

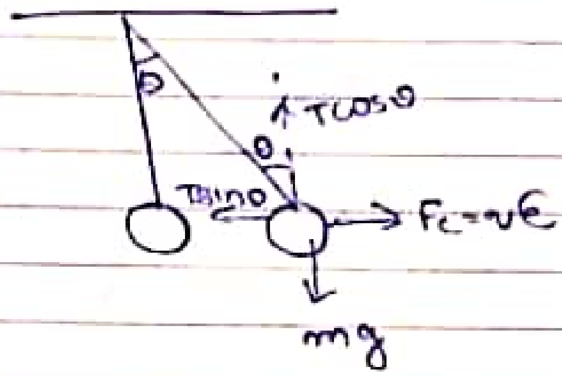
$q = 110\,\mu C$
$= 110\times10^{-6}\,\mu$
$\vec{E} = (10\ N/C)\,\hat{i}$



Initial

at $t=0$, $T = mg$
$E=0$

A/q



$T\cos\theta = mg$
$T\sin\theta = F_c$
$\frac{F_c}{mg} = \tan\theta$ —(1)

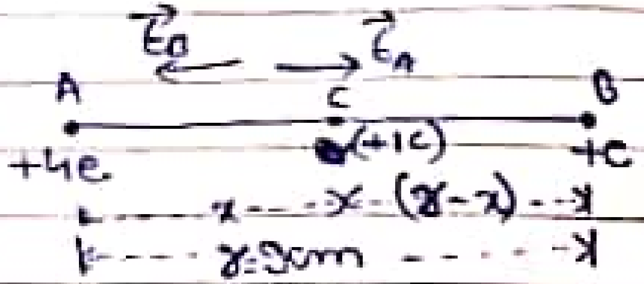
Now,
$F = qE$
$= 1\times10^{-5}\times10$
$= 10^{-4}$

Now, $\frac{10^{-4}}{mg} = \tan\theta$
$= \tan\theta = \frac{1}{10^{4}\times2\times10^{-2}\times10}$
$= \frac{1}{10^{3}\times2}$ $\frac{10^{-3}}{2}$

$\theta = \tan^{-1}\left(\frac{10^{-3}}{2}\right)$ //

2. Two like charge +4e and +e are placed at a seperation of 9 cm. ~~where is~~ what should be the position on their line joining where the net electric field is zero?

3. Two unlike charges +4e and −e are placed at a seperation of 9cm. what should be the position on their line joining where the net Electric field is zero.



2 – No

$E_{net} = 0$

i.e. $\frac{qE}{q} = 0$

F = 0

2. ~~Let at point C~~
Given,

⇒ Let the reqd. charge is C.

A/q

$\vec{E}_C = 0$

$= E_A = E_B$

$= \frac{K \cdot q_1}{x^2} = \frac{K \cdot q_2}{(r-x)^2}$

$= \frac{4e}{x^2} = \frac{e}{(r-x)^2}$

$x^2 = 4(r-x)^2$

$x = 2r - 2x$

$3x = 2r$

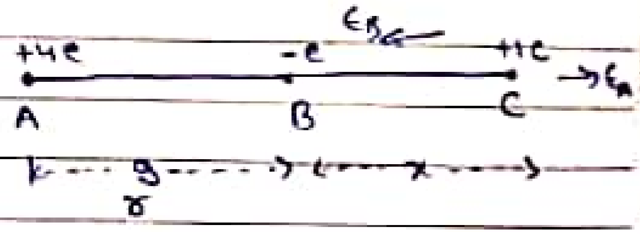
$x = \frac{2r}{3}$

$= \frac{2 \times 9}{3} = 6$ cm from A.

∴ Reqd. position AC = 6 cm

3. A/q

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



$\frac{K \cdot 4e}{(9+x)^2} = \frac{K \cdot e}{x^2}$

$4x^2 = (9+x)^2$

$2x = 9 + x$

$x = 9$ cm

∴ Reqd. position is 9 cm from B

Electric Dipole :- It may be defined as an arrangement of two equal and opposite charges kept at a seperation. In other words, it is a binary system that consist of two equal and opposite charges kept at a seperation.

