# 1 Electrostatics

This is very important chapter in last 15 years more than 40 questions has been asked or advance 2024 में तो चार question यहाँ से पूछे गए थे।



अगर जितना content इस book मे है उतना तुमने कर लिया you can solve more than 80% of JEE advance PYQ by yourself. Let's start from basic to advance.....

## CHARGE

Charge
- At rest = produce electric field only $\vec{E}$
- Moving with const. velocity ⇒ $\vec{E}$, $\vec{B}$ both [$\vec{B}$ → magnetic field]
- Moving with having accelerations ⇒ EMW & radiats energy
  - Electromagnetic wave

## PROPERTIES OF CHARGE

- Invariant, scaler, two type positive and negative.
- For an isolated system total charge is conserve.
- Charge cannot exist without mass.
- Charges quantized $Q = \pm ne$ ($n$ is integer $e = 1.6 \times 10^{-19}$ C)

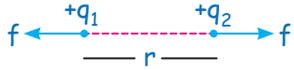
## COULOMB LAW

Electrostatic force of interaction b/w two point charge at separation r is observed as

$f \propto q_1q_2$

$f \propto \frac{1}{r^2}$ and $f \propto \frac{q_1q_2}{r^2}$

$f = \frac{kq_1q_2}{r^2}$

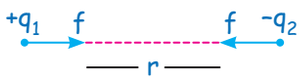



$K = 1/4\pi\varepsilon_0 = 9 \times 10^9\ Nm^2/c^2$

Permitivity of free space ($\varepsilon_0$)

- Two like charge repel each other and unlike charge attract each other.

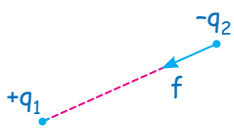
**Ex.**: $f = \frac{kq_1q_2}{r^2}$ ($+q_1$ ⟵ r ⟶ $+q_2$) $f = \frac{kq_1q_2}{r^2}$




$f = \frac{kq_1q_2}{r^2}$ (magnitude)

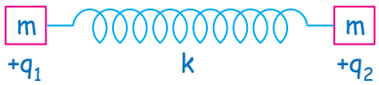



$f = \frac{kq_1q_2}{r^2}$

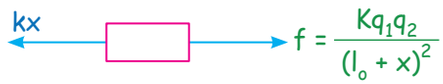



1. This force always act along the line joining two points
2. Central force
3. Electrostatic force b/w two charge particle are action reaction pair
4. Conservative force
5. Force applied by one charge particle on another charge particle is independent on presence or absence of other charge
6. Net force on a given charge is the vector sum of all the individuals forces exerted by each of other charge [Principle of superposition]

Q. If natural length of spring is $l_o$ and blocks are in equillibrium. Find elongation in spring.




**Sol.** Let elongation in spring is x

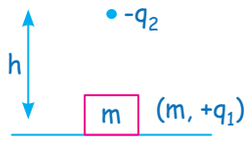



$kx = \frac{Kq_1q_2}{(l_o + x)^2}$



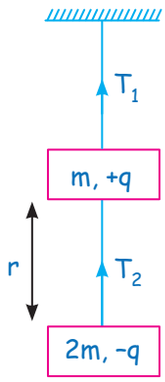
(अबे अब value put करके cubic eqn. बनाके कर लोगे ना ☺)

Q. What should be the minimum value of charge $q_2$ so that block lift off?

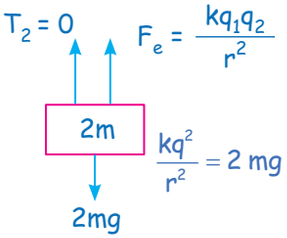



$$mg = \frac{kq_1q_2}{h^2}$$

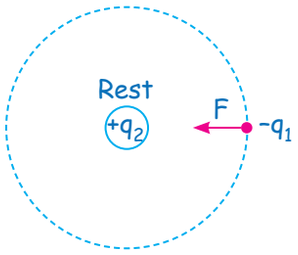
Q. Find the value of q so that tension in lower string becomes zero




Sol.




Q. A charge $(-q_1, m)$ is moving in a circular path of radius r around positive charge $+q_2$ with constant speed. Find speed

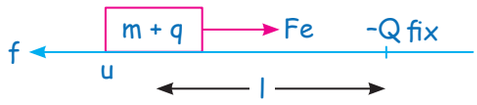



ऐसा तो Bohr's Model के first postulate में भी होता था।



**Sol.** $F_e = \frac{Kq_1q_2}{r^2} = \frac{mv^2}{r} = mrw^2$

Q. Find min value of -Q so that block start moving

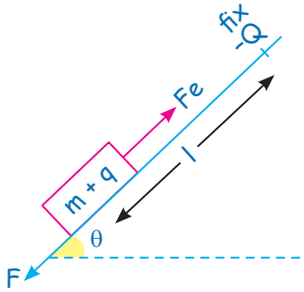



$F_e \geq \mu_s mg$

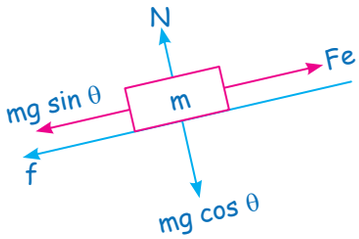
$\frac{kqQ}{l^2} \geq \mu_s mg$ (Assume block is a point mass)

$Q \geq \frac{\mu_s mgl^2}{kq}$

Q. Find min. value of -Q so that block start sliding up



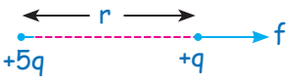

$Fe \geq mg \sin\theta + (f_s)_{max} \Rightarrow \frac{kQq}{l^2} = mg \sin\theta + \mu_s mg \cos\theta$



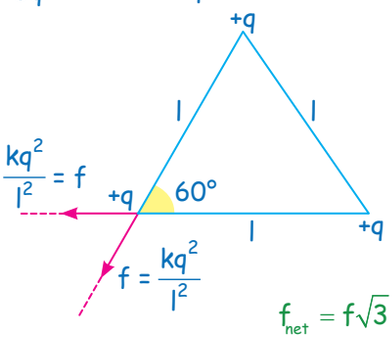

अभी तो chapter की starting है इसलिए पहले coulomb force की feeling लो basically ये question vector के ही है बस इस बात का ध्यान रखना की हमे किस पर force निकालना है और kiss ki वजह से निकालना है।



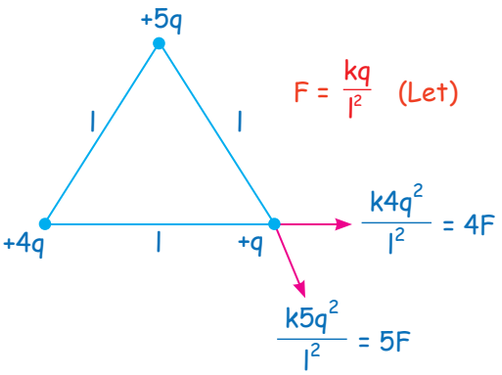
Q. Find the net force on the given charge q

(a) 


$f = \frac{k.5q.q.}{r^2}$

(b) 


$f_{net} = f\sqrt{3} = \frac{kq^2\sqrt{3}}{l^2}$

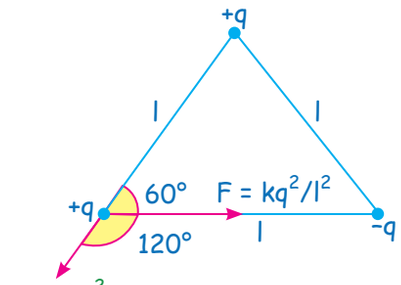
(c) 


$F = \frac{kq}{l^2}$ (Let)

$$F_{net} = \sqrt{(4F)^2 + (5F)^2 + 2 \times 4F \times 5F \cos 60^\circ}$$

$$= \sqrt{61}\, F = \sqrt{61}\, \frac{kq^2}{l^2}$$

(d)



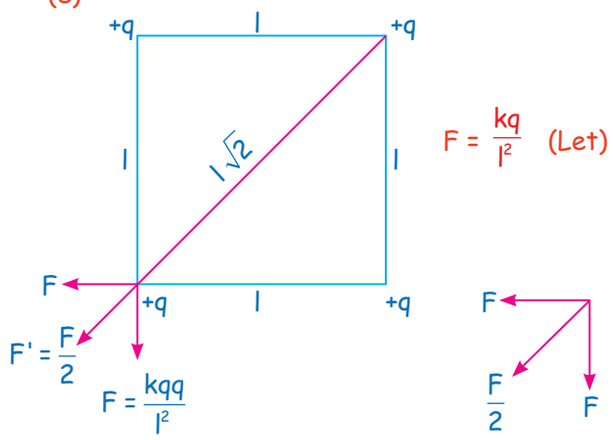

$$F = \frac{kq^2}{l^2}$$

$$F_{net} = \sqrt{F^2 + F^2 + 2F^2 \cos 120^\circ}$$

$$= \sqrt{2F^2 + 2F^2 \cos 120^\circ}$$

$$= F = kq^2 / l^2$$

(e)

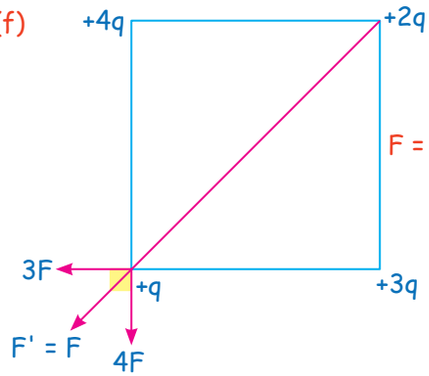



$F = \frac{kq}{l^2}$ (Let)

$$F' = \frac{kq^2}{(l\sqrt{2})^2} = \frac{kq^2}{2l^2} = \frac{F}{2}$$

$$F_{net} = F\sqrt{2} + \frac{F}{2} \Rightarrow F\left(\sqrt{2} + \frac{1}{2}\right)$$

(f)




$F = \frac{kq}{l^2}$ (Let)

तीनो Force का resultant will be answer. 3F और 4F का resultant 5F आयेगा। So answer = 5F + F = 6F अगर तुमने दिया तो तुम बहुत बड़े गधे हो। Bcz 6F is wrong.




$$F' = \frac{2kq^2}{(l\sqrt{2})^2} = F$$

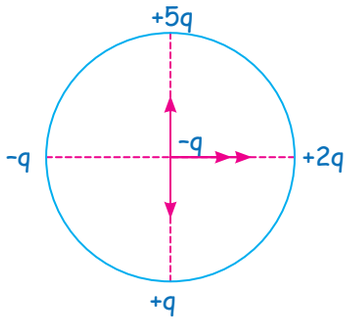
$$F_{net} = -3F\hat{i} - 4F\hat{j} + \left(-\frac{F\hat{i}}{\sqrt{2}} - \frac{F\hat{j}}{\sqrt{2}}\right)$$

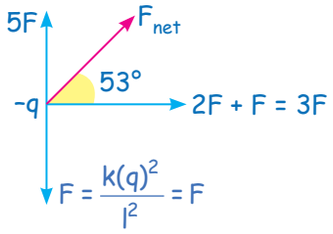





Bcz 3F और 4F का resultant F की तरफ नही आएगा।

(g) Find $F_{net}$ on the charge -q at centre

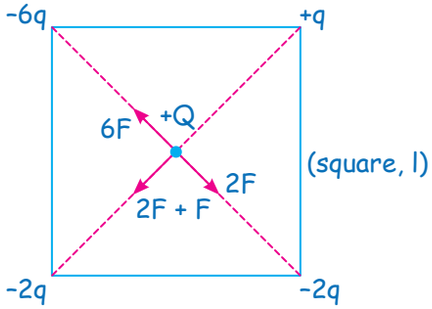



$$F = \frac{k(q)^2}{l^2} = F$$

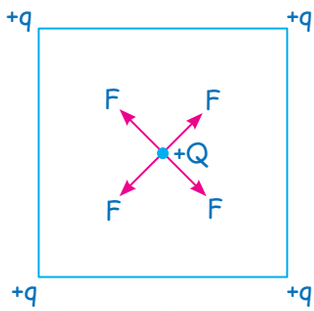
$$F_{net} = 5F = \frac{5kq^2}{r^2}$$

(h) Find $F_{net}$ on + Q at centre of square.



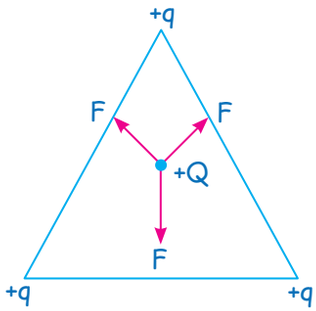
$$F_{net} = 5F = \frac{5kq^2}{(l/\sqrt{2})^2} = \frac{10kq^2}{l^2}$$

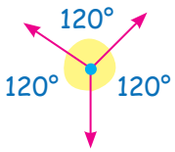
(i) Find $F_{net}$ on + Q at centre of square.




$F_{net} = 0$

(j) Find $F_{net}$ on + Q at the centroid of equilateral triangle.

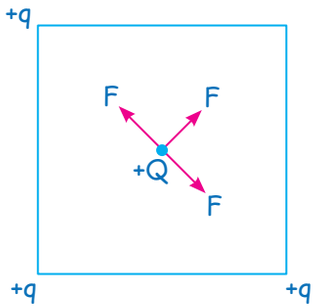



$\Rightarrow 0.$

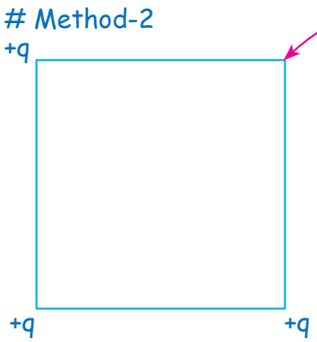
$F_{net} = 0$

(k)



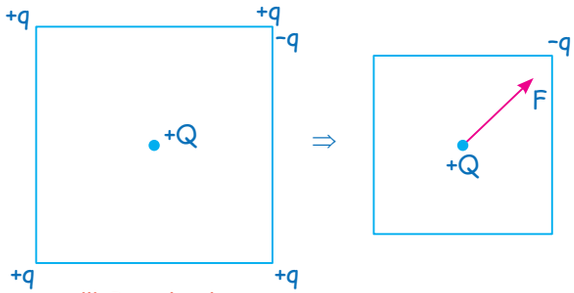

$$F_{net} = F = \frac{kQq}{(l/\sqrt{2})^2}$$

# Method-2

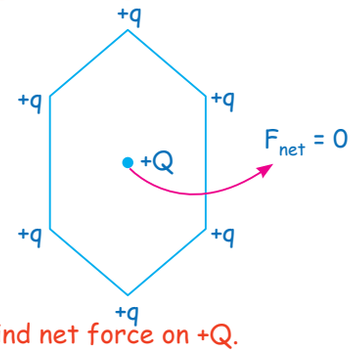




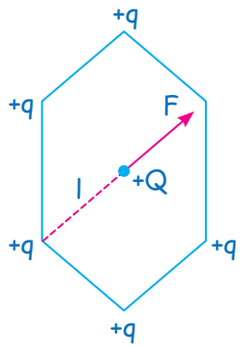




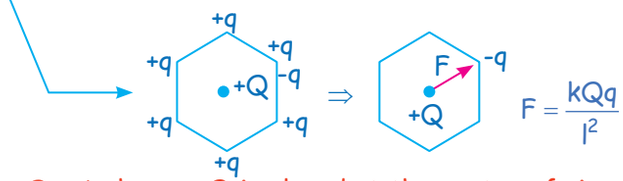

(l) Regular hexagon



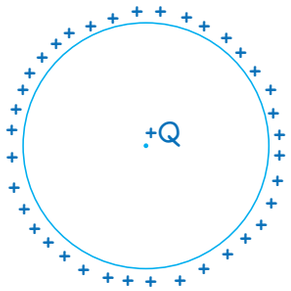

(m) Find net force on +Q.




$$F = \frac{kQq}{r^2}$$



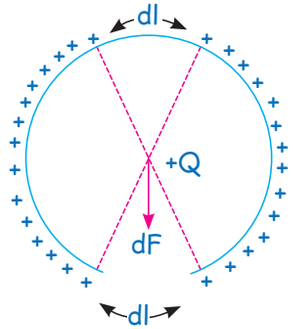

**Q.** A charge +Q is placed at the centre of ring of uniform charge +q, of radius r. $F_{net}$ on + Q at centre will be




**Sol.** $F_{net}$ on + Q at centre = 0

**Q.** In above question if small charge element 'dq' from the ring is removed now find the force on + Q at centre

**Sol.**




$F_{net} = dF = \frac{k(dq)Q}{r^2}$ (केवल dl के charge की वजह से force आयेगा बाकी सब cancel)

$2\pi r \longrightarrow q$ (on ring)

$1 \longrightarrow q/2\pi r$

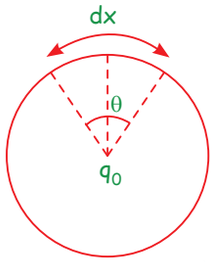
$dl \longrightarrow q/2\pi r \times dl = dq$

$dq = \frac{q}{2\pi r} dl = \lambda dl$

$\Rightarrow F_{net} = k\left(\frac{q\,dl}{2\pi r}\right) \times \frac{Q}{r^2} = \frac{kqQ\,dl}{2\pi r^3}$

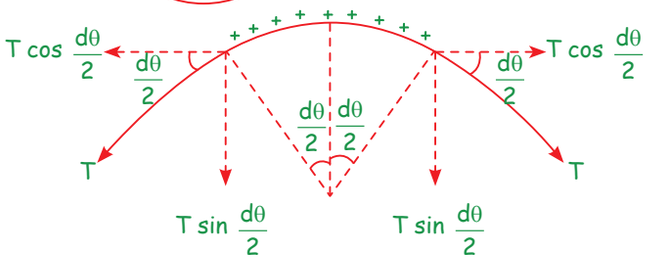
**Q.** A ring of radius R is made out of a thin wire of cross section A ring has uniform charge Q distributed in it. A charge $q_0$ is placed at the center of ring. If Y is young's modulus for material of the ring and $\Delta R$ is the change in radius of ring then find tension develope in ring and $\Delta R$.

**Sol.**




$dq = \lambda dx$ (where $\lambda$ is charge per unit length)

$\theta = \frac{dx}{R}$



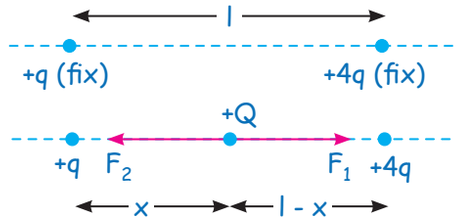

$2T \sin\frac{d\theta}{2} = \frac{k\,dq.\,q_0}{R^2}$

$2T \cdot \frac{d\theta}{2} = \frac{k.\lambda\,(dx)\,q_0}{R^2}$

$T \cdot \frac{dx}{R} = \frac{k.\lambda\,dx\,q_0}{R^2}$

$\boxed{T = \frac{k\lambda q_0}{R}} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{2\pi R}\frac{q_0}{R}$ $\boxed{\frac{T}{A} = Y\frac{\Delta R}{R}}$

**Q.** Where we should place a charge Q so that it remains in eqb$^m$.




$F_1 = \frac{kqQ}{x^2}$, $F_2 = \frac{k4qQ}{(l-x)^2}$

$F_1 = F_2$ [in eqb$^m$]

$\frac{kqQ}{x^2} = \frac{k4qQ}{(l-x)^2}$

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



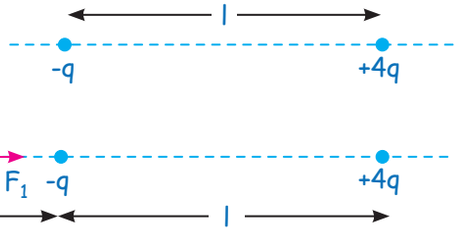
अबे याद है ना
Do vector ka sum 0, tbhi hoga jb vector equal and opposite ho!

$l - x = 2x$

$x = l/3$ Ans.

**Q.** Where we should place a charge Q so that it remains in eqb$^m$.

**Sol.**




$F_1 = \frac{KQq}{x^2}$, $F_2 = \frac{kQ4q}{(l+x)^2}$

$F_1 = F_2$ [in eqb$^m$]

$\frac{1}{x^2} = \frac{4}{(l+x)^2}$

$l + x = 2x$

$x = l$ Ans.




**Q.** Find where we should placed +Q charge so that it remains in eqb$^m$.




**Sol.** लड़का और लड़की के बीच में कभी नहीं आना रे बाबा बहुत लोचा है। इसलिए यहाँ charge को बाहर रखेंगे।




$$\frac{k4qQ}{x^2} = \frac{K9qQ}{(x+l)^2}$$

$$\frac{4}{x^2} = \frac{9}{(x+l)^2}$$

$$\frac{2}{x} = \frac{3}{x+l} \Rightarrow 3x = 2x + 2l$$

$$2l = x$$

## EFFECT OF MEDIUM

### In Vaccum




Force applied by $q_1$ on $q_2 = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2} = F_o$




### In Medium




If medium is upto $\infty$ then net force on the charge $q_2$ will be

$$\frac{1}{4\pi\varepsilon}\frac{q_1q_2}{r^2} = \frac{1}{4\pi\varepsilon_0 k}\frac{q_1q_2}{r^2} = \frac{F_o}{k} \qquad k \rightarrow \text{Dieletric const.}$$

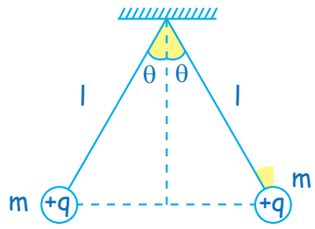
↓

Permittivity of that medium

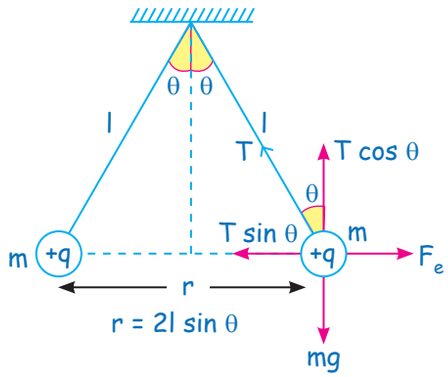
$\varepsilon = \varepsilon_0\,\varepsilon_r$

**Q.** Two Charges are suspended from a common point through the string of length l as show in figure. If charges are in equillibrium find

(a) Find $\theta$, tension etc.




**Sol.**




$T\sin\theta = F_e$ $\qquad [\theta_1 = \theta_2]$

$T\cos\theta = mg$

$$\tan\theta = \frac{F_e}{mg}$$

$$\theta = \tan^{-1}\left(\frac{F_e}{mg}\right)$$

$$F_e = \frac{1}{4\pi\varepsilon_0}\frac{q\,.\,q}{r^2} = \frac{1}{4\pi\varepsilon_0}\frac{q\,.\,q}{(2l\sin\theta)^2}$$

(b) If $q_1 \neq q_2$ and $m_1 = m_2$ repeat above question

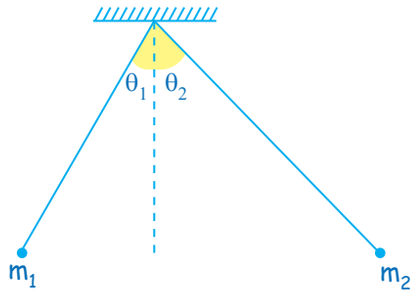
**Sol.** $\theta_1 = \theta_2$

$$F_e = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2} \text{ (same)}$$

$$\tan\theta = \frac{F_e}{mg} \text{ (same)}$$

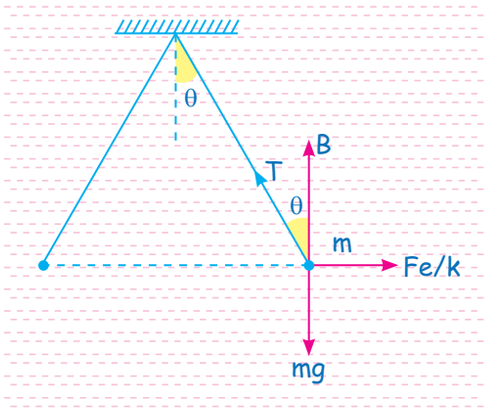
(c) If $q_1 \neq q_2$ and $m_1 > m_2$

**Sol.** Then, $\theta_1 < \theta_2$




(d) If whole system is dipped in water (upto $\infty$) repeat the above question.

**Sol.**

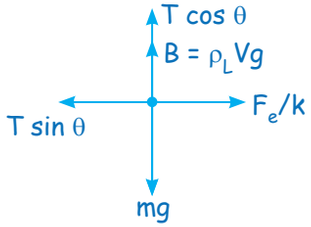



$\tan\theta = \dfrac{F_e/k}{mg - B}$

$T\sin\theta = F_e/k$

$T\cos\theta + B = mg$

B = Buoyant force




(e) In (a) part find the rate dq/dt with which the charge leaks off from each ball. So that their approach velocity varies as $v = \dfrac{a}{\sqrt{x}}$ where a is constant and x is distance between sphere ($x \ll l$). (irodov Q. 3)

**Sol.** Homework

$$\frac{dq}{dt} = \frac{3a}{2}\sqrt{\frac{2\pi\varepsilon_0 mg}{\ell}}$$

अगर पूरा sol. लिखा तो no. of page बढ़ने की वजह से Book की price बढ़ जाएगी।

Hint: $\tan\theta = \dfrac{F_e}{mg} = \dfrac{kq^2}{x^2.mg}$ ...(i)

(x very small) $\tan\theta \approx \sin\theta = \dfrac{x/2}{\ell}$ ...(ii)

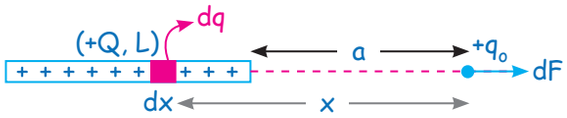
Solve (i) and (ii) and differentiate smartly.




Q. Find force apply by rod on point charge [$q_0$]




**Sol.** Directly columb law नही लगा सकते इसलिए x पर जाकर dx पकड़ो।




$dF = \dfrac{kq_0 dq}{x^2}$ This is a small force due to charge dq.

$L \longrightarrow Q$

$1 \longrightarrow \dfrac{Q}{L}$

$dx \longrightarrow \dfrac{Q}{L}dx = dq$

ये चीज बहुत बार use होगी।

$$F_{net} = \int dF = \int_a^{a+L} \frac{kq_0 dq}{x^2}$$

$$= \int_a^{a+L} \frac{kq_0 Q dx}{Lx^2}$$

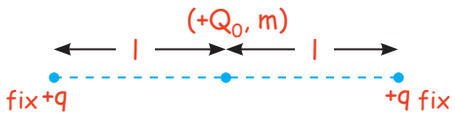
$$= \frac{kqQ}{L}\left[\frac{1}{a} - \frac{1}{a+L}\right] \text{ (After solving)}$$



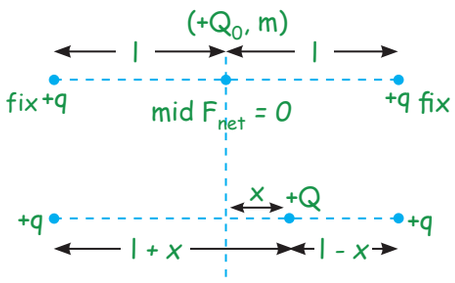
$$= \frac{kqQ}{a(a+L)}$$

If $a >>>> L$, $F_{net} \approx \dfrac{kqQ}{a^2}$ (देखो ये point charge जैसा result आगया)

**Q.** If a charge ($Q_0$, m) is slightly displaced from its mean position along find time period of SHM.




**Sol.**



$F_{net} = F_2 - F_1$




$$= \frac{kQq}{(l+x)^2} - \frac{kQq}{(l-x)^2} = -\frac{(kQq4l)x}{(l^2-x^2)^2}$$

If $x \ll l$

$l^2 - x^2 \approx l^2$

$$F_{net} = \frac{1}{4\pi\varepsilon_0}\frac{Qq\,4l}{l^4}x$$

$$F_{net} = \frac{-Qq}{\pi\varepsilon_0 l^3}x$$

$F_{net} = -kx$

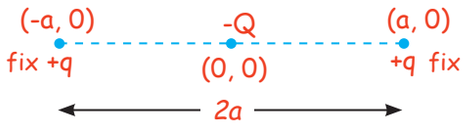
$$T = 2\pi\sqrt{\frac{m}{Qq/\pi\varepsilon_0 l^3}}$$

In SHM

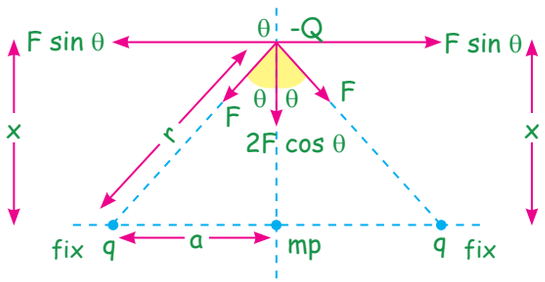
If $\vec{F}_{net} = -k\vec{x}$

$T = 2\pi\sqrt{\frac{m}{k}}$

**Q.** If a charge (-Q, m) is displaced slightely along (+y axis) on smooth horizontal surface in given figure. Find time period of oscillation.




**Sol.**




$F_{net} = 2F\cos\theta$ (नीचे)

$$= \frac{2kQq}{r^2}\frac{x}{r} \text{ (नीचे)}$$

$$F_{net} = \frac{2kQq}{(a^2+x^2)^{3/2}} \cdot x \neq \text{SHM}$$

If $x \ll a$

$$\vec{F}_{net} = -\frac{2kqQ}{a^3}\cdot\vec{x}$$

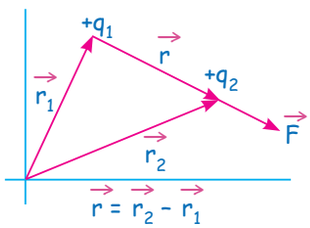
$$T = 2\pi\sqrt{\frac{m}{2kqQ/a^3}}$$

## VECTOR FORM OF COULOMB LAW

Force by $q_1$ on $q_2$

$$= \frac{kq_1q_2}{r^2}\hat{r}$$

$$= \frac{kq_1q_2}{|\vec{r}_2-\vec{r}_1|^2}\frac{\vec{r}}{|\vec{r}_2-\vec{r}_1|}$$




$$= \frac{kq_1q_2}{|\vec{r}_2-\vec{r}_1|^3}(\hat{r})$$

But हम SKC लगा कर सवाल solve करेंगे।



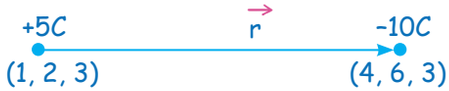

Force on $q_2$ due to $q_1 = \frac{kq_1q_2}{r^2}\hat{r}$

##SKC

$\vec{r}$ की मुंडी वहा रखो जिस पर force पूछ रहा है और $q_1$ & $q_2$ with sign put करो



**Q.** Find force applied by + 5C on -10C:

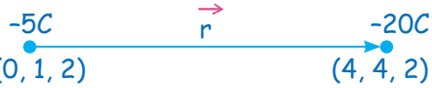



$\vec{r} = 3\hat{i} + 4\hat{j}$

$$F = \frac{k(5)(-10)}{25}\frac{(3\hat{i}+4\hat{j})}{5}$$

$= -36 \times 10^8 (3\hat{i} + 4\hat{j})$N

**Q.**

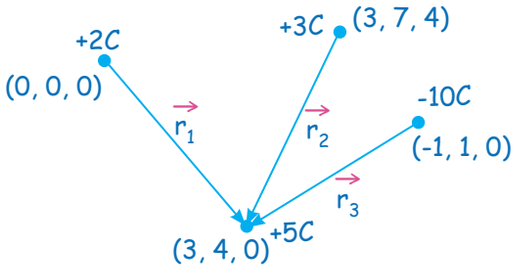



Force applied by -5C on -20C:

$\vec{r} = (4\hat{i} + 3\hat{j})$

$$\text{Force} = \frac{9\times10^9\times(-5)\times(-20)}{5^2}\left(\frac{4\hat{i}+3\hat{j}}{5}\right)$$

**Q.** Find net force on +5C.




Find $F_{net}$ on + 5C

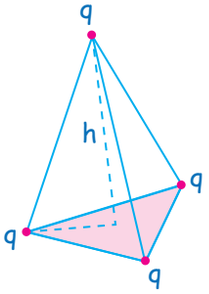
$\vec{r}_1 = 3\hat{i} + 4\hat{j}$

$\vec{r}_2 = -3\hat{j} - 4\hat{k}$

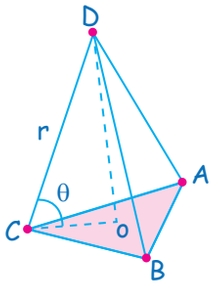
$\vec{r}_3 = 4\hat{i} + 3\hat{j}$

$$F_{net} = \frac{k(2\times5)}{5^2}\frac{(3\hat{i}+4\hat{j})}{5} + \frac{k(3\times5)}{5^2}\left(\frac{-3\hat{j}-4\hat{k}}{5}\right) + \frac{k(-10)\times5}{5^2}\frac{(4\hat{i}+3\hat{j})}{5}$$

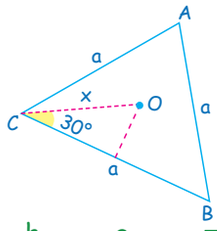
**Q.** Three charges (+q) are placed on the vertices of a equilateral triangle of side a as shown in diagram. Find net force on 4th identical charge particle at a height h = a above the centroid of Δ.




