LAKSHYA JEE

LAKSHYA KO HAR HAAL ME PAANA HAI

Electric Potential & Capacitance

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Today's GOALS!

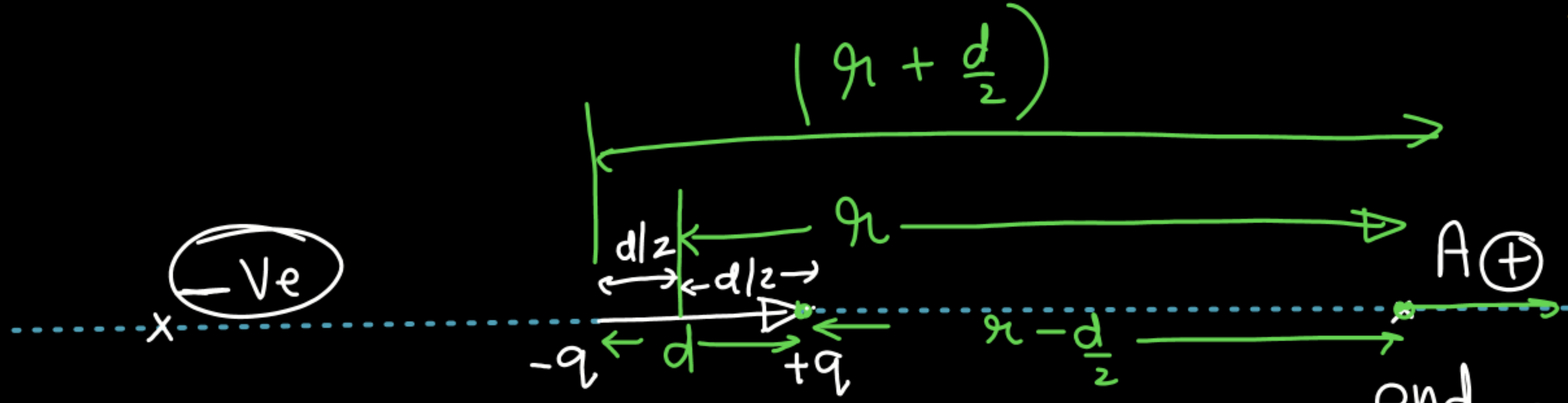
- Potential due to Electric Dipole
- Potential Energy of a dipole
- Dipole-Dipole interaction

Potential due to electric dipole

Axial line

$$\boxed{V = \frac{KP}{r^2}}$$

neglecting $\left(\frac{d}{2}\right)^2$



$$E_A = \frac{2KP}{r^3}$$

axial line

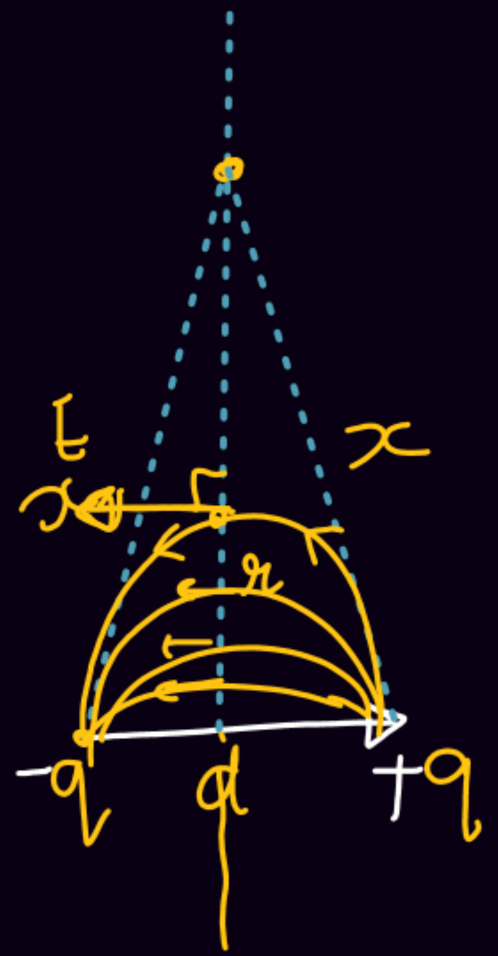
end-on position

$$V_A = V_{A_{+q}} + V_{A_{(-q)}}$$

$$= \frac{Kq}{\left(r-\frac{d}{2}\right)} - \frac{Kq}{\left(r+\frac{d}{2}\right)}$$

$$\Rightarrow Kq\,\frac{\left(\cancel{r}+\frac{d}{2}\right)-\left(\cancel{r}-\frac{d}{2}\right)}{\left(r+\frac{d}{2}\right)\left(r-\frac{d}{2}\right)} = \frac{Kqd}{r^2-\left(\frac{d}{2}\right)^2}$$

