1/04/24
Monday

UNIT-1

ELECTROSTATICS

Electrostatics

Electro — Static

Electric
study

Charge [Coulomb
current (q)

Charge SI unit coulomb (C)

Charge
- நேர் மின்னூட்டம் Positive charge (+) (+q)
- எதிர் மின்னூட்டம் Negative charge (-) (-q)

Charge Characteristic

Same charge / like charge: +q +q, -q -q → Repulsive (விலகுதல்)

Oppositive charge / unlike charge: +q -q, -q +q → Attractive (கவர்தல்)

$\left.\begin{array}{l}+q\\-q\end{array}\right\}$ Benjamin Frankalin

American country

C → coulomb

μC → micro coulomb → $10^{-6}C$

pC → Pico coulomb → $10^{-12}C$

nC → nano coulomb → $10^{-9}C$

Charge	Current
Same charge Repulsive	same direction Attractive
opposite charge Attractive	opposite direction Repulsive

Charge based

Conductor	Semi conductor	Insulator
(Charge Allow)	(semi level) (allow)	(charge not allow)
Ex: Metal, Earth, Human body	Ex: Si, Ge	Ex: Rubber, Plastic, wood

Charge

$+q \rightarrow +1.6\times10^{-19}C \rightarrow$ Proton

$-q \rightarrow -1.6\times10^{-19}C \rightarrow$ Electron

$\boxed{q = ne}$ formula

$q \rightarrow$ charge

$n \rightarrow$ Integer

$e \rightarrow$ electronic charge

Coulomb's force

q_1 ←— r —→ q_2

$$F \propto \frac{q_1 q_2}{r^2}$$

$F \rightarrow$ Force (விசை)

$q_1 q_2 \rightarrow$ charge (மின்னூட்டம்)

$r \rightarrow$ Distance (தொலைவு)

$$F \propto \frac{q_1 q_2}{r^2}$$

$$F = K \frac{q_1 q_2}{r^2}$$

$K \rightarrow$ constant

$$K = \frac{1}{4\pi\varepsilon_0}$$

ε = Epslon

$\varepsilon_0 = 8.854\times10^{-12}$

$$F = K \frac{q_1 q_2}{r^2}$$

$$F = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}$$

note

coulomb's force

formula

① $F \propto \frac{q_1 q_2}{r^2}$

② $F = K \cdot \frac{q_1 q_2}{r^2}$

③ $F = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}$

1) $\frac{1}{4\pi\varepsilon_0}$ Find value

$\pi = \frac{22}{7}$ or 3.14

$$\frac{1}{4\pi\varepsilon_0} = \frac{1}{4 \times 3.14 \times 8.85\cancel{4} \times 10^{-12}}$$

$$= \frac{10^{+12}}{4 \times 3.14 \times 8.854}$$

$$= 9 \times 10^{9}$$

$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^{9}$$

1) $q_1 = 1C$ $q_2 = 1C$ $r = 1m$ Find coulomb force

(or)

one coulomb

$F = ?$

$$F = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2}$$

one coulomb $= 9 \times 10^9 N$

$$F = 9 \times 10^9 \times \frac{1 \times 1}{(1)^2}$$

$$F = 9 \times 10^9 \times \left(\frac{1}{1}\right)$$

$$F = 9 \times 10^9 \times (1)$$

$$F = 9 \times 10^9 N$$

11/04/24

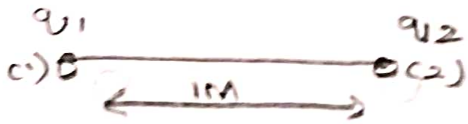
2/04/24
Tuesday

Example 1.2

consider two point charges q_1 and q_2 at rest as shown in the figure

a) $q_1 = +2\mu C$ and $q_2 = +3\mu C$

$r = 1m$



$$\vec{F} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r}$$

$$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{12}$$

$q_1 = 2\mu C$
$= 2 \times 10^{-6} C$

$q_2 = 3\mu C$
$= 3 \times 10^{-6} C$

$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$$

$$\hat{r}_{12} = \hat{i}$$

$$F_{12} = (9 \times 10^9) \times \frac{q_1 q_2}{r^2}$$

$$F_{12} = 9 \times 10^9 \times \frac{(2 \times 10^{-6})(3 \times 10^{-6})}{(1)^2} \hat{i}$$