**Sol.**

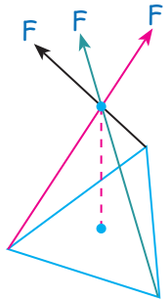


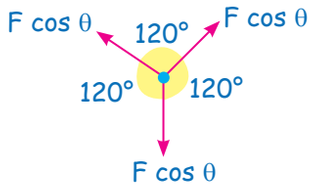

$$\tan\theta = \frac{OD}{OC} = \frac{h}{OC}$$




$$OC = \frac{a}{\sqrt{3}} \text{ and } \tan\theta = \frac{h}{OC} = \frac{a}{a/\sqrt{3}} = \sqrt{3}$$

Hence $\theta = 60°$




$[F_{net} = 3F\sin\theta]$

Top view: F cos θ - cancelled but

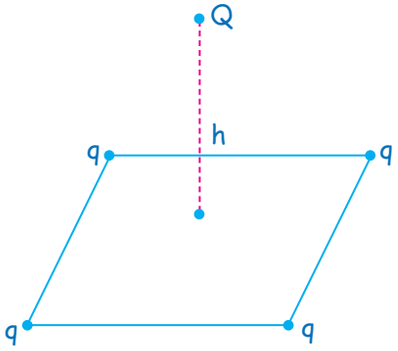
F sin θ + F sin θ + F sin θ

$F_{net} = 3F\sin\theta$

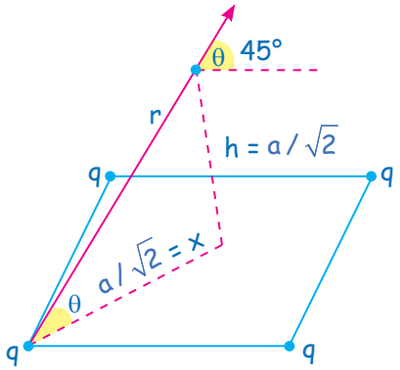
where $F = \frac{kq^2}{r^2}$

$$\begin{cases} r^2 = (OD)^2 + (OC)^2 \\ = h^2 + \left(\frac{a}{\sqrt{3}}\right)^2 \\ = a^2 + \frac{a^2}{3} \\ = \frac{4a^2}{3} \end{cases}$$

**Q.** Four charge (q) are placed on the corner of square of side a. Find force on fifth charge Q placed above at a height $h = \frac{a}{\sqrt{2}}$ from centre of square as shown in figure.




**Sol.**




$$\tan\theta = \frac{a/\sqrt{2}}{a/\sqrt{2}} = 1$$

$(\theta = 45°)$

$$r = \sqrt{x_1^2 + h^2} = \sqrt{\left(\frac{a}{\sqrt{2}}\right)^2 + \left(\frac{a}{\sqrt{2}}\right)^2} = a$$

$$F_{net} = 4F\sin\theta = 4\times\frac{kq^2}{r^2}\sin45° = 4\times\frac{kq^2}{a^2}\times\frac{1}{\sqrt{2}}$$

## ELECTRIC FIELD

1. The region surrounding a charge (or charge distribution)
2. Electric field strength or electric field intensity $\vec{E}$, it measure how strong is the electric field at that particular point.

   ⇒ Electric field intensity is defined as force on unit test charge.

### Electric Field due to Point Charge

(E.F) at A due to + Q = $\frac{\vec{F}}{q_0}$

Force experimental per unit test charge.

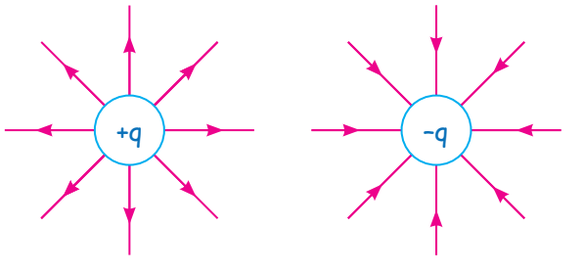


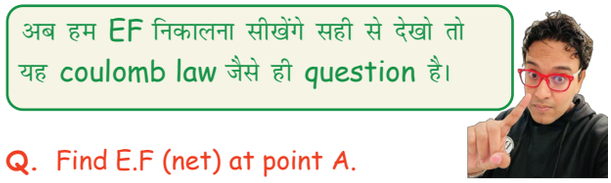

$$E_A = \lim_{q_0 \to 0} \frac{F}{q_0} = \frac{kQq_0}{r^2 q_0} = \frac{kQ}{r^2}$$ (It is the electric field due to +Q at A)




1. $\vec{E} = \frac{\vec{F}}{q_0}$ (unit ⇒ N/coulomb)

2. EF due to +ve point chare is radially outward and due to –ve point charge its radially inward



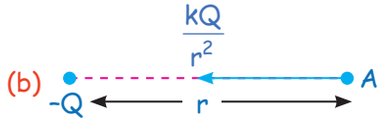

**Q.** Find E.F (net) at point A.

(a)

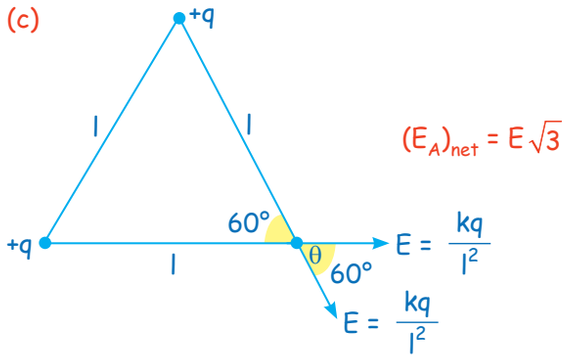



+Q charge की वजह से है।

(b)

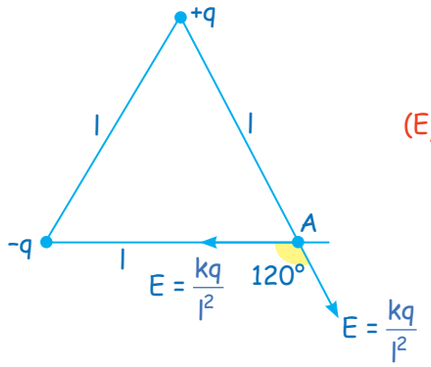



(c)



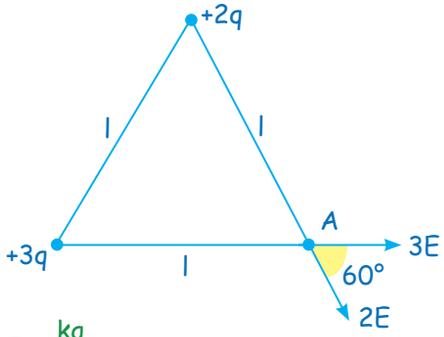

$(E_A)_{net} = E\sqrt{3}$

(d)




$(E_A)_{net} = E = \frac{kq}{l^2}$

(e)

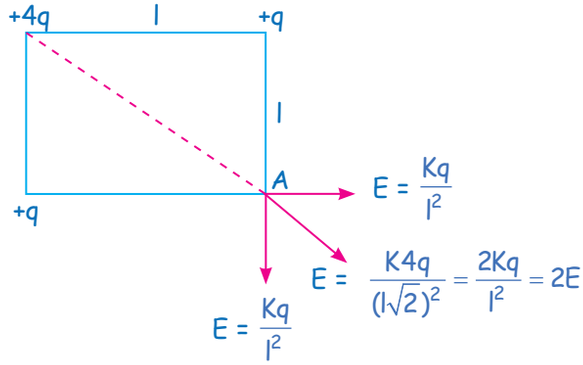



Let $E = \frac{kq}{l^2}$

$E_{net} = \sqrt{(2E)^2 + (3E)^2 + 2 \times 2E \times 3E \times \cos 60°}$

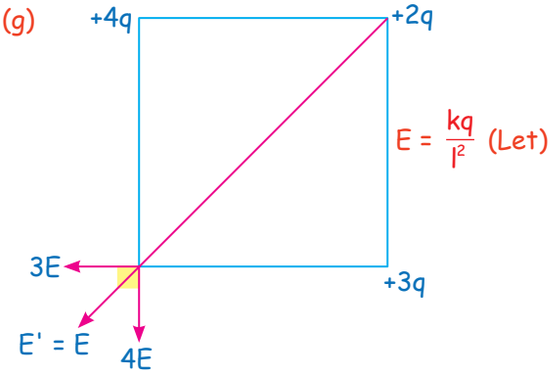
$= E\sqrt{19}$

(f)




$E_{net} = E\sqrt{2} + 2E = \frac{Kq}{l^2}(\sqrt{2} + 2)$

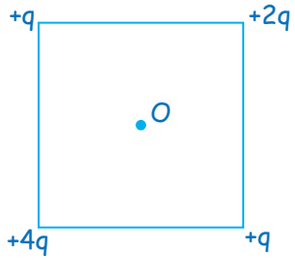
(g)

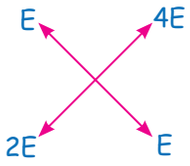


तीनो का resultant will be answer. 3E और 4E का resultant 5E आयेगा। So answer = 5E + E = 6E अगर तुमने दिया तो तुम अब तो और भी बहुत ही ज्यादा बड़े गधे हो। Bcz 6E is wrong.

$$E_{net} = -3E\hat{i} - 4E\hat{j} + \left(-\frac{E\hat{i}}{\sqrt{2}} - \frac{E\hat{j}}{\sqrt{2}}\right)$$

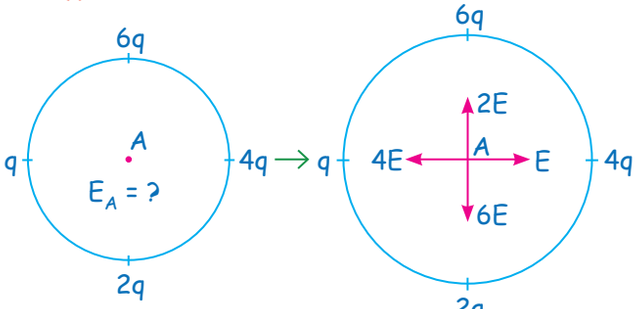
(h) Find electric field at point at centre of square ($l$) at O.

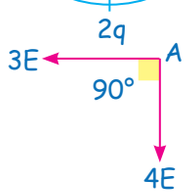



$$= 2E = \frac{2kq}{(l/\sqrt{2})^2}$$

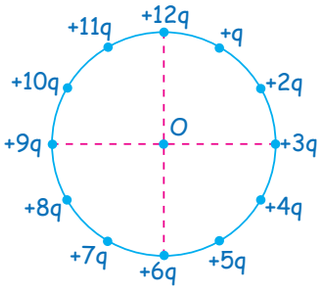
(i)

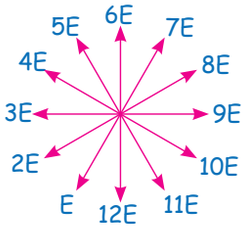


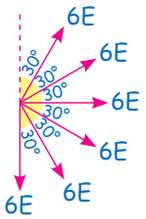




$$(E_{net})_A = 5E = \frac{5kq}{r^2}$$

**Q.** Find $E_{net}$ at centre 0.




अब component लेकर solve करो जैसे vector में करते थे।

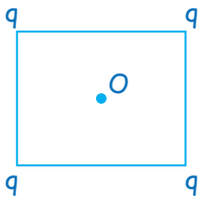
$$\vec{E}_{net} = (12E + 6E\sqrt{3})\hat{i} - 6E\hat{j}$$

**Q.** In above question find the angle made by net E.F at O with x-axis

**Sol.** $\tan\alpha = \frac{Ey}{Ex} = \frac{6E}{12E + 6E\sqrt{3}} = 2 - \sqrt{3}$

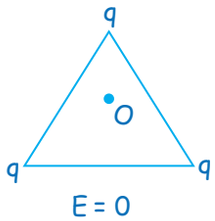
**Q.** Find net electric field at O.

(a)



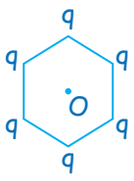

E = 0

(b)




E = 0

(c)




E = 0

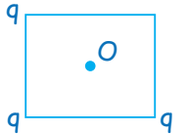
(d)




Uniform (Ring Q, R)

E = 0

(e)



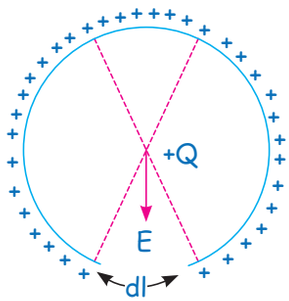

$$E = \frac{kq}{(l/\sqrt{2})^2}$$

पहले की तरह यहाँ खाली corner पर +q & -q दो charge assume कर सकते है जहाँ +q बाकी तीनो corner के charges से setting करके O पर EF zero कर देगा और -q की वजह से O पर net EF आ जाएगी।

**Q.** अब पुराने सवालो में electric field के सवाल बन जाएंगे जैसे

(a) From a uniform charge ring q, R. A small element dl is removed find electric field at centre.

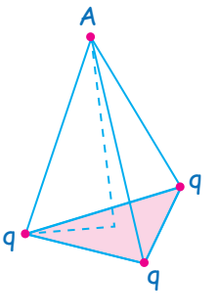
**Sol.**

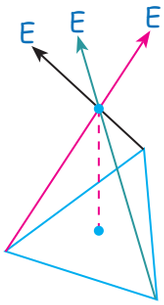



$$E_{net} = \frac{kdq}{R^2} = \frac{kQ}{R^2\,2\pi R}\,dl$$

$$= \frac{kQ}{2\pi R^3}\,dl$$

(b) Three charges (+q) are placed on the vertices of a equilateral triangle of side a as shown in diagram. Find electric field at a height h = a above the centroid of Δ.



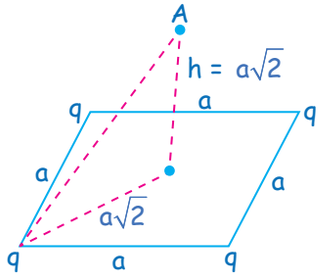

**Sol.** $E_A = 3E \sin\theta$
[$\theta = 60°$ already solved]

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

$r^2 = h^2 + \left(\frac{a}{\sqrt{3}}\right)^2$

(c) Four charge (q) are placed on the corner of square of side a. Find electric field at a height $h = \frac{a}{\sqrt{2}}$ from centre of square as shown in figure.

**Sol.**




$E_A = 4E \sin\theta$ [$\theta = 45°$]

ऐ फिर आ गया रे बाबा




अपने पास इसका भी एक मस्त तरीका है।





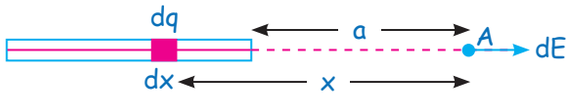




chapter के last में बताऊँगा।

(d) Find EF at A due to rod at shown in figure.



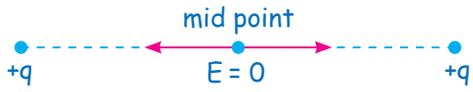

**Sol.** $\int dE = \int_a^{a+L} \frac{kdq}{x^2} = \int_a^{a+L} \frac{kQ}{L}\frac{dx}{x^2} = \frac{kQ}{a(a+L)}$

**Q.** Find where net E.F is zero (null point)

(a)



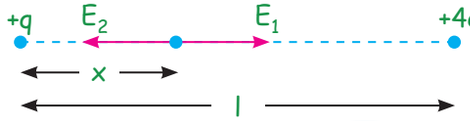

**Sol.**




(b)




**Sol.**




$E_1 = E_2 \Rightarrow \frac{kq}{x^2} = \frac{k4q}{(l-x)^2}$

$l - x = 2x$

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




**Q.** Find where electric field is zero.




**Sol.** लड़का और लड़की के बीच में कभी नहीं आना रे बाबा




$\frac{k4q}{x^2} = \frac{K9q}{(x+l)^2}$

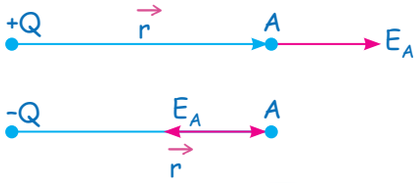
$\frac{4}{x^2} = \frac{9}{(x+l)^2}$

$\frac{2}{x} = \frac{3}{x+l} \Rightarrow 3x = 2x + 2l$

$x = 2l$

## ELECTRIC FIELD DUE TO PT. CHARGE IN VECTOR FORM.

$\vec{E}_A = \lim_{q_0 \to 0} \frac{\vec{F}}{q_0} = \frac{kQq_0}{r^2 q_0}.\hat{r}$




$\vec{E}_A = \frac{k\theta}{r^2}\hat{r}$

due to pt. charge

If $Q > 0 \Rightarrow \vec{E}$ along $\hat{r}$

$Q < 0 \Rightarrow \vec{E}$ opp. to $\hat{r}$

#SKC

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

- $\vec{r}$ का head वहा रखो जहा E.F. निकालनी है।
- q को with sign रख दो।

**Q.** Find net E.F at point A.

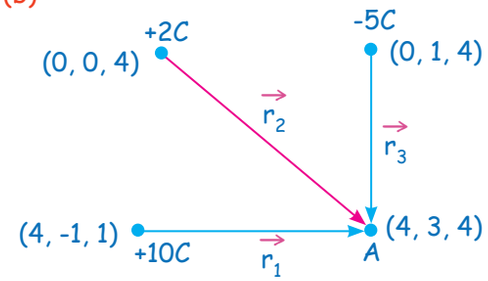
(a)




$\vec{r}_1 = 4\hat{i} + 3\hat{j}$

$\vec{E}_A = \frac{9 \times 10^9 \times (+2)}{5^2}\left(\frac{4\hat{i} + 3\hat{j}}{5}\right)$

(b)




$\vec{r}_1 = 4\hat{j} + 3\hat{k}, \quad \vec{r}_2 = 4\hat{i} + 3\hat{j}, \quad \vec{r}_3 = 4\hat{i} + 2\hat{j}$

$\vec{E}_A = \frac{k(10)}{5^2}\left(\frac{4\hat{j} + 3\hat{k}}{5}\right) + \frac{k(2)}{5^2}\left(\frac{4\hat{i} + 3\hat{j}}{5}\right)$

$+ \frac{k(-5)}{20}\left(\frac{4\hat{i} + 2\hat{j}}{\sqrt{20}}\right)$

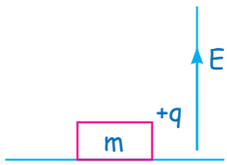
$\vec{F} = q\vec{E}$

Force on charge q placed in electric field $\vec{E}$



मैं q charge को एसी जगह रख दूँ जहाँ electric field E है तो उस पर qE force लगेगा। अगर charge positive है तो $\vec{E}$ की तरफ force लगेगा और अगर charge negative है तो $\vec{E}$ के opposite force लगेगा।

**Q.** Find min. value of E so that block lift off

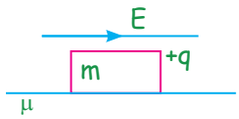



$qE \geq mg$

$(E)_{min} = \frac{mg}{q}$

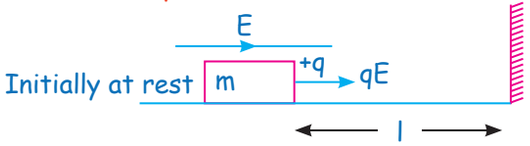
**Q.** Find min. value of E so that block start moving

**Sol.**




$qE = (fs)_{max} = \mu mg$

**Q.** When block will strike the wall in given figure. Find the time after which the block will return to its initial point.




**Sol.** $a = \frac{F}{m} = \frac{qE}{m}$

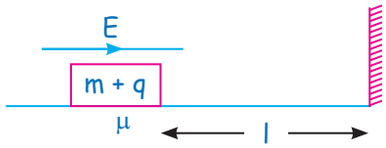
$s = ut + \frac{1}{2}at^2$

$s = 0 + \frac{1}{2}at_o^2$

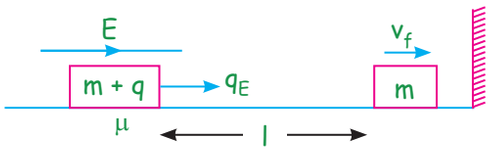
$t_o = \sqrt{\frac{2s}{a}} = \sqrt{\frac{m2s}{qE}}$

If collision is elastic block will return to initial point at $t = 2t_0$

**Q.** Find velocity of block just before it hit the wall if ground is rough (μ)



**Sol.**

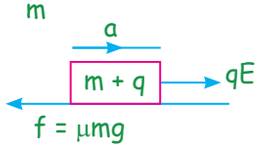



$(WD)_{\text{all force}} = \Delta K.E$

$W_g + W_n + W_f + W_e = \Delta K.E$

$0 + 0 - \mu mgl + qEl = K_f - 0 = \frac{1}{2}mv_f^2 - 0$

$V_f = \sqrt{\frac{2(qEl - \mu mgl)}{m}}$



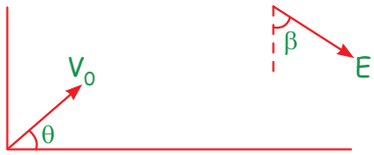

$V^2 = O^2 + 2al$ ...(i)

$l = 0 + \frac{1}{2}at^2$

$a = \frac{qE - \mu mg}{m}$

eq(1)- $V = \sqrt{2 \times \left(\frac{qE - \mu mg}{m}\right) l}$

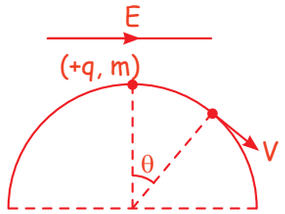
**Q.** A charge particle (q, m) is projected from ground where electric field is also present along with gravitational field. Find is time period and range in following figure.



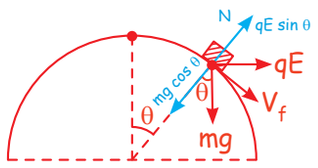

**Sol.** $T = \frac{2U_y}{a_y} = \frac{2 \times V_0 \sin\theta}{g + \frac{qE\cos\beta}{m}}$

$R = (V_o \cos\theta)T + \frac{1}{2}\left(\frac{qE\sin\beta}{m}\right)T^2$

**Q.** If particle is released from rest from top of hemisphere find where it will loose the contact.




**Sol.**




$mg(R - R\cos\theta) + qE\,R\sin\theta + 0 = \frac{1}{2}mV_f^2 - 0$

$mg\cos\theta - qE\sin\theta = \frac{mV_f^2}{R}$ now solve and get

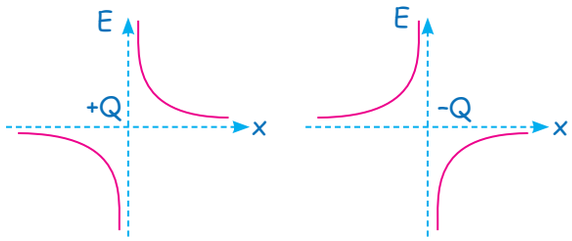
**Q.** A charge particle of radius $5 \times 10^{-7}$m is moving in a horizontal E.F. of intensity $2\pi \times 10^5$ V/m. The surrounding medium is air with coff. of viscosity $\eta = 1.6 \times 10^{-5}$ N.S/$m^2$. If this particle is moving with a uniform horizontal speed of .02 m/s. Find no. of excess electron on the drop.

**Sol.** $6\pi r\,\eta v_T = qE$

**Ans.** $30e^-$

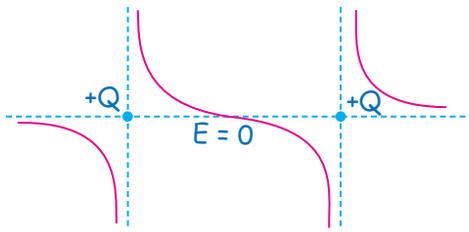
## # Graph b/w E Vs r

\#

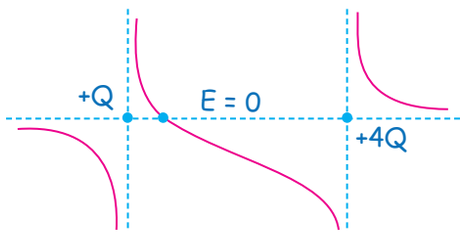



[For +ve, (आगे)] [For -ve]

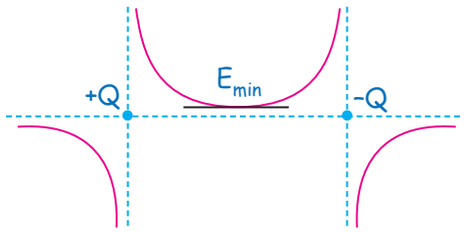
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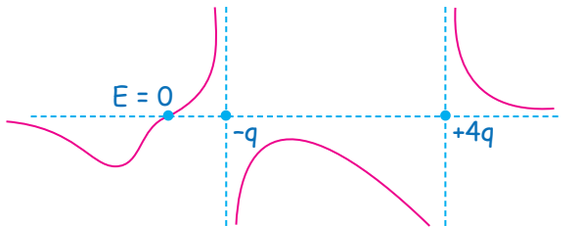

\#




\#



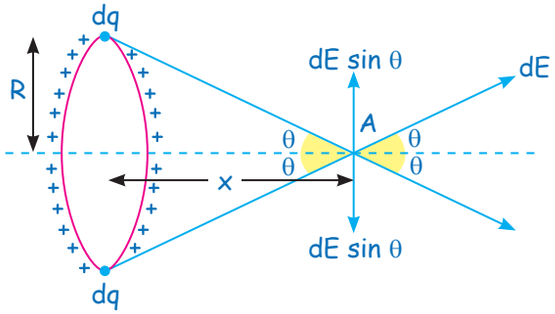

\#



Use

#SKC
लड़का और लड़की के बीच में कभी नहीं आना और कम Magnitude wale charge ke पास में रखना है।

## ELECTRIC FIELD DUE TO CHARGED UNIFORM RING AT AXIS




$E_{net} = \int dE \cos\theta$

$E_{net} = \int \frac{kdq}{r^2} \cdot \frac{x}{r} = \int \frac{k.dq\,.\,x}{(r^2 + x^2)^{3/2}} = \frac{kx}{(R^2 + x^2)^{3/2}} \int dq$

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

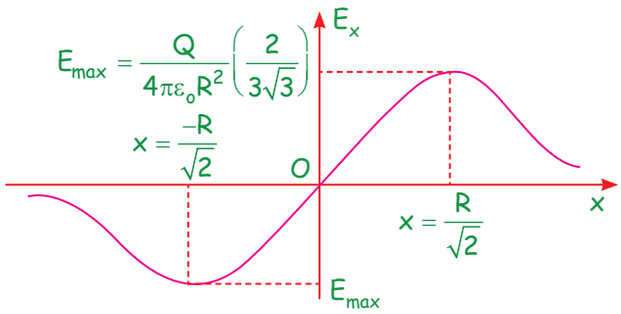
$E_{net} = \frac{kQx}{(R^2 + x^2)^{3/2}}$

at $x = 0, \Rightarrow E.F = 0$

**Q.** Find where $E_{max}$ = ?

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

$\frac{dE}{dx} = 0$ (after solving we got $x = \pm\frac{R}{\sqrt{2}}$)




## Charge Distribution

$\lambda = \frac{dq}{dx}$ = charge per unit lengths.

$dq = \lambda dx$ [Linear Charge Density]

$\sigma = \frac{dq}{dA}$ = charge per unit area.

$dq = \sigma dA$ [Surface Charge Density]

$\rho = \frac{dq}{dV}$ = charge per unit volume.

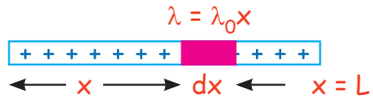
$dq = \rho dV$ [Vol$^n$ Charge Density]

$Q = \int \lambda dx$
$Q = \int \sigma dA$
$Q = \int \rho dV$

**Q.** If $\lambda = \lambda_0 x$ on a rod of length l as shown in figure find the total charge on the rod.




**Sol.**

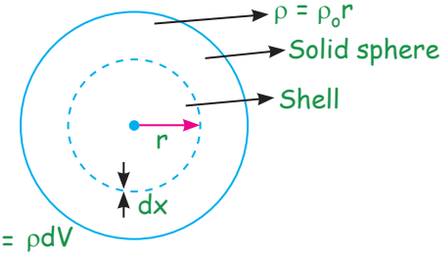



$\int dq = \int \lambda dx$

$Q_{total} = \int_0^L \lambda_0 x dx = \frac{\lambda_0 L^2}{2}$

**Q.** If volume charge density of a solid sphere of radius R varies as $\rho = \rho_0 r$ find total charge on the sphere.

**Sol.**




$dq = \rho dV$

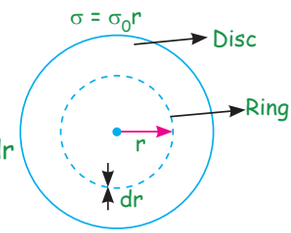
$Q_{total} = \int dq = \int_0^R \rho_0 r.4\pi r^2 dr = \pi\rho_0 R^4$

**Q.** If surface charge density $\sigma$ of a disc of radius R varies as $\sigma = \sigma_0 r$ find total charge on the disc.

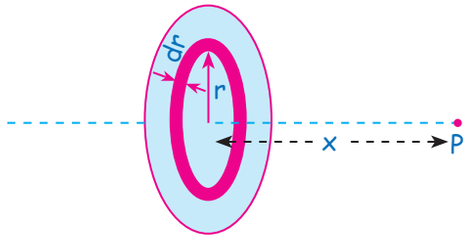
**Sol.** $dq = \sigma dA$

$dq = \sigma_0 r 2\pi r\, dr$

$Q_{total} = \int dq = \int_0^R \sigma_0 r.2\pi r dr$




## ELECTRIC FIELD DUE TO UNIFORM CHARGED DISC AT A POINT ON AXIS [+Q,σ, R]




$dE = \frac{kdq.x}{(r^2 + x^2)^{3/2}}$ it is a E.F due to small ring at P

$E_{net} = \int dE$

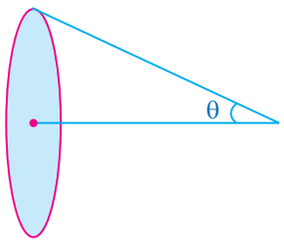
$dq = \sigma.dA = \sigma 2\pi r dr.$

$dx$ ↕ $2\pi r$

$E_{net} = \int_0^R \frac{k\sigma 2\pi r\, dr.x}{(r^2+x^2)^{3/2}}$

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

$E = \frac{\sigma}{2\epsilon_0}(1 - \cos\theta)$

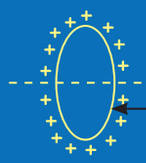



If disc is very large/Infinite sheet.....

$\therefore \quad E_A = \frac{\sigma}{2\varepsilon_0}(1 - \underbrace{\cos 90}_{0})$

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

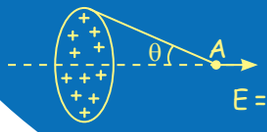
(1) Ring




$E_A = \frac{kQx}{(R^2+x^2)^{3/2}}$

$E_{max.}$ at $\pm \frac{R}{\sqrt{2}}$

(2) Disc




$E = \frac{\sigma}{2\varepsilon_0}(1 - \cos\theta)$

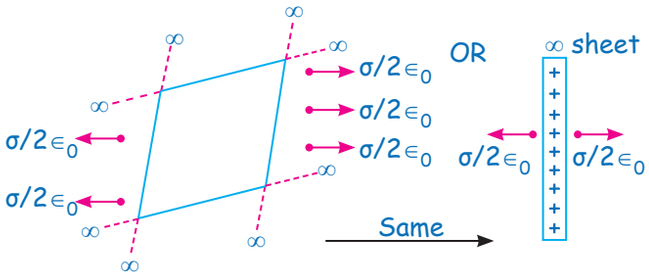
#SKC

∞ sheet के दो मतलब

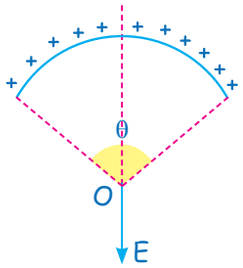
- sheet सच में बहुत बड़ी है।
- या फिर point sheet के बहुत पास है, तो उसे वह ∞ sheet लगेगी।



∞ sheet

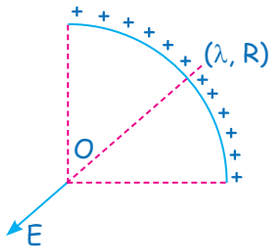



## ELECTRIC FIELD DUE TO CHARGED ARC AT CENTER



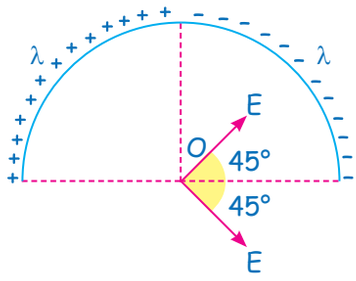

$E = \frac{2k\lambda}{R}\sin\frac{\theta}{2}$

1




$E = \frac{2k\lambda}{R}\sin 45°$

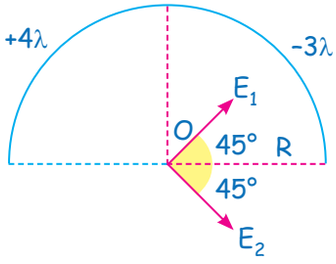
2




$E = \frac{2k\lambda}{R}\sin 45° = \frac{\sqrt{2}k\lambda}{R}$

$(E_0)_{center} = E\sqrt{2}\hat{i} = \frac{2k\lambda}{R}$

3

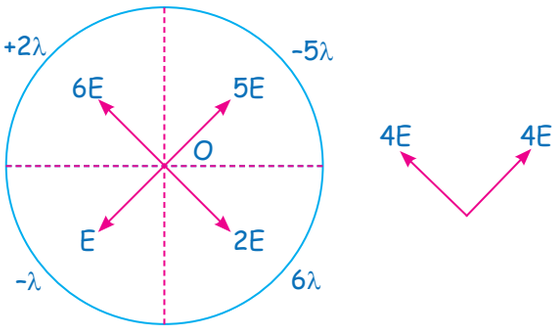


$$E_1 = \frac{2k(3\lambda)}{R}\sin 45° = \frac{3\sqrt{2}\,k\lambda}{R}$$

$$E_2 = \frac{4\sqrt{2}\,k\lambda}{R}$$

$$(E_{net})_0 = \sqrt{E_1^2 + E_2^2} = \frac{k\lambda\, 5\sqrt{2}}{R}$$

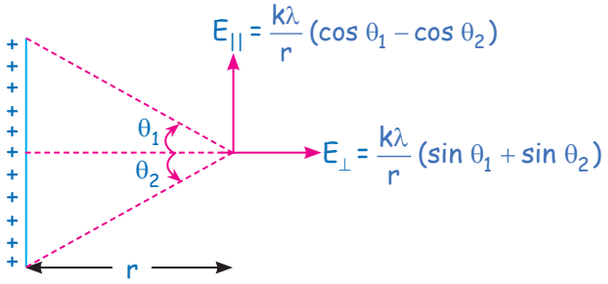
4




$$E = \frac{2k\lambda}{R}\sin\frac{90}{2} = \frac{k\lambda\sqrt{2}}{R}$$

$$E_{net} = 4E\sqrt{2}$$

## ELECTRIC FIELD DUE STRAIGHT CHARGED WIRE AT A POINT

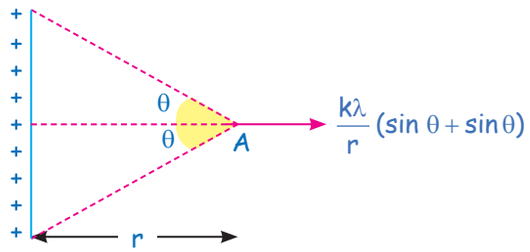



$$E_{||} = \frac{k\lambda}{r}(\cos\theta_1 - \cos\theta_2)$$

$$E_{\perp} = \frac{k\lambda}{r}(\sin\theta_1 + \sin\theta_2)$$

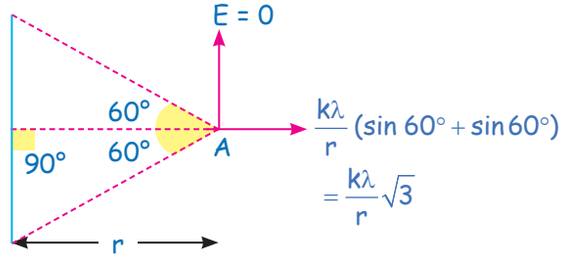
**Q.** Find electric field at point A in following case.

