JEE MAIN

ELECTROSTATICS FORMULAE

Now that's how you REVISE

-Mohit Goenka, IIT Kharagpur

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EDUNITI

Eduniti for Physics

ELECTROSTATICS

$Q = ne^-$, $n \in I$

$e = 1.6 \times 10^{-19}\ C$

COULOMB'S LAW

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

$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ Nm^2/C^2$$

ε_0 : permittivity of free space

$8.85 \times 10^{-12}\ C^2/Nm^2$

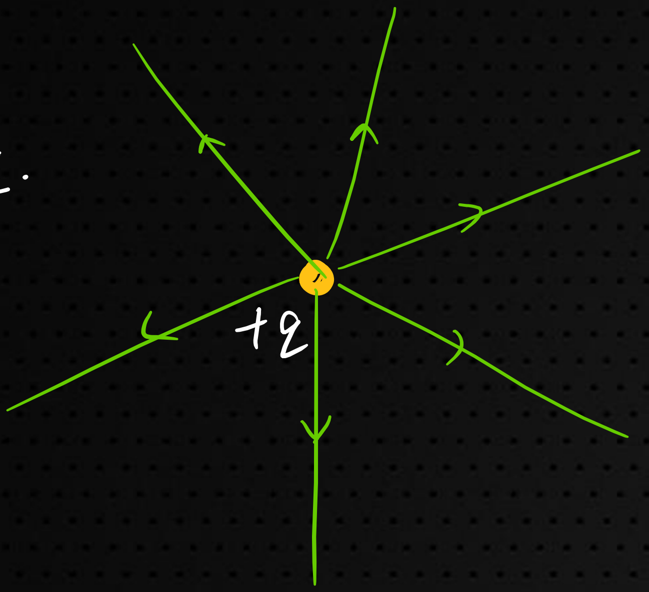
ε_r : Relative permittivity of medium

VECTOR Form : $\vec{F}_{21} = \dfrac{Kq_1q_2(\vec{r}_2 - \vec{r}_1)}{|\vec{r}_2 - \vec{r}_1|^3}$

* Put q_1 and q_2 with sign.

ELECTRIC FIELD $\left(E = Kq/r^2 \right)$, N/C

1.



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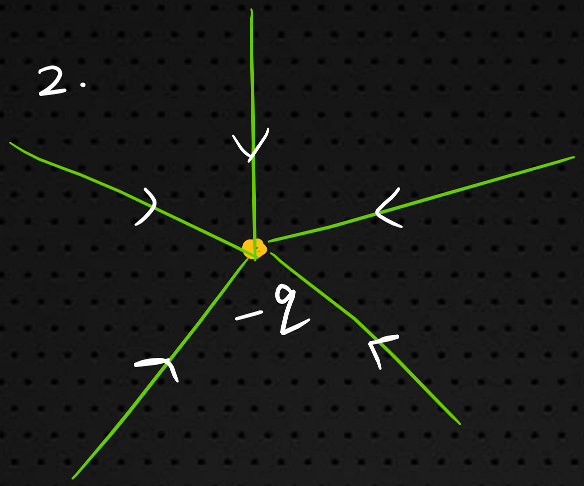

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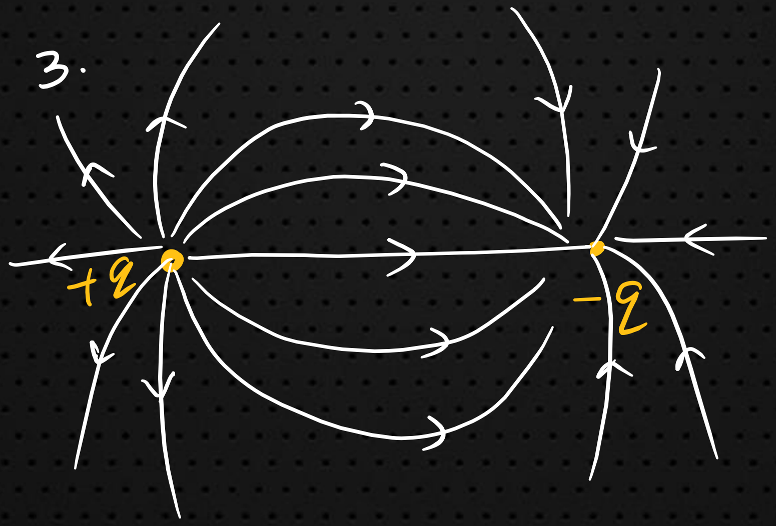


