

CLASS  
12

# SKC

# PHYSICS CRUSH



Class Notes in Handwritten Format

A beautiful journey From basic to JEE advanced via Mains/ NEET

By: Saleem Bhaiya



प्रयास हैं.....  
Lakshya तक उड़ान भरने का

$$\langle \text{कद्दू} \rangle = \frac{\int (\text{कद्दू}) dt}{\int dt}$$

Physics Wallah

## Acknowledgment

Saleem Ahmed Sir sincerely thanks Alakh Pandey Sir, for creating a platform that makes quality education accessible to millions. He also expresses gratitude to Sanyam Badola Sir, for his unwavering support and guidance.

Their trust, encouragement, and shared vision have empowered him to continue inspiring students and helping them achieve their dreams.



## From the Author

- ▶ Hello..... my loving warrior welcome to the 12th part of physics for JEE/NEET.
- ▶ I know it's very challenging task to prepare JEE/NEET because competition is very very tough and आपकी इस journey को और ज्यादा impact full बनाने के लिए here in this book i am trying to contribute something with new ideas from my past 12 years teaching experience in Kota.
- ▶ इस book को more affordable at lowest possible price बनाने के लिए we have constrain in no. of pages so I have tried my best की इस constraint को ध्यान में रखते हुए 350 pages में 12<sup>th</sup> portion का मै आपको अच्छे से अच्छा content provide कर सकूँ from basic to advance. अगर इस book का content आपने अच्छे से cover कर लिया तो Mains/NEET में almost 100% PYQ and upcoming papers और more than 75% in JEE Advance PYQ and it's upcoming paper आप solve कर सकते हैं।
- ▶ If you are preparing for JEE then अपनी calculations, results, mixing of chapters के साथ खेलना सीखें and if you are from NEET इस बात पर ध्यान दे की कैसे कम से कम समय में एक question को जल्दी से पढ़ कर solve करके accuracy के साथ answer निकाला जा सकता है।
- ▶ Class के बाद ये बहुत important होता है की आप बहुत सारे PYQ लगाए it will improve your skills, calculation, concept application process. So I recommend you to solve as much questions as you can. और वैसे तो इस book में already 1000+ question है।
- ▶ Majority 12<sup>th</sup> की physics 11<sup>th</sup> से independent है like Modern Physics, Semiconductor, Current Electricity, Capacitor, Optics, Magnetism, EMI, AC and so on. फिर भी I will recommend you की 11<sup>th</sup> class का Vector, Work Energy Theorem, Potential Energy, Basic SHM, Basic Mechanics Formula अच्छे से कर ले इससे आपको Electrostatics, Magnetism, EMI में काफी help मिलेगी।
- ▶ ये book JEE/NEET aspirants के साथ-साथ New aspiring physics teachers के लिए भी helpful है।
- ▶ From my last 12 year experience I have seen जो बच्चा last तक टिके रहता है उसका selection की possibility very high होती है। So कुछ भी हो जाए बस last तक टिके रहना and just give your best.
- ▶ Try to solve all the question till the last and try to learn something from every question.
- ▶ Because syllabus is very vast and we have limited no. of pages if you found some article missing in this book that means that's not important in JEE or removed from JEE.



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**Saleem.nitt** ✅



# 1

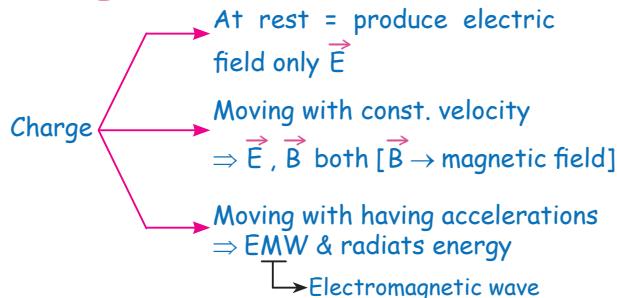
# Electrostatics

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 में है उतना तुमने कर लिया आपको solve more than 80% of JEE advance PYQ by yourself. Let's start from basic to advance....

## CHARGE



## PROPERTIES OF CHARGE

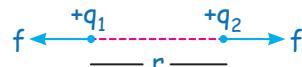
- Invariant, scalar, two type positive and negative.
- For an isolated system total charge is conserve.
- Charge cannot exist without mass.
- Charges quantized  $Q = \pm ne$  ( $n$  is integer  $e = 1.6 \times 10^{-19} C$ )

## COULOMB LAW

Electrostatic force of interaction b/w two point charge at separation  $r$  is observed as  
 $f \propto q_1 q_2$

$$f \propto \frac{1}{r^2} \text{ and } f \propto \frac{q_1 q_2}{r^2}$$

$$f = \frac{k q_1 q_2}{r^2}$$



$$K = 1/4\pi\epsilon_0 = 9 \times 10^9 \text{ Nm}^2/\text{C}^2$$

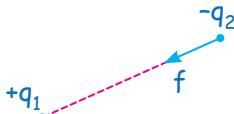
Permitivity of free space ( $\epsilon_0$ )

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

$$\text{Ex.: } f = \frac{k q_1 q_2}{r^2} \quad +q_1 \quad +q_2 \quad f = \frac{k q_1 q_2}{r^2}$$

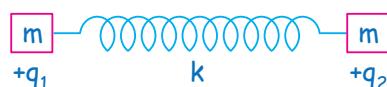
$$+q_1 \quad f \quad -q_2 \quad f = \frac{k q_1 q_2}{r^2} \text{ (magnitude)}$$

$$f \quad -q_1 \quad -q_2 \quad f = \frac{k q_1 q_2}{r^2}$$



- This force always act along the line joining two points
- Central force
- Electrostatic force b/w two charge particle are action reaction pair
- Conservative force
- Force applied by one charge particle on another charge particle is independent on presence or absence of other charge
- 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  $l_0$  and blocks are in equilibrium. Find elongation in spring.



Sol. Let elongation in spring is  $x$

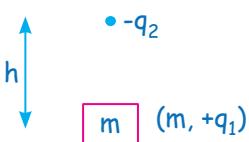
$$kx \quad f = \frac{k q_1 q_2}{(l_0 + x)^2}$$

$$kx = \frac{k q_1 q_2}{(l_0 + x)^2}$$



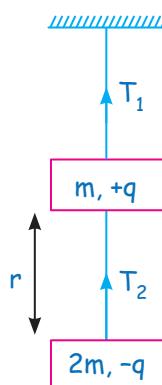
(अब अब value put करके quadratic eqn. बनाके कर लोगे ना 😊)

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



$$mg = \frac{kq_1 q_2}{h^2}$$

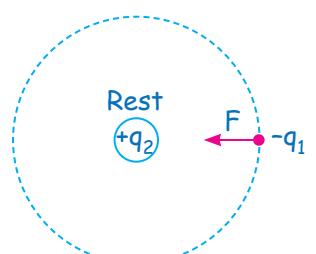
Q. Find the value of  $q$  so that tension in lower string becomes zero



Sol.

$$T_2 = 0 \quad F_e = \frac{kq_1 q_2}{r^2} \quad \frac{kq^2}{r^2} = 2mg$$

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

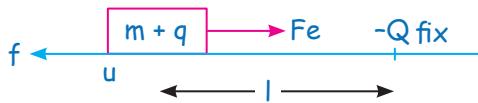


ऐसा तो Bohr's Model के first postulate में भी होता था।



$$\text{Sol. } F_e = \frac{kq_1 q_2}{r^2} = \frac{mv^2}{r} = mrw^2$$

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



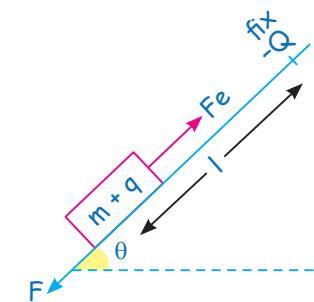
$$F_e \geq \mu_s mg$$

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

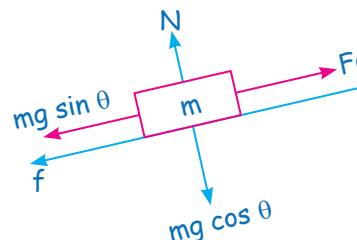
$$Q \geq \frac{\mu_s mg l^2}{kq}$$

2

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



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



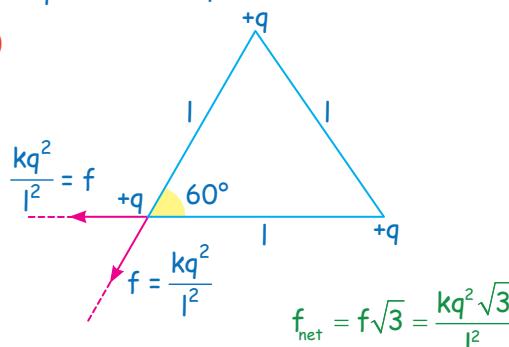
अभी तो chapter की starting है इसलिए पहले coulomb force की feeling लो basically ये question vector के ही हैं बस इस बात का ध्यान रखना की हमें किस पर force निकालना है और kiss ki वजह से निकालना है।



Q. Find the net force on the given charge  $q$

$$(a) \quad \begin{array}{ccc} & \xleftarrow{r} & \\ +5q & & +q \end{array} \quad f = \frac{k.5q.q}{r^2}$$

(b)



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

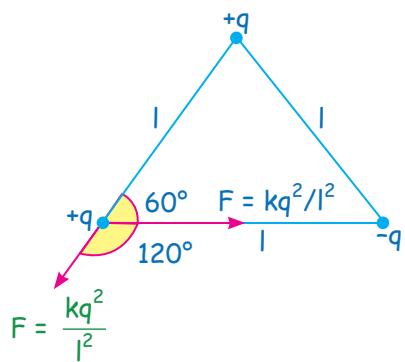
$$(c) \quad \begin{array}{ccc} & +5q & \\ & | & \\ +4q & & +q \end{array} \quad F = \frac{kq^2}{l^2} \quad \frac{k4q^2}{l^2} = 4F \quad \frac{k5q^2}{l^2} = 5F$$

Physics

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

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

(d)

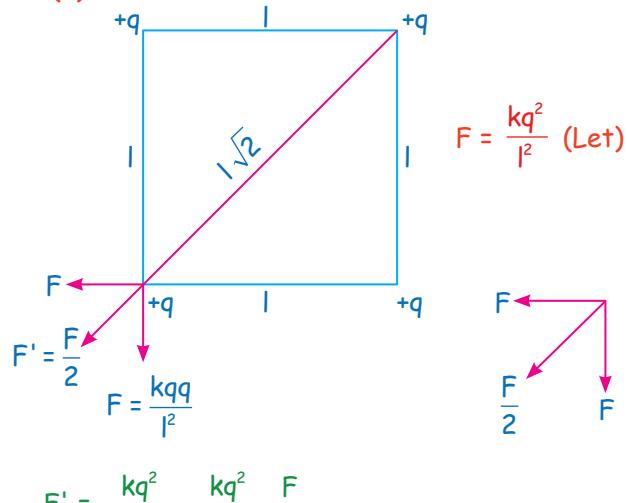


$$F_{\text{net}} = \sqrt{F^2 + F^2 + 2F^2 \cos 120^\circ}$$

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

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

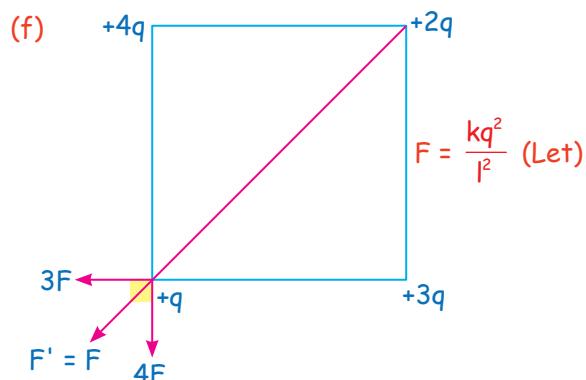
(e)



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

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

(f)



Tीनों 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.



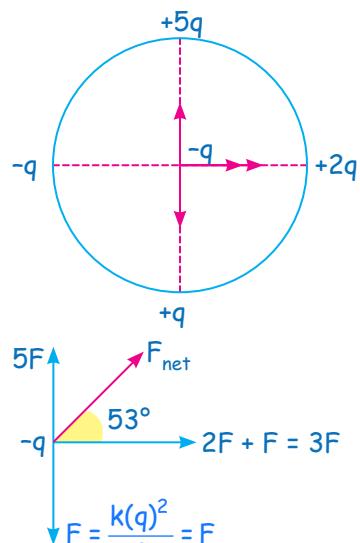
$$F' = \frac{2kq^2}{(\sqrt{2})^2} = F$$

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



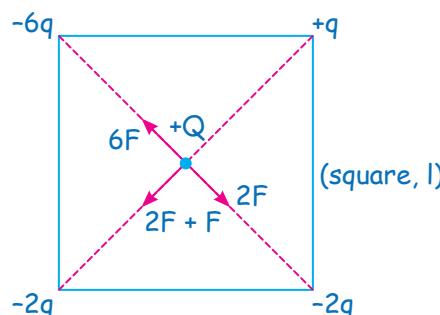
Bcz  $3F$  और  $4F$  का resultant  $F$  की तरफ नहीं आएगा।

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



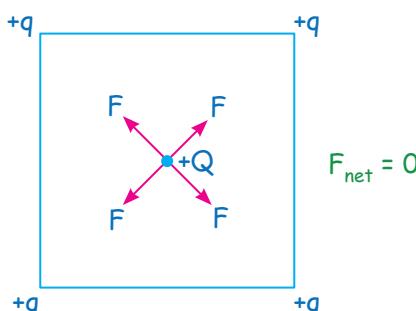
$$F_{\text{net}} = 5F = \frac{5kq^2}{r^2}$$

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

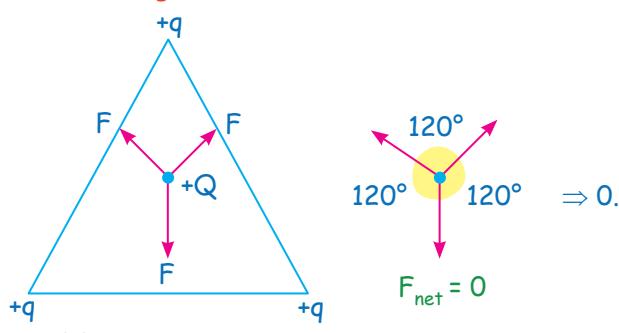


$$F_{\text{net}} = 5F = \frac{5kq^2}{(l/\sqrt{2})^2} = \frac{10kq^2}{l^2}$$

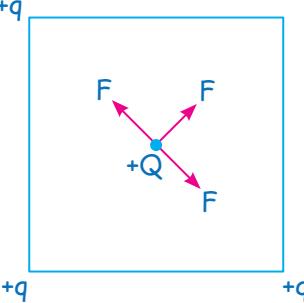
(i) Find  $F_{\text{net}}$  on  $+Q$  at centre of square.



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

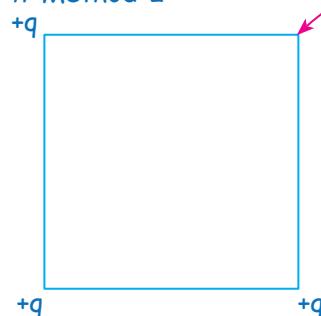


(k)



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

# Method-2

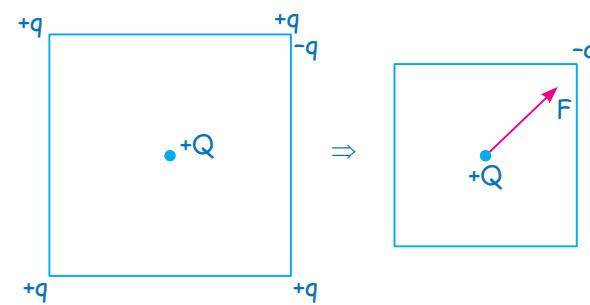


#SKC

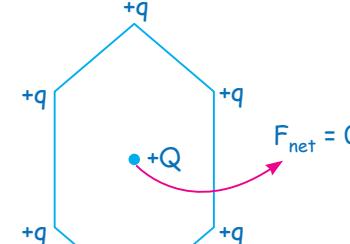
मानलो इस जगह पर 2 charge  $+q$  और  $-q$  रखे हैं।  $+q$  ने बाकी लोगों के साथ सेटिंग करती।



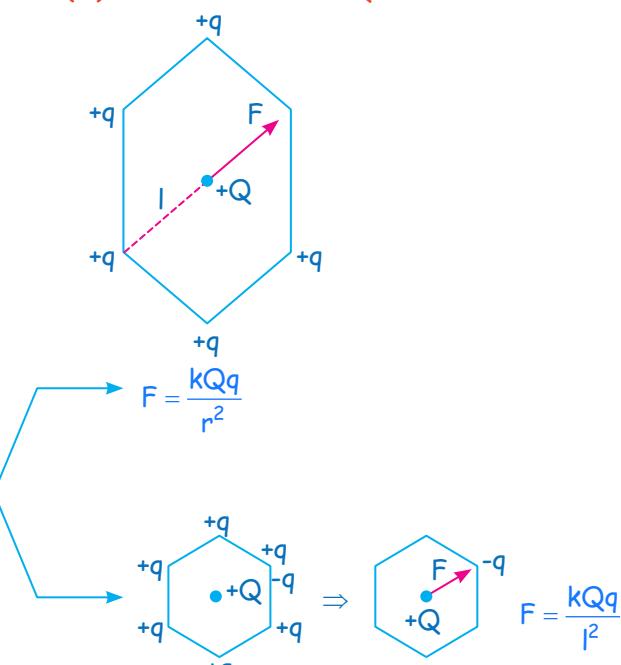
4



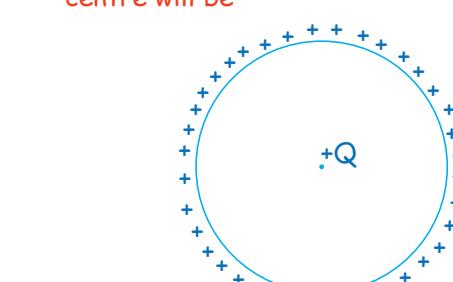
(l) Regular hexagon



(m) Find net force on  $+Q$ .



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

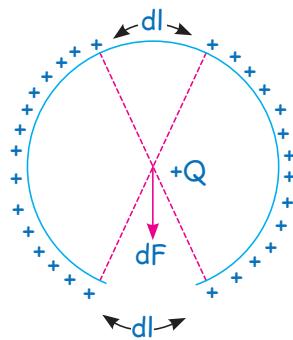


Sol.  $F_{\text{net}}$  on  $+Q$  at centre = 0

Physics

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

**Sol.**



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

$$2\pi r \rightarrow q \quad (\text{on ring})$$

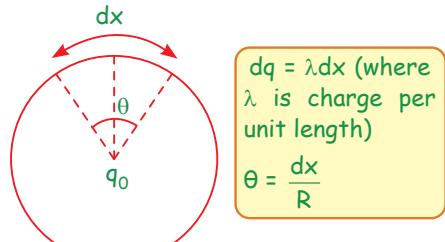
$$1 \rightarrow q/2\pi r$$

$$dl \rightarrow q/2\pi r \times dl = dq \quad dq = \frac{q}{2\pi r} dl = \lambda dl$$

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

**Q.** A ring of radius  $R$  is made out of a thin wire of cross section  $A$ . 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 developed in ring and  $\Delta R$ .

**Sol.**



$$dq = \lambda dx \quad (\text{where } \lambda \text{ is charge per unit length})$$

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

$$T \cos \frac{d\theta}{2} \quad T \sin \frac{d\theta}{2}$$

$$T \cos \frac{d\theta}{2} \quad T \sin \frac{d\theta}{2}$$

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

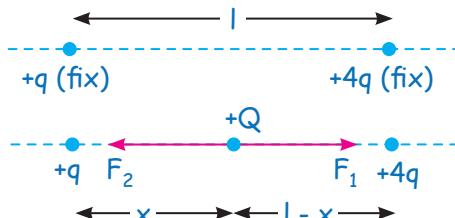
$$2T \cdot \frac{d\theta}{2} = \frac{k \lambda (dx) q_0}{R^2}$$

$$T \cdot \frac{d\lambda}{R} = \frac{k \lambda \frac{d\lambda}{R} q_0}{R^2}$$

$$T = \frac{k \lambda q_0}{R} = \frac{1}{4\pi\epsilon_0} \frac{Q}{2\pi R} \frac{q_0}{R}$$

$$\frac{T}{A} = Y \frac{\Delta R}{R}$$

**Q.** Where we should place a charge  $Q$  so that it remains in eqb<sup>m</sup>.



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

$$F_1 = F_2 \quad [\text{in eqb}^m]$$

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

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



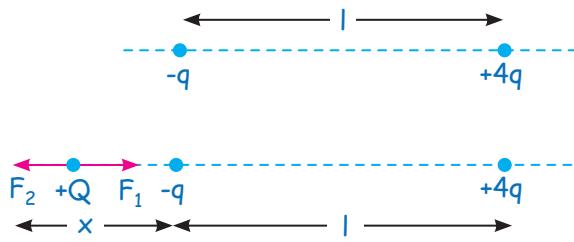
अब याद है ना  
Do vector ka sum 0,  
tbhi hoga jb vector  
equal and opposite  
ho!

$$l-x = 2x$$

$$x = l/3 \quad \text{Ans.}$$

**Q.** Where we should place a charge  $Q$  so that it remains in eqb<sup>m</sup>.

**Sol.**



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

$$F_1 = F_2 \quad [\text{in eqb}^m]$$

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

$$l+x = 2x$$

$$x = l \quad \text{Ans.}$$

#SKC

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

#SKC

+Q हो या -Q हो [रखने वाला charge] तो Ans same aaega. Ans is independent on third placing charge



**Q.** Find where we should place +Q charge so that it remains in eqb<sup>m</sup>.



**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 Vacuum



$$\text{Force applied by } q_1 \text{ on } q_2 = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} = F_0$$



In Medium



6

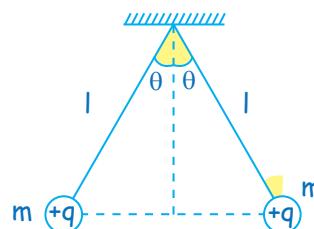
If medium is upto  $\infty$  then net force on the charge  $q_2$  will be

$$\frac{1}{4\pi\epsilon} \frac{q_1 q_2}{r^2} = \frac{1}{4\pi\epsilon_0 k} \frac{q_1 q_2}{r^2} = \frac{F_0}{k} \quad k \rightarrow \text{Dielectric const.}$$

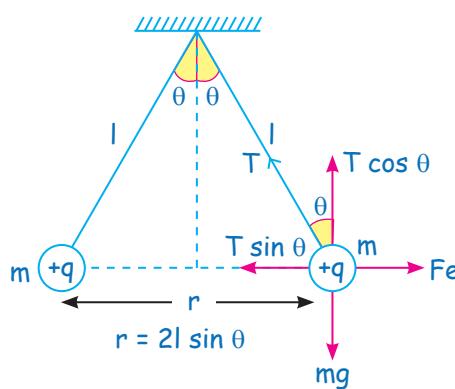
Permittivity of that medium  
 $\epsilon = \epsilon_0 \epsilon_r$

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

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



**Sol.**



$$T \sin \theta = Fe$$

$$[\theta_1 = \theta_2]$$

$$T \cos \theta = mg$$

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

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

$$Fe = \frac{1}{4\pi\epsilon_0} \frac{q \cdot q}{r^2} = \frac{1}{4\pi\epsilon_0} \frac{q \cdot q}{(2l \sin \theta)^2}$$

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

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

$$Fe = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} \text{ (same)}$$

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



$$F_{\text{net}} = F_2 - F_1$$

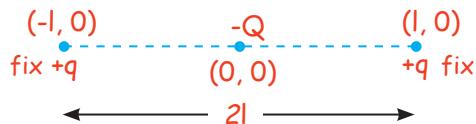
$$= \frac{kQq}{(l+x)^2} - \frac{kQq}{(l-x)^2} = -\frac{(kQq4l)x}{(l^2-x^2)^2}$$

If  $x \ll l$   
 $|l^2 - x^2| \approx l^2$

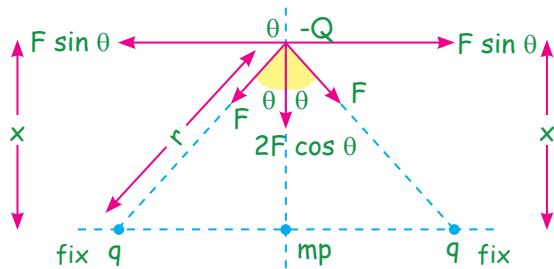
 $F_{\text{net}} = \frac{1}{4\pi\epsilon_0} \frac{Qq4l}{l^4} x$ 
 $F_{\text{net}} = \frac{-Qq}{\pi\epsilon_0 l^3} x$ 
 $F_{\text{net}} = -kx$ 
 $T = 2\pi \sqrt{\frac{m}{k}}$

In SHM  
If  $\vec{F}_{\text{net}} = -k\vec{x}$   
 $T = 2\pi \sqrt{\frac{m}{k}}$

- Q. If a charge  $(-Q, m)$  is displaced slightly along  $(+y \text{ axis})$  on smooth horizontal surface in given figure. Find time period of oscillation.



Sol.



$F_{\text{net}} = 2F \cos \theta \text{ (नीचे)}$

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

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

If  $x \ll a$

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

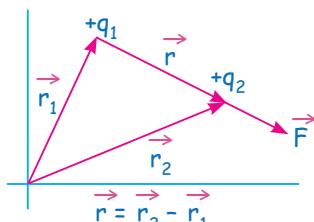
$T = 2\pi \sqrt{\frac{m}{2kQq/a^3}}$

## VECTOR FORM OF COULOMB LAW

Force by  $q_1$  on  $q_2$

$= \frac{kq_1 q_2}{r^2} \hat{r}$

$= \frac{kq_1 q_2}{|\vec{r}_2 - \vec{r}_1|^2} \frac{\vec{r}}{|\vec{r}_2 - \vec{r}_1|}$



$= \frac{kq_1 q_2}{|\vec{r}_2 - \vec{r}_1|^3} (\hat{r})$

But हम SKC लगा कर सवाल solve करेंगे।



$\text{Force on } q_2 \text{ due to } q_1 = \frac{kq_1 q_2}{r^2} \hat{r}$

##SKC

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



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

$+5C \quad \vec{r} \quad -10C$ 
 $(1, 2, 3) \quad (4, 6, 3)$

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

$F = \frac{k(5)(-10)}{25} \frac{(3\hat{i} + 4\hat{j})}{5}$ 
 $= -36 \times 10^8 (3\hat{i} + 4\hat{j}) \text{ N}$

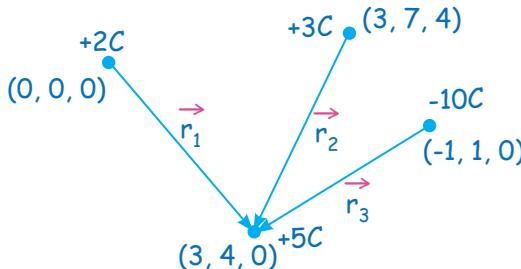
$-5C \quad \vec{r} \quad -20C$ 
 $(0, 1, 2) \quad (4, 4, 2)$

Force applied by  $-5C$  on  $-20C$ :

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

$\text{Force} = \frac{9 \times 10^9 \times (-5) \times (-20)}{5^2} \left( \frac{4\hat{i} + 3\hat{j}}{5} \right)$

- Q. Find net force on  $+5C$ .



Find  $F_{\text{net}}$  on  $+5C$

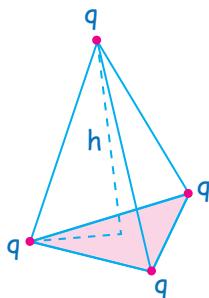
$\vec{r}_1 = 3\hat{i} + 4\hat{j}$

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

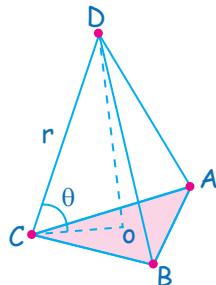
$\vec{r}_3 = 4\hat{i} + 3\hat{j}$

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

- Q.** Three charges ( $+q$ ) are placed on the vertices of an equilateral triangle of side  $a$  as shown in diagram. Find net force on  $4^{\text{th}}$  identical charge particle at a height  $h = a$  above the centroid of  $\Delta$ .



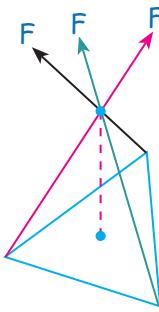
**Sol.**



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

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

Hence  $\theta = 60^\circ$



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

Top view:  $F \cos \theta$  - cancelled but  
 $F \sin \theta + F \sin \theta + F \sin \theta$

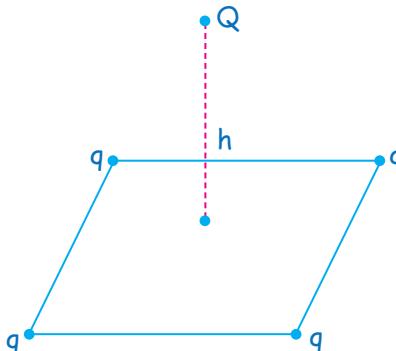
$$F_{\text{net}} = 3F \sin \theta$$

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

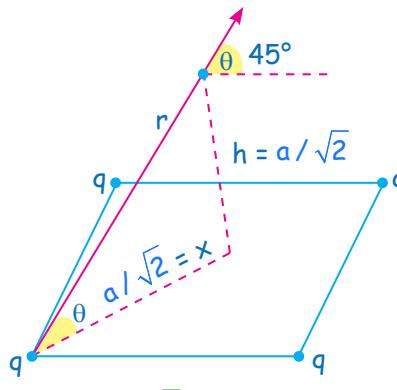
$$\left\{ \begin{array}{l} r^2 = (OD)^2 + (OC)^2 \\ = h^2 + \left( \frac{a}{\sqrt{3}} \right)^2 \\ = a^2 + \frac{a^2}{3} \\ = \frac{4a^2}{3} \end{array} \right.$$

Electrostatics

- 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.**



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

$$\sin \theta = 45^\circ$$

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

$$F_{\text{net}} = 4F \sin \theta = 4 \times \frac{kq^2}{r^2} \sin 45^\circ = 4 \times \frac{kq^2}{a^2} \times \frac{1}{\sqrt{2}}$$

## ELECTRIC FIELD

① The region surrounding a charge (or charge distribution)

② Electric field strength or electric field intensity  $E$ , it measures 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

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

Force experienced per unit test charge.



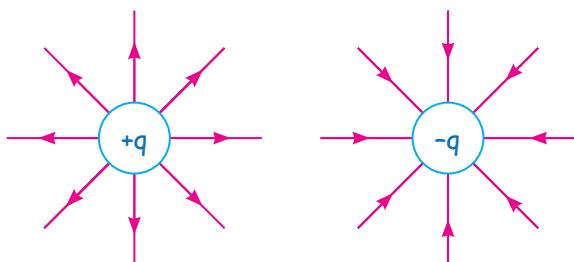
$$E_A = \lim_{q_0 \rightarrow 0} \frac{F}{q_0} = \frac{kQq_0}{r^2 q_0} = \frac{kQ}{r^2} \quad (\text{It is the electric field due to } +Q \text{ at } A)$$

1C charge pr jitna electrostatic force lag rha h, utne magnitude ki electric field hogi.



$$① \vec{E} = \frac{\vec{F}}{q_0} \quad (\text{unit} \Rightarrow \text{N/coulomb})$$

- ② EF due to +ve point charge is radially outward and due to -ve point charge its radially inward



अब हम EF निकालना सीखेंगे सही से देखो तो यह coulomb law जैसे ही question है।



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

$$(a) +Q \quad r \quad A \quad E_A = \frac{kQ}{r^2}$$

+Q charge की वजह से है।

$$(b) -Q \quad r \quad A \quad E = \frac{kQ}{r^2}$$

$$(c) \quad +q \quad +q \quad +q \quad (E_A)_{\text{net}} = E\sqrt{3}$$

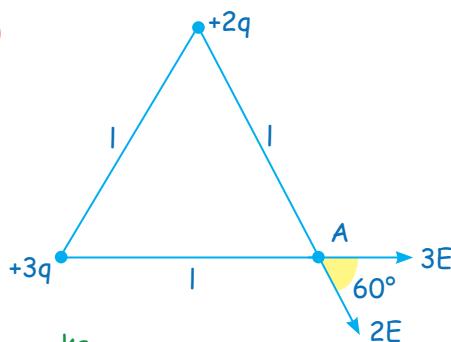
$E = \frac{kq}{l^2}$

10



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

(e)



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

$$E_{\text{net}} = \sqrt{(2E)^2 + (3E)^2 + 2 \times 2E \times 3E \times \cos 60^\circ} = E\sqrt{19}$$

(f)

$$+4q \quad +q \quad A \quad E = \frac{kq}{l^2}$$

$E = \frac{k4q}{(l/\sqrt{2})^2} = \frac{2Kq}{l^2} = 2E$

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

(g)

$$+4q \quad +2q \quad +3q \quad E = \frac{kq^2}{l^2} \quad (\text{Let})$$

$E' = E$

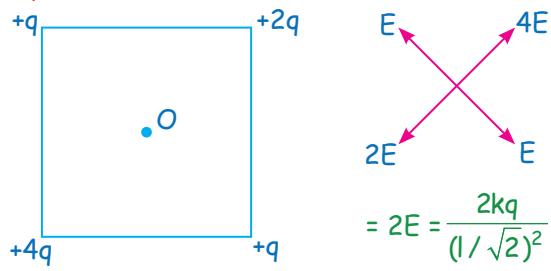
$3E \quad 4E$

Physics

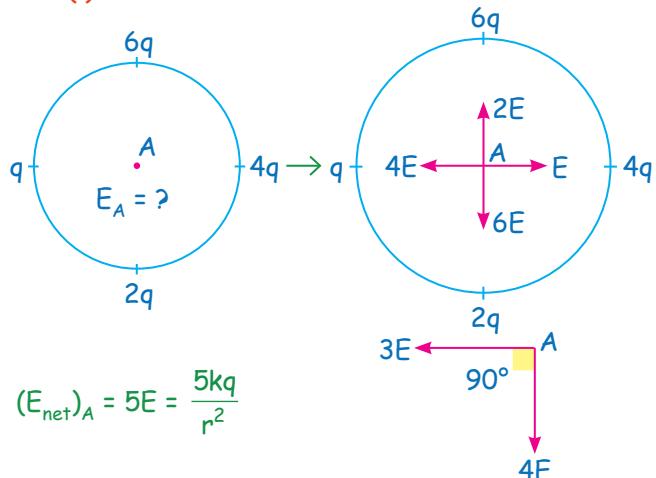
तीनों का resultant will be answer.  $3E$  और  $4E$  का resultant  $5E$  आयेगा। So answer =  $5E + E = 6E$  अगर तुमने दिया तो तुम अब तो और भी बहुत ही ज्यादा बड़े गधे हो। Bcz  $6E$  is wrong.

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

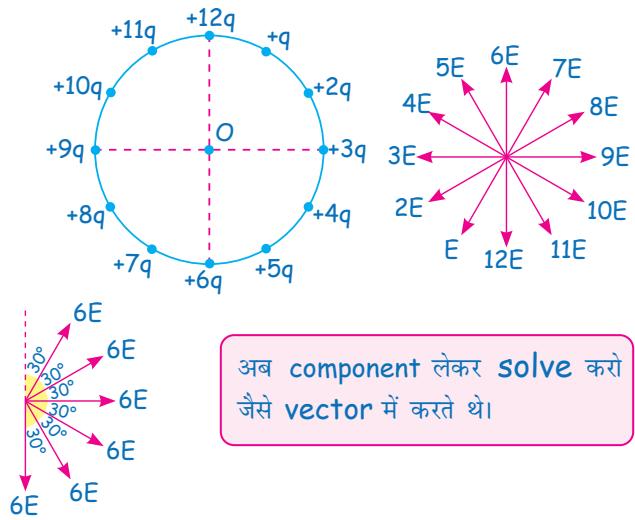
(h) Find electric field at point at centre of square (l) at O.



(i)



Q. Find  $E_{\text{net}}$  at centre O.

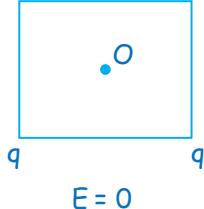


Q. In above question find the angle made by net E.F at O with x-axis

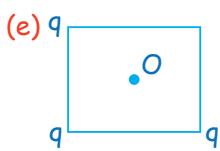
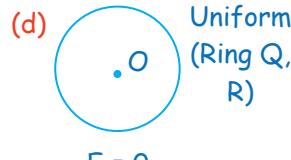
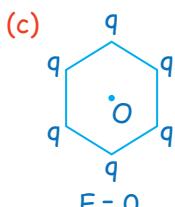
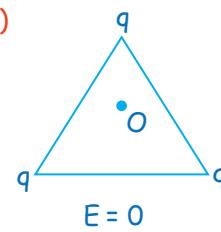
$$\text{Sol. } \tan \alpha = \frac{Ey}{Ex} = \frac{6E}{12E + 6E\sqrt{3}} = 2 - \sqrt{3}$$

Q. Find net electric field at O.

(a)



(b)

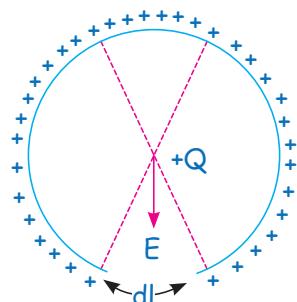


पहले की तरह यहाँ खाली corner पर  $+q$  &  $-q$  को charge assume कर सकते हैं जहाँ  $+q$  वाली तीनों corner के charges से setting करके O पर EF zero कर देगा और  $-q$  की वजह से O पर net EF आ जाएगी।

Q. अब पुराने सवालों 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.

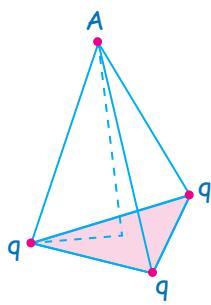
Sol.



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

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

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

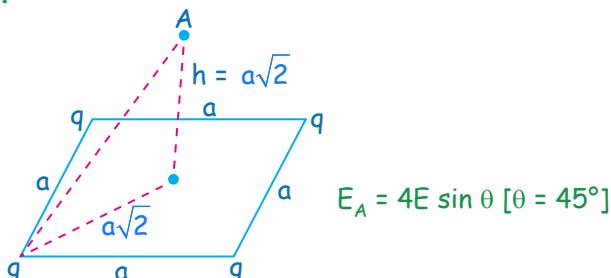


**Sol.**  $E_A = 3E \sin \theta$   
[ $\theta = 60^\circ$  already solved]

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.**



$$E_A = 4E \sin \theta [ \theta = 45^\circ ]$$

ऐ फिर आ गया रे बाबा



tere paas koi or raasta hai ?

अपने पास इसका भी एक मस्त तरीका है।



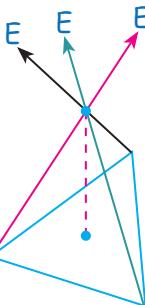
Bta Do Na Bta Do Na



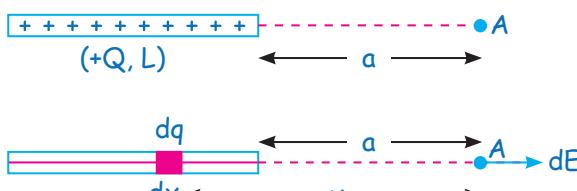
chapter के last में बताऊँगा।



Nahi

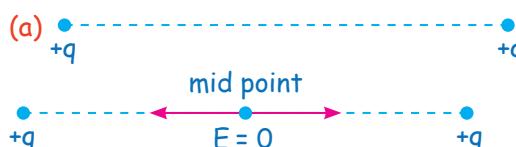


(d) Find EF at A due to rod at shown in figure.

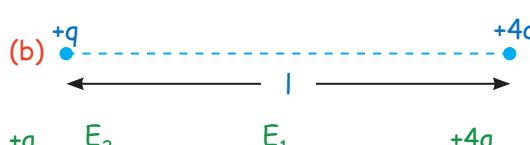


$$\text{Sol. } \int dE = \int_a^{a+L} \frac{kqdq}{x^2} = \int_a^{a+L} \frac{kQ}{L} \frac{dx}{x^2} = \frac{kQ}{a(a+L)}$$

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



**Sol.** mid point  $E = 0$

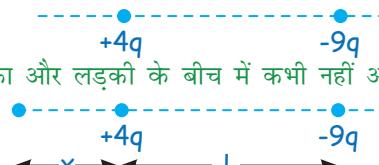


**Sol.**  $E_1 = E_2 \Rightarrow \frac{kq}{x^2} = \frac{k4q}{(l-x)^2}$

$| - x | = 2x$   
 $\frac{l}{3} = x$

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

Q. Find where electric field is zero.



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



$$\frac{k4q}{x^2} = \frac{k9q}{(x+l)^2}$$

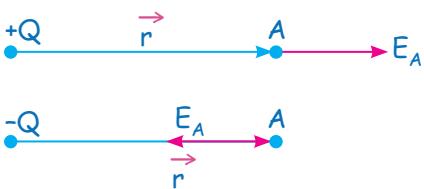
$$\frac{4}{x^2} = \frac{9}{(x+l)^2}$$

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

$$x = 2l$$

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

$$\bar{E}_A = \lim_{q_0 \rightarrow 0} \frac{\bar{F}}{q_0} = \frac{kQq_0}{r^2 q_0} \hat{r}$$



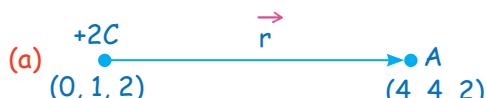
$$\vec{E}_A = \frac{kq}{r^2} \hat{r}$$

due to pt. charge

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

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

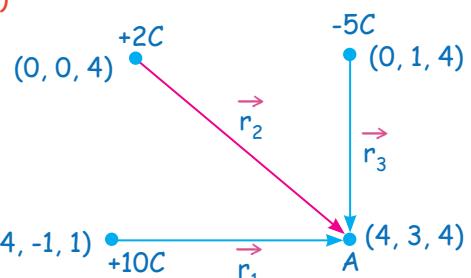
Q. Find net E.F at point A.



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

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

(b)



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

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

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

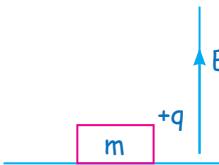
$$\boxed{\vec{F} = q\vec{E}}$$

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

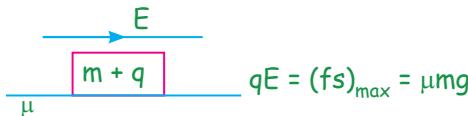


$$qE \geq mg$$

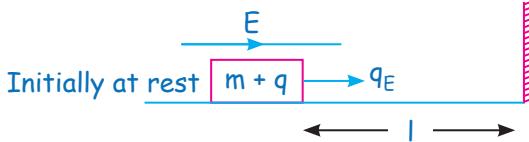
$$(E)_{\min} = \frac{mg}{q}$$

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

Sol.



Q. When block will strike the wall in given figure.



$$SOL. a = \frac{F}{m} = \frac{qE}{m}$$

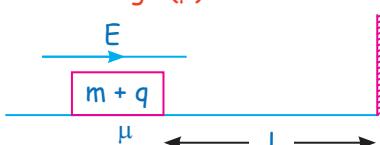
$$s = ut + \frac{1}{2} at^2$$

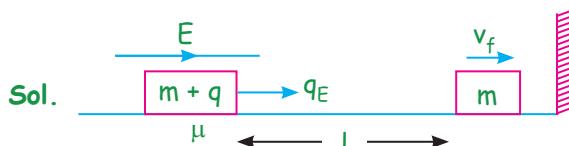
$$s = 0 + \frac{1}{2} at_0^2$$

$$t_0 = \sqrt{\frac{2s}{a}} = \sqrt{\frac{m2s}{qE}}$$

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

Q. Find velocity of block just before it hit the ball if ground is rough ( $\mu$ )



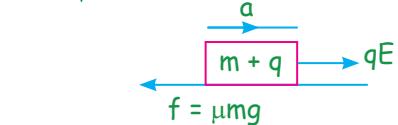


$$(WD)_{\text{all force}} = \Delta K.E$$

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

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

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



$$V^2 = O^2 + 2al$$

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

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

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

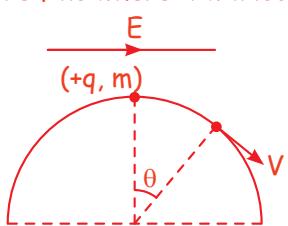
Q. A charge particle ( $q, m$ ) is projected from ground where electric field is also present along with gravitational field. Find is time period and range in following figure.



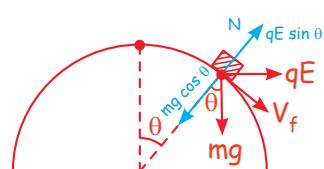
$$\text{Sol. } T = \frac{2U_y}{a_y} = \frac{2 \times V_0 \sin \theta}{g + \frac{qE \cos \beta}{m}}$$

$$R = (V_0 \cos \theta)T + \frac{1}{2} \left( \frac{qE \sin \beta}{m} \right) T^2$$

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



Sol.