Equatorial line $V = 0$



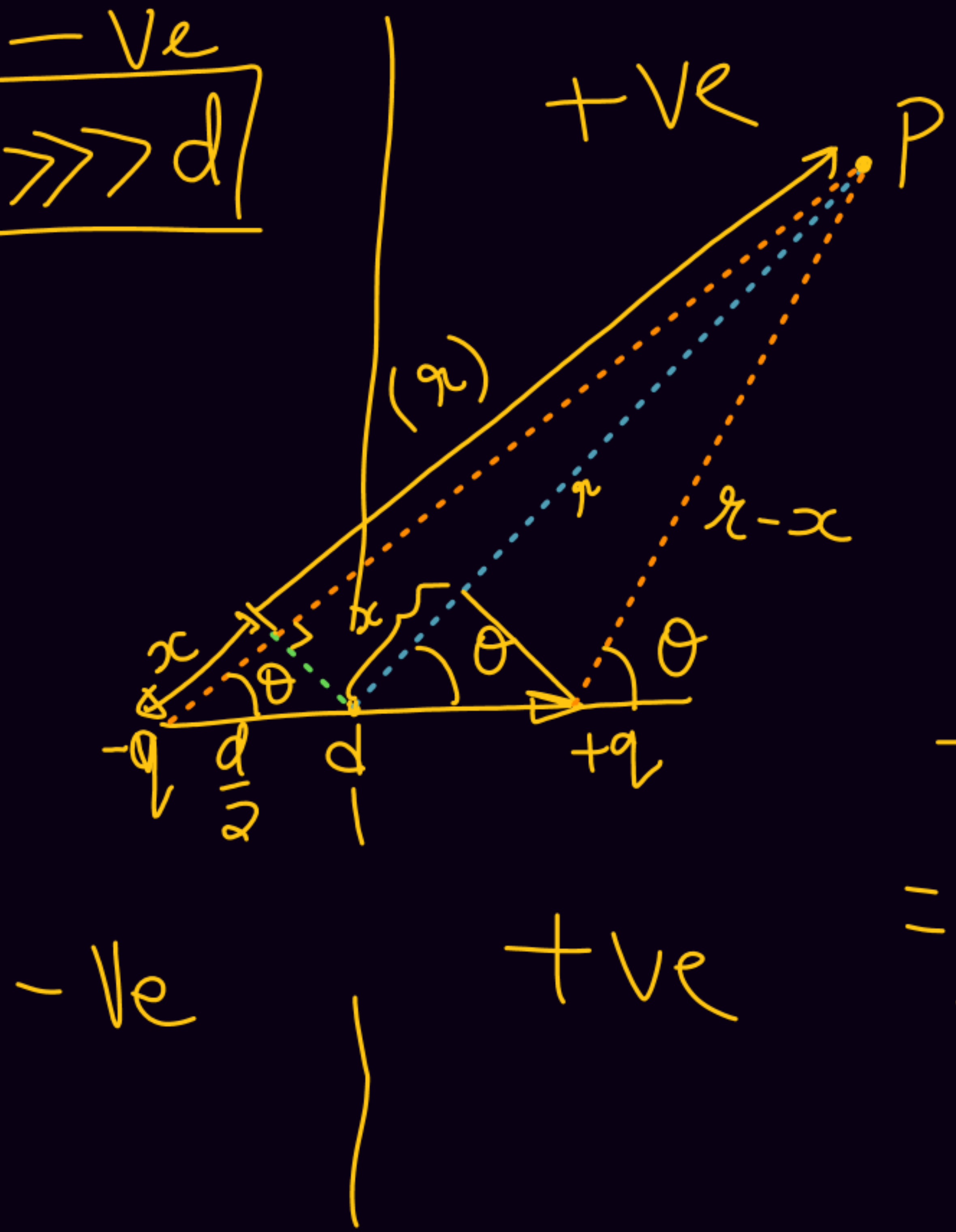
$$\boxed{V_{net} = 0}$$

Equatorial plane has zero potential.

→ equipotential

Electric potential at a general point

$\boxed{r >>> d}$



$\cos\theta = \frac{x}{\left(\frac{d}{2}\right)}$

$$\boxed{x = \frac{d}{2}\cos\theta}$$

$$V_P = \frac{Kq}{r-x} - \frac{Kq}{r+x}$$

$$= Kq\left(\frac{\cancel{r}+x-\cancel{r}+x}{r^2-x^2}\right)$$

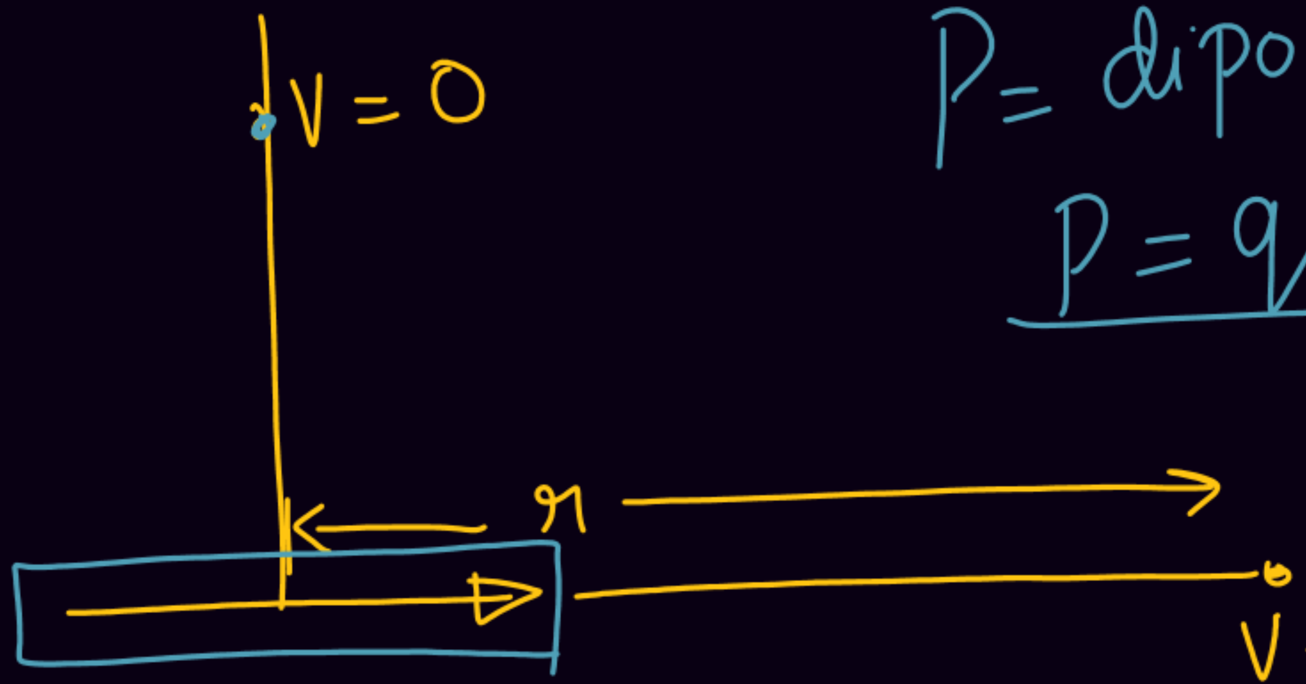
$$= \frac{K2qx}{r^2-x^2}$$

$x^2 << r^2$

x^2 is neglected.