1



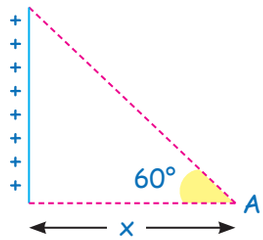

$$\frac{k\lambda}{r}(\sin\theta + \sin\theta)$$

2



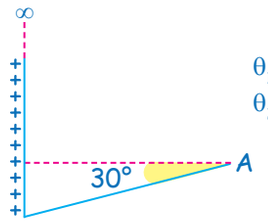

$$\frac{k\lambda}{r}(\sin 60° + \sin 60°) = \frac{k\lambda}{r}\sqrt{3}$$

3



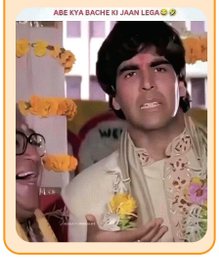

$\theta_1 = 60°$
$\theta_2 = 0°$

4

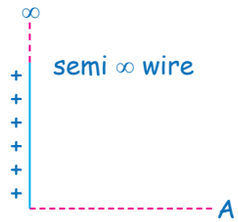



$\theta_1 = 90°$
$\theta_2 = 30°$

Now put the value in formula and get ans. अबे ये भी मै ही करू क्या बच्चे की जान लेगा।




5



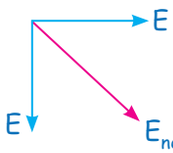

$\theta_1 = 90°$
$\theta_2 = 0°$

$$\frac{k\lambda}{r}(0-1) = -\frac{k\lambda}{r}$$




$$\frac{k\lambda}{r}(1+0)$$

$$E_A = \frac{k\lambda}{r}\hat{i} - \frac{k\lambda}{r}\hat{j}$$

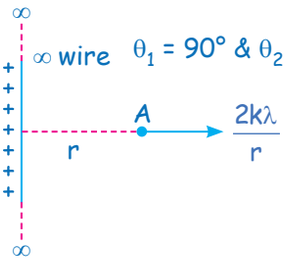



Here

$$E_A = \frac{k\lambda}{r}\sqrt{2}$$

इसे याद करलो

6



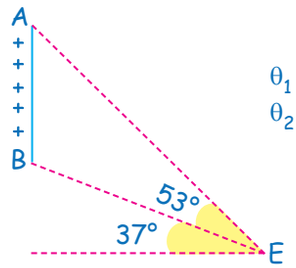

$\theta_1 = 90°$ & $\theta_2 = 90°$

$$\frac{2k\lambda}{r}$$

∞ wire ki वजह से

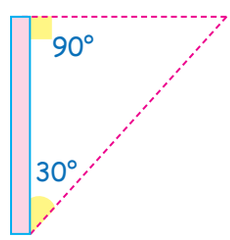
$EF = \frac{2k\lambda}{r}$ होती है

7



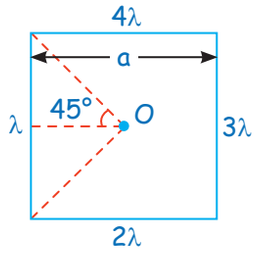

$\theta_1 = 53°$
$\theta_2 = -37°$

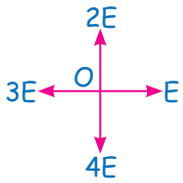
8

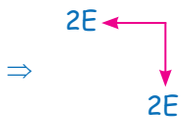



$\theta_1 = 0$
$\theta_2 = 60°$

**9** Find electric field at O.

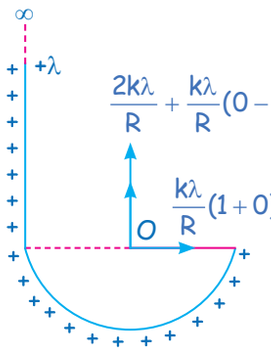



$$E_{net} = 2E\sqrt{2} = 2 \times \frac{2k\lambda}{a/2}(\sin 45°)\sqrt{2}$$

**10**




$\frac{2k\lambda}{R} + \frac{k\lambda}{R}(0-1)$

$\frac{k\lambda}{R}(1+0)$

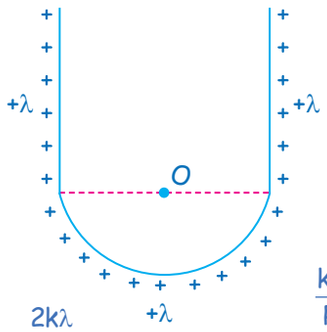
$\theta_1 = 90°$

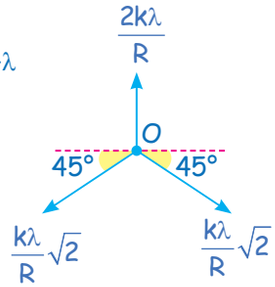
$\theta_2 = 0$

Solve and get

$E_0 = \frac{k\lambda}{R}\sqrt{2}$

**11** Find electric field at O.



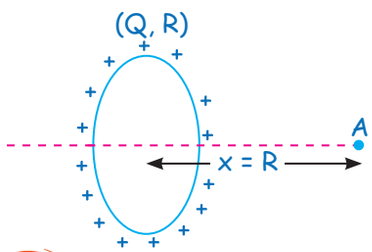







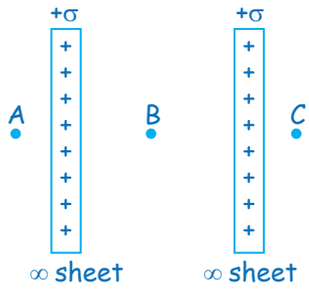
$(E_{net})$ at '0' = 0

**12** Find electric field at distance R from centre of A charge ring (Q, R) on the axis.

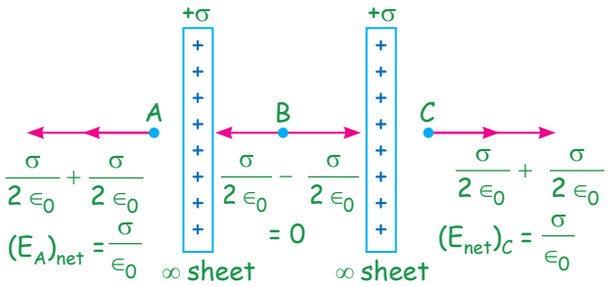



$$E_A = \frac{kQR}{(R^2+R^2)^{3/2}} = \frac{kQ}{2\sqrt{2}R^2}$$

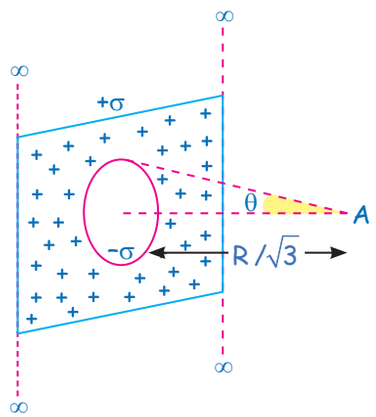
**13** Find electric field at A, B, C



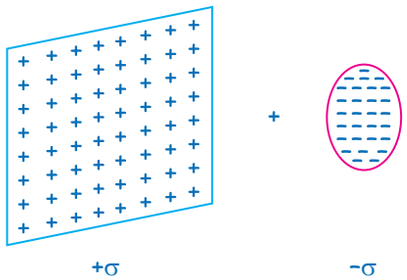

**Sol.**




**Q.** From a infinite charge sheet a disc of radius R is removed. Find electric field at a distance $\frac{R}{\sqrt{3}}$ from O as shown in figure.




**Sol.** The given body can be assume as it made up of two body inifinite sheet (+σ) and disc (-σ)



$(Ef)_{at}$ Point A = $\underbrace{\frac{\sigma}{2\epsilon_0}}_{\vec{E} \text{ due to } \infty \text{ sheet}} - \underbrace{\frac{\sigma}{2\epsilon_0}}_{\vec{E} \text{ due to -ve disc}}(1 - \cos\theta$

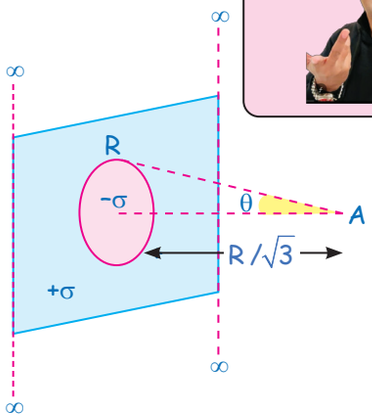
$\tan\theta = \frac{R}{R/\sqrt{3}} \Rightarrow \theta = 60°$

$= \frac{\sigma}{2\epsilon_0} - \frac{\sigma}{4\epsilon_0} = \frac{\sigma}{4\epsilon_0}$

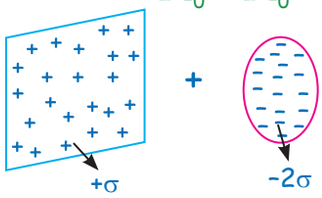
मान लो खाली जगह मे अब मै -σ की disk रख दूँ सोचो कैसे करोगे।



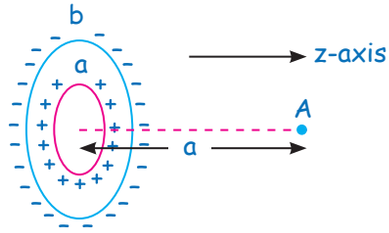
**Q.** Find electric field at A.




**Sol.** $E_A = E_{\infty sheet} - E_{disc} = \frac{\sigma}{2\epsilon_0} - \frac{2\sigma}{2\epsilon_0}(1 - \cos 60°)$




**Q.** Two concentric rings, one of radius 'a' and other of the radius 'b' have the charges +q and $-\left(\frac{2}{5}\right)^{-3/2} q$. Find $\frac{b}{a}$ if a charge particle placed on the axis z = a is in eqb$^m$.




**Sol.** $R_1 = a, R_2 = b, x = a$

$(E_A)_{net} = 0$

$(E)_{Ring1} = (E)_{R_2}$

$$\frac{kq_1 x}{(R_1^2 + x)^{3/2}} = \frac{kq_2 x}{(R_2^2 + x)^{3/2}}$$

$$\frac{q}{(2a^2)^{3/2}} = \frac{(2/5)^{-3/2} q}{(b^2 + a^2)^{3/2}}$$

$$\frac{1}{2a^2} = \frac{5}{2(b^2 + a^2)}$$

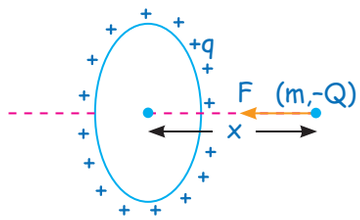
$b^2 = 4a^2$

$b = 2a$

$\frac{b}{a} = 2$

**Q.** A particle of mass m, charge -Q is constrained to move along the axis of radius a. The ring carries a uniform charge density +λ along its circumference. Initially, the particle lies in the place of the ring at a point where no net force acts on it. The period of oscillation of the particle when it displaced slightly from its eqb$^m$ position is

**Sol.** Let charge displaced by distance x from center of ring along the axis now F = q × E



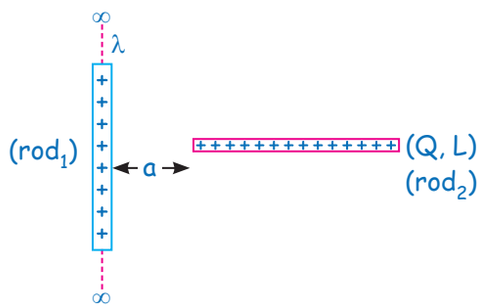

$F_{net} = QE$ (पीछे)

$$F_{net} = \frac{Qkqx}{(R^2 + x^2)^{3/2}} \quad [x<<<R]$$

$$F_{ent} = \frac{kqQ}{R^3}\vec{x}$$

$$T = 2\pi\sqrt{\frac{m}{\left(\frac{KqQ}{R^3}\right)}}$$

**Q.** Find the force applied by infinite ($rod_1$) to ($rod_2$) of length l and charge Q in given figure.



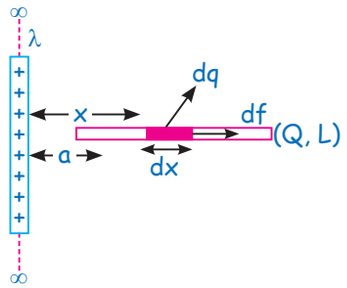
**Sol.** Rod$_2$ में x पर जाकर dx length का छोटा सा charge dq पकड़ा जिस पर let dF force लगा

$dF = dq.E$

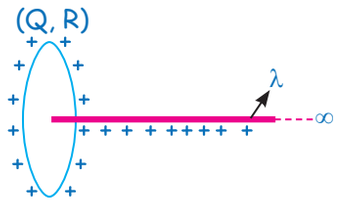
$$dF = \frac{Qdx}{L} \times \frac{2k\lambda}{x}$$

$$\int dF = \int_{a}^{a+L} \frac{Qdx}{L} \times \frac{2k\lambda}{x}$$

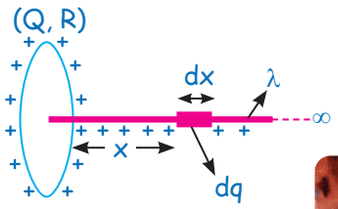
$$= 2k\lambda \frac{Q}{L} \ln\left(\frac{a+l}{a}\right)$$




**Q.** Find the force applied by rod on ring or force applied by ring or rod.




**Sol.**







$dF = dq.E$

$$F_{net} = \int dF = \int_0^{\infty} \lambda dx \cdot \frac{kQx}{(R^2+x^2)^{3/2}}$$

$$\Rightarrow \lambda kQ \int_0^{\infty} \frac{xdx}{(R^2+x^2)^{3/2}}$$

$R^2 + x^2 = t.$

$0 + 2xdx = dt$

$$xdx = \frac{1}{2}dt$$

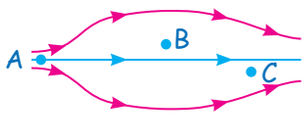
$$F_{net} = \lambda kQ \int_0^{\infty} \frac{xdx}{(R^2+x^2)^{3/2}} = \lambda kQ \int \frac{dt}{2t^{3/2}}$$

$$= \frac{\lambda kQ}{2} \int t^{-3/2}\,dt = \frac{\lambda kQ}{2} \frac{t^{-3/2+1}}{-3/2+1}$$

$$= \frac{k\lambda Q}{2\left(-\frac{1}{2}\right)} \left(\frac{1}{\sqrt{t}}\right) = -\lambda kQ \left[\frac{1}{\sqrt{R^2+x^2}}\right]_0^{\infty} = \frac{\lambda kQ}{R}$$

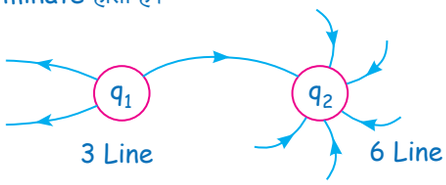
## ELECTRIC FIELD LINE (EFL)

1. The electric line of force is an imaginary line or curve, the tangent to which at any point on it represent the dirx$^n$ of net electric field.
2. Jaha E.F.L density ज्यादा ⇒ wha E.f. jyada
   Jaha no. of EFL jyada ⇒ wha E.F jyada.




$E_A > E_C > E_B$

3. No. of EFL ∝ magnitude of charge
4. EFL ye +ve charge is nikalti he aur -ve charge pe terminate होती है।




$q_1 > 0$ $\quad q_1 = q$(let)

$q_2 < 0$ $\quad q_2 = -2q$

5. EFL never intersect each other
6. EFL never from close loop [Electrostatic] bcz EF. → conservative in nature
7. Agr m kisi charge +q ko E.F.L mein rkh du to vo EFL ke path ko follow ker bhi skta hai aur nhi bhi kar skta.

न उसे हुई मेरे प्यार की कदर
न मुझे हुई उसके प्यार की कदर
फिर मुझे याद आई सलीम भईया
की वो line
Two electric field line never intersect each other.





## ELECTRIC FLUX [$\phi$]

1. Kind of no. of E.F.L. crossing on area perpendicularly.
2. Electric flux through small area dA is defined as

$d\phi = \vec{E}.d\vec{A}$

$$\phi_{net} = \int d\phi = \int \vec{E}.d\vec{A}$$

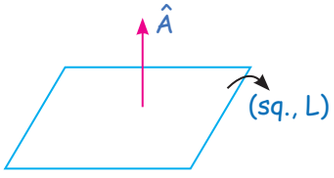
$$\boxed{\phi_{net} = \int \vec{E}.d\vec{A}}$$

If E.F is uniform

$$\Rightarrow \boxed{\phi_{net} = \vec{E}.\vec{A}}$$

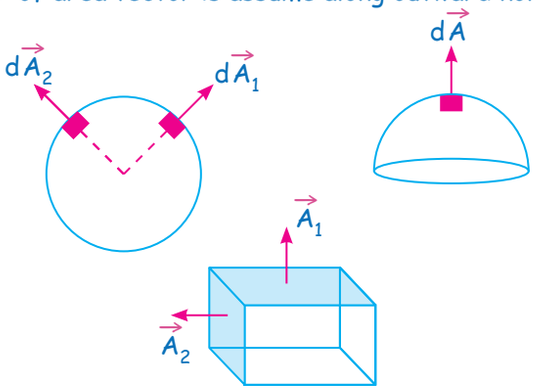
#SKC
Uniform = हर जगह same होना।
Constant = हर वक्त same होना।

## AREA VECTOR [$\vec{A}$]

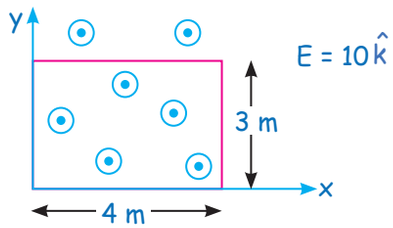



For closed body/surface

Dirx$^{n}$ of area vector is assume along outward normal.




**Q.** Find flux through an area as shown in figure:




(a) $\vec{E} = 10\hat{k} \longrightarrow$ uniform

$\phi = \vec{E} \cdot \vec{A} = 10\hat{k} \cdot (12\hat{k}) = 120$

(b) If $\vec{E} = 3\hat{i} + 4\hat{j} + 10\hat{k}$ = uniform

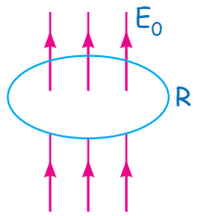
$\vec{A} = 12\hat{k}$

$\phi = \vec{E} \cdot \vec{A} = 0 + 0 + 10 \times 12 = 120$

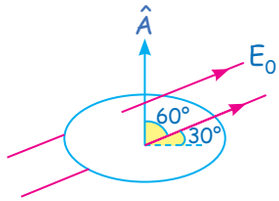
Area = $4 \times 3 = 12$

$\vec{A} = 12\hat{k}$

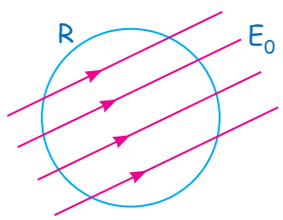
**Q.** Find flux through given area in following question.

1. 

$\Rightarrow \phi = E_0 \cdot \pi R^2$

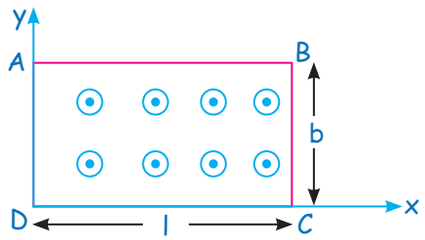
2. 

$\Rightarrow E\pi R^2 \cos 60°$

3. 

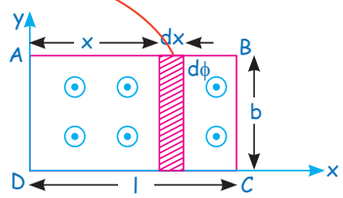
$\Rightarrow \phi = 0$

**Q.** Find flux to the rectangle if $\vec{E} = 10x\,\hat{k}$ (non-uniform) in given diagram.




**Sol.**

$d\phi = \vec{E}.d\vec{A}$ it is small flux through area dA




$\phi_{net} = \int d\phi$

$= \int_0^l 10x\, b.\, dx$

$= 10b \int_0^l x dx = 5bl^2$

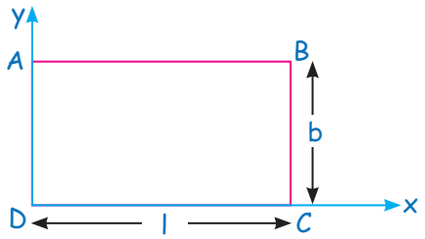
**Q.** In above part $\vec{E} = 5\hat{i} + 10\hat{j} + 10x\hat{k}$

[ABCD] $\phi_{Area} = 0 + 0 + 5bl^2$

↳ Last part

क्योंकि $\vec{E}_x$ और $\vec{E}_y$ area के अंदर घुसकर बाहर नही निकल रहे उनकी वजह से flux = 0

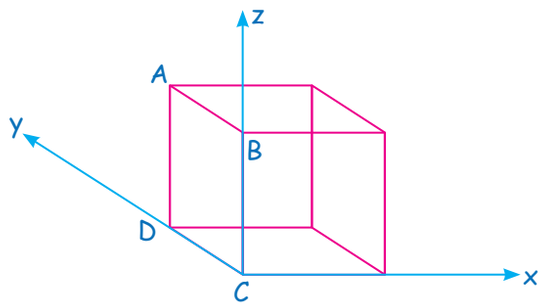
**Q.** Find flux through the rectangle if $\vec{E} = 3x^2y\hat{i} + 4y^3x\hat{j} + 3x^2\hat{k}$ in given diagram



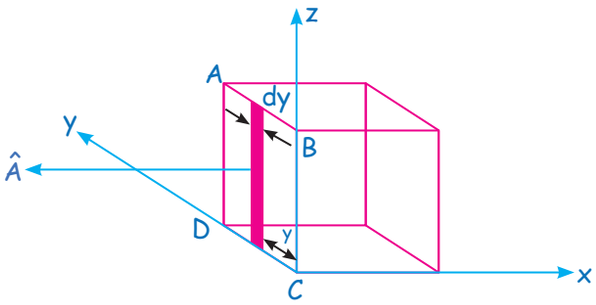

**Sol.** $d\phi = \vec{E}.d\vec{A}$

$\int d\phi = \int_0^l 3x^2 b.dx = bl^3$

**Q.** If $\vec{E} = 10y\hat{i}$ find the flux through the area ABCD and flux through whole cube.




**Sol.**




$d\vec{\phi} = \vec{E} . d\vec{A}$

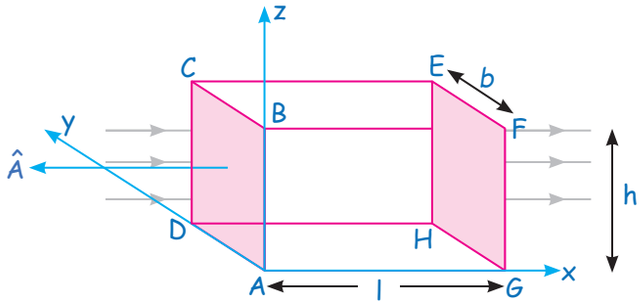
$\phi_{ABCD} = \int_0^L 10y . Ldy$ (magnitude) $= 5L^3$ (magnitude)

net flux through cube = 0

## ☆ $\phi$ Through Body/closed area

$\phi_{net} = |\phi_{\text{जाने वाली}}| - |\phi_{\text{आने वाली}}|$

**Q.** If $\vec{E} = 10\hat{i}$ then find net flux through cuboid ($l \times b \times h$)




$\phi = EA \cos\theta$

$\phi_{ABCD} = 10bh \cos 180° = -10bh = \phi_{in}$

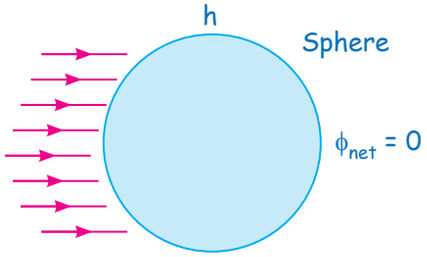
$\phi_{out} = \phi_{EFGH} = EA \cos\theta = 10\ bh$

$|\phi_{net}| = |\phi_{out}| - |\phi_{in}| = 0 \Rightarrow 10bh - 10bh = 0$

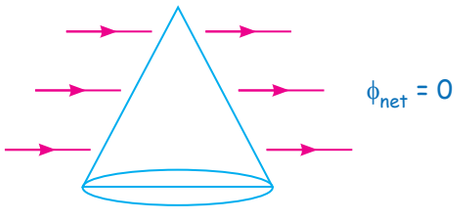
- $\phi_{in} = \phi_{body}$ में आने वाला flux → Negative
- $\phi_{out} = \phi_{body}$ से जाने वाला flux → Positive
- अगर आने वाली = जाने वाली तो body से net flux = 0



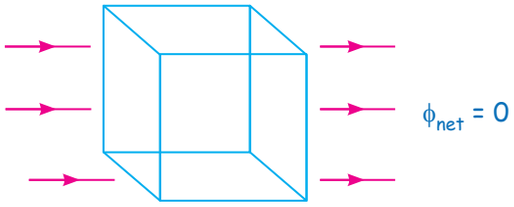
# Sphere



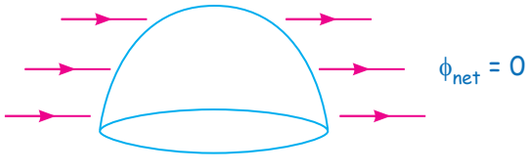

#



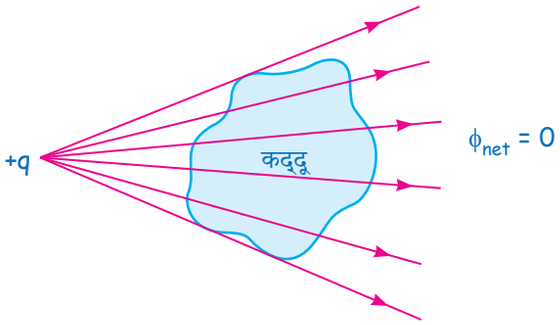

#



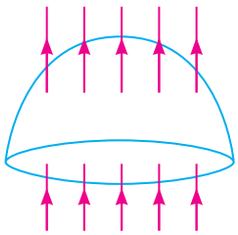

#




#

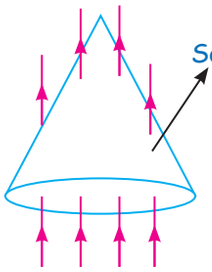


#



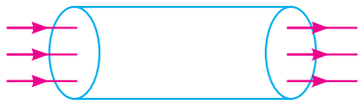
$\phi_{net} = 0$

#



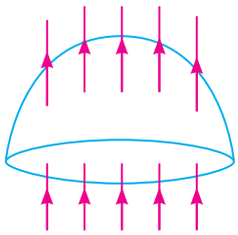

$\phi_{net} = 0$

#



$\phi_{net} = 0$

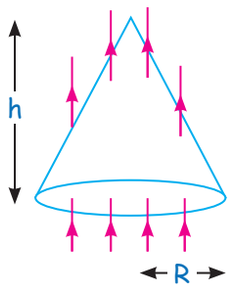
**Q.** Find flux through the curve surface of in hemisphere in following figure.



**Sol.** $\phi_{net} = 0$

$\phi_{in} = -E_0\pi R^2$ Hence $\phi_{curve\ part\ surface} = E_{out} = E_0\pi R^2$

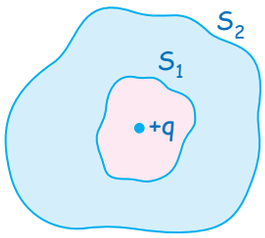
#




$\phi_{curve\ surface} = +E_0\pi R^2$

$\phi_{in} = -E_0\pi R^2$

#




जीतनी E.F.L $S_1$ से पास करेगी उतनी ही $S_2$ से करेगी

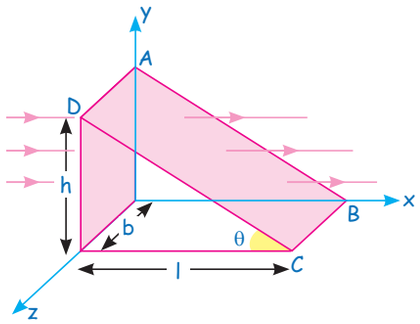
$\phi_{S_1} = \phi_{S_2}$

**Q.** If $\vec{E} = E_0\hat{i}$ find flux coming out from slant Area ABCD in given figure.

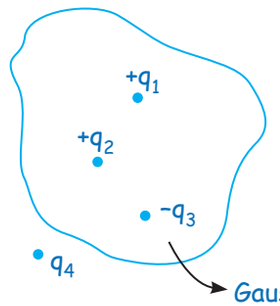
**Sol.** $\phi_{in} = -E_0hb$

$\phi_{out} = E_0hb$

$\phi_{net} = 0$




## GAUSS LAW




$$\phi_{net} = \oint \vec{E}.d\vec{A} = \frac{q_{in}}{\varepsilon_0} = \frac{q_1 + q_2 - q_3}{\varepsilon_0}$$

Gauss Law

due to all the charge

अंदर वाला charge

$$\phi_{net(close\ surface\ area)} = \oint \vec{E}.d\vec{A} = \frac{q_{in}}{\varepsilon_0} = \frac{q_1 + q_2 - q_3}{\varepsilon_0}$$

Gauss Law

# Net flux through a closed surface is equal to the $\frac{1}{\varepsilon_0}$ time to the charge inclose by the closed surface.