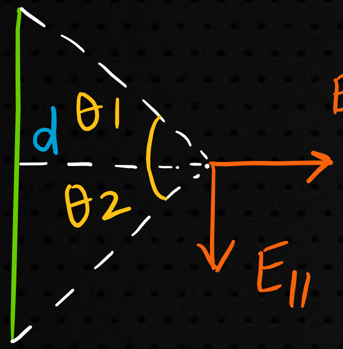
4.

ELECTRIC FIELD DUE TO LINE CHARGE

(CHARGE IS UNIFORMLY DISTRIBUTED)

FINITE LENGTH

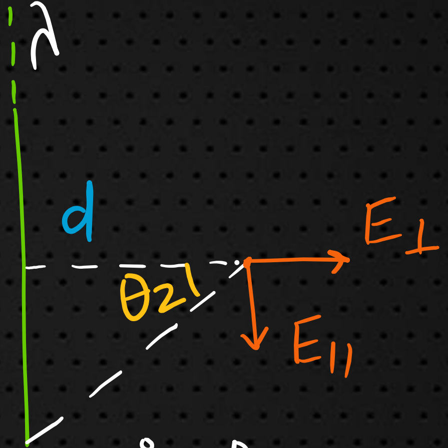
λ C/m



$$E_{\perp} = \frac{K\lambda}{d}\left(\sin\theta_1 + \sin\theta_2\right)$$

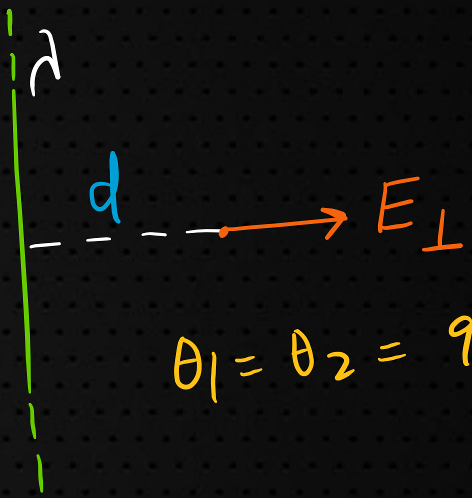
$$E_{\parallel} = \frac{K\lambda}{d}\left(\cos\theta_2 - \cos\theta_1\right)$$