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

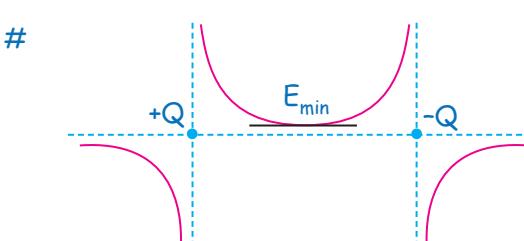
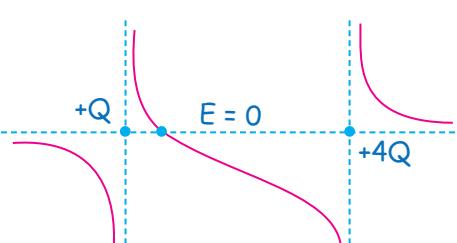
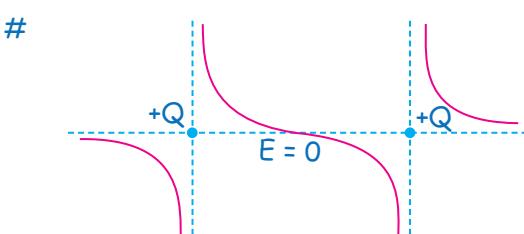
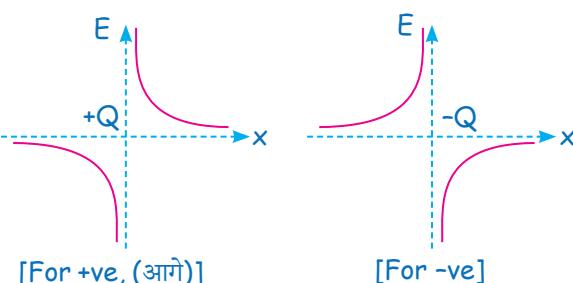
$$mg \cos \theta - qE \sin \theta = \frac{mv_f^2}{R} \text{ now solve and get}$$

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

$$\text{Sol. } 6\pi r \eta v_T = qE$$

$$\text{Ans. } 30e^-$$

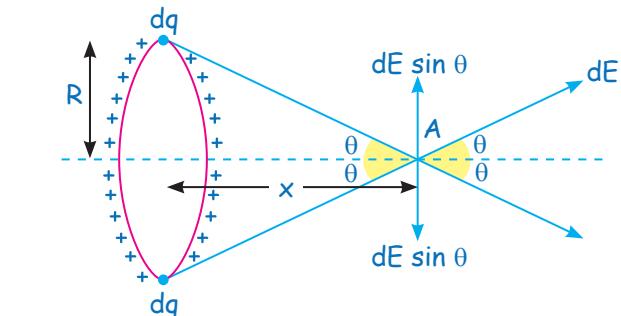
### # Graph b/w E Vs r



Use



## ELECTRIC FIELD DUE TO CHARGED UNIFORM RING AT AXIS



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

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

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

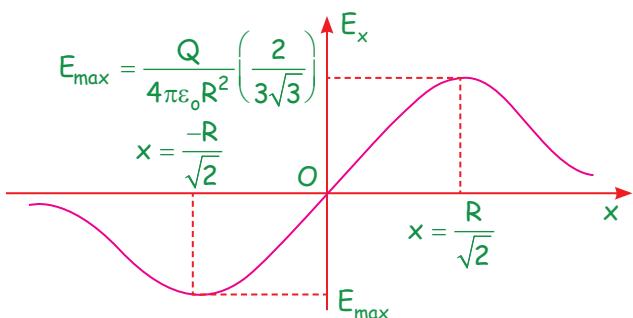
$$E_{\text{net}} = \frac{kQx}{(R^2 + x^2)^{3/2}}$$

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

Q. Find where  $E_{\text{max}} = ?$

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

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



### Charge Distribution

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

$$dq = \lambda dx \text{ [Linear Charge Density]}$$

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

$$Q = \int \lambda dx$$

$$Q = \int \sigma dA$$

$$Q = \int \rho dV$$

$$dA = \sigma dA \text{ [Surface Charge Density]}$$

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

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

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

$$\lambda = \lambda_0 x$$



Sol.

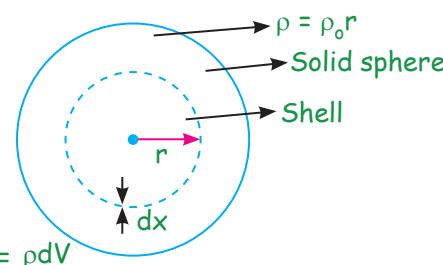


$$\int dq = \int \lambda dx$$

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

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.



$$dq = \rho dV$$

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

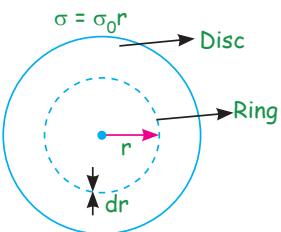
Q. If surface charge density  $\sigma$  of a disc of radius R varies as  $\sigma = \sigma_0 r$  find total charge on the disc.

Sol.

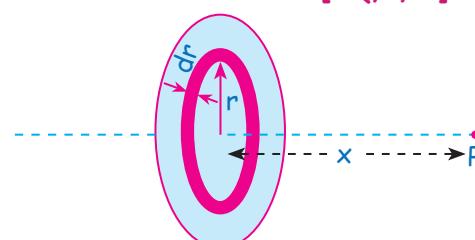
$$dq = \sigma dA$$

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

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



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



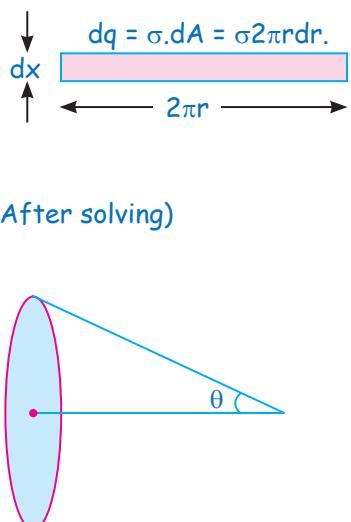
$$dE = \frac{k dq \cdot x}{(r^2 + x^2)^{3/2}} \text{ it is a E.F due to small ring at P}$$

$$E_{\text{net}} = \int dE$$

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

$$E = \frac{\sigma}{2E_0} \left( 1 - \frac{x}{\sqrt{R^2 + x^2}} \right) \quad (\text{After solving})$$

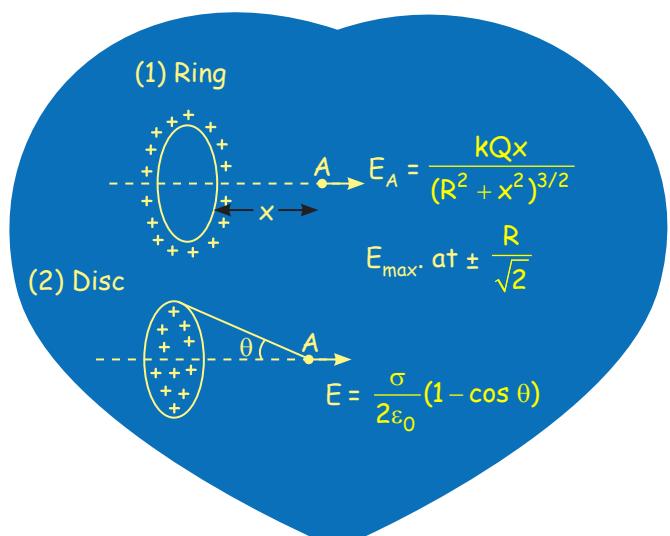
$$E = \frac{\sigma}{2E_0} (1 - \cos \theta)$$



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

$$\therefore E_A = \frac{\sigma}{2\epsilon_0} (1 - \cos 90^\circ)$$

$$E_A = \frac{\sigma}{2\epsilon_0}$$

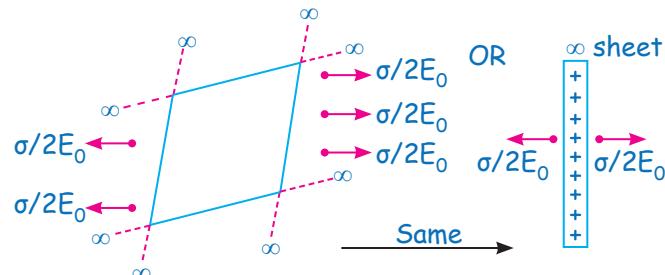


#SKC

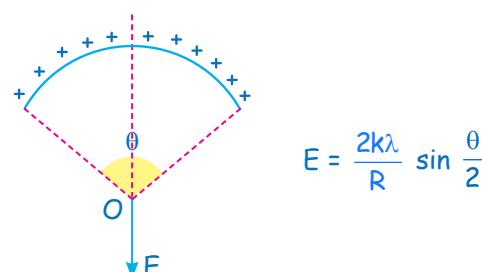
- sheet के दो मतलब
- sheet सच में बहुत बड़ी है।
- या फिर point sheet के बहुत पास है, तो उसे वह sheet लगेगी।



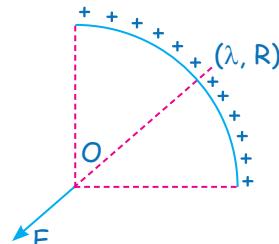
$\infty$  sheet



### ELECTRIC FIELD DUE TO CHARGED ARC AT CENTER

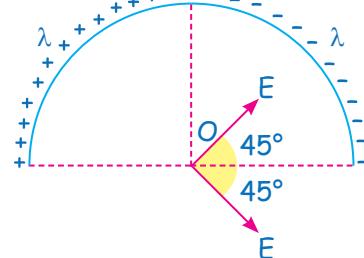


1



2

$$E = \frac{2k\lambda}{R} \sin 45^\circ$$



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

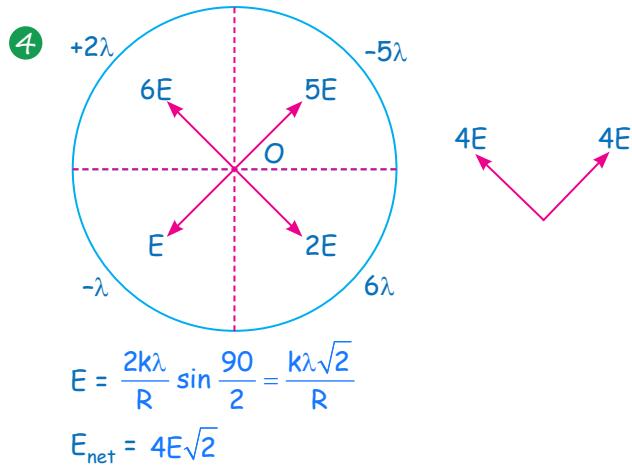
$$(E_0)_{\text{center}} = E\sqrt{2}\hat{i} = \frac{2k\lambda}{R}$$

3

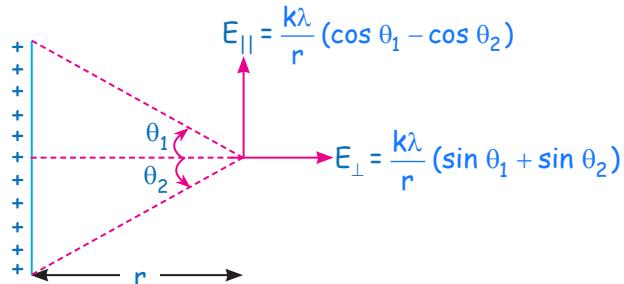
$$E_1 = \frac{2k(3\lambda)}{R} \sin 45^\circ = \frac{3\sqrt{2} k\lambda}{R}$$

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

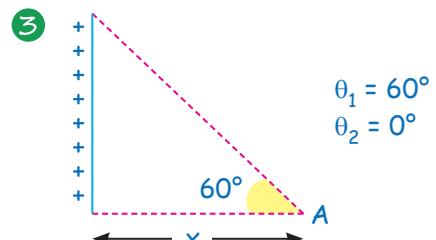
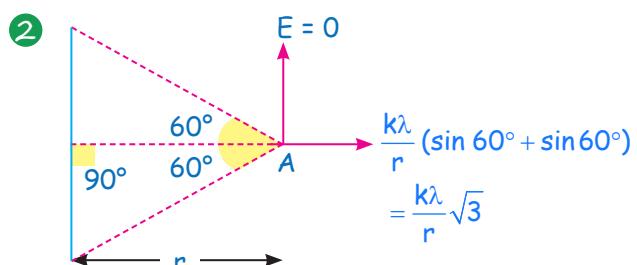
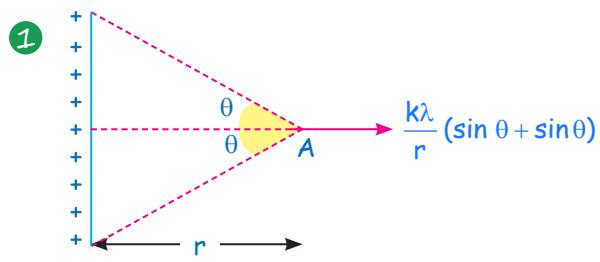
$$(E_{\text{net}})_0 = \sqrt{E_1^2 + E_2^2} = \frac{k\lambda 5\sqrt{2}}{R}$$



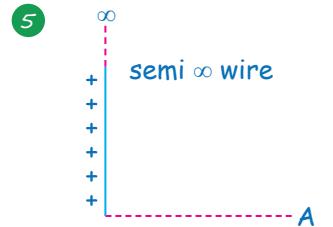
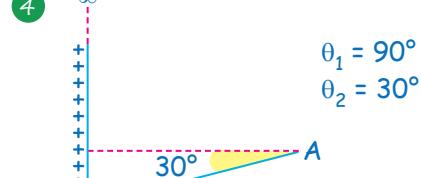
### ELECTRIC FIELD DUE STRAIGHT CHARGED WIRE AT A POINT



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



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



Here

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

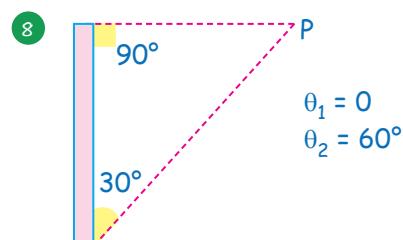
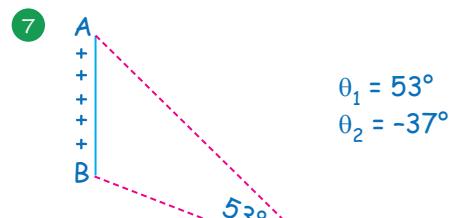
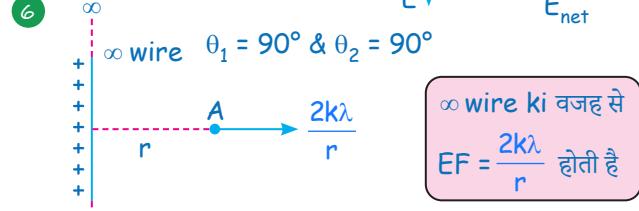
इसे याद करलो

6

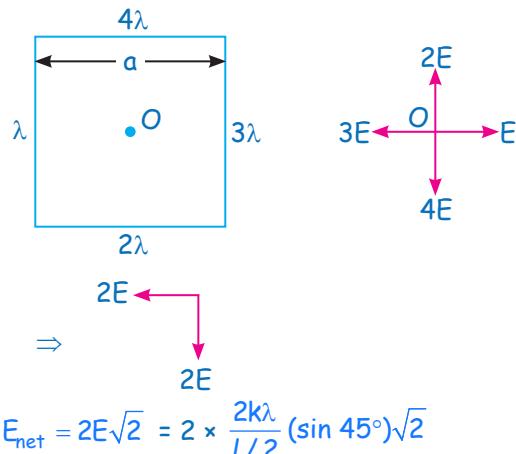
$$\frac{k\lambda}{r} (0 - 1) = -\frac{k\lambda}{r}$$

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

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



9 Find electric field at O.



10

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

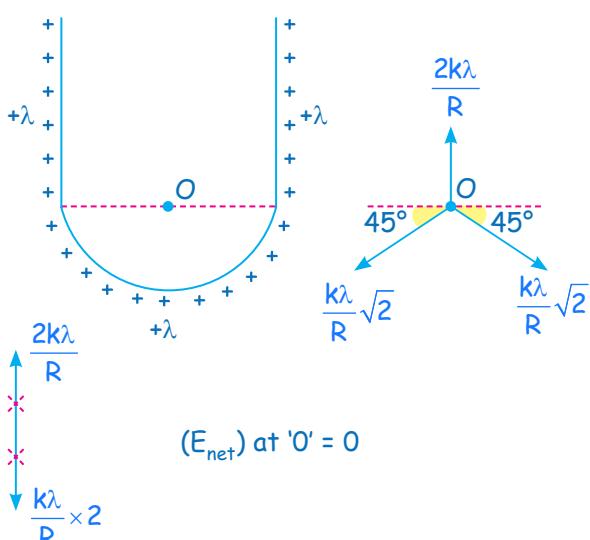
$$\theta_1 = 90^\circ$$

$$\theta_2 = 0$$

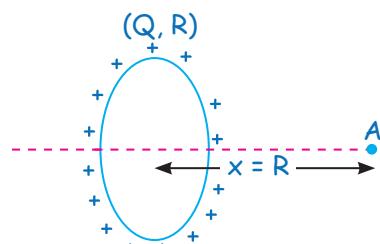
Solve and get

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

11 Find electric field at O.



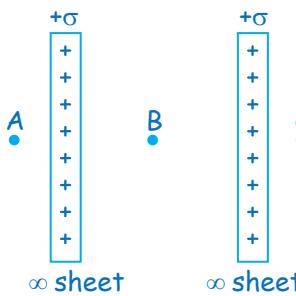
12 Find electric field at distance R from centre of A charge ring (Q, R) on the axis.



18

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

13 Find electric field at A, B, C

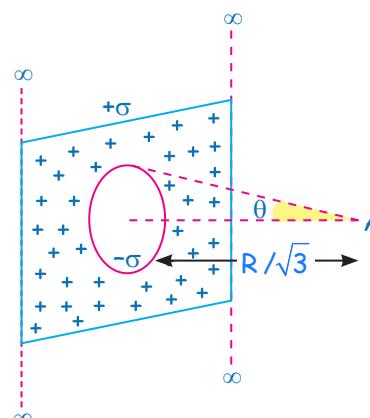


Sol.

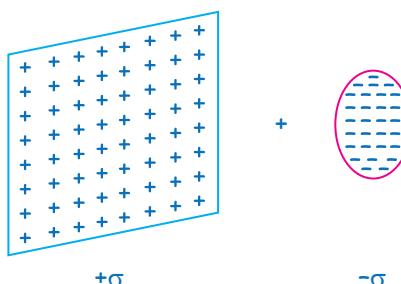
$$(E_A)_{\text{net}} = \frac{\sigma}{2E_0} + \frac{\sigma}{2E_0} = 0$$

$$(E_{\text{net}})_C = \frac{\sigma}{E_0}$$

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 infinite sheet (+σ) and disc (-σ)



Physics

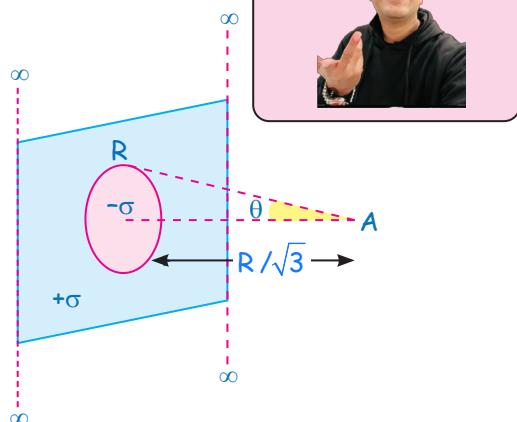
$$(Ef)_{\text{at Point A}} = \frac{\sigma}{2E_0} - \frac{\sigma}{2E_0}(1 - \cos \theta)$$

$\vec{E}$  due to  $\infty$  sheet       $\vec{E}$  due to -ve disc

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

$$= \frac{\sigma}{2E_0} - \frac{\sigma}{4E_0} = \frac{\sigma}{4E_0}$$

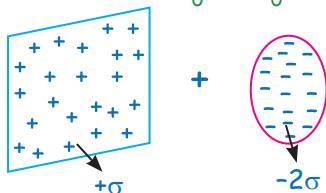
**Q.** Find electric field at A.



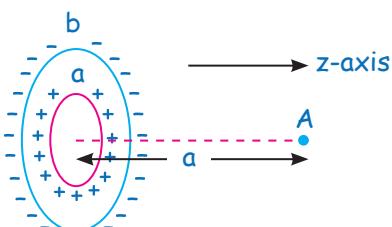
मान लो खाली जगह मे  
अब मै -σ की disk रख  
दूँ सोचो कैसे करोगे।



$$\text{Sol. } E_A = E_{\infty \text{sheet}} - E_{\text{disc}} = \frac{\sigma}{2E_0} - \frac{2\sigma}{2E_0}(1 - \cos 60^\circ)$$



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



$$\text{Sol. } R_1 = a, R_2 = b, x = a$$

$$(E_A)_{\text{net}} = 0$$

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

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

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

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

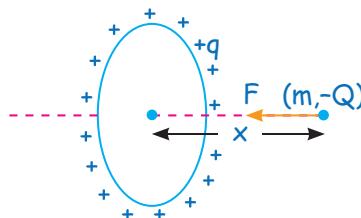
$$b^2 = 4a^2$$

$$b = 2a$$

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

**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  $+\lambda$  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<sup>m</sup> position is

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



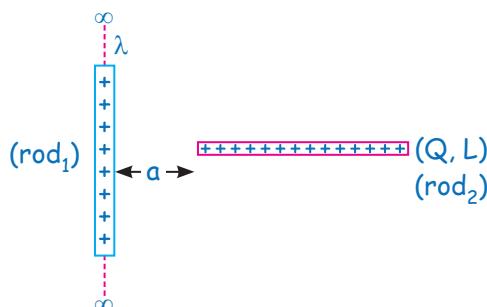
$$F_{\text{net}} = QE \quad (\text{पीछे})$$

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

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

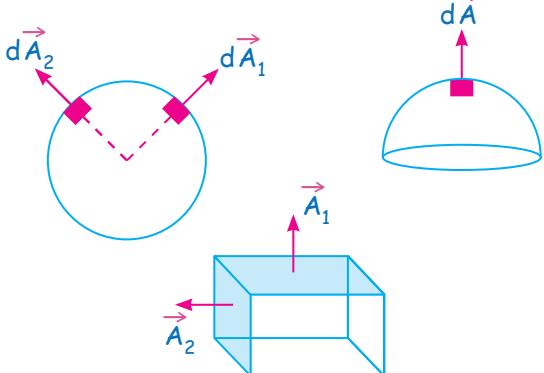
$$T = 2\pi \sqrt{\frac{m}{\left(\frac{kqQ}{R^3}\right)}}$$

**Q.** Find the force applied by infinite (rod<sub>1</sub>) to (rod<sub>2</sub>) of length L and charge Q in given figure.

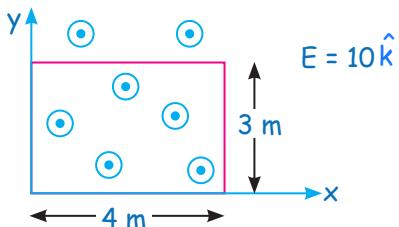




Dirx<sup>n</sup> of area vector is assume along outward normal.



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



- (a)  $\vec{E} = 10 \hat{k}$  → 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 =  $4 \times 3 = 12$   
 $\vec{A} = 12 \hat{k}$

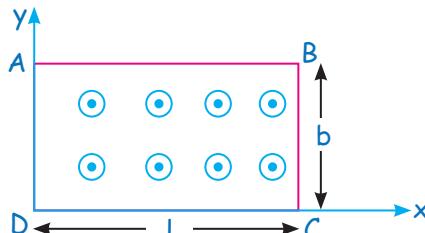
Q. Find flux through given area in following question.

1.   
 $\Rightarrow \phi = E_0 \cdot \pi R^2$

2.   
 $\Rightarrow E_0 \pi R^2 \cos 60^\circ$

3.   
 $\Rightarrow \phi = 0$

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



Sol.

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

$$\phi_{\text{net}} = \int d\phi = \int_0^l 10x \cdot b \cdot dx$$

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

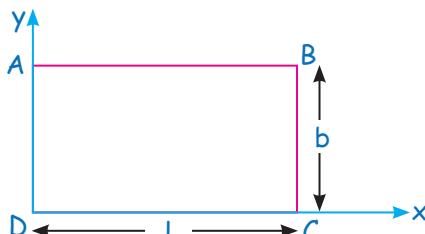
Q. In above part  $\vec{E} = 5\hat{i} + 10\hat{j} + 10x\hat{k}$

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

Last part

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

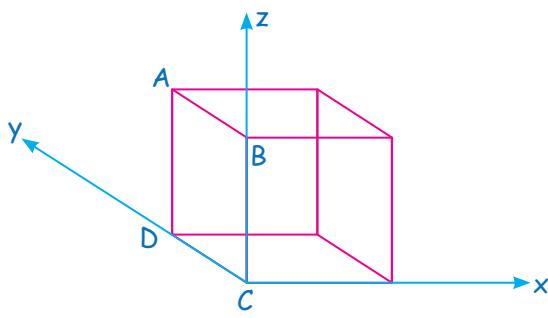
Q. Find flux through the rectangle if  $\vec{E} = 3x^2y\hat{i} + 4y^3x\hat{j} + 3x^2\hat{k}$  in given diagram



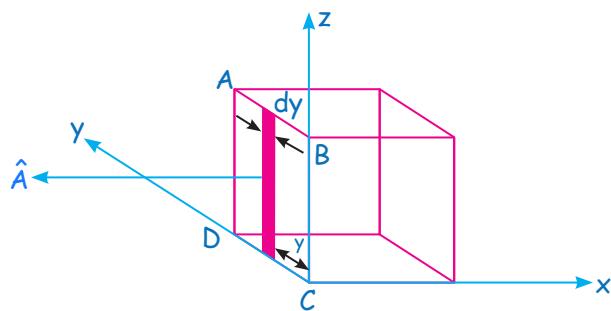
Sol.  $d\phi = \vec{E} \cdot d\vec{A}$

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

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



Sol.



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

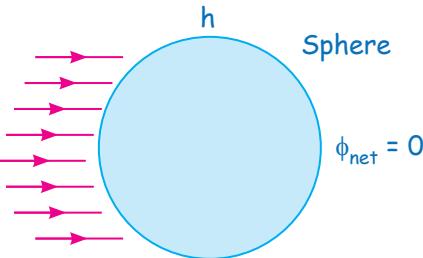
$$\phi_{ABCD} = \int_0^L 10y \cdot L dy \text{ (magnitude)} = 5L^3 \text{ (magnitude)}$$

net flux through cube = 0

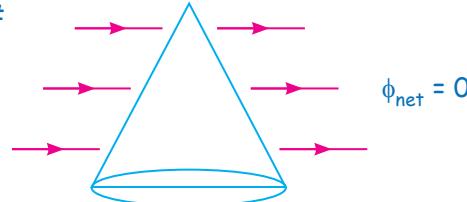
- $\phi_{in} = \phi_{body}$  में आने वाला flux  
→ Negative
- $\phi_{out} = \phi_{body}$  से जाने वाला flux  
→ Positive
- अगर आने वाली = जाने वाली  
तो body से net flux = 0



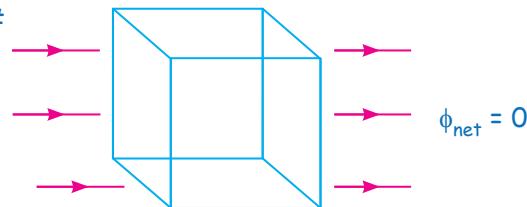
# Sphere



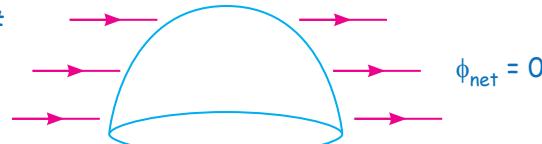
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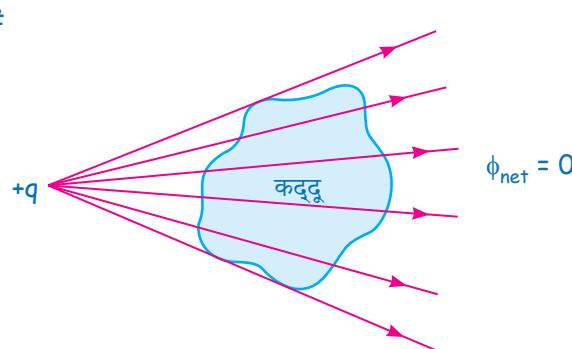
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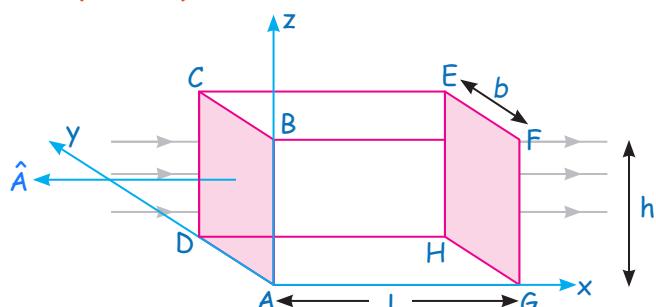
#



### ★ $\phi$ Through Body/closed area

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

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

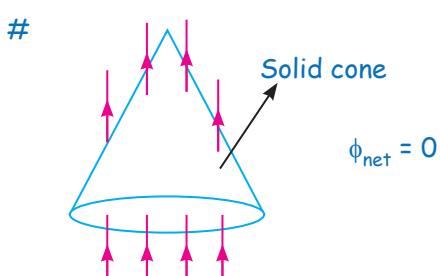
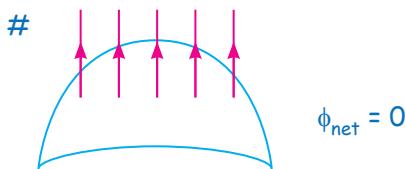


$$\phi = \vec{E} \cdot \vec{A} \cos \theta$$

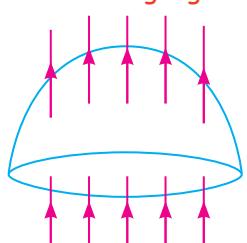
$$\phi_{ABCD} = 10bh \cos 180^\circ = -10bh = \phi_{in}$$

$$\phi_{out} = \phi_{EFGH} = \vec{E} \cdot \vec{A} \cos \theta = 10 bh$$

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

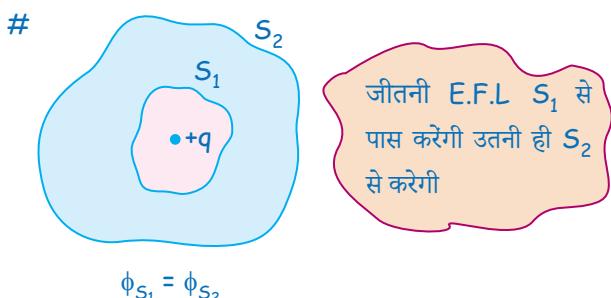
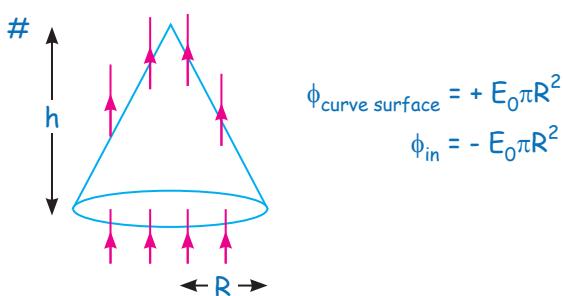


Q. Find flux through the curve surface of in hemisphere in following figure.



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

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



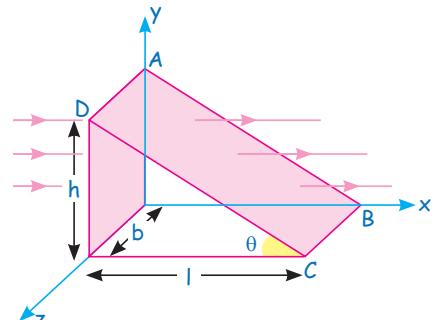
Electrostatics

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

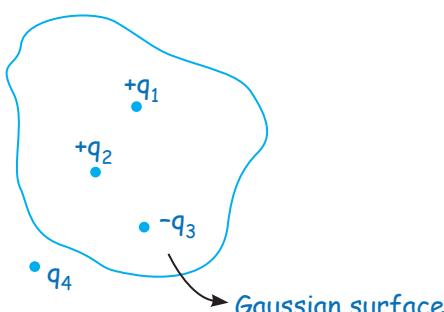
Sol.  $\phi_{\text{in}} = -E_0 hb$

$\phi_{\text{out}} = E_0 hb$

$\phi_{\text{net}} = 0$



### GAUSS LAW



$$\phi_{\text{net}} = \oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{in}}}{\epsilon_0} = \frac{q_1 + q_2 - q_3}{\epsilon_0}$$

Gauss Law

due to all the charge

$$\phi_{\text{net}(\text{close surface area})} = \oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{in}}}{\epsilon_0} = \frac{q_1 + q_2 - q_3}{\epsilon_0}$$

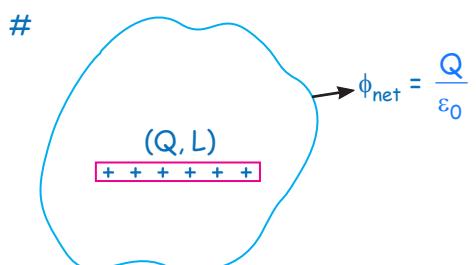
Gauss Law

# Net flux through a closed surface is equal to the  $\frac{1}{\epsilon_0}$  time to the charge inclose by the closed surface.

$$\cdot \oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{in}}}{\epsilon_0} \quad \cdot \phi_{\text{net}} = \frac{q_{\text{in}}}{\epsilon_0}$$

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$$\phi_{\text{net}} = \frac{2+4-3+5}{\epsilon_0} = \frac{8}{\epsilon_0}$$

भाई आगे  $\epsilon_0$  की जगह  $E_0$  type हो गया है इसलिए बुरा मत मानना।

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

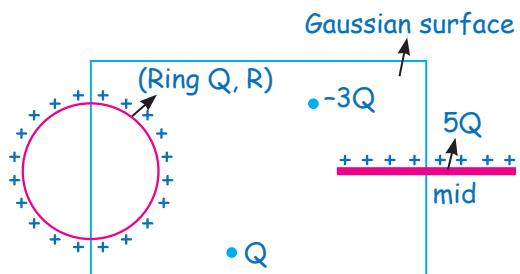


Kaisa laga mera majak

चलो अब पढ़ाई करते हैं।



### Q. Find flux through the Gaussian surface



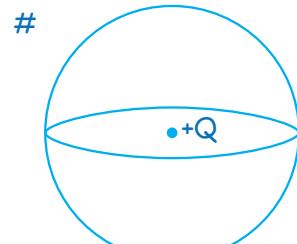
$$\phi_{\text{net}} = \frac{Q}{2E_0} - \frac{3Q}{E_0} + \frac{Q}{E_0} + \frac{5Q}{2E_0} = \frac{Q}{E_0}$$

#

$$\phi_{\text{net}} = \frac{Q}{E_0}$$

#

$$\phi_{S_1} = \phi_{S_2} \quad [\phi_{S_2} = Q/E_0, \phi_{S_1} = Q/E_0]$$



$$(\phi_{\text{net}})_{\text{full gaussian surface}} = \frac{Q}{E_0}$$

$$(\phi)_{\text{upper half hemisphere}} = \frac{Q}{2E_0} = \phi_{\text{lower half hemispheres}}$$

#

$$\phi = \frac{Q}{2E_0}$$

#

$$\phi = \frac{Q}{2E_0}$$

### # काम का डब्बा

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



- $\phi_{\text{net}} = \oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{in}}}{E_0}$

- यहां Electric field due to all charges hai. [अंदर वाले भी बाहर वाले भी]



- $q_{\text{in}} \rightarrow$  Gaussian surface के अंदर वाले charge.

- बाहर वाला charge net flux में participate नहीं करता [through closed Gaussian surface]

- Gauss Law की मदद से हम हर जगह E.F नहीं निकाल सकते, कुछ selected symmetrical cases में निकाल सकते हैं।

- Gaussian surface smartly मानना है, वर्ना कदम मिलेगा, और Gaussian surface ऐसे मानों की हर जगह पर  $\theta$  की value  $0^\circ, 90^\circ, 180^\circ$  मिले

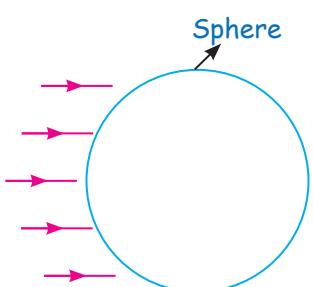


Gauss law पर based two type of question पूछे जाते हैं पहला

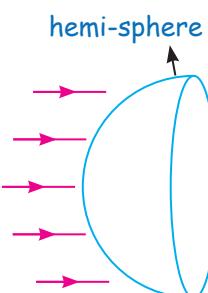
- Flux calculation based
- EF calculation based

पहले हम flux calculation based questions करेंगे

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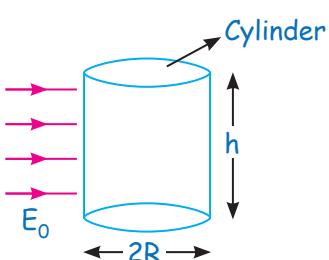


$$\begin{aligned}\phi_{\text{net}} &= 0 \\ \phi_{\text{entering}} &= \phi_{\text{in}} = -E_0\pi R^2 \\ \phi_{\text{out}} &= E_0\pi R^2\end{aligned}$$



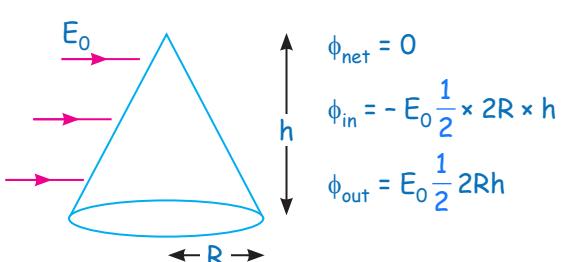
$$\begin{aligned}\phi_{\text{net}} &= 0 \\ \phi_{\text{in}} &= -E_0\pi R^2 \\ \phi_{\text{out}} &= E_0\pi R^2\end{aligned}$$

#



$$\begin{aligned}\phi_{\text{net}} &= 0 \\ \phi_{\text{in}} &= -E_0 2Rh \\ \phi_{\text{out}} &= E_0 2Rh\end{aligned}$$

#



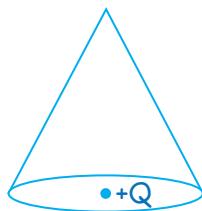
$$\begin{aligned}\phi_{\text{net}} &= 0 \\ \phi_{\text{in}} &= -E_0 \frac{1}{2} \times 2R \times h \\ \phi_{\text{out}} &= E_0 \frac{1}{2} 2Rh\end{aligned}$$

#



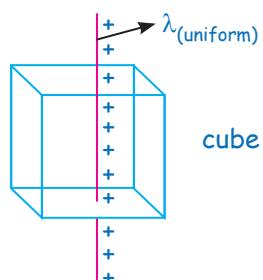
$$\phi_{\text{semi-sphere}} = \frac{Q}{2E_0}$$

#

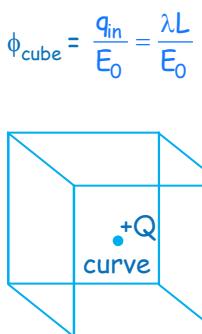
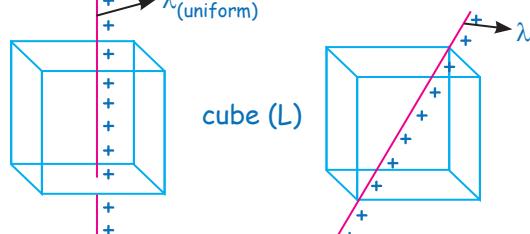


$$\phi_{\text{slant-surface}} = \frac{Q}{2E_0}$$

#



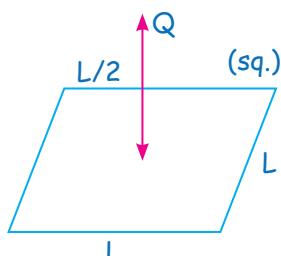
cube (L)



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

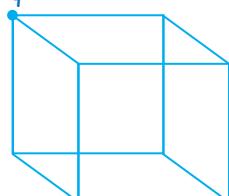
$$\phi_{\text{face}} = \frac{Q}{6E_0}$$

#



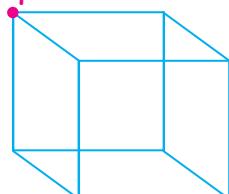
$$\phi_{\text{sq.face}} = \frac{Q}{6E_0}$$

# q

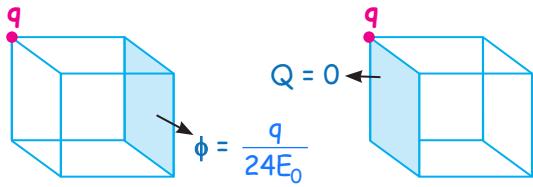


$$\phi_{\text{cube}} = \frac{Q}{8E_0}$$

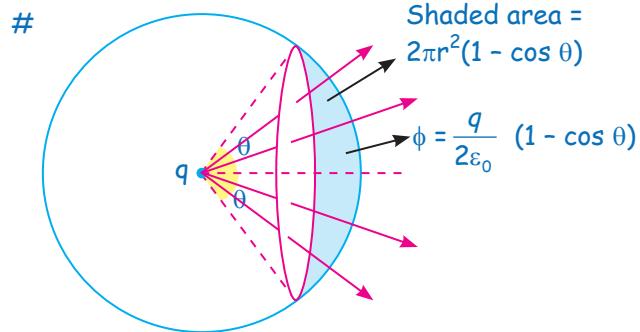
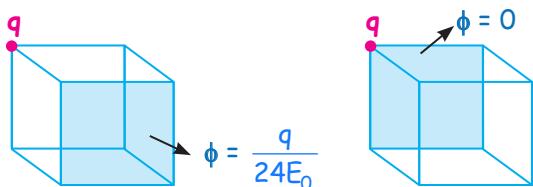
# q



$$\begin{aligned}\phi_{\text{cube}} &= \frac{Q}{8E_0} \\ \phi_{3\text{faces}} &= 0 \\ \phi_{\text{same balla}} &= \frac{q}{24E_0}\end{aligned}$$

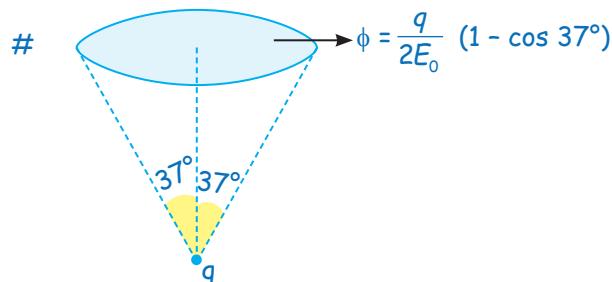
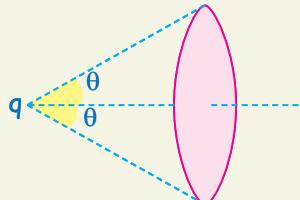


$$\text{Q. } \phi = \frac{q}{24E_0}$$

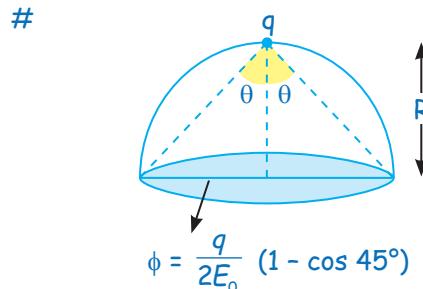


बहुत important formula ये मत भूलना  
Flux through the disc  $\phi$

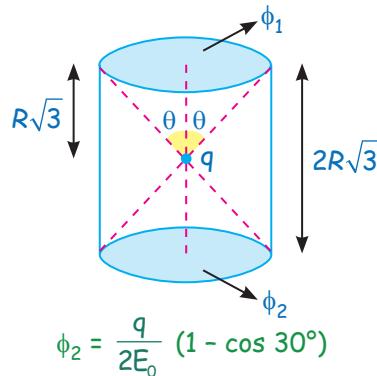
$$\phi = \frac{q}{2\epsilon_0} (1 - \cos \theta)$$



26



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



$$\phi_2 = \frac{q}{2E_0} (1 - \cos 30^\circ)$$

$$\phi_1 = \frac{q}{2E_0} (1 - \cos \theta)$$

$$\left[ \tan \theta = \frac{R}{R\sqrt{3}} \Rightarrow \theta = 30^\circ \right]$$

$$\phi_1 = \frac{q}{2E_0} (1 - \cos 30^\circ)$$

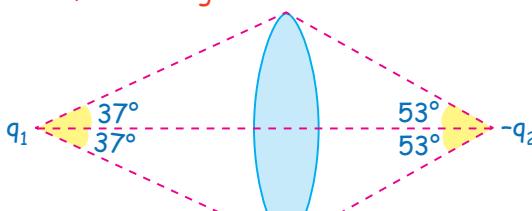
$$\phi_{\text{curve area}} = \frac{q}{E_0} - (\phi_1 + \phi_2)$$

$$= \frac{q}{E_0} - \frac{q}{E_0} (1 - \cos 30^\circ)$$

$$= \frac{q}{E_0} \frac{\sqrt{3}}{2}$$

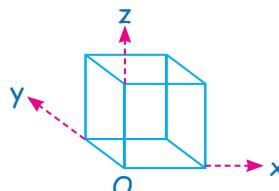
$\phi_1 \rightarrow$  flux through upper circular area  
 $\phi_2 \rightarrow$  flux through lower circular area

Q. Net flux through the disc will be



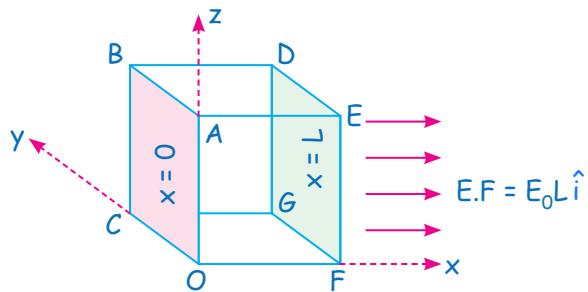
$$\phi_{\text{net}} = \frac{q_1}{2E_0} (1 - \cos 37^\circ) + \frac{q_2}{2E_0} (1 - \cos 53^\circ)$$

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



Physics

Sol.



