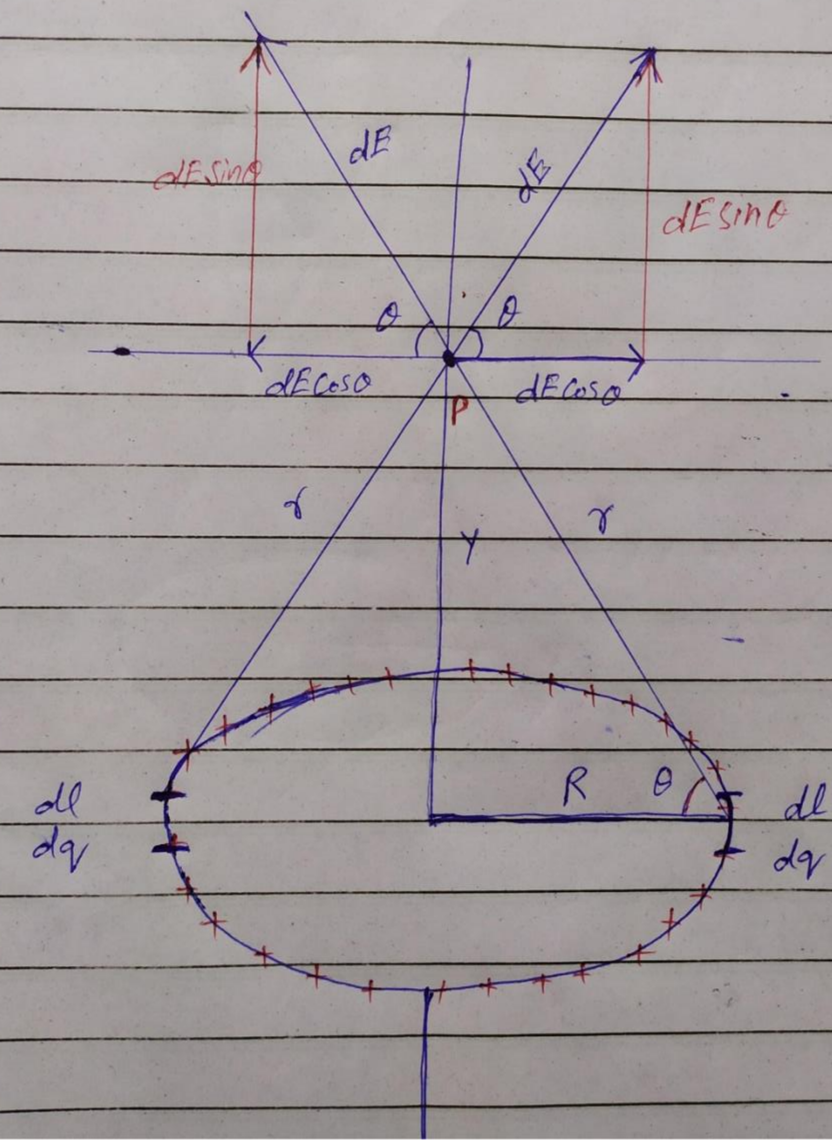


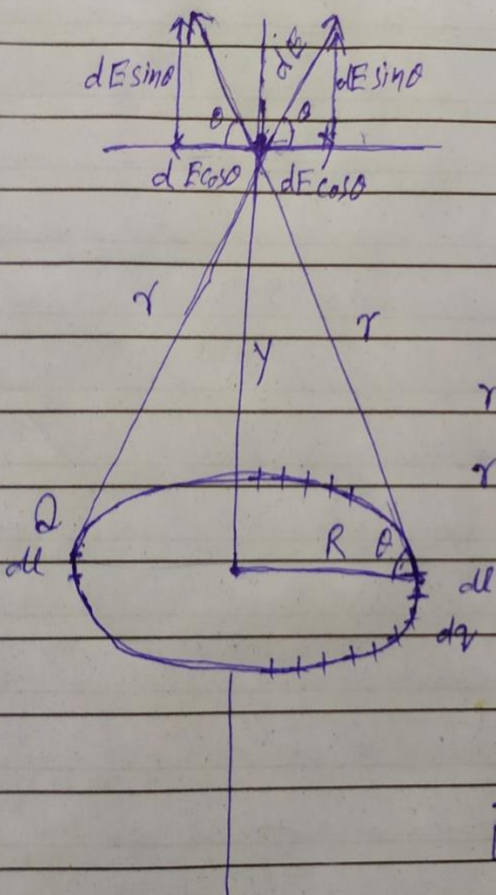
$$\sin\theta = \frac{Y}{r}$$

$$r^2 = Y^2 + R^2$$

$$r = \sqrt{Y^2 + R^2}$$

$$r^3 = (Y^2 + R^2)^{3/2}$$

Electric field due to Ring of charge



$\sin\theta = \frac{y}{r}$

$r^2 = y^2 + R^2$

$r = (y^2 + R^2)^{1/2}$

$r^3 = (y^2 + R^2)^{3/2}$

$\vec{E} = K\frac{q}{r^2}\hat{r}$

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

charge density due to line of charge

$\lambda = \frac{Q}{L}$ ✓

charge density due to surface/area of charge

$\sigma = \frac{Q}{A}$

volume charge density

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