SEMI-INFINITE



$\theta_1 = 90^\circ,\ \theta_2$

INFINITE



$\theta_1 = \theta_2 = 90^\circ$

$$E_{\perp} = \frac{2K\lambda}{d} = \frac{\lambda}{2\pi\varepsilon_0 d}$$

$$E_{\parallel} = 0$$

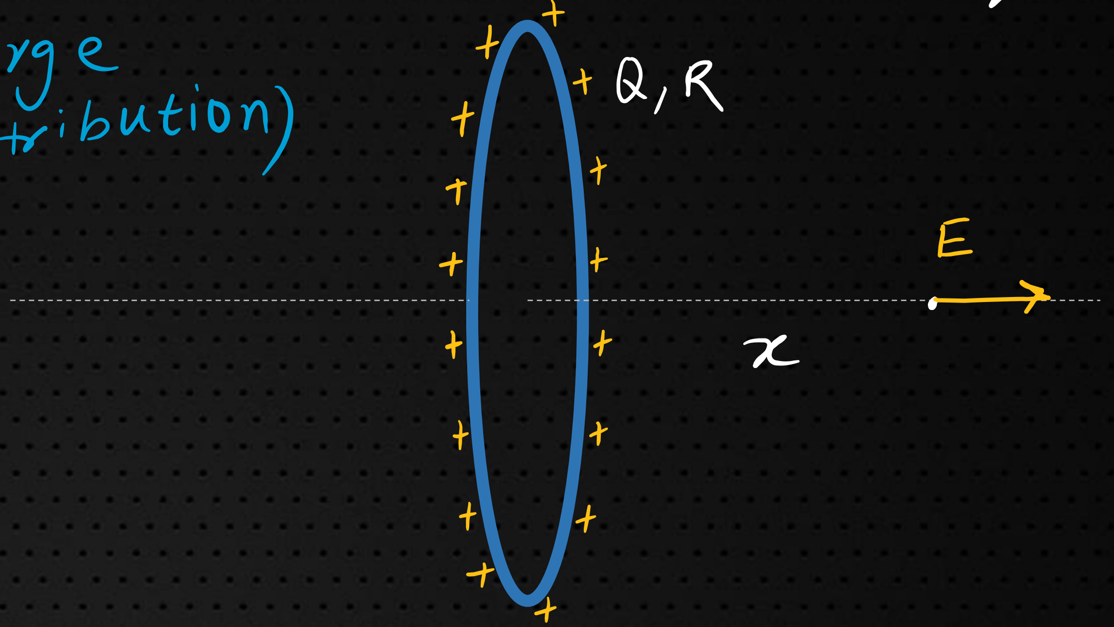
ELECTRIC FIELD DUE TO CHARGED RING

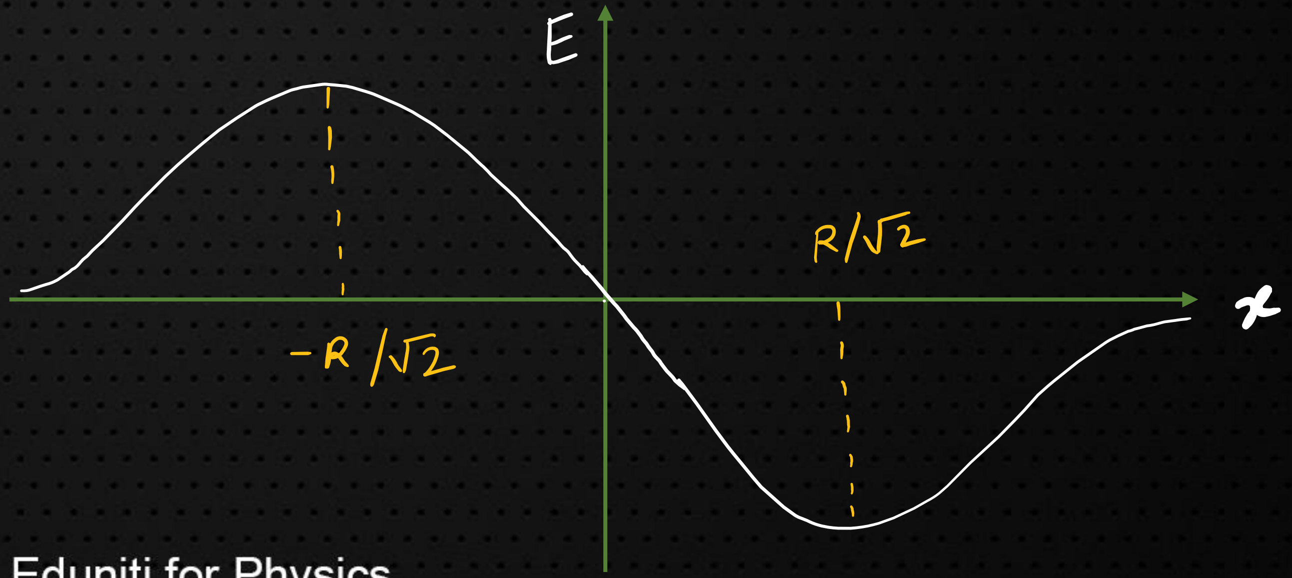
(uniform charge Distribution)