$$= \frac{K\cancel{2}q\,\frac{d\cos\theta}{\cancel{2}}}{r^2}$$

$$\boxed{V = \frac{K\,P\cos\theta}{r^2}}$$

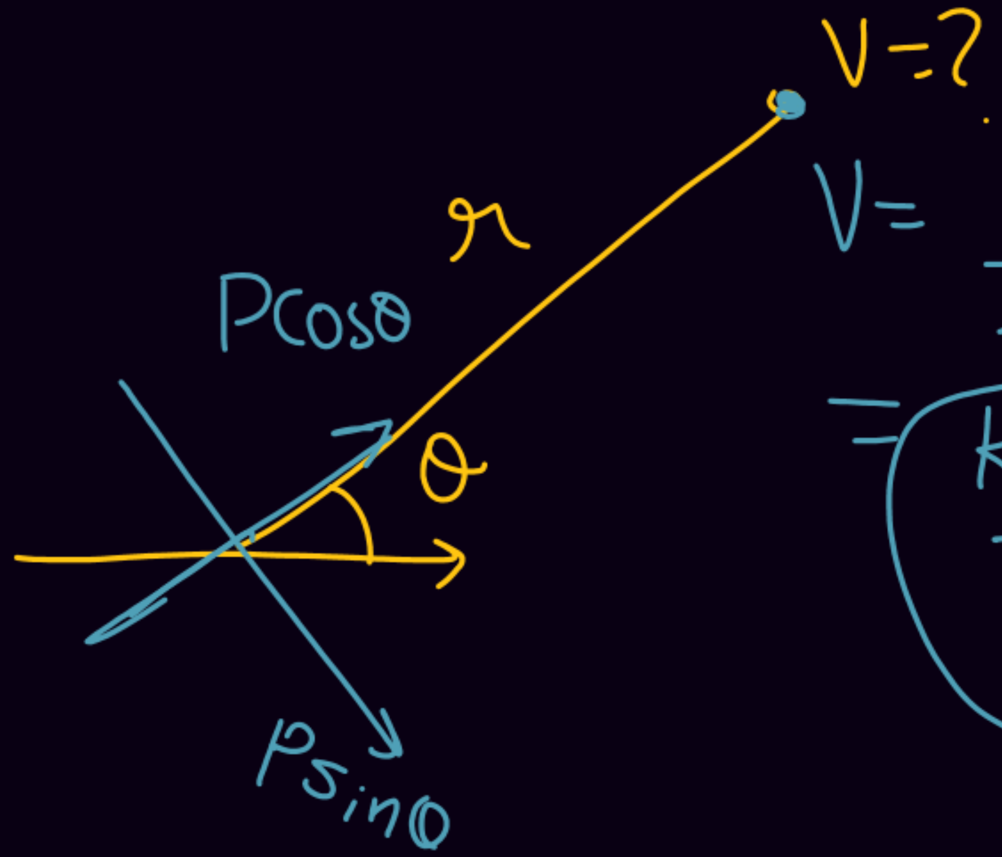


P = dipole moment

$$P = q\,d$$

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

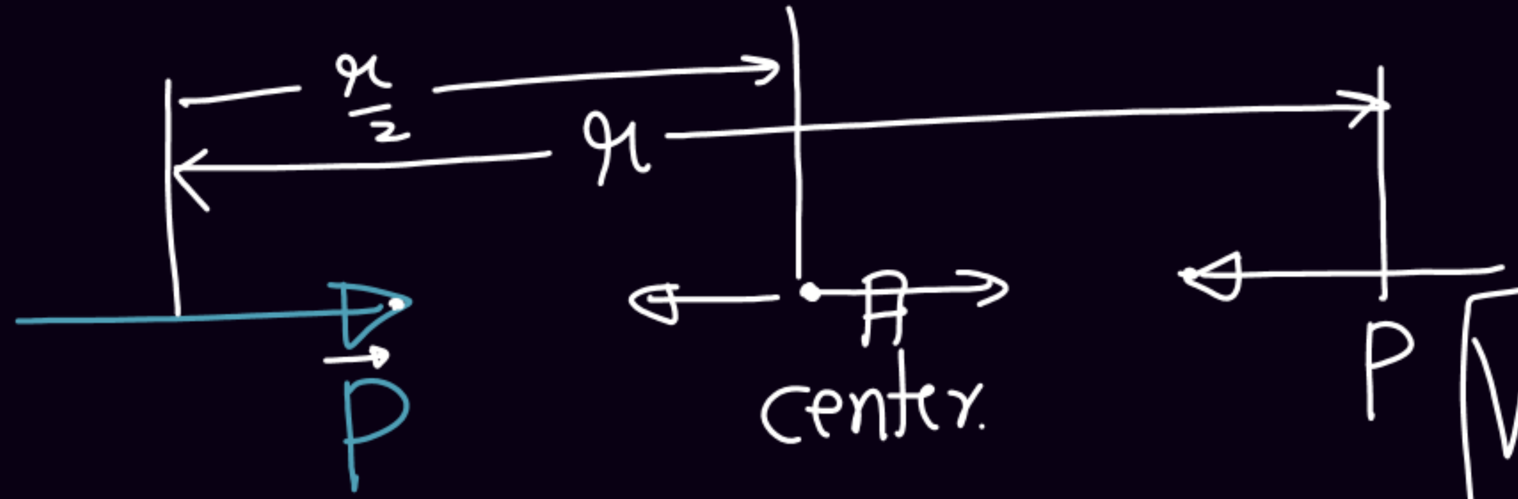
$$\frac{K}{r^2}(P\cos\theta) + 0$$



$$V = \frac{K}{r^2} P\cos\theta + 0$$

$$= \frac{KP\cos\theta}{r^2}$$

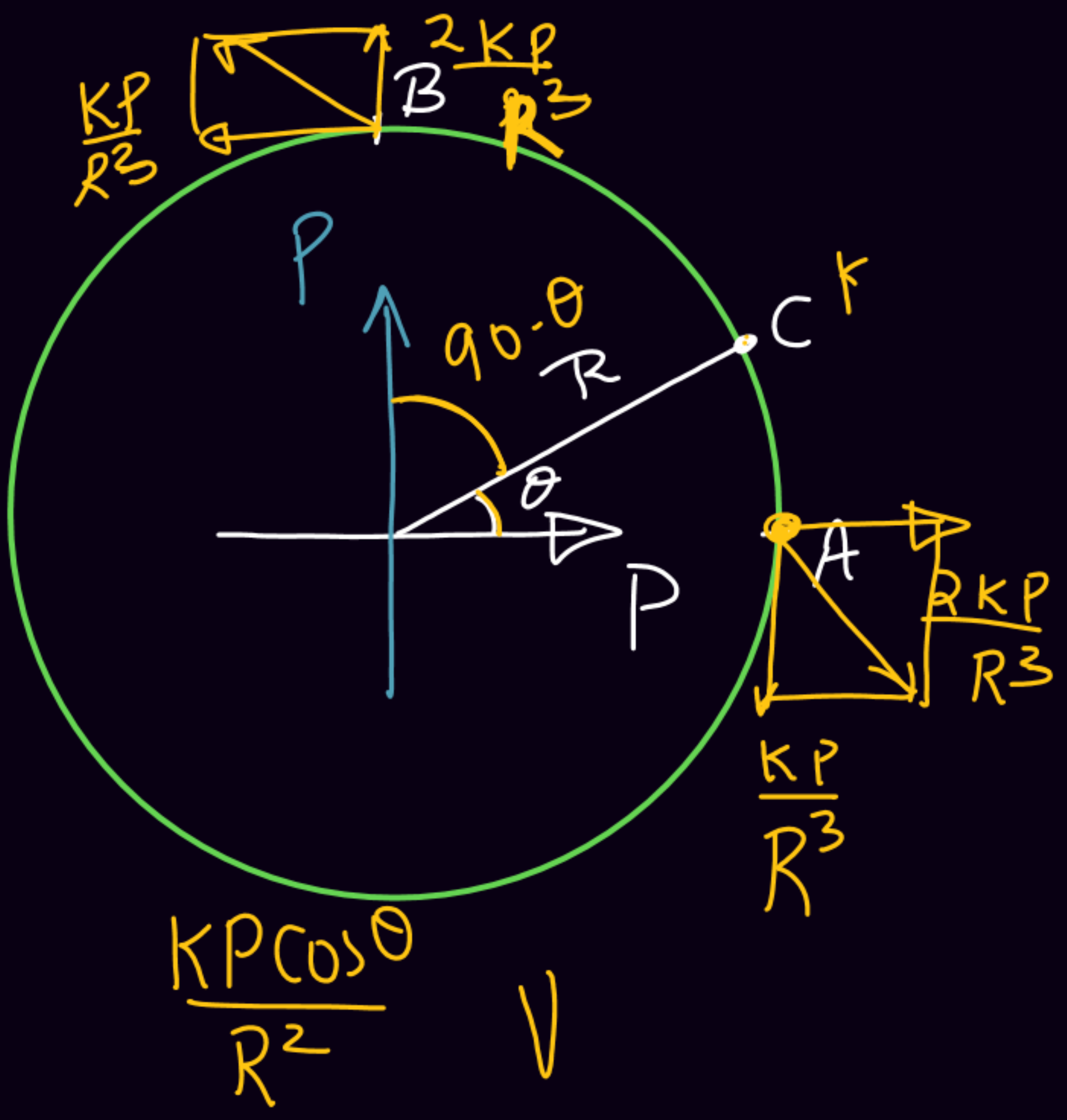
$$\frac{KP}{\left(\frac{r}{2}\right)^2} \times 2$$



$$\boxed{V_A = \frac{8KP}{r^2}}$$

Find V_A =

E_A.



$$E_A = \sqrt{\left(\frac{2KP}{R^3}\right)^2 + \left(\frac{KP}{R^3}\right)^2} = \sqrt{5}\,\frac{KP}{R^3}.$$