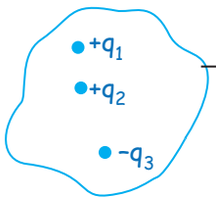
- $\oint \vec{E}.d\vec{A} = \frac{q_{in}}{\varepsilon_0}$
- $\phi_{net} = \frac{q_{in}}{\varepsilon_0}$

#



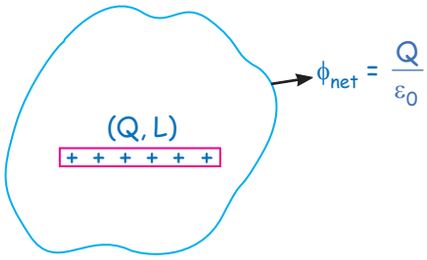

$\phi_{net} = \frac{q_1 + q_2}{\varepsilon_0}$

#



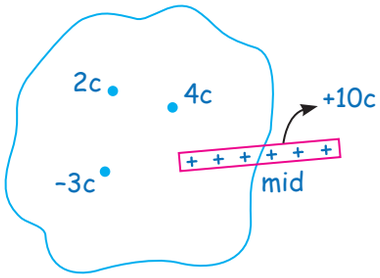

$\phi_{net} = \frac{q_1 + q_2 - q_3}{\varepsilon_0}$

#




$$\phi_{net} = \frac{Q}{\varepsilon_0}$$

#




$$\phi_{net} = \frac{2+4-3+5}{\varepsilon_0} = \frac{8}{\varepsilon_0}$$

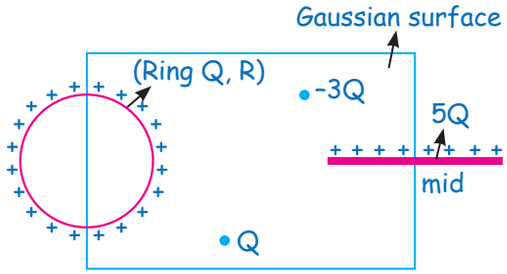
बुरा मानेगा तो क्या कर लेगा.....Book तो खरीद ही चुका है। (I'm joking)





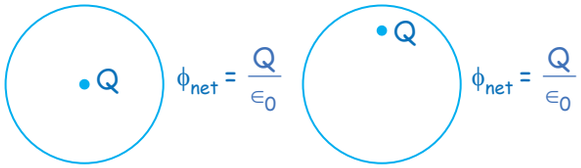

चलो अब पढ़ाई करते है।

**Q.** Find flux through the Gaussian surface



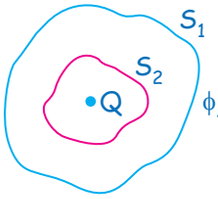

$$\phi_{net} = \frac{Q}{2\epsilon_0} + \frac{-3Q}{\epsilon_0} + \frac{Q}{\epsilon_0} + \frac{5Q}{2\epsilon_0} = \frac{Q}{\epsilon_0}$$

#



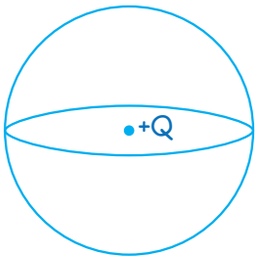

$$\phi_{net} = \frac{Q}{\epsilon_0} \qquad \phi_{net} = \frac{Q}{\epsilon_0}$$

#




$\phi_{S_1} = \phi_{S_2}$ $[\phi_{S_2} = Q/\epsilon_0 . \phi_{S_1} = Q/\epsilon_0]$

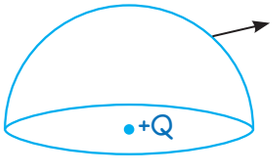
#




$$(\phi_{net})_{\text{full gaussian surface}} = \frac{Q}{\epsilon_0}$$

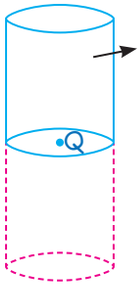
$$(\phi)_{\text{upper half hemisphere}} = \frac{Q}{2\epsilon_0} = \phi_{\text{lower half hemispheres}}$$

#




$$\phi = \frac{Q}{2\epsilon_0}$$

#




$$\phi = \frac{Q}{2\epsilon_0}$$

**# काम का डब्बा**

भाई Gauss law आप हर जगह electric field तो निकाल दोगे ना



- $\phi_{net} = \oint \vec{E} . d\vec{A} = \frac{q_{in}}{\epsilon_0}$
- यहां Electric field due to all charges hai. [अंदर वाले भी बाहर वाले भी]




- $q_{in} \rightarrow$ Gausian surface के अंदर वाले charge.
- बाहर वाला charge net flux में participate नहीं करता [through closed Gausian surface]
- Gauss Law की मदद से हम हर जगह E.F नही निकाल सकते, कुछ selected symmetrical cases में निकाल सकते है।

- Gaussian surface smartly मानना है, वर्ना कद्दू मिलेगा, और Gaussian surface ऐसे मानो की हर जगह पर $\theta$ की value 0°, 90°, 180° मिले

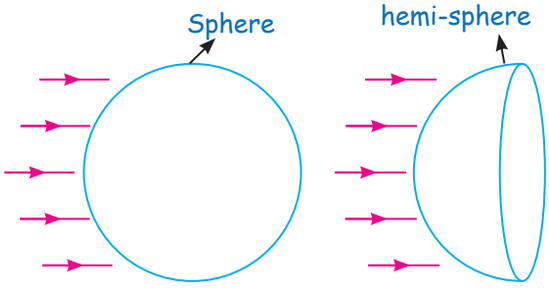


Gauss law पर based two type of question पूछे जाते है पहला

1. Flux calculation based
2. EF calculation based

पहले हम flux calculation based questions करेंगे

#




$\phi_{net} = 0$

$\phi_{entering} = \phi_{in} = -E_0\pi R^2$

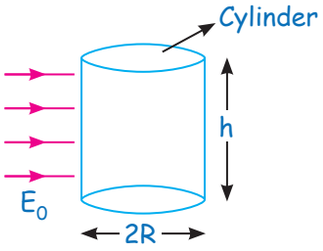
$\phi_{out} = E_0\pi R^2$

$\phi_{net} = 0$

$\phi_{in} = -E_0\pi R^2$

$\phi_{out} = E_0\pi R^2$

#

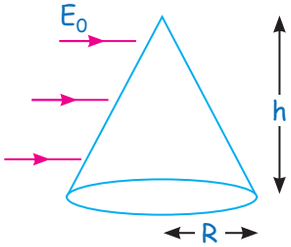



$\phi_{net} = 0$

$\phi_{in} = -E_0\ 2Rh$

$\phi_{out} = E_0\ 2Rh$

#

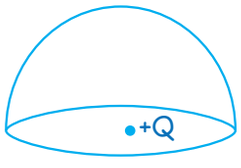



$\phi_{net} = 0$

$\phi_{in} = -E_0 \frac{1}{2} \times 2R \times h$

$\phi_{out} = E_0 \frac{1}{2} 2Rh$

#



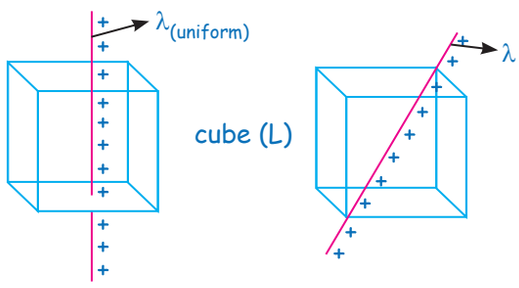

$\phi_{semi\text{-}sphere} = \frac{Q}{2\epsilon_0}$

#




$\phi_{slant\text{-}surface} = \frac{Q}{2\epsilon_0}$

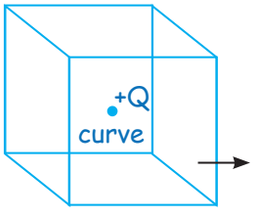
#




$\phi_{cube} = \frac{q_{in}}{\epsilon_0} = \frac{\lambda L}{\epsilon_0}$

$\phi_{cube} = \frac{q_{in}}{\epsilon_0} = \frac{\lambda L\sqrt{3}}{\epsilon_0}$

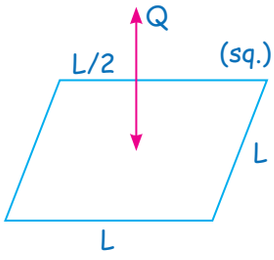
#




$\phi_{cube} = \frac{Q}{E_0}$

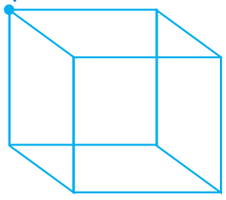
$\phi_{face} = \frac{Q}{6\epsilon_0}$

#



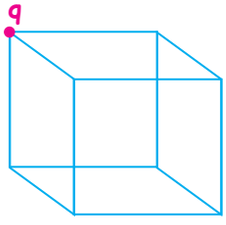

$\phi_{sq.face} = \frac{Q}{6\epsilon_0}$

# q



$\phi_{cube} = \frac{Q}{8\epsilon_0}$

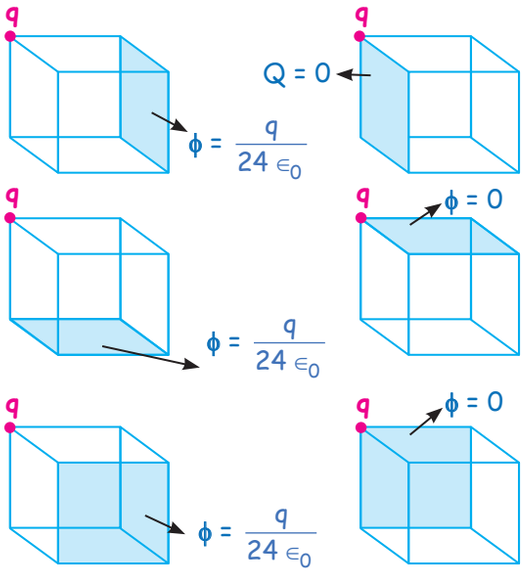
# q



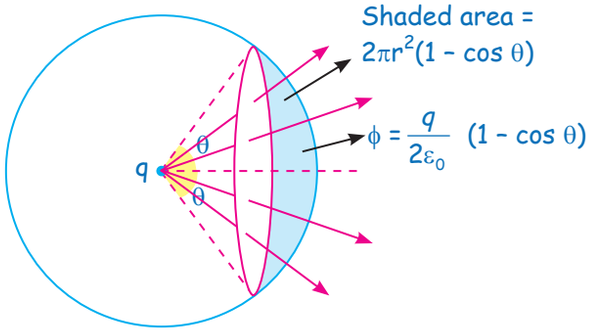
$\phi_{cube} = \frac{Q}{8\epsilon_0}$

$\phi_{3faces} = 0$

$\phi_{samne\ bala} = \frac{q}{24\epsilon_0}$



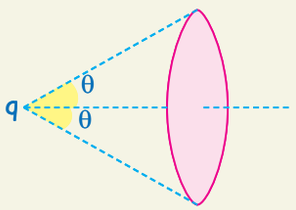

#




बहुत important formula ये मत भूलना

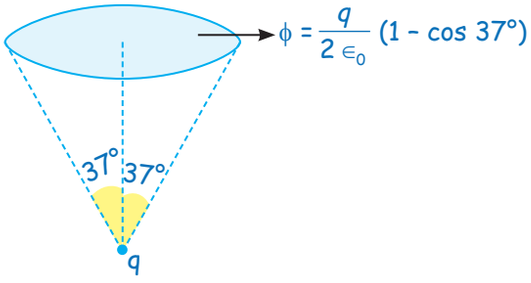
Flux through the disc $\phi$

$$\phi = \frac{q}{2\varepsilon_0}(1 - \cos\theta)$$

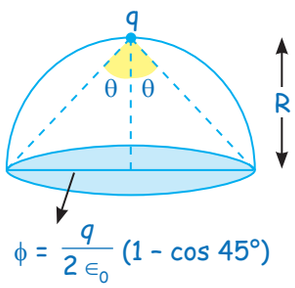





#

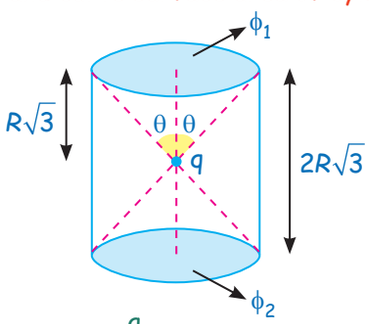



#




$$\phi = \frac{q}{2\epsilon_0}(1 - \cos 45°)$$

**Q.** Inside a cylinder a charge q is placed as shown in figure. Find flux through the circular area and curve surface area of cylinder.




$$\phi_2 = \frac{q}{2\epsilon_0}(1 - \cos 30°)$$

$$\phi_1 = \frac{q}{2\epsilon_0}(1 - \cos\theta) \qquad \left[\tan\theta = \frac{R}{R\sqrt{3}} \Rightarrow \theta = 30°\right]$$

$$\phi_1 = \frac{q}{2\epsilon_0}(1 - \cos 30°)$$

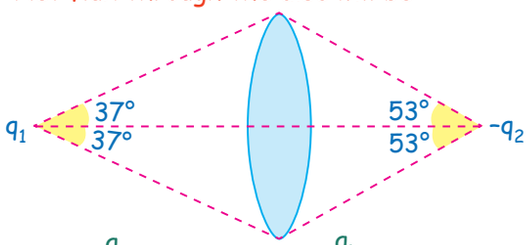
$\phi_1 \rightarrow$ flux through upper circular area
$\phi_2 \rightarrow$ flux through lower circular area

$$\phi_{\text{curve area}} = \frac{q}{\epsilon_0} - (\phi_1 + \phi_2)$$

$$= \frac{q}{\epsilon_0} - \frac{q}{\epsilon_0}(1 - \cos 30°)$$

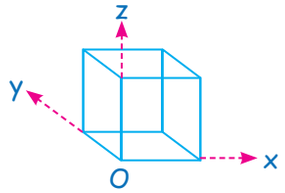
$$= \frac{q}{\epsilon_0}\frac{\sqrt{3}}{2}$$

**Q.** Net flux through the disc will be

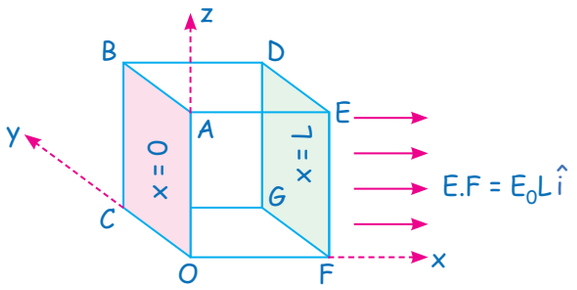



$$\phi_{\text{net}} = \frac{q_1}{2\epsilon_0}(1 - \cos 37°) + \frac{q_2}{2\epsilon_0}(1 - \cos 53°)$$

**Q.** Find net flux through the cube of length l if $\vec{E} = E_0 x\hat{i}$ also find charge inside the cube.



**Sol.**




$(\phi_{in})_{cube} = \phi_{0\ ABC} = 0$ (because x = 0 so E = 0)

$(\phi_{out})_{cube} = \phi_{DEFG} = E_0L.L^2 = E_0L^3$

Net flux through cube = $E_0L^3 - 0$

$(\phi_{cube})_{net} = q_{in}/\epsilon_0$

$E_0L^3 = q_{in}/\varepsilon_0$

$q_{in} = \varepsilon_0 E_0 L^3$

#SKC
जब भी कभी मुझसे charge enclose पूछेगा, मैं
$\phi_{net} = q_{in}/\varepsilon_0$ सबसे पहले सोचूंगी

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\epsilon_0}$$

Gaussian surface area

## VERIFICATION OF GAUSS LAW

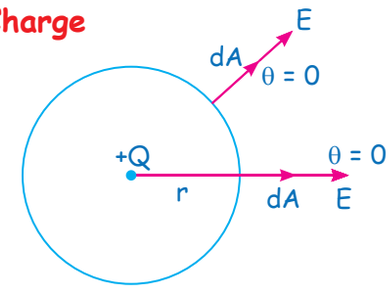
### E.F Due to Pt. Charge

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\epsilon_0}$$

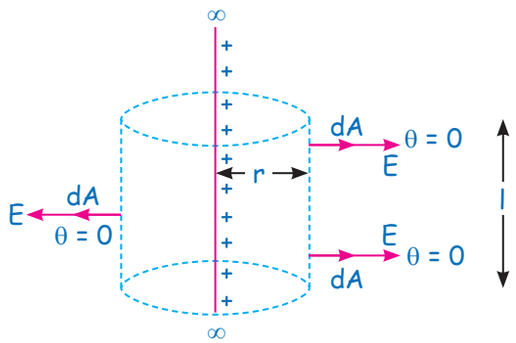
$$E\int dA = \frac{Q}{\epsilon_0}$$

$$E4\pi r^2 = \frac{Q}{\epsilon_0}$$

$$E = \frac{Q}{4\pi\epsilon_0 r^2} = \frac{KQ}{r^2}$$




### E.F DUE TO ∞ LINE-WIRE



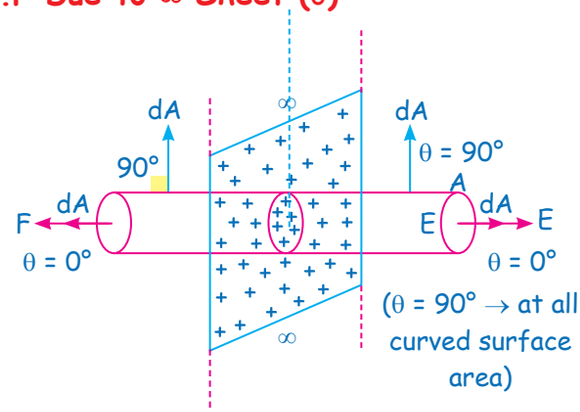

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\varepsilon_0}$$

$$E\int dA = \frac{q_{in}}{\varepsilon_0}$$

$$E2\pi rl = \frac{\lambda l}{\varepsilon_0}$$

$$E = \frac{\lambda}{2\pi r\varepsilon_0} = \frac{2k\lambda}{r}$$

### E.F Due to ∞ Sheet (σ)




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

$$EdA + EdA\cos 90° + EdA = \frac{q_{in}}{\varepsilon_0}$$

Curved Surface area

$$2EdA = \frac{\sigma dA}{\varepsilon_0} \Rightarrow E = \frac{\sigma}{2\varepsilon_0}$$

### E.F due to hollow sphere (Q, R) [Non-Conducting] or spherical shell

(a) E.F inside the hollow sphere

For r < R

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

$q_{in} = 0$

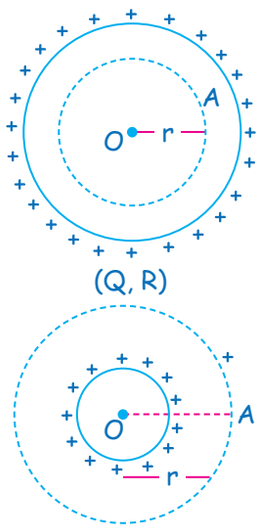
E = 0

(b) For r > R (E.F outside)

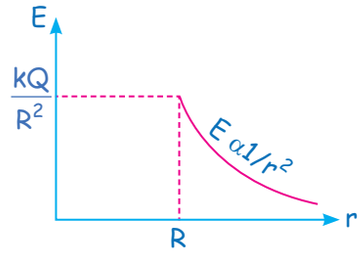
$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\varepsilon_0}$$

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

$$E4\pi r^2 = \frac{Q}{\varepsilon_0}$$

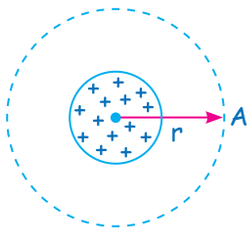


$$E = \frac{Q}{4\pi r^2 \varepsilon_0} = \frac{kQ}{r^2}$$




## E.F DUE TO SOLID SPHERE (Q, R, ρ) [NON-CONDUCTING]

1. Outside (r > R)




$$E\int dA = \frac{q_{in}}{\varepsilon_0}$$

$$E.4\pi r^2 = \frac{Q}{\varepsilon_0}$$

$$E = \frac{Q}{4\pi r^2 \varepsilon_0} = \frac{kQ}{r^2}$$

$$\rho = \frac{Q}{\frac{4}{3}\pi R^3}$$

2. Inside (r < R)

$$E.4\pi r^2 = \frac{q_{in}}{\in_0}$$

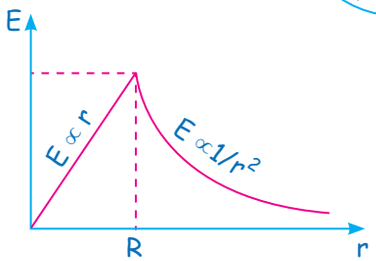
$$E.\ 4\pi r^2 = \frac{\rho\ .\ 4/3\ \pi r^3}{\in_0}$$

$$E = \rho\frac{p}{3\in_0}$$

$$\vec{E} = \rho\frac{\vec{r}}{3\in_0} \quad \rho \Rightarrow \text{uniform}$$

हमें यहाँ O से r radius तक के गोले के अंदर का charge चाहिए।




**Very Important Result**

[Solid sphere uniform Q, R, ρ]

बाहर → $E = \frac{kQ}{r^2} \Rightarrow E \propto \frac{1}{r^2}$

अंदर → $E = \frac{\rho r}{3\in_0} \Rightarrow E \propto r$

at surface → $E = \frac{kQ}{R^2}$

## E.F Due to non-uniform Solid Sphere

**Q.** If volume charge density of a sphere of radius R varies as $\rho = \rho_0 r$ ... $(r \le R)$ find

(1) Total charge of this sphere

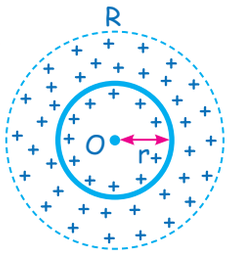
(2) Total charge of vol$^n$ from r = 0 to r = R/2

(3) Electric field outside the sphere

(4) Electric field inside the sphere at r = R/2

**Sol.**

1. Total charge of this sphere




$dq = \rho dV$

$dq = \rho_0 r\ 4\pi r^2 dr$

$$\int dq = \int_0^R \rho_0 r.4\pi r^2 dr$$

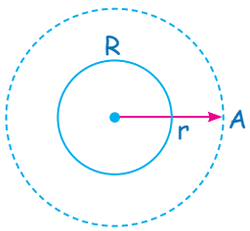
$dV = 4\pi r^2 dr$ [learn it]

$$Q_0 = \rho_0 \frac{4\pi R^4}{4} = \rho\pi R^4$$

2. Total charge of vol$^n$ from r = 0 to r = R/2

$$\int dq = \int_0^{R/2} \rho_0 r.4\pi r^2 dr$$

3. For calculation of electric field at a point outside the sphere.




$$E.\int dA = \frac{q_{in}}{\in_0}$$

$$E4\pi r^2 = \frac{Q_{total}}{\in_0}$$

$$E = \frac{kQ_{total}}{r^2}$$

4. For E.F at r = R/2

$E.4\pi r^2 = \frac{q_{in}}{\in_0}$ Gaussian surface ke andr ka charge

$q_{in} \Rightarrow$ r = 0 से R/2 तक charge

$$q_{in} = \int \rho dV = \int_0^{R/2} \rho_0 r\ 4\pi r^2 dr$$

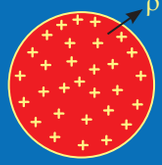
$$E.4\pi\left(\frac{R}{2}\right)^2 = \frac{\int_0^{R/2} \rho_0 r 4\pi r^2 dr}{\varepsilon_o}$$

$$E = \frac{\rho_0 R^2}{16\varepsilon_o}$$

#SKC
*Very very important

$\rightarrow Q_{total} = \int_0^R \rho 4\pi r^2 dr.$

$\rightarrow$ Inside E.F = $E.4\pi r^2 = \dfrac{\int_0^r \rho 4\pi r^2 dr}{\epsilon_0}$




$\rightarrow$ Outside E.F. = $E.4\pi r^2 = \dfrac{\int_0^R \rho 4\pi r^2 dr}{\epsilon_0}$

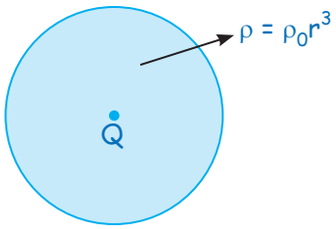


देख भाई rough copy में इसकी practice जरूर कर लेना वरना exam में तू बोलेगा।




**********

**Q.** Find the electric field at a point outside and inside the sphere if sphere has volume charge density $\rho = \rho_o r^3$ and a point charge +Q is placed at centre of sphere. (Homework)




**Sol.** Hint:

1. Outside E.F

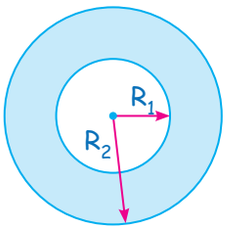
$E = \dfrac{kq_{in}}{r^2}$

$q_{in} = Q' + \int_0^R \rho_0 r^3 . 4\pi r^2 dr$

2. Inside E.F [r < R]

$E.4\pi r^2 = \dfrac{\left[\int_0^r \rho_0 r^3 . 4\pi r^2 dr\right] + Q'}{\epsilon_0}$

**Q.** Suppose we have a hollow sphere of charge Q and having inner radius $R_1$ and outer radius $R_2$. Find E.F at a point inside, middle, outside.




**Sol.**

1. For $r > R_2$ outside

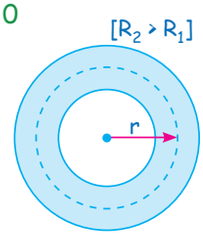
$E.4\pi r^2 = \dfrac{q_{in}}{\epsilon_0} = \dfrac{Q}{\epsilon_0}$

$E = \dfrac{kQ}{r^2}$

2. Inside $r < R_1$

$E.4\pi r^2 = \dfrac{q_{in}}{\epsilon_0} = 0$

$E = 0$



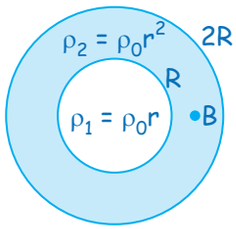

3. For $R_1 < r < R_2$

$E.4\pi r^2 = \dfrac{q_{in}}{\epsilon_0}$

$E.4\pi r^2 = \dfrac{\dfrac{Q}{4/3\pi (R_2^3 - R_1^3)} \times \dfrac{4}{3}\pi(r^3 - R_1^3)}{\epsilon_0}$

$E =$ _____ solve and get

**Q.** Find total charge enclose inside spherical region from r = 0 to r = 2R.




$\rho_1 = \rho_o r \quad 0 < r \leq R$

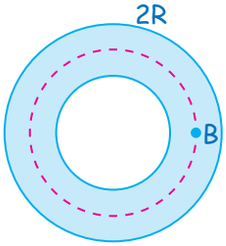
$\rho_2 = \rho_o r^2 \quad R < r \leq 2R$

1. Total charge $dq = \int 4\pi r^2 dr$

$Q_{total} = \int_0^R \rho_0 r . 4\pi r^2 dr + \int_R^{2R} \rho_0 r^2 . 4\pi r^2 dr$

$E_{outside} = E_A = \dfrac{kQ_{total}}{r^2}$

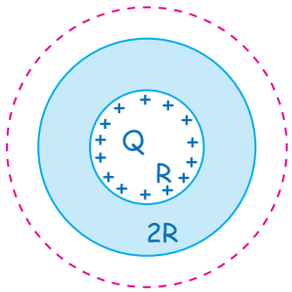
2. Find E.F at r = 1.5 R



$$E4\pi r^2 = \frac{q_{in}}{\epsilon_0} = \int_0^{1.5R} \frac{\rho 4\pi r^2 dr}{\epsilon_0}$$

$$E.4\pi\left(\frac{3R}{2}\right)^2 = \frac{\int_0^R \rho_0 r 4\pi r^2 dr + \int_R^{1.5R} \rho_0 r^2\ 4\pi r^2 dr}{\epsilon_0}$$

**Q.** A system consists of uniformally charge sphere of radius R and a surrounding medium filled by a charge with the vol$^n$ density P = $\alpha/r$, where $\alpha$ is a +ve const. and r is the distance from the center of the sphere. the charge of the sphere for which electric field intensity E outside the sphere is independent of r is:




$$E4\pi r^2 = \frac{q_{in}}{\epsilon_0} = \frac{Q + \int_R^r \rho 4\pi r^2 dr}{\epsilon_0}$$

$$E4\pi r^2 = \frac{Q + \int_R^r \alpha / r\ 4\pi r^2 dr}{\epsilon_0}$$

$$E = \frac{Q + \alpha 2\pi (r^2 - R^2)}{4\pi r^2\ \epsilon_0}$$

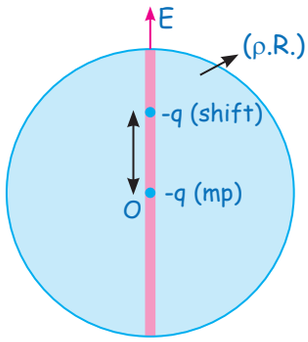
$$E = \frac{(Q - \alpha 2\pi R^2) + 2\pi r^2 \alpha}{4\pi r^2\ \epsilon_0}$$

$$E = \frac{2\pi r^2 \alpha}{4\pi r^2\ E_0} = \frac{\alpha}{2\ \epsilon_0}$$

$\therefore$ If $Q - \alpha\ 2\pi R^2 = 0$

then, E will independent of r.

**Q.** A narrow tunnel is made inside a solid uniform sphere such that -q charge at centre of sphere. Charge is displaced along tunnel by x and release find time period of oscillation.




**Sol.** mp $\rightarrow$ centre

$$F_{net} = qE = q\frac{\rho x}{3\ \epsilon_0} \text{ (नीचे)}$$

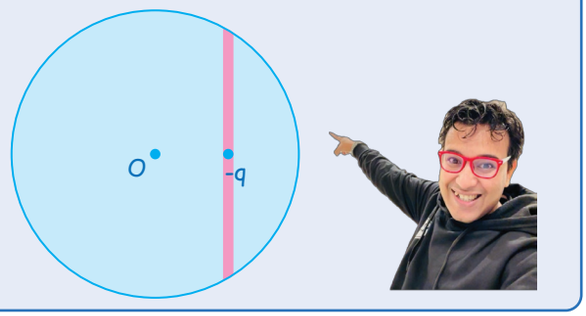
$$\vec{F}_{net} = -q\frac{\rho \vec{x}}{3\ \epsilon_0} = -K\vec{x} \text{ (SHM)}$$

$$k = \frac{q\rho}{3\ \epsilon_0}$$

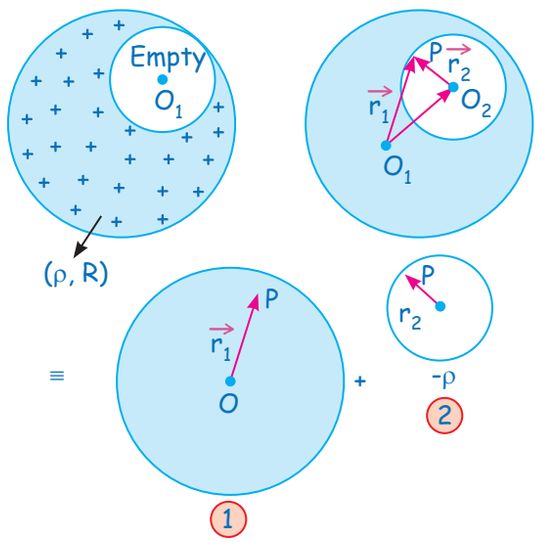
in SHM if $F = -kx$

then time period $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{m}{q\rho/3\ \epsilon_0}}$

अगर ये tunnel यहाँ होती तो भी time period same आता।
It's your homework to prove it.




## E.F inside cavity of solid sphere

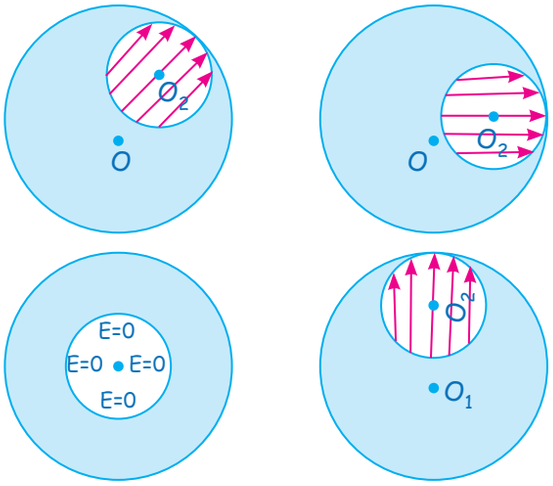


$$(\vec{E}_{at\ P}) = \vec{E}_1 + \vec{E}_2 = \frac{\rho\vec{r}_1}{3\epsilon_0} + \left(\frac{-\rho\vec{r}_2}{3\epsilon_0}\right) = \frac{\rho}{3\epsilon_0}[\vec{r}_1 - \vec{r}_2]$$

$$= \frac{\rho}{3\epsilon_0}\overrightarrow{O_1O_2}$$

$$\boxed{\vec{E}_{\text{inside cavity}} = \frac{\rho\,\overrightarrow{O_1.O_2}}{3\epsilon_0}}$$

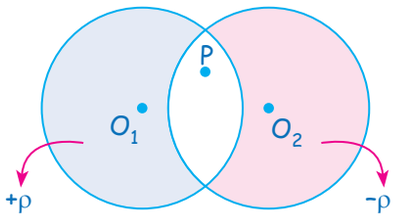
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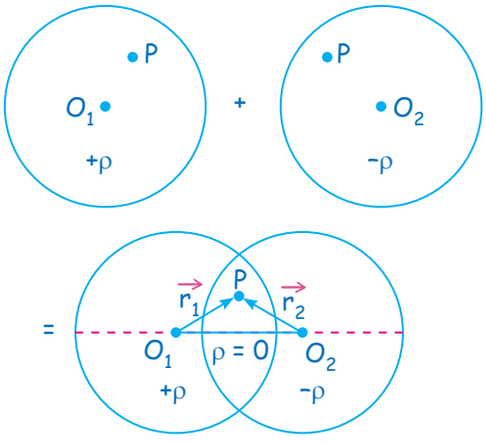

$\overrightarrow{O_1O_2} = 0$

E = 0 (अंदर)

**Q.** Find the E.F at point P = ?




**Sol.** First we have to find E.F at point P due to individual sphere and then add them vectorly.

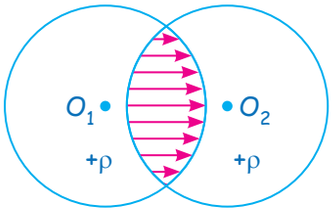



$$\vec{E}_P = \vec{E}_1 + \vec{E}_2$$

$$\vec{E}_P = \rho\frac{\overrightarrow{O_1P}}{3\epsilon_0} + \left(\frac{-\rho\overrightarrow{O_2P}}{3\epsilon_0}\right) = \frac{\rho\vec{r}_1}{3\epsilon_0} - \frac{\rho\vec{r}_2}{3\epsilon_0}$$

$$= \frac{\rho}{3\epsilon_0}[\vec{r}_1 - \vec{r}_2] = \frac{\rho}{3\epsilon_0}\overrightarrow{O_1O_2}$$

#



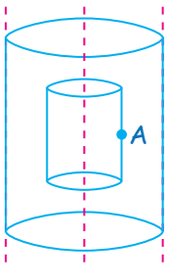

$$\Rightarrow \frac{\rho}{3\epsilon_0}(\overrightarrow{O_1O_2})$$

## E.F due to long hollow cylinder (σ, R)

1. E.F inside r < R

$$E\int dA = \frac{q_{in}}{\epsilon_0} = 0$$

$$E = 0$$

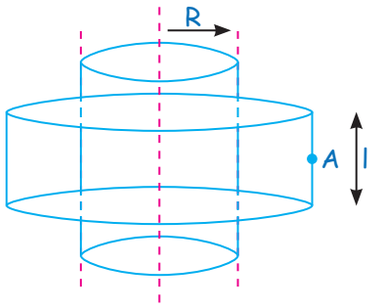


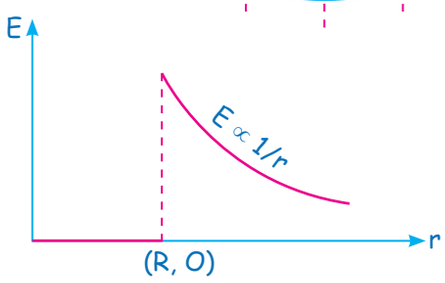

2. E.F Outside r > R

$$E\int dA = \frac{q_{in}}{\epsilon_0}$$

$$E.2\pi rl = \frac{\sigma 2\pi Rl}{\epsilon_0}$$

$$E = \frac{\sigma R}{\epsilon_0 r}$$




## E.F due to solid cylinder (long) [ρ, R]

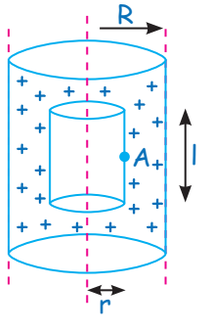
1. E.F inside r < R

$$\int dA = \frac{q_{in}}{\epsilon_0}$$

$$E\,2\pi rl = \rho\frac{vol^n}{\epsilon_0}$$

$$E\,2\pi rl = \rho\frac{\pi r^2 l}{\epsilon_0}$$

$$E = \rho\frac{r}{2\epsilon_0}$$



$$E = \rho\frac{r}{2\epsilon_0}$$

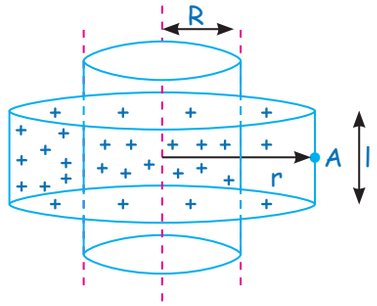
2. E.F outside r > R

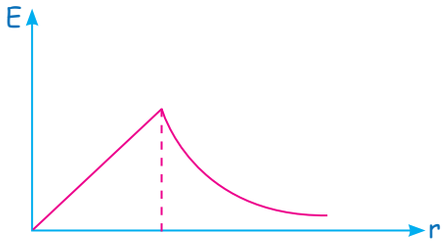
$$E\int dA = \frac{q_{in}}{\epsilon_0}$$

$$E.2\pi rl = \rho\frac{vol^n}{\epsilon_0}$$

$$E\,.\,2\pi rl = \rho\frac{\pi R^2 l}{\epsilon_0}$$

$$E = \rho\frac{R^2}{2\epsilon_0 r}$$



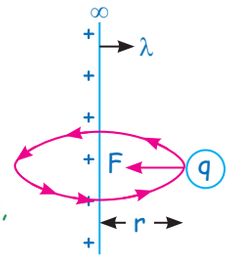

## Circular motion वाले सवाल

**Q.** A charge (-q, m) is moving in a circular path around the infinite long wire ($\lambda$) in a radius r. Find its speed.