$$E = \frac{KQx}{(x^2+R^2)^{3/2}}$$

↳ at $x = \pm R/\sqrt{2}$, E is Max

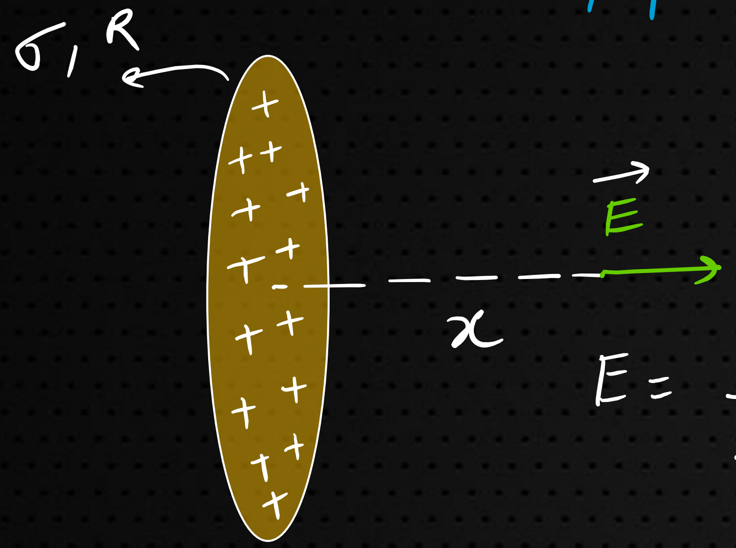
↳ at $x = 0$, $E = 0$
(center)





ELECTRIC FIELD DUE TO CHARGED DISC

σ C/m^2 (UNIFORM CHARGE Distribution)



$$E = \frac{\sigma}{2\epsilon_0}\left(1 - \frac{x}{\sqrt{x^2+R^2}}\right)$$

Case If Disc is very large ($x << R$)

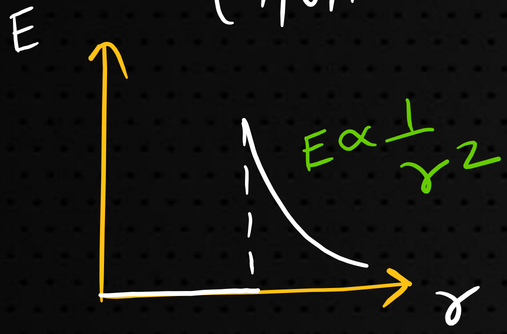
$$\boxed{E = \frac{\sigma}{2\epsilon_0}}$$

↳ for infinite sheet

ELECTRIC FIELD DUE TO CHARGED SPHERE

CONDUCTOR

(Hollow or solid, Q is on surface)



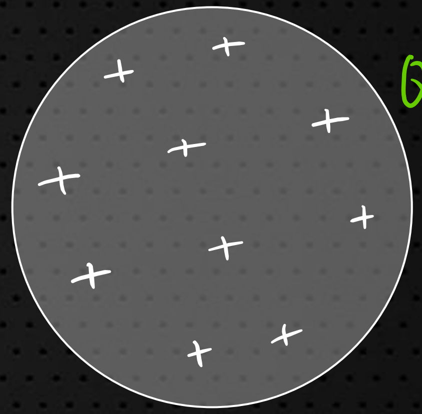
(1) For $r < R$, $E = 0$

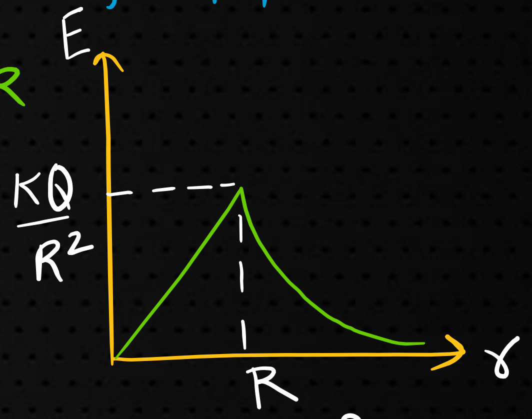
(2) For $r \geq R$, $E = \frac{KQ}{r^2}$

NON-CONDUCTOR

(uniformly in solid)