$$F_{12} = 9\times10^9 \times \frac{6\times10^{-6}\times10^{-6}}{(1)}$$

$$F_{12} = 9\times10^9 \times 6\times10^{-12}$$

$$F_{12} = 5.4\times10^9\times10^{-12}\,N$$

$$F_{12} = 54\times10^{9-12}\,N$$

$$\boxed{F_{12} = 54\times10^{-3}\,N}$$

Applying newtons third law

$$F_{12} = -F_{21}$$

$$F_{12} = -54\times10^{-3}\,N$$

$$q_1 = +2\mu C$$

$$q_2 = +3\mu C$$

same charge

like charge

Repulsive

b) $q_1 = +2\mu C$ and $q_2 = -3\mu C$

$$F_{12} = -F_{21}$$

$$q_1 = +2\mu C$$

$$q_2 = -3\mu C$$

$$r = 1m$$

$$q_1 = +2\mu C = 2\times10^{-6}C$$

$$q_2 = -3\mu C = -3\times10^{-6}C$$

$$\vec{F_{21}} = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}\hat{r}_{12}$$

$$\vec{F_{21}} = 9\times10^9\frac{(2\times10^{-6})(-3\times10^{-6})}{(1)^2}$$

$$\vec{F_{21}} = 9\times10^9\times\frac{(-6)\times10^{-6}\times10^{-6}}{(1)}\hat{r}_{12}$$

$\vec{F_{21}} = -54 \times 10^{9} \times 10^{-12} \hat{r}$

$\vec{F_{21}} = -54 \times 10^{-3} \hat{r}$

Applying Newton's Third law

$\vec{F_{12}} = -\vec{F_{21}}$

$\vec{F_{12}} = (-54 \times 10^{-3}) \hat{r}$

$\vec{F_{12}} = 54 \times 10^{-3} N \hat{r}$

$q_1 = 2 \mu c$

$q_2 = -3 \mu c$

opposite charge

unlike charge

Attractive

c) $q_1 = +2 \mu c$ and $q_2 = -3 \mu c$ kept in water ($\epsilon_r = 80$)

$q_1 = +2 \mu c = 2 \times 10^{-6} c$

$q_2 = -3 \mu c = -3 \times 10^{-6} c$

water

$\epsilon_r = 80$

coulomb force

$$F_{21} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{12}$$

$$F_{21} = 9 \times 10^{9} \left(\frac{(2 \times 10^{-6} \times 1 \cdot 3) \times 10^{-6}}{(1)^2} \right) \hat{r}_{12}$$

$\vec{F_{21}} = 9 \times 10^{9} \times (-6) \times 10^{-6} \times 10^{-6} \hat{r}$

$\vec{F_{21}} = -54 \times 10^{9} \times 10^{-12} \hat{r}$

$\vec{F_{21}} = -54 \times 10^{-3} \hat{r}$

$$\frac{F_{21}}{W} = \frac{-54 \times 10^{-3} \hat{i}}{80} = \left(\frac{-54}{80}\right) \times 10^{-3} \hat{i}$$

$$= -0.675 \times 10^{-3} N \hat{i}$$

another Method

a) $q_1 = +2\mu C = 2 \times 10^{-6} C$

$q_2 = +3\mu C = 3 \times 10^{-6} C$

$$F_{21} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r^2} \hat{r}_{12}$$

$$F_{21} = (9 \times 10^9) \times \frac{(2 \times 10^{-6} \times 3 \times 10^{-6})}{(1)^2} \hat{r}_{12}$$

$$F_{21} = 9 \times 10^9 \times 6 \times 10^{-12} \hat{r}_{12}$$

$$F_{21} = 54 \times 10^9 \times 10^{-12} \hat{r}_{12}$$

$$F_{21} = 54 \times 10^{-3} \hat{i}$$

Applying Newton's third law

$$F_{12} = -F_{21}$$

$$\vec{F}_{12} = -54 \times 10^{-3} \hat{i}$$

Same charge

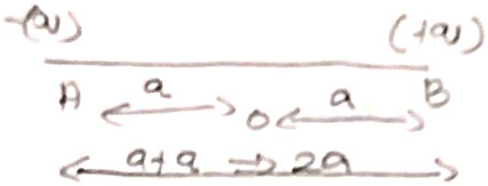
like charge

Replusive

10/4/2019

3/4/24
wednesday

Electric dipole moment → (P)
Symbol



$OA = a$
$OB = a$
$AB = 2a$

$P = q \times 2a$

$2a$ → small distance

Two equal and opposite charge separated small distance

P → Electric dipole moment
q → charge

vector quantity
unit : Cm

concept

Electric field → (E) $E \propto q$
Magnetic field → (B) $B \propto Idl$
charge - q - Electric field
current - I - Magnetic field