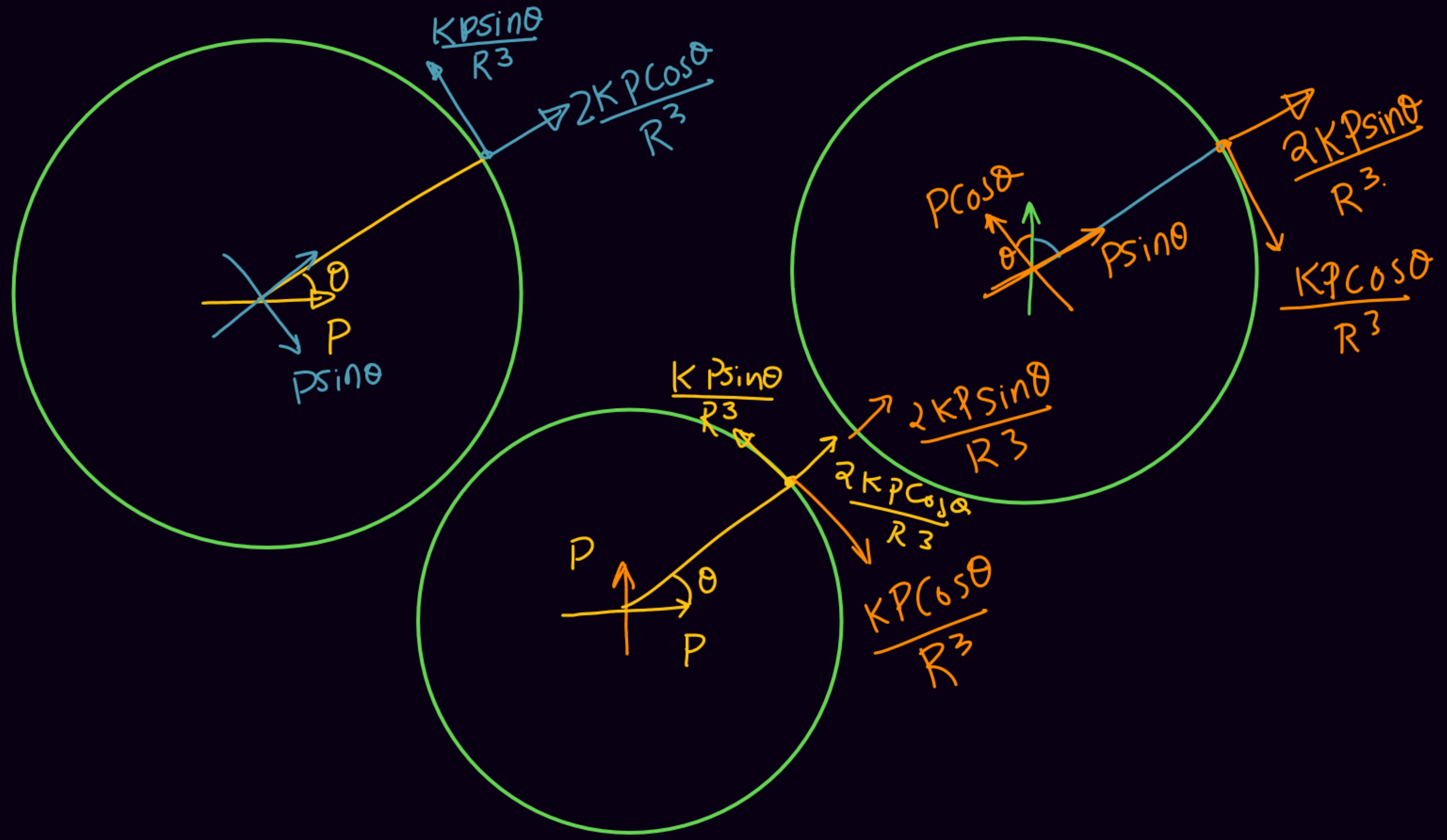
$$E_B = \sqrt{5}\,\frac{KP}{R^3}.$$

$$\underline{\underline{E_C}} =$$

$$V_A = \frac{KP}{R^2}.$$

$$V_B = \frac{KP}{R^2}.$$

$$V_C = \frac{KP\cos\theta}{R^2} + \frac{KP\cos(90-\theta)}{R^2} = \underline{\frac{KP}{R^2}\left[\cos\theta + \sin\theta\right]}$$