$\rho \ c/m^3$





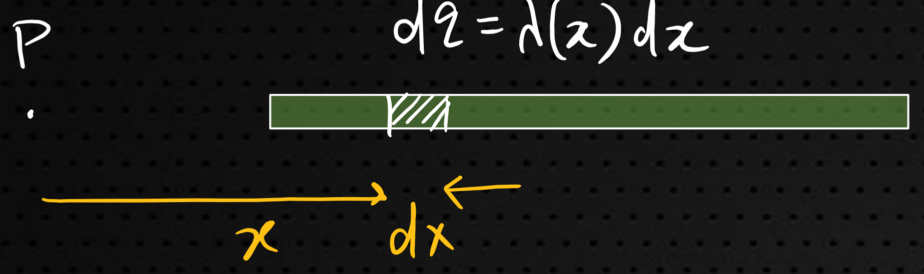
(1) $r < R$, $E = \frac{KQr}{R^3}$ or $\frac{\rho r}{3\epsilon_0}$

(2) $r \geq R$, $E = \frac{KQ}{r^2}$

ELECTRIC FIELD (NON-UNIFORM CHARGE Distribution)

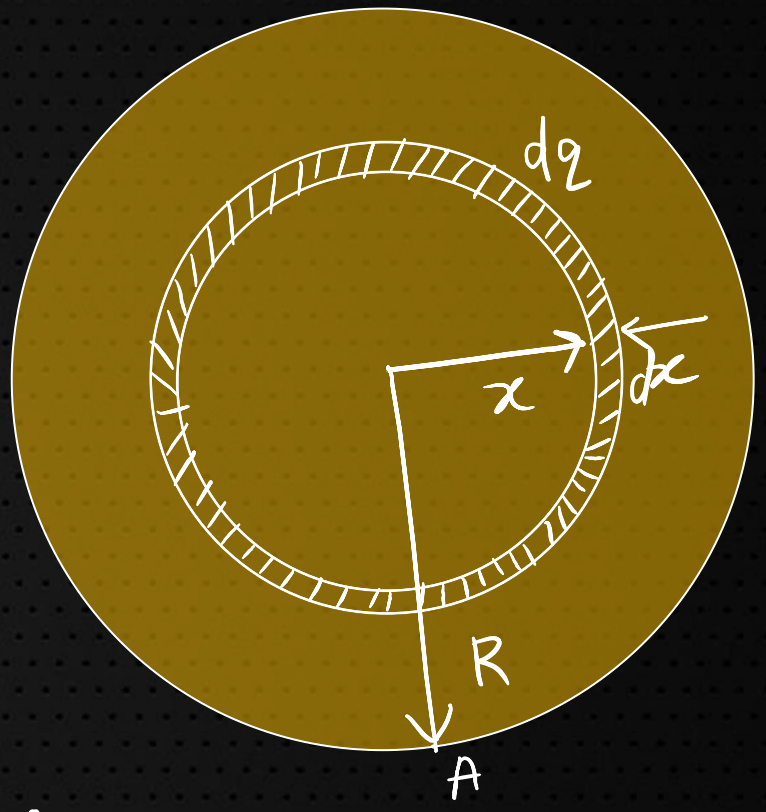
1.

$dq = \lambda(x)\,dx$



$$E = \int_a^b \frac{K\lambda(x)\,dx}{x^2}$$

2.



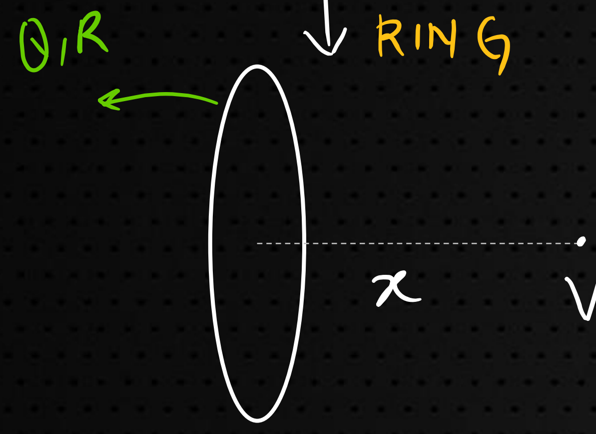
$$E_A = \frac{K\,Q_{in}}{R^2}$$

$$Q_{in} = \int dq = \int_0^R \rho(x) \times 4\pi x^2\,dx$$

ELECTROSTATIC POTENTIAL

$V = \frac{Kq}{r}$, put q with sign.