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

$$(\phi_{out})_{cube} = \phi_{DEFHG} = E_0 L \cdot L^2 = E_0 L^3$$

$$\text{Net flux through cube} = E_0 L^3 - 0$$

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

$$E_0 L^3 = q_{in}/\epsilon_0$$

$$q_{in} = \epsilon_0 E_0 L^3$$

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

#SKC

जब भी कभी मुझसे charge enclose पूछेगा, मैं  $\phi_{net} = q_{in}/\epsilon_0$  सबसे पहले सोचूँगी

## VERIFICATION OF GAUSS LAW

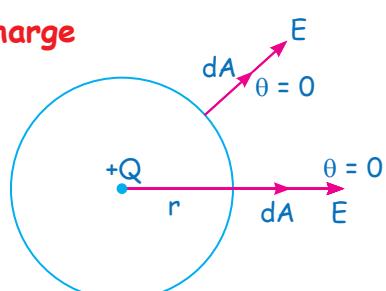
### E.F Due to Pt. Charge

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

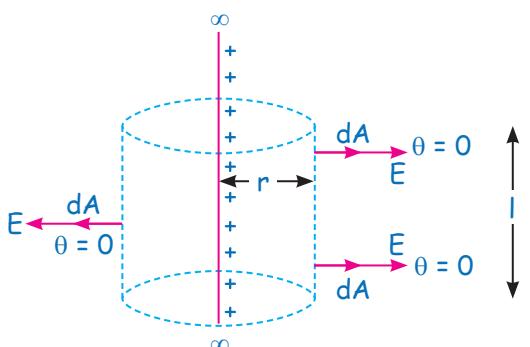
$$E \int dA = \frac{Q}{\epsilon_0}$$

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

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



### E.F DUE TO $\infty$ LINE-WIRE



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

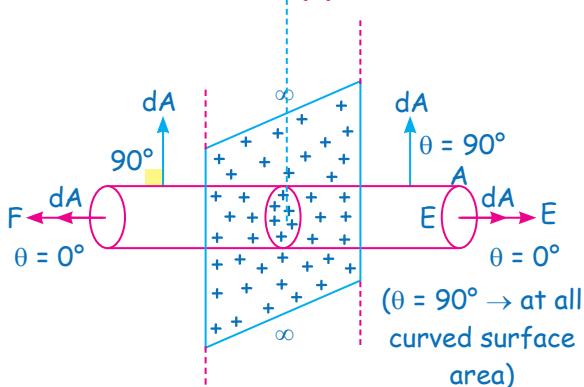
Electrostatics

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

$$E 2\pi r l = \frac{\lambda l}{\epsilon_0}$$

$$E = \frac{\lambda}{2\pi r \epsilon_0} = \frac{2k\lambda}{r}$$

### E.F Due to $\infty$ Sheet ( $\sigma$ )



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

$$EdA + EdA \cos 90^\circ + EdA = \frac{q_{in}}{\epsilon_0}$$

Curved Surface area

$$2EdA = \frac{\sigma dA}{\epsilon_0} \Rightarrow E = \frac{\sigma}{2\epsilon_0}$$

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

#### (a) E.F inside the hollow sphere

For  $r < R$

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

$$q_{in} = 0$$

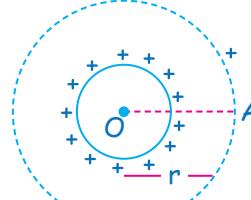
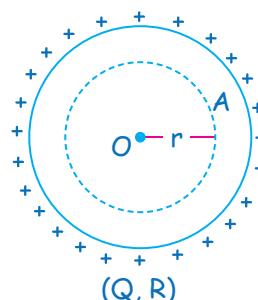
$$E = 0$$

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

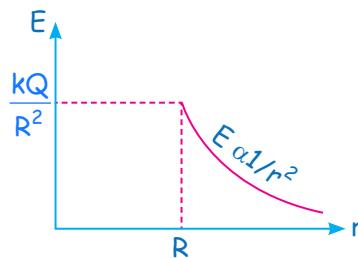
$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{in}}{\epsilon_0}$$

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

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



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



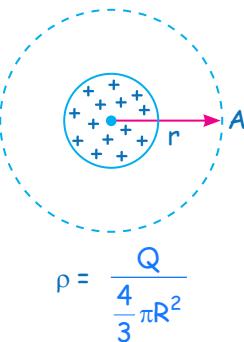
### E.F DUE TO SOLID SPHERE ( $Q$ , $R$ , $\rho$ ) [NON-CONDUCTING]

1 Outside ( $r > R$ )

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

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

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



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

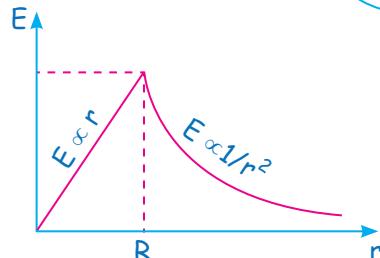
2 Inside ( $r < R$ )

$$E \cdot 4\pi r^2 = \frac{q_{in}}{E_0}$$

$$E \cdot 4\pi r^2 = \frac{\rho \cdot \frac{4}{3}\pi r^3}{E_0}$$

$$E = \frac{\rho r}{3E_0}$$

$$\vec{E} = \rho \frac{\vec{r}}{3E_0} \quad \rho \Rightarrow \text{uniform}$$



#### Very Important Result

[Solid sphere uniform  $Q$ ,  $R$ ,  $\rho$ ]

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

$$\text{अंदर} \rightarrow E = \frac{\rho r}{3E_0} \Rightarrow E \propto r$$

$$\text{at surface} \rightarrow E = \frac{kQ}{R^2}$$

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

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

- (1) Total charge of this sphere
- (2) Total charge of vol<sup>n</sup> from  $r = 0$  to  $r = R/2$
- (3) Electric field outside the sphere
- (4) Electric field inside the sphere at  $r = R/2$

Sol.

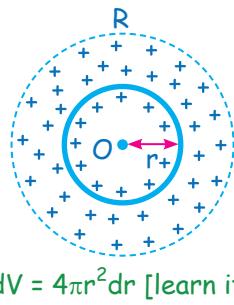
1 Total charge of this sphere

$$dq = \rho dV$$

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

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

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



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

2 Total charge of vol<sup>n</sup> from  $r = 0$  to  $r = R/2$

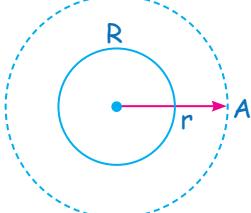
$$\int dq = \int_0^{R/2} \rho_0 r \cdot 4\pi r^2 dr$$

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

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

$$E \cdot 4\pi r^2 = \frac{Q_{\text{total}}}{\epsilon_0}$$

$$E = \frac{kQ_{\text{total}}}{\epsilon_0 r}$$



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

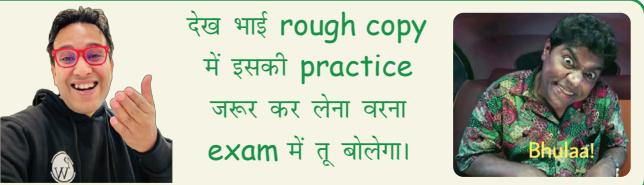
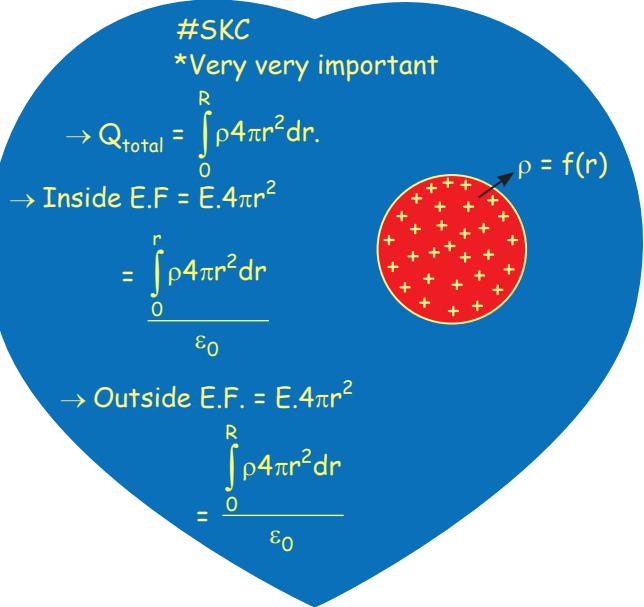
$$E \cdot 4\pi r^2 = \frac{q_{in}}{\epsilon_0} \quad \text{Gaussian surface ke andr ka charge}$$

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

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

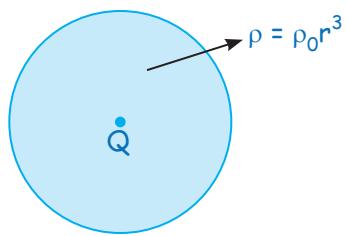
$$E \cdot 4\pi \left(\frac{R}{2}\right)^2 = \frac{\int_0^{R/2} \rho_0 r \cdot 4\pi r^2 dr}{\epsilon_0}$$

$$E = \frac{\rho_0 R^2}{4\epsilon_0}$$



\*\*\*\*\*

**Q.** Find the electric field at a point outside and inside the sphere if sphere has volume charge density  $\rho = \rho_0 r^3$  and a point charge  $+Q$  is placed at centre of sphere. (Homework)



**Sol.** Hint:

① Outside E.F

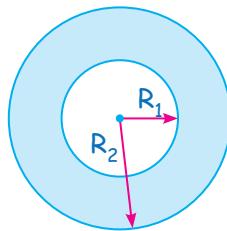
$$E = \frac{kq_{in}}{r^2}$$

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

② Inside E.F [ $r < R$ ]

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

**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

$$E \cdot 4\pi r^2 = \frac{q_{in}}{\epsilon_0} = \frac{Q}{\epsilon_0}$$

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

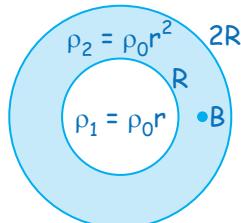
③ For  $R_1 < r < R_2$

$$E \cdot 4\pi r^2 = \frac{q_{in}}{\epsilon_0}$$

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

$$E = \text{_____ solve and get}$$

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



$$\rho_1 = \rho_0 r \quad 0 < r \leq R$$

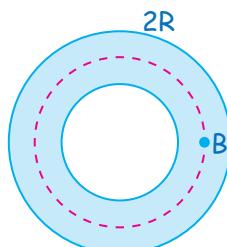
$$\rho_2 = \rho_0 r^2 \quad R < r \leq 2R$$

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

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

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

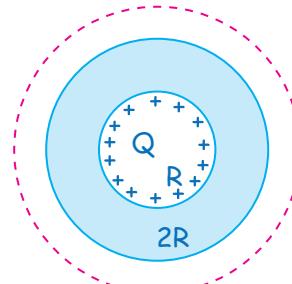
② Find E.F at  $r = 1.5 R$



$$E \cdot 4\pi r^2 = \frac{q_{in}}{E_0} = \int_0^{1.5R} \frac{\rho 4\pi r^2 dr}{E_0}$$

$$E \cdot 4\pi \left(\frac{R}{2}\right)^2 = \frac{\int_0^R \rho_0 r 4\pi r^2 dr + \int_R^{1.5R} \rho_0 r^2 4\pi r^2 dr}{E_0}$$

- Q.** A system consists of uniformly charged sphere of radius  $R$  and a surrounding medium filled by a charge with the vol<sup>n</sup> 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:



$$E \cdot 4\pi r^2 = \frac{q_{in}}{E_0} = \frac{Q + \int_0^r \rho 4\pi r^2 dr}{E_0}$$

$$E \cdot 4\pi r^2 = \frac{Q + \int_0^r \alpha/r 4\pi r^2 dr}{E_0}$$

$$E = \frac{Q + \alpha 2\pi (r^2 - R^2)}{4\pi r^2 E_0}$$

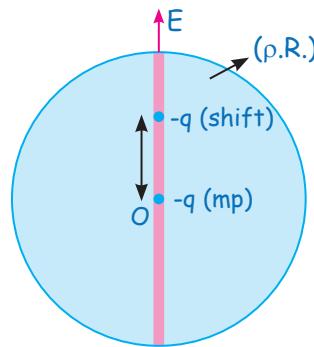
$$E = \frac{(Q - \alpha 2\pi R^2) + 2\pi r^2 \alpha}{4\pi r^2 E_0}$$

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

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

then,  $E$  will be 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 released. Find time period of oscillation.



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

$$F_{net} = qE = q \frac{\rho x}{3E_0} \quad (\text{नीचे})$$

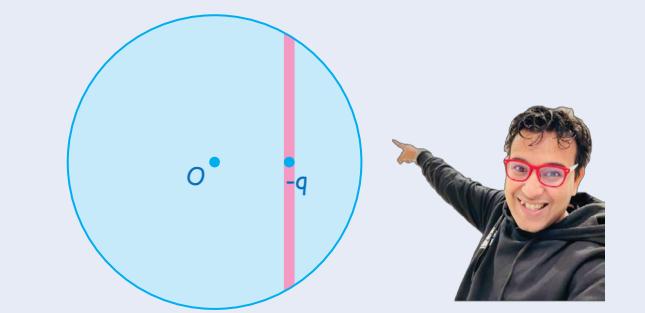
$$\vec{F}_{net} = -q \frac{\rho \vec{x}}{3E_0} = -K\vec{x} \quad (\text{SHM})$$

$$k = \frac{q\rho}{3E_0}$$

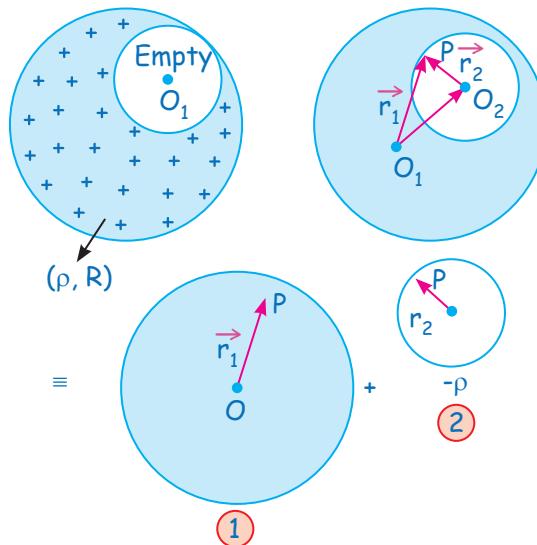
in SHM if  $F = -kx$

$$\text{then time period } T = 2\pi \sqrt{\frac{m}{k}} = 2\pi \sqrt{\frac{m}{qp/3E_0}}$$

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

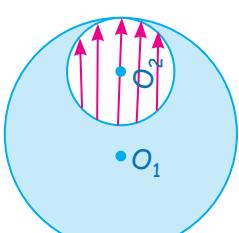
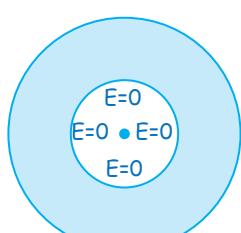
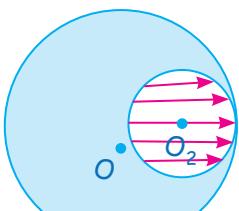
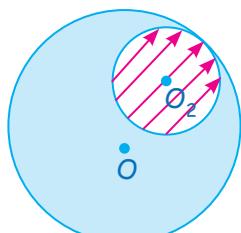


$$(\vec{E}_{\text{at } P}) = \vec{E}_1 + \vec{E}_2 = \frac{\rho \vec{r}_1}{3E_0} + \left( \frac{-\rho \vec{r}_2}{3E_0} \right) = \frac{\rho}{3E_0} [\vec{r}_1 - \vec{r}_2]$$

$$= \frac{\rho}{3E_0} \overrightarrow{O_1 O_2}$$

$$\vec{E}_{\text{inside cavity}} = \frac{r \overrightarrow{O_1 O_2}}{3E_0}$$

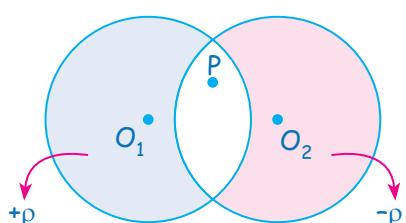
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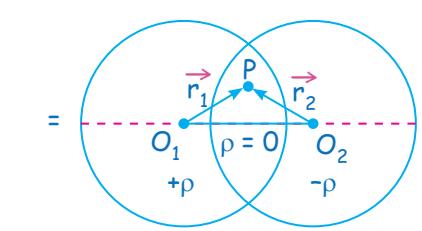
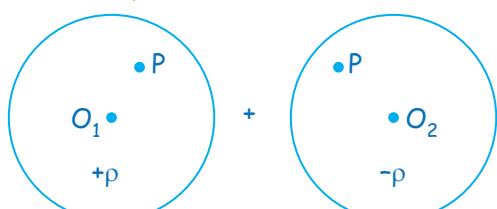
$$\overrightarrow{O_1 O_2} = 0$$

$E = 0$  (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.

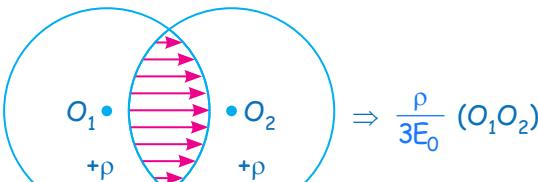


$$\vec{E}_P = \vec{E}_1 + \vec{E}_2$$

$$\vec{E}_P = \rho \frac{\vec{O}_1 \vec{P}}{3E_0} + \left( \frac{-\rho \vec{O}_2 \vec{P}}{3E_0} \right) = \frac{\rho \vec{r}_1}{3E_0} - \frac{\rho \vec{r}_2}{3E_0}$$

$$= \frac{\rho}{3E_0} [\vec{r}_1 - \vec{r}_2] = \frac{\rho}{3E_0} \overrightarrow{O_1 O_2}$$

#



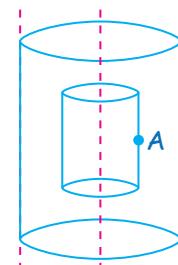
$$\Rightarrow \frac{\rho}{3E_0} (O_1 O_2)$$

### E.F due to long hollow cylinder ( $\sigma$ , R)

1 E.F inside  $r < R$

$$E \int dA = \frac{q_{in}}{E_0} = 0$$

$$E = 0$$

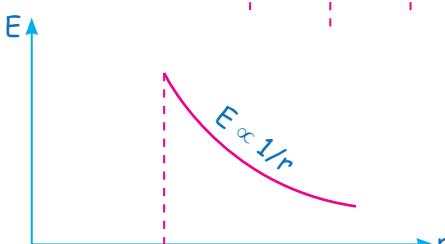
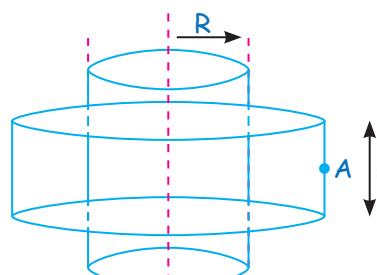


2 E.F Outside  $r > R$

$$E \int dA = \frac{q_{in}}{E_0}$$

$$E \cdot 2\pi rl = \frac{\sigma 2\pi Rl}{E_0}$$

$$E = \frac{\sigma R}{E_0 r}$$



### E.F due to solid cylinder (long) [ $\rho$ , R]

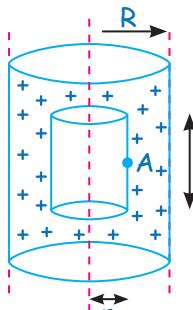
1 E.F inside  $r < R$

$$\int dA = \frac{q_{in}}{E_0}$$

$$E \cdot 2\pi rl = \rho \frac{vol^n}{E_0}$$

$$E \cdot 2\pi rl = \rho \frac{\pi r^2 l}{E_0}$$

$$E = \rho \frac{r}{2\varepsilon_0}$$



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

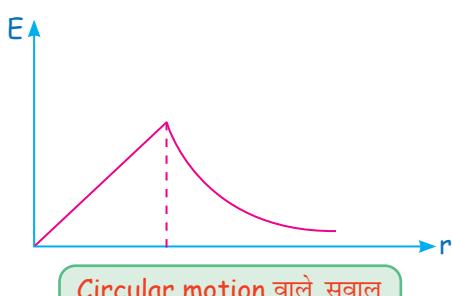
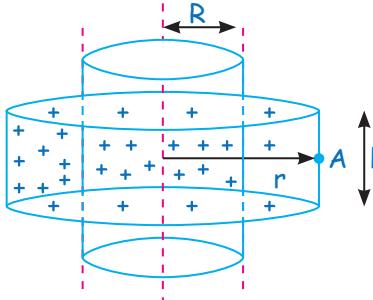
② E.F outside  $r > R$

$$E \int dA = \frac{q_{in}}{E_0}$$

$$E \cdot 2\pi rl = \rho \frac{vol^n}{E_0}$$

$$E \cdot 2\pi rl = \rho \frac{\pi R^2 l}{E_0}$$

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



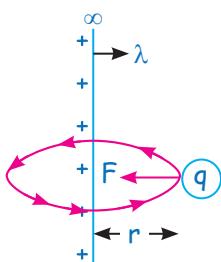
Circular motion वाले सवाल

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

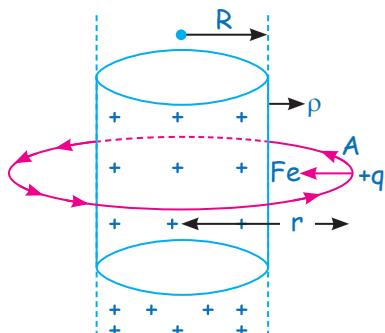
$$Sol. q \frac{2k\lambda}{r} = \frac{mv^2}{r}$$

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

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



Q. Repeat the above question if infinite wire is replaced 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.)



$$dU = dw$$

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

$$\int_{U_\infty}^U dU = - \int_{\infty}^r \frac{kq_1 q_2}{x^2} dx$$

$$U - U_\infty = \frac{kq_1 q_2}{r} \Rightarrow \text{If } U_\infty = 0 \Rightarrow U = \frac{kq_1 q_2}{r}$$

# Find P.E of system



$$U = \frac{kq_1 q_2}{r}$$

#SKC

$$\bullet U = \frac{kq_1 q_2}{r}, (U_\infty = 0) [q_1 q_2 \rightarrow \text{with sign}]$$



• 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.

• Charge 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.

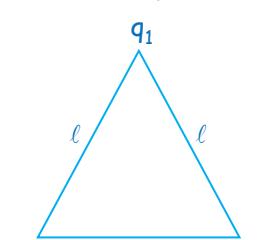


Q. Find P.E of system

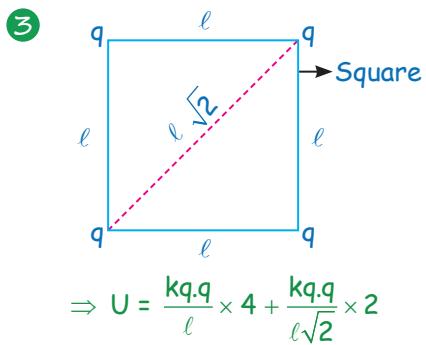


$$\Rightarrow U = \frac{kq(-3q)}{r}$$

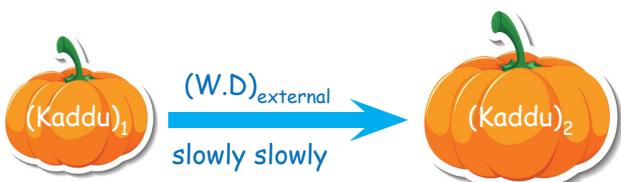
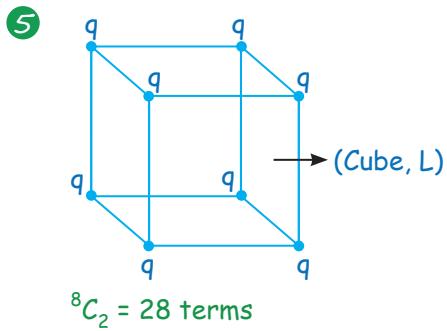
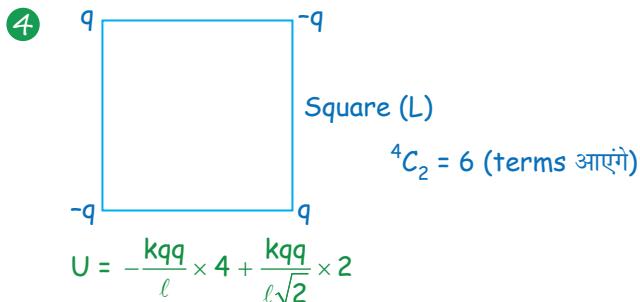
2



$$\Rightarrow U = \frac{kq_1 q_2}{l} + \frac{kq_2 q_3}{l} + \frac{kq_1 q_3}{l}$$

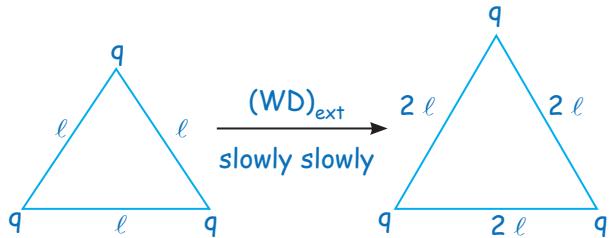


${}^nC_2 \Rightarrow$  Total no. of sets.



(kaddu)<sub>1</sub> से (kaddu)<sub>2</sub> 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.

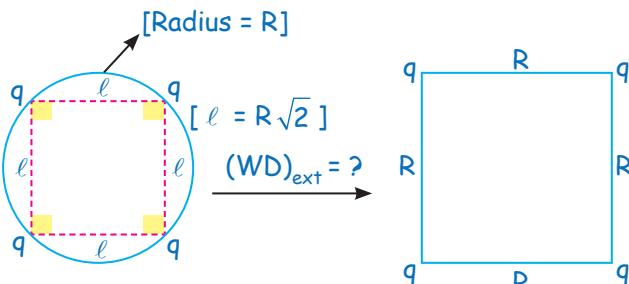


$$U_i = \frac{kq^2}{l} \times 3$$

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

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

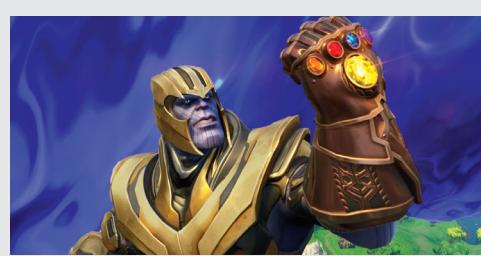
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$$U_i = \frac{kq^2}{R\sqrt{2}} \times 4 + \frac{kq^2}{2R} \times 2$$

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

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



Q. A charge  $q_1$  is fixed and another charge ( $q_2$ , m) is projected from infinity with velocity  $v_0$  directly towards  $q_1$ . Find min separation b/w them

Sol.



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

M.E  $\rightarrow$  conserve

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

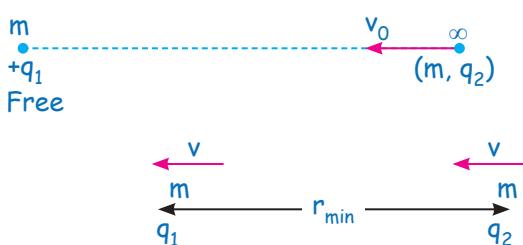
$$K_i + U_i = K_f + U_f$$

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

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

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

**Sol.**



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

$$P_i = P_f$$

$$0 + mv_0 = mv + mv$$

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

$$k_i + U_i = k_f + U_f \quad (\text{apply thanos MEC})$$

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

Solve (i) and (ii).

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



$$1 \quad k_i + U_i = k_f + U_f$$

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

$$2 \quad \text{abt point 'O' angular momentum will conserve}$$

$$L_i = L_f \quad (\text{abt 'O'}) \text{ because } \tau = 0$$

$$mv_0 d = mv_f r_{\min} \quad \text{---(2)}$$

Solve (1) and (2)

## ELECTRIC POTENTIAL

1 Potential at a pt. is defined as  $(WD)_{\text{by ext. agent}}$  required to move unit +ve charge from  $\infty$  to that point slowly - slowly (or without acc.) [ $v_{\infty} = 0$  assume]

2  $(WD)_{\text{ext.}} = \Delta U = - (WD)_{E,F}$  [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  $\Rightarrow$  interaction energy of unit +ve charge.



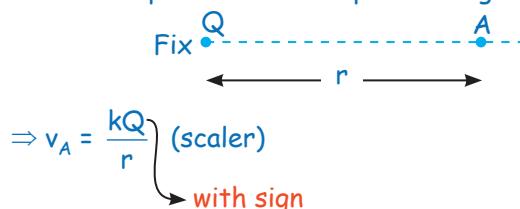
- अगर मैं  $q$  charge को ऐसी जगह रख दूँ, जहाँ potential  $v$  है तो उस वक्त [या setup] की P.E.  $= qv$  होगी।
- अगर मैं  $q$  charge को  $\infty$  से ऐसे point पर laskr रख दूँ। (होले -होले), जहाँ potential  $v$  है तो मुझे  $qv$  work done krna padega.
- $\vec{F} = q\vec{E}$ :  $-q$  को ऐसी जगह रख दूँ जहाँ  $\vec{E}$  है तो उस पर उस वक्त  $q\vec{E}$  electrostatic force lagega.
- अगर मैं किसी charge को [होले-होले] A point se B पर लेकर जाऊं तो  $(WD)_{\text{ext.}} = \Delta U$   
 $(WD)_{\text{electric field}} = -\Delta U$   
 $(WD)_{\text{ext.}} = \Delta U = - (WD)_{E,F}$

# काम का ढब्बा

- $\vec{F} = q\vec{E}$
- $U = qv$
- $\Delta U = q\Delta v$
- $k_i + U_i = k_f + U_f$  (Thanos) ME  $\rightarrow$  conserve

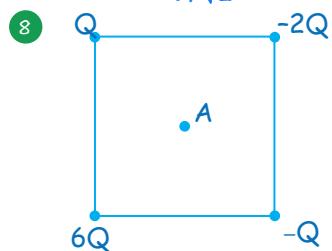
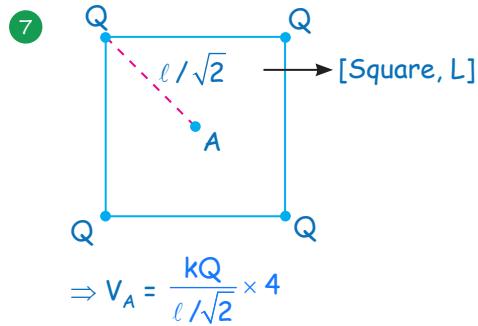
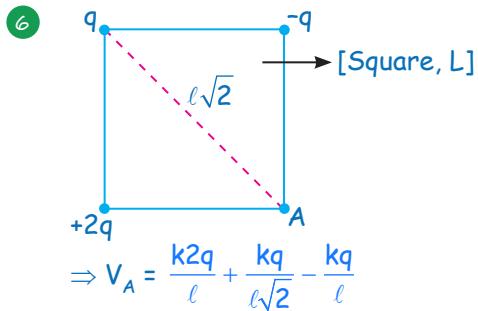
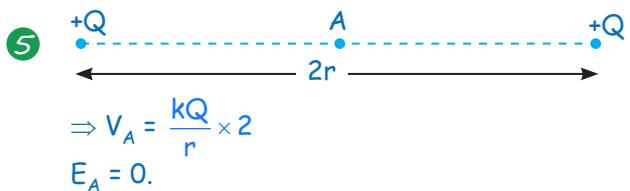
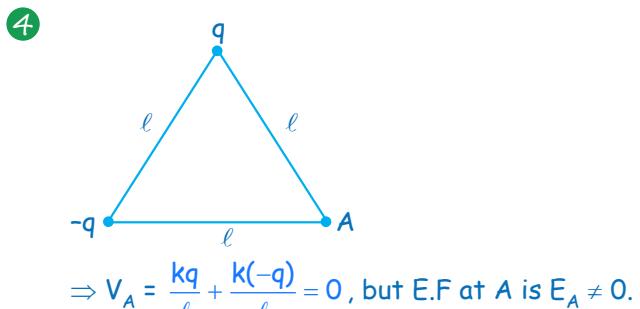
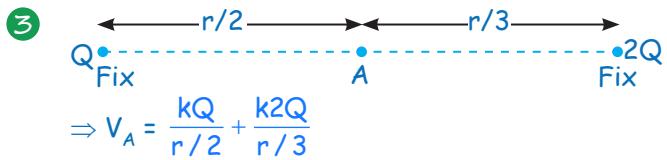
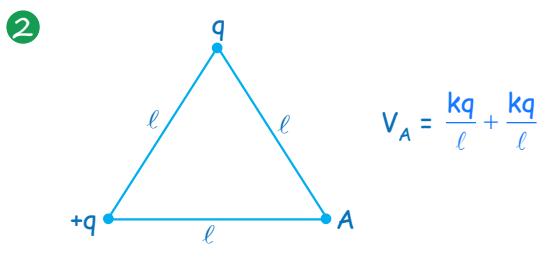
- $+Q$   $\frac{A}{r}$  E.F.  $= \frac{kQ}{r^2}$ , Potential at 'A'  $\frac{kQ}{r}$
- +1C charge ko  $\infty$  se 'A' pr laane me Ext. WD = Potential at A [होले -होले]

# Electric potential due to point charge Q at a pint



# Find electric potential at Pt. 'A'.

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

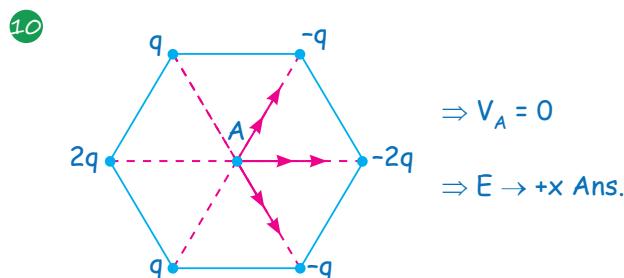
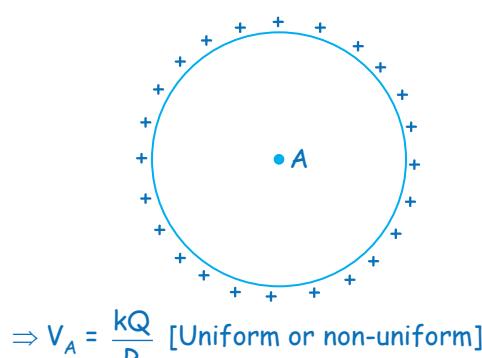


Electrostatics

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

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

9. ring (Q, R)

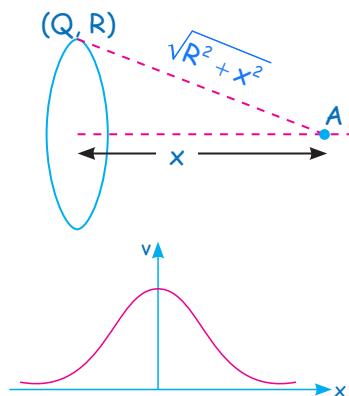


Potential at a point x from center of charged ring

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

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

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

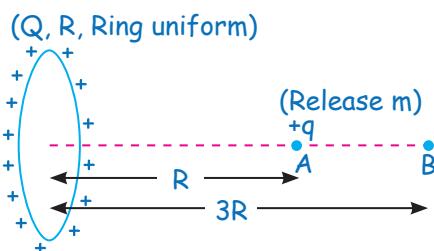


Q. Find potential at A due to charge ring (Q, R).

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)



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

$$q \cdot \frac{kQ}{\sqrt{2R^2}} = \frac{1}{2}mv^2 + q \cdot \frac{kQ}{\sqrt{10R^2}}$$

(Solve and get v)

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

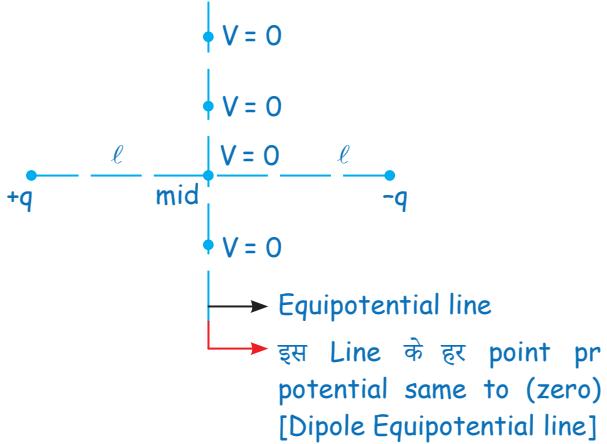
Sol.  $k_A + U_A = k_\infty + U_B$



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

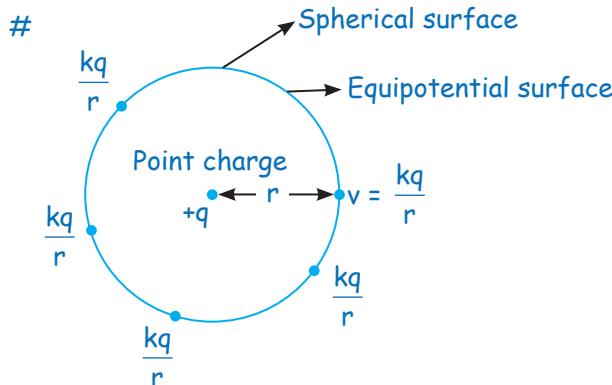
$$\frac{qkQ}{\sqrt{2R^2}} = \frac{1}{2}mv_f^2$$

#



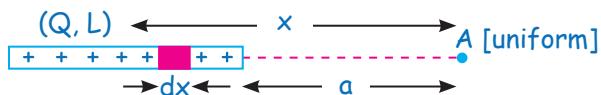
#SKC

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 hogा.



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

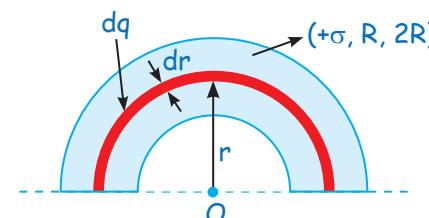
Sol.



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

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

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



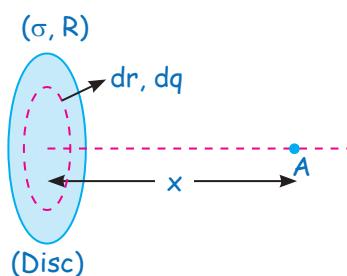
$$\int dv = \int \frac{k dq}{r} = \int_R^{2R} \frac{k \sigma \pi r dr}{r} = k \sigma \pi r$$

$$dq = \sigma dA$$

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



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



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

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

Solve and get and याद करलो

$$V_A = \frac{\sigma}{2E_0} (1 - \cos \theta) \times (\sqrt{R^2 + x^2})$$

$$\text{or } V_A = \frac{\sigma}{2\epsilon_0} \left( \sqrt{R^2 + x^2} - x \right)$$

$$V_{\text{near center}} = \frac{\sigma}{2\epsilon_0} R \text{ (just bahar)}$$

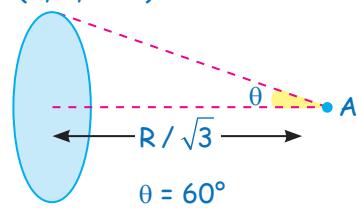
$$E_A = \frac{\sigma}{2E_0} (1 - \cos \theta)$$

$$E_{\text{near center}} = \frac{\sigma}{2\epsilon_0} \text{ (just bahar)}$$



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

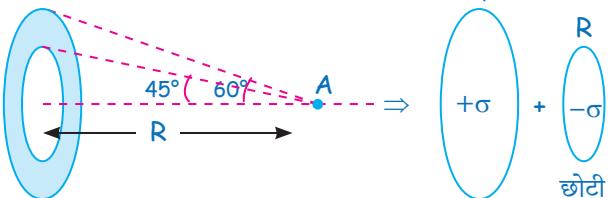
#  $(\sigma, R, \text{Disc})$



$$E_A = \frac{\sigma}{2E_0} (1 - \cos 60^\circ)$$

$$v_A = \frac{\sigma}{2E_0} (1 - \cos 60^\circ) \left( \sqrt{R^2 + \left( \frac{R}{\sqrt{3}} \right)^2} \right)$$

#  $(\sigma, \text{Disc outer radius } R\sqrt{3})$



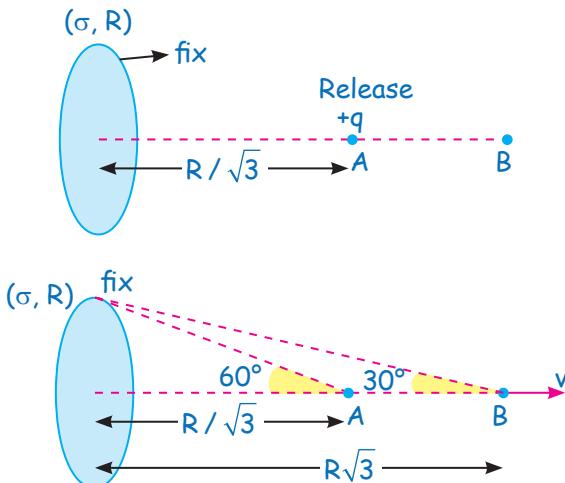
$$\vec{E}_A = \vec{E}_{\text{बड़ी Disc}} + \vec{E}_{\text{छोटी Disc}} (-\sigma)$$

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

$$\rightarrow v_A = \left[ \frac{\sigma}{2E_0} (1 - \cos 60^\circ) \sqrt{(R\sqrt{3})^2 + R^2} \right]$$

$$- \left[ \frac{\sigma}{2E_0} (1 - \cos 45^\circ) \sqrt{2R^2} \right]$$

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



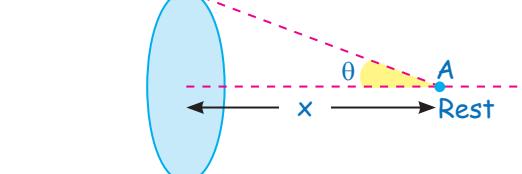
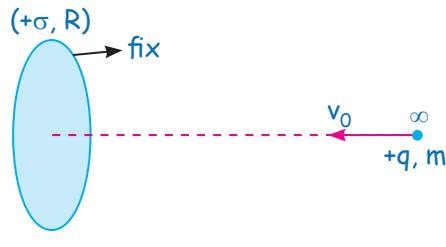
$$k_A + U_A = k_B + U_B$$

$$k_A + qv_A = k_B + qv_B$$

$$0 + q \frac{\sigma}{2E_0} (1 - \cos 60^\circ) \sqrt{R^2 + \left( \frac{R}{\sqrt{3}} \right)^2}$$

$$= \frac{1}{2} mv_B^2 + q \frac{\sigma}{2E_0} (1 - \cos 30^\circ) \sqrt{R^2 + (R\sqrt{3})^2}$$

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



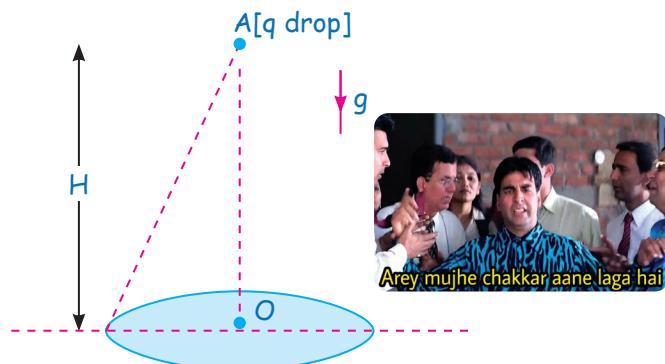
$$k_i + U_i = k_f + U_f$$

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

$$\frac{1}{2} mv_0^2 = q \frac{\sigma}{2E_0} (1 - \cos \theta) \times (\sqrt{R^2 + x^2})$$

Q. A non-conducting disc of radius a and uniform positive surface charge density  $\sigma$  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  $q/m = 4 \epsilon_0 g/\sigma$

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



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

$$0 + mgH + qV_A = 0 + 0 + qV_0$$

$$0 + mgH + q \frac{\sigma}{2\epsilon_0} (\sqrt{R^2 + H^2} - H) = 0 + 0 + q \frac{\sigma}{2\epsilon_0} \times R$$

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

### RELATION BETWEEN ELECTRIC POTENTIAL AND ELECTRIC FIELD

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

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

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

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

### Potential Due to Point Charge

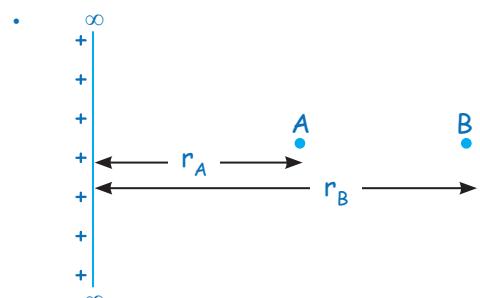
$$dv = - \vec{E} \cdot d\vec{r}$$

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

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

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

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



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

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

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

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

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

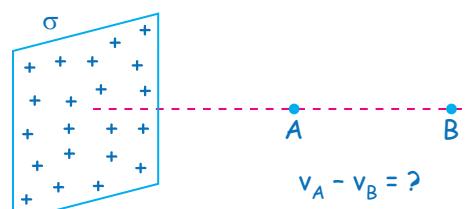
#SKC

$$V_{\text{बड़ा}} - V_{\text{छोटा}}$$

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

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

### Potential Difference Between Two Point Due to $\infty$ Sheet



$$v_A - v_B = ?$$

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

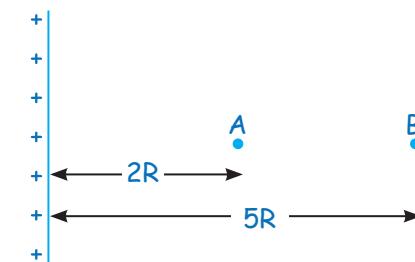
$$\int_A^B dv = - \int_{r_A}^{r_B} \frac{\sigma}{2\epsilon_0} dr$$

$$v_B - v_A = \frac{-\sigma}{2\epsilon_0} \int_{r_A}^{r_B} dr$$

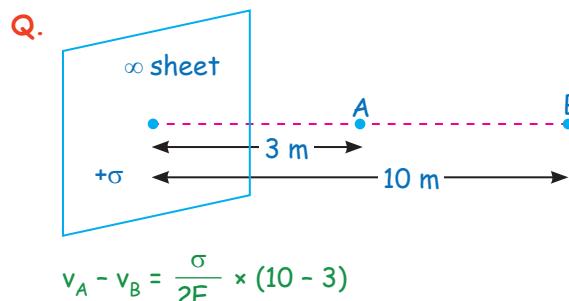
$$v_A - v_B = \frac{\sigma}{2\epsilon_0} (r_B - r_A)$$

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

Q. Find potential difference between A and B.

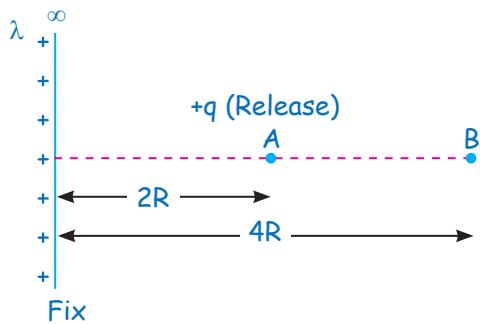


$$v_A - v_B = 2k\lambda \ln \left( \frac{5R}{2R} \right)$$



$$v_A - v_B = \frac{\sigma}{2\epsilon_0} \times (10 - 3)$$

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



$$V_A - V_B = 2k\lambda \ell \ln \left( \frac{4R}{2R} \right)$$

$$k_A + U_A = k_B + U_B$$

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

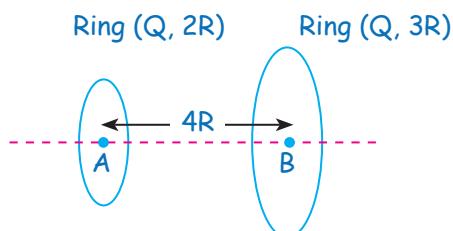
$$qv_A - qv_B = \frac{1}{2} mv_B^2$$

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



आवाज आ रही है ना सभी को.....  
ring disk infinite sheet, infinite  
wire etc. में thanos वाले सवाल बनाए  
जा सकते हैं 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  $V_A - V_B$

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

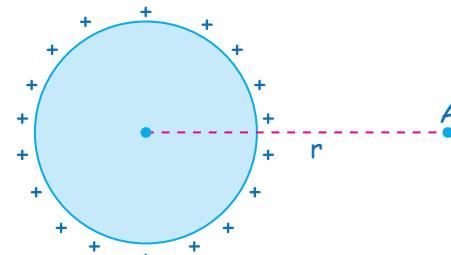
$$= - \int \frac{q \vec{E} \cdot d\vec{r}}{q} = - \int \vec{E} \cdot d\vec{r}$$

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

# If  $E = 0 \Rightarrow \Delta V = 0 \Rightarrow V \rightarrow \text{const.}$

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

1  $r > R$  [outside]



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

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

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

$$\Rightarrow v = \frac{kQ}{r} \Rightarrow V_{\text{outside}}$$

$$\Rightarrow V_{\text{surface}} = \frac{kQ}{R}$$

•  $v = \frac{kQ}{R}$  [अंदर]

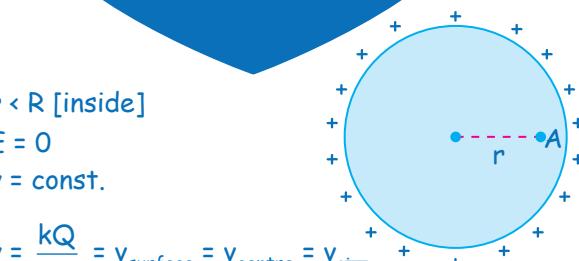
•  $v = \frac{kQ}{r}$  [बाहर]

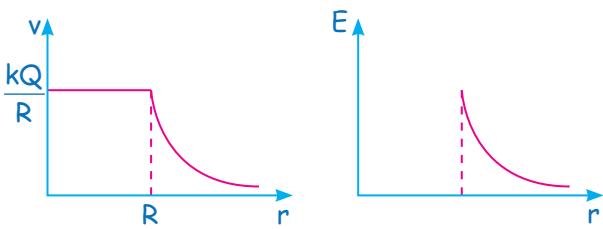
2  $r < R$  [inside]

$$E = 0$$

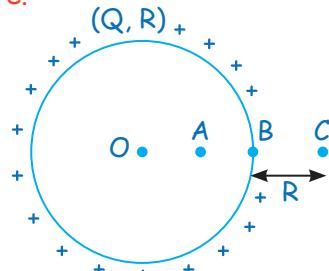
$$v = \text{const.}$$

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





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

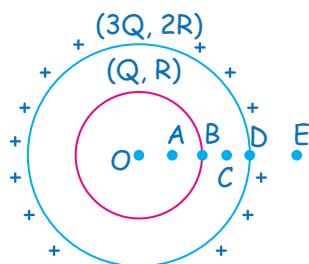


$$v_O = \frac{kQ}{R}, v_A = \frac{kQ}{R}, v_B = \frac{kQ}{R}, v_C = \frac{kQ}{2R}$$

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.

$$OA = R/2, OB = R, OC = 1.5R, OD = 2R, OE = 3R$$

Sol.