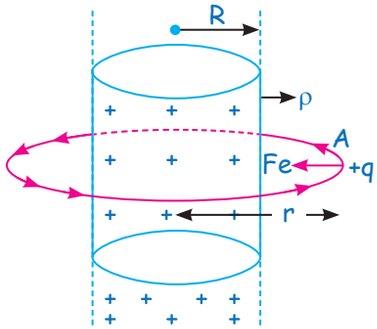
**Sol.** $q\frac{2k\lambda}{r} = \frac{mv^2}{r}$

$$v = \sqrt{\frac{2k\lambda q}{m}}$$

$v \propto r^0$ (v is independent on r),




**Q.** Repeat the above question if infinite wire is replace by solid cylinder ($\rho$, R)



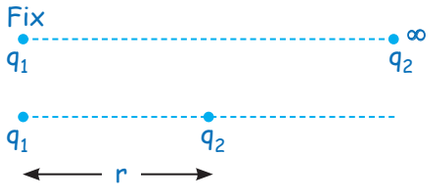

$$E_A = \frac{\rho R^2}{2\epsilon_0 r}$$

$$q\frac{\rho R^2}{2\epsilon_0 r} = \frac{mv^2}{r}$$

$v \propto r^0$

## ELECTROSTATIC POTENTIAL ENERGY

Electrostatic P.E. b/w two charge particle at a separation 'r' is the amount of ext work done required to bring the two charge $q_1$ and $q_2$ from $\infty$ to separation 'r' slowly, slowly (without change in K.E without acc.)



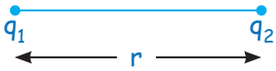

$dU = dw$

$$dU = -\int F_{electrost}.dx$$

$$\int_{u_\infty}^{u} dU = -\int_{\infty}^{r}\frac{kq_1.q_2}{x^2}.dx$$

$$U - U_\infty = \frac{kq_1q_2}{r} \Rightarrow \text{If } U_\infty = 0 \Rightarrow U = \frac{kq_1q_2}{r}$$

# Find P.E of system




$$U = \frac{kq_1q_2}{r}$$

#SKC

- $U = \frac{kq_1q_2}{r}$, $(U_\infty = 0)$ $[q_1q_2 \rightarrow$ with sign.]

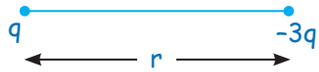



- इसका मतलब है ये set up बनाने में मुझे इतना WD करना पड़ेगा।
- P.E is the energy due to interaction. Hence it is define for system of particles.
- Change in P.E is -ve of work done by internal conservative forces.
- (WD) by internal force are frame independent. Hence, change in P.E also frame independent.



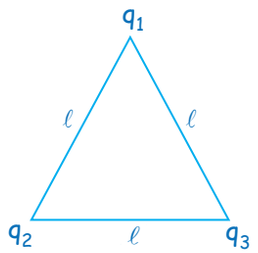
**Q.** Find P.E of system

1.



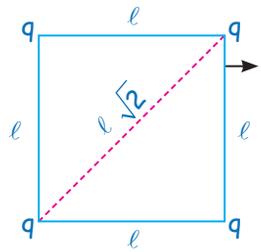

$$\Rightarrow U = \frac{kq(-3q)}{r}$$

2.




$$\Rightarrow U = \frac{kq_1q_2}{\ell} + \frac{kq_2q_3}{\ell} + \frac{kq_1q_3}{\ell}$$

**3**

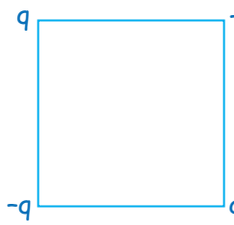



Square

$^nC_2 \Rightarrow$ Total no. of sets.

$$\Rightarrow U = \frac{kq.q}{\ell} \times 4 + \frac{kq.q}{\ell\sqrt{2}} \times 2$$

**4**

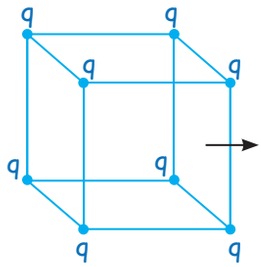



Square (L)

$^4C_2 = 6$ (terms आएंगे)

$$U = -\frac{kqq}{\ell} \times 4 + \frac{kqq}{\ell\sqrt{2}} \times 2$$

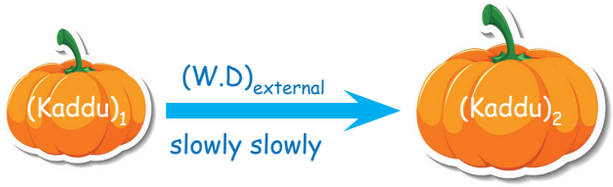
**5**




(Cube, L)

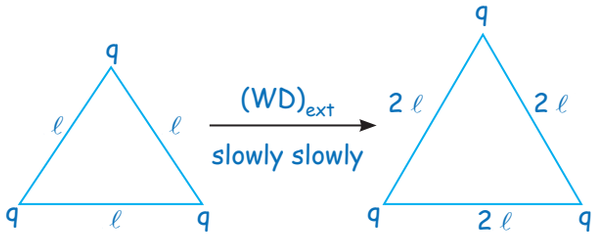
$^8C_2 = 28$ terms

$$U = \frac{kqq}{\ell} \times 12 + \frac{kqq}{\ell\sqrt{2}} \times 12 + \frac{kqq}{\ell\sqrt{3}} \times 4$$




$(kaddu)_1$ से $(kaddu)_2$ slowly slowly बनाने में work done by external agent = $\Delta U = U_f - U_i = -(W.D)_{\text{by electric field}}$

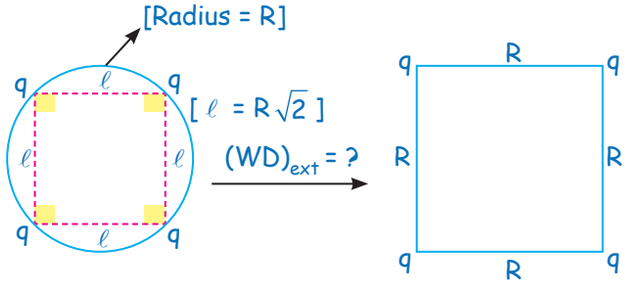
**Q.** Find WD ext.




$$U_i = \frac{kq^2}{\ell} \times 3 \qquad U_i = \frac{kq^2}{2\ell} \times 3$$

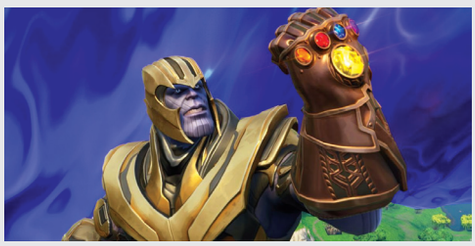
$$(WD)_{ext} = U_f - U_i \Rightarrow \frac{kq^2}{2\ell} \times 3 - \frac{kq^2}{\ell} \times 3$$

#




$$U_i = \frac{kq^2}{R\sqrt{2}} \times 4 + \frac{kq^2}{2R} \times 2 \qquad U_f = \frac{kq^2}{R} \times 4 + \frac{kq^2}{R\sqrt{2}} \times 2$$

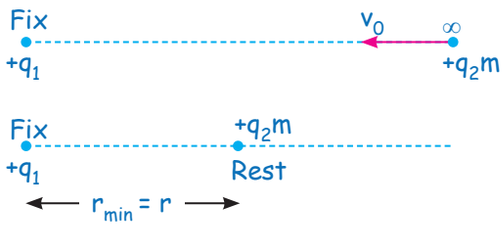
$$(WD)_{ext} = U_f - U_i$$



## THANOS WALE SAWAL (CONSERVATION OF MECH. ENERGY)

**Q.** A charge $q_1$ is fixed and another charge ($q_2$, m) is projected from infinity with velocity $v_o$ directly towards $q_1$. Find min separation b/w them

**Sol.**




$(WD)_{\text{hinged force}} = 0$

M.E → conserve

$(K.E)_i + (P.E)_i = (K.E)_f + (P.E)_f$

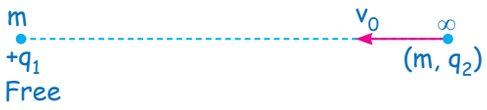
$K_i + U_i = k_f + U_f$

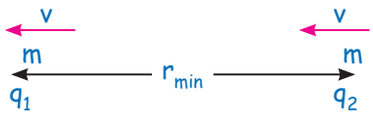
$$\left(0 + \frac{1}{2}mV_0^2\right) + \frac{kq_1q_2}{\infty} = (0 + 0) + \frac{kq_1q_2}{r_{min}}$$

$$r_{min} = \frac{kq_1q_2 \times 2}{mv_0^2}$$

**Q.** If in above question $q_1$ is kept free. Find min separation b/w $q_1$ and $q_2$

**Sol.**




Since, $(F_{net})_{ext} = 0$

$P_i = P_f$

$0 + mv_0 = mv + mv$

$v = \frac{v_0}{2}$ ----------(i)

#SKC
Mininum separation tab hoga, jab dono particle ki velocity same ho jayegi.

$k_i + U_i = k_f + U_f$ (apply thanos MEC)

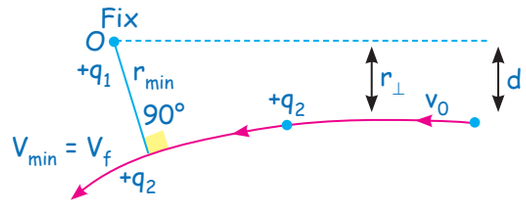
$0 + \frac{1}{2}mv_0^2 + 0 = \left(\frac{1}{2}mv^2 + \frac{1}{2}mv^2\right) + \frac{kq_1q_2}{r_{min}}$

----------(ii)

Solve (i) and (ii).

**Q.** Find min. separation for the given diagram.




1. $k_i + U_i = k_f + U_f$

$0 + \frac{1}{2}mv_0^2 + 0 = \frac{1}{2}mv_f^2 + \frac{kq_1q_2}{r_{min.}}$ ----------(1)

2. abt point 'O' angular momentum will conserve

$L_i = L_f$ (abt 'O') because $\tau = 0$

$mv_0d = mv_f r_{min}$----------(2)

Solve (1) and (2)

## ELECTRIC POTENTIAL

1. Potential at a pt. is defined as $(WD)_{by}$ ext. agent required to move unit +ve charge from ∞ to that point slowly – slowly (or without acc.) [$v_\infty$ = 0 assume]
2. $\boxed{(WD)_{ext.} = \Delta U = -(WD)_{E.F}}$ [without acc.]
3. Pot difference is defined as change in P.E per unit charge

$\Delta v = \frac{\Delta U}{q} \Rightarrow v - v_\infty = \frac{U - U_\infty}{q}$

$\Delta v = \frac{\Delta U}{q} \Rightarrow v = \frac{U}{q} = \boxed{U = qv}$

4. Electric potential ⇒ interaction energy of unit +ve charge.



- अगर मै q charge को ऐसी जगह रख दू, जहां potential v है तो उस वक्त [या setup] की P.E = qv होगी।
- अगर मैं q charge को ∞ से ऐसे point pr lakr रख दू। (होले -होले), जहां potential v है तो मुझे qv work done krna padega.
- $\vec{F} = q\vec{E}$:- q को ऐसी जगह रख दू जहां $\vec{E}$ है तो उस पर उस वक्त $q\vec{E}$ electrostatic force lagega.
- अगर मै किसी charge को [होले-होले] A point se B पर लेकर जाऊं तो

$(WD)_{ext.} = \Delta U$

$(WD)_{electric\ feild} = -\Delta U$

$(WD)_{ext.} = \Delta U = -(WD)_{E.F}$

**# काम का डब्बा**

- $\vec{F} = q\vec{E}$
- $U = qv$
- $\Delta U = q\Delta v$
- $k_i + U_i = k_f + U_f$ (Thanos) ME → conserve
- $+Q$ ---- r ---- A $E.F = \frac{kQ}{r^2}$, Potential at 'A' $\frac{kQ}{r}$
- +1C charge ko ∞ se 'A' pr laane me Ext. WD = Potential at A [होले -होले]

# Electric potential due to point charge Q at a pint

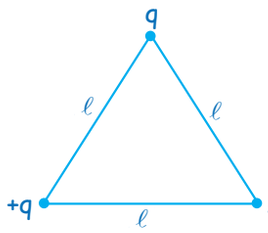



$\Rightarrow v_A = \frac{kQ}{r}$ (scalar) → with sign

# Find electric potential at Pt. 'A'.

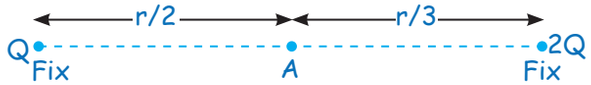
1. $-Q$ ---- r ---- A $V_A = \frac{k(-Q)}{r}$

**2**



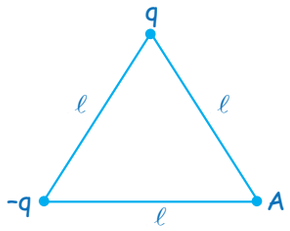

$$V_A = \frac{kq}{\ell} + \frac{kq}{\ell}$$

**3**



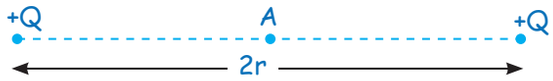

$$\Rightarrow V_A = \frac{kQ}{r/2} + \frac{k2Q}{r/3}$$

**4**




$$\Rightarrow V_A = \frac{kq}{\ell} + \frac{k(-q)}{\ell} = 0$$, but E.F at A is $E_A \neq 0$.

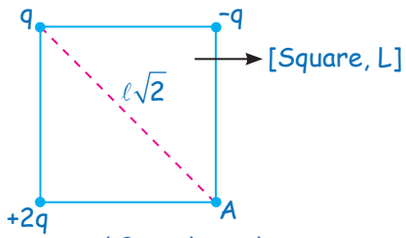
**5**




$$\Rightarrow V_A = \frac{kQ}{r} \times 2$$

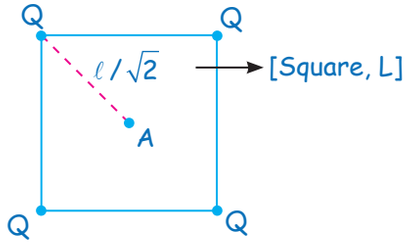
$E_A = 0$.

**6**



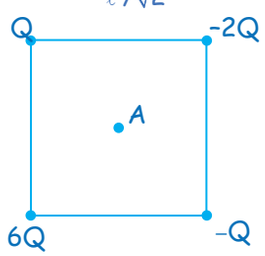

$$\Rightarrow V_A = \frac{k2q}{\ell} + \frac{kq}{\ell\sqrt{2}} - \frac{kq}{\ell}$$

**7**




$$\Rightarrow V_A = \frac{kQ}{\ell/\sqrt{2}} \times 4$$

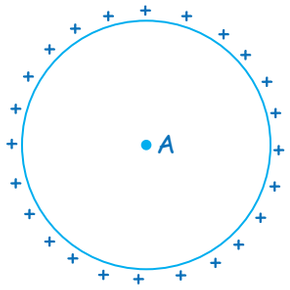
**8**




$$\Rightarrow V_A = \frac{kQ}{\ell/\sqrt{2}} + \frac{k6Q}{\ell/\sqrt{2}} - \frac{k2Q}{\ell/\sqrt{2}} - \frac{kQ}{\ell/\sqrt{2}}$$

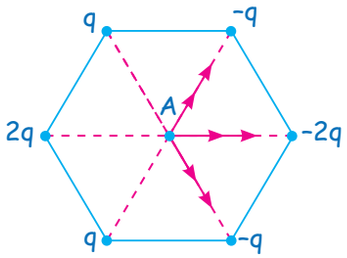
$$V_A = \frac{4kQ}{\ell/\sqrt{2}}$$

**9** ring (Q, R)




$$\Rightarrow V_A = \frac{kQ}{R}$$ [Uniform or non-uniform]

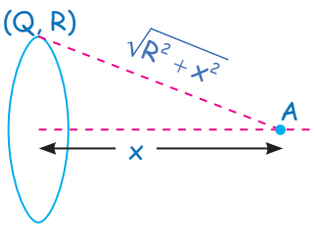
**10**




$\Rightarrow V_A = 0$

$\Rightarrow E \rightarrow +x$ Ans.

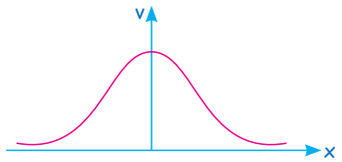
## Potential at a point x from center of charged ring




$$V_A = \frac{kQ}{\sqrt{R^2 + x^2}}$$

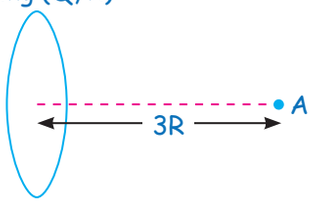
$$V_{center} = \frac{kQ}{R}$$

$$E_A = \frac{kQx}{(R^2 + x^2)^{3/2}}$$



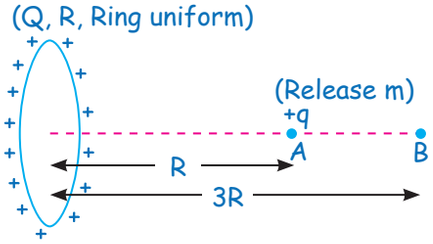

**Q.** Find potential at A due to charge ring (Q, R).

Ring (Q, R)




$$V_A = \frac{kQ}{\sqrt{(R)^2 + (3R)^2}} = \frac{kQ}{R\sqrt{10}}$$

**Q.** If a charge (q, m) is released from point A find its speed when it reaches at B in give diagram.




**Sol.** $k_A + U_A = k_B + U_B$ (Thanos)



$$0 + 0 + qV_A = 0 + \frac{1}{2}mv^2 + qV_B$$

$$q\cdot\frac{kQ}{\sqrt{2R^2}} = \frac{1}{2}mv^2 + q\frac{kQ}{\sqrt{10R^2}}$$ (Solve and get v)

**Q.** Repeat the above problem when charge reaches at infinity.

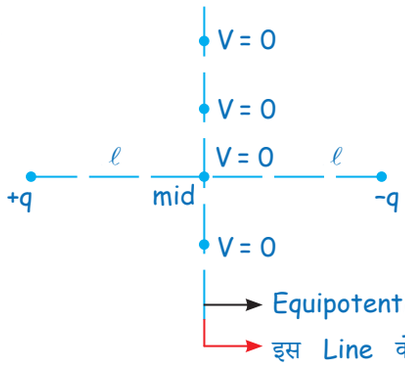
**Sol.** $k_A + U_A = k_B + U_B$



$$0 + 0 + qv_A = 0 + \frac{1}{2}mv_f^2 + 0$$

$$\frac{qkQ}{\sqrt{2R^2}} = \frac{1}{2}mv_f^2$$

#



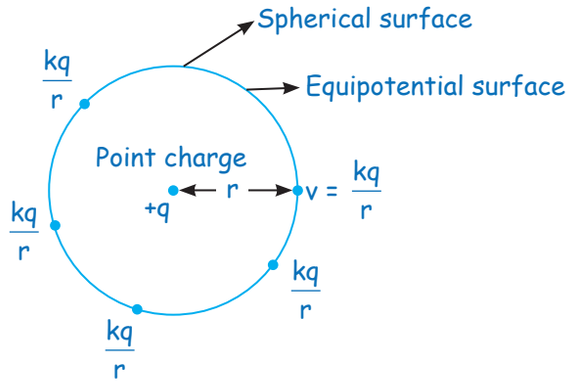

Equipotential line

इस Line के हर point pr potential same to (zero) [Dipole Equipotential line]

#SKC

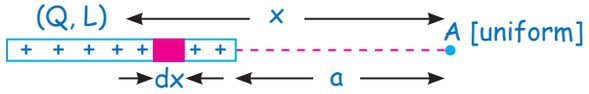
Equipotential line ka मतलब उस line Ke hr point ka potential 0 hai, aur equipotential surface ka मतलब उस surface k hr point ka potential same hoga.

#




**Q.** Find potential at A due to uniform charge rod as shown in figure.

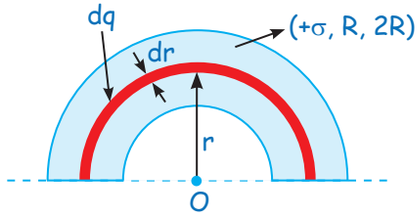
**Sol.**




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

$$\int dv = \int_a^{a+L}\frac{kdq}{x} = \int_a^{a+L}k\frac{Q}{L}\frac{dx}{x} = \frac{kQ}{L}\ln\left(\frac{a+\ell}{a}\right)$$

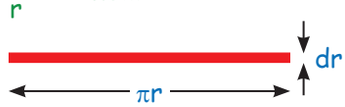
**SSSQ.** Find the potential at 'O' due to given part of disc.



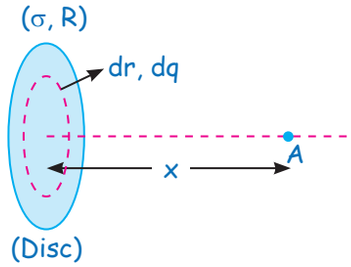

$$\int dv = \int\frac{kdq}{r} = \int_R^{2R}\frac{k\sigma\,\pi r dr}{r} = k\sigma\pi r$$

$$dq = \sigma dA$$

$$dq = \sigma\pi r dr$$




## POTENTIAL DUE TO DISC AT A POINT X FROM CENTER OF DISC



$$dv = \frac{kdq}{\sqrt{r^2+x^2}} \qquad dq = \sigma dA$$

$$v_A = \int dv = \int_0^R \frac{k\sigma 2\pi r dr}{\sqrt{r^2+x^2}}$$

⋮

Solve and get and याद करलो

$$V_A = \frac{\sigma}{2\varepsilon_0}(1-\cos\theta)\times(\sqrt{R^2+x^2})$$

$$\text{or } V_A = \frac{\sigma}{2\varepsilon_0}\left(\sqrt{R^2+x^2}-x\right)$$

$$V_{\text{near center}} = \frac{\sigma}{2\varepsilon_0}R \text{ (just bahar)}$$

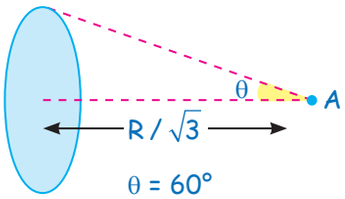
$$E_A = \frac{\sigma}{2\varepsilon_0}(1-\cos\theta)$$

$$E_{\text{near center}} = \frac{\sigma}{2\varepsilon_0} \text{ (just bahar)}$$



रूक रूक जा कहाँ रहा है पहले यह सारे formula याद कर फिर आगे बढ़।

# (σ, R, Disc)

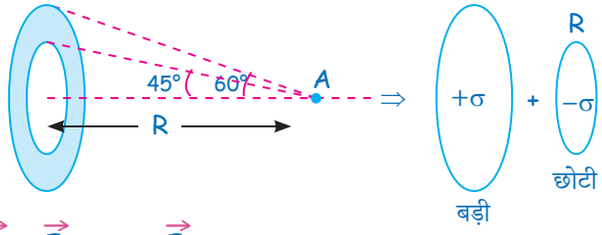



$\theta = 60°$

$$E_A = \frac{\sigma}{2\varepsilon_0}(1-\cos 60°)$$

$$v_A = \frac{\sigma}{2\varepsilon_0}(1-\cos 60°)\left(\sqrt{R^2+\left(\frac{R}{\sqrt{3}}\right)^2}\right)$$

# (σ, Disc outer radius $R\sqrt{3}$)



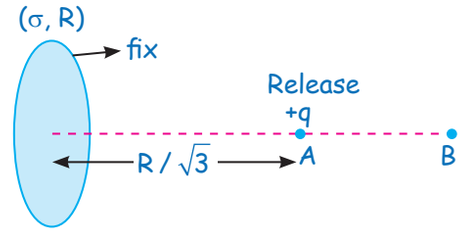

$$\vec{E}_A = \vec{E}_{\text{बड़ी Disc}} + \vec{E}_{\text{छोटी Disc}(-\sigma)}$$

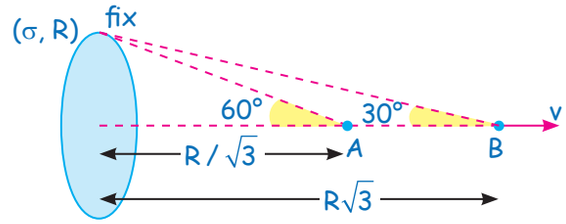
$$\rightarrow E_A = \frac{\sigma}{2\varepsilon_0}(1-\cos 60°) + \frac{-\sigma}{2E_0}(1-\cos 45°)$$

$$\rightarrow v_A = \left[\frac{\sigma}{2\varepsilon_0}(1-\cos 60°)\sqrt{(R\sqrt{3})^2+R^2}\right]$$

$$- \left[\frac{\sigma}{2\varepsilon_0}(1-\cos 45°)\sqrt{2R^2}\right]$$

**Q.** Find the speed of charge (q, m) when it reaches at B.



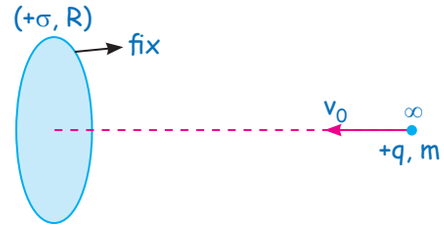

$$k_A + U_A = k_B + U_B$$

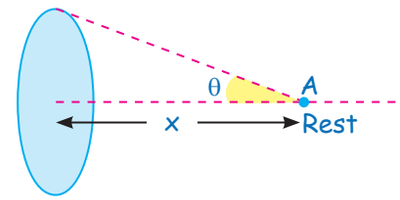
$$k_A + qv_A = k_B + qv_B$$

$$0 + q\frac{\sigma}{2\varepsilon_0}(1-\cos 60°)\sqrt{R^2+\left(\frac{R}{\sqrt{3}}\right)^2}$$

$$= \frac{1}{2}mv_B^2 + q\frac{\sigma}{2\varepsilon_0}(1-\cos 30°)\sqrt{R^2+(R\sqrt{3})^2}$$

**Q.** Find min. sepr$^n$ b/w Disc and charge particle



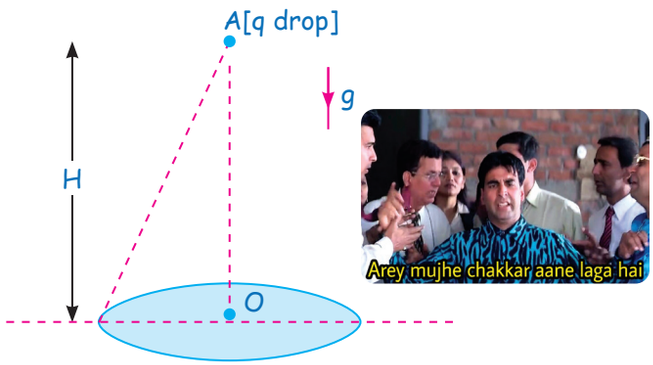

$$k_i + U_i = k_f + U_f$$

$$\frac{1}{2}mv_0^2 + 0 = 0 + qv_A$$

$$\frac{1}{2}mv_0^2 = q\frac{\sigma}{2\varepsilon_0}(1-\cos\theta)\times(\sqrt{R^2+x^2})$$

**Q.** A non-conducting disc of radius a and uniform positive surface charge density σ is placed on the ground, with its axis vertical. A particle of mass m and positive charge q is dropped, along the axis of the disc, from a height H with zero initial velocity. The particle has $q/m = 4\varepsilon_0 g/\sigma$

Find the value of H if the particle just reaches the disc.




$k_A + U_A = k_{center} + U_{center}$

$0 + mg\,H + qV_A = 0 + 0 + qV_O$

$$0 + mgH + q\frac{\sigma}{2\varepsilon_o}\left(\sqrt{R^2+H^2} - H\right) = 0 + 0 + q\frac{\sigma}{2\varepsilon_o} \times R$$

Solve and get $H = \frac{4R}{3}$ (Thanos जिंदाबाद)

## RELATION BETWEEN ELECTRIC POTENTIAL AND ELECTRIC FIELD

$$\Delta U = -(WD)_{EF} = -\int q\vec{E}.d\vec{r}$$

$$q\Delta V = -\int q\vec{E}.d\vec{r}$$

$$\Delta V = -\int_{r_i}^{r_f} \vec{E}.d\vec{r}$$

$$dV = -\vec{E}.d\vec{r}$$

## Potential Due to Point Charge

$dv = -\vec{E}\cdot d\vec{r}$

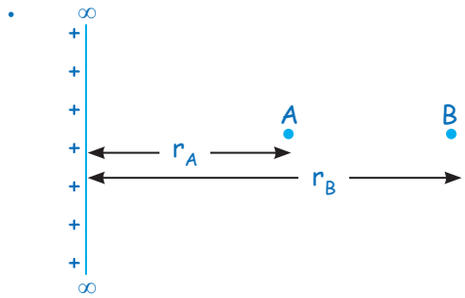
$$\int_0^v dv = -\int_\infty^r \frac{kq}{r^2}dr$$




$$v - 0 = -kq\left[\frac{1}{-r}\right]_\infty^r$$

$$v = \frac{kq}{r}$$

## Potential Difference Between Two Point Due to Infinite Line Charge Wire




$dv = -\vec{E}\cdot d\vec{r}$

$$\int_{v_A}^{v_B} dv = -\int_{r_A}^{r_B} \frac{2k\lambda}{r}dr$$

$$v_B - v_A = 2k\lambda\ \ell n\, r\Big|_{r_A}^{r_B}$$

$$v_B - v_A = 2k\lambda\ \ell n\,\frac{r_B}{r_A}$$

$$v_A - v_B = 2k\lambda\ \ell n\,\frac{r_B}{r_A}$$

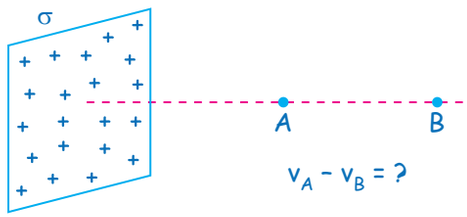
#SKC

$V_{\text{बड़ा}} - V_{\text{छोटा}}$

$= 2k\lambda\ \ell n\left(\frac{r_{\text{बड़ा}}}{r_{\text{छोटा}}}\right)$

वैसे $r_A$ and $r_B$ shortest perpendicular distance है।

## Potential Difference Between Two Point Due to ∝ Sheet




$v_A - v_B = ?$

$dv = -\vec{E}\cdot d\vec{r}$

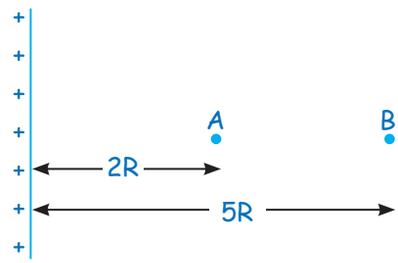
$$\int_A^B dv = -\int_{r_A}^{r_B} \frac{\sigma}{2\varepsilon_0}dr$$

$$v_B - v_A = \frac{-\sigma}{2\varepsilon_0}\int_{r_A}^{r_B} dr$$

$$v_A - v_B = \frac{\sigma}{2\varepsilon_0}(r_B - r_A)$$

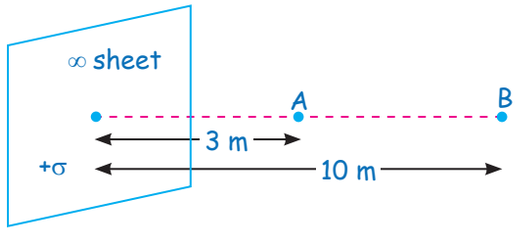
वैसे $r_A$ and $r_B$ shortest perpendicular distance है।

**Q.** Find potential difference between A and B.



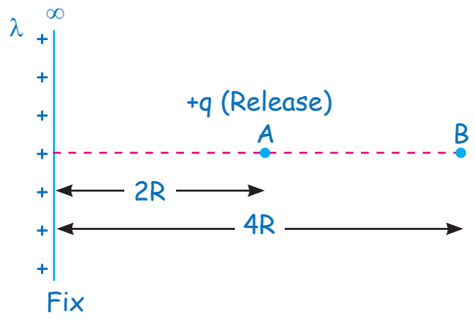

$$v_A - v_B = 2k\lambda\ \ell n\left(\frac{5R}{2R}\right)$$

**Q.**




$$v_A - v_B = \frac{\sigma}{2\varepsilon_0} \times (10 - 3)$$

**Q.** Find speed of +q, m when reaches at 'B'.




$$v_A - v_B = 2k\lambda\ \ell n\left(\frac{4R}{2R}\right)$$

$$k_A + U_A = k_B + U_B$$

$$0 + qv_A = \frac{1}{2}mv_B^2 + qv_B$$

$$q(v_A - v_B) = \frac{1}{2}mv_B^2$$

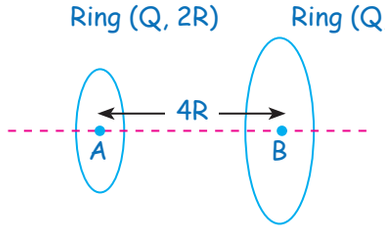
$$q2k\lambda\ \ell n2 = \frac{1}{2}mv_B^2$$





आवाज आ रही है ना सभी को.....
ring disk infinite sheet, infinite wire etc. में thanos वाले सवाल बनाए जा सकते है बस अच्छे से mech energy conservation सीख लेना।

**Q.** Find $V_A - V_B$ if distance btw center of ring is 4R.




$$v_A = \frac{kQ}{2R} + \frac{kQ}{\sqrt{(3R)^2 + (4R)^2}}$$

$$v_B = \frac{kQ}{3R} + \frac{kQ}{\sqrt{(2R)^2 + (4R)^2}}$$

Now find $V_A - V_B$

$$\# \ \Delta V = \frac{\Delta U}{q} = -\frac{(WD)_{E.F}}{q} = -\int \frac{\vec{F}\cdot d\vec{r}}{q}$$