RING

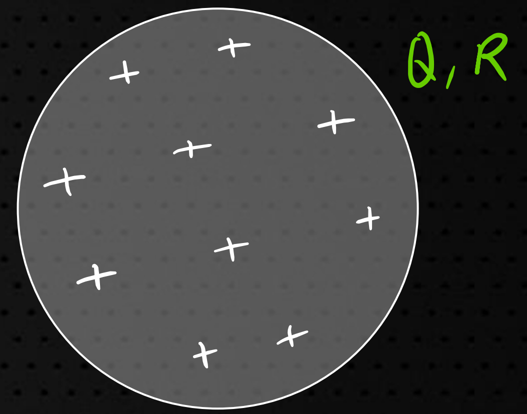


$V = \frac{KQ}{\sqrt{x^2+R^2}}$

SHELL

1. $r < R$, $V = KQ/R$
2. $r \geq R$, $V = KQ/r$

SOLID SPHERE



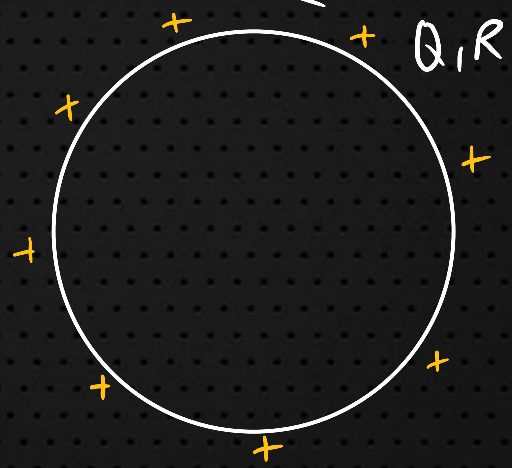
1. $r < R$, $V = \frac{KQ}{2R^3}(3R^2 - r^2)$
2. $r \geq R$, $V = KQ/r$

ELECTROSTATIC POTENTIAL ENERGY

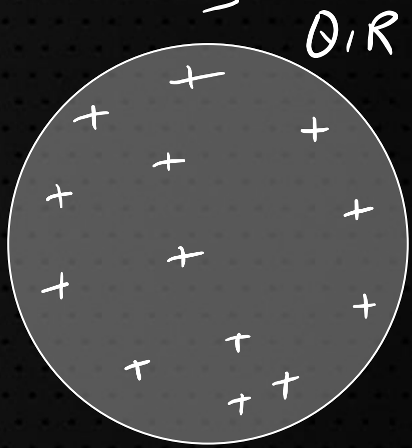
$$U = Kq_1q_2/r$$

↳ put q_1 and q_2 with sign

SELF ENERGY



$$U = \frac{KQ^2}{2R}$$



$$U = \frac{3KQ^2}{5R}$$

RELATION BETWEEN E and V

(1.) $\vec{E} = -\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j} - \frac{\partial V}{\partial z}\hat{k}$

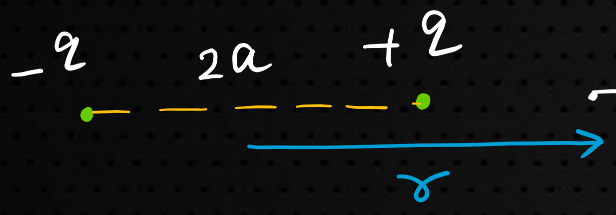
(2.) $\Delta V = -\int \vec{E} \cdot \vec{dr}$

Here $\frac{\partial V}{\partial x}$ means differentiate V w.r.t x keeping y and z constant.