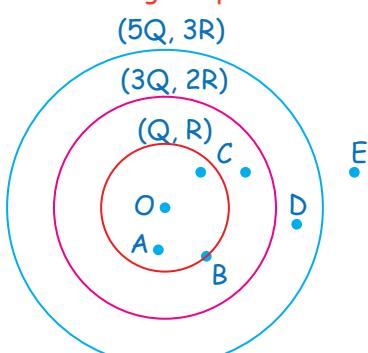
$$v_O = \frac{kQ}{R} + \frac{k3Q}{2R} = v_A = v_B$$

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

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

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

Q. Find potential at given point.



40

$$v_0 = \frac{kQ}{R} + \frac{k3Q}{2R} + \frac{k5Q}{2R} = v_A = v_B$$

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

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

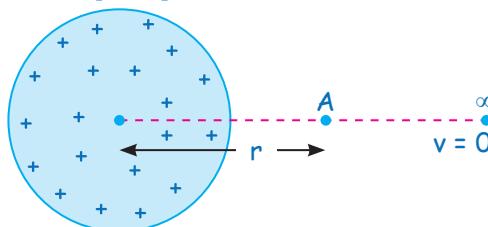
$$v_E = \frac{kQ}{OE} + \frac{k3Q}{OE} + \frac{k5Q}{OE}$$

यहाँ पर distances बहुत ध्यान से लेने हैं अक्सर बच्चों से गलती हो जाती है।



## Electric Potential Due to Solid Sphere

1 Outside [ $R > r$ ]

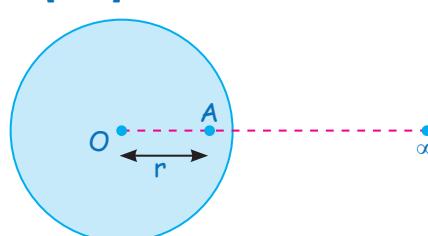


$$\int_0^r dv = - \int_{\infty}^r \vec{E} \cdot d\vec{r}$$

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

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

2 Inside [ $r < R$ ]



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

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

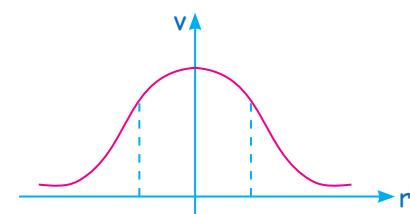


$$v_A = v_{\text{inside}} = \frac{kQ}{2R^3} (3R^2 - r^2)$$

चुड़ेल वाला formula

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

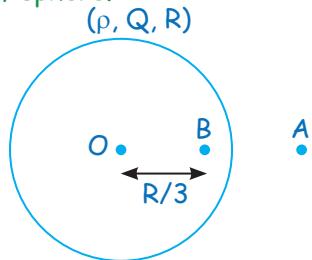
$$4 v_{\text{centre}} = \frac{3kQ}{2R}$$



Physics

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

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



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

- Find E.F and potential at centre of sphere

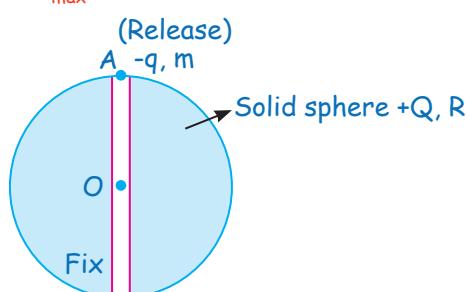
$$E_0 = 0, V_0 = \frac{3kQ}{2R}$$

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

$$E_B = \frac{\rho r}{3E_0} = \frac{\rho_0 R/3}{3E_0} \text{ or } E_B = \frac{kQr}{R^3} = \frac{kQR/3}{R^3}$$

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

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



$$\text{Sol. } k_A + U_A = k_0 + U_0$$

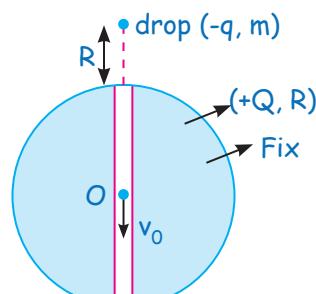
$$0 + (-qv_A) = \frac{1}{2}mv_0^2 + (-qv_{\text{centre}})$$

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

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

#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



$$k_i + U_i = k_f + U_f$$

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

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



$$k_i + U_i = k_f + U_f$$

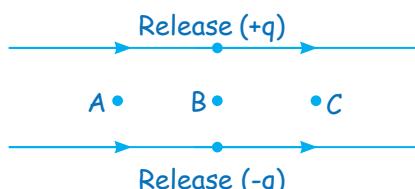
$$0 + qv_A = \frac{1}{2}mv_B^2 + q \times 40$$

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

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

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

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



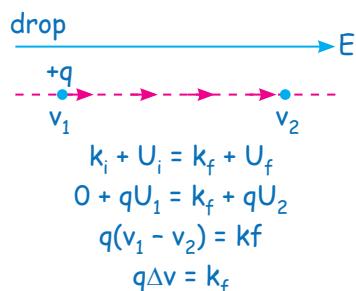
$$\Rightarrow v_A > v_B > v_C \text{ (potential)}$$

- If a +ve charge is released from rest in E.F it move high potential energy state to low potential energy state
  - If a -ve charge is released from rest in E.F it move high potential energy state to low potential energy state
- ♦ Dirx<sup>n</sup> 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 में बार बार use होगा अच्छे से याद करलो



## EQUIPOTENTIAL SURFACE

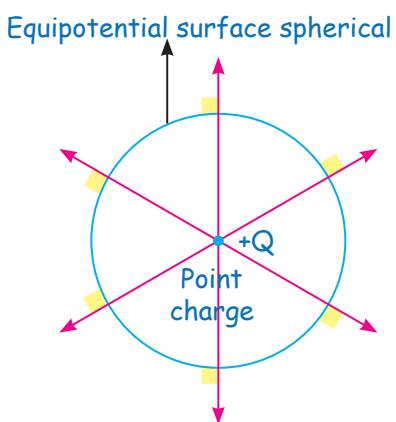
- 1 Locus of all point having same potential. Surface of all point of which potential is same.

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

$v \rightarrow$  same

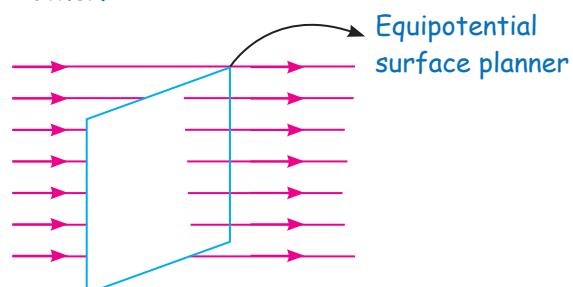
$$dv = 0 \Rightarrow E = 0 \text{ or } \theta = 90^\circ$$

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

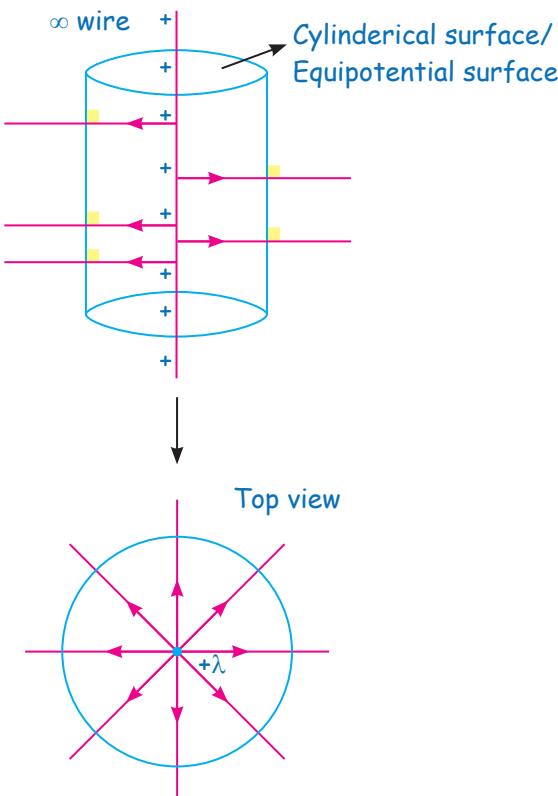


- 2 If a charge is moved from one point to the other over an equipotential surface  
then,  $W_{AB} = -U_{AB} = q(v_B - v_A) = 0 \quad [\because v_B = v_A]$

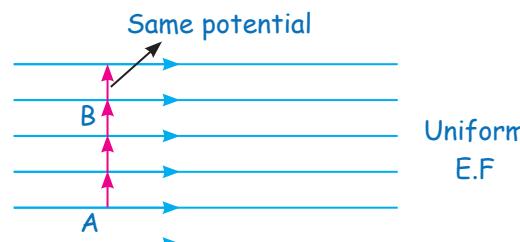
3 Equipotential surfaces can never cross each other.



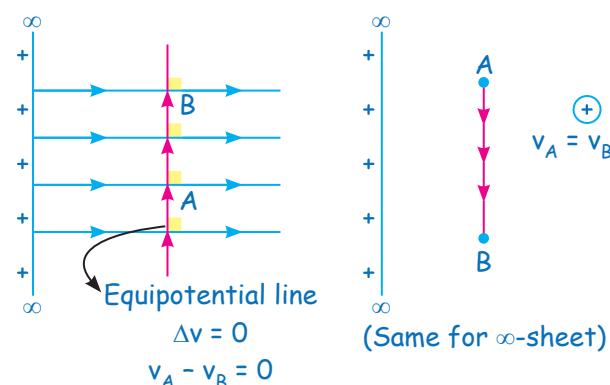
42

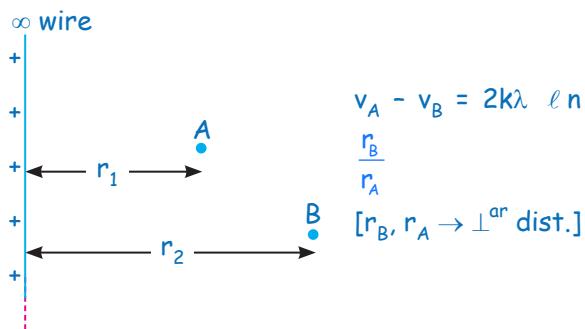


- 4** E.F.L ki trf chaloge to H.P to low potential jaoge  
**5** E.FL ke  $\perp^{ar}$  jaoge to no charge in potential



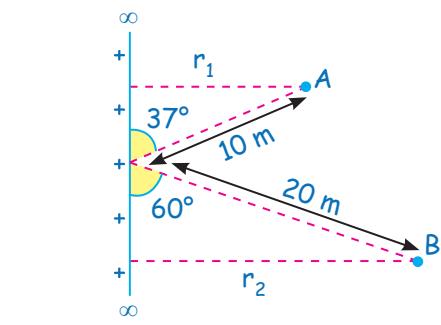
$$dv = \vec{E} \cdot \vec{dr}$$





#SKC  
 $\infty$  sheet,  $\infty$  wire ke ||rl chlogे to potential main koi bhi change nhi aayega

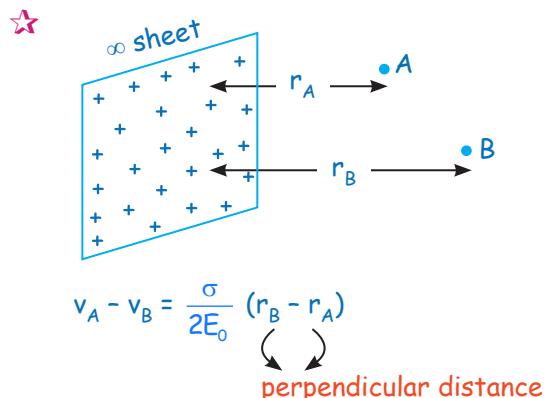
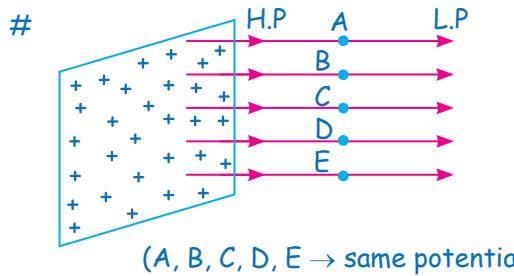
Q. Find potential difference A and B.



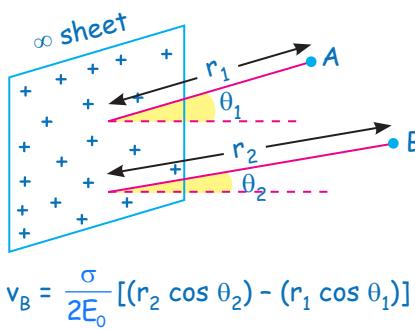
$$v_A - v_B = 2k\lambda \ln \left( \frac{r_2}{r_1} \right)$$

$$r_1 = 10 \sin 37^\circ$$

$$r_2 = 20 \sin 60^\circ$$



Electrostatics



Electric field और electric

potential के relation पर based question maximum mathematically होते हैं 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)

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

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

$$v = 10 - 90 = -80$$

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

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

$$v = -7 \text{ solve and get}$$

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)

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

$$v = -14 \text{ solve and get}$$

or

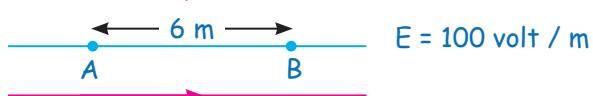
$E \rightarrow$  uniform

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

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

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

$$v_f = -14$$





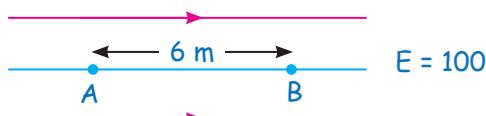
#SKC  
अगर uniform E.F है और  
E.F की दिशा में हम d चले तो pot. में  
Ed का drop aa jayega  $\Rightarrow$  pot.  
Ed कम हो जायेगा

H.P  $\rightarrow A$

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

$$V_B - V_A = -600$$

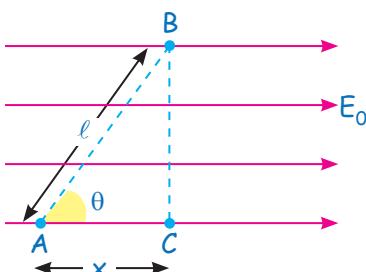
$$V_A - V_B = 600$$



$A \rightarrow B$  चलोगे तो pot. कम  $100 \times 6 = 600$

$$V_A - V_B = 600$$

Q. Find  $V_A - V_B$



$$Sol. E = E_0\hat{i}$$

$$\vec{d} = l \cos \theta \hat{i} + l \sin \theta \hat{j}$$

$$\Delta V = -\vec{E} \cdot \vec{d} = -E_0 l \cos \theta + 0$$

$$V_B - V_A = -E_0 x.$$

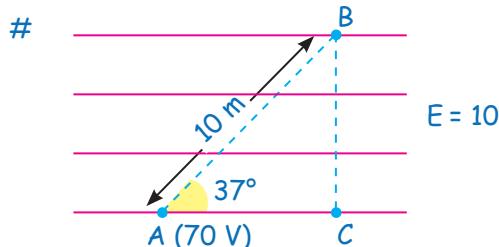
Pot. at B = pot. at C

$$V_A - V_C = Ex$$

$$V_A - V_B = Ex$$

$$V_C - V_A = -E_0 x$$

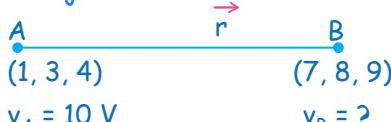
$$\therefore V_B - V_A = -E_0 x$$



$$\Rightarrow V_B = V_C$$

$$V_B = 70 - 10 \times 8 = -10$$

$$\# \vec{E} = 10\hat{i} + 20\hat{j} + 5\hat{k}$$



$$\Delta V = -\vec{E} \cdot \vec{d} \quad \vec{d} = 6\hat{i} + 5\hat{j} + 5\hat{k}$$

$$V_B - 10 = -[60 + 100 + 25]$$

$$V_B = -175$$

Q. If  $v = 4x^2$  find E.F at (2, 3, 4)

$$E_x = -\frac{\partial v}{\partial x} = -8x$$

$$at x = 2, E = -8 \times 2 = -16\hat{i}$$

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#

$$dV = -\vec{E} \cdot dr$$

\*  $\vec{E}_x = -\frac{\partial v}{\partial x}\hat{i}$   $\Rightarrow$  partial diff. of v wrt. x

\*  $\vec{E}_y = -\frac{\partial v}{\partial y}\hat{j}$   $\Rightarrow$  diff. of v wrt x by assuming y, z, constant

\*  $\vec{E}_z = -\frac{\partial v}{\partial z}\hat{k}$   $\Rightarrow$  const.

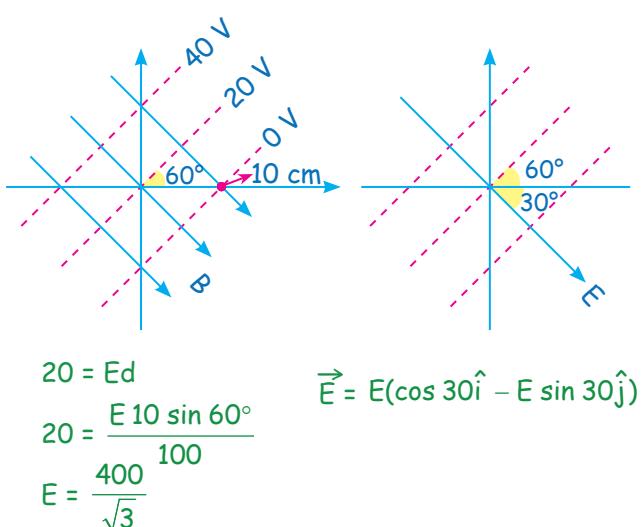
Q. If  $v = x^2yz$  find E.F at (1, 2, 3)

$$\vec{E} = -\left[ \frac{\partial v}{\partial x}\hat{i} + \frac{\partial v}{\partial y}\hat{j} + \frac{\partial v}{\partial z}\hat{k} \right] = -\left[ 2xyz\hat{i} + x^2z\hat{j} + x^2y\hat{k} \right]$$

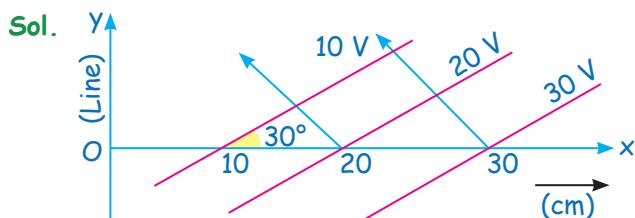
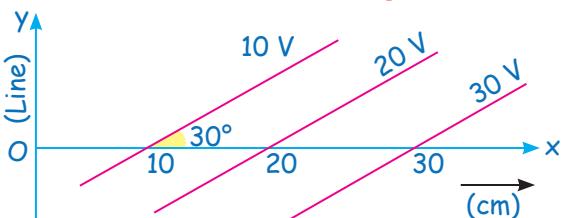
at (1, 2, 3) put x = 1, y = 2, z = 3

$$\vec{E} = -[12\hat{i} + 3\hat{j} + 2\hat{k}]$$

Q. Some equipotential lines are shown in the diagram. Write down the corresponding E.F in vector form?



Q. Equipotential surfaces are shown in figure. Then the electric field strength will be:



$$d = 10 \sin 30 \text{ cm} = 5 \text{ cm}$$
 $10 = Ed$ 
 $10 = E \times \frac{5}{100}$ 
 $E = 200 \text{ V/m}$

## DIPOLE

System of 2 equal and opposite charge separated by a small distance  $d$ .

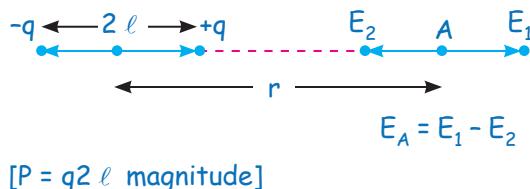
$\text{Dirx}^n \text{ moment} = \vec{Q} = qd$   
 Direx<sup>n</sup> is -ve  
 +ve charge  
 magnitude =  $qd$

#

$-2C$	$\xrightarrow{d}$	$+2C$
(1, 2, 3)		(4, 5, 7)

 $\vec{P} = 2 \times (3\hat{i} + 3\hat{j} + 4\hat{k})$

## ELECTRIC FIELD DUE TO SHORT DIPOLE AT A POINT ON AXIS.



$$\begin{aligned}
 E_A &= E_1 - E_2 = \frac{kq}{(r-l)^2} - \frac{kq}{(r+l)^2} \\
 &= kq \left[ \frac{(r+l)^2 - (r-l)^2}{(r-l)^2(r+l)^2} \right] \\
 &= \frac{kq \cdot 2r \cdot 2l}{(r^2 - l^2)^2} = \frac{2kq \cdot 2lr}{(r^2 - l^2)^2}
 \end{aligned}$$

If  $l \ll r$

$$\begin{aligned}
 E_A &= \frac{2kq \cdot 2lr}{r^4} = \frac{2k(q2l)}{r^3} = \frac{2kP}{r^3} \\
 \vec{E}_{\text{axis}} &= \frac{2kP}{r^3}
 \end{aligned}$$

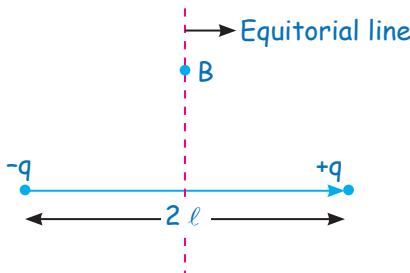
Potential at A

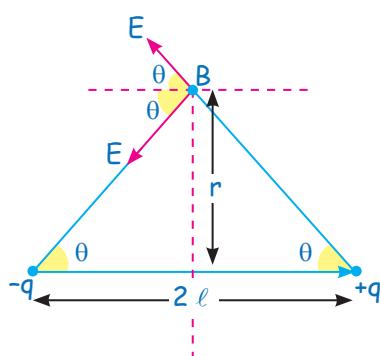
$$V_A = \frac{kq}{(r-l)} + \frac{k(-q)}{(r+l)} = kq \frac{(r+l) - (r-l)}{(r^2 - l^2)}$$

$$V_A = \frac{kq2l}{r^2 - l^2} \quad [l \ll r]$$

$$V_A = \frac{kP}{r^2}$$

## E.F AT A POINT ON A EQUITORIAL LINE DUE TO SHORT DIPOLE



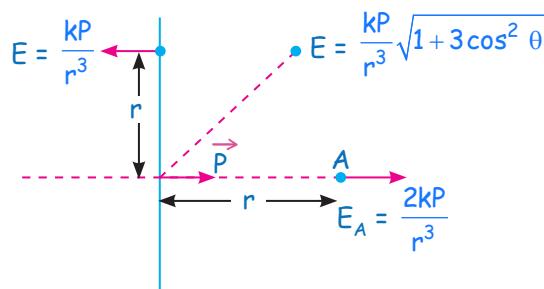


$$E_{\text{at } B} = 2E \cos \theta \text{ (पीछे)}$$

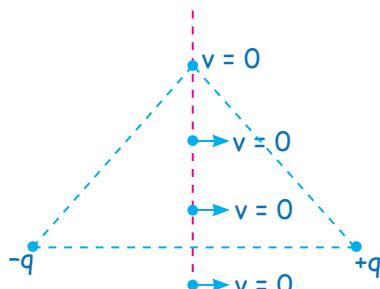
$$= \frac{2kq}{(\sqrt{r^2 + l^2})^2} \frac{l}{\sqrt{r^2 + l^2}} = \frac{kq2l}{(r^2 + l^2)^{3/2}}$$

$$\text{If } l \ll r = E_{\text{equit}} = \frac{kP}{r^3} \text{ (पीछे)}$$

$$\vec{E}_{\text{equit}} = -\frac{kP}{r^3}$$



**Electric Potential due to Short Dipole at Equitorial line = zero.**

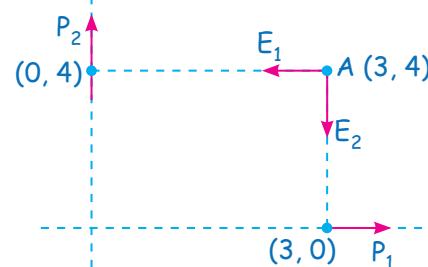


- Axis wale pt pr EF  $\frac{2kP}{r^3}$  dipole की दिशा में।

- Equitorial वाले point pr E.F  $\frac{kP}{r^3}$ , dipole के opposite दिशा में।



**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  $(3, 4)$ .

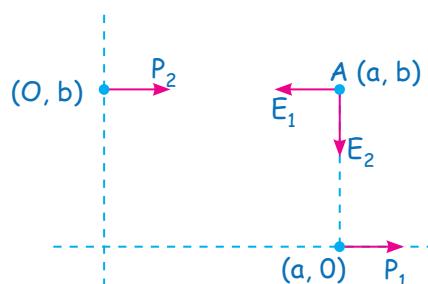


$$\text{E.F at } A \text{ due to } P_1 = \frac{kP_1}{4^3}(-\hat{i})$$

$$\text{E.F at } A \text{ due to } P_2 = \frac{kP_2}{3^3}(-\hat{j})$$

$$\vec{E}_{\text{net}} = +\frac{kP_1}{64}(-\hat{i}) - \frac{kP_2}{27}\hat{j}$$

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



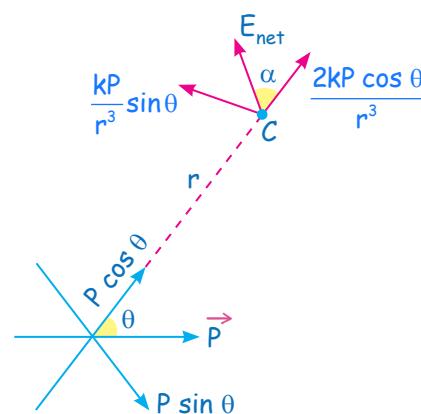
$$\text{Pot at } A = 0 + \frac{kP_2}{a^2}$$

$$\vec{E}_1 = \frac{kP_1}{b^3}(-\hat{i})$$

$$\vec{E}_2 = \frac{2kP_2}{a^3}(\hat{i})$$

$$(\vec{E}_{\text{net}}) \text{ at 'A'} = \frac{kP_1}{b^3}(-\hat{i}) + \frac{2kP_2}{a^3}(\hat{i})$$

**E.F at a general point due to short Dipole**



$$\tan \alpha = \frac{\frac{kP \sin \theta}{r^3}}{\frac{2kP \cos \theta}{r^3}} = \frac{\tan \theta}{2}$$

$$E_c = \sqrt{\left(\frac{2kP \cos \theta}{r^3}\right)^2 + \left(\frac{kP \sin \theta}{r^3}\right)^2} = \frac{kP}{r^3} \sqrt{4 \cos^2 \theta + \sin^2 \theta}$$

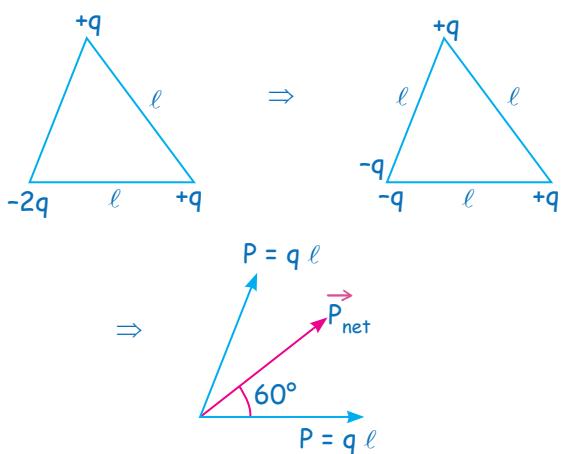
$$E = \frac{kP}{r^3} \sqrt{1 + 3 \cos^2 \theta} \Rightarrow E.F \text{ kabhi zero nhi hogi}$$

$$E_{\max} \Rightarrow \theta = 0^\circ \Rightarrow E = \frac{2kP}{r^3} \text{ (Axis)}$$

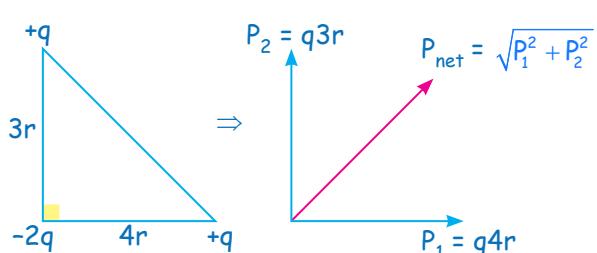
$$E_{\max} \Rightarrow \theta = 90^\circ \Rightarrow E = \frac{kP}{r^3} \text{ (Equatorial)}$$

# Find dipole moment of following cases

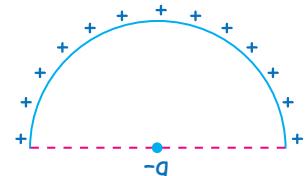
1



2

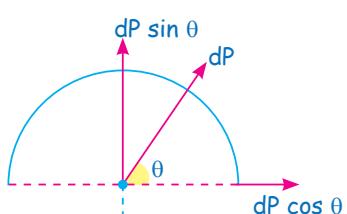


3



Sol.

$$dq = \lambda dx$$



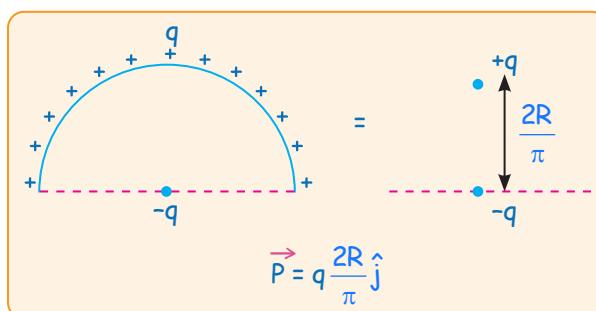
Electrostatics

$$P_{\text{net}} = \int dP \sin \theta = \int dq \cdot R \cdot \sin \theta$$

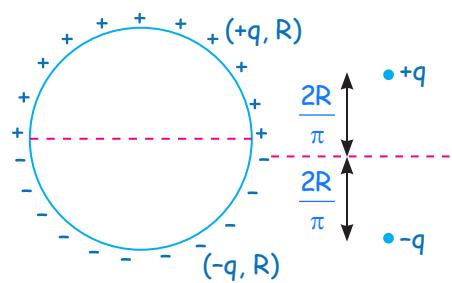
$$P_{\text{net}} = \int_0^\pi \lambda R d\theta \cdot R \sin \theta = \int_0^\pi \lambda R^2 \sin \theta d\theta$$

$$= \lambda R^2 \cdot 2 = \frac{q}{\pi R} R^2 \cdot 2$$

$$= q \times \frac{2R}{\pi}$$

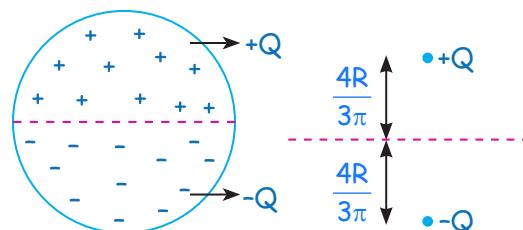


4

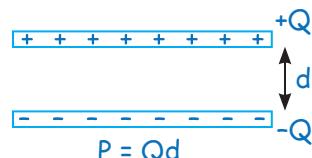


$$\vec{P} = q \frac{4R}{\pi} \hat{j}$$

5



6



## DIPOLE IN UNIFORM E.F

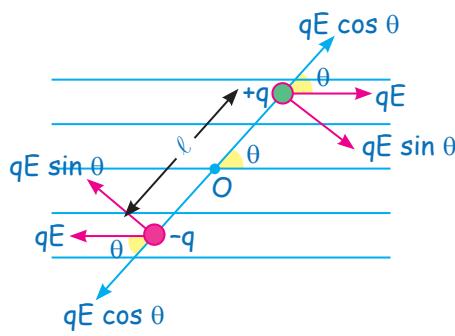
$$\vec{\tau} = \vec{P} \times \vec{E}$$

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

$$\vec{F}_{\text{net}} = 0$$



#SKC  
Agar system pr net force zero hai, to hr point ke about torque same aayega.



$$F_{\text{net}} = 0$$

$$\tau_0 = qE \sin \theta \times \frac{L}{2} + qE \sin \theta \frac{L}{2}$$

$$\tau_0 = qE \sin \theta L$$

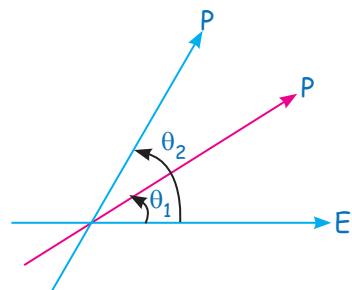
$$\boxed{\tau = PE \sin \theta}$$

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

$$\text{If } \theta = 0, \tau = 0 \quad \theta = 180^\circ, \tau = 0 \quad P \leftarrow E$$

## Potential Energy of Dipole in Uniform E.F

$(WD)_{\text{ext.}}$  to rotate dipole from  $\theta_1$  to  $\theta_2$  [slowly - slowly]



$$dW = \int \tau d\theta$$

$$dW = \int_{\theta_1}^{\theta_2} PE \sin \theta d\theta$$

$$\Rightarrow (WD)_{\text{ext.}} \Delta U = -PE (\cos \theta_2 - \cos \theta_1)$$

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

$$= U_f - U_i$$

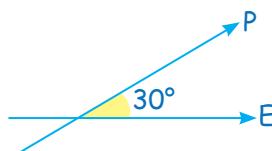
$$U_f = -PE \cos \theta_2$$

$$U_i = -PE \cos \theta_1$$

$$U_f = -\vec{P} \cdot \vec{E}$$

$$\boxed{U_f = -\vec{P} \cdot \vec{E}}$$

Q. Let E.F is along + x-axis and dipole is making angle  $30^\circ$  with x-axis as shown in figure. Find

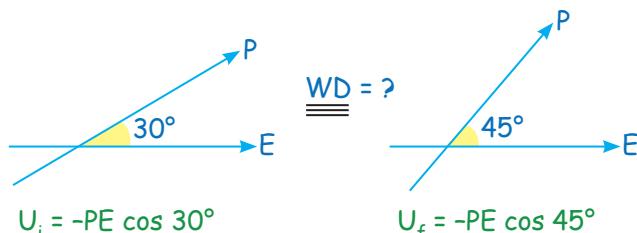


Sol.

$$1 \quad \tau = PE \sin \theta = PE \sin 30^\circ = \frac{PE}{2}$$

$$2 \quad P.E = -\vec{P} \cdot \vec{E} = -PE \cos \theta = -PE \cos 30^\circ$$

3 Find  $(WD)_{\text{ext.}}$  agent to rotate dipole so that angle b/w dipole and E.F become  $45^\circ$



$$(WD)_{\text{ext.}} = U_f - U_i = -PE(\cos 45^\circ - \cos 30^\circ)$$

VV Imp हर साल JEE Mains मे यह

आता है।

$(WD)_{\text{by ext.}}$  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



(a) Find F,  $\tau$ , U

$$F = 0$$

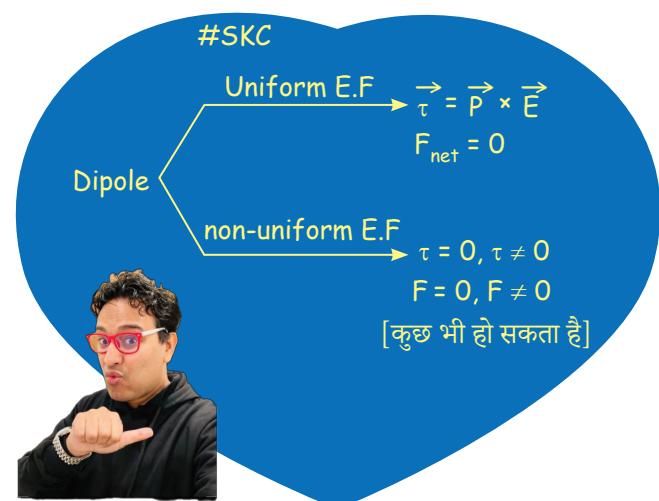
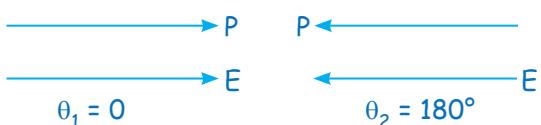
$$\tau = 0 \quad [\tau = PE \sin 0^\circ = 0]$$

$$U_i = -PE \cos 0^\circ = -PE$$

(b) (WD)<sub>ext.</sub> required to rotate st dipole become  $\perp^{\text{ar}}$  to E.F =  $-PE (\cos 90^\circ - \cos 0^\circ)$   
 $= +PE$

(c) (WD)<sub>ext.</sub> require to totate st dipole become antiparallel to E.F [from  $\theta_1 = 0$ ]

$$= -PE [\cos 180^\circ - \cos 0^\circ] = 2PE$$

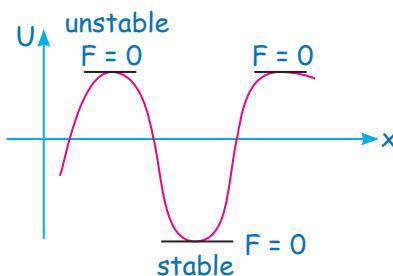


★  $\theta = 0$   $\rightarrow \vec{P}$   
 $\rightarrow \vec{E}$   
 $\tau = 0$   
 $U = -PE$   
 $U \rightarrow \min$   
Eqb<sup>m</sup> stable

★  $\theta = 90^\circ$   
 $\rightarrow \vec{P}$   
 $\rightarrow \vec{E}$   
 $\tau = PE$   
 $U = 0$

★  $\theta = 180^\circ$   $\rightarrow \vec{E}$   
 $\rightarrow \vec{P}$   
 $\tau = 0$   
 $P.E = +PE$   
 $U \rightarrow \max$   
unstable equilibrium

★ 11<sup>th</sup> class



# काम का डब्बा

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

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

$$\tau = PE \sin \theta$$

$$U = -PE \cos \theta$$

•  $\theta = 0^\circ, \tau = 0, U_{\min}, (U_{\min} = -PE), \text{stable eq}^m, \vec{F}_{\text{net}} = 0$

•  $\theta = 180^\circ, \tau = 0, U_{\max}, (U_{\max} = +PE), \text{unstable eq}^m, \vec{F}_{\text{net}} = 0$

•  $\theta = 90^\circ, \tau_{\max} U = 0$  No equilibrium

# Initially a dipole is in eqb<sup>m</sup> st it is parallel to E.F E (uniform). Time period of oscillation if it rotated by small angle  $\theta$  is:

Sol. If  $\theta$  is very small

$$\tau = -PE \cdot \theta$$

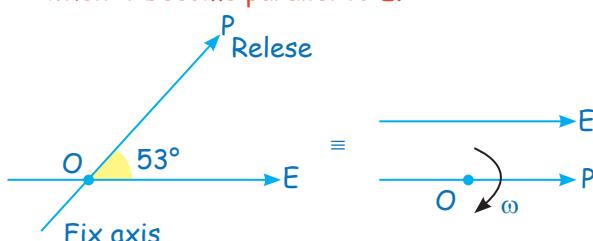
$$\tau = PE \sin \theta$$

$\tau = PE \sin \theta = PE \theta$  (Approx because  $\theta$  is very small) Hence

$$T = 2\pi \sqrt{\frac{I}{PE}}$$

I = moment of inertia

Q. Initially dipole makes angle  $53^\circ$  with E.f as shown in diagram and release. Find K.E of dipole when it becomes parallel to E.



$$K_i + U_i = K_f + U_f$$

$$0 - PE \cos 53^\circ = K_f - PE \cos 0^\circ$$

$$K_f = \frac{2}{5} PE = \frac{1}{2} I \omega^2$$

**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

$$\text{Sol. } U = -\vec{P} \cdot \vec{E} = -[6x + 12y]$$

$$f_x = -\frac{\partial U}{\partial x} = -[-6 + 0] = 6$$

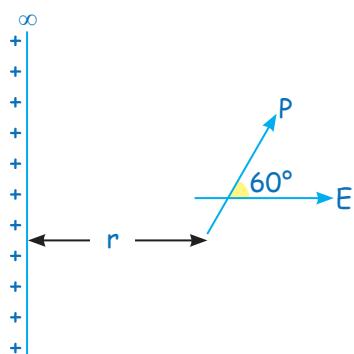
$$f_y = -\frac{\partial U}{\partial y} = -[0 + 12] = -12$$

**Q.** If a short dipole  $\vec{p} = p_0\hat{r}$  is placed in non-uniform E.f.  $\vec{E} = E_0 r^2 (\hat{r})$  find force on dipole

$$\text{Sol. } U = -\vec{P} \cdot \vec{E} = -[P_0 E_0 r^2 \hat{r} \cdot \hat{r}] = -P_0 E_0 r^2$$

$$F = -\frac{dU}{dr} = [-P_0 E_0 2r] = P_0 E_0 2r$$

**Q.** Force by  $\infty$ -wire on short dipole



$$\text{Sol. } U = -\vec{P} \cdot \vec{E} = -P \cdot E \cos 60^\circ$$

$$U = -\frac{P 2k\lambda}{r} \cos 60^\circ$$

$$F = -\frac{du}{dr} = -\frac{P 2k\lambda \cos 60^\circ}{r^2}$$

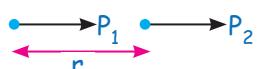
$$\vec{F} = -\frac{P 2k\lambda \cos 60^\circ}{r^2} \hat{r}$$



अब 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]



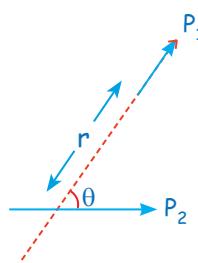
**Sol.**  $U = -\vec{P}_2 \cdot (\vec{E}_f)_{\text{due to } P_1 \text{ on } P_2}$

$$= -\vec{P}_2 \cdot \frac{2K\vec{P}_1}{r^3}$$

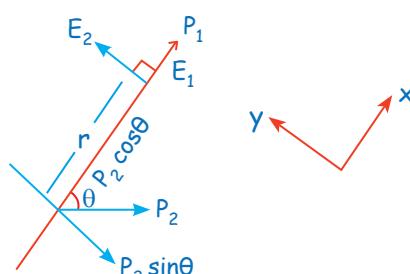
$$U = -\frac{2K\vec{P}_1 \vec{P}_2}{r^3}$$

$$F = -\frac{dU}{dr} = -\frac{6K\vec{P}_1 \vec{P}_2}{r^4}$$

**Q.** Two short dipole are placed as shown. The energy of electric field interaction b/w these dipoles will be:-



**Sol.**



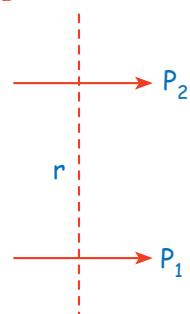
$$U = -\vec{P}_1 \cdot \vec{E}$$

$$U = -\vec{P}_1 \cdot (\hat{E}_1 \hat{i} + \hat{E}_2 \hat{j})$$

$$U = -P_1 E_1$$

$$U = -P_1 \frac{2K P_2 \cos \theta}{r^3}$$

**Q.** Find force of interaction b/w  $P_1$  &  $P_2$  or find force  $P_1$  on  $P_2$  [short dipole]



$$U = -\vec{P}_2 \cdot \vec{E} = -P_2 E \cos 180^\circ$$

$$U = -P_2 \frac{K P_1}{r^3} \times (-1)$$

$$U = \frac{K P_1 P_2}{r^3}$$

$$f = -\frac{dU}{dr} = -K P_1 P_2 \frac{(-3)}{r^4}$$

$$f = \frac{3 K P_1 P_2}{r^4}$$

Conductor → Free  $e^-$  bahut saare.

Semi-Conductor → Bahut Kam free  $e^-$  [12<sup>th</sup> last]

Insulator → No free  $e^-$

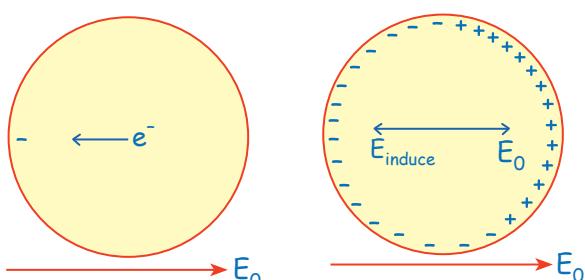
## CONDUCTOR

→ 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 separate 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<sup>n</sup> me charge spr<sup>n</sup> ki vajah se induce ho gyi.