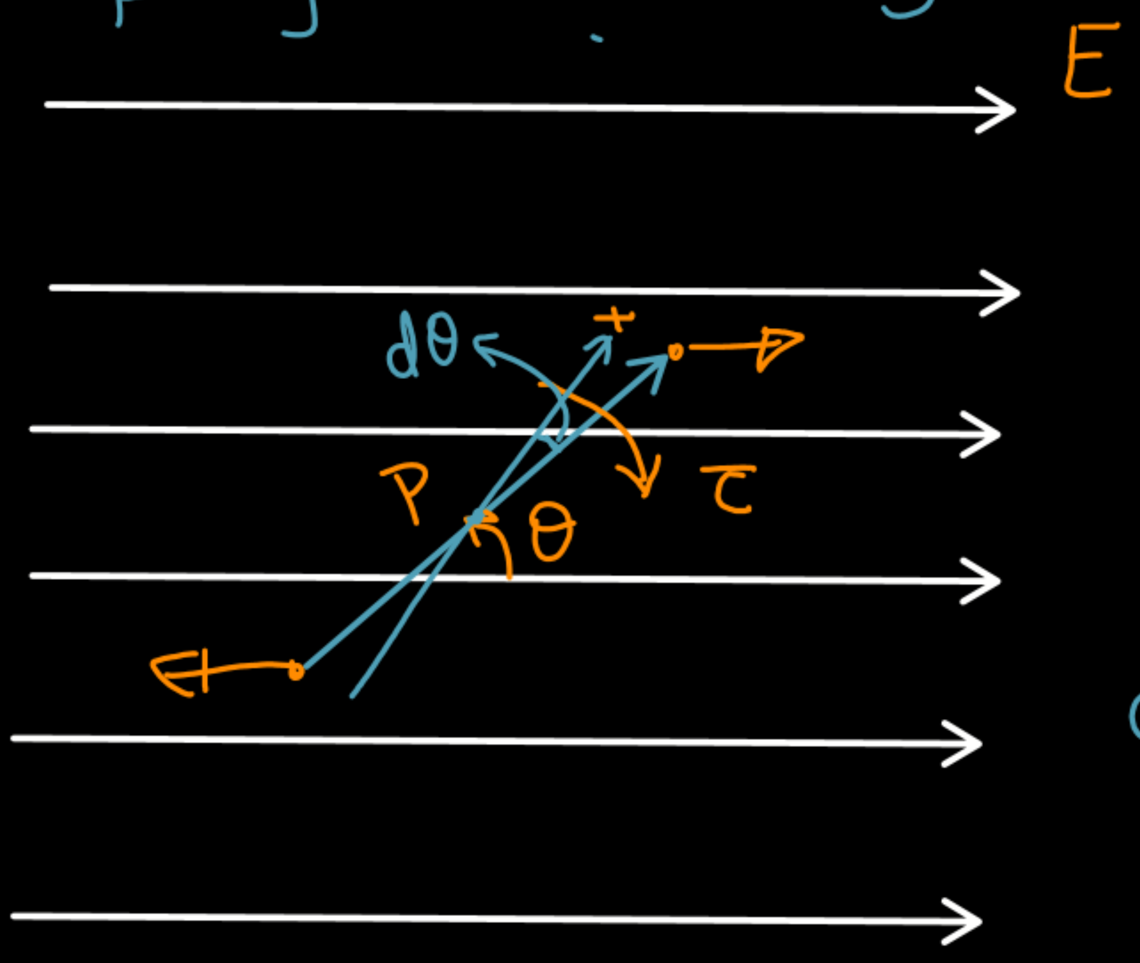


Kpsinθ / R3
2KPCosθ / R3
θ
P
Psinθ
KPsinθ / R3
2KPsinθ / R3
2KPCosθ / R3
θ
P
P
KPCosθ / R3
PCosθ
θ
Psinθ
2KPsinθ / R3.
KPCosθ / R3

Potential energy of dipole

$W_F = \int \vec{F} \cdot d\vec{x}$; $W_\tau = \int \vec{\tau} \cdot d\vec{\theta}$

$$\boxed{\vec{\tau} = \vec{P} \times \vec{E}}$$



Torque tries to align the dipole moment parallel to the electric field.

$dU = -W_{EF}$

$$dU \Big|_{U(\theta_1)}^{U(\theta_2)} = \cancel{+} \left[\cancel{+} \int_{\theta_1}^{\theta_2} PE \sin\theta \, d\theta \right]$$

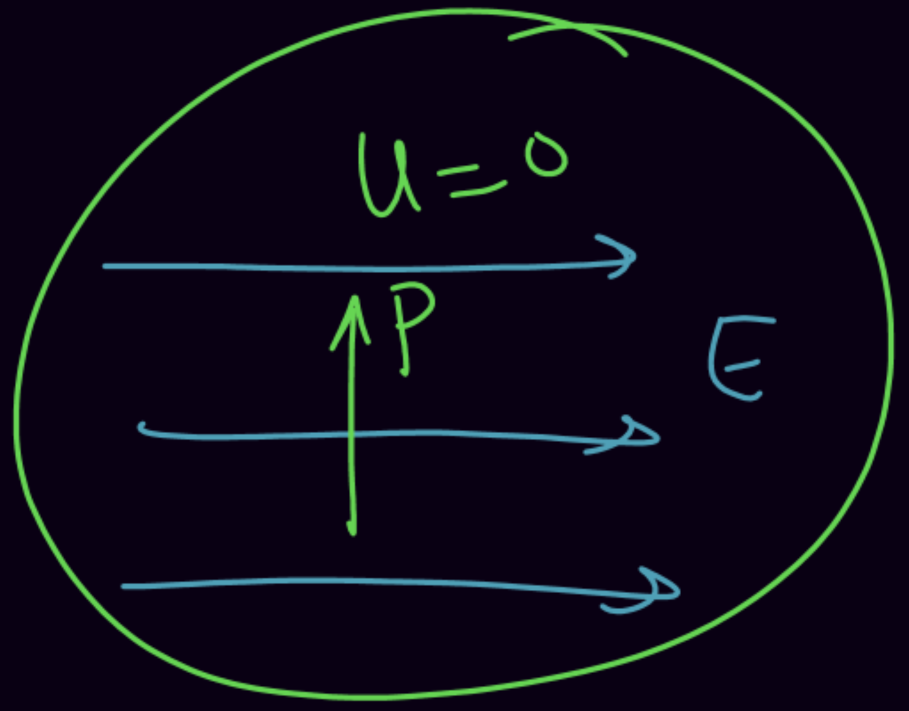
$$U(\theta_2) - U(\theta_1) = -PE \cos\theta \Big|_{\theta_1}^{\theta_2}$$