Electric field → E

$$E = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \hat{r}$$

E = Electric field

$\frac{1}{4\pi\epsilon_0} = \frac{1}{4 \times 3.14 \times 8.854 \times 10^{-12}}$

$= 9 \times 10^9$

q = charge

Quantity: Vector quantity

unit: NC^{-1} (N/C)

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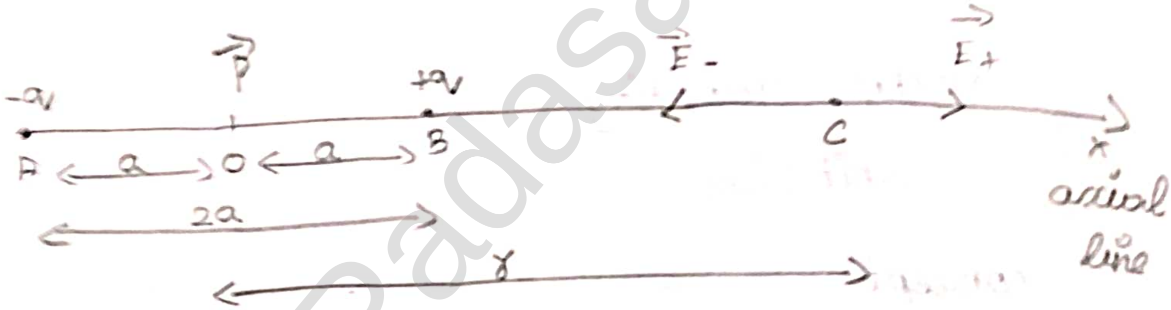
5 Mark [LA]

4) calculate the electric field due to a dipole on its axial line



AB -> Two Point

-q Negative charge

+q Positive charge

O centre of point

a Distance

r Distance

E_- Negative Electric field

E_+ Positive Electric field

2a very samll distance

$AB = 2a$

$OA = a$

$OB = a$

$OC = r$

Electric field

$$\vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \hat{r}$$

P -> Electric dipole Moment

$$P = q \times 2a$$

$$\vec{P} = q \times 2a \cdot \hat{P}$$

+q charge (B Point)

E_+ Electric field

$$\vec{E_+} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \hat{r}$$

$$\vec{E_+} = \frac{1}{4\pi\varepsilon_0} \frac{q}{(r-a)^2} \hat{P} \longrightarrow (1)$$

-q charge (A Point).

E_- Electric field

$$\vec{E_-} = \frac{1}{4\pi\varepsilon_0} \frac{-q}{(r+a)^2} \hat{P} \longrightarrow (2)$$

Total Electric field

$$\vec{E}_{Total} = \vec{E_+} + \vec{E_-}$$

$$\vec{E}_{Total} = \left(\frac{1}{4\pi\varepsilon_0} \frac{q}{(r-a)^2} \cdot \hat{P}\right) + \left(\frac{1}{4\pi\varepsilon_0} \frac{-q}{(r+a)^2} \cdot \hat{P}\right)$$

$$\vec{E}_{Total} = \left[\left(\frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2}\right) + \left(-\frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\right)\right]\cdot\hat{p}$$

$$\vec{E}_{Total} = \left[\frac{1}{4\pi\varepsilon_0}\frac{q}{(r-a)^2} - \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+a)^2}\right]\cdot\hat{p}$$

$$\vec{E}_{Total} = \left[\frac{q}{4\pi\varepsilon_0}\frac{1}{(r-a)^2} - \frac{q}{4\pi\varepsilon_0}\frac{1}{(r+a)^2}\right]\cdot\hat{p}$$

$$\vec{E}_{Total} = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{(r-a)^2} - \frac{1}{(r+a)^2}\right]\cdot\hat{p}$$

$$\vec{E}_{Total} = \frac{q}{4\pi\varepsilon_0}\left[\frac{(r+a)^2 - (r-a)^2}{(r-a)^2(r+a)^2}\right]\cdot\hat{p}$$

$$(a+b)^2 = a^2+b^2+2ab$$
$$(r+a)^2 = r^2+a^2+2ra$$
$$(a-b)^2 = a^2+b^2-2ab$$
$$(r-a)^2 = r^2+a^2-2ra$$

$$\vec{E}_{Total} = \frac{q}{4\pi\varepsilon_0}\left[\frac{(r^2+a^2+2ra) - (r^2+a^2-2ra)}{(r+a)^2\cdot(r-a)^2}\right]\cdot\hat{p}$$