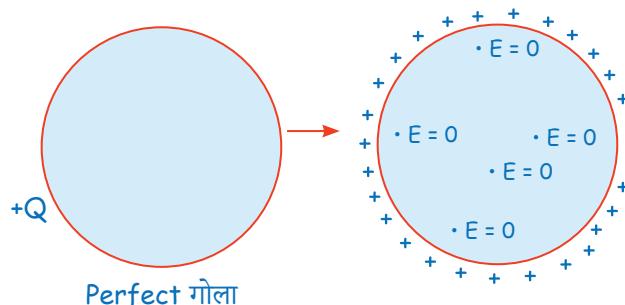
$$E_{net} = E_0 - E_{induce}$$

↓

$$0 \quad E_{induce} = E_0$$

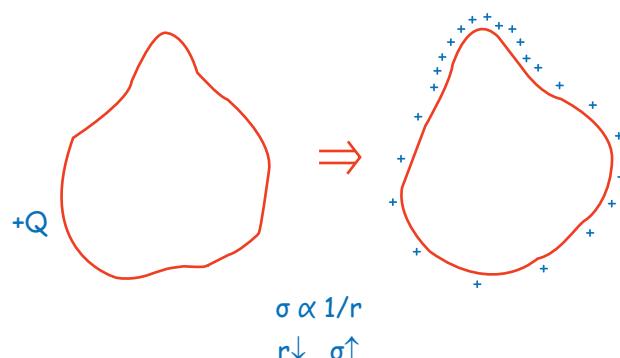
→ Agr kisi conductor ko charge dedu to,

$$\sigma \propto \frac{1}{r}, r \downarrow, \sigma \uparrow$$



$R \rightarrow$  same

$\sigma \rightarrow$  same uniform



→ 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

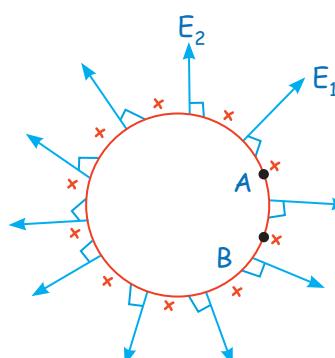
$$dv = -\vec{E} \cdot d\vec{r} = -Edr \cos\theta$$

$V \rightarrow$  same

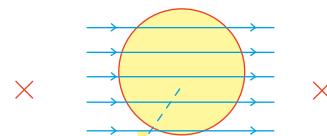
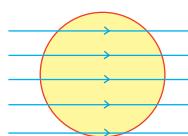
$$dv = 0 \Rightarrow E = 0 \text{ or}$$

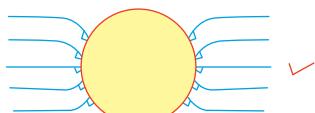
$$\theta = 90^\circ$$

$$\vec{E} \perp d\vec{r}$$



Q. Which of the following diagram is not possible for a conductor?





### Spherical Conductor of 'R', +Q.

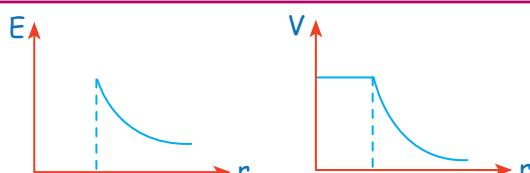
$$\rightarrow E_{\text{inside}} = 0$$

$$\rightarrow E_{\text{outside}} = \frac{KQ}{r^2}$$

$$V_{\text{inside}} = \frac{KQ}{R}$$

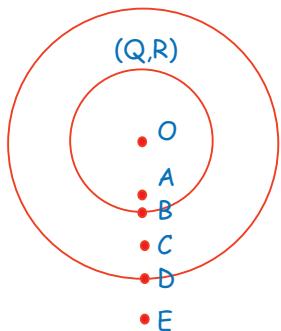
$$V_{\text{outside}} = \frac{KQ}{r}$$

Results are same as non conducting shell.



- Q. In following diagram we have two conducting spheres. Find potential at A, B, C, D, E.

(3Q, 2R)



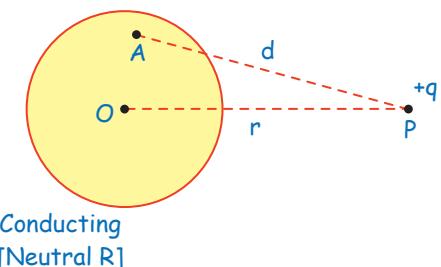
$$V_0 = \frac{KQ}{R} + \frac{K3Q}{2R} = V_A = V_B$$

$$V_C = \frac{KQ}{OC} + \frac{K3Q}{2R}$$

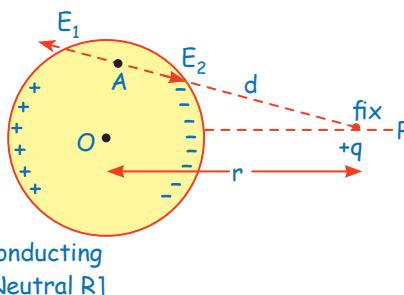
$$V_D = \frac{KQ}{2R} + \frac{K3Q}{2R}$$

$$V_E = \frac{KQ}{OE} + \frac{K3Q}{OE}$$

- 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.



Sol.



E.F at Pt. A = 0

$$\text{E.F at pt. A due to pt. charge } q = \frac{Kq}{d^2} = E_1$$

E.F at pt. A due to induce charge =  $E_2$

$$E_2 = \frac{Kq}{d^2} \text{ (opposite to } E_1)$$

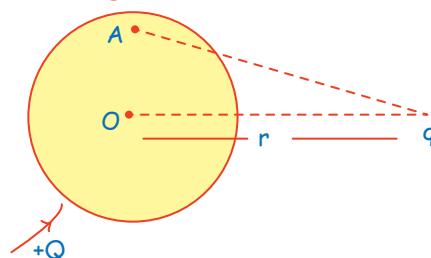
$$V_A = V_0$$

$$V_A = V_{\text{at } A \text{ due to } q} + V_{\text{at } A \text{ due to induce charge}}$$

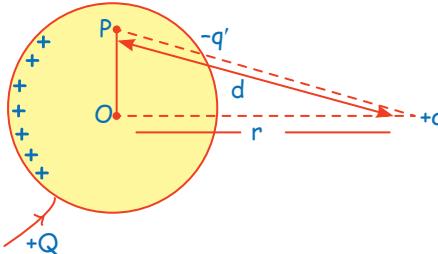
$$\frac{Kq}{r} = \frac{Kq}{d} + V_{\text{at } A \text{ due to induce charge}}$$

$$V_{\text{at } A \text{ due to induce charge}} = \frac{Kq}{r} - \frac{Kq}{d}$$

- Q. Repeat the last all parts if conducting sphere is given + Q charge. Find potential at A due to induce charge.



Sol.



$$V_p = V_0 = \frac{Kq}{r} + \frac{K(Q+q'-q')}{R}$$

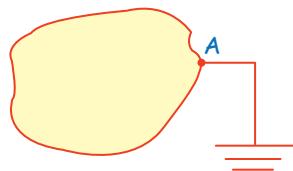
$$V_p = V_0 = \frac{Kq}{r} + \frac{KQ}{R}$$

Pot. at 'P' due to induce charge = कट्टू

$$V_p = V_{\text{due to } q'} + V_{\text{induce charge}}$$

$$\frac{Kq}{r} + \frac{KQ}{R} = \frac{Kq}{d} + V_{\text{due to induce charge}}$$

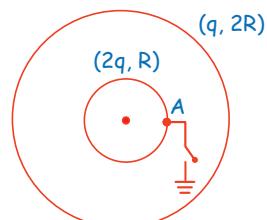
## IDEA OF EARTHING



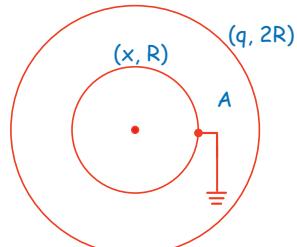
$$V_A = 0 \text{ कर दिया}$$

#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.



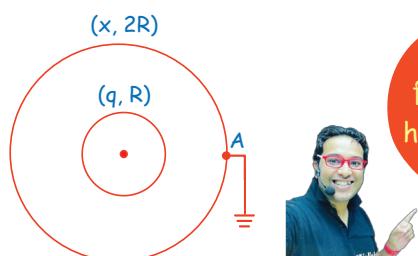
Sol.



$$V_A = \frac{kx}{R} + \frac{kq}{2R} = 0$$

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

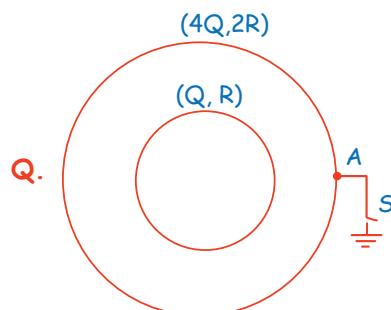
- Q. Find the charge on outer sphere



$$V_A = \frac{kq}{2R} + \frac{kx}{2R} = 0$$

$$x = -q$$

#SKC  
जिसको Earth Kiya hai, uska potential zero Krna. hai.



- Find charge flow through switch after switch closed

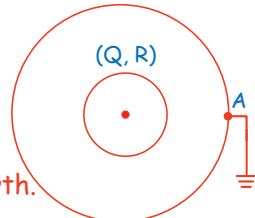
$$V_A = 0$$

$$\frac{Kx}{2R} + \frac{KQ}{2R} = 0$$

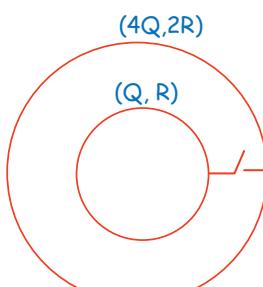
$$x = -Q$$

∴ + 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 करते

- Sol. Suppose inner sphere has charge x  
 $V_A = V_B$

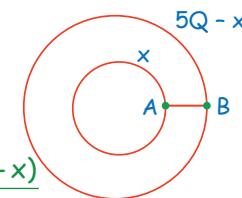
$$\frac{kx}{R} + \frac{K(5Q-x)}{R} = \frac{kx}{2R} + \frac{K(5Q-x)}{2R}$$

$$\frac{kx}{R} = \frac{kx}{2R}$$

$$x = \frac{x}{2}$$

$$x - \frac{x}{2} = 0$$

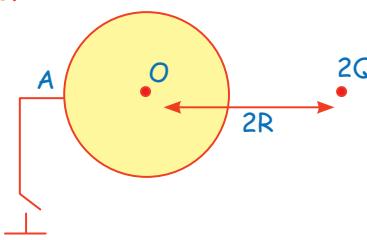
$$[\text{inner}] x = 0$$



सारा का सारा charge बाहर चला गया  
Sorry Shubham\* Bhaiya



- Q. Find net charge on conductor after switch is closed.



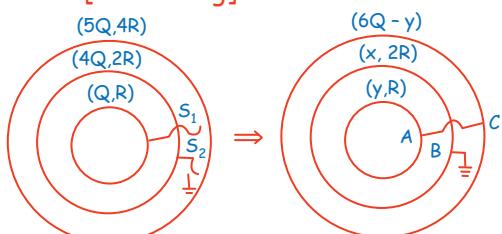
**Sol.** Let charge on the sphere is  $x$  after switches close

$$V_A = 0 = V_0$$

$$\frac{K2Q}{2R} + \frac{Kx}{R} = 0$$

$$x = -Q$$

**Q.** Find charge on each sphere after  $S_1$  and  $S_2$  closed [conducting]



**Sol.**  $V_B = 0$

$$\frac{Ky}{2R} + \frac{Kx}{2R} + \frac{K(6Q-y)}{4R} = 0 \quad \dots(1)$$

$$V_A = V_C$$

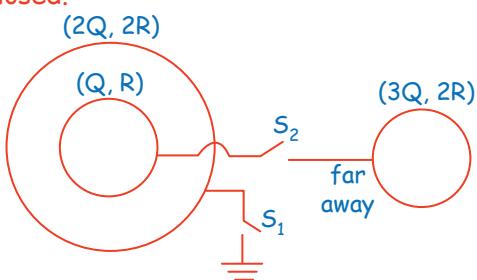
$$\frac{Ky}{R} + \frac{Kx}{R} + \frac{K(6Q-y)}{4R} = \frac{Ky}{4R} + \frac{Kx}{4R} + \frac{K(6Q-y)}{4R} \quad \dots(2)$$

By Solving (1) and (2) we can get the answer focus on concept.

#SKC  
Jb bhi, kisiko  
earth Kroge, uska  
charge x maan  
lo!



**Q.** Find charge on each sphere after  $S_1$ ,  $S_2$  is closed.



**Sol.**

$$(x, 2R)$$

$$(y, R)$$

$$(4Q, -y), 2R$$

$$V_A = 0$$

$$\frac{Ky}{2R} + \frac{Kx}{2R} + 0 = 0$$

$$x + y = 0 \quad \dots(1)$$

$$V_B = V_C$$

$$\frac{Ky}{R} + \frac{Kx}{2R} + 0 = \frac{K(4Q-y)}{2R}$$

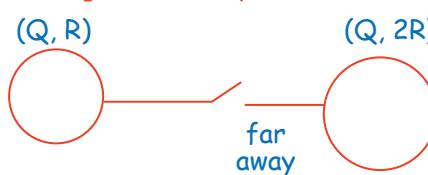
$$x + 3y = 4Q \quad \dots(2)$$

Solve (1) and (2)

$$\therefore y = +2Q$$

$$x = -2Q$$

**Q.** Find charge on small sphere after switch close



**Sol.**

$$(x, R)$$

$$(2Q-x), 2R$$

$$V_A = V_B$$

$$\frac{Kx}{R} + 0 = 0 + \frac{K(2Q-x)}{2R}$$

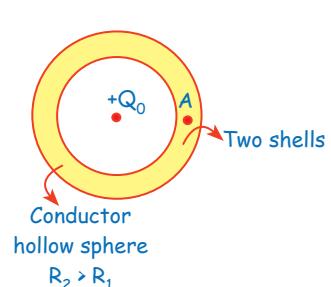
$$x = \frac{2Q}{3}$$

$$q_1 = 2Q/3$$

$$q_2 = 2Q - \frac{2Q}{3} = \frac{4Q}{3}$$

**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.**

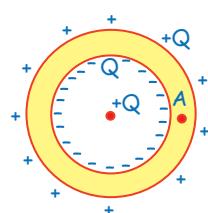
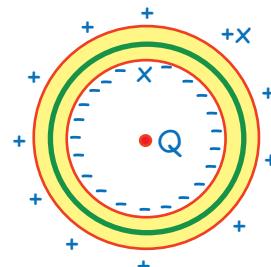


$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{in}}{\epsilon_0}$$

$$0 = \frac{Q - x}{\epsilon_0}$$

$$Q = x$$

$$\sigma_{inner} = \frac{-Q}{4\pi R_1^2}$$



$$\sigma_{\text{outer}} = \frac{Q}{4\pi R_2^2}$$

Inner surface pr charge  $-x h$ , mtlb  $-Q/h$

#SKC

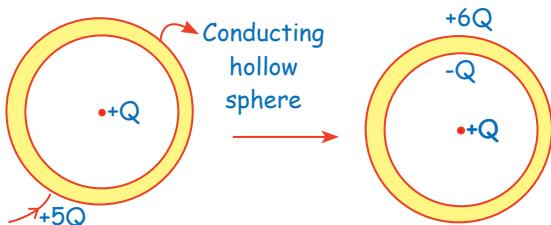
इसमें 2 shell हैं  
 $\rightarrow -Q \cdot R_1$   
 $\rightarrow +Q \cdot R_2$

→ Last Quesn में

#SKC

Chore Ka samne. barabar  
Ki age ki chori Ko bitha K setting  
Kr do and उसी प्रकार आगर छोरी है तो सामने  
बराबर age का छोरा बैठा दो। उसके  
बाद क्या होगा अपको पता  
ही है।

Q. Find charges &  $\sigma$  on inner and Outer surface after proper induction

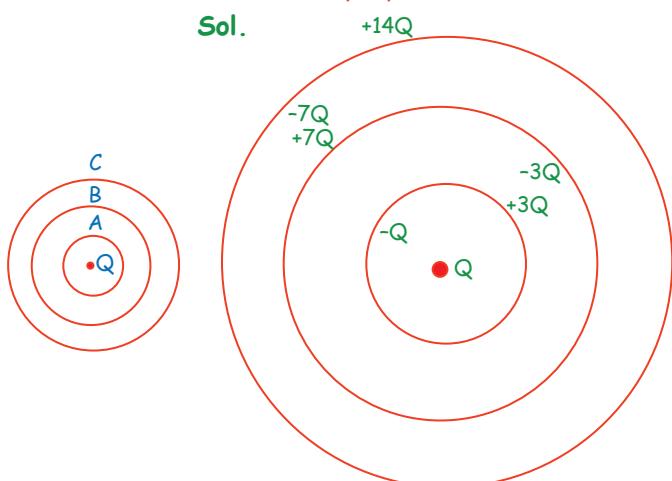


$$\sigma_{\text{inner}} = \frac{-Q}{4\pi R_1^2}$$

$$\sigma_{\text{outer}} = \frac{+6Q}{4\pi R_2^2}$$

Q. If  $2Q$ ,  $4Q$ ,  $7Q$  charge is given to  $A$ ,  $B$ ,  $C$  respectively. Find charges &  $\sigma$  on inner and Outer surface after proper induction.

Sol.

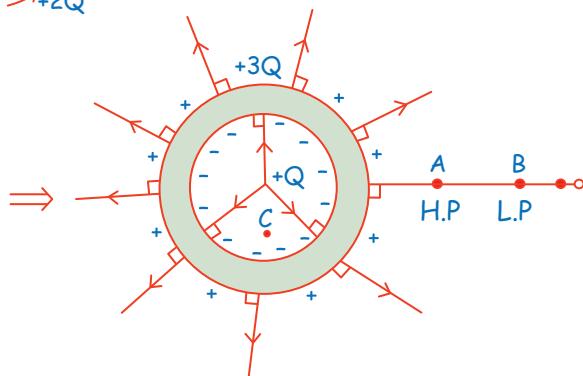
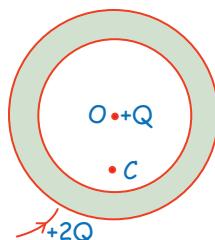


Q. Suppose we have a thin conductor of inner radius  $R$  and thickness  $t$  and charge  $+7Q$ . If  $+Q$  charge is placed at center. Find  $\sigma_{\text{inner}}$  and  $\sigma_{\text{outer}}$ .

$$\sigma_{\text{inside}} = \frac{-Q}{4\pi R^2}$$

$$\sigma_{\text{outside}} = \frac{8Q}{4\pi(R+t)^2}$$

★ Draw E.F pattern.



→ Electric field and potential at  $A$ .

$$\bar{E}_A = \frac{KQ}{(OA)^2} + \frac{K(-Q)}{(OA)^2} + \frac{K3Q}{(OA)^2}$$

$$V_A = \frac{KQ}{OA} + \frac{K(-Q)}{OA} + \frac{K3Q}{OA}$$

→ E.F at point  $C$  inside खाली जगह -

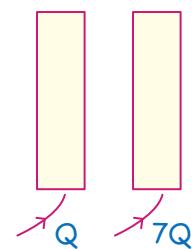
$$\bar{E}_C = \bar{E}_{\text{due to point charge}} + \bar{E}_{\text{inner shell}} + \bar{E}_{\text{outer shell}}$$

$$= \frac{KQ}{(OC)^2} + 0 + 0$$

$$E_c = \frac{KQ}{(OC)^2}$$

### CONDUCTING PLATE VERY CLOSE TO EACH OTHER / (LIKE $\infty$ 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.

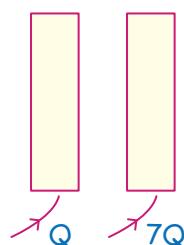


**Sol.** ABCD के लिए gauss law लगाकर और

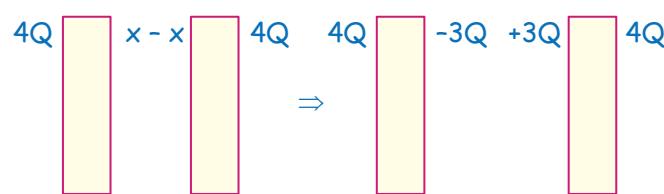
$E_A = 0$  करके we found

Plate के आपने सामने equal & opposite charge होंगा और दोनो outer surface

पर total का half charge होंगा।

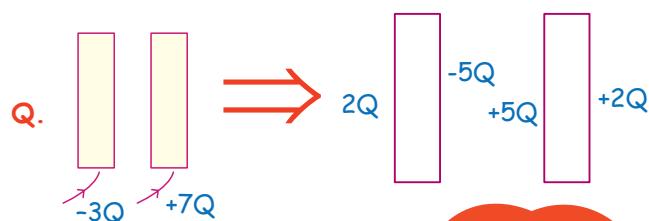
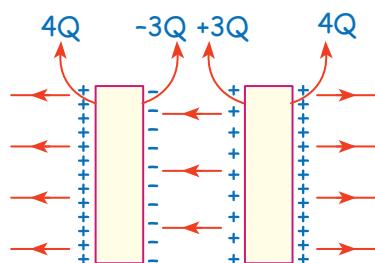


$$Q_{\text{outer}} = \frac{Q_{\text{total}}}{2} = \frac{Q + 7Q}{2} = 4Q$$



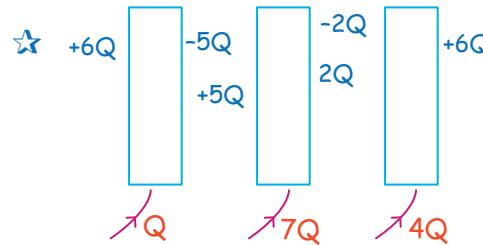
Total charge on this plate =  $Q$   
So  $x = -3Q$

So final charge distribution and E.F pattern will be

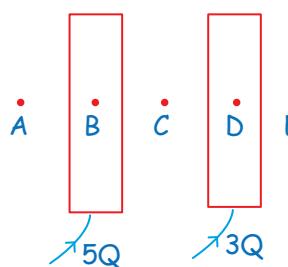


$$Q_{\text{outer}} = \frac{Q_{\text{total}}}{2} = \frac{-3Q + 7Q}{2} = 2Q$$

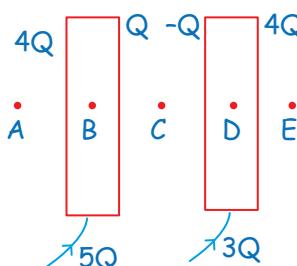
#SKC  
Total charge ko  
आधा आधा करके outer  
surface ko de do,  
fir setting kr  
do.



**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.**



$$E_B = E_D = 0$$

$$E_c = \frac{4Q/A}{2E_0} - \frac{4Q/A}{2E_0} + \frac{Q/A}{2E_0} + \frac{Q/A}{2E_0}$$

$$E_c = E_{\text{बीच में}} = \frac{Q}{AE_0} = \frac{Q_{\text{अंदर वाला}}}{AE_0}$$

$$= \frac{\sigma_{\text{अंदर वाला}}}{E_0}$$

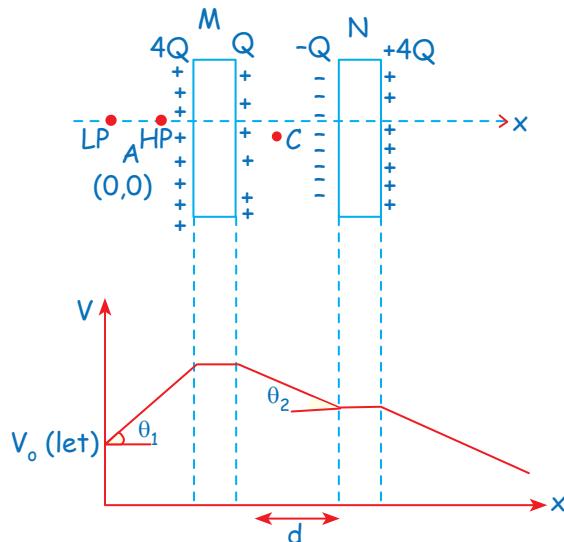
$$E_A = \frac{-4Q/A}{2E_0} - \frac{Q/A}{2E_0} + \frac{Q/A}{2E_0} - \frac{4Q/A}{2E_0}$$

$$= \frac{-8Q/A}{2E_0} = \frac{-4Q/A}{E_0}$$

$$E_E = \frac{4Q/A}{2E_0} \times 2 = \frac{4Q/A}{E_0}$$



### GRAPH-



$$\tan \theta_1 = E_A \text{ (magn.)}$$

$$\tan \theta_2 = E_C \text{ (magn.)}$$

### 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.

$$\rightarrow \text{S.P.E of a pt. charge} = 0$$

$$\rightarrow \text{S.P.E of a shell, conducting sphere} = \frac{KQ^2}{2R}$$

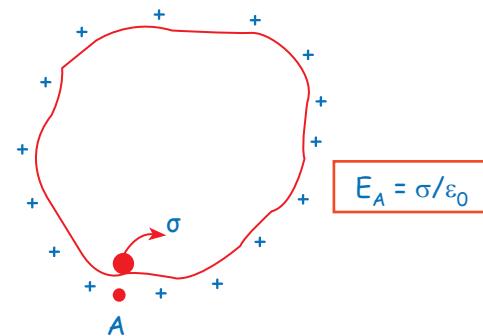
$$\rightarrow \text{S.P. E of a solid sphere} = \frac{3}{5} \frac{KQ^2}{R}$$

**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.

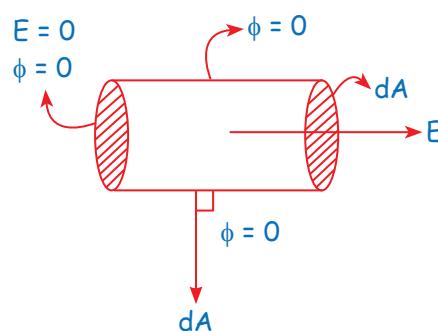
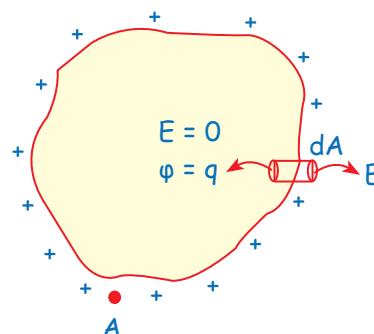
$$\text{Sol. } (WD) = U_f - U_i$$

$$= \frac{Kq^2}{2R_2} - \frac{Kq^2}{2R_1}$$

### E.F IN THE VICINITY OF CONDUCTOR



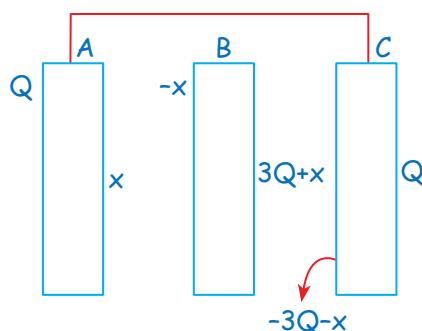
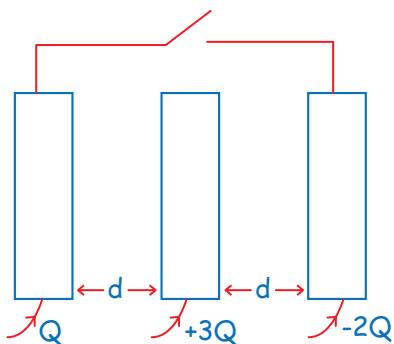
### Proof:



$$EdA + 0 + 0 + 0 = \frac{q_{in}}{\epsilon_0} = \frac{\sigma dA}{\epsilon_0}$$

$$E = \sigma/\epsilon_0$$

Q. Find charge on each surface after switch closed.



$$Q_{\text{total}} = Q + 3Q - 2Q$$

$$V_A = V_C$$

$$(V_A - V_B) + (V_B - V_C) = 0$$

$$E_1 d + E_2 d = 0$$

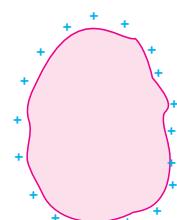
$$\left(\frac{x/A}{2E_0}\right) + \frac{(3Q+x)/A}{2E_0} = 0$$

$$x + 3Q + x = 0$$

$$x = \frac{-3Q}{2}$$

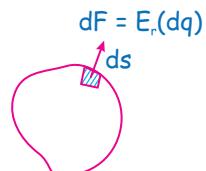
## ELECTROSTATIC PRESSURE

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, let's take a small surface element having area 'ds' and elemental charge dq.

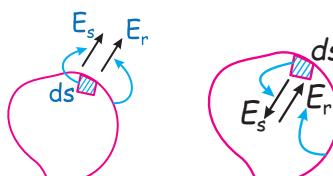
Force on this element due to the remaining charges:



$$dF = \left( \begin{array}{l} \text{electric field at} \\ \text{that place due to} \\ \text{remaining charges} \end{array} \right) \left( \begin{array}{l} \text{charge of} \\ \text{the small} \\ \text{element} \end{array} \right)$$

$$dF = E_r \times dq \quad \dots(i)$$

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

$$\text{the conductor surface} = \frac{\sigma}{\epsilon_0}$$

$$\Rightarrow E_s + E_r = \frac{\sigma}{\epsilon_0} \quad \dots(ii)$$

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

$$\text{So, } E_r - E_s = 0 \Rightarrow E_r = E_s \quad \dots(iii)$$

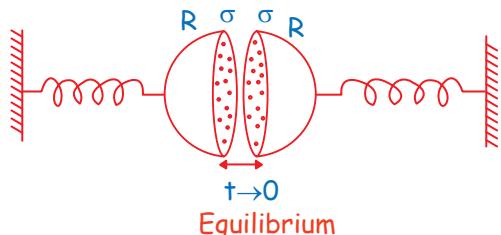
From eqn. (ii) and eqn. (iii), we can say that:

$$2E_r = \frac{\sigma}{\epsilon_0} \Rightarrow E_r = \frac{\sigma}{2\epsilon_0}$$

$$P = \frac{dF}{dA} = \frac{dq \cdot E_r}{dA} = \frac{\sigma \cdot \sigma}{2\epsilon_0}$$

$$\text{Electrostatic Pressure} = \frac{\sigma^2}{2E_0}$$

Q. Hemisphere are in equilibrium find compression in string.



$$\frac{\sigma^2}{2E_0} \times \pi R^2 = Kx$$

## IMPORTANT QUESTIONS

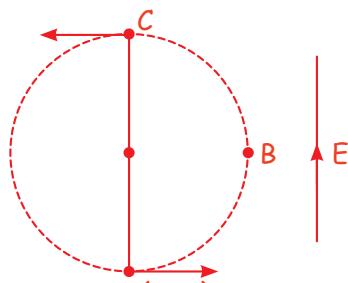
q charge को EF मे रखने पर उसके force  $qE$  लगता है इस concept को पूरी mechanics मे use करके सवाल बनाए जा सकते हैं।



**Abhi maza ayega na bhidu**

Q. If  $T_A = 15 \text{ mg}$

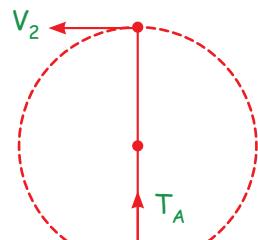
What should be velocity at C



OR

What horizontal velocity must be impart to ball at C so that tension at A become 15 times of weight.

Sol.

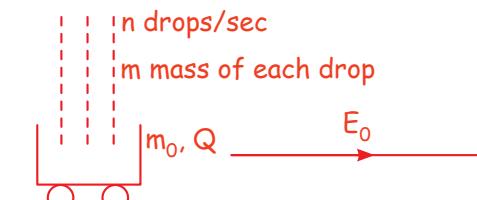


$$(1) T_A + qE - mg = \frac{mV_A^2}{R}$$

$$15mg + qE - mg = \frac{mV_A^2}{R}$$

$$(2) -mg 2R + 0 + qE 2R = \frac{1}{2}mV_2^2 - \frac{1}{2}mV_1^2$$

Q. n droper second m → mass of each drop.



Find velocity of car/tank as  $f(x)$  of time.

Sol. At any time 't' mass of car =  $M_0 + n t m$

Impulse momentum theorem  $J = \Delta P$

$$QE_0 t = (M_0 + n t m)V_f - 0$$

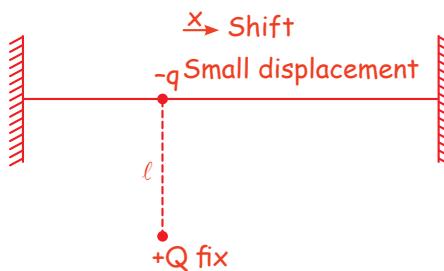
$$V_f = \frac{QE_0 t}{M_0 + mnt}$$



*Bhai, yeh toh shuru hote hi khataam ho gaya*

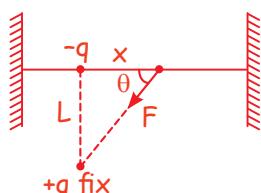
Q. Find time period of SHM

if -q charge is slightly displaced in following figure along x-axis.

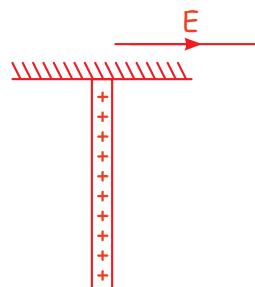


Sol.  $F_{\text{net}} = F \cos \theta$

$$= \frac{Kq\theta}{(L^2 + x^2)} \frac{x}{\sqrt{L^2 + x^2}}$$



Q. Suddenly  $E_0$  apply St. rod rotated max angle  $90^\circ$ .  $E = ?$



Rod AB of length (L, Q, m)

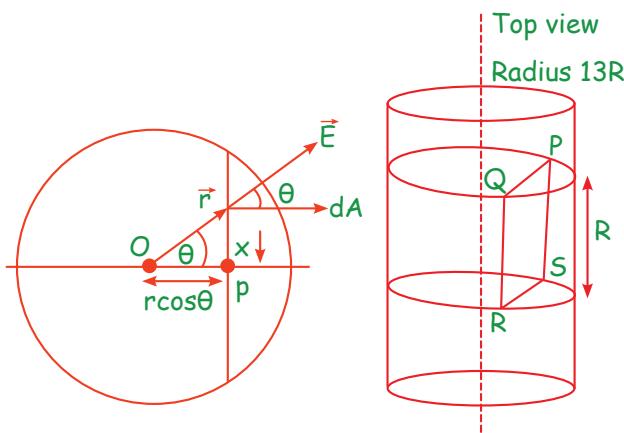
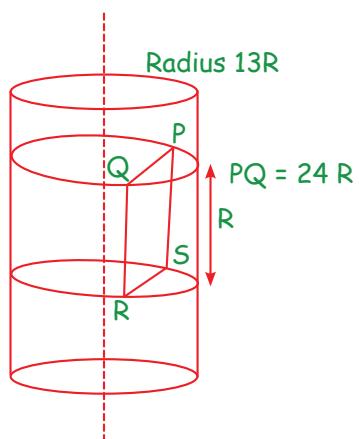
Sol. W.E.T

$$W_g + W_{EF} = \Delta K.E.$$

$$-mg\frac{L}{2} + qE\frac{L}{2} = 0 - 0$$

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

SSSQ. A long non conducting solid cylinder of radius  $13R$  has charge density  $s$ . Find flux through shaded rectangle PQRS



$$\text{Sol. } \phi_{net} = \int d\phi = \int \vec{E} \cdot d\vec{A} = \int E dA \cos \theta = \int \frac{\rho r}{2\epsilon_0} dA \cos \theta$$

$$= \frac{\rho}{2\epsilon_0} \int r \cos \theta dA \quad (OP = 5R \text{ after solving})$$

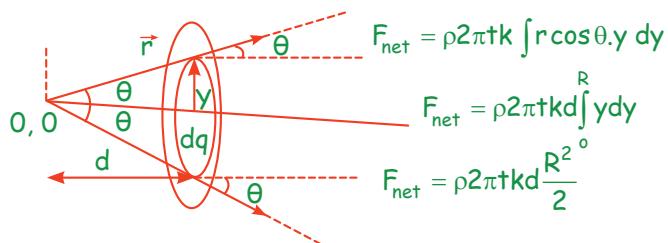
$$= \left( \frac{\rho}{2\epsilon_0} \right) (op) \int dA = \frac{\rho}{2\epsilon_0} \cdot 5R \cdot 24R \cdot R$$

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  $\rho$ . The external electric field in the space is given by  $\vec{E} = K \vec{r}$  where  $K = \text{Constant}$  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.

$$\text{Sol. } F_{net} = \int dF \cos \theta$$

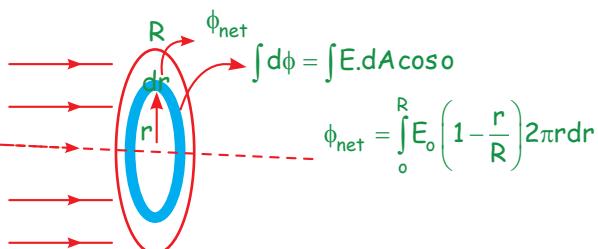
$$= \int (dq) E \cos \theta$$

$$= \int (\rho 2\pi y dt) kr \cos \theta$$



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  $\phi_{disc} = ?$

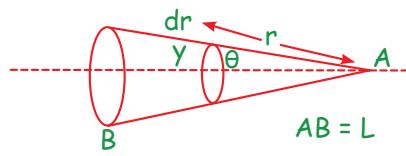
Sol.



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  $L$ .

$$\text{Sol. } dv = \frac{k dq}{\sqrt{y^2 + x^2}} = \frac{k dq}{r}$$

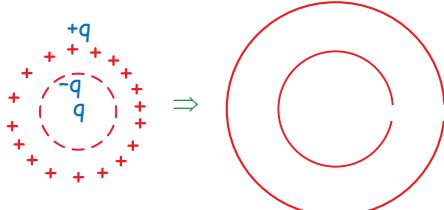
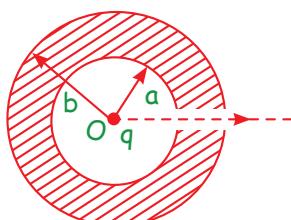
$$\sin \theta = \frac{y}{r} = \frac{R}{L}, y = \frac{Rr}{L}$$



$$\int dv = \int_0^L \frac{k\sigma 2\pi y dr}{r} = k\sigma 2\pi \int_0^L \frac{Rr' dr'}{L} = k \frac{\theta}{\pi RL} 2\pi \frac{R}{L} \cdot L$$

$$= \frac{2k\theta}{L}$$

- 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?



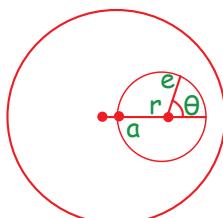
**Sol.**

$$T.P.E = (SPE)_1 + (SPE)_2 + (SPE)_3 + U_{12} + U_{31} + U_{23}$$

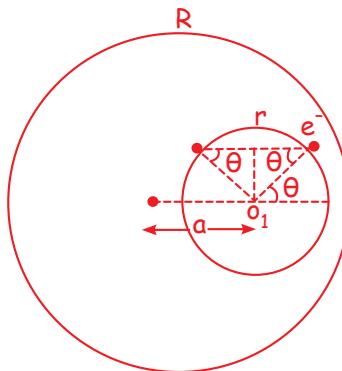
$$U_i = O + \frac{k(-q)^2}{2a} + \frac{kq^2}{2b} + \left( \frac{-kq}{a} \cdot q \right) + \left( \frac{kq}{b} \cdot q \right) + \frac{kq}{b} (-q)$$

$$U_f = 0. \text{ Ans. } = U_f - U_i$$

- Q.** A cavity of radius  $r$  is present inside a solid dielectric sphere of radius  $R$ , having a volume charge density of  $\rho$ . The distance between the centres of the sphere and the cavity is  $a$ . An electron  $e$  is kept inside the cavity at an angle  $\theta = 45^\circ$  as shown. How long will it take to touch the sphere again?



**Sol.**

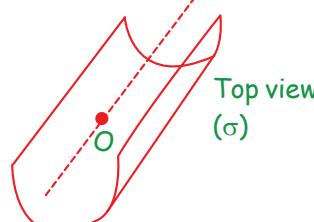


$$2rcos\theta = 0 + \frac{1}{2} - \frac{eE}{m} \cdot t^2$$

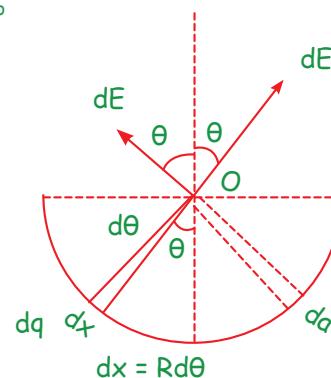
$$2rcos\theta = \frac{1}{2} \frac{epa}{3\epsilon_0 m} t^2$$

$$t = \sqrt{\frac{12\epsilon_0 m r cos\theta}{epa}}, \theta = 45^\circ$$

- Q.** Thin long strip whose cross-section is a semicircle find EF at 'O' located midway on the axis



$$SOL. E_0 = \int_0^{\pi/2} 2dE \cos\theta$$



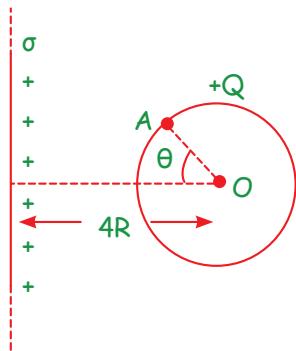
$$= \int_0^{\pi/2} 2 \cdot \frac{2k\sigma R d\theta \cos\theta}{R}$$

$$= 4k\sigma \int_0^{\pi/2} \cos\theta d\theta$$

$$= \frac{\sigma}{\pi\epsilon_0}$$

**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  $\sigma$ . Then find the potential at point  $A$  (on the surface of sphere) due to charge on sphere

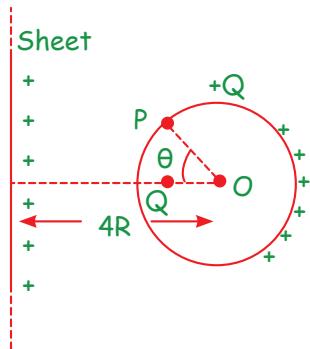
$$(\text{here } K = \frac{1}{4\pi\epsilon_0}, \theta_0 = \frac{\pi}{3})$$



$$\text{Sol. } V_p = V_o$$

$$(V_p)_{\text{due to sheet}} + (V_p)_{\text{gola}} = (V_o)_{\text{Sheet}} + (V_o)_{\text{Gola}}$$

$$(V_Q)_{\text{due to sheet}} - (V_o)_{\text{sheet}} + (V_p)_{\text{gola}} = (V_o)_{\text{Gola}}$$



$$\frac{\sigma}{2\epsilon_0} (4R - (4R - R\cos\theta)) + (V_p)_{\text{gola}} = \frac{kQ}{R}$$

$$(V_p)_{\text{Gola}} = \frac{kQ}{R} = \frac{\sigma R \cos\theta}{2\epsilon_0}$$

**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  $+4\mu\text{C}$  moves from the point  $(0, 0, 0.1\text{m})$  to the origin is  $50\mu\text{J}$ . The radius of the circle of the equipotential curve corresponding to  $V = 6250$  volts and  $z = \sqrt{2}\text{ m}$  is  $\alpha$  m. Fill  $\alpha^2$  in OMR sheet.

$$\text{Sol. } (\text{WD})_{\text{ext}} = -\Delta V = -q\Delta V = -q\left(0 - \frac{a}{50}\right) = \frac{aq}{50}$$

$$50 \times 10^{-6} = \frac{a \times 4 \times 10^{-6}}{50}$$

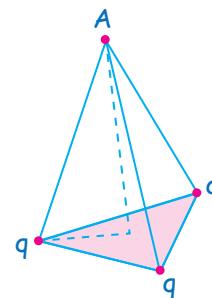
$$a = \frac{50 \times 50}{4} = 625$$

$$V = 6250 = 625x^2 + 625y^2 + 625 \times 2 \times 2$$

$$10 = x^2 + y^2 + 4$$

$$x^2 + y^2 = (\sqrt{6})^2$$

**Q.** Three charges ( $+q$ ) are placed on the vertices of an equilateral triangle of side  $a$  as shown in diagram. Find electric field at a height  $h = a$  above the centroid of  $\Delta$ .

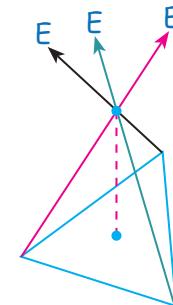


$$\text{Sol. } E_A = 3E \sin \theta$$

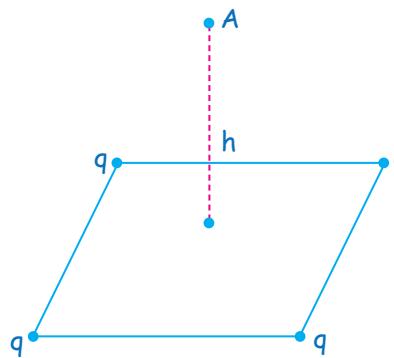
[ $\theta = 60^\circ$  already solved]

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

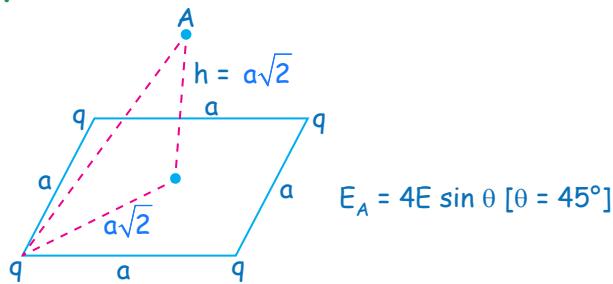
$$r^2 = h^2 + \left(\frac{a}{\sqrt{3}}\right)^2$$



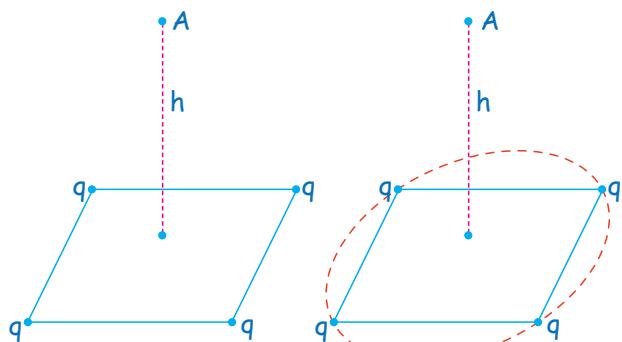
**Q.** Four charges ( $q$ ) are placed on the corners of a square of side  $a$ . Find electric field at a height  $h$  =  $\frac{a}{\sqrt{2}}$  from centre of square as shown in figure.



Sol.