ELECTRIC DIPOLE ($-q$ --- d --- $+q$, $P = qd$, direction from −VE to +VE)

ELECTRIC FIELD

AXIAL POINT



$$E = \frac{2PKr}{(r^2-a^2)^2}$$

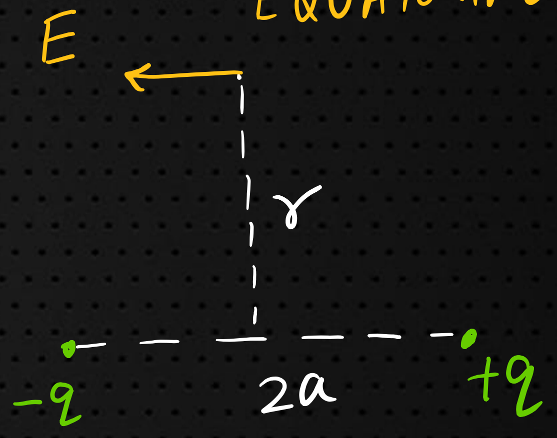
*** SHORT DIPOLE** $(r >> a)$

$$E_{axial} = 2PK/r^3$$

Direction : Along $\vec{P}$

$$P = 2aq$$

EQUATORIAL POINT



$$E = \frac{PK}{(r^2+a^2)^{3/2}}$$

*** SHORT DIPOLE** $(r >> a)$

$$E_{eq} = PK/r^3$$

Dir^n : OPP $\vec{P}$

ELECTRIC DIPOLE ($-q$ ——— d ——— $+q$, $P = qd$, direction from -VE to +VE)

POTENTIAL

AXIAL POINT

$$V = \frac{PK}{r^2 - a^2}$$

SHORT DIPOLE ($r >> a$)

$$V = \frac{PK}{r^2}$$

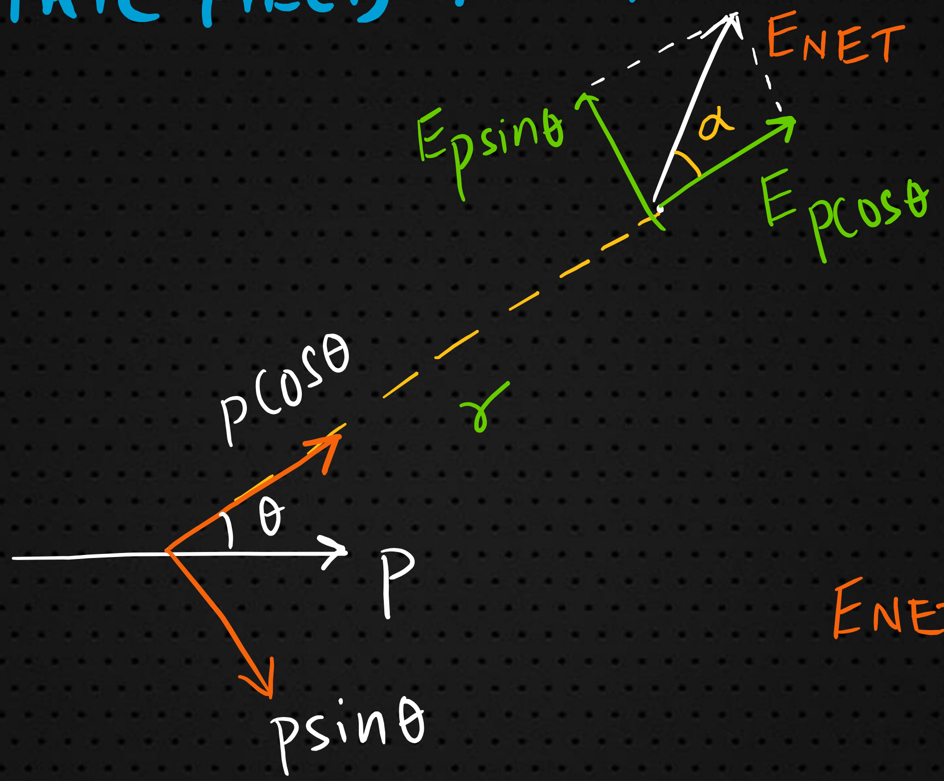
$$P = 2aq$$

Equatorial point

$$V = 0$$

ELECTRIC DIPOLE ($-q$ —— d —— $+q$, $P = qd$, direction from $-$VE to $+$VE)