$$\vec{E}_{Total} = \frac{q}{4\pi\varepsilon_0}\left[\frac{r^2+a^2+2ra - r^2-a^2+2ra}{(r+a)^2\cdot(r-a)^2}\right]\cdot\hat{p}$$

$$\vec{E}_{Total} = \frac{q}{4\pi\varepsilon_0}\left[\frac{2ra+2ra}{(r^2-a^2)^2}\right]\cdot\hat{p}$$

$$\vec{E}_{Total} = \frac{q}{4\pi\varepsilon_0}\left[\frac{4ra}{(r^2-a^2)^2}\right]\cdot\hat{p}$$

$$\vec{E}_{Total} = \frac{q}{4\pi\varepsilon_0}\left[\frac{4ra}{(r^2)^2}\right]\cdot\hat{p}$$

$r >> a$

$r \rightarrow$ large $a \rightarrow$ small

↳ neglected

$$\vec{E}_{Total} = \frac{q}{4\pi\varepsilon_0}\left[\frac{4ra}{r^4}\right]\cdot\hat{p}$$

$$\vec{E}_{Total} = \frac{q}{4\pi\varepsilon_0}\left[\frac{4a}{r^3}\right]\cdot\hat{p}$$

$$\vec{E}_{Total} = \left[\frac{1}{4\pi\varepsilon_0}\,\frac{q\times 4a}{r^3}\right]\cdot\hat{p}$$

$\vec{p} = q\times 2a\cdot\hat{p}$

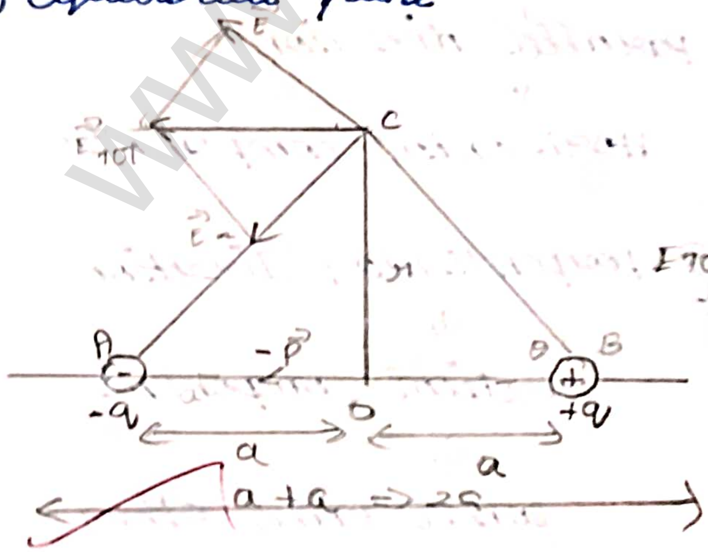
$2\vec{p} = q\times 4a\cdot\hat{p}$

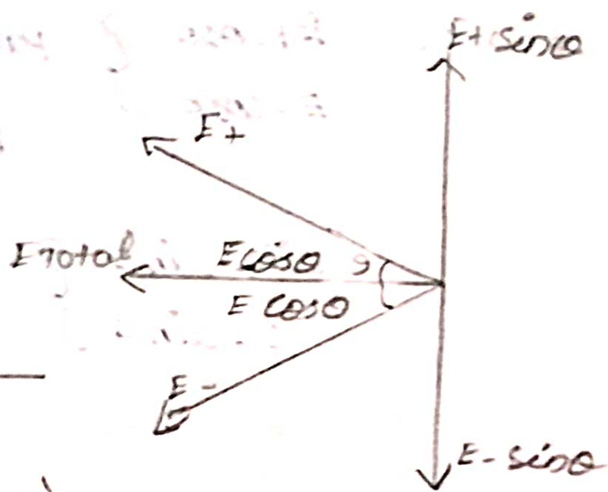
$$\vec{E}_{Total} = \frac{1}{4\pi\varepsilon_0}\,\frac{2p}{r^3}$$

03/04/2024

4/04/24 Thursday

4) b) equatorial plane





AB → line point

O → centre of the point

a → Distance

r → Distance

2a → small distance

θ → Angle

E_+ → Positive Electric field

E_- → negative Electric field

E_{Tot} → Total electric field

$-q$ → negative charge

$+q$ → positive charge

OA = a

OB = a

AB = 2a

OC = r

ΔABC

P → Electric dipole moment

$P = q \times 2a$, $\vec{P} = q \times 2a \cdot \hat{P}$

$\left.\begin{array}{l} E_+ \cos\theta \\ E_- \cos\theta \end{array}\right\}$ parallel direction