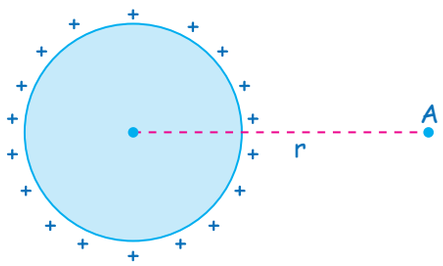
$$= -\int \frac{q\vec{E}\cdot d\vec{r}}{q} = -\int \vec{E}\cdot d\vec{r}$$

$$\# \ \Delta V = -\int \vec{E}\cdot d\vec{r}$$

# If $E = 0 \Rightarrow \Delta V = 0 \Rightarrow V \to$ const.

## ELECTRIC POTENTIAL DUE TO HOLLOW SPHERE/SHELL/SPHERICAL CONDUCTOR

1. r > R [outside]




$$\int dv = -\int \vec{E}\cdot d\vec{r}$$

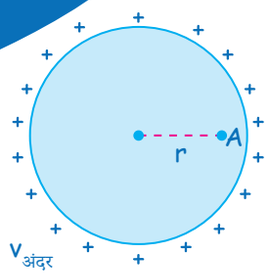
$$\int_0^v dv = -\int_\infty^r \frac{kQ}{r^2}dr$$

$$v - 0 = \frac{kQ}{r}\Big|_\infty^r$$

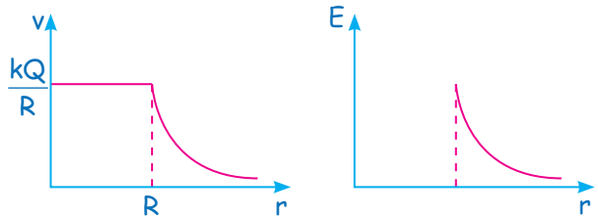
$$\Rightarrow \boxed{v = \frac{kQ}{r} \Rightarrow V_{outside}} \qquad \Rightarrow \boxed{v_{surface} = \frac{kQ}{R}}$$

- $v = \frac{kQ}{R}$ [अंदर] → Radius
- $v = \frac{kQ}{r}$ [बाहर] → Distance

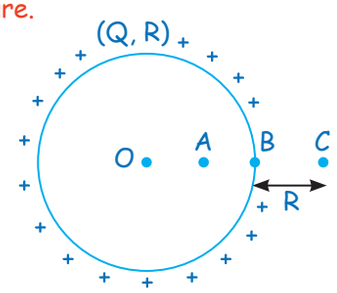
2. r < R [inside]
E = 0
v = const.




$$v = \frac{kQ}{R} = v_{surface} = v_{centre} = v_{अंदर}$$



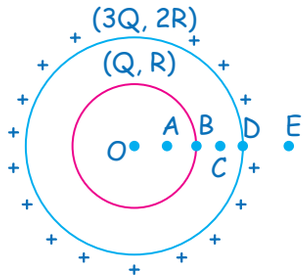

**Q.** Find potential at O, A, B, C due to shell as shown in figure.




$$v_O = \frac{kQ}{R},\ v_A = \frac{kQ}{R},\ v_B = \frac{kQ}{R},\ v_C = \frac{kQ}{2R}$$

**Q.** Suppose we have to concentric shell (Q, R) and (3Q, 2R) as shown in figure. Find potential at O, A, B, C, D, E points.
OA = R/2, OB = R, OC = 1.5 R, OD = 2R, OE = 3R

**Sol.**



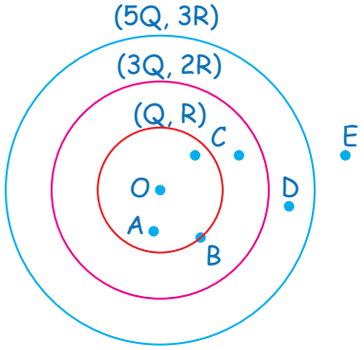

$$v_O = \frac{kQ}{R} + \frac{k3Q}{2R} = v_A = v_B$$

$$v_C = \frac{kQ}{1.5R} + \frac{k3Q}{2R}$$

$$v_D = \frac{kQ}{2R} + \frac{3kQ}{2R}$$

$$v_E = \frac{kQ}{3R} + \frac{k3Q}{3R}$$

**Q.** Find potential at given point.




$$v_O = \frac{kQ}{R} + \frac{k3Q}{2R} + \frac{k5Q}{3R} = v_A = v_B$$

$$v_C = \frac{kQ}{OC} + \frac{k3Q}{2R} + \frac{k5Q}{3R}$$

$$v_D = \frac{kQ}{OD} + \frac{k3Q}{OD} + \frac{k5Q}{3R}$$

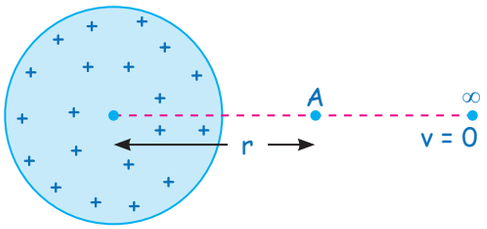
$$v_E = \frac{kQ}{OE} + \frac{k3Q}{OE} + \frac{k5Q}{OE}$$

यहाँ पर distances बहुत ध्यान से लेने है अकसर बच्चो से गलती हो जाती है।



## Electric Potential Due to Solid Sphere

1. Outside [R > r]

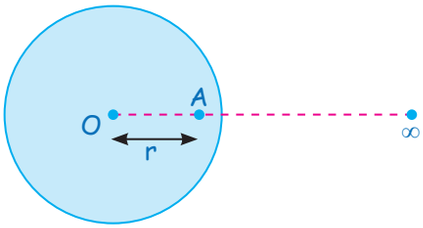



$$\int_0^v dv = -\int_\infty^r \vec{E}\cdot d\vec{r}$$

$$v - 0 = -\int_0^r \frac{kq}{r^2}dr$$

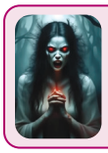
$$v = \frac{kQ}{r}$$

2. Inside [r < R]




$$\int_0^{v_A} dv = -\int_\infty^A \vec{E}\cdot d\vec{r}$$

$$v_A - 0 = -\left[\int_\infty^R \frac{kQ}{r^2}dr + \int_R^r \frac{kQR}{R^3}dr\right]$$

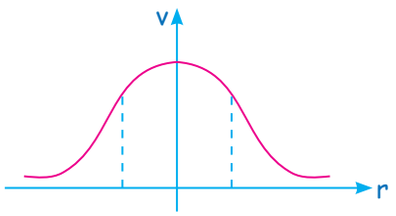


$$v_A = v_{inside} = \frac{kQ}{2R^3}(3R^2 - r^2)$$

चुड़ैल वाला formula

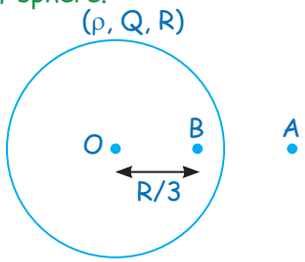
3. $v_{surface} = \frac{kQ}{R}$

4. $v_{centre} = \frac{3kQ}{2R}$



**Q.** We have a solid charge sphere uniform density $\rho$ total charge Q and radius R.

1. Find E.F and potential at a distance 3R from centre of sphere.




$$E_A = E = \frac{kQ}{(3R)^2}, V = \frac{kQ}{3R}$$

2. Find E.F and potential at centre of sphere

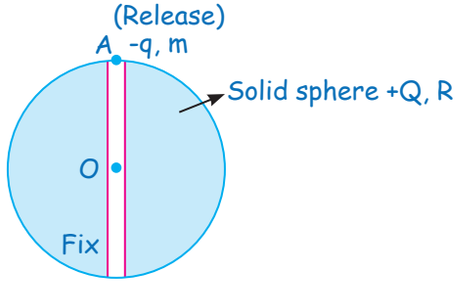
$$E_0 = 0, v_0 = \frac{3}{2}\frac{kQ}{R}$$

3. Find E.F and potential at a distance R/3 from centre of sphere.

$$E_B = \frac{\rho r}{3\epsilon_0} = \frac{\rho_0 R/3}{3\epsilon_0} \text{ or } E_B = \frac{kQr}{R^3} = \frac{kQR/3}{R^3}$$

$$V_B = \frac{kQ(3R^2 - (R/3)^2}{2R^3}$$

**Q.** Find speed of particle when reaches at centre and $v_{max}$? [Vel at centre]




**Sol.** $k_A + U_A = k_0 + U_0$

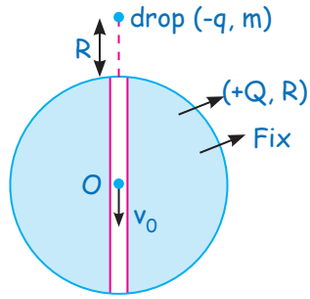
$$0 + (-qv_A) = \frac{1}{2}mv_0^2 + (-q\, v_{centre})$$

$$-q\frac{kQ}{R} = \frac{1}{2}mv_0^2 - q\frac{3}{2}\frac{kQ}{R}$$

$$v_0 = \sqrt{\frac{kQq}{Rm}} \Rightarrow v_{max}.$$

#SKC
ये particle SHM krega, jiska time period hm nikal chuke hai, aur amplitude R hoga and $v_{max} = A\omega$

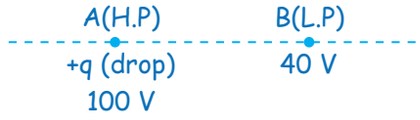
**Q.** Find speed of charge -q where reaches at centre




$$k_i + U_i = k_f + U_f$$

$$0 + \left(-q\frac{kQ}{2R}\right) = \frac{1}{2}mv_0^2 + \left(-q\frac{3}{2}\frac{kQ}{R}\right)$$

**Q.** Find vel. of particle when reaches at B.




$$k_i + U_i = k_f + U_f$$

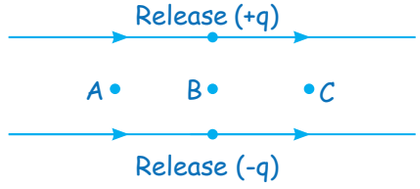
$$0 + qv_A = \frac{1}{2}mv_B^2 + q \times 40$$

$$q \times 100 = \frac{1}{2}mv_B^2 + q \times 40$$

$$v_B = \sqrt{\frac{120}{m}q}$$

## Important Point (H.P मतलब High Potential, L.P मतलब Low Potential)

1. If a +ve charge is released from rest in a E.F it move from H.P to L.P
2. If a -ve charge is released from rest in a E.F it moves from L.P to H.P.




$\Rightarrow v_A > v_B > v_C$ (potential)

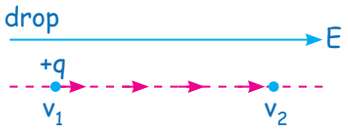
3. If a +ve charge is released from rest in E.F it move high potential energy state to low potential energy state
4. If a -ve charge is released from rest in E.F it move low potential energy state to high potential energy state

- Dirx$^n$ of E.F is from H.P to L.P

Agar main a charge ko rest se potential difference $\Delta v$ se accelerate karu to uski $k_f = q\Delta v$ hogi.



यह बहुत important है magnetism, modern physics मे बार बार use होगा अच्छे से याद करलो




$k_i + U_i = k_f + U_f$

$0 + qV_1 = k_f + qV_2$

$q(v_1 - v_2) = k_f$

$q\Delta v = k_f$

## EQUIPOTENTIAL SURFACE

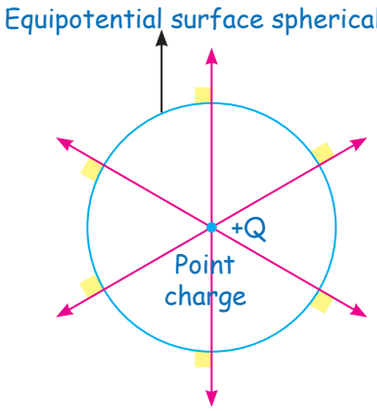
1. Locus of all point havig same potential. Surface of all point of which potential is ame.

   $dv = -\vec{E} \cdot d\vec{r} = -Edr\cos\theta$

   $v \rightarrow$ same

   $dv = 0 \Rightarrow E = 0$ or $\theta = 90°$

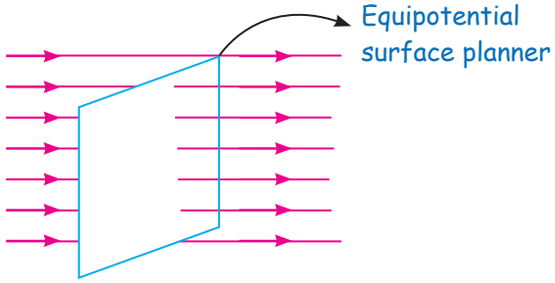
   i.e., E.F is $\perp^{ar}$ to equipotential surface.

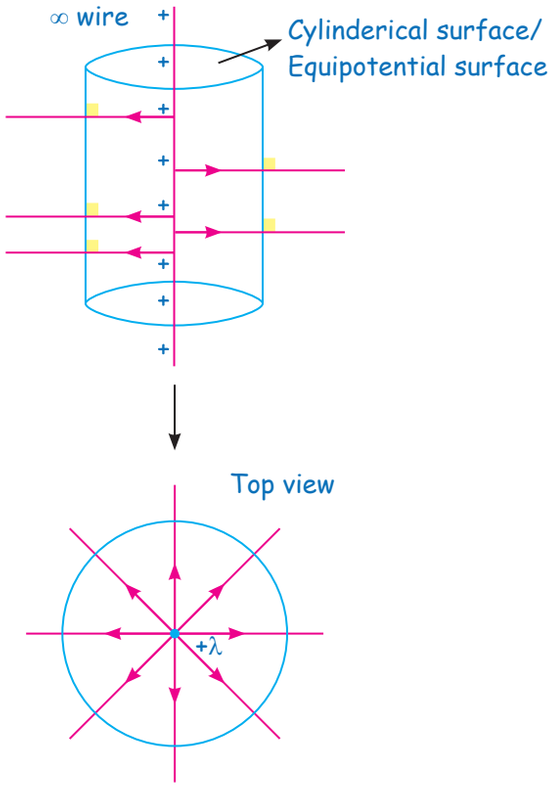



2. If a charge is moved from one point to the over an equipotential surface

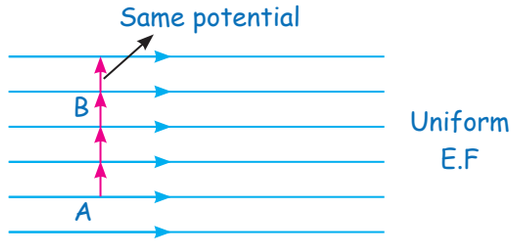
   then, $W_{AB} = -U_{AB} = q(v_B - v_A) = 0$ [$\because v_B = v_A$]

3. Equipotential surfaces can never cross each other.




4. E.F.L ki trf chaloge to H.P to low potential jaoge
5. E.FL ke $\perp^{ar}$ jaoge to no charge in potential

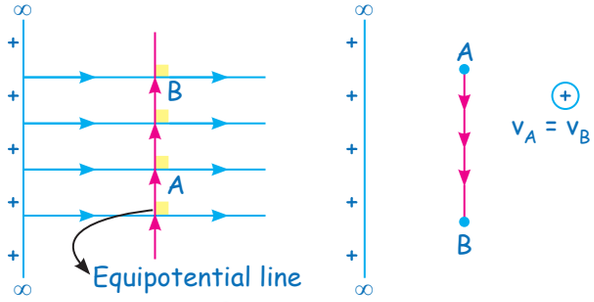


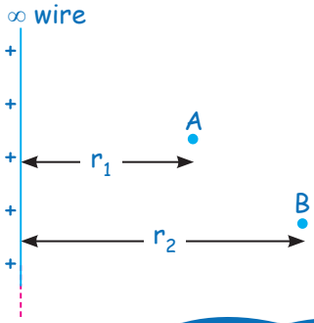

$dv = \vec{E} \cdot d\vec{r}$

$dv = -Edr\cos\theta$

$\theta = 90° \Rightarrow dv = 0$

$v \rightarrow$ const.



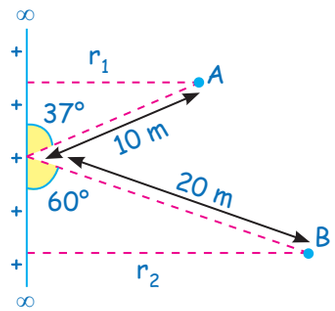



$$v_A - v_B = 2k\lambda \ell n \frac{r_B}{r_A}$$

$[r_B, r_A \rightarrow \perp^{ar}$ dist.]

#SKC
∞ sheet, ∞ wire ke ||rl chloge to potential main koi bhi change nhi aayega

**Q.** Find potential different A and B.

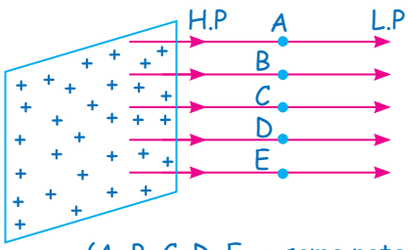



$$v_A - v_B = 2k\lambda \ell n \left(\frac{r_2}{r_1}\right)$$

$r_1 = 10 \sin 37°$

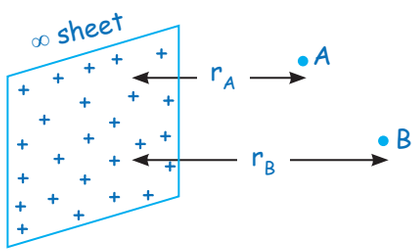
$r_2 = 20 \sin 60°$

\#



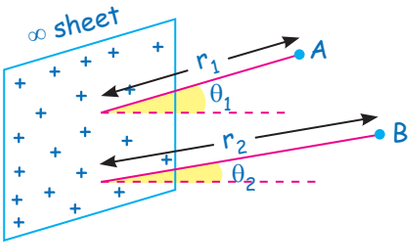

(A, B, C, D, E → same potential)

☆




$$v_A - v_B = \frac{\sigma}{2E_0}(r_B - r_A)$$

perpendicular distance




$$v_A - v_B = \frac{\sigma}{2E_0}[(r_2 \cos\theta_2) - (r_1 \cos\theta_1)]$$

Electric field और electric potential के relation पर based question maximum mathematicaly होते है so अब mathematics का दिमाग ON करदो गलती से भी defination वाला minus मत भूलना। Let's practice it.



**Q.** If $\vec{E} = 2x\hat{i} + 3y^2\hat{j} + 4z^3\hat{k}$ if pot at (0, 0, 0) is 10 volt. Find pot at (1, 2, 3)

$$\int_{10}^{v} dv = -\left[\int_0^1 2x\,dx + \int_0^2 3y^2\,dy + \int_0^3 4z^3\,dx\right]$$

$v - 10 = -[1 + 2^3 + 3^4]$

$v = 10 - 90 = -80$

**Q.** $\vec{E} = 2x\hat{i} + 10y\hat{j} + 4z\hat{k}$ if pot at (1, 2, 3) is 20 v. Find pot at (2, 3, 4)

$$\int_{20}^{v} dv = -\left[\int_1^2 2x\,dx + \int_2^3 10y\,dy + \int_3^4 4z\,dz\right]$$

v = - 7 solve and get

**Q.** If $\vec{E} = 3\hat{i} + 4\hat{j} + 5\hat{k}$. If pot diff. at (0, 0, 0) is 10 v. Find potential at (2, 2, 2)

$$\int_{10}^{v} dv = -\left[\int_0^2 3dx + \int_0^2 4dy + \int_0^2 5dz\right]$$

v = - 14 solve and get

or

$E \rightarrow$ uniform

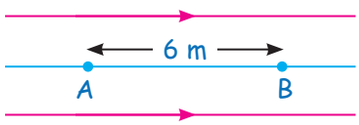
$\int dv = -\vec{E} \cdot d\vec{r}$ $\qquad \Delta\vec{r} = 2\hat{i} + 2\hat{j} + 2\hat{k}$

$\Delta v = \vec{E} \cdot \vec{r}$

$v_f - 10 = -[6 + 8 + 10]$

$v_f = -14$

☆




E = 100 volt / m



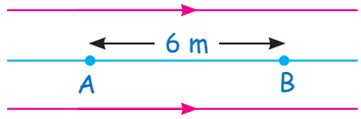
#SKC
अगर uniform E.F है और E.F की दिशा मे हम d चले तो pot. में Ed का drop aa jayega ⇒ pot. Ed कम हो जायेगा

H.P → A

$\Delta V = -100\hat{i} \cdot 6\hat{i}$

$V_B - V_A = -600$

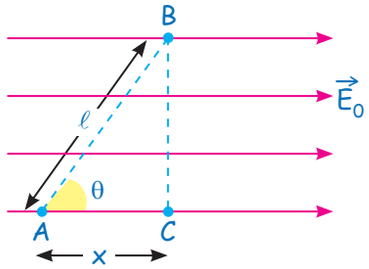
$V_A - V_B = 600$




A → B चलोगे तो pot. कम 100 × 6 = 600

$V_A - V_B = 600$

**Q.** Find $V_A - V_B$




**Sol.** $E = E_0\hat{i}$

$\vec{d} = \ell\cos\theta\hat{i} + \ell\sin\theta\hat{j}$

$\Delta v = -\vec{E}\cdot\vec{d} = -E_0\ \ell\cos\theta + 0$

$v_B - v_A = -E_0x.$

Pot. at B = pot at C

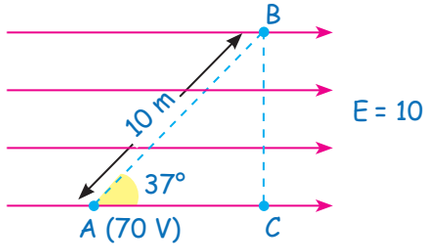
$v_A - v_C = Ex$

$v_A - v_B = Ex$

$v_C - v_A = -E_0x$

$\therefore\ v_B - v_A = -E_0x$

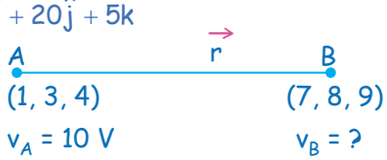
#




⇒ $V_B = V_C$

$V_B = 70 - 10 \times 8 = -10$

# $\vec{E} = 10\hat{i} + 20\hat{j} + 5\hat{k}$




$\Delta v = -\vec{E}\cdot\vec{d}$ $\qquad \vec{d} = 6\hat{i} + 5\hat{j} + 5\hat{k}$

$v_B - 10 = -[60 + 100 + 25]$

$v_B = -185$

**Q.** If $v = 4x^2$ find E.F at (2, 3, 4)

$E_x = -\frac{\partial v}{\partial x} = -8x$

at $x = 2$, $\vec{E} = -8 \times 2 = -16\hat{i}$

**Q.** If $v = 4x^2y^3z$ (let) find E.F at and E.F at (1, 1, 1)

$\vec{E}_x = -\frac{\partial v}{\partial x}\hat{i} = -[4 \times 2xy^3z]\hat{i}$

$\vec{E}_x = 8xy^3z\hat{i}$

$\vec{E}_y = -\frac{\partial v}{\partial y}\hat{j} = -[4x^2z\ 3y^2] = -[12x^2y^2z]\hat{j}$

$\vec{E}_k = -4x^2y^3\hat{k}$

$\vec{E} = -8xy^2z\hat{i} - 12x^2y^2z\hat{j} - 4x^2y^3\hat{k}$

at (1, 1, 1) $= -8\hat{i} - 12\hat{j} - 4\hat{k}$

#SKC#

$dV = -\vec{E}\cdot d\vec{r}$

* $\vec{E}_x = -\frac{\partial v}{\partial x}\hat{i}$ ⇒ partial diff. of v wrt. x

* $\vec{E}_y = -\frac{\partial v}{\partial y}\hat{j}$ ⇒ diff of v wrt x by assuming y, z, constant

* $\vec{E}_z = -\frac{\partial v}{\partial z}\hat{k}$ ⇒ const.

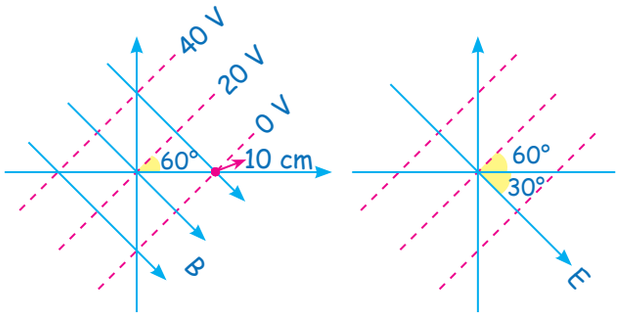
**Q.** If $v = x^2yz$ find E.F at (1, 2, 3)

$\vec{E} = -\left[\frac{\partial v}{\partial x}\hat{i} + \frac{\partial v}{\partial y}\hat{j} + \frac{\partial v}{\partial z}\hat{k}\right] = -\left[2xyz\hat{i} + x^2z\hat{j} + x^2y\hat{k}\right]$

at (1, 2, 3) put x = 1, y = 2, z = 3

$\vec{E} = -\left[12\hat{i} + 3\hat{j} + 2\hat{k}\right]$

**Q.** Some equipotential lines are shown in the diagram. Write down the corresponding E.F in vector form?



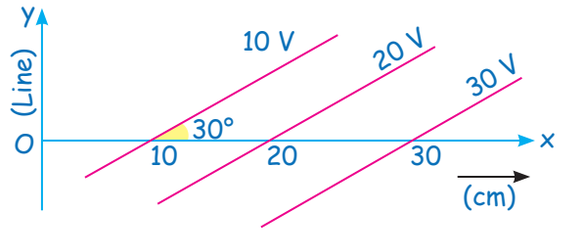

$20 = Ed$

$20 = \frac{E\,10 \sin 60°}{100}$

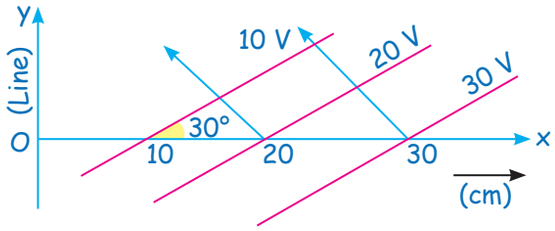
$E = \frac{400}{\sqrt{3}}$

$\vec{E} = E(\cos 30\hat{i} - E \sin 30\hat{j})$

**Q.** Equipotential surfaces are shown in figure. Then the electric field strength will be:




**Sol.**




$d = 10 \sin 30\ cm = 5\ cm$

$10 = Ed$

$10 = E \times \frac{5}{100}$

$E = 200\ v/m$

## DIPOLE

System of 2 equal and opposite charge separated by a small distance d.




Dirx$^n$ moment = $\vec{Q} = q\vec{d}$

Direx$^n$ is -ve

+ve charge

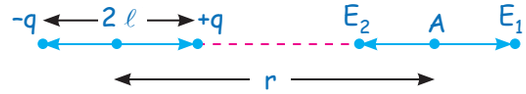
magnitude = qd

#




$\vec{P} = 2 \times (3\hat{i} + 3\hat{j} + 4\hat{k})$

## ELECTRIC FIELD DUE TO SHORT DIPOLE AT A POINT ON AXIS.




$E_A = E_1 - E_2$

[P = q2 ℓ magnitude]

$$E_A = E_1 - E_2 = \frac{kq}{(r-\ell)^2} - \frac{kq}{(r+\ell)^2}$$

$$= kq\left[\frac{(r+\ell)^2 - (r-\ell)^2}{(r-\ell)^2(r+\ell)^2}\right]$$

$$= \frac{kq.\,2r\,2\ell}{(r^2-\ell^2)^2} = \frac{2kq\,2\ell r}{(r^2-\ell^2)^2}$$

If $\ell << r$

$$E_A = \frac{2kq\,2\ell r}{r^4} = \frac{2k\,(q2\ell)}{r} = \frac{2kP}{r^3}$$

$$\vec{E}_{axis} = \frac{2k\vec{P}}{r^3}$$

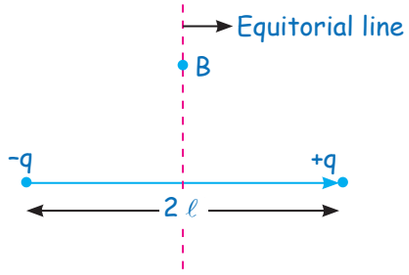
Potential at A

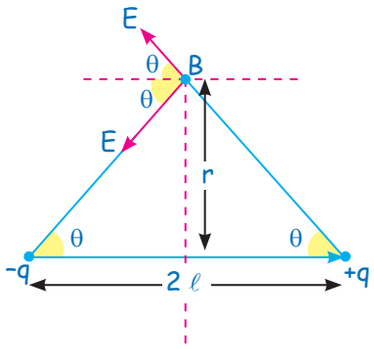
$$v_A = \frac{kq}{(r-\ell)} + \frac{k(-q)}{(r+\ell)} = kq\,\frac{(r+\ell)-(r-\ell)}{(r^2-\ell^2)}$$

$$v_A = \frac{kq2\ell}{r^2-\ell^2} \quad [\ell <<< r]$$

$$v_A = \frac{kP}{r^2}$$

## E.F AT A POINT ON A EQUITORIAL LINE DUE TO SHORT DIPOLE



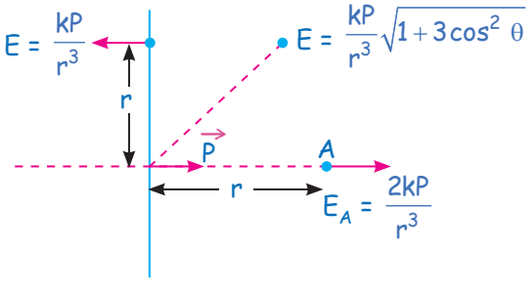



$E_{at\ B} = 2E\cos\theta$ (पीछे)

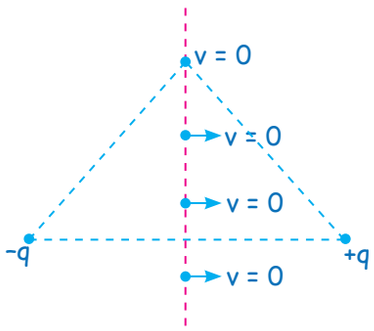
$$= \frac{2kq}{(\sqrt{r^2+\ell^2})^2}\frac{l}{\sqrt{r^2+\ell^2}} = \frac{kq2\ell}{(r^2+\ell^2)^{3/2}}$$

If $l << r = E_{equit} = \frac{kP}{r^3}$ (पीछे)

$$\vec{E}_{equit} = -\frac{k\vec{P}}{r^3}$$



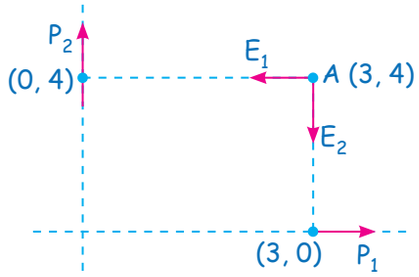

## Electric Potential due to Short Dipole at Equitorial line = zero.







**Q.** Two short dipole $P_1$ and $P_2$ at (3, 0) and (0, 4) respectively are placed along + x-axis and + y-axis as shown in figure find net electric field at (3, 4).