An electric dipole has following two characteristics:-

(i) Electric dipole length – vector quantity & given as,

$\vec{AB} = \vec{2l}$ $\longrightarrow (\vec{2l})$

(always from –ve to +ve) A $-q$ $\longrightarrow \vec{p}$ B $+q$

(ii) Electric dipole moment ($\vec{P}$) is given as. (vector)

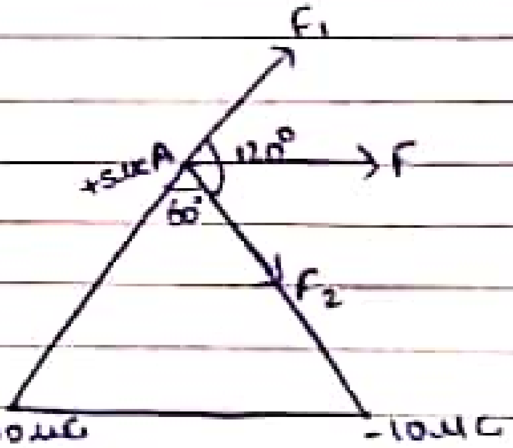
$$\boxed{\vec{P} = q(\vec{2l})} \quad \text{i.e. } (\vec{P}) \parallel (\vec{2l})$$

SI = unit Cm

Q Define Electric field lines. Write its physical importance. Also state the importance of charactistics of electric lines of force.

Self

Numerical



1. $F_1 = \dfrac{k.q_1q_2}{r^2} = 180\text{ N}$

collinear

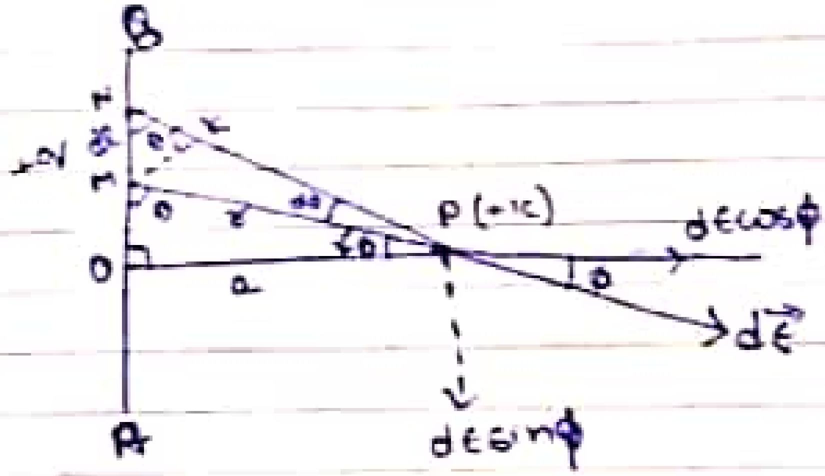
$F_2 = \dfrac{k.q_1q_2}{r^2} = 180\text{ N}$

$F = \sqrt{(F_1)^2 + (F_2)^2 + 2F_1F_2(-\frac{1}{2})}$

$F = \sqrt{(F_1)^2 + (F_2)^2 + (F_1 \cdot F_2)}$

Electric field strength ($\vec{E}$) at a point

(1) — due to uniformly charged straight wire (line charge)



λ = linear charge density, $\lambda = \dfrac{dq}{dl}$

consider an elementary charge

$MN = dl$

Let $MP \approx NP = r$

At P

$$dE = \frac{k\,dq}{r^2}$$

$$= \frac{k\lambda\,dl}{r^2}$$

$\because$ By theory of plane of symmetry, the existing component of $d\vec{E}$ at P is $dE\cos\phi$.

i.e.

$$dE_p = \frac{k\lambda\,dl}{r^2}\cos\phi \quad \text{——— (1)}$$

In rt. $\triangle MKP$ & $\triangle MKN$

$MK = r\sin\phi = dl\sin\theta$

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$$r\,d\phi = dl \times \frac{a}{r} \quad \left\{\sin\theta = \frac{a}{r}\right\}$$

$$\therefore\ dl = \frac{r^2}{a}\,d\phi \quad \text{—— (n)}$$

from (1) & (n)

$$dE_p = \frac{k\lambda}{r^2} \times \frac{r^2}{a}\,d\phi\cos\phi$$

$$\frac{k\lambda}{a}\cos\phi\,d\phi \quad \text{—— (1b)}$$

$$\therefore\ E_p = \int_{-\phi_1}^{+\phi_2} dE_p$$

$$= \frac{k\lambda}{a}\int_{-\phi_1}^{+\phi_2}\cos\phi\,d\phi$$

$$\frac{k\lambda}{a}\left[\sin\phi\right]_{-\phi_2}^{+\phi_2}$$

$$\boxed{E_p = \frac{k\lambda}{a}\left[\sin\phi_2 + \sin\phi_1\right]} \quad \text{—— (2)}$$

case For a line charge of infinite length (both ends are unknown)

i.e. $\phi_1 = \phi_2 = 90^\circ$

from (2)