$$U(\theta_2) - U(\theta_1) = -PE\left[\cos\theta_2 - \cos\theta_1\right]$$

$$U(\theta_2) - U(\theta_1) = -PE(\cos\theta_2 - \cos\theta_1)$$

If $\theta_1 = 90^\circ$ & $U(90^\circ) = 0$

& $\theta_2 = \theta$



$$U(\theta) - U(90) = -PE(\cos\theta - \cos 90)$$

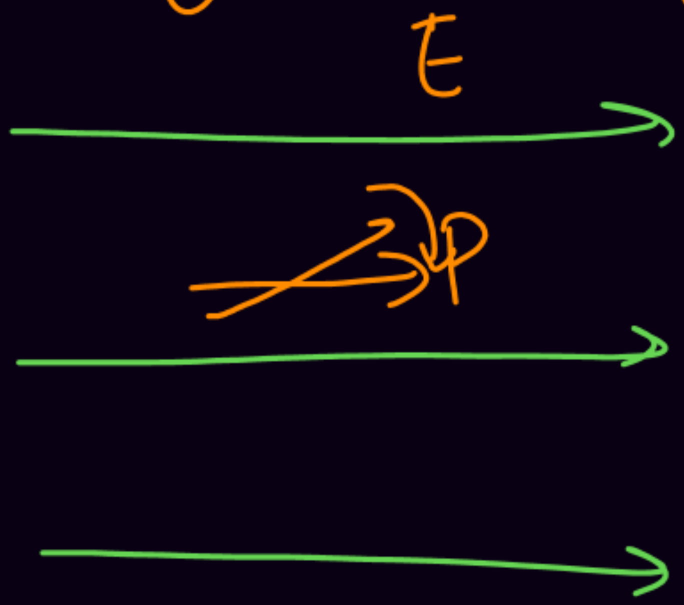
$$\boxed{U(\theta) = -PE\cos\theta}$$

$$\boxed{\begin{aligned} U(\theta) &= -\vec{P}\cdot\vec{E} \\ \vec{\tau} &= \vec{P}\times\vec{E} \end{aligned}}$$