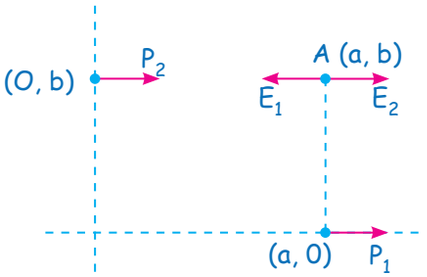



E.F at A due to $P_1 = \frac{kP_1}{4^3}(-\hat{i})$

E.F at A due to $P_2 = \frac{kP_2}{3^3}(-\hat{j})$

$$\vec{E}_{net} = +\frac{kP_1}{64}(-\hat{i}) - \frac{kP_2}{27}\hat{j}$$

**Q.** Find E.F at A.



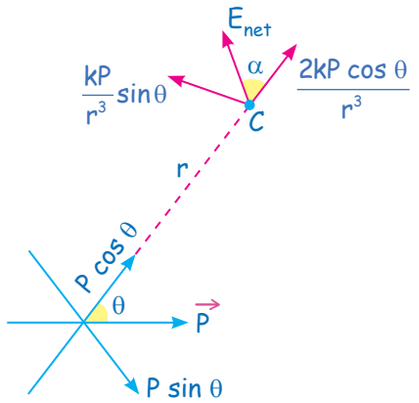

Pot at $A = 0 + \frac{kP_2}{a^2}$

$\vec{E}_1 = \frac{kP_1}{b^3}(-\hat{i})$

$\vec{E}_2 = \frac{2kP_2}{a^3}(\hat{i})$

$(\vec{E}_{net})$ at 'A' $= \frac{kP_1}{b^3}(-\hat{i}) + \frac{2kP_2}{a^3}(\hat{i})$

## E.F at a general point due to short Dipole



$$\tan\alpha = \frac{\frac{kP\sin\theta}{r^3}}{\frac{2kP\cos\theta}{r^3}} = \frac{\tan\theta}{2}$$

$$E_C = \sqrt{\left(\frac{2kP\cos\theta}{r^3}\right)^2 + \left(\frac{kP\sin\theta}{r^3}\right)^2}$$

$$= \frac{kP}{r^3}\sqrt{4\cos^2\theta + \sin^2\theta}$$

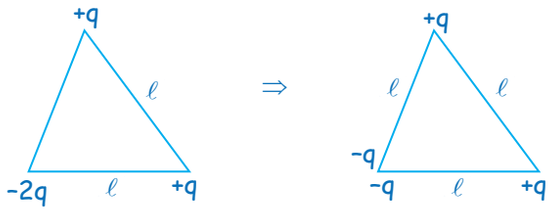
$$E = \frac{kP}{r^3}\sqrt{1+3\cos^2\theta} \Rightarrow \text{E.F kabhi zero nhi hogi}$$

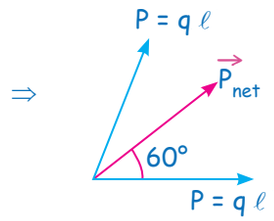
$$E_{max} \Rightarrow \theta = 0° \Rightarrow E = \frac{2kP}{r^3} \text{ (Axis)}$$

$$E_{max} \Rightarrow \theta = 90° \Rightarrow E = \frac{kP}{r^3} \text{ (Equitorial)}$$

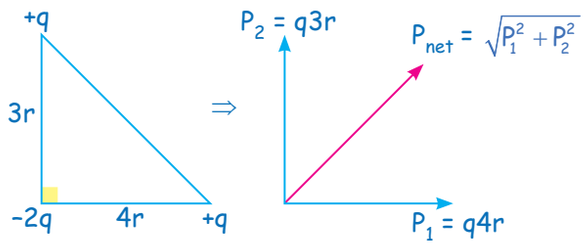
# Find dipole moment of following cases

**1**

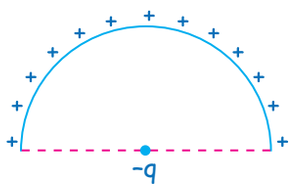


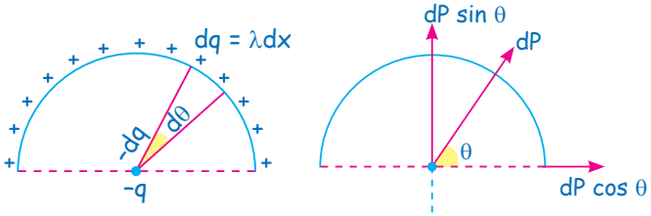

**2**




**3**




**Sol.**

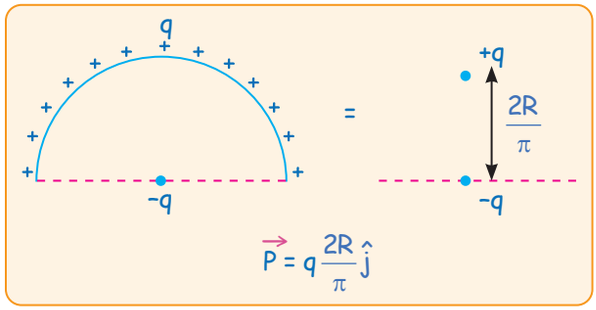



$$P_{net} = \int dP\sin\theta = \int dq\cdot R\cdot\sin\theta$$

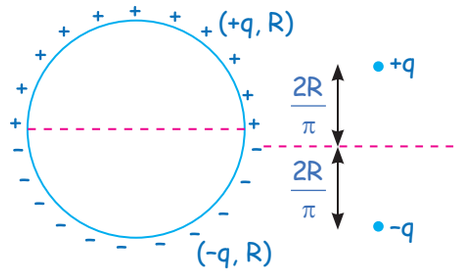
$$P_{net} = \int_0^{\pi} \lambda R d\theta\cdot R\sin\theta = \int_0^{\pi} \lambda R^2\sin\theta\, d\theta$$

$$= \lambda R^2\cdot 2 = \frac{q}{\pi R}R^2\cdot 2$$

$$= q\times\frac{2R}{\pi}$$

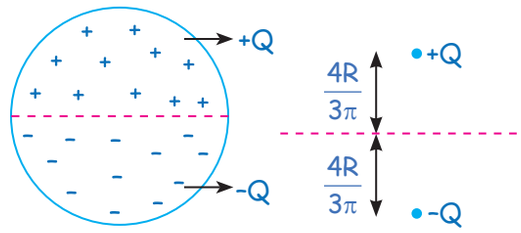



**4**

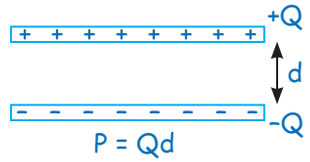



$$\vec{P} = q\frac{4R}{\pi}\hat{j}$$

**5**

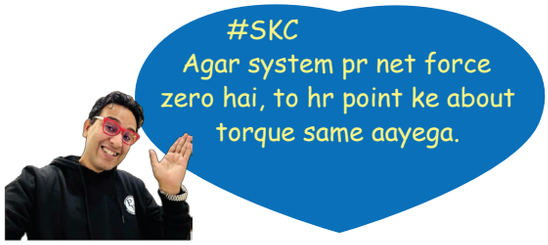


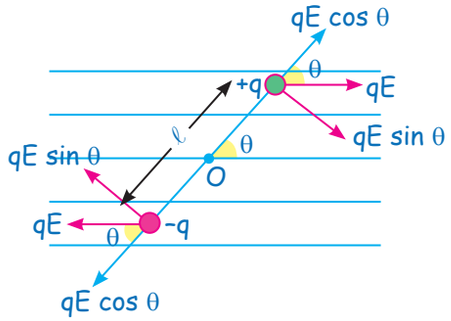

**6**




## DIPOLE IN UNIFORM E.F

$\vec{\tau} = \vec{P}\times\vec{E}$ | $U = -\vec{P}\,\vec{E}$ | $F_{net} = 0$




$F_{net} = 0$

$\tau_0 = qE \sin\theta \times \frac{L}{2} + qE \sin\theta \frac{L}{2}$

$\tau_0 = qE \sin\theta\, L$

#SKC
Uniform electric field चाहती है की, $\vec{P}$ electric field के parallel rhe

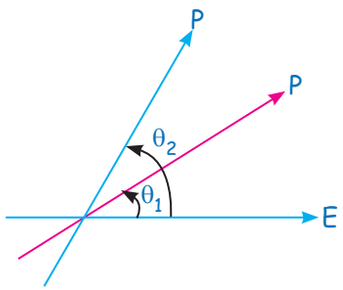
$\tau = PE \sin\theta$

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

If $\theta = 0, \tau = 0$ $\quad \theta = 180°, \tau = 0$ $\quad P \longleftarrow E$

## Potential Energy of Dipole in Uniform E.F

$(WD)_{ext.}$ to rotate dipole from $\theta_1$ to $\theta_2$ [slowly - slowly]




$dW = \int \tau d\theta$

$dW = \int_{\theta_1}^{\theta_2} PE \sin\theta\, d\theta$

$\Rightarrow (WD)_{ext.}\ \Delta U = -PE(\cos\theta_2 - \cos\theta_1)$

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

$= U_f - U_i$

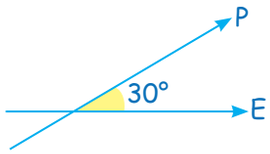
$U_f = -PE\cos\theta_2$

$U_i = -PE\cos\theta_1$

$U_f = -\vec{P}\cdot\vec{E}$

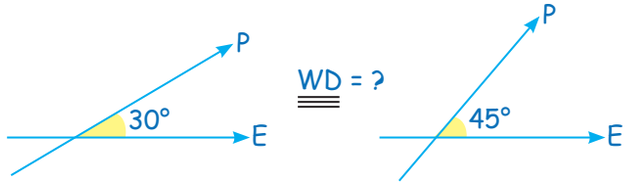
$$\boxed{U_f = -\vec{P}\cdot\vec{E}}$$

**Q.** Let E.F is along + x-axis and dipole is making angle 30° with x-axis as shown in figure. Find




**Sol.**

1. $\tau = PE\sin\theta = PE\sin 30° = \frac{PE}{2}$
2. $P.E = -\vec{P}\cdot\vec{E} = -PE\cos\theta = -PE\cos 30°$
3. Find $(WD)_{ext.}$ agent to rotate dipole so that angle b/w dipole and E.F become 45°




$U_i = -PE\cos 30°$ $\qquad$ $U_f = -PE\cos 45°$

$(WD)_{ext.} = U_f - U_i = -PE(\cos 45° - \cos 30°)$

VV Imp हर साल JEE Mains मे यह आता है।

$(WD)_{by\ ext.}$ agent to rotate a dipole from $\theta_1$ to $\theta_2$

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

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



**Q.** Initially dipole is placed in a E.F st. it is parallel to E.F

$\longrightarrow P$

$\longrightarrow E$

(a) Find F, τ, U

$F = 0$

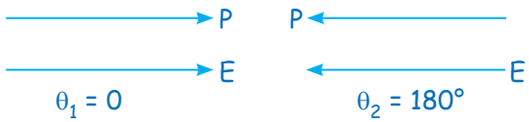
$\tau = 0$ [$\tau = PE\sin 0 = 0$]

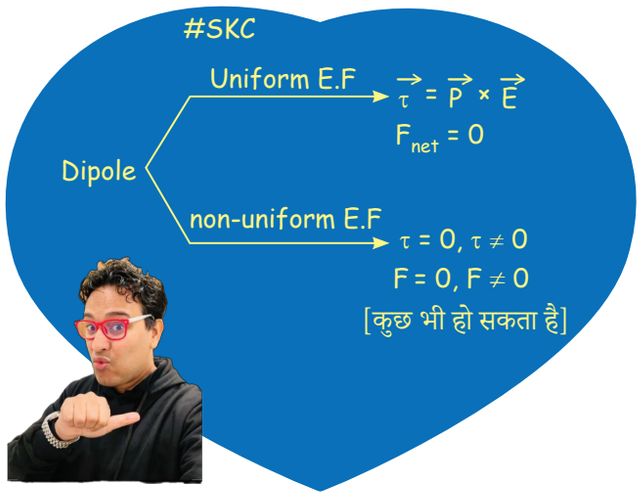
$U_i = -PE\cos 0° = -PE$

(b) (WD)ext. required to rotate st dipole become $\perp^{ar}$ to E.F = – PE (cos 90° – cos 0°) = + PE

(c) $(WD)_{ext.}$ require to totate st dipole become antiparallel to E.F [from $\theta_1 = 0$]

= – PE [cos 180° – cos 0°] = 2PE




☆ $\theta = 0$

$\vec{P}$

$\vec{E}$

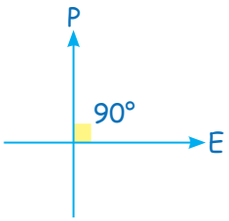
$\vec{\tau} = 0$

U = – PE

U → min

Eqb$^m$ stable

☆




$\tau$ = PE

U = 0

☆ $\theta = 180°$ E

P

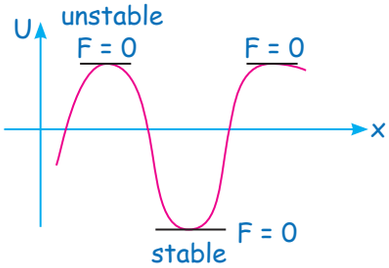
$\tau = 0$

P.E = + PE

U → max

unstable equilibrium

☆ 11$^{th}$ class




# काम का डब्बा

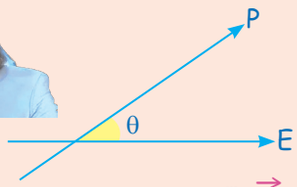


$U = -\vec{P} \cdot \vec{E}$

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

$\tau$ = PE sin $\theta$

U = – PE cos $\theta$

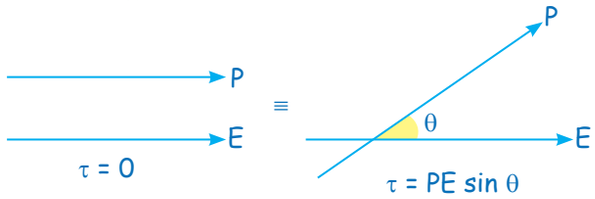



- $\theta = 0°, \tau = 0, U_{min}, (U_{min} = -PE)$, stable eq$^m$, $\vec{F}_{net} = 0$
- $\theta = 180°, \tau = 0, U_{max}, (U_{max} = +PE)$, unstable eq$^m$, $\vec{F}_{net} = 0$
- $\theta = 90°$, $\tau_{max}$ U = 0 No equillibrium

# Initially a dipole is in eqb$^m$ st it is parallel to E.F E (uniform). Time period of oscillation if it rotated by small angle θ is:

**Sol.** If θ is very small

$\vec{\tau} = -PE \cdot \vec{\theta}$

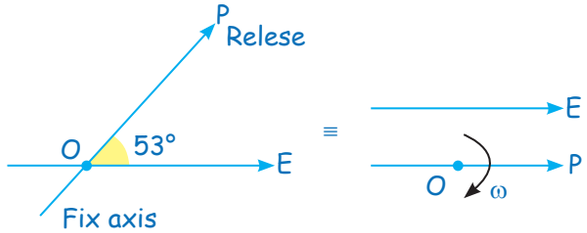



$\tau$ = PE sin $\theta$ = PE $\theta$ (Approx because $\theta$ is very small) Hence

$$T = 2\pi\sqrt{\frac{I}{PE}}$$

I = moment of inertia

**Q.** Initially dipole makes angle 53° with E.f as shown is diagram and release. Find K.E of dipole when it become parallel to E.




$K_i + U_i = K_f + U_f$

$0 - PE\cos 53° = K_f - PE \cos 0°$

$$K_f = \frac{2}{5}PE = \frac{1}{2}I\omega^2$$

**Q.** If a Dipole $\vec{P} = 2\hat{i} + 3\hat{j}$ is placed at (1, 2) and electric field in non uniform $\vec{E} = 3x\hat{i} + 4y\hat{j}$. Find force on the dipole

**Sol.** $U = -\vec{P}\cdot\vec{E} = -\left[6x + 12y\right]$

$$f_x = -\frac{\partial U}{\partial x} = -\left[-6 + 0\right] = 6$$

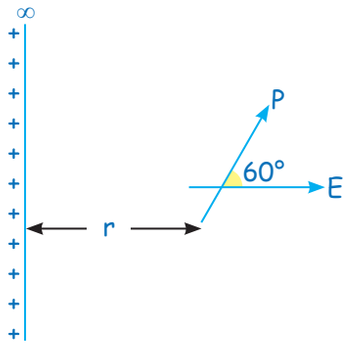
$$f_y = -\frac{\partial U}{\partial y} = -\left[0 + 12\right] = -12$$

**Q.** If a short dipole $\vec{p} = \rho_0\hat{r}$ is placed in non-uniform E.f. $\vec{E} = E_0 r^2\,(\hat{r})$ find force on dipole

**Sol.** $U = -\vec{P}\cdot\vec{E} = -[P_0E_0r^2\,\hat{r}\cdot\hat{r}] = -P_0E_0r^2$

$$F = -\frac{dU}{dr} = -[-P_0E_0 2r] = P_0E_0 2r$$

**Q.** Force by ∞-wire on short dipole




**Sol.** $U = -\vec{P}\cdot\vec{E} = -P\cdot\vec{E}\cos60°$

$$U = -\frac{P2k\lambda}{r}\cos60°$$

$$F = -\frac{du}{dr} = -\frac{P2k\lambda\cos60}{r^2}$$

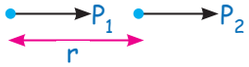
$$\vec{F} = -\frac{P2K\lambda\cos60}{r^2}\hat{r}$$



अबे infinite wire की जगह अगर ring दे दूँ तो उसकी EF का formula तूम्हें याद है ही तो dipole पर force निकाल लोगे ना।




**Q.** Force b/w them [short dipole]



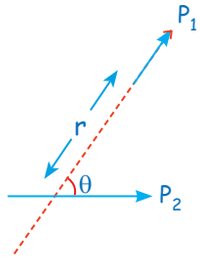

**Sol.** $U = -\vec{P_2}\cdot(Ef)_{due\ to\ P,\ on\ P_2}$

$$= -\vec{P_2}\cdot\frac{2K\vec{P_1}}{r^3}$$

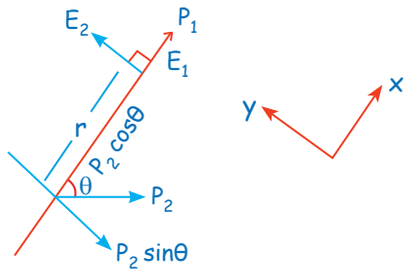
$$U = -\frac{2kP_1P_2}{r^3}$$

$$f = -\frac{dU}{dr} = -\frac{6KP_1P_2}{r^4}$$

**Q.** Two short dipole are placed as shown. The energy of electric field interaction b/w these dipoles will be:-




**Sol.**



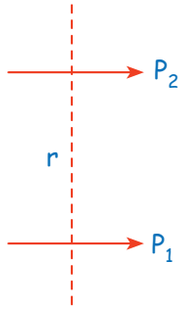

$U = -\vec{P_1}\vec{E}$

$U = -\vec{P_1}\hat{i}\,(E_1\hat{i} + E_2\hat{j})$

$U = -P_1E_1$

$$U = -P_1\frac{2KP_2\cos\theta}{r^3}$$

**Q.** Find force of interaction b/w $P_1$ & $P_2$ or find force $P_1$ on $P_2$ [short dipole




$U = -\vec{P_2}\cdot\vec{E} = -P_2E\,Cos180°$

$$U = -P_2 \frac{KP_1}{r^3} \times (-1)$$

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

$$f = -\frac{dU}{dr} = -KP_1P_2 \frac{(-3)}{r^4}$$

$$f = \frac{3KP_1P_2}{r^4}$$

→ Conductor → Free $e^-$ bahut saare.

→ Semi-Conductor → Bahut Kam free $e^-$ [$12^{th}$ last]

→ Insulator → No free $e^-$

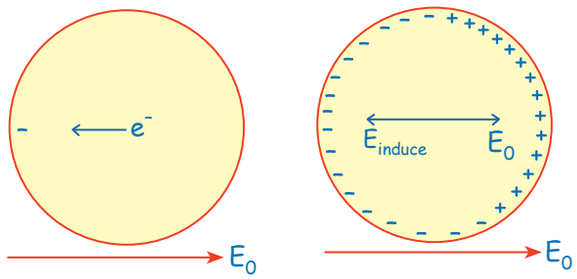
## CONDUCTOR

→ They have free $e^-$. Which are free to move inside conductor.

→ Inside the conductor, E.F = 0 [jha jha maal bhra hua h] [In Electrostatic]

→ Metals are good conductor

→ Agar m kisi conductor ko E.F mein rakh du to, conductor Ke ander free e- ke motion ki vajah se charge seprate ho jayenge, mtlb induce ho jayenge, or ye to tab tak hota rahega, jab tak ander net electric field zero na ho jaye. Mtlb, jitne External E.F ho utni hi opposite dirx$^n$ me charge sepr$^n$ ki vajah se induce ho gyi.



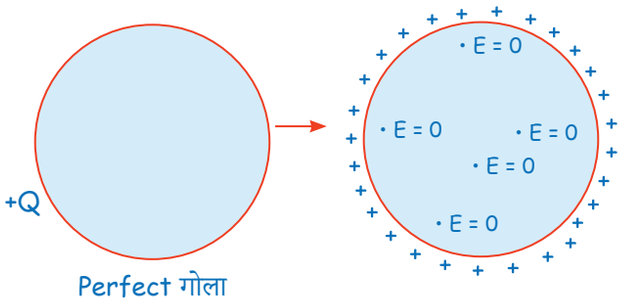

$E_{net} = E_0 - E_{induce}$

⇓

0 $E_{induce} = E_0$

→ Agr kisi conductor ko charge dedu to,

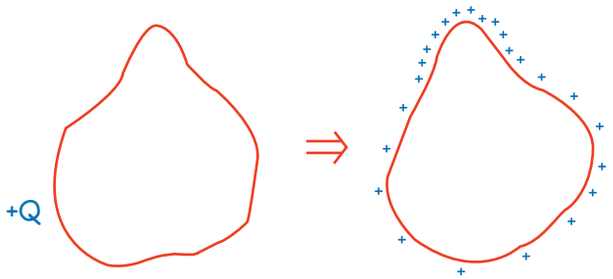
$\sigma \propto \frac{1}{r}, r \downarrow, \sigma \uparrow$




Perfect गोला

R → same

σ → same uniform




$\sigma \propto 1/r$

$r \downarrow, \sigma \uparrow$

→ Potential of every point of conductor are same.

→ Hence, we can say that surface of conductor is Equipotential surface

→ Since E.F is always $\perp^{ar}$ to Equipotential surface Hence E.F is always $\perp^{ar}$ to conducting surface

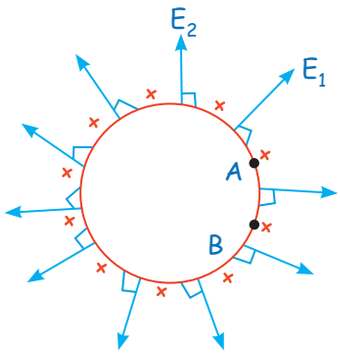
$dv = -\vec{E} \cdot d\vec{r} = -Edr\cos\theta$

V → same

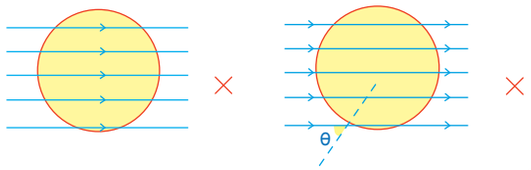
$dv = 0 \Rightarrow E = 0$ or

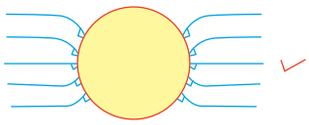
$\theta = 90°$

$\vec{E} \perp d\vec{r}$




**Q.** Which of the following diagram is not possible for a conductor?



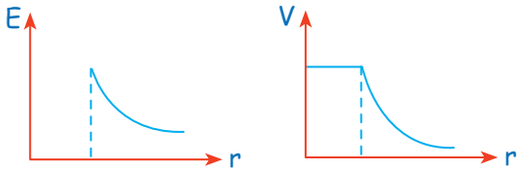


## SPHERICAL CONDUCTOR OF 'R', +Q.

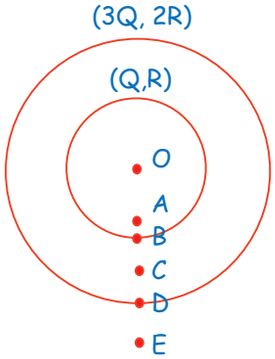
$\rightarrow E_{inside} = 0$ $\qquad \rightarrow E_{outside} = \frac{KQ}{r^2}$

$V_{inside} = \frac{KQ}{R}$ $\qquad V_{outside} = \frac{KQ}{r}$

Results are same as non conducting shell.




**Q.** In following diagram we have two conducting sphere. Find potential at A, B, C, D, E.



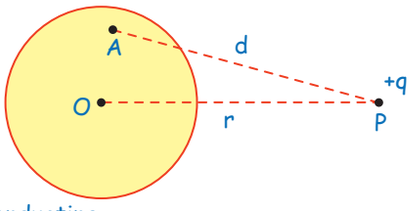

$V_0 = \frac{KQ}{R} + \frac{K3Q}{2R} = V_A = V_B$

$V_C = \frac{KQ}{OC} + \frac{K3Q}{2R}$

$V_D = \frac{KQ}{2R} + \frac{K3Q}{2R}$

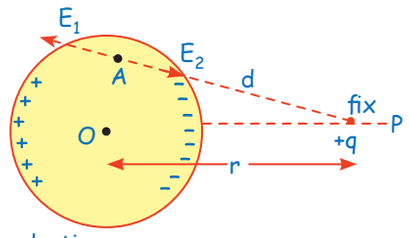
$V_E = \frac{KQ}{OE} + \frac{K3Q}{OE}$

**Q.** A charge q is placed at P outside at a distance r from the center of a conducting neutral sphere of radius R (r > R). Find EF and EP at A due to induce charge.




Conducting
[Neutral R]

**Sol.**




Conducting
[Neutral R]

E.F at Pt. A = 0

E.F at pt. A due to pt. charge q = $\frac{Kq}{d^2} = E_1$

E.F at pt. A due to induce charge = $E_2$

$E_2 = \frac{Kq}{d^2}$ (opposite to $E_1$)

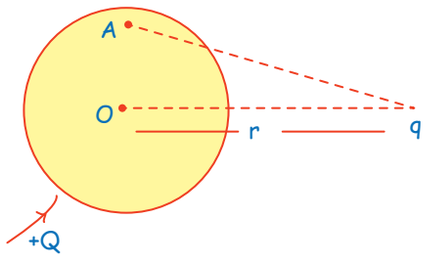
$V_A = V_0$

$V_A = V_{\text{at A due to q}} + V_{\text{at A due to induce charge}}$

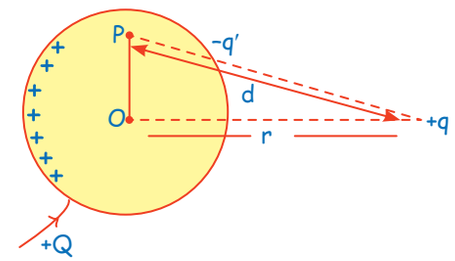
$\frac{Kq}{r} = \frac{Kq}{d} + V_{\text{at A due to induce charge}}$

$V_{\text{at A due to induce charge}} = \frac{Kq}{r} - \frac{Kq}{d}$

**Q.** Repeat the last all parts if conducting sphere is given + Q charge. Find potential at A due to induce charge.




**Sol.**




$V_p = V_0 = \frac{Kq}{r} + \frac{K(Q + q' - q')}{R}$

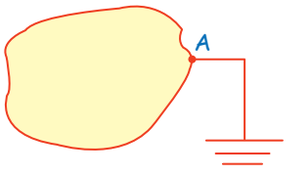
$V_p = V_0 = \frac{Kq}{r} + \frac{KQ}{R}$

Pot. at 'P' due to induce charge = कद्दू

$V_p = V_{\text{due to 'q'}} + V_{\text{induce charge}}$

$\frac{Kq}{r} + \frac{KQ}{R} = \frac{Kq}{d} + V_{\text{due to induce charge}}$

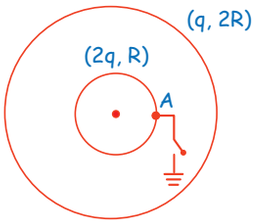
## IDEA OF EARTHING



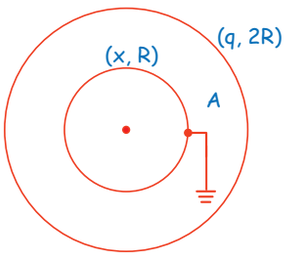

$V_A = 0$ कर दिया

#SKC
जिसको Earth Kiya hai, uska potential zero Krna. hai.

**Q.** Suppose we have two concentric conductor as shown in figure. Find the charge on inner conducting sphere after switch close.



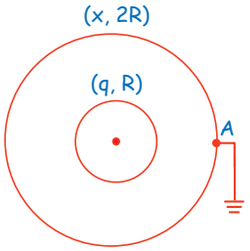

**Sol.**




$$V_A = \frac{Kx}{R} + \frac{Kq}{2R} = 0$$

$x = -q/2$

**Q.** Find the charge on outer sphere

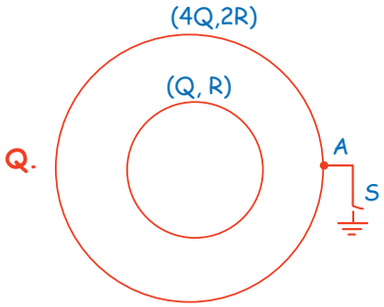





#SKC
जिसको Earth Kiya hai, uska potential zero Krna. hai.

$$V_A = \frac{kq}{2R} + \frac{kx}{2R} = 0$$

$x = -q$




**Q.**

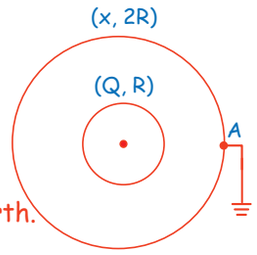
→ Find charge flow through switch after switch closed

$V_A = 0$

$$\frac{Kx}{2R} + \frac{KQ}{2R} = 0$$

$x = -Q$

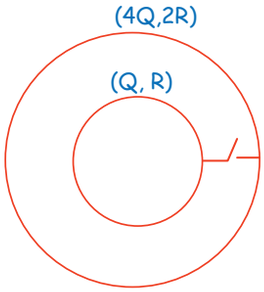
$\therefore$ + 5Q charge flow.




→ find no. of $e^-$ supply by earth.

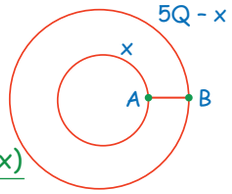
$5Q = ne$

**Q.** Find charge on inner sphere & outer sphere after switch closed




#SKC
जिन दो conducting surface को तारो से जोड़ा है उनका potential बराबर करदो

**Sol.** Suppose inner sphere has charge x




$V_A = V_B$

$$\frac{Kx}{R} + \frac{K(5Q - x)}{R} = \frac{Kx}{2R} + \frac{K(5Q - x)}{2R}$$

$$\frac{Kx}{R} = \frac{Kx}{2R}$$

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

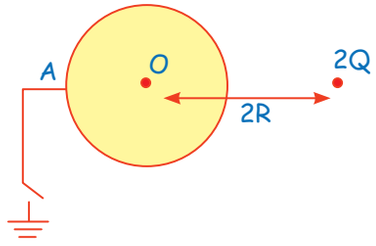
$$x - \frac{x}{2} = 0$$

[inner] $x = 0$

सारा का सारा charge बाहर चला गया
Sorry Shubham* Bhaiya



**Q.** Find net charge on conductor after switch is closed.



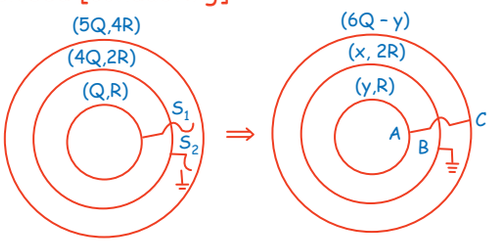
**Sol.** Let charge on the sphere is x after switches close

$V_A = 0 = V_0$

$$\frac{K2Q}{2R} + \frac{Kx}{R} = 0$$

$x = -Q$

**Q.** Find charge on each sphere after $S_1$ and $S_2$ closed [conducting]




**Sol.** $V_B = 0$

$$\frac{Ky}{2R} + \frac{Kx}{2R} + \frac{K(6Q-y)}{4R} = 0 \quad ...(1)$$

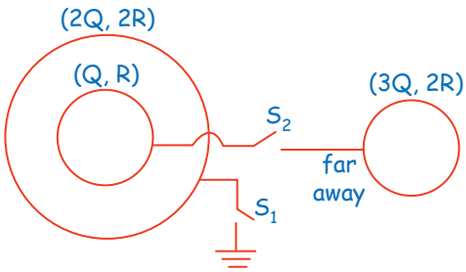
$V_A = V_C$

$$\frac{Ky}{R} + \frac{Kx}{R} + \frac{K(6Q-y)}{4R} = \frac{Ky}{4R} + \frac{Kx}{4R} + \frac{K(6Q-y)}{4R} \quad ...(2)$$

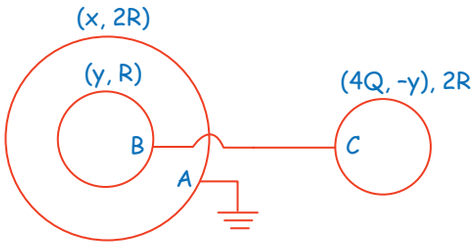
By Solving (1) and (2) we can get the answer focus on concept.




**Q.** Find charge on each sphere after $S_1$, $S_2$ is closed.




**Sol.**




$V_A = 0$

$$\frac{Ky}{2R} + \frac{Kx}{2R} + 0 = 0$$

$x + y = 0$ ....(1)

$V_B = V_C$

$$\frac{Ky}{R} + \frac{Kx}{2R} + 0 = \frac{K(4Q-y)}{2R}$$

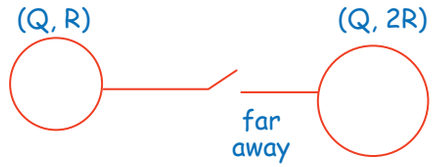
$x + 3y = 4Q$ ....(2)

Solve (1) and (2)

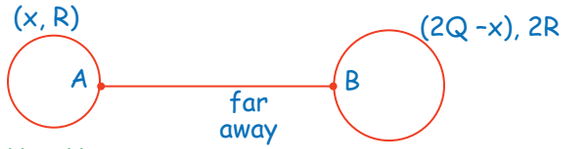
$\therefore y = +2Q$

$x = -2Q$

**Q.** Find charge on small sphere after switch close




**Sol.**




$V_A = V_B$

$$\frac{Kx}{R} + 0 = 0 + \frac{K(2Q-x)}{2R}$$

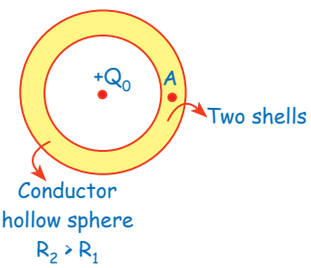
$$x = \frac{2Q}{3}$$

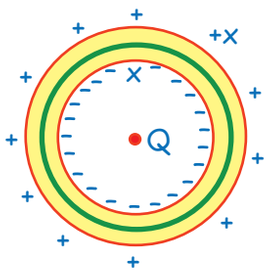
$q_1 = 2Q/3$

$$q_2 = 2Q - \frac{2Q}{3} = \frac{4Q}{3}$$

**Q.** Suppose we have a neutral hollow conducting sphere of inner radius $R_1$ and outer radius $R_2$. A point charge $+Q_0$ is placed at center. Find charge density inner and outer surface

**Sol.**



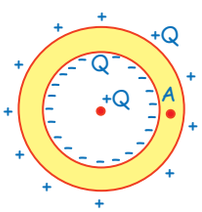




$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{in}}{\epsilon_0}$$

$$0 = \frac{Q - x}{\epsilon_0}$$

$Q = x$

$$\sigma_{inner} = \frac{-Q}{4\pi R_1^2}$$



$$\sigma_{outer} = \frac{Q}{4\pi R_2^2}$$

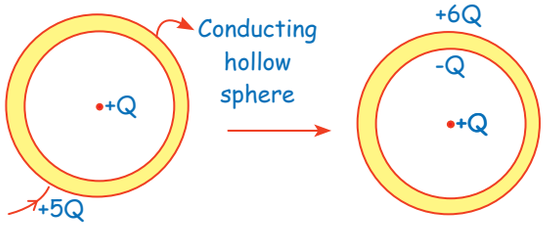
Inner surface pr charge -x h, mtlb -Q h

#SKC
इसमें 2 shell है
→ -Q . $R_1$
→ +Q . $R_2$

→Last Quesn में

#SKC
Chore Ka samne. barabar Ki age ki chori Ko bitha K setting Kr do and उसी प्रकार अगर छोरी है तो सामने बराबर age का छोरा बैठा दो। उसके बाद क्या होगा अपको पता ही है।

**Q.** Find charges & σ on inner and Outer surface after proper induction

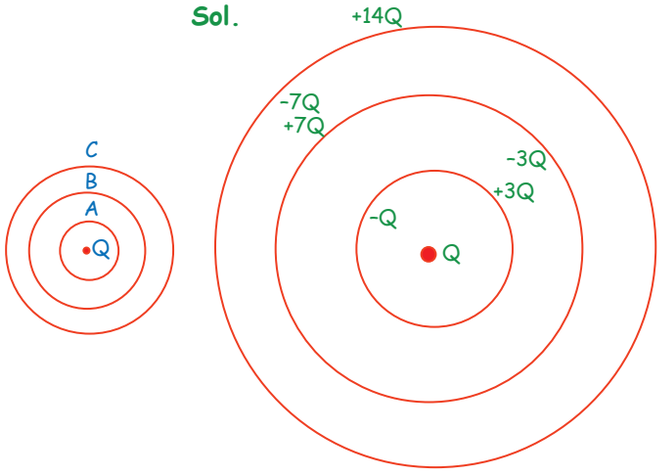



$$\sigma_{inner} = \frac{-Q}{4\pi R_1^2}$$

$$\sigma_{outer} = \frac{+6Q}{4\pi R_2^2}$$

**Q.** If 2Q, 4Q, 7Q charge is given to A, B, C respectively. Find charges & σ on inner and Outer surface after proper induction.