↓

Horizontal components

$\left.\begin{array}{l} E_+ \sin\theta \\ E_- \sin\theta \end{array}\right\}$ perpendicular direction

↓

vertical component

↓

cancel each other

 Electric field

$$E = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2}$$

E_+ and E_- Same Magnitude

$$\vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \hat{r}$$

$$E_+ = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2+a^2} \rightarrow (1)$$

$$E_- = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2+a^2} \rightarrow (2)$$

Total Electric field

$$\vec{E}_{Total} = -|\vec{E_+}| \cos\theta \, \hat{p} - |\vec{E_-}| \cos\theta \, \hat{p}$$

$$\vec{E}_{Total} = -E\cos\theta \, \hat{p} - E\cos \hat{p}$$

$$\vec{E}_{Total} = -2E\cos\theta \, \hat{p}$$

$$\vec{E}_{Total} = -2\left(\frac{1}{4\pi\varepsilon_0} \frac{q}{r^2+a^2}\right) \cos\theta . \hat{p}$$

$$\vec{E}_{Total} = -\frac{1}{4\pi\varepsilon_0} \frac{2q}{r^2+a^2} \cos\theta . \hat{p}$$

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

$$\vec{E}_{Total} = -\frac{1}{4\pi\varepsilon_0} \frac{2q}{r^2+a^2}\left(\frac{a}{\sqrt{r^2+a^2}}\right) . \hat{p}$$

$$\vec{E}_{Total} = -\frac{1}{4\pi\varepsilon_0}\left(\frac{2qa}{(r^2+a^2)\sqrt{r^2+a^2}}\right) . \hat{p}$$

$$\vec{E}_{Total} = -\frac{1}{4\pi\varepsilon_0} \frac{2qa}{(r^2+a^2)(r^2+a^2)^{1/2}} . \hat{p}$$

$$\vec{E}_{total} = -\frac{1}{4\pi\varepsilon_0} \frac{2qa}{(r^2+a^2)^{1+1/2}} \cdot \vec{p}$$

$$\vec{E}_{total} = -\frac{1}{4\pi\varepsilon_0} \frac{2qa}{(r^2+a^2)^{3/2}} \cdot \vec{p}$$

$1+1/2$

$\frac{2+1}{2} = 3/2$

$$\vec{E}_{total} = -\frac{1}{4\pi\varepsilon_0} \frac{2qa \cdot \vec{p}}{(r^2+a^2)^{3/2}}$$

$2qa \cdot \vec{p} = \vec{p}$

$$\vec{E}_{total} = -\frac{1}{4\pi\varepsilon_0} \frac{\vec{p}}{(r^2)^{3/2}}$$

$r >> a$

$r \uparrow$

$a \downarrow$

$$\vec{E}_{total} = -\frac{1}{4\pi\varepsilon_0} \frac{\vec{p}}{r^3}$$

Torque

τ (Tau)

Greek Letters

$\tau = PE \sin\theta$

$\tau \Rightarrow$ Torque

$P \rightarrow$ Electric dipole Moment

$E \rightarrow$ Electric field

$\theta \rightarrow$ Angle

$\tau = PE \sin\theta$

$\tau_{Max} = PE \sin(90°)$

$\tau_{Max} = PE(1)$

$\tau_{Max} = PE$

$\tau_{Min} = PE \sin(0^\circ)$ $\quad$ $\sin 90^\circ = 1$

$\tau_{min} = PE(0)$ $\quad$ $\theta^\circ = 0$

$\tau_{Min} = 0$ $\quad$ $\sin(0^\circ) = 0$

vector quantity

Example 1.11

pg:25

$E = 3 \times 10^4\ NC^{-1}$

$P = 3.4 \times 10^{-30}\ Cm$

$\tau_{max} = ?$

$\tau_{max} = PE \sin\theta$

$\tau_{max} = 3.4 \times 10^{-30}\ Cm \times 3 \times 10^4\ NC^{-1} \times \sin\theta$

$\tau_{max} = 3.4 \times 3 \times 10^{-30} \times 10^4\ Nm \times (1)$

$\tau_{max} = 10.2 \times 10^{-30-4}\ Nm$

$\tau_{max} = 10.2 \times 10^{-26}\ Nm$

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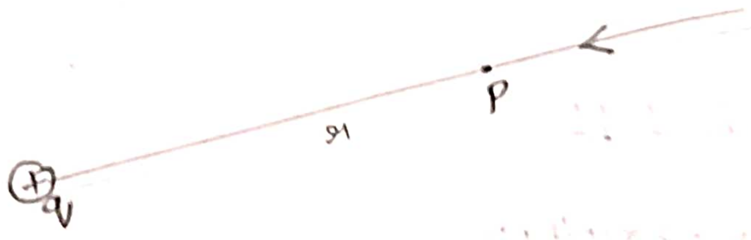
LA