electric field at point P is

$$E = dE\sin\theta + dE\sin\theta$$

$$E = \int 2\,dE\sin\theta \qquad dE = K\frac{dq}{r^2}$$

$$= \int 2K\frac{dq}{r^2}\sin\theta$$

$$= \int 2K\frac{dq}{r^2}\frac{y}{r} = \int 2K\frac{dq}{r^3}y$$

$$= 2K\int\frac{dq}{r^3}y$$

$$\vec{E} = \frac{KQY}{(Y^2+R^2)^{3/2}}\,\hat{Y} = \frac{KQY}{Y^3\left(1+\frac{R^2}{Y^2}\right)^{3/2}}$$

1st case . when $Y >> R$

$$E = \frac{KQ}{Y^2\left(1+\frac{R^2}{Y^2}\right)^{3/2}}$$

binomial expension

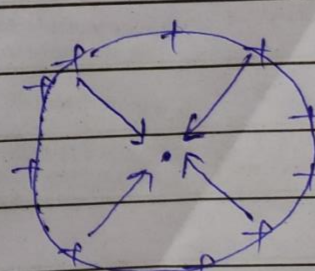
$$\left(1+\frac{R^2}{Y^2}\right)^{3/2} = 1 + \frac{3}{2}\frac{R^2}{Y^2} + \left(\frac{3}{2}-1\right)\frac{R^4}{Y^4} + \cdots$$