$(\tau = PE\sin\theta)$

$U = -PE\cos\theta$

$\theta = 0$



$\tau = 0$

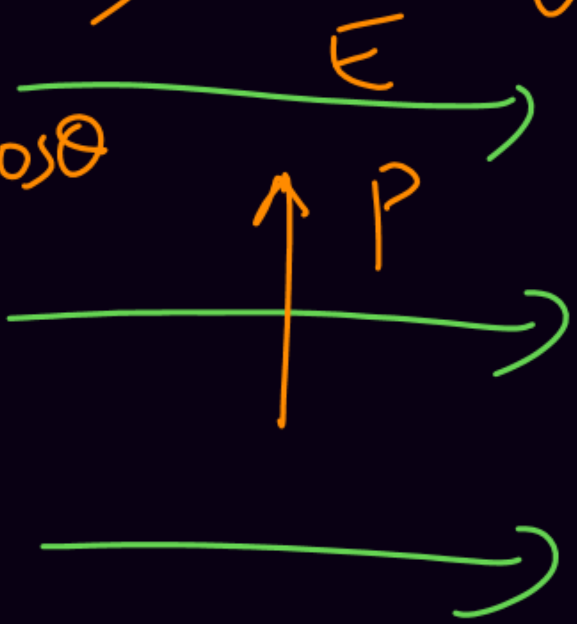
$U = -PE$

$\Downarrow$ minimum potential energy

<u>Stable equilibrium</u>

$\theta = 90°$

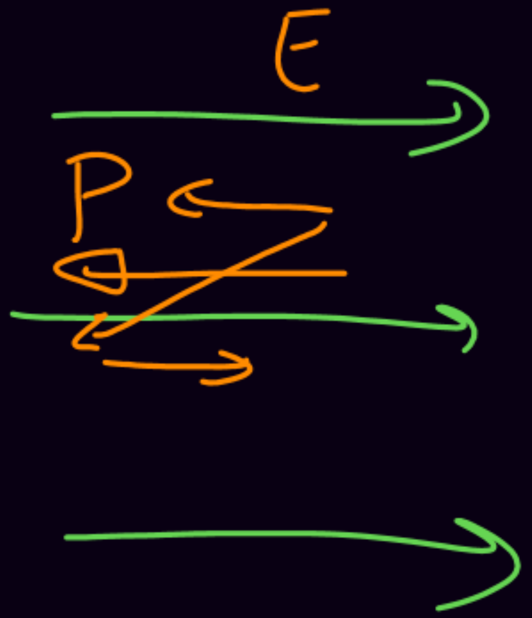
$U = PE\cos 90°$



$\tau = PE$

$U = 0$

$\theta = 180°$



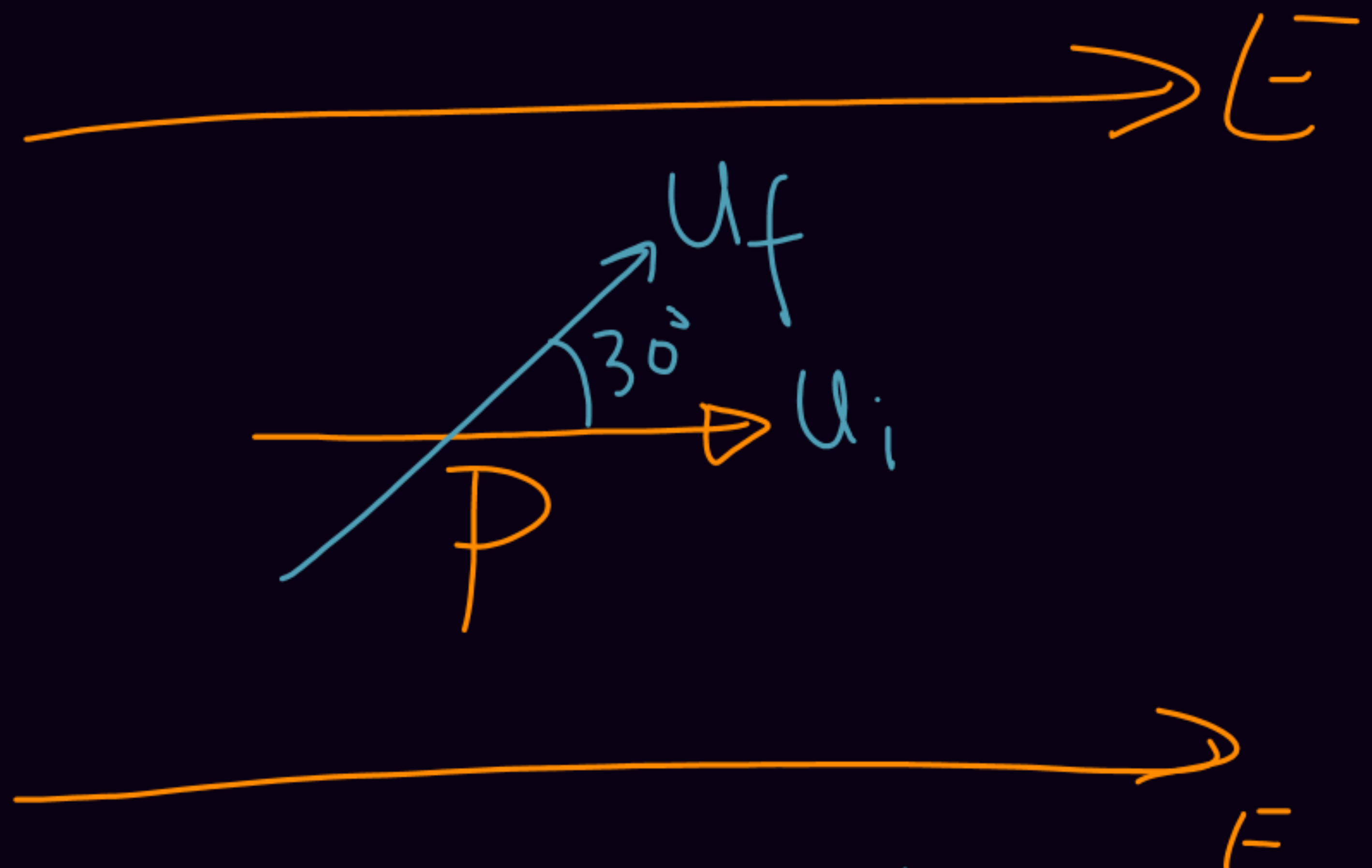
$\tau = 0$

$U = -PE\cos(180)$

$U = PE$

<u>max. pot. energy</u>

<u>Unstable equilibrium</u>



Find the work dobe done to rotate the dipole by an angle 30°.

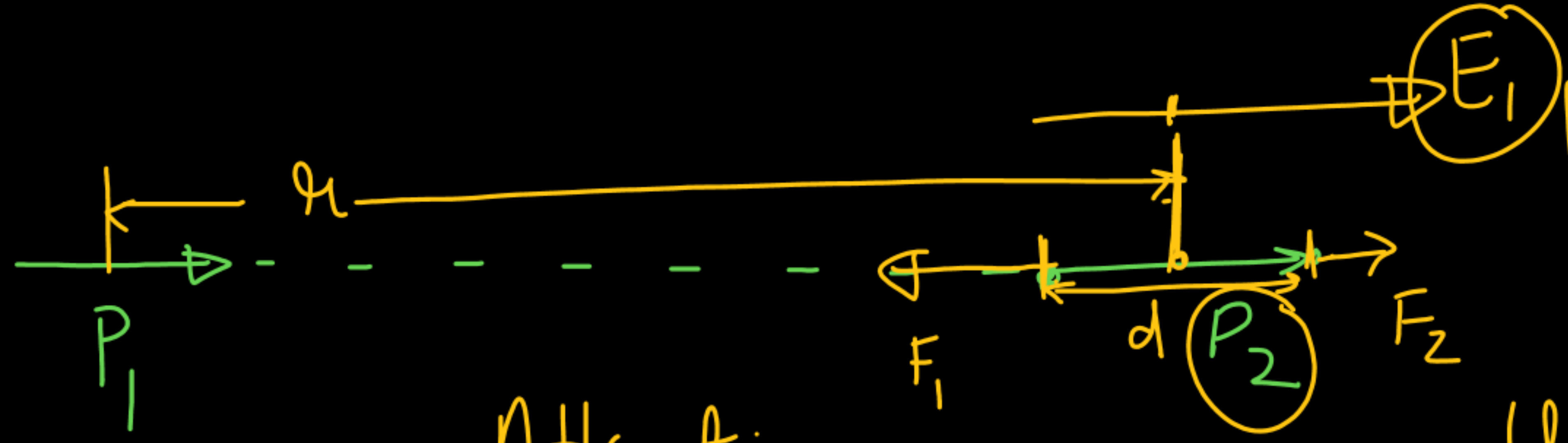
$U_f = -PE\cos 30^\circ = -PE\frac{\sqrt{3}}{2}$

$U_i = -PE\cos 0$

$W = -PE\frac{\sqrt{3}}{2} - (-PE)$

$$\boxed{W = PE\left(1 - \frac{\sqrt{3}}{2}\right)}$$

Dipole-Dipole Interaction



$$\boxed{E_1 = \frac{2kP_1}{r^3}}$$

Attraction

$F_{net} = F_1 - F_2$

$$U = -P_2 E_1 \cos 0$$

$$U = -P_2 \frac{2kP_1}{r^3}$$

$$U = -\frac{2kP_1P_2}{r^3}$$

$$F = -\frac{du}{dr} \quad \Big| \quad qE = -\frac{dvq}{dr}$$

$$F = -\frac{d}{dr}\left(\frac{-2KP_1P_2}{r^3}\right)$$

$$F = 2KP_1P_2 \frac{d}{dr}\left(\frac{1}{r^3}\right)$$

$$2KP_1P_2\left(-3r^{-4}\right)$$

$$F = \frac{-6KP_1P_2}{r^4}$$

Thank You Lakshyians