ऐ फिर आ गया रे बाबा

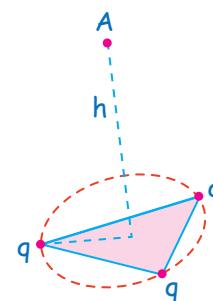


ऐसे symmetric सवालो में हम  $4q$  charge की एक ring मान सकते हैं जिसकी radius center से किसी भी एक charge के बीच की दूरी होगी यहाँ पर

$$R = \left( \frac{A}{\sqrt{2}} \right) \text{ और } x = h.$$

$$E = \frac{KQx}{(R^2 + x^2)^{3/2}} = \frac{K(4q)h}{\left[ \left( \frac{a}{\sqrt{2}} \right)^2 + h^2 \right]^{3/2}}$$

अब ये मत बोलना की ये पहले क्यों नहीं बताया अगर पहले बता देता तो तुम्हारी physics and visualisation develop नहीं 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 हैं। It's your homework verify the result. जब verify हो जाए तो मुझे insta पर खुशी खुशी बताना। (Saleem.nitt) अगर आप insta पर नहीं हो तो account मत बनाना।



# 2

# Current Electricity

- ★ Current ( $i$ )  $\Rightarrow$  Rate of flow of charge, scalar quantity

$$i = \frac{dq}{dt}$$

- ★ Inst Current  $= i = \frac{dq}{dt}$

- ★ Average Current  $= \langle i \rangle = \frac{\int i \cdot dt}{\int dt} = \frac{\Delta q}{\Delta t}$

- ★  $\langle V \rangle = \text{Average velocity} = \frac{\int v dt}{\int dt}$   $\langle \text{कदम्ब} \rangle = \frac{\int \text{कदम्ब} dt}{\int dt}$

Q. Given  $i = 3t^2$

(a) Find current at  $t = 2$  sec

Sol.  $i = 3 \times 2^2 = 12$

(b) Finds average current from  $t = 0 \rightarrow t = 2$

$$\langle i \rangle = \frac{\int_0^2 idt}{\int_0^2 dt} = \frac{\int_0^2 3t^2 dt}{\int_0^2 dt} = \frac{8}{2} = 4$$

(c)  $i = 3t^2$  Find the charge flow from  $t = 0 \rightarrow t = 2$  sec

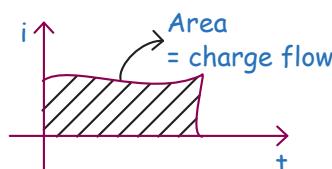
$$\Delta q = \int idt = \int_0^2 3t^2 dt = 8$$

★  $i = \frac{dq}{dt}$

$$\int dq = \int idt$$

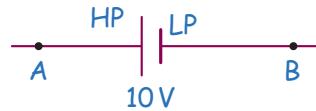
$$\Delta q = \int idt = \text{Area}$$

$\downarrow$   
charge flow

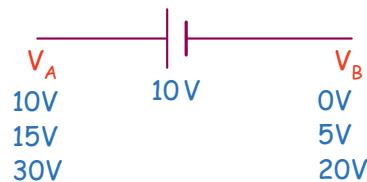


अबे सुनो Current electricity में सबसे जरूरी होता है circuit analysis तो sequence change करके saleem bhaiya के sequence में पढ़ते हैं from basic to advance.

- ★ Ideal battery



$$V_A - V_B = 10$$



- ★ Ohm's Law (derivation बाद में देखेंगे)

CE में बहुत जरूरी है  $V = iR$  लगाना सीखना  
let's start it.

$$i \Delta V = iR$$

$$V_A - V_B = iR \quad \text{or} \quad V = iR$$

$i \rightarrow$  Resist में H.P to L.P



Q. Find current in the resistance in following cases.



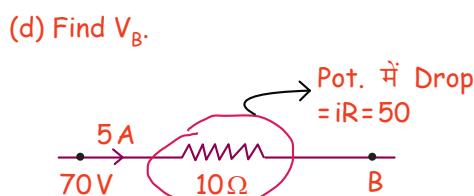
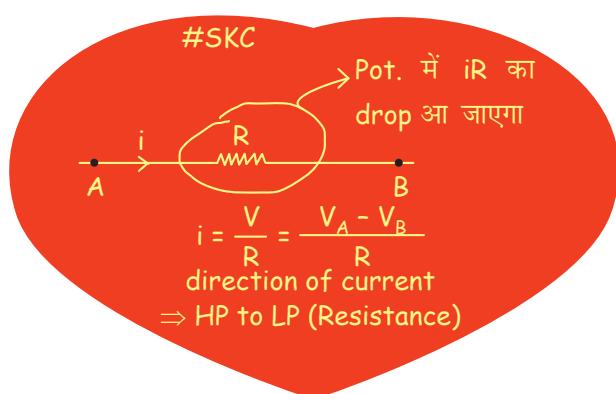
Sol.  $i = \frac{40 - 0}{10} = 4$



Sol.  $i = \frac{50}{10} = 5$



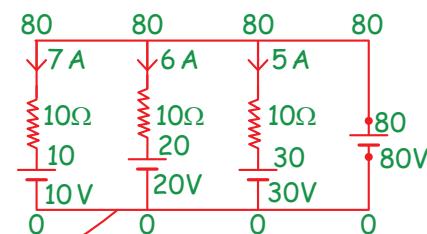
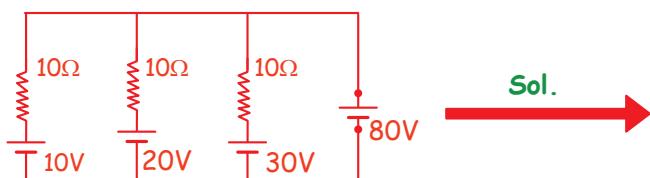
Sol.  $i = \frac{50 - (-10)}{10} = \frac{60}{10} = 6$



Sol.  $V_B = 70 - 50 = 20V$

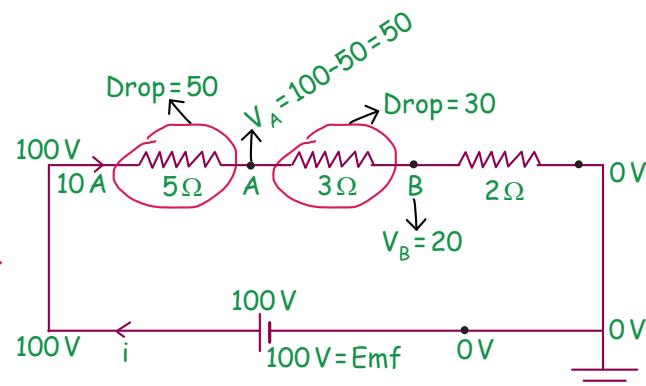
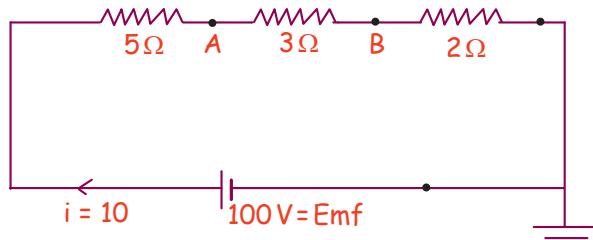
#SKC  
Resistance में current H.P to L.P flow करेगा but Battery में कैसे भी कर सकता है

Q. Find current through each resistors.



wire का resist = 0

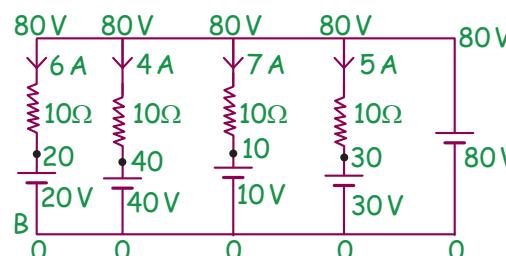
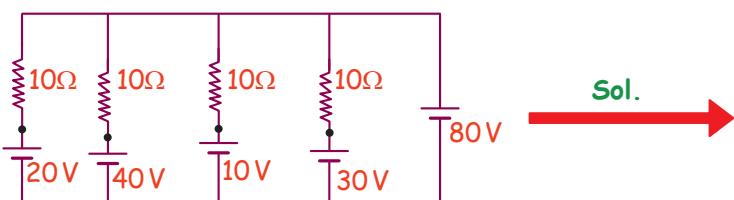
Q. Find current and potential at A & B.



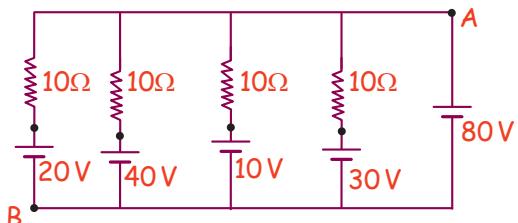
$$i = \frac{E}{R_{eq}} = \frac{100}{10} = 10A$$

$$R_{eq} = 5 + 3 + 2 = 10\Omega$$

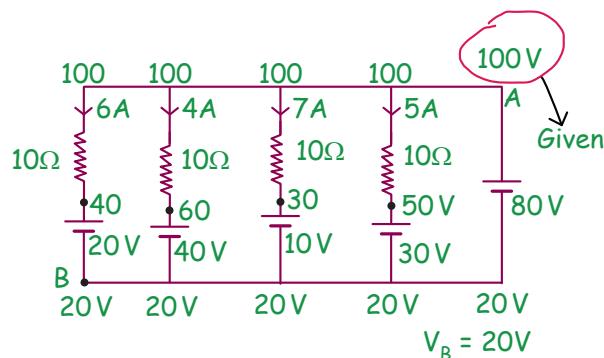
Q. Find current through each resistors ( $R = 10\Omega$  each)



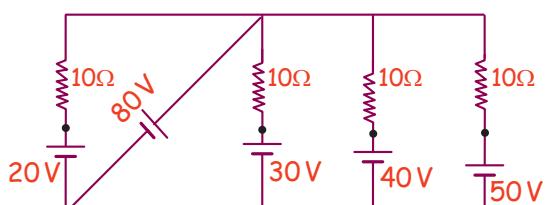
Q. If pot. at A is 100V, find  $V_B$  & Current. ( $R = 10\Omega$  each)



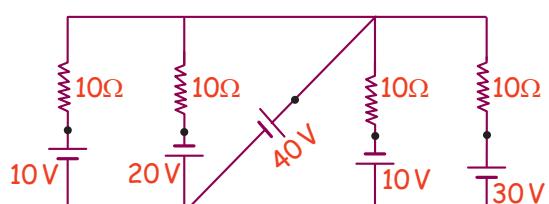
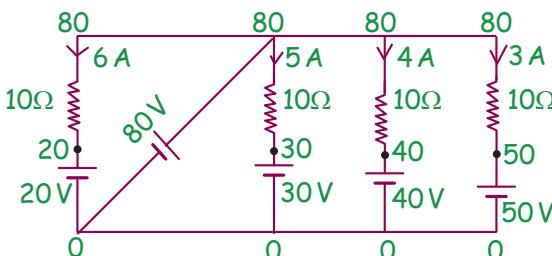
Sol.



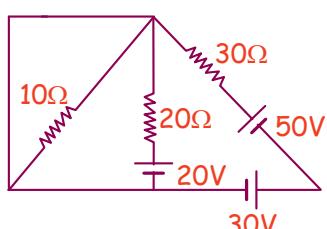
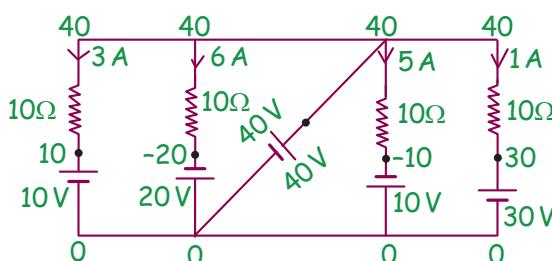
Q. Find  $i$  in each resistance



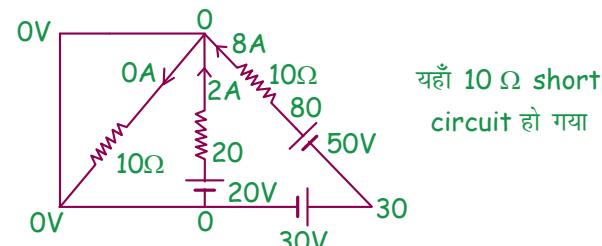
Sol.



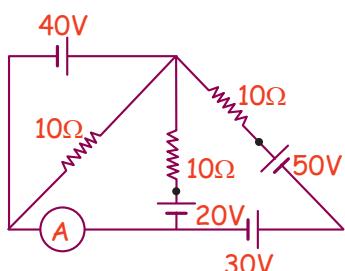
Sol.



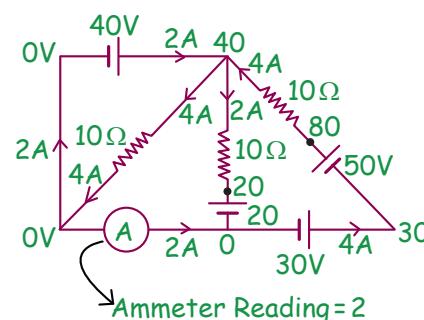
Sol.



Q. What is ammeter reading?



Sol.



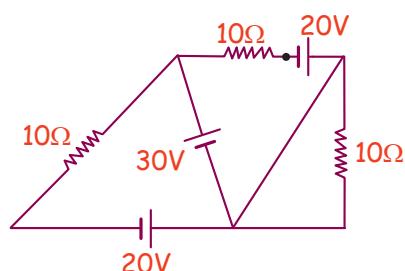


माना की no. of pages of book को कम से कम रखने का pressure है to minimise the MRP/- लेकिन circuit analysis के सवाल हम भर-भर कर practice करेंगे। (Bcz it's vry imp)

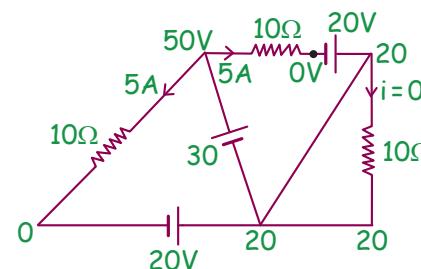


अब ready हो ना मुझे ऐसा लग रहा है ये तुम्हीं हो..... नीचे के left side के सारे सवाल खुद से solve करो और right side से match कराओ..... और जब सारे सवाल हो जाए मुझे insta पर confirmation दो। (ID: saleem.nitt)

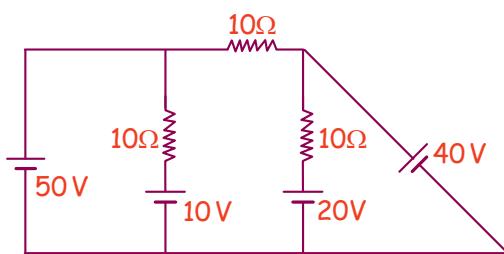
**Q.** Find current in each resistors.



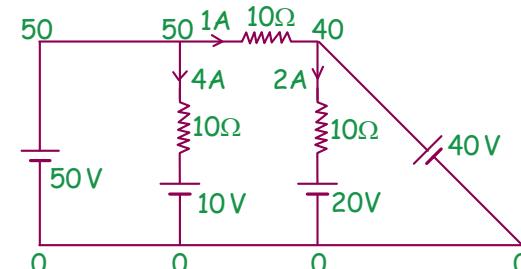
Sol.



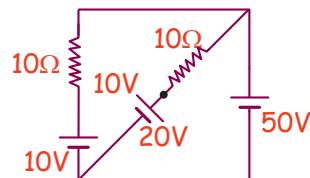
**Q.** Find current in each resistors.



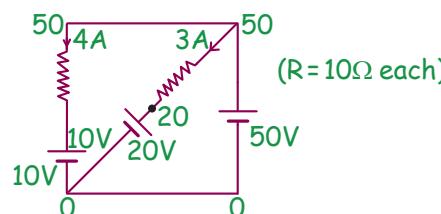
Sol.



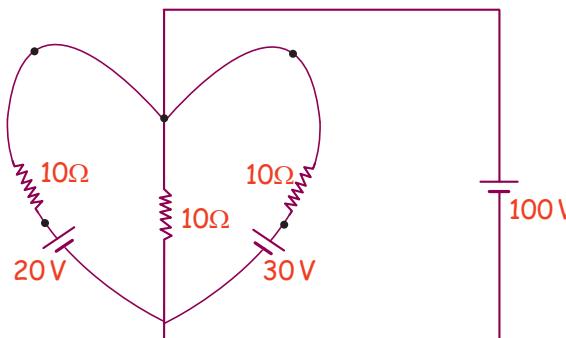
**Q.** Find current in each resistors.



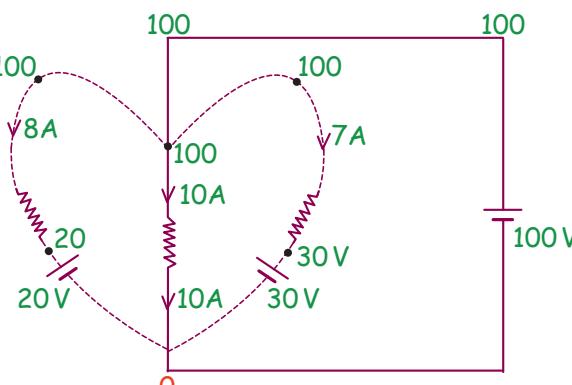
Sol.

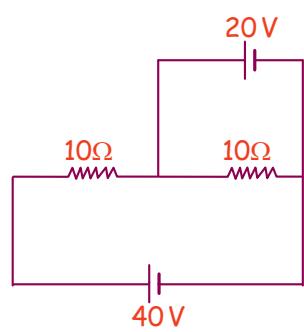


**Q.** Find current in each resistors.

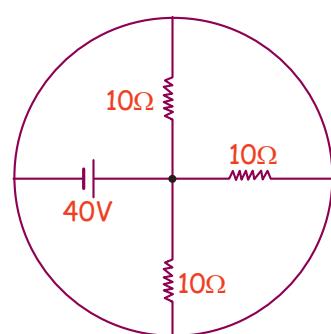
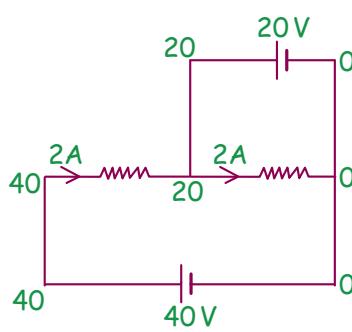


Sol.

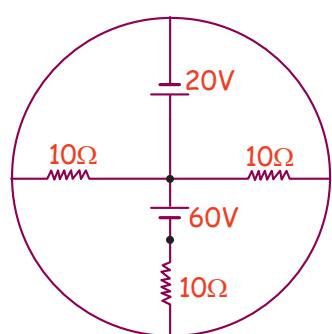
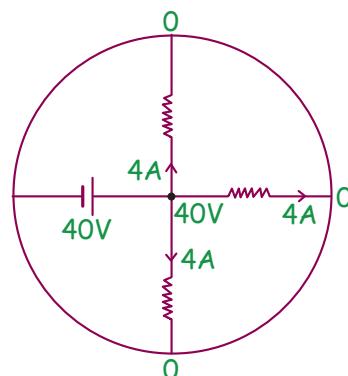




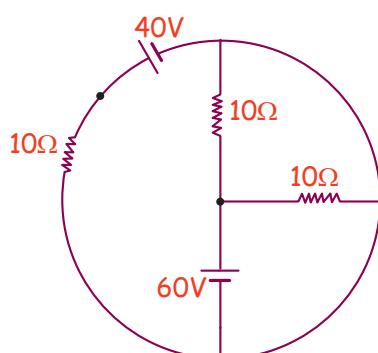
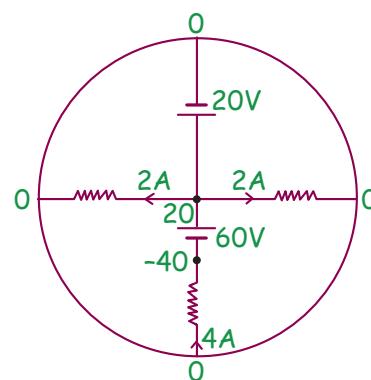
Sol.



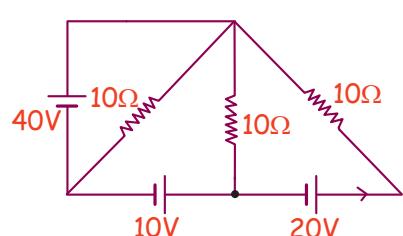
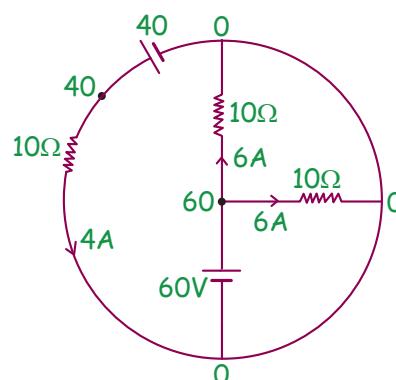
Sol.



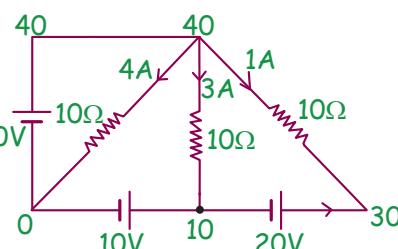
Sol.



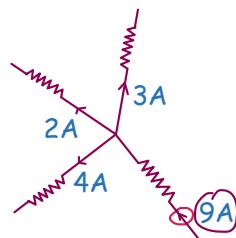
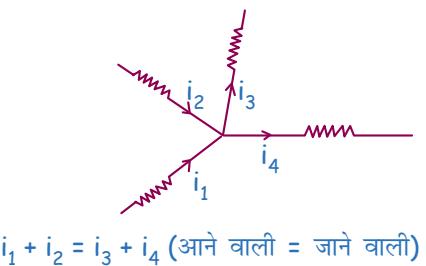
Sol.



Sol.

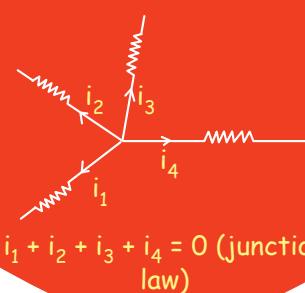


## JUNCTION LAW

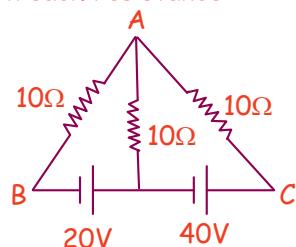


OR

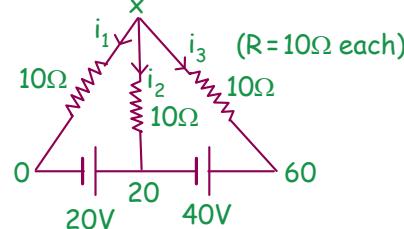
#SKC  
किसी भी junction से total जाने वाला current का sum = 0



Q. Find current in each resistance



Sol.



#SKC  
अगर B का potential 0 मानू तो C का potential will be 60 volt लेकिन हम A का potential नहीं बता सकते, हम फँस गए.....  
जहाँ फँस जाओ वहाँ EX को याद करो..... 😊  
अब emotional मत हो I mean जहाँ फँसे वहाँ potential X मान लो और junction law लगादो

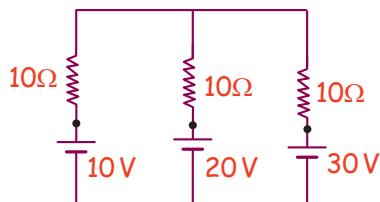


$$i_1 + i_2 + i_3 = 0$$

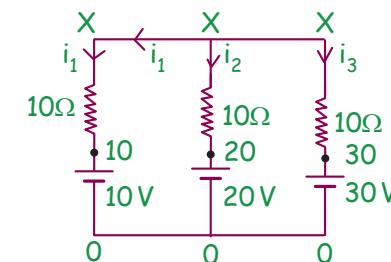
$$\frac{x - 0}{10} + \frac{x - 20}{10} + \frac{x - 60}{10} = 0$$

$$x = \boxed{\frac{80}{3}}$$

Q. Find current through each resistance.



Sol.



$$i_1 + i_2 + i_3 = 0$$

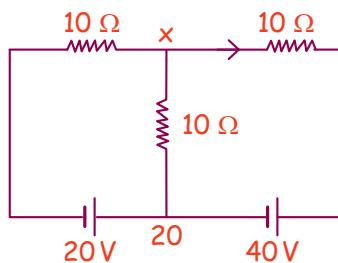
$$\frac{x - 10}{10} + \frac{x - 20}{10} + \frac{x - 30}{10} = 0$$

$$x = 20$$

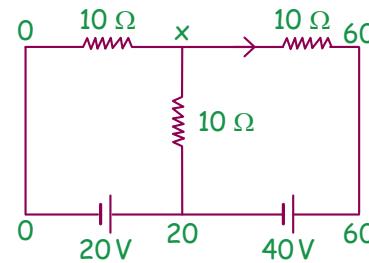
now we can find current through any wire

$$i_1 = \frac{x - 10}{10} = 1A \text{ and } i_2 = \frac{x - 20}{10} = 0$$

Q. Find current through each resistors.



Sol.

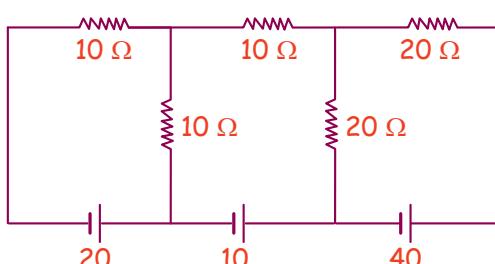


$$i_1 + i_2 + i_3 = 0$$

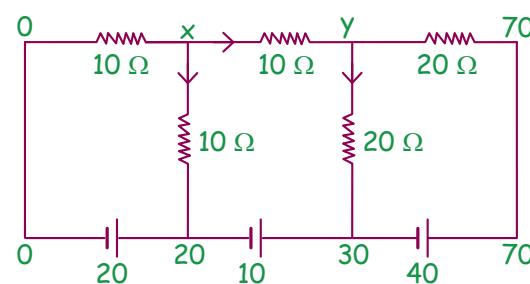
$$\frac{x - 0}{10} + \frac{x - 20}{10} + \frac{x - 60}{10}$$

$$x = \frac{80}{3}$$

Q. Find potential (x).



Sol.



$$\frac{x - 0}{10} + \frac{x - 20}{10} + \frac{x - y}{10} = 0$$

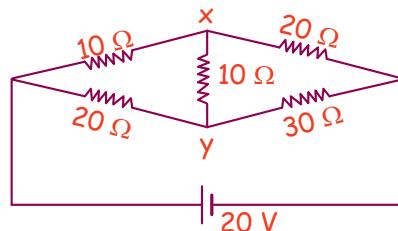
$$3x - y = 20 \quad \dots(1)$$

$$\frac{y - x}{10} + \frac{y - 30}{20} + \frac{y - 70}{20} = 0$$

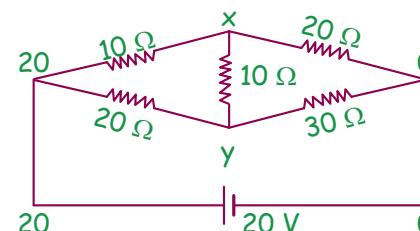
$$4y - 2x = 100 \quad \dots(2)$$

Now we solve both eqn. and get answer

Q. Find  $V_x - V_y = ?$



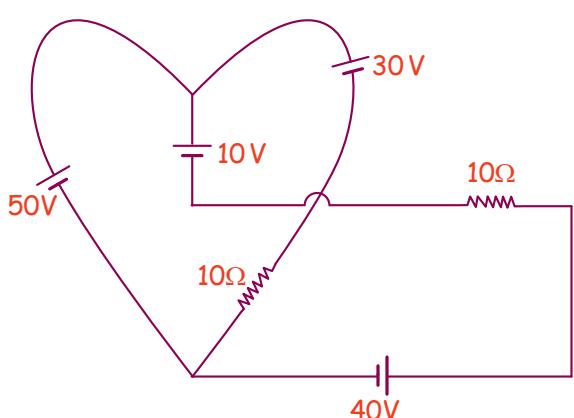
Sol.



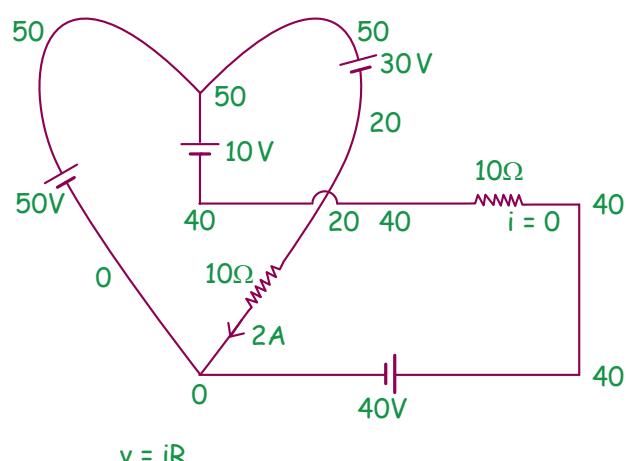
$$\frac{x - 20}{10} + \frac{x - y}{10} + \frac{x - 0}{20} = 0$$

$$\frac{y - 20}{20} + \frac{y - x}{10} + \frac{y - 0}{30} = 0$$

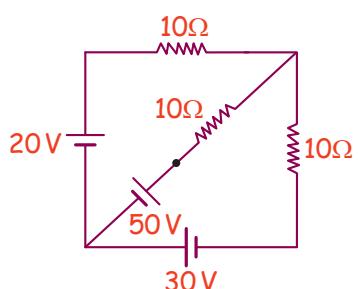
Q. Find current through each resistors.



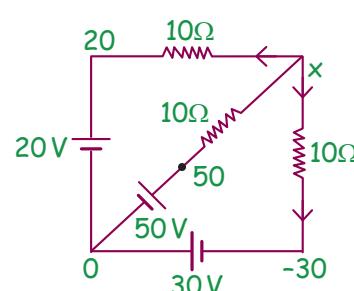
Sol.



Q. Find current through each resistors.



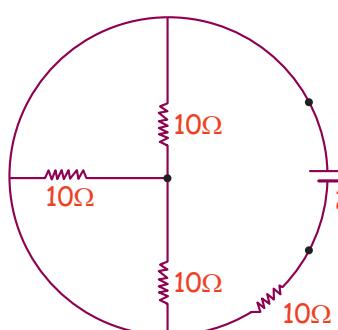
Sol.



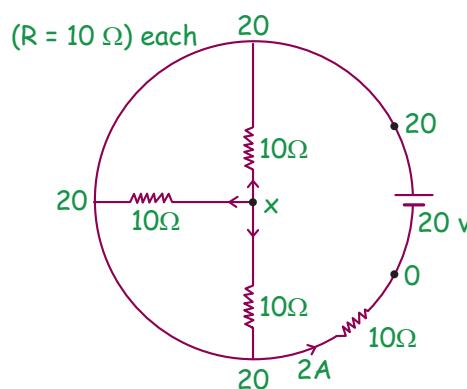
$$\frac{x - 20}{10} + \frac{x - 50}{10} + \frac{x + 30}{10} = 0$$

$$x = \frac{40}{3}$$

Q. Find current through each resistors.



Sol.

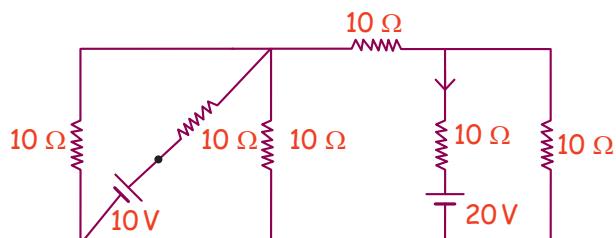


$$\frac{x - 20}{10} + \frac{x - 20}{10} + \frac{x - 20}{10} = 0$$

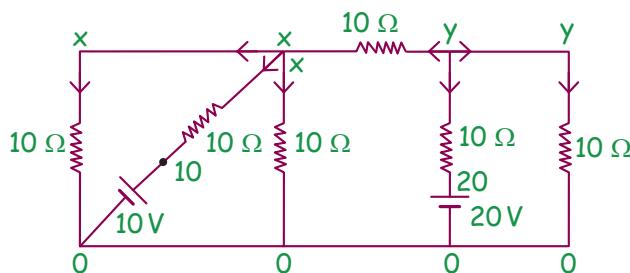
$$x = 20$$

$$i_1 = i_2 = i_3 = 0$$

Q. Find current through each resistors.



Sol.



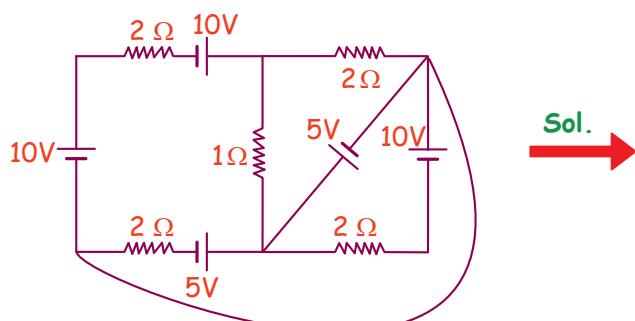
Apply junction law at x

$$\frac{x-0}{10} + \frac{x-10}{10} + \frac{x-0}{10} + \frac{x-y}{10} = 0$$

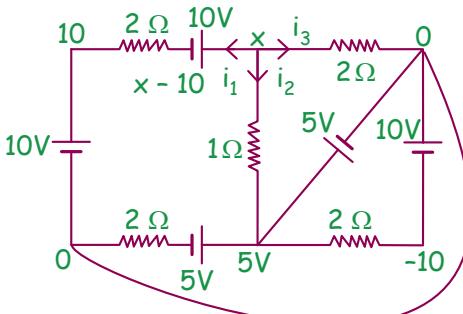
Apply junction law at y

$$\frac{y-x}{10} + \frac{y-20}{10} + \frac{y-0}{10} = 0$$

Q. Find current through each resistors.

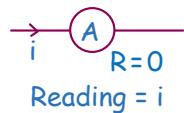


Sol.



#SKC  
ideal Ammeter का Resistance  
⇒ Zero  
ideal Voltmeter का Resistance ⇒ ∞  
क्योंकि हम चाहते हैं (A) (V) का  
इस्तेमाल करते बहुत circuit  
ना बदले

\* Ideal Ammeter



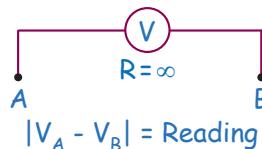
$$\frac{x-10-10}{2} + \frac{x-5}{1} + \frac{x-0}{2} = 0$$

$$x - 20 + 2x - 10 + x = 0$$

$$4x = 30 = 7.5$$

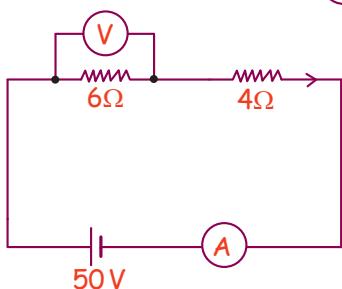
$$i_2 = \frac{x-5}{1} = 7.5 - 5 = 2.5$$

\* Ideal Voltmeter

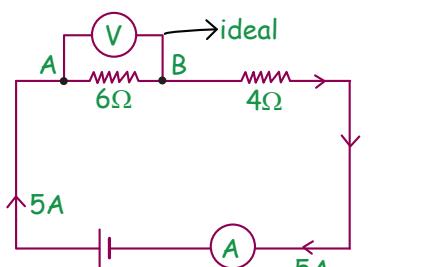


$$|V_A - V_B| = \text{Reading}$$

Q. Find the reading of ideal (V) & (A)

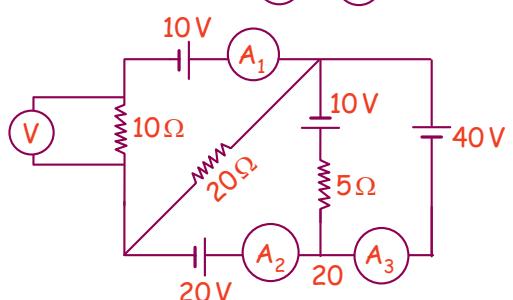


Sol.

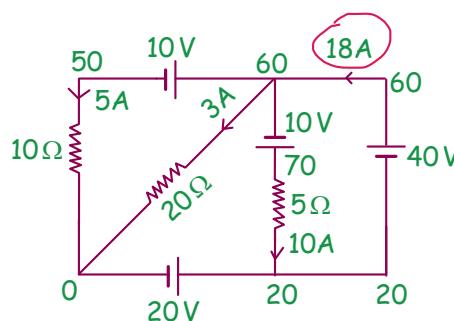


$$V_A - V_B = 5 \times 6 = \text{Reading of voltmeter}$$

Q. Find the reading of  $A_1$  &  $V$



Sol.



Ammeter की reading मतलब उससे कितना current pass कर रहा है अगर ammeter ideal है तो उसे wire मान लो। voltmeter की reading मतलब जिन दो point के बीच उसे connect किया है उनके बीच potential difference अगर voltmeter ideal है तो उसके through  $i = 0$

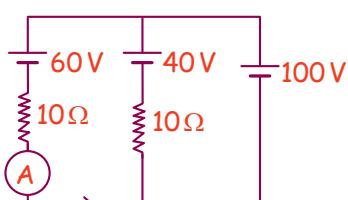
Reading of  $A_1 = 5A$

Reading of  $A_2 = 8A$

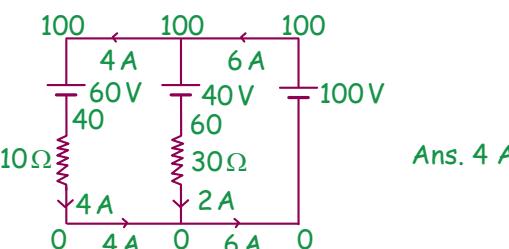
Reading of  $A_3 = 18A$

Reading of Voltmeter = 50

Q. Find the reading of  $A$

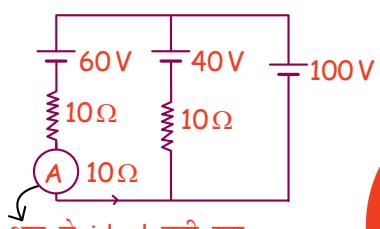


Sol.



Ans. 4 A

Q. What is the reading of non-ideal ammeter?

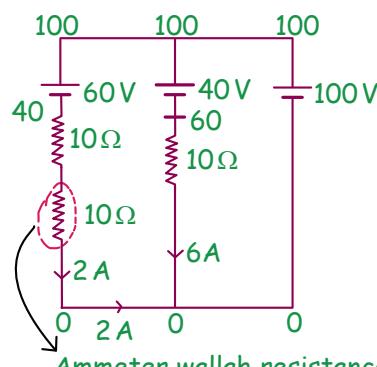


Sol.



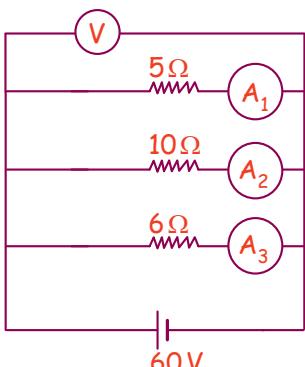
अब ये ideal नहीं रहा

#SKC  
अगर  $A - V$  का Resistance given हो तो ये Non-ideal है। तो  $A - V$  को हटाओ और Resistance रखदो

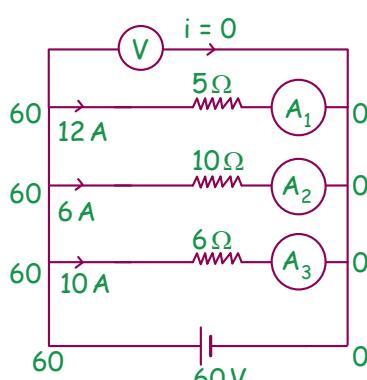


Ammeter wallah resistance

Q. What will be the readings?



Sol.

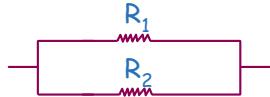


All are ideal:  
Reading of  $V = 60V$   
Reading of  $A_1 = 12A$   
Reading of  $A_2 = 6A$   
Reading of  $A_3 = 10A$

If two resistance  $R_1$  and  $R_2$  are in parallel then

## Parallel

$\Delta V \rightarrow \text{same}$



$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{R_2 + R_1}{R_1 R_2}$$

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2} = \frac{\text{multiply}}{\text{sum}}$$

Q. Sol.  $R_{eq} = \frac{10 \times 6}{10 + 6} = \frac{60}{16} = 3.75\Omega$

#SKC



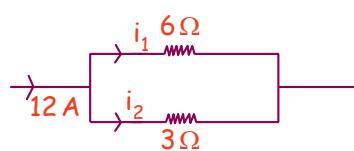
IMP

$i_1 = \text{सामने वाला } 'R' \times \text{total current}/\text{total } R$

$$i_1 = \frac{R_2}{R_1 + R_2} \times i_0$$

$$i_2 = \frac{R_1}{R_1 + R_2} \times i_0$$

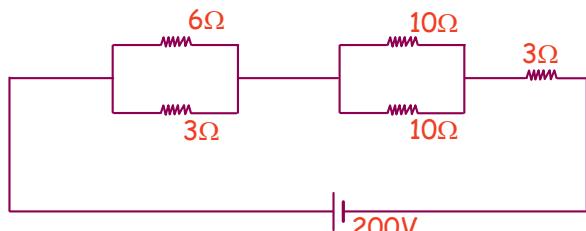
Q. Find  $i_1$  and  $i_2$



$$i_1 = \frac{3}{9} \times 12 = 4A$$

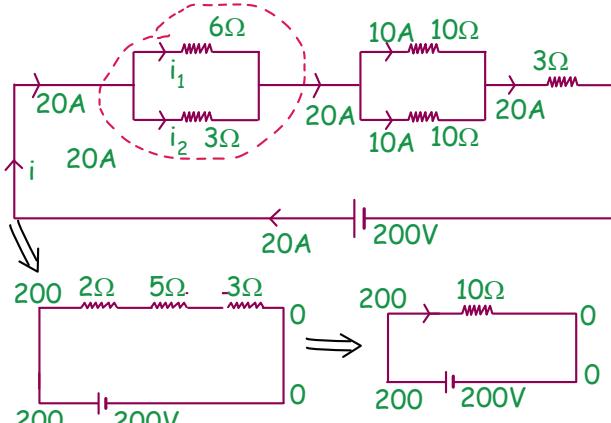
$$i_2 = \frac{6}{9} \times 12 = 8A$$

Q. Find current through each resistors.



Sol.

$$R_{eq} = \frac{\text{Multiply}}{\text{sum}}$$



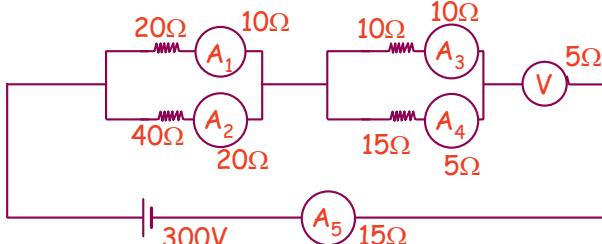
$$R_{eq} = 2 + 5 + 3 = 10\Omega$$

$$i = \frac{V}{R_{eq}} = \frac{200}{10} = 20A$$

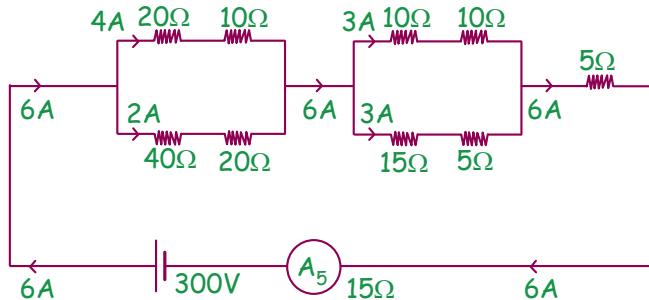
$$i_1 = \frac{3}{3+6} \times 20 = \frac{20}{3}$$

$$i_2 = \frac{6}{3+6} \times 20 = \frac{120}{9}$$

SSSQ. What will be reading of  $A_1, A_2, A_3, A_4$  and  $V$ ?



Sol.



Reading of  $A_1 \rightarrow 4A$

Reading of  $A_2 \rightarrow 2A$

Reading of  $A_3 \rightarrow 3A$

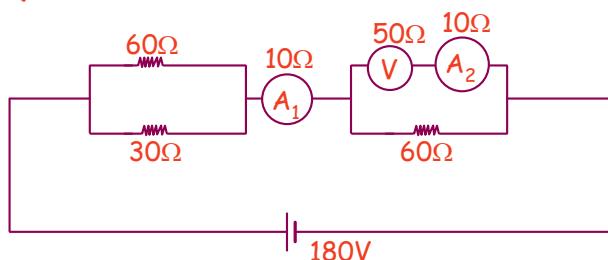
Reading of  $A_4 \rightarrow 3A$

Reading of  $A_5 \rightarrow 6A$

Reading of voltmeter =  $6 \times 5 = 30$

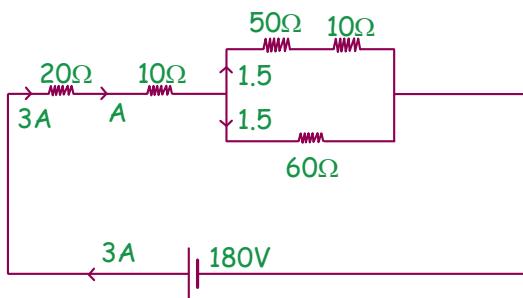
### SSSQ. Saleem Sir Special Question

**Q.**



If reading  $A_1$ ,  $A_2$  &  $V$   
are  $x$ ,  $y$ ,  $z$ , find  $\frac{z}{xy}$

**Sol.**



$$R_{eq} = 20 + 10 + 30 = 60\Omega$$

$$A_1 = 3A = x$$

$$A_2 = 1.5A = y$$

$$V = 75 \text{ volt} = z$$

$$\frac{z}{xy} = \frac{75}{3 \times 1.5} = 16.6$$



अब हम  $R_{eq}$  निकालना सीखेंगे

\* If resistance are in series then

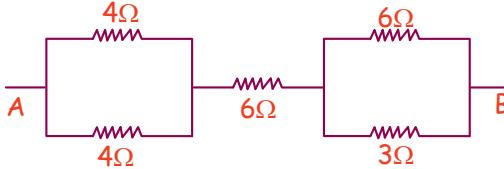
$$R_{eq} = R_1 + R_2 + R_3 + \dots$$

\* If resistance in parallel

$$R_{eq} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

\* If  $R_1$  and  $R_2$  are in parallel then  $R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$

**Q. Find  $R_{eq}$**

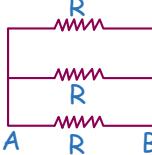
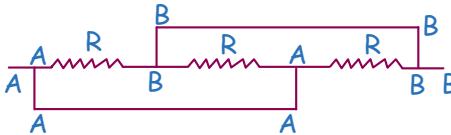


$$R_{eq} = 2 + 6 + 2 = 10\Omega$$

**Q. Find  $R_{eq}$  between A and B.**

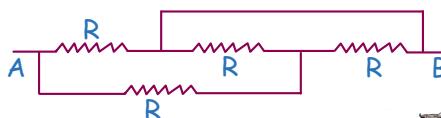


**Sol.**

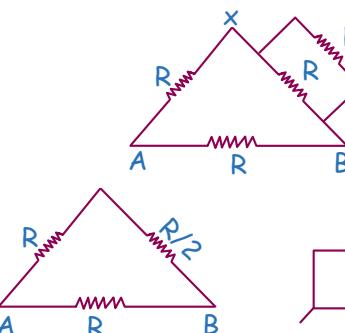
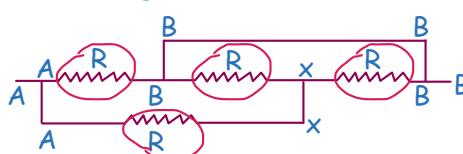


$$\frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} = \frac{3}{R} \quad R_{eq} = R/3$$

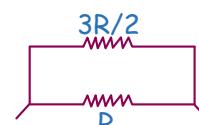
**Q. Find  $R_{eq}$  between A and B.**



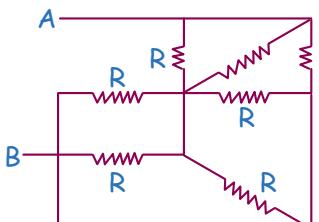
**Sol.** यहाँ फसो वहाँ  $x$  को याद करे और उसके खराब, बेकार, डरावनी सूरत को सूधार लो..... अब मतलब नया circuit diagram बनाओ।



$$\text{Ans. } R_{eq} = 0.6R$$

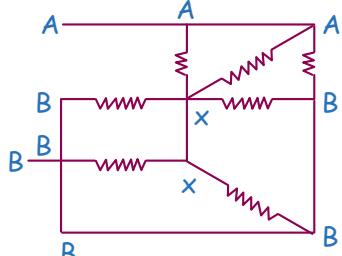


Q. Find the  $R_{eq}$  between A and B.

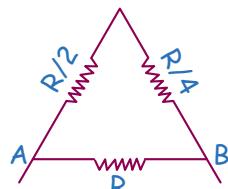
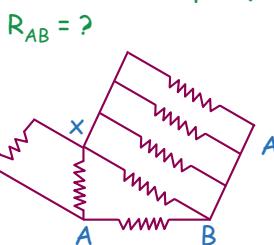


Sol.