$$\boxed{E = \frac{KQ}{Y^2}}$$

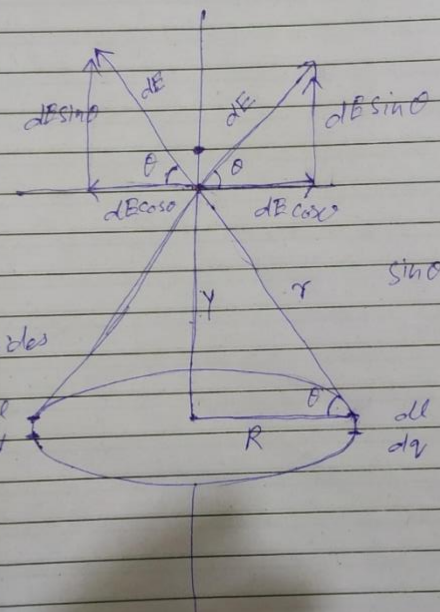
$= 1 +$ neglect all terms

2nd case $Y = 0$

$$E = \frac{KQ(0)}{(0+R^2)^{3/2}} = 0$$



$\lambda = \frac{Q}{L}$



$r^2 = Y^2 + R^2$

$r = \sqrt{Y^2 + R^2}$

take cube on both sides

$r^3 = (Y^2+R^2)^{3/2}$

$\sin\theta = \frac{Y}{r}$

$dE = dE\sin\theta + dE\sin\theta$

$\int dE = \int 2\, dE \sin\theta$

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

$E = \int 2 \frac{K\,dq}{r^3} Y$

$\lambda = \frac{Q}{L}$

$\Rightarrow \int \frac{2K\,dq \cdot Y}{(Y^2+R^2)^{3/2}}$

$\lambda = \frac{Q}{2\pi R}$

$= \int \frac{\cancel{2}K\,Q\,dl}{\cancel{2}\pi R} \frac{Y}{(Y^2+R^2)^{3/2}}$

$\lambda = \frac{dq}{dl}$

$dl\,\lambda = dq$

$\frac{KQY}{\pi R (Y^2+R^2)^{3/2}} \int dl$

$dl \frac{Q}{2\pi R} = dq$

$$E = \frac{KQY}{\pi R (y^2+R^2)^{3/2}} \int dl$$

$$= \frac{KQY}{\cancel{\pi} \cancel{R} (y^2+R^2)^{3/2}} \frac{\cancel{2\pi R}}{\cancel{2}}$$

$$\boxed{E = \frac{KQY}{(y^2+R^2)^{3/2}}}$$

Case $y >> R$

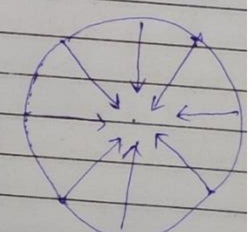
$$\frac{KQY}{y^3\left(1 + \frac{R^2}{y^2}\right)^{3/2}} = \frac{KQ}{y^2}$$

Case 2

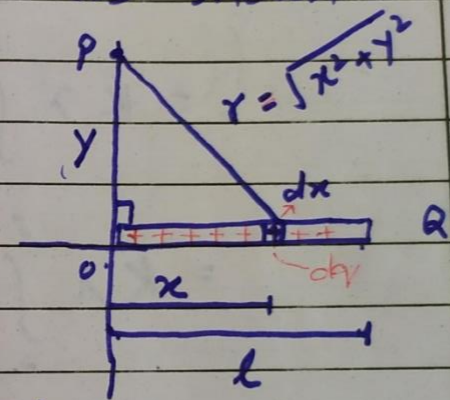
$y = 0$

$$E = \frac{KQY}{(y^2+R^2)^{3/2}}$$

$E = 0$



Electric potential due to rod of charge at its one end as shown in Figure at point P



$$V = K\frac{Q}{r}$$

$$\int dV = \int \frac{K\,dq}{r}$$

$$V = K\int_0^l \frac{\lambda\,dx}{\sqrt{x^2+y^2}}$$

y : constant

$$\lambda = \frac{Q}{l}$$

$$\lambda = \frac{dq}{dx}$$

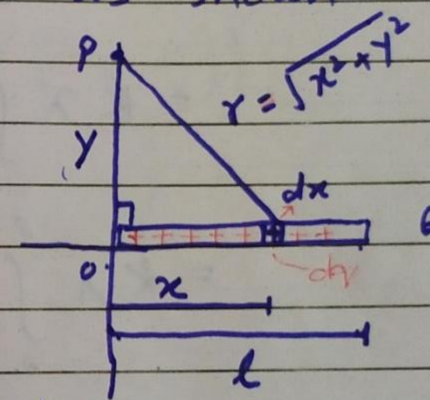
$$\lambda\,dx = dq$$

$$x = y\tan\theta$$

$$\frac{dx}{d\theta} = y\sec^2\theta$$

$$dx = y\sec^2\theta\,d\theta$$

Electric potential due to rod of charge at its one end as shown in Figure at point P