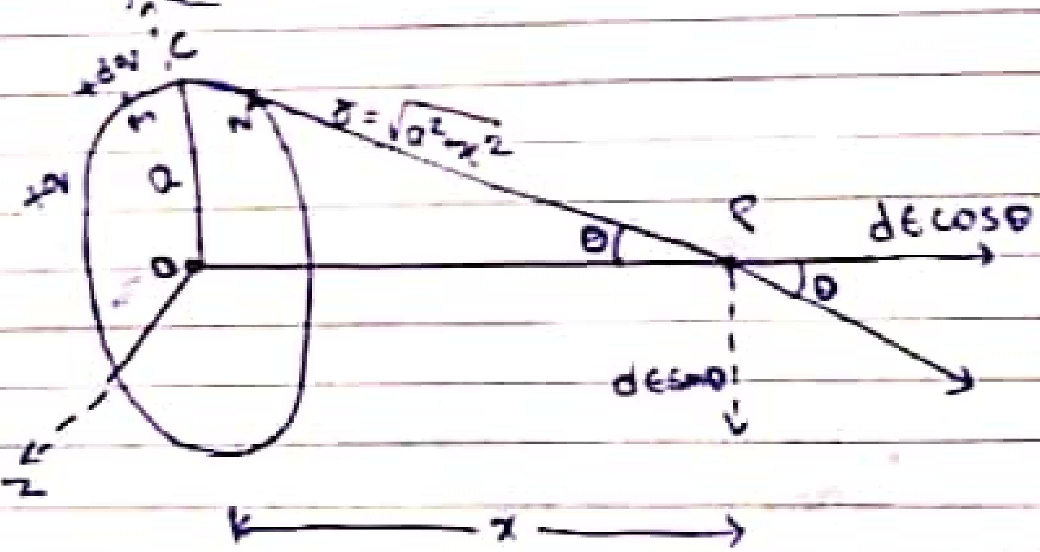
$$\boxed{E_p = \cancel{k\lambda}\left(\frac{1}{4\pi\epsilon_0}\right)\frac{2\lambda}{a}}$$

(2) - on the axes of a uniformly charged circular charging loop :-

→ consider a circular loop (0,0) is placed in yz plane, uniformly charged having linear charge density $\lambda = \frac{q}{2\pi a} = \frac{dq}{dl}$ —(1a)

consider an elementary charge MN = such that

$dq = \lambda dl$



At P

$dE = \frac{k\,dq}{r^2}$ where $k = \left(\frac{1}{4\pi\epsilon_0}\right)$

$\frac{k\lambda dl}{(a^2+x^2)}$

∵ By theory of plane of symmetry, we have, net $E_p = dE\cos\theta$ (along PX)

$$= \frac{k\lambda\, dl}{(a^2+x^2)} \cdot \frac{x}{\sqrt{a^2+x^2}}$$

$$E_p = \left(\frac{1}{4\pi\epsilon_0}\right)\frac{\lambda x\, dl}{(a^2+x^2)^{3/2}} \quad \text{— (1b)}$$

$$\therefore E_p = \int_0^{2\pi a} dE_p$$

$$= \frac{k\lambda x}{(a^2+x^2)^{3/2}} \int_0^{2\pi a} dl$$

$$E_p = \left(\frac{1}{4\pi\epsilon_0}\right)\frac{\lambda x \times 2\pi a}{(a^2+x^2)^{3/2}}$$

$$\therefore \boxed{E_p = \left(\frac{1}{4\pi\epsilon_0}\right)\left(\frac{qx}{(a^2+x^2)^{3/2}}\right)} \quad \text{— (2)}$$

Sp case

At the centre (i.e. $P \to O$)

i.e. $x = 0$

from 2 $\boxed{E_{centre} = 0}$ — (2a)

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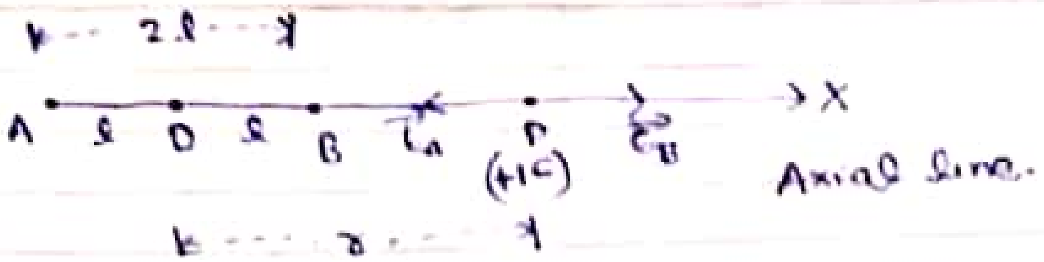
(axial line)