Resistance  
 $R\Omega$  each

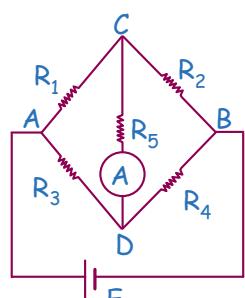


All resistance are equal ( $R\Omega$ )



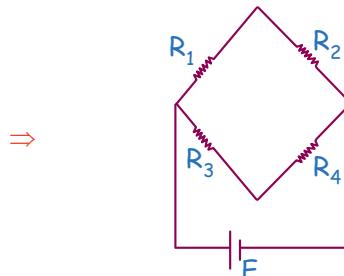
### Wheatstone Bridge

★ In following circuit

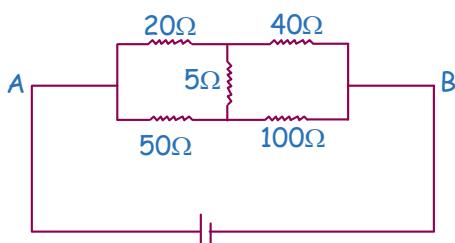


If  $\frac{R_1}{R_2} = \frac{R_3}{R_4}$  then be observed

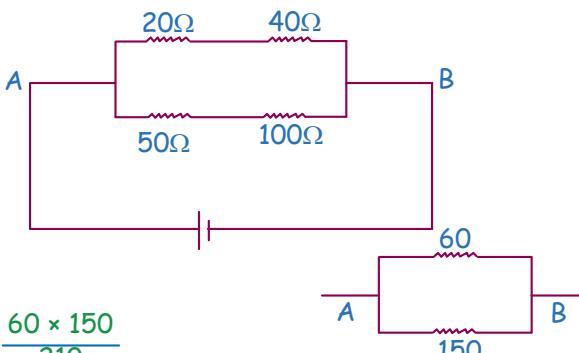
that  $V_C = V_D$  and current through  $R_5$  is zero तो  $R_5$  को circuit से उड़ा दो such type of circuit called balance wheatstone bridge



Q. Find  $R_{eq}$  between A & B

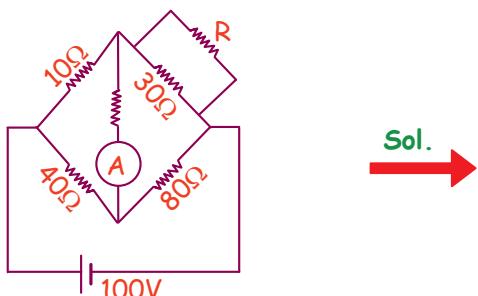


Sol.



$$R_{AB} = \frac{60 \times 150}{210}$$

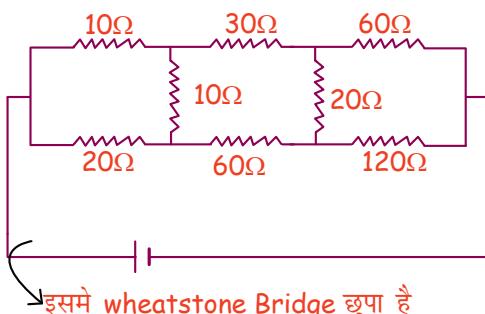
Q. Find value of R for which ammeter reading is zero



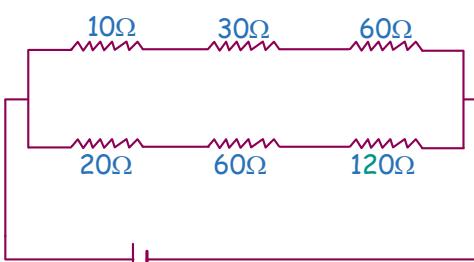
Sol.

$$R = 60 \quad \Rightarrow 20 \Omega \text{ होना चाहिए}$$

Q. Find equivalent resistance.

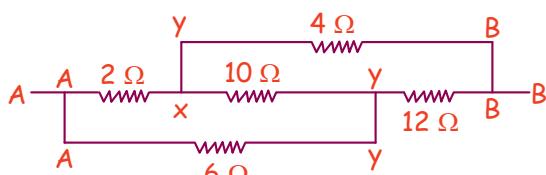


Sol.

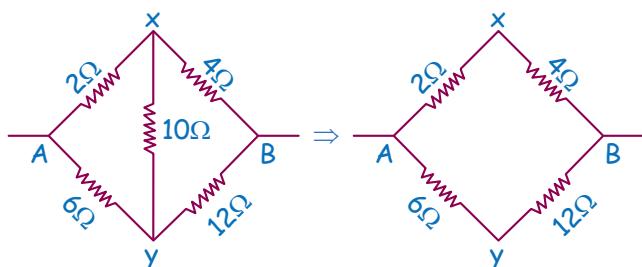


इसमे wheatstone Bridge लगा है

Q. find  $R_{AB} = ?$



Sol.



$$R_{eq} = \frac{6 \times 18}{6 + 18} = \frac{6 \times 18}{24} = 4.5$$

### Kirchhoff Voltage Law (KVL)



$$V_A - V_B = 10$$



$$V_A - V_B = iR$$

$$V_A - iR = V_B$$

$$A \xrightarrow{50V} +2\Omega \xrightarrow{10A} B \quad \text{drop} = 20$$

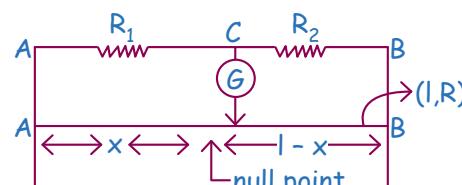
$$V_A - iR = V_B \\ 50 - 10 \times 2 = V_B \\ V_B = 30$$

### Meter Bridge

- It is used to find unknown resistance.
- Its concept based on balance wheat stone bridge.
- When current through galvanometer is Zero.

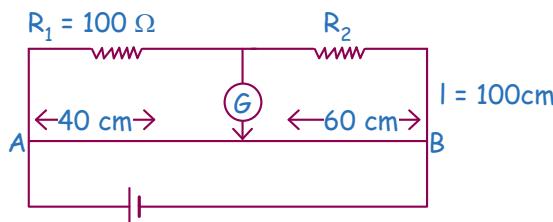
$$\frac{R_1}{R_2} = \frac{R_{AD}}{R_{DB}} = \frac{x}{l-x} \quad (l = 100 \text{ cm})$$

$$\boxed{\frac{R_1}{R_2} = \frac{x}{l-x}}$$



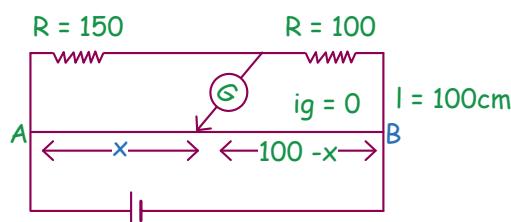
$$\left( \begin{array}{l} R = \frac{\rho l}{A} \\ R \propto \text{length} \end{array} \right)$$

**Q.** In a meter bridge (as shown in fig), if null point is found at a distance of 40 cm from A. Find shift in the null point if  $R_1$  &  $R_2$  interchanged



$$\text{Sol. } \frac{R_1}{R_2} = \frac{40}{60}$$

$$\frac{100}{R_2} = \frac{40}{60} \Rightarrow R_2 = 150$$



$$\frac{150}{100} = \frac{x}{100 - x}$$

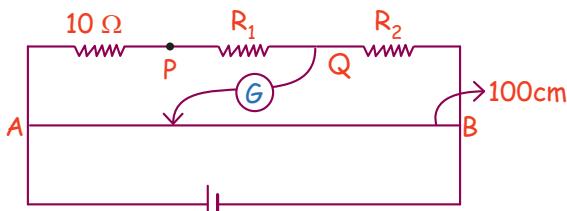
$$\frac{3}{2} = \frac{x}{100 - x}$$

$$300 - 3x = 2x$$

$$x = 60$$

$$\text{Ans. shift} = 60 - 40 = 20\text{cm}$$

**Q.** When galvanometer is connected to point P, null point at a distance 40 cm. From point A when galvanometer is connected to point Q, null point is found at a distance 30 cm from end B. Find  $R_1$  &  $R_2$ .

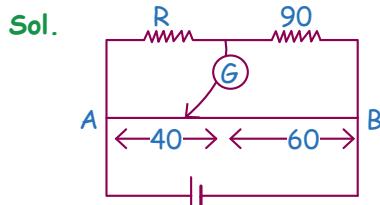


$$\text{Sol. } \frac{10}{R_1 + R_2} = \frac{40}{60} \quad \dots(1)$$

$$\frac{10 + R_1}{R_2} = \frac{70}{30} \quad \dots(2)$$

$$\text{Solve and get } R_1 = R_2 = 7.5\Omega$$

**Q.** In a meter Bridge find value of R if end correction are 1cm & 3cm at end A & end B



$$\frac{R}{90} = \frac{40 + 1}{60 + 3}$$

## POWER DISSIPATED ACROSS RESISTANCE

Power dissipated across the resistance =  $i^2 R$

$$\star P = V \cdot i = iR \cdot i = i^2 R = \frac{V^2}{R}$$

$$\star H = \int_0^t i^2 R dt$$

If current is constant heat =  $i^2 R t$

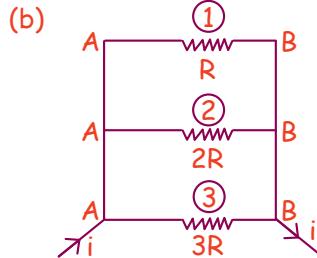
**Q.** Find the order of power dissipated across the resistance in following question.



$$\text{Sol. } P = i^2 R$$

$R \uparrow \Rightarrow P \uparrow$  Power loss  $\uparrow$

$$P_3 > P_2 > P_1$$



$$\text{Sol. } V \rightarrow \text{same}$$

$$P = \frac{V^2}{R} \qquad R \uparrow \Rightarrow P \downarrow$$

$$P_3 < P_2 < P_1$$



Student: sir ये बताओ कि  
कब  $P = I^2 R$  लगाना है कब  
 $P = V^2/R$  लगाना है।



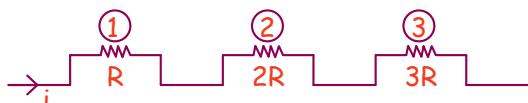
Saleem  
sir be  
like

दोनों में से जो चाहे formula  
लगा दो ans. same आयेगा।

**kya re tu, naak mein dum  
kar rakha hai tuney**

फिर भी अगर resistance series में है तो  $P = I^2 R$  try करो  
और अगर resistance parallel में है तो  $P = V^2/R$  try करो  
calculation आसान रहेगी।

- Q. Three different bulb of resistance  $R$ ,  $2R$ ,  $3R$  are in series as shown in figure. Find order of their brightness.



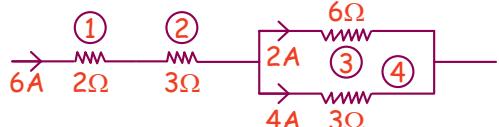
Sol.  $i \rightarrow$  same  $P = i^2 R$

$$P \rightarrow P_3 > P_2 > P_1$$

$$\text{Brig} \rightarrow B_3 > B_2 > B_1$$

Bulb के case में जिसके across power  
↑ तो Brightness ↑

- Q. Repeat the above problem in following case.



$$P_1 = 6^2 \times 2 = 72$$

$$P_2 = 6^2 \times 3 = 108$$

$$P_3 = 2^2 \times 6 = 24$$

$$P_4 = 4^2 \times 3 = 48$$

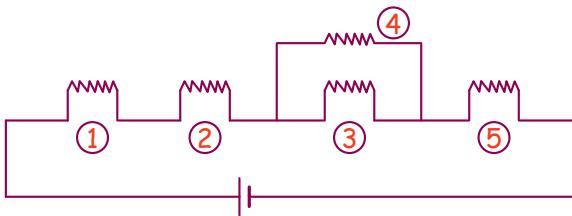
$$P_2 > P_1 > P_4 > P_3$$

$$\text{Brightness } B_2 > B_1 > B_4 > B_3$$

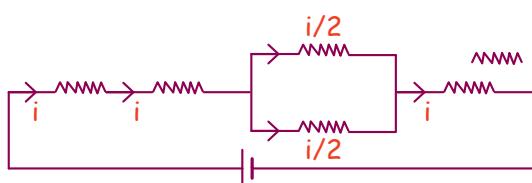
- Q. Compare brighten of bulb

All are identical bulb

$R \rightarrow$  same

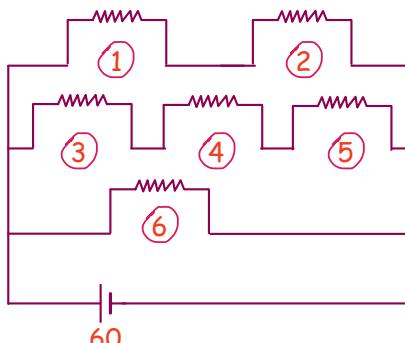


Sol.

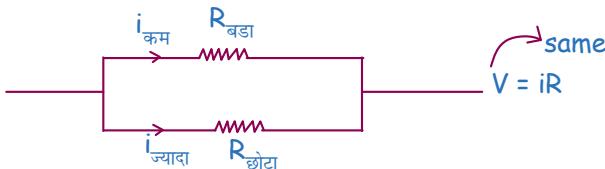


$$B_1 = B_2 = B_5 > B_4 = B_3$$

- Q. All bulbs are identical having same resistance  $10\Omega$ . Find order of brightness

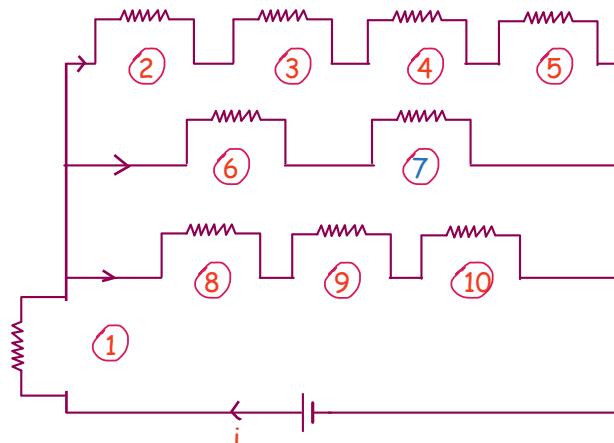


Sol.  $B_6 > B_1 = B_2 > B_3 = B_4 = B_5$



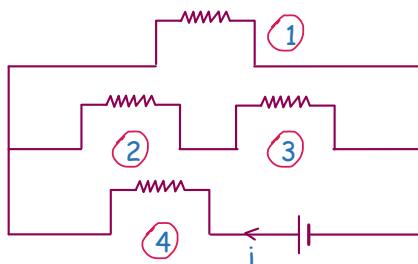
- Q. All are identical

(a)



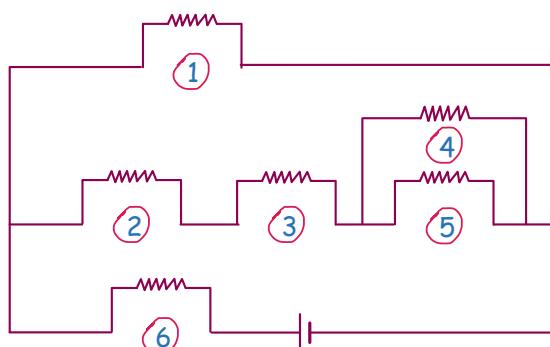
Sol.  $B_1 > B_6 = B_7 > B_8 = B_9 = B_{10} > B_2 = B_3 = B_4 = B_5$

(b) All bulbs are identical



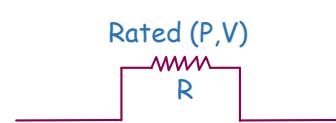
Sol.  $B_4 > B_1 = B_2 = B_3$

(c)



Sol.  $B_6 > B_1 > B_2 = B_3 > B_4 = B_5$

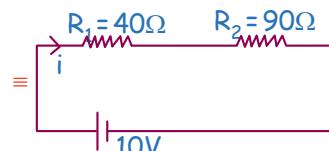
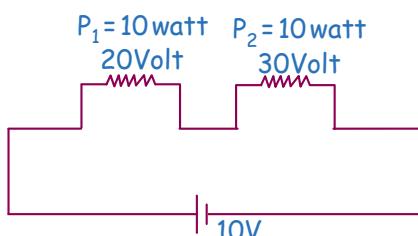
## # Bulb



Suppose it's given that rated voltage of bulb is  $V$  and rated power is  $P$  it means यह bulb का resistance देने का तरीका है

$$\text{Resistance of bulb} = \frac{V^2}{P}$$

Q. Compare brighter of bulbs.



$$\text{Sol. } R = \frac{V^2}{P} \Rightarrow R_1 = \frac{(20)^2}{10} = 40\Omega$$

$$i = \frac{10}{130}$$

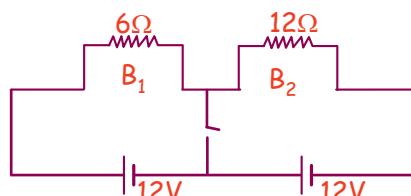
$$R_2 = \frac{(30)^2}{10} = 90\Omega$$

$$\text{Power across } B_1 = i^2 R_1 = (1/13)^2 \times 40$$

$$B_2 = i^2 R_2 = (1/13)^2 \times 90$$

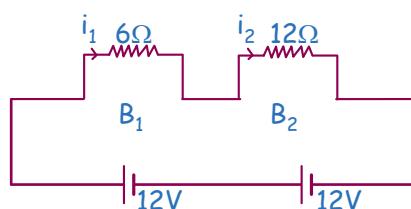
$B_2 > B_1$  (or  $i \rightarrow \text{same} \Rightarrow$  जिसका  $R \uparrow$  उसकी  $P \uparrow B \uparrow$ ).

Q.  $B_1$  and  $B_2$  are bulbs. What happens to brightness of bulbs after switch close?



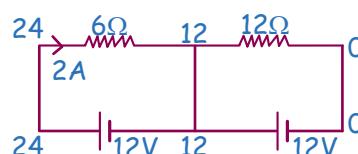
1. Brightness of  $B_1$  inc
2. Brightness of  $B_1$  dec
3. Brightness of  $B_2$  inc
4. Brightness of  $B_2$  dec

Sol. Before switch is close



$$i_1 = i_2 = 1.33$$

Now after switch is closed.



$$i_1 = 2 \text{ and } i_2 = 1$$

We observed that after switch is closed current through  $B_1$  increased hence power across bulb  $B_1$  increased similarly current across bulb 2 decreased. Hence power across bulb 2 decreased.

Ans: 1 & 4

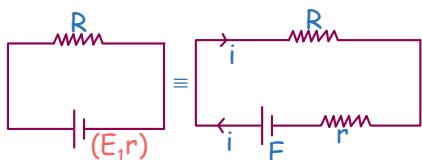
★ When connected voltage and rated voltage are same then total power dissipated for  $n$  number of bulbs in series,

$$\frac{1}{P_T} = \frac{1}{P_1} + \frac{1}{P_2} + \frac{1}{P_3} + \dots + \frac{1}{P_n}$$

★ When connected voltage and rated voltage are same then total power dissipated for  $n$  number of bulbs in parallel,

$$P_T = P_1 + P_2 + P_3 + \dots + P_n$$

### ★ Max Power Theorem



$$\text{Power dissipated across } R = i^2 R = \left( \frac{E}{R+r} \right)^2 R$$

$$P = \frac{E^2 R}{(R+r)^2}$$

At what condition  $P \rightarrow \max$

$$\text{Do } \frac{dP}{dR} = 0 \Rightarrow \text{Solve and get } R = r$$

So maximum power will be delivered to load  $R$  if value is equal to that of internal resistance of cell. In above case  $P_{\max} = E^2 / 4R$  (after solve).



अब हम KVL लिखना सिखेंगे जिसका आपको बहुत देर से इंतजार है बस नीचे की बाते याद रखो।

$$V_A - iR = V_B$$

(Resistance में current की दिशा में  $iR$  का drop)

$$V_A - V_B = E$$

(irrespective of dir<sup>n</sup> of current)

$$V_B - V_A = E$$

(चाहे current हो या ना हो या कही भी हो)

$$V_B - V_A = E$$

Q. Find  $V_A - V_B$



#SKC



Sol.

$$\begin{aligned} & A \xrightarrow{10A} + \ominus \xrightarrow{R=2\Omega} - \oplus \xrightarrow{30V} B \\ & V_A - iR + E = V_B \end{aligned}$$

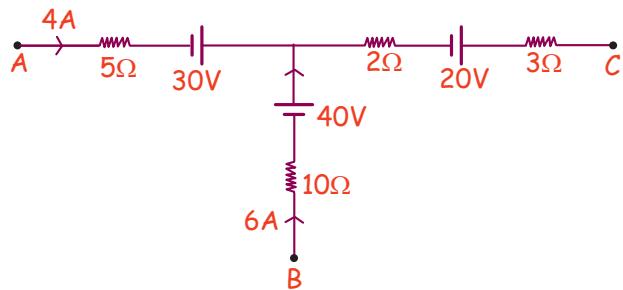
$$\begin{aligned} & V_A - 20 + 30 = V_B \\ & V_A - V_B = -10 \end{aligned}$$



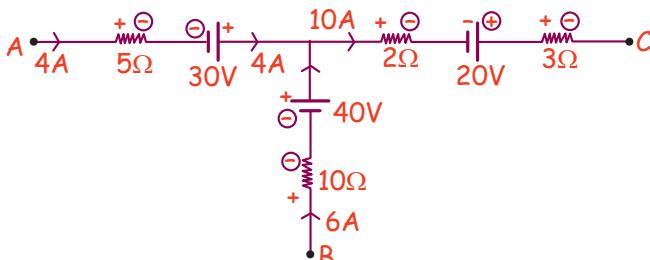
$$\text{Sol. } V_A - E_1 - iR_1 + E_2 - iR_2 - E_3 - iR_3 = V_B$$

$$V_A - V_B = \checkmark$$

Q. Find (1)  $V_A - V_C$  (2)  $V_A - V_B$  (3)  $V_B - V_C$



Sol.



$$(1) V_A - V_C = ?$$

$$V_A - 20 + 30 - 10 \times 2 + 20 - 30 = +V_C$$

$$V_A - V_C = 20$$

(2)  $V_A - V_B = ?$

$$V_A - 20 + 30 - 40 + 6 \times 10 = V_B$$

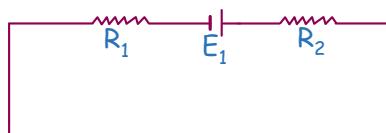
$$V_A - V_B = -30$$

(3)  $V_B - V_C = ?$

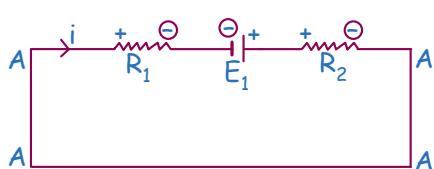
$$V_B - 60 + 40 - 20 + 20 - 30 = V_C$$

$$V_B - V_C = 50$$

Q. Find current in the circuit.



Sol.

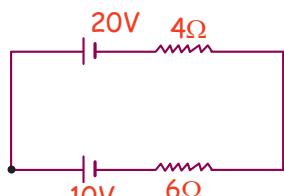


$$V_A - iR_1 + E_1 - iR_2 = V_A$$

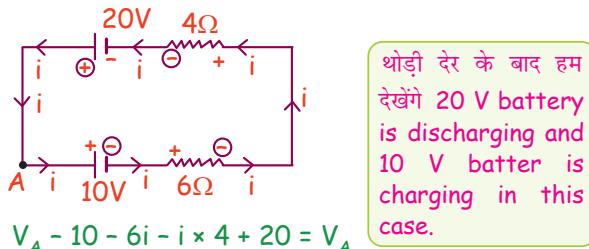
$$E_1 = iR_1 + iR_2$$

$$i = \frac{E_1}{R_1 + R_2}$$

Q. Find current in the circuit.



Sol.



$$V_A - 10 - 6i - i \times 4 + 20 = V_A$$

$$-10 - 10i + 20 = 0$$

$$i = 1A$$

#SKC

i → loop में Cω/Acω

जो दिल चाहे मान लो अगर

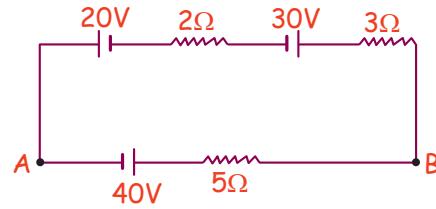
गलत direction मानी तो current negative

आ जाएगा

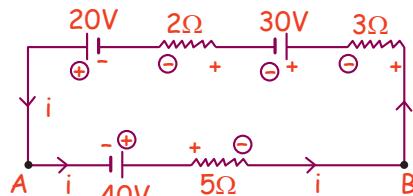


Q. (1) Find current in circuit

(2)  $V_A - V_B = ?$



Sol.



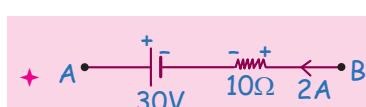
(1)  $i \rightarrow \text{Acw} \text{ मान लो (let)}$

$$V_A + 40 - 5i - 3i - 30 - 2i + 20 = V_A$$

$$i = 3A$$

(2)  $V_A + 40 - 3 \times 5 = V_B$

$$V_A - V_B = -25$$



1. A से B चलते हैं

$$V_A - 30 + 2 \times 10 = V_B$$

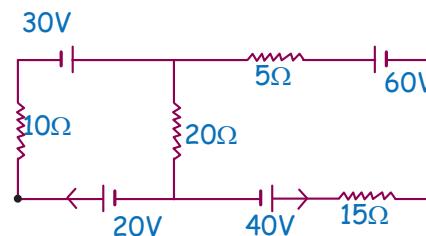
$$V_A - V_B = 10V$$

2. B से A चलते हैं

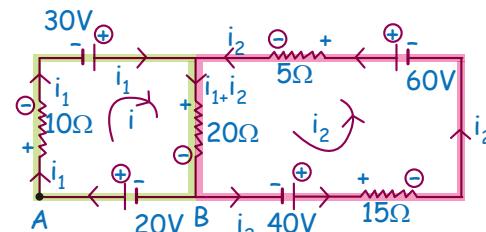
$$V_B - 2 \times 10 + 30 = V_A$$

$$V_A - V_B = 10$$

Q. Find current in each in each resistors



Sol.



$$V_A - 10i + 30 - (i_1 + i_2) \times 20 + 20 = V_A$$

$$-10i_1 + 30 - (i_1 + i_2) \times 20 + 20 = 0 \quad \dots(1)$$

$$VB + 40 - 15i_2 + 60 - 5i_2 - (i_1 + i_2) \times 20 = VB$$

$$40 - 15i_2 + 60 - 5i_2 - (i_1 + i_2) \times 20 = 0 \quad \dots(2)$$

Solve (1) & (2) And get Ans:

### Charging & Discharging of Batteries

#SKC

अगर battery के बड़े डंडे से बाहर current निकल रहा है तो battery discharge हो रही है और बड़े डंडे के अंदर current आ रहा है तो battery charge हो रही है



#### Charging of battery



$$V_A - E - ir = V_B$$

$$V_A - V_B = E + ir$$

(Pot diff across battery, terminal voltage)

#### Discharging of battery



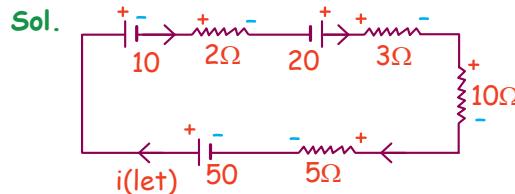
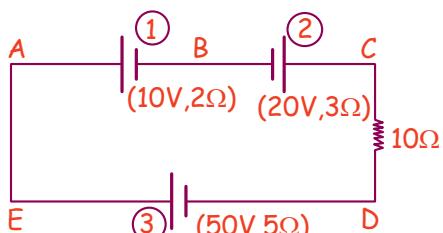
$$V_A - E + ir = V_B$$

$$V_A - V_B = E - ir$$

(Pot diff across battery, terminal voltage)

अब पिछले page में SKC के पास वाले questions solve करो और देखो कौनसी battery charge हो रही है और कौनसी discharge.

#### Q. Find potential difference across each battery



$$V_A - 10 - 2i + 20V - 3i - 10i - 5i + 50 = V_A$$

$$60 = 2i$$

$$i = 3A$$

(1) → Charging      2, 3 → discharge

Potential diff across each battery

$$|V_{AB}| = E + ir = 10 + 3 \times 2 = 16V$$

$$|V_{BC}| = |E - ir| = |20 - 3 \times 3| = 11V$$

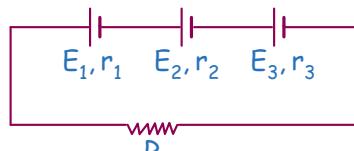
$$|V_{ED}| = |50 - 3 \times 5| = 35$$

#SKC

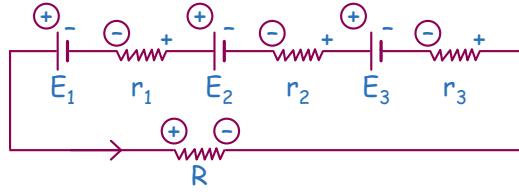
Battery के internal resistance से बिलकुल नहीं डरना है बस battery के बाजू से उतना resistance लगा देना है



#### Q. Find current in circuit



Sol.

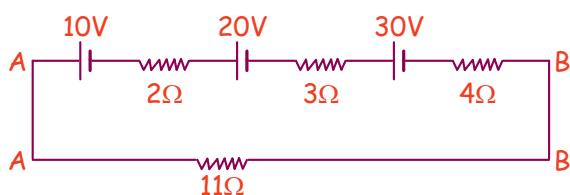


$$-iR - iR_3 + E_3 - iR_2 + E_2 - iR_1 + E_1 = 0$$

$$i = \frac{E_1 + E_2 + E_3}{r_1 + r_2 + r_3 + R}$$

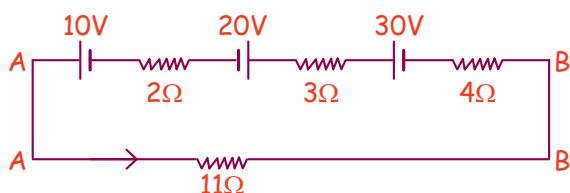
$$i = \frac{E_1 + E_2 + ...}{(r_1 + r_2 + ...) + R}$$

**Q.** Find current in circuit



$$\text{Sol. } i = \frac{10 + 20 + 30}{2 + 3 + 4 + 11} \quad V_{AB} = \checkmark$$

**Q.** Find current in circuit



$$\text{Sol. } i = \frac{10 - 20 + 30}{2 + 3 + 4 + 11}$$

**Q.** (a) n identical cells are connected in series as shown in diagram. Find  $i$  through  $R$



$$\text{Sol. } i = \frac{E + E + \dots}{(r + r + r \dots)R} = \frac{nE}{nr + R}$$

(b) If one cell is reversed find current in  $R$

$$\text{Sol. } i = \frac{nE - 2E}{nr + R}$$

(c) If m battery reversed

$$\text{Sol. } i = \frac{nE - 2mE}{nr + R} = \frac{(n - 2m)E}{nr + R}$$

## Results

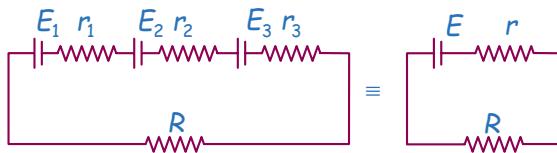
(i) Series Combination

If  $n$  sources of emf are connected in series with same polarity, then the equivalent emf is given by

$$E = E_1 + E_2 + E_3 + \dots + E_n$$

And, total internal resistance is

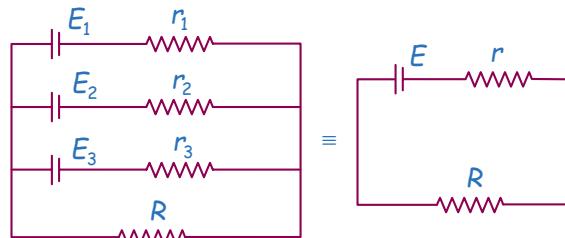
$$r = r_1 + r_2 + r_3 + \dots + r_n$$



\* If there are ' $n$ ' identical cells with emf  $E$  and internal resistance ' $r$ ' and they are connected in such a way that  $p$  cells are connected in opposite polarity then,

$$E_{\text{net}} = (n - 2p)E \text{ and } r_{\text{net}} = nr$$

(ii) Parallel Combination



The emf and internal resistance of the equivalent battery are given by

$$E = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2} + \frac{E_3}{r_3}}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}}$$

$$\text{and } \frac{1}{r} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}$$

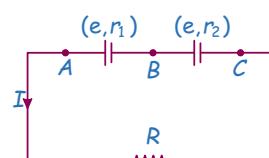
मेरे सपने में आई सुन्दर परी.....

And नीचे वाला question is compulsory



**Q.** Two batteries having the same emf  $\varepsilon$  but different internal resistances  $r_1$  and  $r_2$  are connected in series in same polarity with an external resistor  $R$ . For what value of  $R$  does the potential difference between the terminals of the first battery become zero?

**Sol.**



Net resistance in the circuit is  $(r_1 + r_2 + R)$ .

Current in the circuit

$$I = \frac{2\varepsilon}{(r_1 + r_2 + R)}$$

The potential difference between the terminals of first battery is  $(V_A - V_B)$ . Terminal potential difference is given by

$$(V_A - V_B) = \varepsilon - Ir_1$$

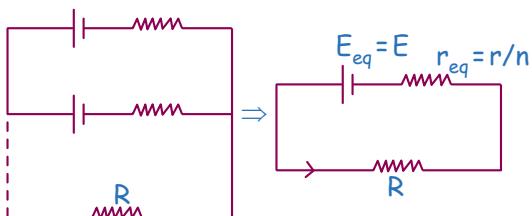
$$V_A - V_B = \varepsilon - \frac{2\varepsilon r_1}{r_1 + r_2 + R} = \varepsilon \frac{(R + r_2 - r_1)}{(R + r_2 + r_1)}$$

For  $(V_A - V_B)$  to be zero, we must have

$$R = (r_1 - r_2)$$

This gives meaningful result only if  $r_1 > r_2$ . Otherwise, if  $r_2 > r_1$ , then  $R = r_2 - r_1$  will produce terminal voltage across second cell to be zero ( $V_{BC} = 0$ ).

#### \* If n identical ( $E, r$ ) cells are in parallel



$$i = \frac{E}{\frac{r}{n} + R}$$

$$E_{eq} = \frac{E/r + E/r + \dots n \text{ times}}{1/r + 1/r + \dots n \text{ times}}$$

$$E_{eq} = E$$

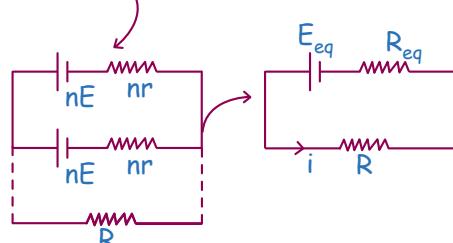
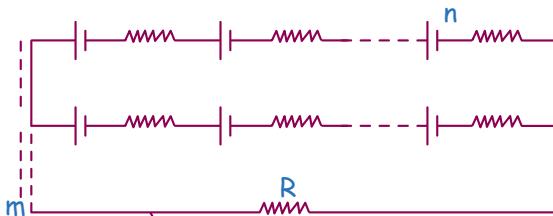
$$\frac{1}{R_{eq}} = \frac{1}{r} + \frac{1}{r} + \dots n \text{ times}$$

$$req = \frac{r}{n}$$

#### \* Mixed Grouping

n identical cell in row in series

m → no of row



net emf =  $nE$

$$\text{Total internal resistance} = \frac{nr}{m}$$

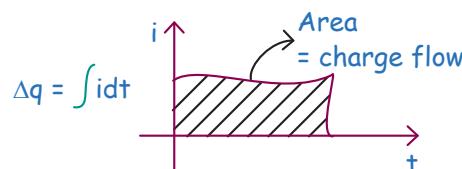
$$i = \frac{nE}{\frac{nr}{m} + R}$$

अब हम पढ़ेंगे वो  
चीज जो सारी दुनिया  
इस chapter मे सबसे  
पहले पढ़ती है।



## Current Electricity

$$\text{Current} = i = \frac{dq}{dt} = \text{Rate of flow of charge}$$



# Conventionally direction of flow of current is taken to be in direction of flow of +ve charge

# If moving charge is negative (जैसे electron) current direction is opposite to direction of motion of charge.



## Current Density

- \* It is the current flowing per unit area normal to the surface
- \* vector quantity
- \* Flux of current density is current
- \* It's direction is same as direction of current



$$i = \vec{J} \cdot \vec{A} = JA \cos \theta$$

$$\Rightarrow J = \frac{i}{A \cos \theta}$$

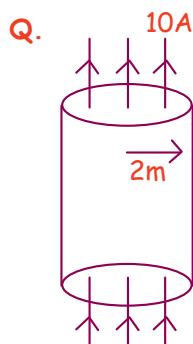
For special case

$$\theta = 0$$



$$i = JA \Rightarrow J = \frac{i}{A}$$

$$i = \int \vec{J} \cdot d\vec{A} \quad \text{अगर } J \text{ बदला तो we will use this}$$



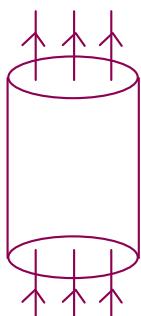
**Sol.**  $\vec{J} = \frac{10}{\pi 2^2} \hat{i}$

$$\phi = \int \vec{E} \cdot d\vec{A}$$

Current density

$$\text{का flux} = \int \vec{J} \cdot d\vec{A} = i$$

**Q.** If  $J = J_0 r$ , Find total current flowing through long cylindrical wire

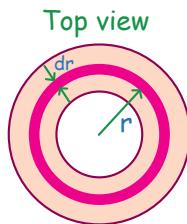


**Sol.**  $r$  पर जाके  $dr$  thickness का एक hollow cylinder पकड़ा suppose इससे  $di$  current पास किया।

$$di = \vec{J} \cdot d\vec{A}$$

$$\int di = \int_0^R J_0 r 2\pi r dr$$

$$i = J_0 2\pi \frac{R^3}{3}$$



## MOTION OF ELECTRON INSIDE CONDUCTOR

In absence of applied potential difference electrons have random motion.

All the free electrons are in random motion due to the thermal energy and follow the relationship given by

$$\frac{3}{2} k_B T = \frac{1}{2} mv^2$$

where,  $k_B$  = Boltzmann's constant

At room temperature their speed is around  $10^6$  m/s but the average velocity is zero, so net current is also zero.

### Mean Free Path

The average distance travelled by a free electron between two consecutive collisions is called as mean free path  $\lambda$ .

Mean free path  $\lambda = \frac{\text{total distance travelled}}{\text{number of collisions}}$

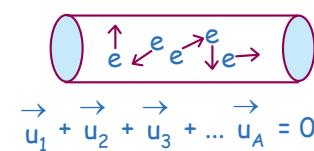
### Relaxation Time

The time taken by an electron between two successive collisions is called as relaxation time  $\tau$ . ( $\tau \sim 10^{-14}$  s)

Relaxation time  $\tau = \frac{\text{total time taken}}{\text{number of collisions}}$

The thermal speed can be written as  $v_T = \frac{\lambda}{\tau}$

Thermal energy Random direct, zigzag path

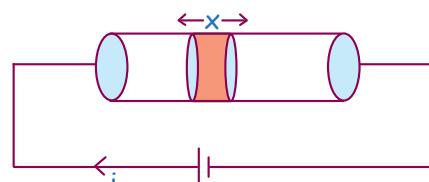


Now battery is applied due which potential different created across conductor result into electric field.

### Drift Velocity

- Rate at which random motion of free electron drift in the presence of applied electric field is called velocity (mm/sec order).
- It is the average of velocity of charge carriers over the no of charge carrier.
- Drift velocity is  $v$  with which the free electron get drifted toward the positive terminal under the effect of applied external Electric field.