Derive an expression for electrostatic Potential due to a point charge



Electrostatic potential unit = V (Volt)

$$V = \int_{\infty}^{r} -\vec{E}\, dr$$

V → Electrostatic potential

$\vec{E}$ → Electric field

$$\vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \hat{r}$$

$$V = \int_{\infty}^{r} -\vec{E}\, d\vec{r} \qquad d\vec{r} = dr\, \hat{r}$$

$$V = -\int_{\infty}^{r} E\, d\vec{r} \qquad \hat{r}\hat{r} = 1$$

$$V = -\int_{\infty}^{r} \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} \hat{r}\, d\vec{r}$$

$$V = -\int_{\infty}^{r} \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} d\vec{r}\, \hat{r}$$

$$V = -\int_{\infty}^{r} \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} dr\, \hat{r}\hat{r}$$

$$V = -\int_{\infty}^{r} \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} dr \quad (1)$$

$$V = -\int_{\infty}^{r} \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} dr$$

$$V = -\int_{\infty}^{r} \frac{1}{4\pi\varepsilon_0} \frac{q}{r^2} dr$$

$$V = -\int_{\infty}^{r} \frac{q}{4\pi\varepsilon_0} \frac{1}{r^2} dr$$

$$V = \frac{-q}{4\pi\varepsilon_0} \int_{\infty}^{r} \frac{1}{r^2} dr$$

$$V = \frac{-q}{4\pi\varepsilon_0} \int_{\infty}^{r} r^{-2} dr$$

$$\int x\,dx = \frac{x^{n+1}}{n+1} + c$$

$$V = \frac{-q}{4\pi\varepsilon_0} \left[\frac{r^{-2+1}}{-2+1}\right]_{\infty}^{r}$$

$$V = -\frac{q}{4\pi\varepsilon_0} \left[\frac{r^{-1}}{-1}\right]_{\infty}^{r}$$

$$V = -\frac{q}{4\pi\varepsilon_0} \left[-r^{-1}\right]_{\infty}^{r}$$

$$V = \frac{q}{4\pi\varepsilon_0} \left[r^{-1}\right]_{\infty}^{r} \qquad 1/\infty = 0$$

$$V = \frac{q}{4\pi\varepsilon_0} \left[\frac{1}{r}\right]_{\infty}^{r}$$

$$V = \frac{q}{4\pi\varepsilon_0} \left[\frac{1}{r} - \frac{1}{\infty}\right]$$

$$V = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r} - 0\right]$$

$$V = \frac{q}{4\pi\varepsilon_0}\frac{1}{r}$$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

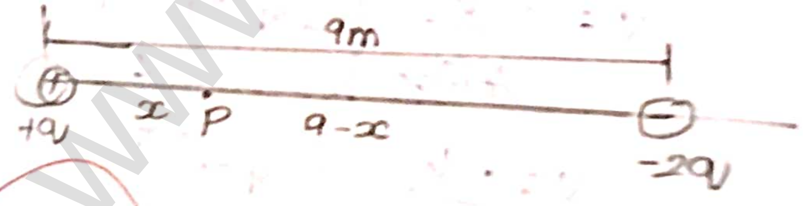
+q → potential decreases → distance increases

−q → potential increases → distance increases

$r = \infty \qquad V = 0$

Example 1.13

consider a point charge +q placed at the origin and another point charge −2q placed at a distance of 9m the charge +q. The point between two charge.



Electrostatic potential

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

$$V_{total} = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{x} - \frac{2q}{(9-x)}\right) = 0$$

$$\frac{q}{x} - \frac{2q}{(9-x)} = 0$$

$$\frac{q}{x} = \frac{2q}{9-x}$$

$$\frac{1}{x} = \frac{2}{9-x}$$

$$9-x = 2x$$

$$9 = 2x + x$$

$$9 = 3x$$

$$\frac{9}{3} = x$$

$$\frac{3 \times \cancel{3}}{\cancel{3}} = x$$

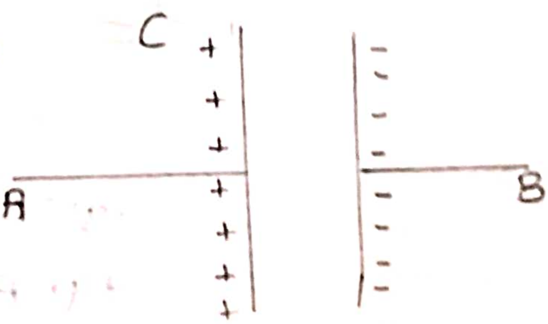
$$3 = x$$

$$x = 3m$$

---

capacitance of conductor

"Charge" storage" device



$$C = \frac{Q}{V}$$

C → capacitance of conductor

Q → charge

V → potential difference

unit : farad (f)