(3) ... at a point on the axis of an electric dipole



If $OP = r$

$\therefore AP = (r+l)$

$BP = (r-l)$

$E_A = \frac{kq_A}{AP^2}$ (Along PA)

$E_A = \frac{kq}{(r+l)^2}$

$E_B = \frac{k \cdot q_2}{(BP)^2}$

$E_B = \frac{kq}{(r-l)^2}$ $\quad \therefore E_P = \vec{E}_A + \vec{E}_B$

$\theta = 180^\circ$

$\& \, |\vec{E}_B| > |\vec{E}_A|$

$\therefore E_P = kq\left(\frac{(r+l)^2 - (r-l)^2}{(r-l)^2(r+l)^2}\right)$

$= \frac{kq(4rl)}{(r^2-l^2)^2}$

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

$$\boxed{E_p = \left(\frac{1}{4\pi\epsilon_0}\right)\frac{2pr}{(r^2-l^2)^2}} \longrightarrow (2) \quad \text{Along } px$$

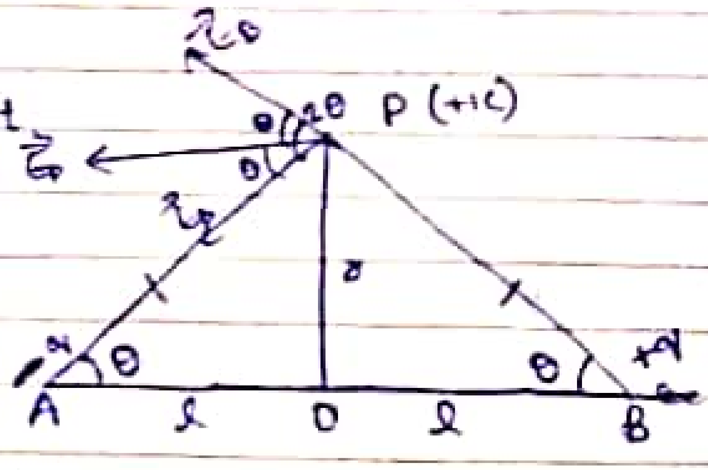
$\rightarrow$ (Along dipole length)

Special case

For a very short electric dipole
Such that $r^2 >>> l^2$, So, eq^n becomes

$$\boxed{E_p = \left(\frac{1}{4\pi\epsilon_0}\right)\frac{2p}{r^3}} \longrightarrow (2a) \quad \text{Along } px$$

4. ... on the equitorial line of an electric dipole
(⊥^{r} bisector of the dipole)



Electric dipole moment
is $p = q(2l)$ — (10)

Consider,

$OP = r$

$AP = BP = (r^2+l^2)^{1/2}$

$E_A = \frac{kq}{(r^2+l^2)}$ (along PA)

$E_B = \frac{kq}{(r^2+l^2)}$ (along BP)

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$\because \vec{E_P} = \vec{E_A} + \vec{E_B}$ $\quad \theta' = 2\theta$

& $|\vec{E_A}| = |\vec{E_B}| = E$

(opp. to dipole length)

$$E_P = \sqrt{E_A^2 + E_B^2 + 2E_AE_B\cos 2\theta}$$

$$\sqrt{E^2 + E^2 + 2E^2\cos 2\theta}$$

$$= \sqrt{2E^2(1+\cos 2\theta)}$$

$$\sqrt{2E^2 \cdot 2\cos^2\theta} \qquad (1+\cos 2\theta = 2\cos^2\theta)$$

$$= 2E\cos\theta$$

$$= 2 \cdot \frac{kq}{r^2+l^2} \cdot \frac{l}{\sqrt{r^2+l^2}}$$

$$\boxed{E_P = \left(\frac{1}{4\pi\epsilon_0}\right)\frac{p}{(r^2+l^2)^{3/2}}} \quad (2) \quad \{p = q(2l)\}$$

opp. to dipole lgth.

Sp. case

for a short electric dipole,
such that, $r^2 >>> l^2$, so, eqn (2) from

$$\boxed{E_{P\,equatorial} = \left(\frac{1}{4\pi\epsilon_0}\right)\frac{p}{r^3}} \quad - (2a)$$