$$V = K\frac{Q}{r}$$

$$\int dV = \int \frac{K\,dq}{r}$$

$$V = K\int_0^{\ell} \frac{\lambda\,dx}{\sqrt{x^2+y^2}}$$

y = constant

$$\lambda = \frac{Q}{\ell}$$

$$\lambda = \frac{dq}{dx}$$

$$\lambda\,dx = dq$$

$$x = y\tan\theta$$

$$\frac{dx}{d\theta} = y\sec^2\theta$$

$$dx = y\sec^2\theta\,d\theta$$

$$= K\lambda^{\ln}\left[\frac{\sqrt{y^2+x^2}}{y} + \frac{x}{y}\right]_0^l$$

$$= K\lambda\left[\ln\left(\frac{\sqrt{y^2+l^2}}{y} + \frac{l}{y}\right) - \ln\left(\frac{y}{y} + \frac{0}{y}\right)\right]$$

$$= K\lambda\left[\ln\left(\frac{\sqrt{y^2+l^2}+l}{y}\right) - \cancelto{0}{\ln(1)}\right]$$

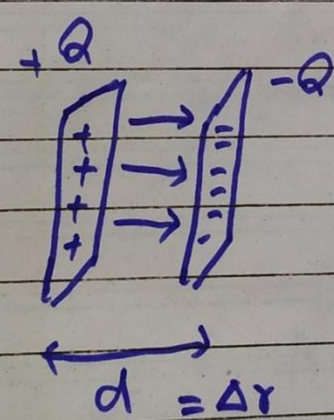
$$V = K\lambda \ln\left[\frac{\sqrt{y^2+l^2}+l}{y}\right]$$

Capacitor

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

Q is the charge of any one plate

ΔV = p.diff between the plates



$\Delta V = ?$

$$\vec{E} = -\frac{\vec{\Delta V}}{\Delta r}$$

$$E = \frac{\Delta V}{d} \qquad d = \Delta r$$

$$Ed = \Delta V$$

$$E = \frac{\sigma}{2\varepsilon_0}$$

as there are two charge sheets

$$E = \sigma/\varepsilon_0 = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$$

$$\Delta V = \frac{\sigma}{\varepsilon_0} d \qquad C = \frac{Q}{\frac{\sigma}{\varepsilon_0} d}$$

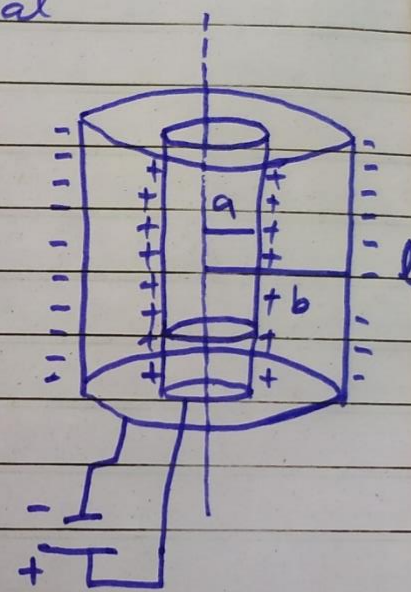
$$C = \frac{\varepsilon_0 Q}{\sigma d} = \frac{\varepsilon_0 Q}{\frac{Q}{A} d} \qquad \sigma = \frac{Q}{A}$$

$$\boxed{C = \frac{\varepsilon_0 A}{d}}$$

if there dielectric medium of relative permativity ε_r

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

capacitance of cylindrical capacitor



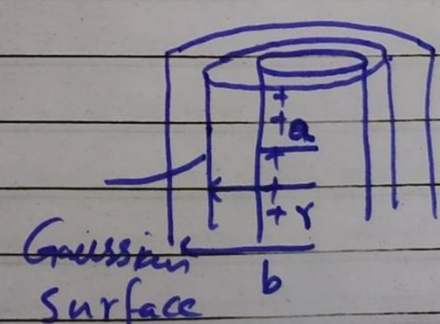
$$C = \frac{Q}{\Delta V} \longrightarrow ?$$

$$\Delta V = -\int_a^b \bar{E} \cdot \bar{dr}$$

$$V_B - V_A = -\int_a^b E\, dr \cos 0^\circ$$

?