μf → micro farad $= 10^{-6} f$

pf → pico farad $= 10^{-12} f$

↓

practical unit

nf ⇒ nano farad $= 10^{-9} f$

capacitance connection

series connection

$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

parallel connection

$$C_p = C_1 + C_2 + C_3$$

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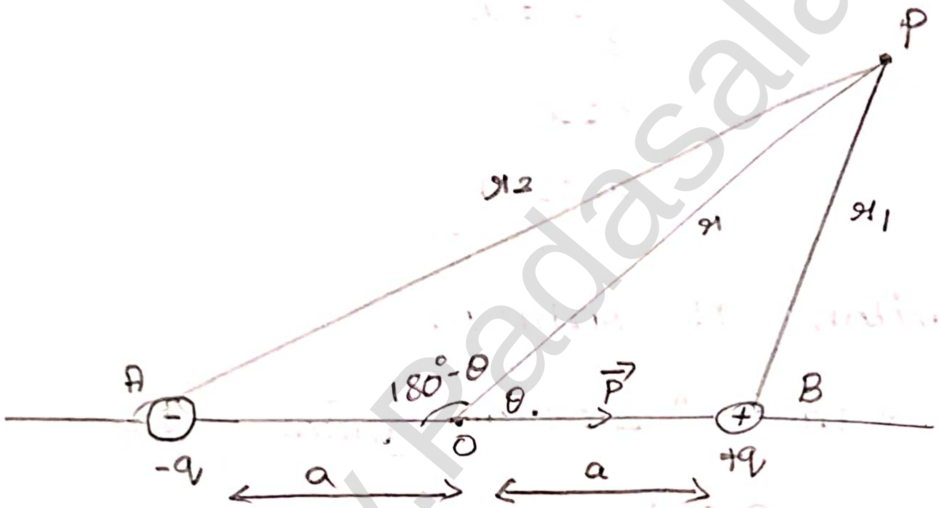
-) Derive an expression for electrostatic potential due to an electric dipole



$-q$ Negative charge

$+q$ positive charge

O centre of the point

r Distance

a Distance

2a small distance

A B Two points

$AOP = r_2$

$BOP = r_1$

$OA = a$

$OB = a$

AOP

BOP

$AOP = (180° - \theta)$

$BOP = \theta°$

AB = a + a = 2a

OP = r

B point

+q charge (BOP)

Electrostatic potential (V)

$$V = \frac{1}{4\pi\varepsilon_0} \frac{q}{r}$$

$$V_1 = \frac{1}{4\pi\varepsilon_0} \frac{+q}{r_1}$$

$$V_1 = \frac{1}{4\pi\varepsilon_0} \frac{q}{r_1} \longrightarrow (1)$$

A Point

-q charge (AOP)

Electrostatic potential (V)

$$V = \frac{1}{4\pi\varepsilon_0} \frac{q}{r}$$

$$V_2 = \frac{1}{4\pi\varepsilon_0} \frac{-q}{r_2}$$

$$V_2 = \frac{1}{4\pi\varepsilon_0} \frac{-q}{r_2} \longrightarrow (2)$$

Total Electrostatic potential

$$V = V_1 + V_2$$

$$V = \left(\frac{1}{4\pi\varepsilon_0} \frac{q}{r_1}\right) + \left(\frac{1}{4\pi\varepsilon_0} \frac{-q}{r_2}\right)$$

$$V = \left\{\frac{1}{4\pi\varepsilon_0} \frac{q}{r_1} - \frac{1}{4\pi\varepsilon_0} \frac{q}{r_2}\right.$$

$$V = \frac{q}{4\pi\varepsilon_0} \frac{1}{r_1} - \frac{q}{4\pi\varepsilon_0} \frac{1}{r_2}$$

$$V = \frac{q}{4\pi\varepsilon_0}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \rightarrow (3)$$

To ~~fiad~~ find $1/r_1$

Triangle BOP (+q charge)

cosine law

$$r_1^2 = r^2 + a^2 - 2ra\cos\theta.$$

Rearrange $r >> a$

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

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

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

Inverse

high power reduce

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

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

using Binomial theorem

$$\frac{1}{r_1} = \frac{1}{r}\left(1 + \frac{a}{r}\cos\theta\right) \rightarrow (4)$$