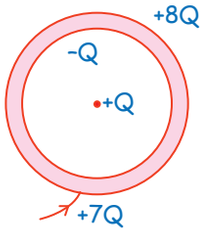
**Sol.**



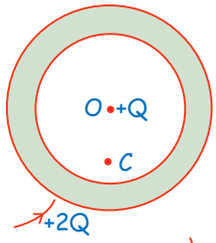

**Q.** Suppose we have a thin conductor of inner radius R and thickness t and charge +7Q. If +Q charge is placed at center. Find $\sigma_{inner}$ and $\sigma_{outer}$.

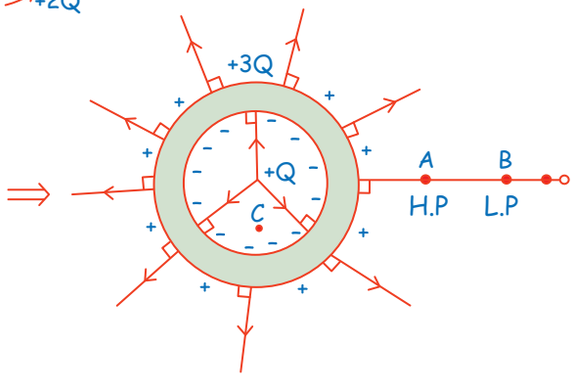
**Sol.** $\sigma_{inside} = \frac{-Q}{4\pi R^2}$

$$\sigma_{outside} = \frac{8Q}{4\pi(R+t)^2}$$




☆ Draw E.F pattern.




→ Electric field and potential at A.

$$\vec{E}_A = \frac{KQ}{(OA)^2} + \frac{K(-Q)}{(OA)^2} + \frac{K3Q}{(OA)^2}$$

$$V_A = \frac{KQ}{OA} + \frac{K(-Q)}{OA} + \frac{K3Q}{OA}$$

→ E.F at point C inside खाली जगाह -

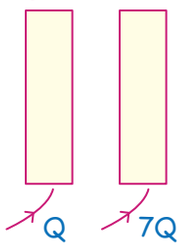
$$\vec{E}_C = \vec{E}_{due\ to\ point\ charge} + \vec{E}_{inner\ shell} + \vec{E}_{outer\ shell}$$

$$= \frac{KQ}{(OC)^2} + 0 + 0$$

$$E_c = \frac{KQ}{(OC)^2}$$

## CONDUCTING PLATE VERY CLOSE TO EACH OTHER / (LIKE ∞ PLATE)

**Q.** Suppose we have two conducting plate very close to each other and charge +Q, +7Q is given to both the plate as shown in figure. Find charge on every surface of both plates.



**Sol.** ABCD के लिए gauss law लगाकर और

$E_A = 0$ करके we found

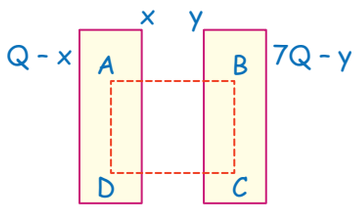
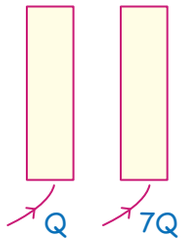
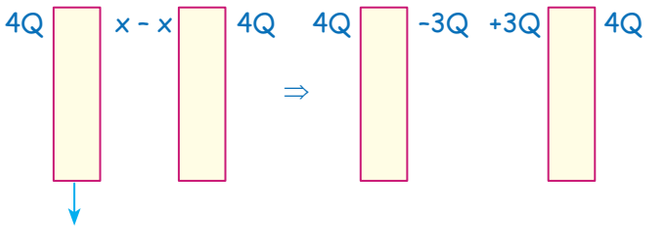



Plate के आमने सामने equal & opposite charge होगा और दोनो outer surface पर total का half charge होगा।

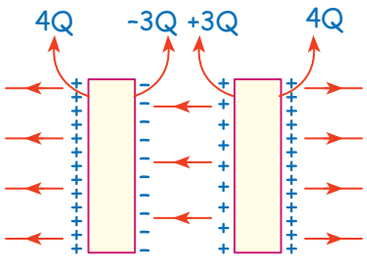



$$Q_{outer} = \frac{Q_{total}}{2} = \frac{Q + 7Q}{2} = 4Q$$

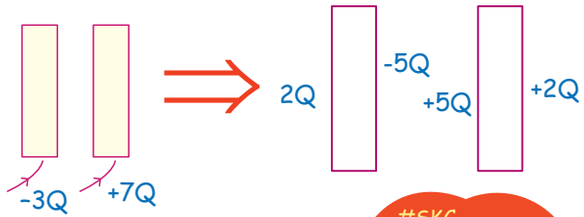



Total charge on this plate = Q
So x = -3Q

So final charge distribution and E.F pattern will be



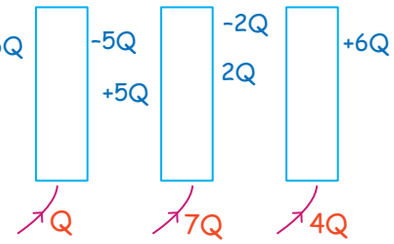

**Q.**



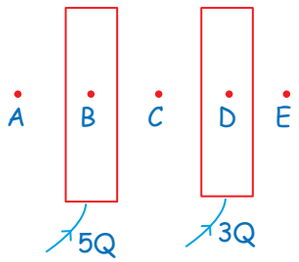

$$Q_{outer} = \frac{Q_{total}}{2} = \frac{-3Q + 7Q}{2} = 2Q$$

#SKC
Total charge ko आधा आधा करके outer suface ko de do, fir setting kr do.

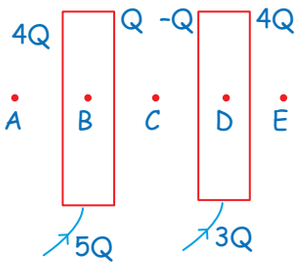
☆




**Q.** Charge 5Q and 3Q are given to two conducting plate very close to each other find charge on each face and Find E.F at A, B, C, D, E.




**Sol.**




$$E_B = E_D = 0$$

$$E_c = \frac{4Q/A}{2\varepsilon_0} - \frac{4Q/A}{2\varepsilon_0} + \frac{Q/A}{2\varepsilon_0} + \frac{Q/A}{2\varepsilon_0}$$

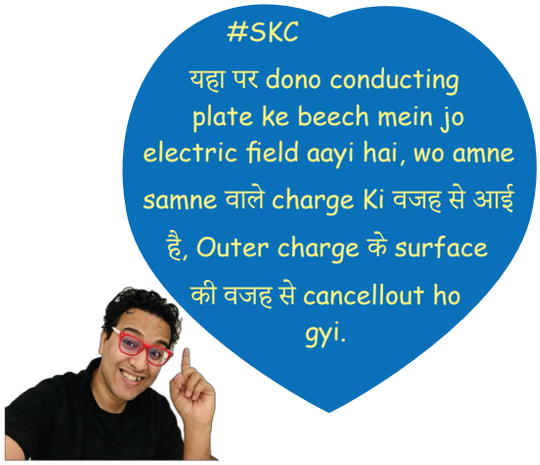
$$E_C = E_{\text{बीच में}} = \frac{Q}{A\varepsilon_0} = \frac{Q_{\text{अंदर वाला}}}{A\varepsilon_0}$$

$$= \frac{\sigma_{\text{अंदर वाला}}}{E_0}$$

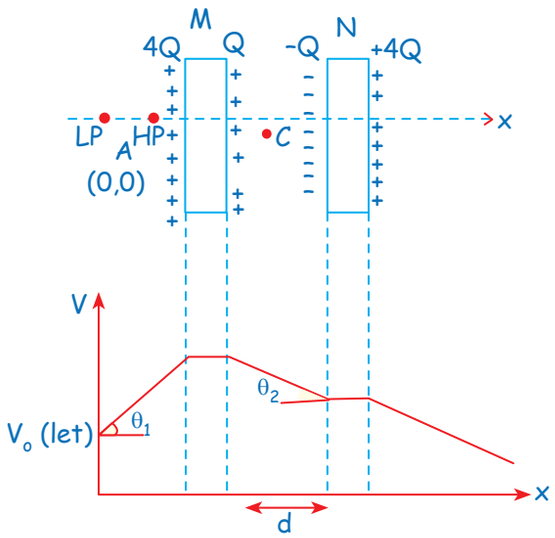
$$E_A = \frac{-4Q/A}{2\varepsilon_0} - \frac{Q/A}{2\varepsilon_0} + \frac{Q/A}{2\varepsilon_0} - \frac{4Q/A}{2\varepsilon_0}$$

$$= \frac{-8Q/A}{2\varepsilon_0} = \frac{-4Q/A}{\varepsilon_0}$$

$$E_E = \frac{4Q/A}{2\varepsilon_0} \times 2 = \frac{4Q/A}{\varepsilon_0}$$




## GRAPH-




$\tan \theta_1 = E_A$ (magn.)

$\tan \theta_2 = E_C$ (magn.)

## SELF-POTENTIAL ENERGY

- Self-potential energy of a charge system is the total electrostatic potential energy due to interactions between the charges in the system.
- For a system of point charges, it is the sum of the potential energies of all distinct pairs of charges.

→ S.P.E of a pt. charge = 0

→ S.P.E of a shell, conducting sphere = $\frac{KQ^2}{2R}$

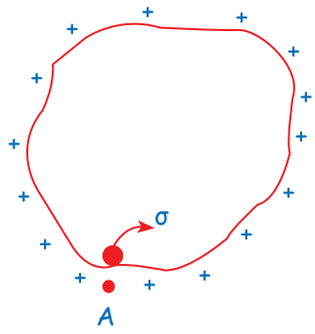
→ S.P. E of a solid sphere = $\frac{3}{5}\frac{KQ^2}{R}$

**Q.** A spherical shell of radius $R_1$ with uniform charge q is expanded to a radius $R_2$. Find the work performed by the electric forces in this process.

**Sol.** $(WD) = U_f - U_i$

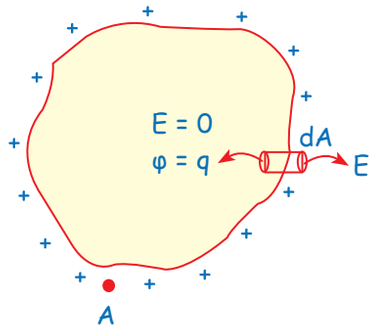
$$= \frac{Kq^2}{2R_2} - \frac{Kq^2}{2R_1}$$

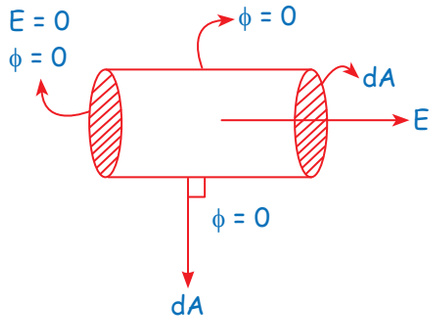
## E.F IN THE VICINITY OF CONDUCTOR




$E_A = \sigma/\varepsilon_0$

**Proof:**

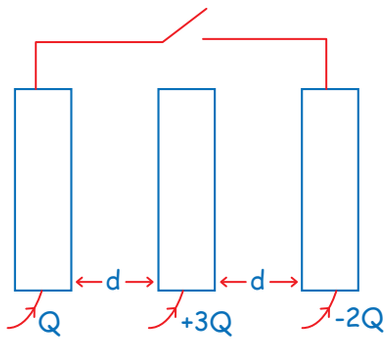


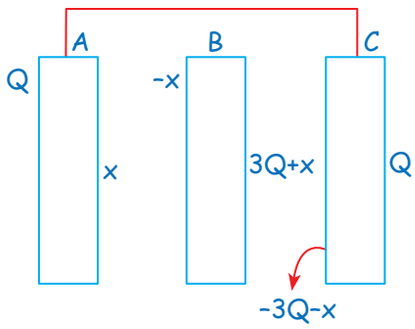




$$EdA + 0 + 0 + 0 = \frac{q_{in}}{\varepsilon_0} = \frac{\sigma dA}{\varepsilon_0}$$

$E = \sigma/\varepsilon_0$

**Q.** Find charge on each surface after switch closed.




$Q_{total} = Q + 3Q - 2Q$

$V_A = V_C$

$(V_A - V_B) + (V_B - V_C) = 0$

$E_1 d + E_2 d = 0$

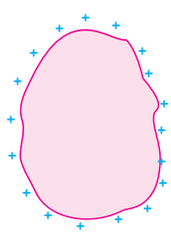
$$\left(\frac{x/A}{2E_0}\right) + \frac{(3Q+x)/A}{2E_0} = 0$$

$x + 3Q + x = 0$

$$x = \frac{-3Q}{2}$$

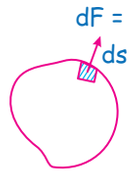
## ELECTROSTATIC PRESSURE

Suppose a conductor is given some charge. Due to repulsion, all the charges will reach the surface of the conductor. But the charges will still repel each other. So an outward force will be felt by each charge due to others. Due to this force, there will be some pressure at the surface, which is called electrostatic pressure.



To find the electrostatic pressure, lets take a small surface element having area '*ds*' and elemental charge dq.

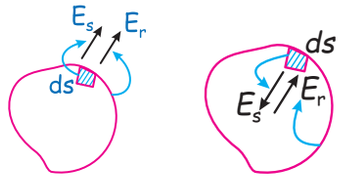
Force on this element due to the remaining charges:




$$dF = \begin{pmatrix} \text{electric field at} \\ \text{that place due to} \\ \text{remaining charges} \end{pmatrix} \begin{pmatrix} \text{charge of} \\ \text{the small} \\ \text{element} \end{pmatrix}$$

$dF = E_2 \times dq$ ...(*i*)

At a point just outside the surface, electric field due to the small element ($E_s$) will be normally outwards, and electric field due to the remaining part ($E_r$) will also be normally outwards.




So net electric field just outside the surface = $E_s + E_r$.
We have already proved that electric field just outside the conductor surface $= \frac{\sigma}{\varepsilon_0}$

$$\Rightarrow E_s + E_r = \frac{\sigma}{\varepsilon_0} \quad \text{...(ii)}$$

Electric field just inside the metal surface. Due to the remaining charges ($E_r$) will be in the same direction (normally outward), but the electric field due to the small element will be in opposite direction (normally inward)

So net electric field just inside the metal surface = $E_r - E_s$ and electric field inside a conductor = 0

So, $E_r - E_s = 0 \Rightarrow E_r = E_s$ ...(iii)

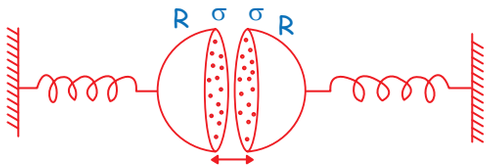
From eqn. (ii) and eqn. (iii), we can say that:

$$2E_r = \frac{\sigma}{\varepsilon_0} \Rightarrow E_r = \frac{\sigma}{2\varepsilon_0}$$

$$P = \frac{dF}{dA} = \frac{dq.E_r}{dA} = \frac{\sigma.\sigma}{2\varepsilon_0}$$

Electrost. Pressure = $\frac{\sigma^2}{2E_0}$

**Q.** Hemisphere are in equillibrium find compression in string.




Equilibrium

$\frac{\sigma^2}{2E_0} \times \pi R^2 = Kx$

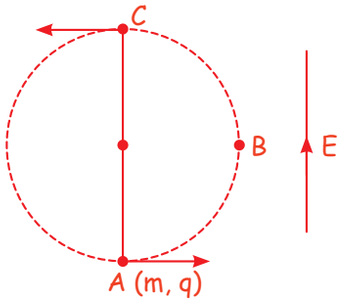
## IMPORTANT QUESTIONS

q charge को EF मे रखने पर उसके force qE लगता है इस concept को पूरी mechanics मे use करके सवाल बनाए जा सकते है।





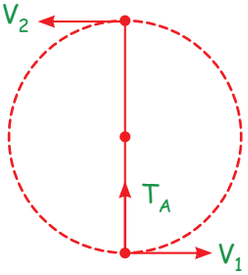

**Q.** If $T_A = 15$ mg
What should be velocity at C




OR

What horizontal velocity must be impart to ball at C so that tension at A become 15 times of weight.

**Sol.**

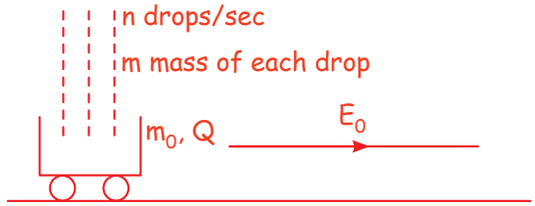



(1) $T_A + qE - mg = \frac{mV_A^2}{R}$

$15mg + qE - mg = \frac{mV_A^2}{R}$

(2) $-mg\,2R + 0 + qE\,2R = \frac{1}{2}mV_2^2 - \frac{1}{2}mV_1^2$

**Q.** n droper second m → mass of each drop.




Find velocity of car/tank as $f x_n$ of time.

**Sol.** At any time 't' mass of car = $M_0 + n\,t\,m$

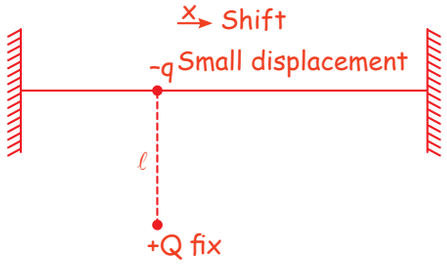
Impulse momentum theorem $\boxed{J = \Delta P}$

$QE_0t = (M_0 + n\,t\,m)V_f - 0$

$V_f = \frac{QE_0t}{M_0 + mnt}$

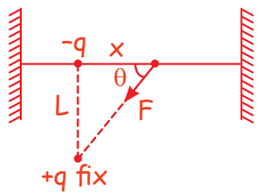



**Q.** Find time period of SHM if -q charge is slightly displaced in following figure along x-axis.

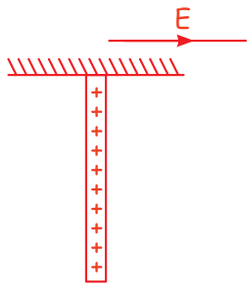



**Sol.** $F_{net} = F\cos\theta$

$= \frac{Kq\theta}{(L^2 + x^2)} \frac{x}{\sqrt{L^2 + x^2}}$



**Q.** Suddenly $E_0$ apply St. rod rotated max angle 90°. E = ?




Rod AB of length (L, Q, m)

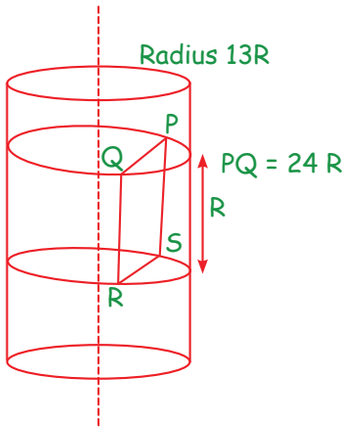
**Sol.** WET

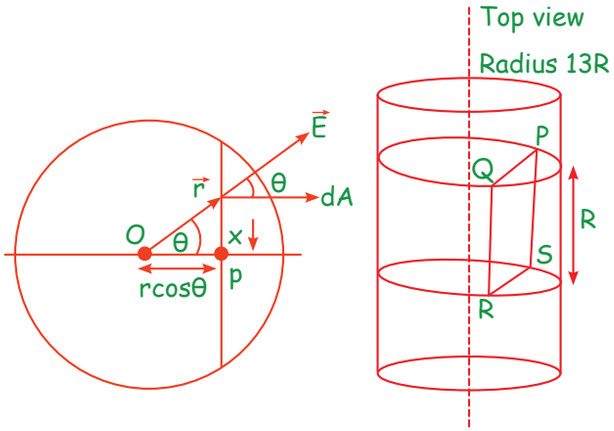
$W_g + W_{EF} = \Delta K.E.$

$-mg\frac{L}{2} + qE\frac{L}{2} = 0-0$

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

**SSSQ.** A long non conducting solid cylinder of radius 13R has charge density s. Find flux through shaded ractangle. PQRS




**Sol.** $\phi_{net} = \int d\phi = \int \vec{E}.d\vec{A} = \int E\,dA\cos\theta = \int \frac{\rho r}{2\varepsilon_0} dA\cos\theta$

$= \frac{\rho}{2\varepsilon_0}\int r\cos\theta\, dA$ (OP = 5R after solving)

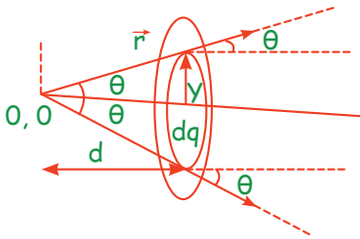
$= \left(\frac{\rho}{2\varepsilon_0}\right)(op)\int dA = \frac{\rho}{2\varepsilon_0}.5R(24R.R)$

**Q.** A disc of radius R is kept such that its axis coincide with the x-axis and its centre is at (d,0,0). The thickness of disc is t and it carries a uniform volume charge density ρ. The external electric field in the space is given by $\vec{E} = K\vec{r}$ where K = Constant and $\vec{r}$ is position vector of any point in space with respect to the origin of the coordinate system. Find the electric force on the disc.

**Sol.** $F_{net} = \int dF\cos\theta$

$= \int (dq)\, E\cos\theta$

$= \int (\rho 2\pi y dy t) kr\cos\theta$



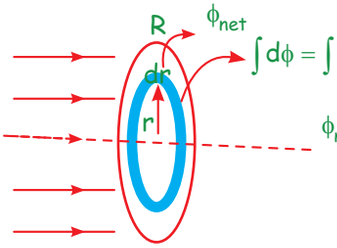

$F_{net} = \rho 2\pi tk \int r\cos\theta.y\, dy$

$F_{net} = \rho 2\pi tkd\int_0^R y dy$

$F_{net} = \rho 2\pi tkd\frac{R^2}{2}$

**Q.** E.F is normal to Disc $\vec{E} = E_0\left(1-\frac{r}{R}\right)\hat{i}$ Where r is distance from center of Disc, Find $\phi_{disc}$ = ?

**Sol.**



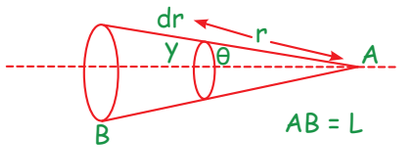

$\int d\phi = \int E.dA\cos o$

$\phi_{net} = \int_o^R E_o\left(1-\frac{r}{R}\right)2\pi r dr$

**Q.** A cone made of insulating material has a total charge Q spread uniformly over its sloping surface. Calculate the energy required to take a test charge q from infinity to apex A of cone. The slant length is L.

**Sol.** $dv = \frac{kdq}{\sqrt{y^2+x^2}} = \frac{kdq}{r}$

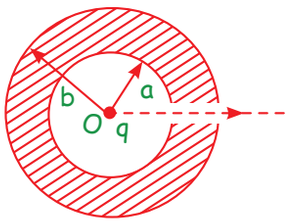
$\sin\theta = \frac{y}{r} = \frac{R}{L}, y = \frac{Rr}{L}$



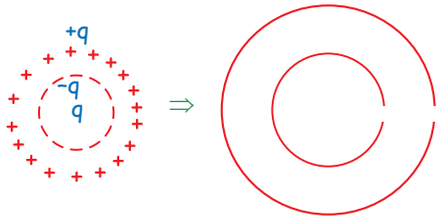

$$\int dv = \int_0^L \frac{k\sigma 2\pi y dr}{r} = k\sigma 2\pi \int_0^L \frac{R\cancel{r}}{L}\frac{dr}{\cancel{r}} = k\frac{\theta}{\pi RL} 2\pi \frac{R}{L}.L$$

$$= \frac{2K\theta}{L}$$

**Q.** A point charge q is located at the centre O of a spherical uncharged conducting layer provided with a small orifice. The inside and outside radii of the layer are equal to a and b respectively. What amount of work has to be performed to slowly transfer the charge q from the point O through the orifice and into infinity?




**Sol.**

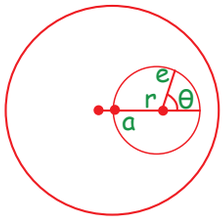



$$T.P.E = (SPE)_1 + (SPE)_2 + (SPE)_3 + U_{12} + U_{31} + U_{23}$$

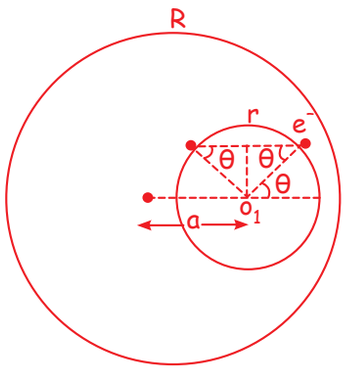
$$U_i = O + \frac{k(-q)^2}{2a} + \frac{kq^2}{2b} + \left(\frac{-kq}{a}.q\right) + \left(\frac{kq}{b}.q\right) + \frac{kq}{b}(-q)$$

$U_f = 0$. Ans. $= U_f - U_i$

**Q.** A cavity of radius r is present inside a solid dielectric sphere of radius R, having a volume charge density of ρ. The distance between the centres of the sphere and the cavity is a. An electron e is kept inside the cavity at an angle thet θ = 45° as shown. How long will it take to touch the sphere again?




**Sol.**

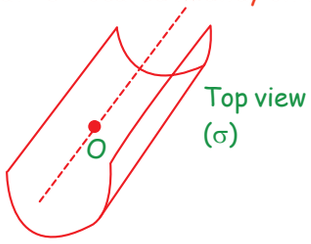



$$2r\cos\theta = 0 + \frac{1}{2} - \frac{eE}{m}.t^2$$

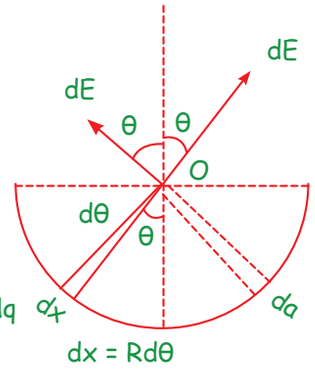
$$2r\cos\theta = \frac{1}{2}\frac{e\rho a}{3\varepsilon_0 m}t^2$$

$$t = \sqrt{\frac{12\varepsilon_0 m\, r\cos\theta}{e\rho a}}, \theta = 45°$$

**Q.** Thin long strip whose cross-section is a semicircle find EF at 'O' located midway on the axis




**Sol.** $E_0 = \int_0^{\pi/2} 2dE\cos\theta$



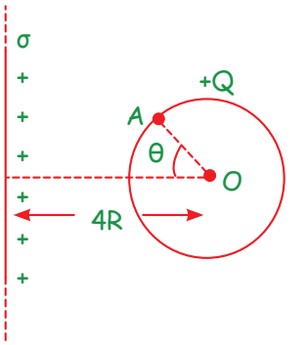

$$= \int_0^{\pi/2} 2.\frac{2k\sigma R d\theta\cos\theta}{R}$$

$$= 4k\sigma\int_0^{\pi/2}\cos\theta d\theta$$

$$= \frac{\sigma}{\pi\varepsilon_0}$$

**Q.** A conducting sphere of radius R and charge Q is placed near a uniformly charged nonconducting infinitely large thin plate having surface charge density σ. Then find the potential at point A (on the surface of sphere) due to charge on sphere

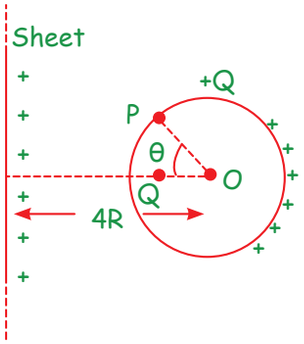
(here $K = \frac{1}{4\pi\in}, \theta_0 = \frac{\pi}{3}$)




**Sol.** $V_p = V_O$

$(V_p)_{\text{due to sheet}} + (V_p)_{\text{gola}} = (V_o)_{\text{Sheet}} + (V_o)_{\text{Gola}}$

$(V_Q)_{\text{due to sheet}} - (V_o)_{\text{sheet}} + (V_p)_{\text{gola}} = (V_o)_{\text{Gola}}$




$$\frac{\sigma}{2\varepsilon_0}\left(4R-(4R-R\cos\theta)\right)+\left(V_p\right)_{gola}=\frac{kQ}{R}$$

$$(V_p)_{Gola}=\frac{kQ}{R}=\frac{\sigma R\cos\theta}{2\varepsilon_0}$$

**Q.** The electric potential in a region is given by $V(x, y, z) = ax^2 + ay^2 + abz^2$ 'a' is a positive constant of appropriate dimensions and b, a positive constant such that V is volts when x, y, z are in m Let b = 2 The work done by the electric field when a point charge +4μC moves from the point (0, 0, 0.1m) to the origin is 50 μJ. The radius of the circle of the equipotential curve corresponding to V = 6250 volts and z = √2 m is $\alpha$ m. Fill $\alpha^2$ in OMR sheet.

**Sol.** $(WD)_{ext} = -\Delta V = -q\Delta V = -q\left(0-\frac{a}{50}\right)=\frac{aq}{50}$

$$50\times10^{-6}=\frac{a\times4\times10^{-6}}{50}$$

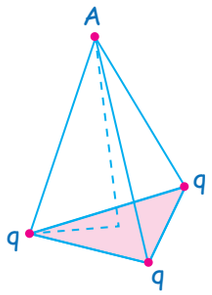
$$a=\frac{50\times50}{4}=625$$

$$V = 6250 = 625x^2 + 625y^2 + 625\times2\times2$$

$$10 = x^2 + y^2 + 4$$

$$x^2 + y^2 = (\sqrt{6})^2$$

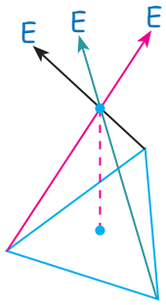
**Q.** Three charges (+q) are placed on the vertices of a equilateral triangle of side a as shown in diagram. Find electric field at a height h = a above the centroid of Δ.



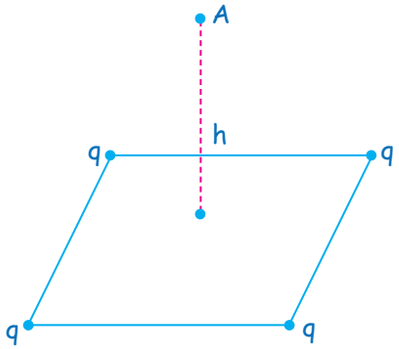

Sol. $E_A = 3E\sin\theta$
[θ = 60° already solved]

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

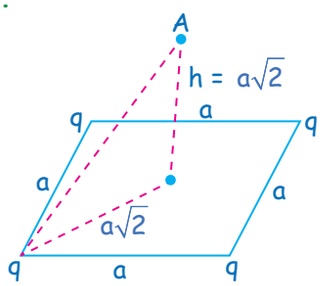
$$r^2 = h^2 + \left(\frac{a}{\sqrt{3}}\right)^2$$




**Q.** Four charge (q) are placed on the corner of square of side a. Find electric field at a height h = $\frac{a}{\sqrt{2}}$ from centre of square as shown in figure.



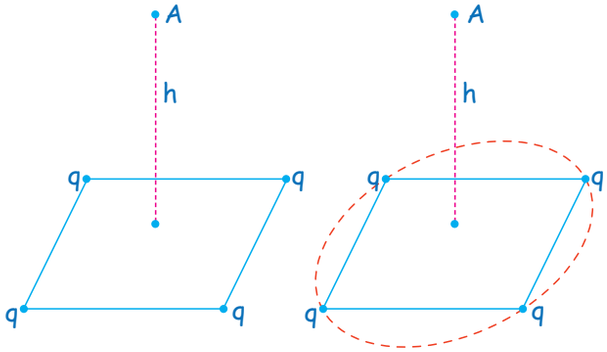
**Sol.**




$E_A = 4E \sin\theta \ [\theta = 45°]$

ऐ फिर आ गया रे बाबा



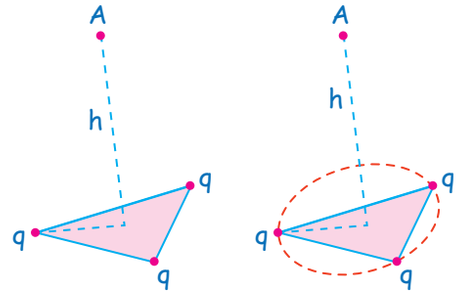

ऐसे symmetric सवालो मे हम 4q charge की एक ring मान सकते है जिसकी radius center से किसी भी एक charge के बीच की दूरी होगी यहाँ पर



$R = \left(\frac{A}{\sqrt{2}}\right)$ और $x = h$.

$$E = \frac{KQx}{\left(R^2 + x^2\right)^{3/2}} = \frac{K(4q)h}{\left[\left(\frac{a}{\sqrt{2}}\right)^2 + h^2\right]^{3/2}}$$

अब ये मत बोलना की ये पहले क्यों नही बताया अगर पहले बता देता तो तुम्हारी physics and visualisation develop नही हो पाता अब बोलो thank you saleem भईया।



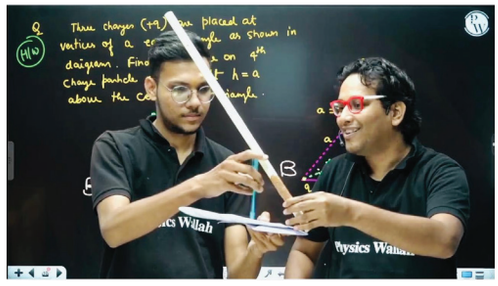
इसको भी 3q charge का ring मानकर जिसकी radius $\frac{a}{\sqrt{3}}$ है, A पर EF निकाल सकते है। It's your homework verify the result. जब verify हो जाए तो मुझे insta पर खुशी खुशी बताना। (Saleem.nitt) अगर आप insta पर नही हो तो account मत बनाना।