to find E we use gauss's law



$$\int E \cdot dA = \frac{Q}{\varepsilon_0}$$

$$E \int dA = \frac{\sigma 2\pi a l}{\varepsilon_0}$$

$$\sigma = \frac{Q}{A}$$

$$E \, \cancel{2\pi} r \cancel{l} = \frac{\sigma \cancel{2\pi} a \cancel{l}}{\varepsilon_0}$$

$$\sigma = \frac{Q}{2\pi a l}$$

$$E = \frac{\sigma a}{\varepsilon_0 r} \times \frac{4\pi}{4\pi}$$

$$\sigma 2\pi a l = Q$$

$$E = \frac{4\pi \sigma a}{4\pi \varepsilon_0 r} = K \frac{4\pi \sigma a}{r}$$

$$V_B - V_A = -\int_a^b K \frac{4\pi \sigma a}{r} \, dr$$

$$\cancel{-}(V_A - V_B) = \cancel{-}K 4\pi \sigma a \int_a^b \frac{dr}{r}$$

$$V_A - V_B = \Delta V = K 4\pi \sigma a \ln r \Big|_a^b$$

$$= K 4\pi \sigma a (\ln b - \ln a)$$

$$\Delta V = K 4\pi \sigma a \ln\left(\frac{b}{a}\right)$$

$$Q = \sigma A$$

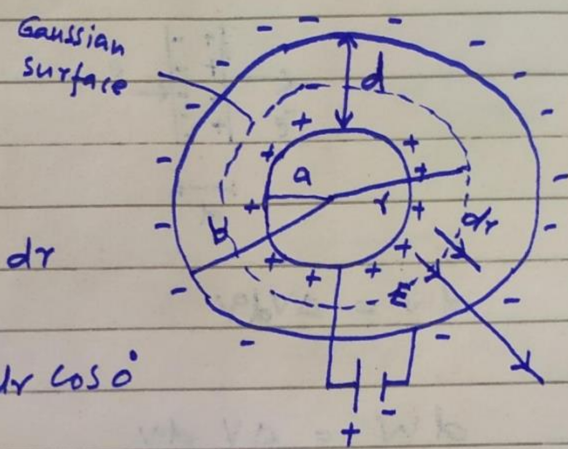
$$Q = \sigma 2\pi a l$$

$$C = \frac{Q}{\Delta V} = \frac{\cancel{\sigma} 2\cancel{\pi} \cancel{a} l}{K 4\cancel{\pi} \cancel{\sigma} \cancel{a} \ln(b/a)}$$

$$C = \frac{l}{K 2 \ln(b/a)}$$

$$C = \frac{l}{2K \ln(b/a)}$$

Capacitance of Spherical capacitor



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

$$\Delta V = \int_a^b E \cdot dr$$

$$= \int_a^b E\,dr\cos 0^\circ$$

$$\because \quad E = K\frac{Q}{r^2}$$

$$= \int_a^b K\frac{Q}{r^2}\,dr$$

$$\Delta V = KQ\left(-\frac{1}{r}\right)\Big|_a^b \qquad \because \int \frac{1}{r^2}\,dr$$

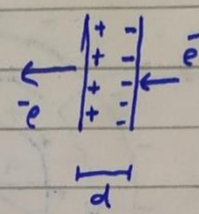
$$= KQ\left[-\frac{1}{b} - \left(-\frac{1}{a}\right)\right] \qquad = \int r^{-2}\,dr$$

$$= KQ\left[\frac{1}{a} - \frac{1}{b}\right] \qquad = \frac{r^{-2+1}}{-2+1} = \frac{r^{-1}}{-1}$$

$$\Delta V = KQ\left[\frac{b-a}{ab}\right] \qquad = -\frac{1}{r}$$

$$C = \frac{\cancel{Q}}{K\cancel{Q}\left[\frac{b-a}{ab}\right]} = \frac{ab}{K[b-a]}$$