To find $1/r_2$

cosine law (AOP) (-q charge)

$(180° - \theta)$

$$r_2^2 = r^2 + a^2 - 2ra\cos(180° - \theta)$$

$$\cos(180°) = -1$$

$$\cos(180° - \theta) = -\cos\theta$$

$$r_2^2 = r^2 + a^2 - 2ra(-\cos\theta)$$

$$r_2^2 = r^2 + a^2 + 2ra\cos\theta$$

Rearrange

$$r_2^2 = r^2\left(1 + \frac{a^2}{r^2} + \frac{2a}{r}\cos\theta\right)$$

$r >> a$ $\frac{a^2}{r^2}$ neglected

$$r_2^2 = r^2\left(1 + \frac{2a}{r}\cos\theta\right)$$

$$r_2 = r\left(1 + \frac{2a}{r}\cos\theta\right)^{1/2}$$

Inverse

$$1/r_2 = 1/r \frac{1}{\left(1 + 2a/r\cos\theta\right)^{1/2}}$$

$$1/r_2 = 1/r\left(1 + 2a/r\cos\theta\right)^{-1/2}$$

using Binomial Theorem

$$1/r_2 = 1/r\left(1 - \frac{a}{r}\cos\theta\right) \longrightarrow (5)$$

From equation (3)

$$V = \frac{q}{4\pi\varepsilon_0}\left(1/r_1 - 1/r_2\right)$$

$$V = \frac{q}{4\pi\varepsilon_0}\left[\left(1/r\left(1 + \frac{2a}{r}\cos\theta\right) - \left(1/r\left(1 - a/r\cos\theta\right)\right)\right]$$

$$V = \frac{q}{4\pi\varepsilon_0} 1/r\left[\left(1 + a/r\cos\theta\right) - \left(1 - a/r\cos\theta\right)\right]$$

$$V = \frac{q}{4\pi\varepsilon_0} 1/r\left[1 + a/r\cos\theta - 1 + a/r\cos\theta\right]$$

$$V = \frac{q}{4\pi\varepsilon_0} 1/r\left[a/r\cos\theta + a/r\cos\theta\right]$$

$$V = \frac{q}{4\pi\varepsilon_0} \frac{1}{r} \left[\left(\frac{a}{r} + \frac{a}{r} \right) \cos\theta \right]$$

$$V = \frac{q}{4\pi\varepsilon_0} \frac{1}{r} \left[\frac{2a}{r} \cos\theta \right]$$

$$V = \frac{q}{4\pi\varepsilon_0} \frac{2a\cos\theta}{r^2}$$

$$V = \frac{1}{4\pi\varepsilon_0} \frac{q \times 2a \cos\theta}{r^2} \qquad q \times 2a = p$$

$$V = \frac{1}{4\pi\varepsilon_0} \frac{p\cos\theta}{r^2}$$

$$p\cos\theta = \vec{p} \cdot \hat{r}$$

$$V = \frac{1}{4\pi\varepsilon_0} \frac{\vec{p} \cdot \hat{r}}{r^2} \rightarrow (6)$$

special case

i) +q charge Axis line

$\theta = 0°$

$$V = \frac{1}{4\pi\varepsilon_0} \frac{p\cos\theta}{r^2}$$

$$V = \frac{1}{4\pi\varepsilon_0} \frac{p\cos(0°)}{r^2} \qquad \cos\theta(0°) = 1$$

$$V = \frac{1}{4\pi\varepsilon_0} \frac{p(1)}{r^2}$$

$$V = \frac{1}{4\pi\varepsilon_0} p/r^2$$

ii) −q charge Axis line

$\theta = 180°$

$$V = \frac{1}{4\pi\varepsilon_0} \frac{p\cos\theta}{r^2}$$

$$V = \frac{1}{4\pi\varepsilon_0} \frac{P\cos(180^\circ)}{r^2}$$

$$V = \frac{1}{4\pi\varepsilon_0} \frac{P(-1)}{r^2}$$

$$V = \frac{-1}{4\pi\varepsilon_0} \frac{P}{r^2}$$

iii) Equatorial line

$$V = \frac{1}{4\pi\varepsilon_0} \frac{P\cos\theta}{r^2} \qquad \theta = 90^\circ \qquad \cos 90^\circ = 0$$

$$V = \frac{1}{4\pi\varepsilon_0} \frac{P\cos\theta(90^\circ)}{r^2}$$

$$V = 0$$

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