Let  $n \rightarrow$  no of electron per unit vol<sup>m</sup>



$$i = \frac{\Delta q}{\Delta t} \quad \Delta q = nAxe$$

$$i = \frac{nAxe}{x/v_d} = nAev_d$$

Charge on electron

$$i = neAV_d \rightarrow \text{Drift velocity}$$

No. of free  $e^-$  per unit vol<sup>m</sup>

## Derivation for Drift Velocity, $J$

$$\vec{v}_1 = \vec{u}_1 + \vec{a}\tau_1$$

where,  $\vec{a}$  = acceleration of electron =  $\frac{-e\vec{E}}{m_e}$

$\tau$  = Relaxation time



Similarly for other electrons:

$$\vec{v}_2 = \vec{u}_2 + \vec{a}\tau_2$$

$$\vec{v}_n = \vec{u}_n + \vec{a}\tau_n$$

Average velocity of all the free electrons in the conductor is equal to the drift velocity  $\vec{v}_d$  of the free electrons.

$$\begin{aligned} \vec{v}_d &= \frac{\vec{v}_1 + \vec{v}_2 + \vec{v}_3 + \dots + \vec{v}_n}{n} \\ &= \frac{(\vec{u}_1 + \vec{a}\tau_1) + (\vec{u}_2 + \vec{a}\tau_2) + \dots + (\vec{u}_n + \vec{a}\tau_n)}{n} \\ &= \left( \frac{\vec{u}_1 + \vec{u}_2 + \vec{u}_3 + \dots + \vec{u}_n}{n} \right) + \vec{a} \left( \frac{\tau_1 + \tau_2 + \tau_3 + \dots + \tau_n}{n} \right) \end{aligned}$$

Since average thermal speed = 0

$$\text{So, } \frac{\vec{u}_1 + \vec{u}_2 + \vec{u}_3 + \dots + \vec{u}_n}{n} = 0 \text{ and}$$

$$\frac{\tau_1 + \tau_2 + \tau_3 + \dots + \tau_n}{n} = \tau = \text{average relaxation time.}$$

$$\text{So, } \vec{v}_d = \vec{a}\tau \Rightarrow \vec{v}_d = \frac{-e\vec{E}}{m_e}(\tau)$$

Where,



$\vec{v}_d$  = Drift velocity of electrons

$\vec{E}$  = Electric field applied

$m_e$  = Mass of electron

$\tau$  = Average relaxation time

The direction of drift velocity for electrons in a metal is opposite to that of applied field  $\vec{E}$ .

$$i = V_d enA = \left( \frac{eE}{m} \right) \tau enA = \frac{eV}{ml} \tau enA$$



$$i = \frac{e^2 \tau n v A}{ml} = \frac{v}{\left( \frac{ml}{e^2 n A} \right)} = \frac{V}{R} = \frac{\Delta V}{R}$$

$$E = \frac{V}{l} = \frac{\text{Pot. diff}}{\text{length}}$$

$$\Delta V = iR$$

Ohm's Law

and

$$i = V_d enA$$

$$\frac{i}{A} = V_d en = \frac{eE}{m} \tau en$$

$$J = \frac{e^2 \tau n}{m} E = \sigma E$$

$$\vec{J} = \sigma \vec{E}$$

$$\text{mobility} = \mu = \frac{\text{Drift velocity}}{\text{E.F}}$$

$$\mu = \frac{V_d}{E}$$

$$\Delta V = iR \text{ (ohm's law)}$$



substance which follow ohm's law called ohmic structure.

$$\frac{1}{\rho} = \sigma = \frac{\tau e^2 n}{m} = \text{conductivity}$$

$$R = \rho \frac{l}{A} = \frac{l}{\sigma A}$$

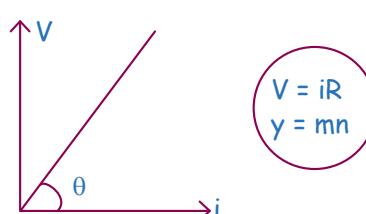


- ★  $V = iR$
- ★  $i = V_d enA$
- ★  $v_d = \frac{eE}{m} \tau$
- ★  $\vec{J} = \sigma \vec{E}$
- ★  $R = \rho \frac{l}{A} = \frac{l}{\sigma A}$  ( $\rho$  = resistivity,  $\sigma$  = conductivity)
- ★  $\frac{1}{\rho} = \sigma = \frac{\tau e^2 n}{m} = \text{conductivity}$
- ★  $\text{mobility} = \mu = \frac{\text{Drift velocity}}{\text{E.F}} = \frac{V_d}{E}$



सवाल आएगा तो  
इसी BOX से  
आएगा।

★ Ohm's law  $i \propto V$

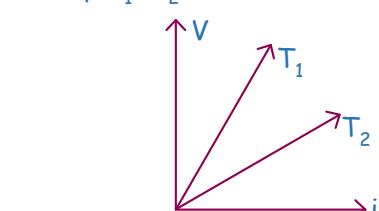


$$i = \frac{V}{R} \text{ Electric Resistance}$$

$$\tan \theta = \frac{V}{i} = \text{Resistance}$$

As  $T \uparrow \Rightarrow R \uparrow \Rightarrow \text{slope} \uparrow$

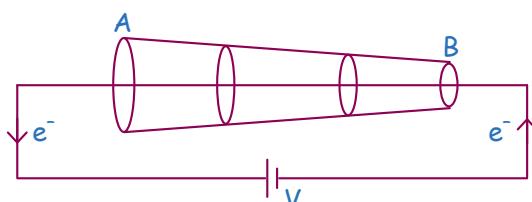
For a given material graph between  $\Delta V$  &  $i$  is plotted at diff temp  $T_1$  &  $T_2$



$$(\text{Slope})_1 > (\text{Slope})_2$$

$$(T \uparrow, R \uparrow, \text{slope} \uparrow) \Rightarrow T_1 > T_2$$

**Q.** As we move from right to left A to B analyse the question.



**Sol.** A to B  $\Rightarrow$  Area of cross section decrease

$$i = V_d e n A$$

1. Current  $\rightarrow$  same

$$2. \text{ Current density } = \frac{i}{A} = J \uparrow \text{ (increase)}$$

$$3. \text{ Electric field } = E \uparrow \text{ (increase bcz } \vec{J} = \sigma \vec{E} \text{ )}$$

$$4. \text{ Drift velocity } V_d \uparrow \text{ (increase bcz } V_d = \frac{i}{enA} \text{ )}$$

## TEMP DEPENDENCY OF $\rho$ & R

$$\star \rho = \rho_0(1 + \alpha \Delta T)$$

$$\star R = R_0(1 + \alpha \Delta T)$$

$$\star R = R_0[1 + \alpha(T - T_0)]$$

$\star R_0$  is the resistance at Temp  $T_0$

$\star T_0 = 0^\circ C \Rightarrow R_0$  is resistance at  $0^\circ C$

$\star$  For metal/conductor  $\Rightarrow \alpha > 0 \quad T \uparrow, R \uparrow$

$\star$  For semi conductor  $\Rightarrow \alpha < 0 \quad T \uparrow, R \downarrow$

**Q.** Value of resistance at  $10^\circ C$  is  $50\Omega$  and at  $30^\circ C$  is  $60\Omega$ . Find resistance at  $50^\circ C$

$$\text{Sol. } R = R_0(1 + \alpha \Delta T)$$

$$50 = R_0[(1 + \alpha(10 - 0))]$$

$$60 = R_0[(1 + \alpha(30 - 0))]$$

$$60 + 600\alpha = 50 + 1500\alpha$$

$$\alpha = \frac{1}{90}$$

$$50 = R_0(1 + 1/90 \times 10)$$

$$R_0 = 45$$

$$R_f = R_0(1 + \alpha \Delta T)$$

$$= 45(1 + 1/90 \times (50 - 0))$$

$$= 45(1 + 5/9) = \frac{45 \times 14}{9}$$

अब in following case में  $R_{eq}$  की अच्छे से practice करलो (apply smartly  $R = \rho l/A$ )



$$1. \rightarrow \text{---} \quad A = \pi r^2$$

$$\text{Solid Cylinder } R = \rho \frac{l}{\pi r^2}$$

$$2. \rightarrow \text{---} \quad \begin{array}{c} i \\ \parallel \\ \text{---} \end{array} \quad \begin{array}{c} i \\ \parallel \\ \text{---} \end{array}$$

$$R = \rho \frac{a}{cb}$$

$$3. \rightarrow \text{---} \quad \begin{array}{c} i \\ \parallel \\ \text{---} \end{array} \quad \begin{array}{c} i \\ \parallel \\ \text{---} \end{array}$$

$$R = \rho \frac{c}{ab}$$

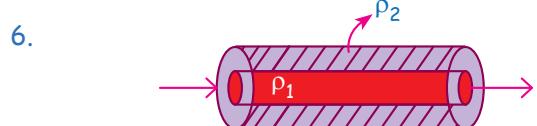
$$4. \rightarrow \text{---} \quad \begin{array}{c} i \\ \parallel \\ \text{---} \end{array}$$

$$R = \rho \frac{l}{A} = \rho \frac{l}{\pi r^2}$$

$$5. \rightarrow \text{---} \quad \begin{array}{c} i \\ \parallel \\ \text{---} \end{array}$$

$$R = \rho \frac{l}{\pi (R_2^2 - R_1^2)}$$

( $R_1$  is inner radius  $R_2$  is outer radius)

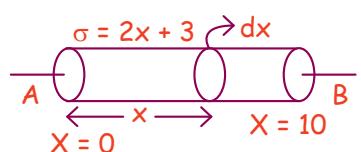


$$R_1 = R \text{ अंदर} = \rho_1 \frac{l}{\pi R_1^2}$$

$$R_2 = R \text{ बाहर} = \rho_2 \frac{l}{\pi (R_2^2 - R_1^2)}$$

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

Q.  $R_{eq}$  between A & B



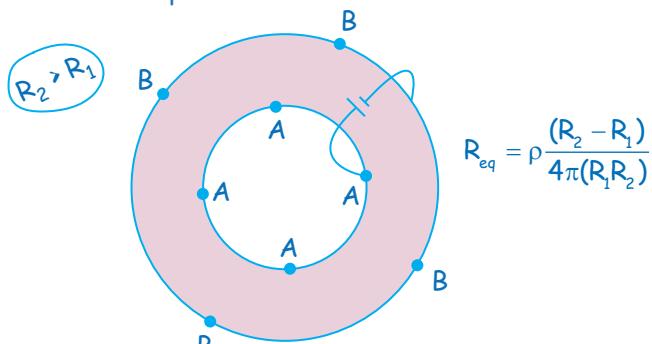
$$Sol. dR = \rho \frac{dx}{\pi r^2} = \frac{l}{\sigma} \frac{dx}{\pi r^2}$$

$$\int dR = \int \frac{1}{2x+3} \times \frac{dx}{\pi r^2}$$

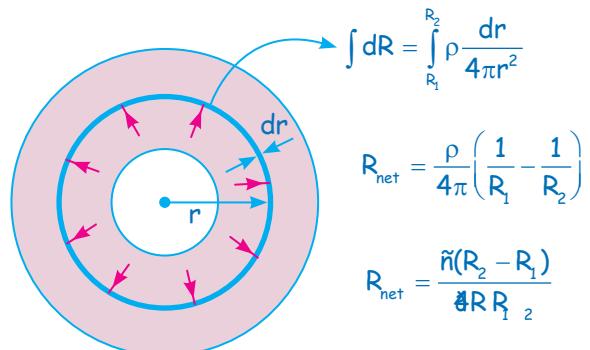
$$R_{eq} = \frac{1}{\pi r^2} \int_0^{10} \frac{dx}{2x+3}$$

$$Ans: R = \frac{1}{\pi r^2 \times 2} \ln \left( \frac{23}{3} \right)$$

7. Hollow sphere



$$R_{eq} = \rho \frac{(R_2 - R_1)}{4\pi(R_1 R_2)}$$

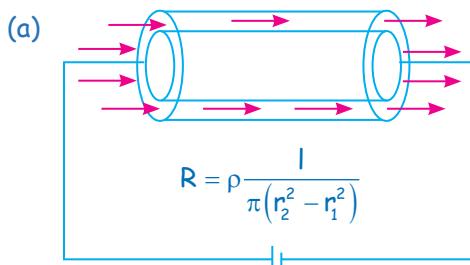


$$\int dR = \int_{R_1}^{R_2} \rho \frac{dr}{4\pi r^2}$$

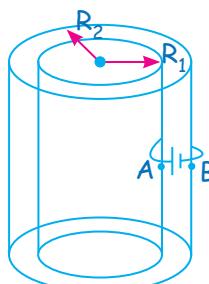
$$R_{net} = \frac{\rho}{4\pi} \left( \frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$R_{net} = \frac{\rho(R_2 - R_1)}{4\pi R_1 R_2}$$

8. Hollow cylinder



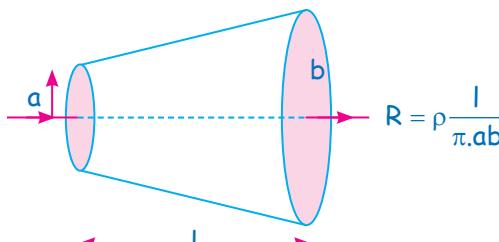
(b)  $R_2 > R_1$



$$\int dR = \int_{R_1}^{R_2} \rho \frac{dr}{2\pi rl}$$

$$R_{eq} = \frac{\rho}{2\pi l} \ln \left( \frac{R_2}{R_1} \right)$$

9.



Q. If length of resistance is increased by 5% Find % increase in resistance.

$$Sol. R = \rho \frac{l}{A} = \rho \frac{l^2}{Al} \quad (V \rightarrow \text{const})$$

$$R \propto l^2 \quad \frac{\Delta l}{l} \times 100 = 5$$

$$\frac{\Delta R}{R} = \frac{2\Delta l}{l}$$

$$\frac{\Delta R}{R} \times 100 = 2 \left( \frac{\Delta l \times 100}{l} \right)$$

$$= 2 \times 5 = 10\%$$

Q. A cylindrical wire is increased double its original length the % increase in the Resistance of wire

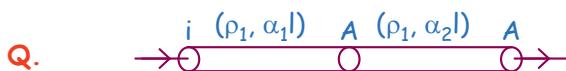
$$Sol. R = \frac{\rho l}{A} = \frac{\rho l^2}{Al} = \frac{2l^2}{vol^n}$$

$$R \propto l^2 \quad l \rightarrow \text{double}$$

$R \rightarrow 4$  times

$$\% \frac{\Delta R}{R} = \frac{R_f - R_i}{R} \times 100$$

Ans. 300%



Find the condition for which this combination  $R_{eq}$  is independent on the Temp

$$Sol. R_i = R_1 + R_2 = \rho_1 \frac{1}{A} + \rho_2 \frac{1}{A}$$

$$R_f = (R_1 \text{नया}) + (R_2 \text{नया}) = R_1(1 + \alpha_1 \Delta T) + R_2(1 + \alpha_2 \Delta T)$$

$$R_i = R_f$$

$$\rho_1 \frac{1}{A} + \rho_2 \frac{1}{A} = \rho_1 \frac{1}{A}(1 + \alpha_1 \Delta T) + \rho_2 \frac{1}{A}(1 + \alpha_2 \Delta T)$$

$$\text{Solve and get } \rho_1 \alpha_1 + \rho_2 \alpha_2 = 0$$

(अब यह मत सोचना ऐसा कैसे हुआ इसका मतलब है कोई एक  $\alpha$  negative है)

## CONVERSION OF GALVANOMETER INTO AMMETER/VOLTMETER.

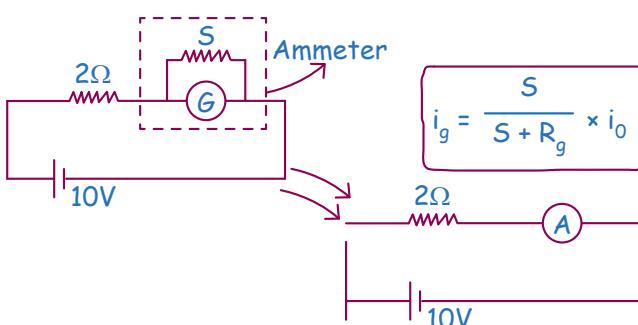
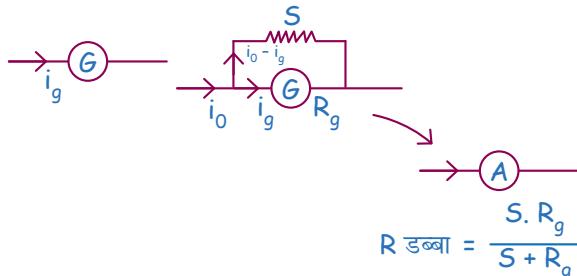


तीनों दिखने में एक जैसे ही होते हैं बस labelling का अंतर है यकीन नहीं आता ऊपर के image को ठीक से देखा। बस इतना याद रखो galvanometer के parallel में छोटा सा resistance लगाने पर यह ammeter बन जाता है और galvanometer के बाजू में बहुत बड़ा resistance लगाने पर ये voltmeter बन जाता है।

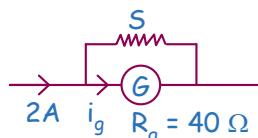
Ideal ammeter का resistance zero or ideal voltmeter का resistance infinity होता है।



### Conversion of Galvanometer into Ammeter



Q. A Galvanometer of resistance  $40\Omega$  can read max current of  $50\text{mA}$ . Find the resistance require to that it converted into ammeter which can measure the current upto  $2\text{A}$ .



$$Sol. i_g = \frac{S}{S + R_g} \times i_{\text{total}}$$

$$50 \times 10^{-3} = \frac{S}{S + 40} \times 2$$

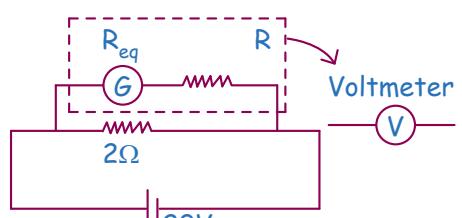
$$50(S + 40) = 2000S$$

$$50S + 2000 = 2000S$$

$$2000 = 1950S$$

$$S = \frac{2000}{1950}$$

### Conversion of Galvanometer into Voltmeter

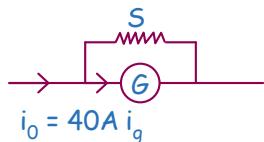


$$V_{AB} = i_g(R + R_g) \text{ (ideally } V \text{ Resist infinity)}$$

**Q.** A galvanometer has coil of resistance  $40\Omega$  showing full scale deflection of  $80mA$  what resistance should be added and how so that

1. It become Ammeter of range  $40A$

**Sol.**



$$i = \frac{S}{S+g} \times i_0$$

$$80 \times 10^{-3} = \frac{S}{S+40} \times 40$$

$$80S + 3200 = 40000 \text{ 'S'}$$

$$S = \frac{3200}{39920}$$

2. It become voltmeter of range  $40$  volt



$$V_{AB} = i_g(R_g + R)$$

$$40 = 80 \times 10^{-3}(40 + R)$$

$$R = 460\Omega$$

Now few important questions practice them sincerely

**Q.** In following case find  $r_{eq}$  &  $\rho_{eq}$  if rods A & B are connected in series of length  $3l_0$ .

Rod A:  $\rho_0, l_0, 3\alpha, A$

Rod B  $\Rightarrow 2\rho_0, 2l_0, 2\alpha, A$

**Sol.**

$$R_1 = \rho_0(1 + 3\alpha\Delta T) \frac{l_0}{A}$$

at only temp

$$R_2 = 2\rho_0(1 + 2\alpha\Delta T) \frac{2l_0}{A}$$

$$R_{eq} = R_1 + R_2 = \rho_0 \frac{1}{A} (1 + 3\alpha\Delta T) + 4\rho_0 \frac{1}{A} (1 + 2\alpha\Delta T)$$

$$\rho_{eq}(1 + \alpha_{eq}\Delta T) \frac{3l_0}{A} = R_{eq} = \rho_0 \frac{l_0}{A} (1 + 3\alpha\Delta T) + 4\rho_0 \frac{1}{A} (1 + 2\alpha\Delta T)$$

$$3\rho_{eq}(1 + \alpha_{eq}\Delta T) = \rho_0 + 3\alpha\rho_0\Delta T + 4\rho_0 + 8\alpha\rho_0\Delta T$$

$$3\rho_{eq} + (3\rho_{eq}\alpha_{eq})\Delta T = 5\rho_0 + 11\alpha\rho_0\Delta T$$

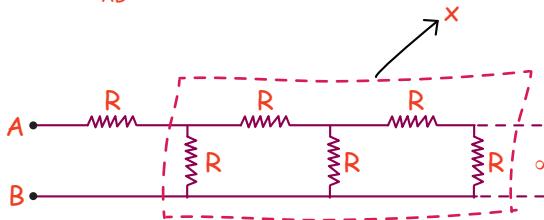
$$3\rho_{eq} = 5\rho_0 \quad \boxed{\rho_{eq} = 5/3\rho_0}$$

$$3\rho_{eq}\alpha_{eq} = 11\alpha\rho_0 \quad 5\rho_0\alpha_{eq} = 11\alpha\rho_0$$

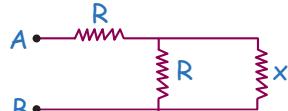
$$\alpha_{eq} = \frac{11}{5}\alpha$$

★  $\infty$  ladder question

**Q.** Find  $R_{AB}$  ?



**Sol.**



Circuit को शुरू मे कितना मिटा दू की उसकी शक्ल सूत वैसी की वैसी ही रहे

$$R_{AB} = x$$

$$R_{AB} = x = R + \frac{Rx}{R+x}$$

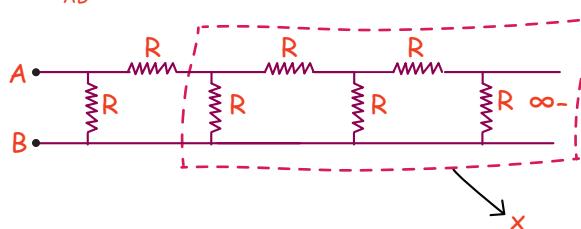
$$x = \frac{R(R+x) + Rx}{R+x}$$

$$xR + x^2 = R^2 + Rx + Rx$$

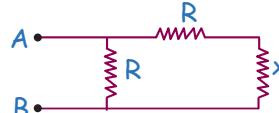
$$x^2 - Rx - R^2 = 0$$

$$x = \text{solve } \& \text{ get, } x = \frac{R + \sqrt{5}R}{2}$$

**Q.**  $R_{AB} = ?$



**Sol.**



$$R_{AB} = \frac{R(R+x)}{R+R+x} = x = \frac{R^2 + Rx}{2R+x} = x$$

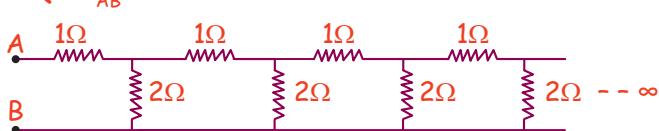
$$R^2 + Rx = 2Rx + x^2$$

$$x^2 - Rx - R^2 = 0$$

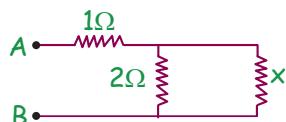
$$x = \frac{-R + \sqrt{R^2 + 4R^2}}{2}$$

$$x = R \left( \frac{\sqrt{5} - 1}{2} \right)$$

**Q.**  $R_{AB} = ?$



Sol.



$$R_{AB} = x = 1 + \frac{2x}{x+2}$$

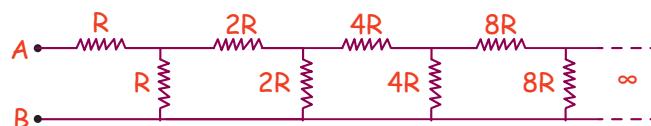
$$x - 1 = \frac{2x}{x+2}$$

$$(x-1)(x+2) = 2x$$

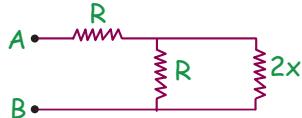
$$x^2 + 2x - x - 2 = 2x$$

$$x = \frac{1 - \sqrt{1 + 8}}{2} = 2$$

Q. Find  $R_{AB} = ?$



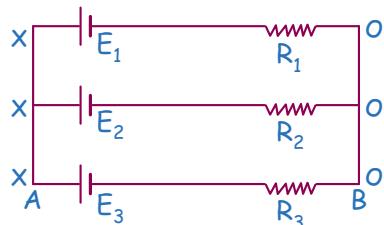
Sol.



$$R_{AB} = x = \frac{R \cdot 2x}{R + 2x} + R$$

Solve & get

### Grouping of Cell



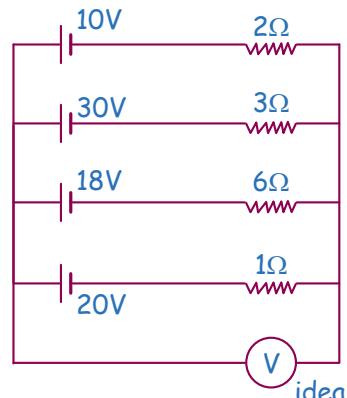
#SKC

$$x = V_{AB} = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2} + \frac{E_3}{r_3}}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}}$$

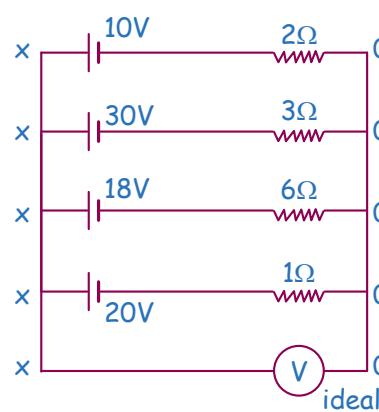
अगर इस तरह के सवाल में direct x पूछे तो बिंदास SKC लगाओ।



Q. Find reading of ideal voltmeter.



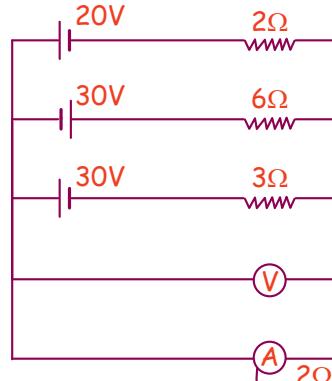
Sol.



$$x = \frac{10/2 + 30/3 + 18/6 + 20/1}{1/2 + 1/3 + 1/6 + 1/1} = \frac{5 + 10 + 3 + 20}{2}$$

$$x = V_{AB} = 19$$

SSSQ. Find volt meter and ammeter reading



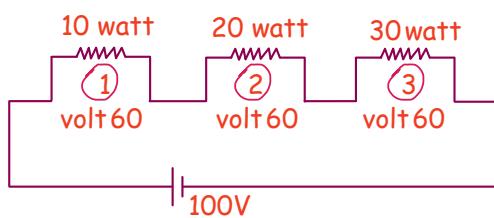
Reading of A

$$Sol. x = \frac{20/2 - 30/6 + 30/3 + 0/2}{1/2 + 1/6 + 1/3 + 1/2} = 10$$

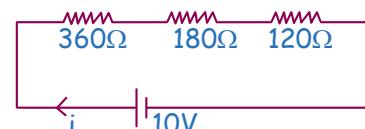
$$= 10 (V) \text{ (Voltmeter Reading)}$$

$$i = \frac{x - 0}{2} = \frac{10 - 0}{2} = 5 = \text{Ammeter reading}$$

Q. Compare brighter of bulbs.



$$\text{Sol. } R = \frac{V^2}{P} = \frac{60 \times 60}{10} = 360$$



$$B_1 > B_2 > B_3$$

$$i = \frac{10}{360 + 180 + 120}$$

Q. Find the total average momentum of electrons in a straight wire of length  $l = 1000\text{ m}$  carrying current  $I = 704\text{ A}$ .

**Sol.** Let  $n$  be no. of electrons per unit volume.

No. of electrons in length  $l$

$$N = nSl \quad (\text{S is cross-sectional area})$$

Momentum of one electron =  $mv_d$

$$\text{Total momentum } P = (nSl)mv_d$$

$$\text{As } v_d = \frac{I}{neS}$$

$$P = (nSl)m \frac{I}{(neS)} = \frac{mI}{e}$$

On substituting numerical values, we get

$$P = 4\mu Ns$$

Q. The temperature coefficient of resistivity  $\alpha$  is given by  $\alpha = \left(\frac{1}{\rho}\right) \frac{d\rho}{dT}$ , where  $\rho$  is the resistivity at temperature  $T$ . Assume that  $\alpha$  is not constant and follows the relation  $\alpha = -\frac{a}{T}$ , where  $T$  is the absolute temperature and  $a$  is a constant. Show that the resistivity  $\rho$  is given by  $\rho = \frac{b}{T^a}$ , where  $b$  is another constant.

$$\text{Sol. } \alpha = \frac{1}{\rho} \frac{d\rho}{dT} \Rightarrow \frac{d\rho}{\rho} = \alpha dT = -a \frac{dT}{T}$$

Let  $\rho = \rho_0$  at  $T = T_0$ , then

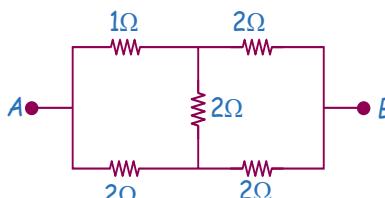
$$\int_{\rho_0}^{\rho} \frac{d\rho}{\rho} = -a \int_{T_0}^{T} \frac{dT}{T}$$

$$\Rightarrow \log_e \left( \frac{\rho}{\rho_0} \right) = -a \log_e \left( \frac{T}{T_0} \right) = \log_e \left( \frac{T_0}{T} \right)^a$$

$$\Rightarrow \rho = (\rho_0 T_0^a) \frac{1}{T^a} = \frac{b}{T^a}$$

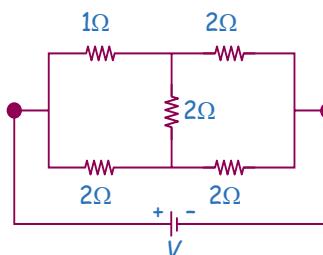
$$\text{Here, } b = \rho_0 T_0^a$$

Q. Find the equivalent resistance across terminals A and B.

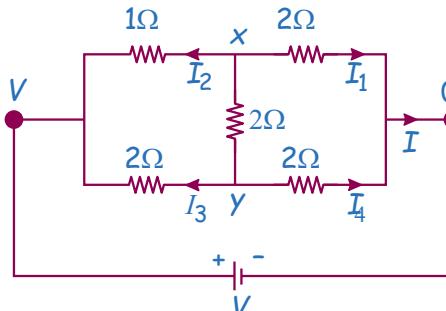


**Sol.** This is a case of unbalanced Wheatstone bridge.

**Step 1:** Connect a battery across the terminal.



**Step 2:** Mark the voltages of nodes.



$$\text{Step 3: Calculate } R_{eq} = \frac{V}{I}$$

Apply KCL at node 'X'

$$\Rightarrow \frac{x-V}{1} + \frac{x-0}{2} + \frac{x-y}{2} = 0$$

$$\Rightarrow 2x - 2V + x + x - y = 0 \Rightarrow 4x - 2V = y \dots (i)$$

Apply KCL at node 'Y'

$$\frac{y-x}{2} + \frac{y-V}{2} + \frac{y}{2} = 0 \Rightarrow 3y - V = x \dots (ii)$$

Solve equations (i) and (ii),

$$x = \frac{7V}{11}, y = \frac{6V}{11}$$

Now calculate:  $I_1 = \frac{x-0}{2} = \frac{7V}{22}$  and  $I_2 = \frac{y}{2} = \frac{6V}{22}$

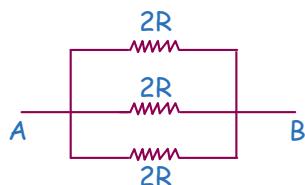
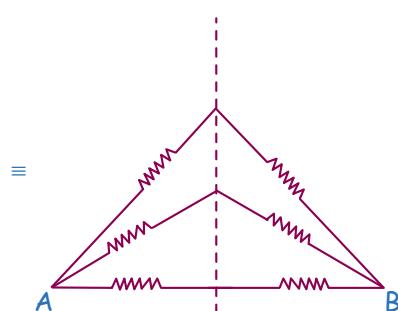
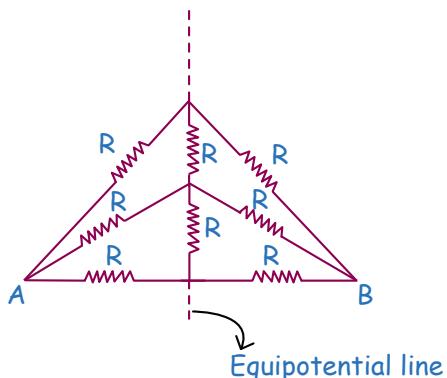
So, equivalent resistance

$$R_{eq} = \frac{V}{I} = \frac{V}{I_1 + I_2} = \frac{V}{\frac{7V}{22} + \frac{6V}{22}} = \frac{V}{\frac{13V}{22}} \Rightarrow R_{eq} = \frac{22}{13} \Omega$$

## SYMMETRY (Not much important for jee mains)

- ⇒ Perpendicular Bisector symm
- ⇒ Folding symm
- ⇒ input output symm

### Perpendicular Bisector symmetry example

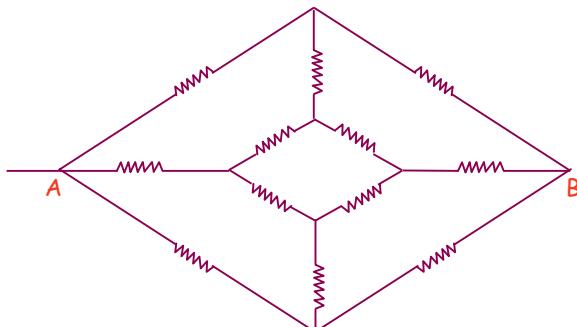


#SKC

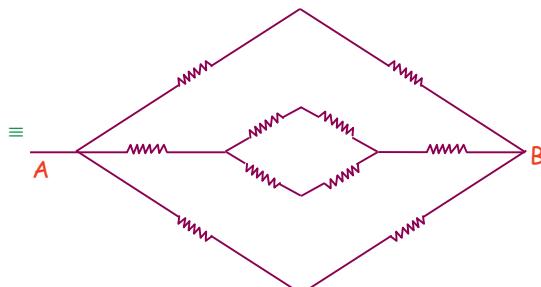
A को B से connect करो और AB के  $\perp^{ar}$  Bisector लो

उसके आजू-बाजू अगर circuit mirror image हैं तो bisector line के resistance उड़ा दो

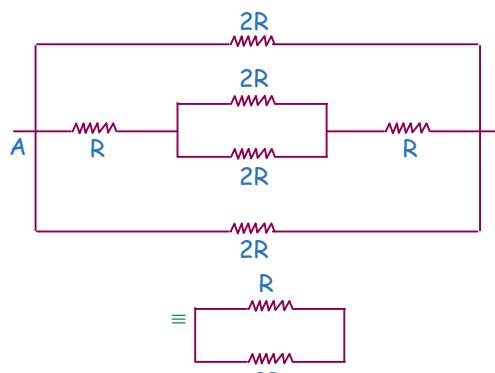
Q. All resistors have same value 'R'. Find  $R_{AB}$



Sol.



All resistance have same 'R'



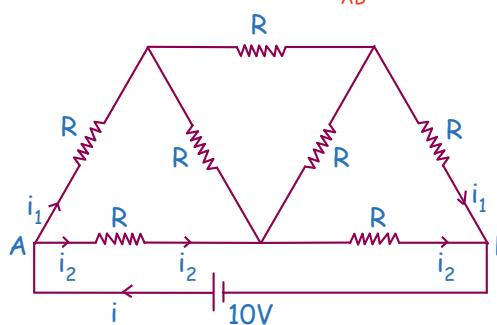
$$\frac{3R}{4} = R_{AB}$$

### \* Input output symmetry

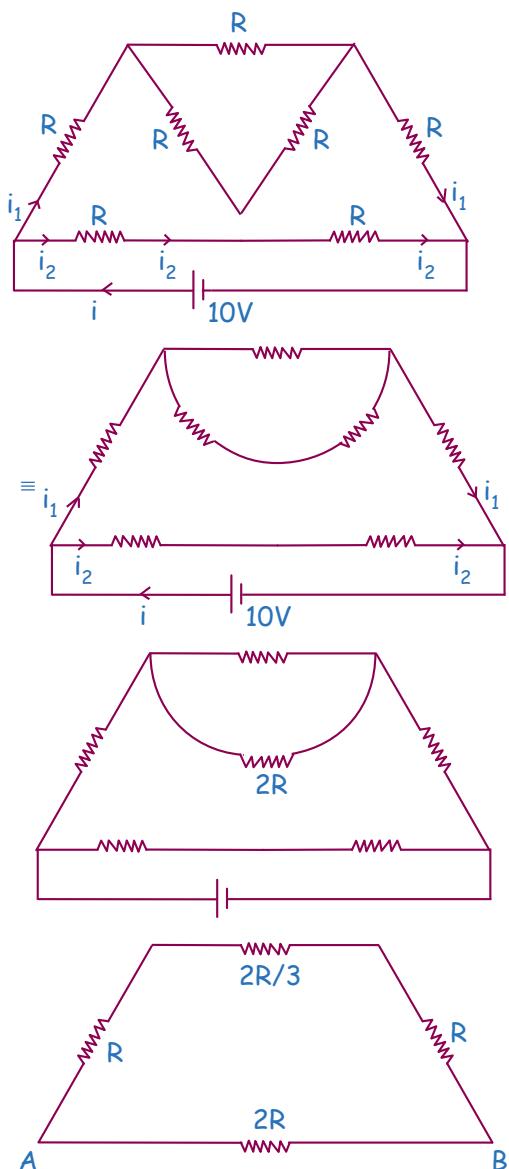
If current has similar path in entering side to exit & vice versa then circuit is said to be input output symmetry.

Under such condition for entry side & exit side are same

Q. Each resistance = R, Find  $R_{AB}$



Sol.

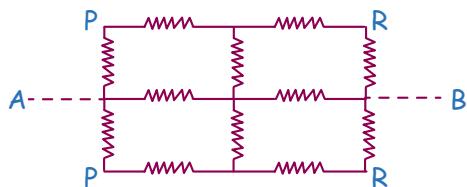


### Folding Symmetry

#SKC

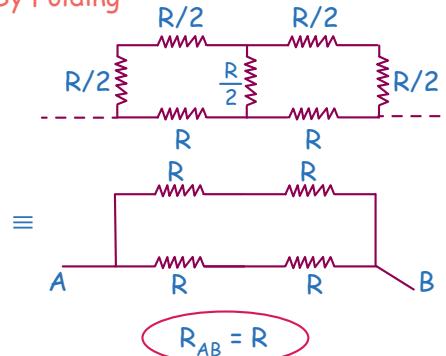
अगर AB line के ऊपर नीचे circuit  
ek जैसा हो तो नीचे वाले को ऊपर वाले  
पर fold करदो मतलब ऊपर के सारे  
**resistance** आधे करदा

Q. Each resistance = R, Find  $R_{AB}$

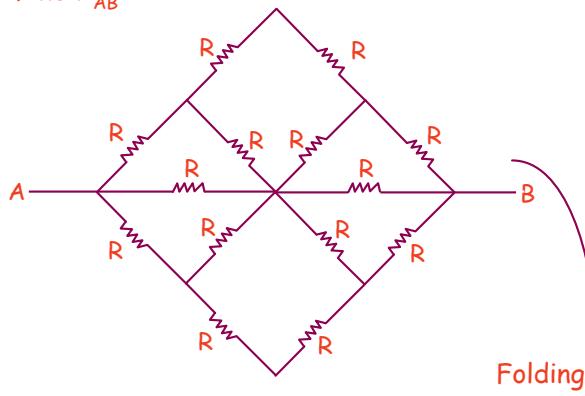


Current Electricity

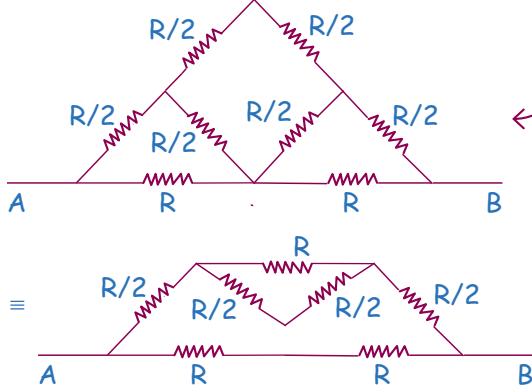
By Folding



Q. Find  $R_{AB}$

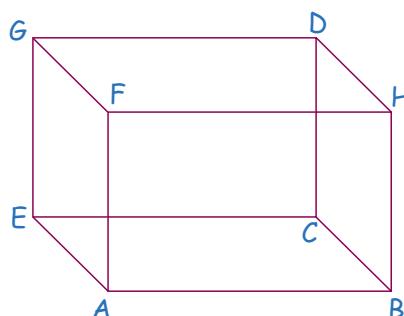


Sol.



Now you can solve.

\* Cube each of length l, Resistance R(each)



$$\frac{7R}{12} \cdot \frac{3R}{4} \cdot \frac{5R}{6} \\ R_{AB} \quad R_{AC} \quad R_{AD}$$

पास-पास      थोड़ा-दूर      दूर-दूर

\* If two appliances with rating  $(W_1, V)$  &  $(W_2, V)$  are connected to  $V$ .

1. In Parallel



$$\text{Total power dissipated} = \omega_1 + \omega_2$$

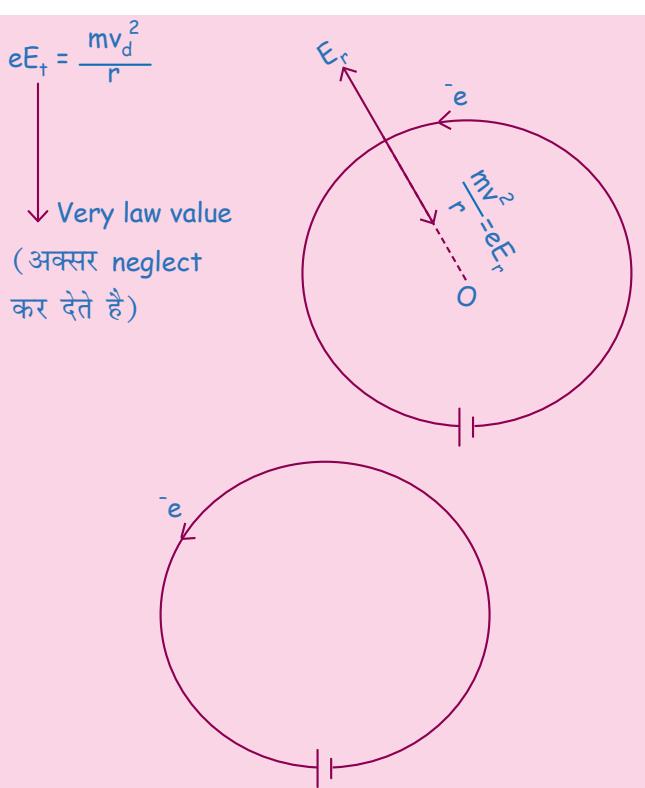
2. In series



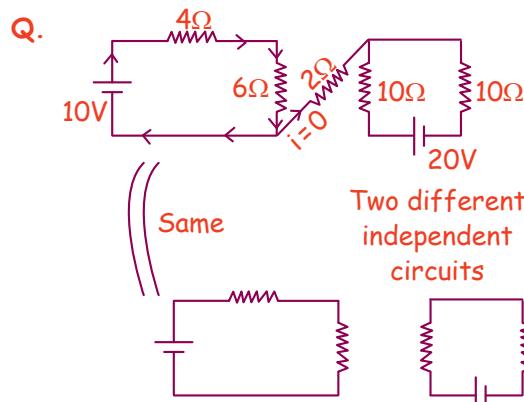
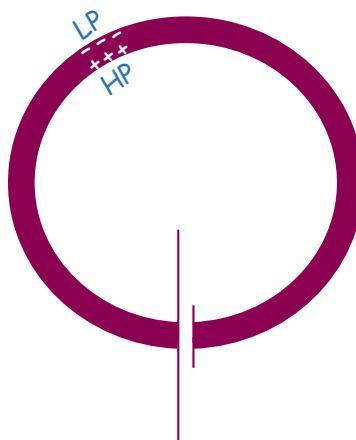
$$\text{Total power dissipated} = \omega_{\text{net}}$$

$$\frac{1}{\omega_{\text{net}}} = \frac{1}{\omega_1} + \frac{1}{\omega_2}$$

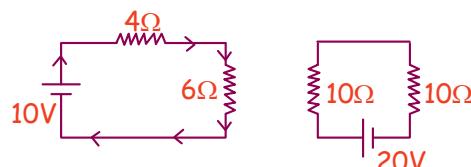
Q. A wire is in a circular shape connected to a battery as shown in figure. Find value of radial electric field.



#SKC  
यह ध्यान से देखना Current किसकी वजह से आया?  $e^-$  की वजह या +ve charge के motion की वजह से



Now solve and get

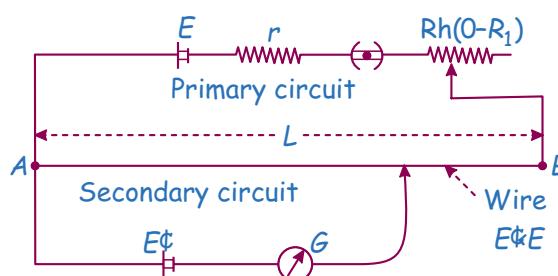


## POTENTIOMETER (Not in Jee Mains 2025)

### Working Principle of Potentiometer

Any unknown potential difference is balanced on a known potential difference which is uniformly distributed over entire length of potentiometer wire. This process is named as zero deflection or null deflection method.

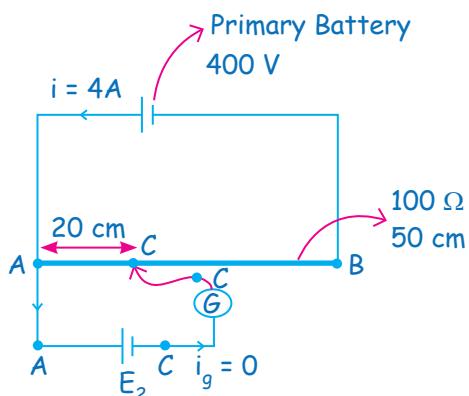
### Circuit of Potentiometer



**Primary circuit** contains constant source of voltage and a rheostat (a resistance box).

**Secondary, unknown or galvanometer circuit** contains components with unknown parameters.

Q. Find emf of the battery if galvanometer show null deflection at C.



$$V_{AB} = 400 \text{ V}$$

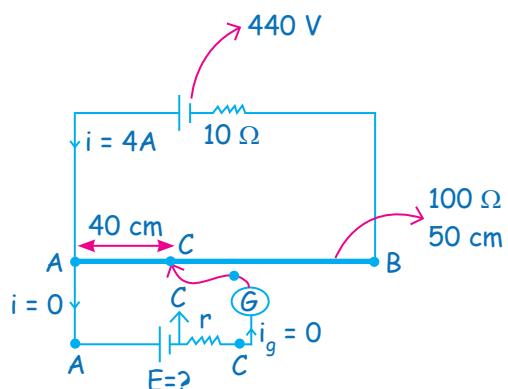
$$50 \text{ cm} \rightarrow 400 \text{ V}$$

$$1 \text{ cm} \rightarrow \frac{400}{50}$$

$$20 \text{ cm} \rightarrow \frac{400}{50} \times 20$$

$$= 160 = V_{AC} = E_2$$

Q. Find emf of the battery if galvanometer show null deflection at C.

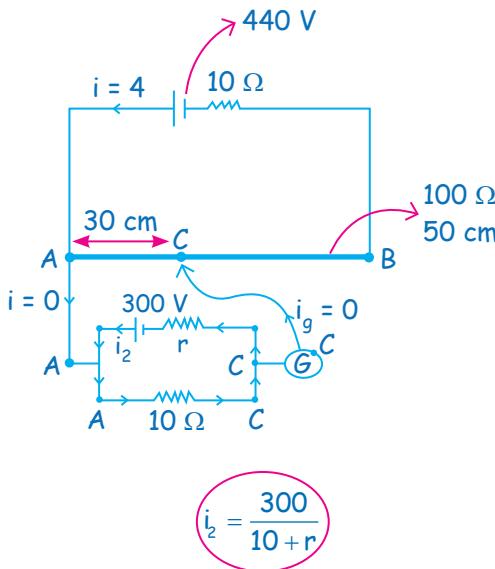


$$V_{AB} = 400 \text{ V}$$

$$50 \text{ cm} \rightarrow 400 \text{ V}$$

$$40 \text{ cm} \rightarrow \frac{400}{50} \times 40 = 320 \text{ V}$$

Q. Find internal resistance of the battery if galvanometer show null deflection at C.



$$i_2 = \frac{300}{10+r}$$

$$V_{AB} = 400$$

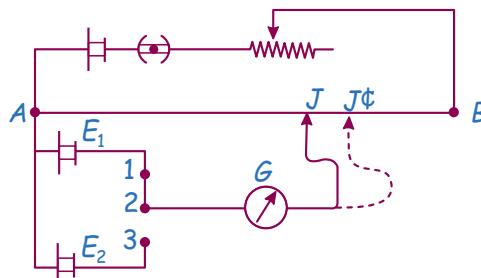
$$V_{AC} = \frac{400}{50} \times 30 = 240$$

$$V_{AC} = \frac{300}{10+r} \times 10$$

$$240 = \frac{3000}{10+r}$$

$$r = 2.5 \Omega$$

### ★ Comparison of emf of two cells



Plug only in (1 - 2): Balance length AJ =  $\ell_1$

Plug only in (2 - 3): Balance length AJ =  $\ell_2$

$$E_1 = x \ell_1 \text{ and } E_2 = x \ell_2$$

$$\Rightarrow \frac{E_1}{E_2} = \frac{\ell_1}{\ell_2}$$

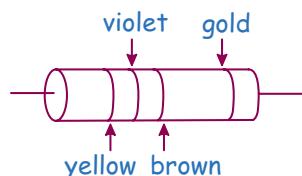
## COLOUR CODE FOR CARBON RESISTORS (Removed from Mains 2025 and in Advance also)



	Strip A (digit 1)	Strip B (digit 2)	Strip C (Multiplier)	Strip D (Tolerance)
Black	0	0	$10^0$	
Brown	1	1	$10^1$	
Red	2	2	$10^2$	
Orange	3	3	$10^3$	
Yellow	4	4	$10^4$	
Green	5	5	$10^5$	
Blue	6	6	$10^6$	
Violet	7	7	$10^7$	
Grey	8	8	$10^8$	
White	9	9	$10^9$	
Gold	-	-	$10^{-1}$	$\pm 5\%$
Silver	-	-	$10^{-2}$	$\pm 10\%$
No Colour	-	-	-	$\pm 20\%$

○ Aid to memory BBROY of Great Britain does a Very Good Work.

Q. What is the resistance of the following resistor?



Sol. Number for yellow is 4. Number for violet is 7.

Brown colour gives multiplier  $10^1$ , Gold gives a tolerance of  $\pm 5\%$

So, resistance of resistor is

$$47 \times 10^1 \Omega \pm 5\% = (470 \pm 5\%) \Omega$$

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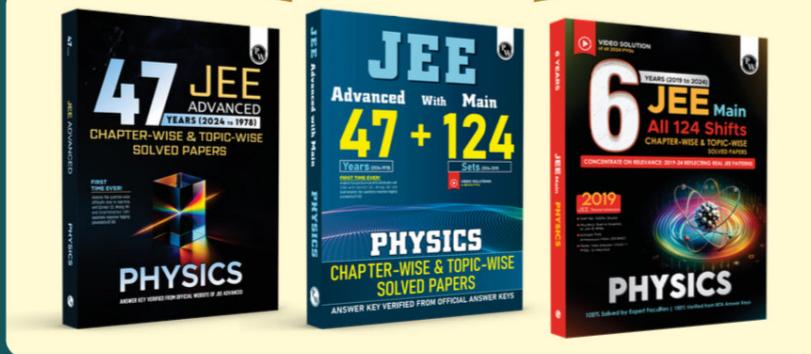
## About the Author

**Saleem Ahmed**, an alumnus of NIT Trichy with a B.Tech in Electronics and Communication Engineering (ECE), is a highly respected Physics educator with experience of **12+ Years** known for his **engaging teaching style** and **student-centric approach**.

With over **8 years** of experience as a **Senior and Star Faculty** at Allen Career Institute, Kota, he has mentored **lakhs** of students, including many with **top ranks under 100** and **under 50** in JEE. Currently, he is a core member of **Physics Wallah**, continuing to guide students with **conceptual clarity** and **problem-solving expertise**.

Affectionately called "**Saleem Bhaiya**", his classes focus on **building concepts from basic to advanced**, helping students unlock their potential. His **17-hour and 19-hour marathon sessions** on the **JEE Wallah YouTube channel** reflect his dedication to student success. Saleem Ahmed's commitment has left a lasting impact on JEE aspirants across the country.

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