Energy stored in a capacitor



$$\Delta W = \Delta V q$$

$$V = \frac{W}{q}$$

$$qV = W$$

$$dW = \Delta V dq$$

$$dW = \Delta V\, dq$$

$$\int_{W_i=0}^{W_f=W} dW = \int_0^Q \frac{q}{C}\, dq$$

$$\because \quad C = \frac{q}{\Delta V}$$

$$\Delta V = \frac{q}{C}$$

$$W\Big|_0^W = \frac{1}{C}\int_0^Q q\, dq$$

Work done = change in energy

$$(W-0) = \frac{1}{C}\frac{q^2}{2}\Big|_0^Q$$

$$W = \Delta U$$

$$W = \frac{1}{2C}\left(Q^2 - 0^2\right)$$

electric potential energy is stored in capacitors

$$W = \frac{Q^2}{2C}$$

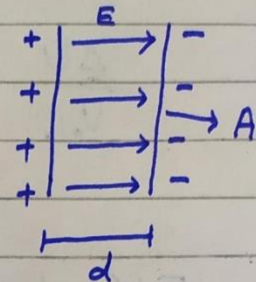
$$\Delta U = \frac{Q^2}{2C}$$

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

$$\Delta U = \frac{1}{2\cancel{C}} C^{\cancel{2}} \Delta V^2$$

$$C^2 \Delta V^2 = Q^2$$

$$\Delta U = \frac{1}{2} C (\Delta V)^2$$



capacitance of parallel plate capacitor

$$C = \frac{\varepsilon_0 A}{d}$$

area of plate $= A$

$$\Delta U = \frac{1}{2} \frac{\varepsilon_0 A}{d} (\Delta V)^2$$

volume between the plates

$$V = A d$$

we know that

$$E = \frac{\Delta V}{d}$$

$$E d = \Delta V$$ put in above eq

$$\Delta U = \frac{1}{2} \frac{\varepsilon_0 A}{\cancel{d}} (E^2 d^{\cancel{2}})$$

$$\Delta U = \frac{1}{2} \varepsilon_0 A E^2 d = \frac{1}{2} \varepsilon_0 A d E^2$$

energy density ΔU/volume

$$\frac{\Delta U}{Vol} = \frac{1}{2} \frac{\varepsilon_0 \cancel{Ad} E}{\cancel{Volu}}$$

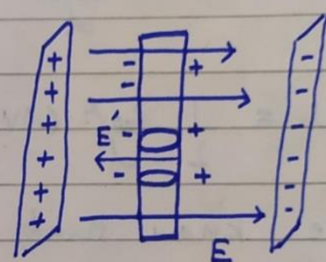
energy density

$$\frac{\Delta U}{V_{olu}} = \frac{1}{2} \varepsilon_0 E^2$$

$$Ad = V_{olu}$$

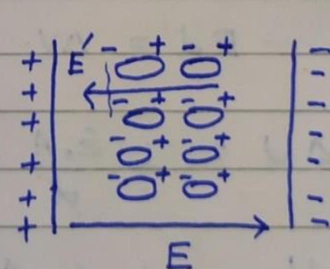
Effect of Dielectric medium

when we introduce dielectric medium between the plates then due polarization E' is created which in opposite direction to E



$$E_{net} = E - E'$$

the E_{net} reduces



$$E_{net} = E - E'$$

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

$$\Delta V = \int E \cdot dr$$

$$\Delta V = Ed$$

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

$$C = \frac{Q}{E_{net}\, d}$$

permitivity of vacume $= \varepsilon_0$

" " medium $= \varepsilon_m$

relative permitivity $= \varepsilon_r = \dfrac{\varepsilon_m}{\varepsilon_0}$

$$C_0 = \frac{\varepsilon_0 A}{d} \qquad \boxed{C_m = \varepsilon_0 \varepsilon_r \frac{A}{d}}$$

$$\frac{C_m}{C_0} = \frac{\dfrac{\varepsilon_m \cancel{A}}{\cancel{d}}}{\dfrac{\varepsilon_0 \cancel{A}}{\cancel{d}}} \qquad C_m = \frac{\cancel{\varepsilon_0} \dfrac{\varepsilon_m}{\cancel{\varepsilon_0}} A}{d}$$

$$\boxed{C_m = \frac{\varepsilon_m A}{d}}$$

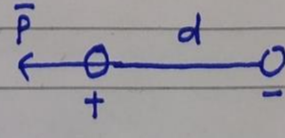
$$\frac{C_m}{C_0} = \frac{\varepsilon_m}{\varepsilon_0} = \varepsilon_r$$