ELECTRIC FIELD AT GENERAL POINT



$$E_{p\cos\theta} = \frac{2p\cos\theta K}{r^3}$$

$$E_{p\sin\theta} = \frac{p\sin\theta K}{r^3}$$

$$E_{NET} = \sqrt{E^2_{p\cos\theta} + E^2_{p\sin\theta}}$$

$$= \frac{pK}{r^3}\sqrt{1+3\cos^2\theta}$$

$$\boxed{\tan\alpha = \frac{\tan\theta}{2}}$$

ELECTRIC DIPOLE ($-q$ ---- d ---- $+q$, $p = qd$, direction from $-ve$ to $+ve$)

DIPOLE IN E (uniform)

TORQUE

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

↳ SHM based Question

Potential Energy

$$U = -\vec{p} \cdot \vec{E}$$

STABLE ↳ $\theta = 0^\circ$, $U_{min} = -pE$

UNSTABLE ↳ $\theta = 180^\circ$, $U_{max} = pE$

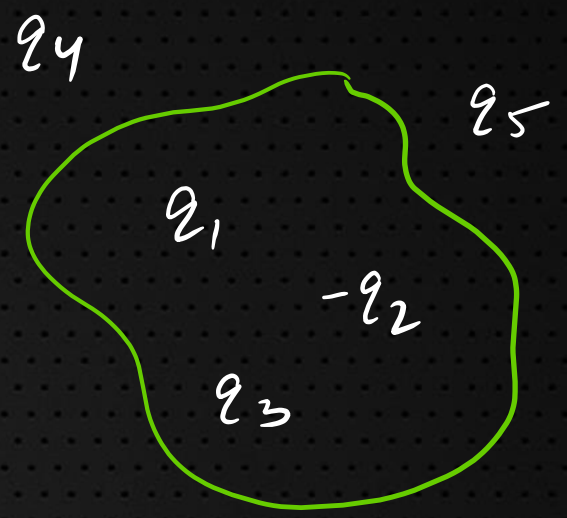
↳ $\theta = 90^\circ$, $U = 0$

ELECTRIC FLUX ($\phi = \vec{E} \cdot \vec{A}$)

GAUSS'S LAW

↳ $\oint \vec{E} \cdot d\vec{A} = \dfrac{q_{in}}{\varepsilon_0}$

1. q_{in} : charge enclosed
2. E : Electric field is due to all the charges.



$$\phi = \frac{q_1 - q_2 + q_3}{\varepsilon_0}$$

Solid ANGLE

$$\Omega = 2\pi(1 - \cos\alpha)$$

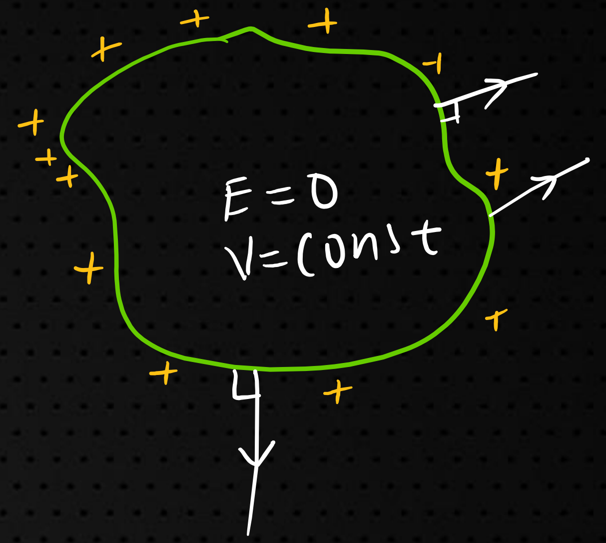
CONDUCTOR

(1.) charge remains on surface

(2.) Electric field inside is zero

(3.) V is constant

(4.) Field lines are $\perp$ to surface



(5.) CONNECTING TWO CONDUCTORS

↳ they share charge untill V of both bodies are same.

(6.) EARTHING:

V of body will always be zero