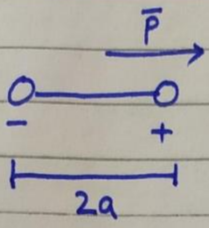
$$\frac{C_m}{C_0} = \varepsilon_r$$

Electric ~~dipde~~ dipole in

Enternal electric fied

$\bar{p} = qd$





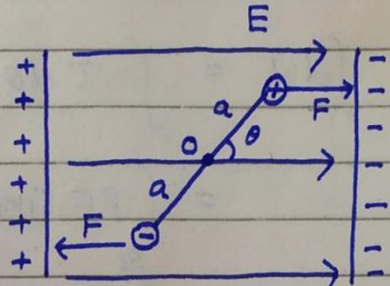
$\bar{P} = q\,2a$

$\bar{\tau} = \bar{r} \times \bar{F}$

$\bar{\tau} = \bar{a} \times \bar{F}$

$\tau_+ = aF\sin\theta$

$\tau_- = aF\sin\theta$



the central point 'O' of the dipole act as pivot point

$\tau_{total} = \tau_+ + \tau_-$

$E = \frac{F}{q}$

$\tau_{tol} = 2aF\sin\theta$

$Eq = F$

$= 2aEq\sin\theta$

$= 2aqE\sin\theta$

$\because P = 2aq$

$= PE\sin\theta$

$\bar{\tau}_{tol} = \bar{P} \times \bar{E}$

energy of dipole

$W = \Delta U$

$dW = \bar{\tau} . \overline{d\theta}$

$\int dW = \int \tau \, d\theta \cos\theta$ $\qquad \theta = 0^\circ$

$\tau \parallel \theta$

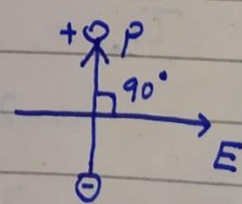
$= \int PE \sin\theta \, d\theta \cos 0^\circ$

$W = \int_{\theta_i}^{\theta_f} PE \sin\theta \, d\theta$

$= -PE \cos\theta \Big|_{\theta_i}^{\theta_f}$

$= -PE(\cos\theta_f - \cos\theta_i)$

for $\theta_i = 90^\circ$



$\Delta U = -PE(\cos\theta_f - \cos 90^\circ)$

$\Delta U = -PE\cos\theta$ $\qquad \theta_f = \theta$

$\Delta U = -\bar{P} . \bar{E}$

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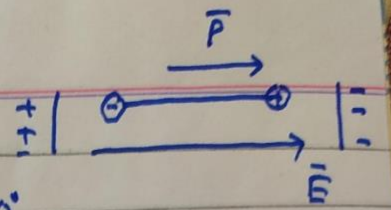
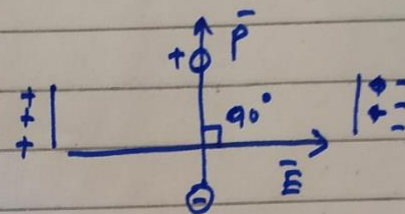


$\Delta U = -PE\cos 0°$

$\theta = 0$

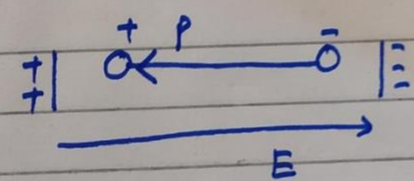
$= -PE$

$\Delta U = -PE\cos 90°$



$\Delta U = 0$

$\Delta U = -PE\cos 180°$



$= -PE(-1)$

$\theta = 180°$

$\Delta U = PE$