CLASS-12

SKC PHYSICS CRUSH

Saleem Bhaiya

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 है......................

Lakshya तक उड़ान भरने का

$$<\text{कद्दू}> = \frac{\int (\text{कद्दू})\,dt}{\int dt}$$

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 मे रखते हुए 350 pages मे 12^{th} portion का मै आपको अच्छे से अच्छा content provide कर सकूं from basic to advance. अगर इस book का content आपने अच्छे से cover कर लिया तो Mains/NEET मे almost 100% PYQ and upcoming papers और more than 75% in JEE Advance PYQ and it's upcoming paper आप solve कर सकते है।
- 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 मे 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 मे already 1000+ question है।
- Majority 12^{th} की physics 11^{th} 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^{th} class का Vector, Work Energy Theorem, Potential Energy, Basic SHM, Basic Mechanics Formula अच्छे से कर ले इससे आपको Electrostatics, Magnetism, EMI मे 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.

Contents

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

CHARGE

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

PROPERTIES OF CHARGE

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

COULOMB LAW

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

$f \propto q_1 q_2$

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

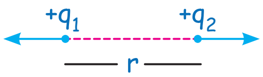
$f = \dfrac{kq_1q_2}{r^2}$

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

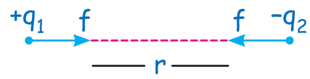
ε_0 → Permitivity of free space (ε_0)

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

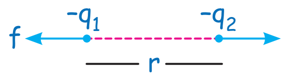
Ex.: $f = \dfrac{kq_1q_2}{r^2}$



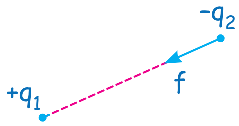
$f = \dfrac{kq_1q_2}{r^2}$



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

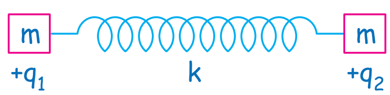


$f = \dfrac{kq_1q_2}{r^2}$



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

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



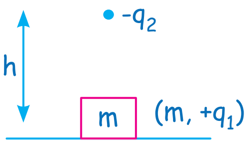
Sol. Let elongation in spring is x

$f = \dfrac{kq_1q_2}{(l_o + x)^2}$

$kx = \dfrac{kq_1q_2}{(l_o + x)^2}$

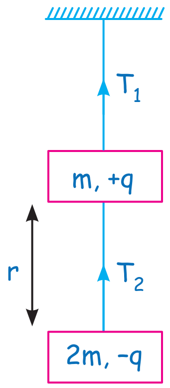
(अबे अब value put करके quadratic eqn. बनाके कर लोगे ना ☺)

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

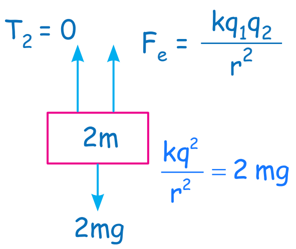


$$mg = \frac{kq_1q_2}{h^2}$$

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

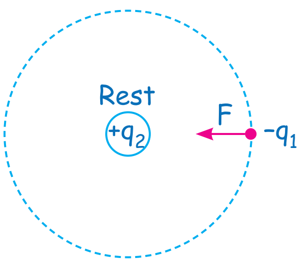


Sol.



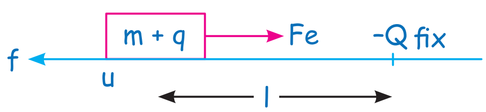
Q. A charge $(-q_1, m)$ is moving in a circular path of radius r around positive charge $+q_2$ with constant speed. Find speed

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



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

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

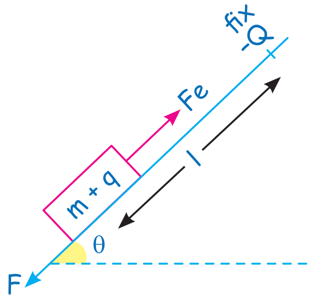


$F_e \geq \mu_s mg$

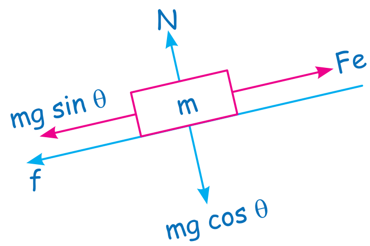
$\frac{kqQ}{l^2} \geq \mu_s mg$ (Assume block is a point mass)

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

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



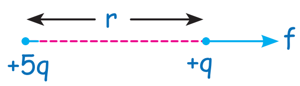
$Fe \geq mg \sin\theta + (f_s)_{max} \Rightarrow \frac{kQq}{l^2} = mg \sin\theta + \mu_s mg \cos\theta$



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

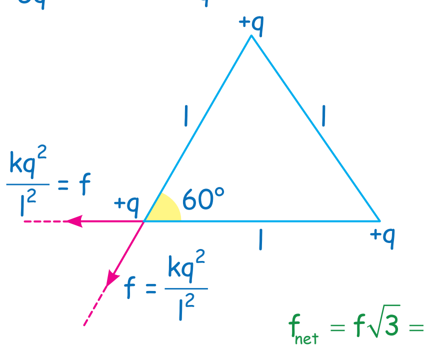
Q. Find the net force on the given charge q

(a)



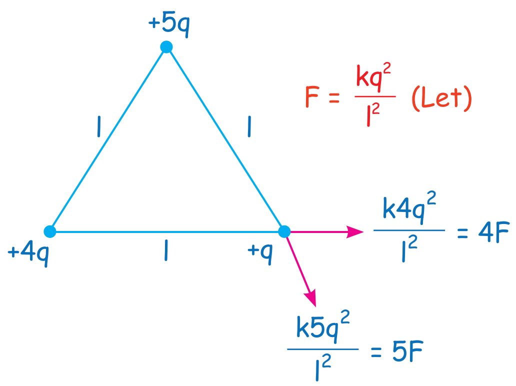
$f = \frac{k.5q.q.}{r^2}$

(b)



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

(c)

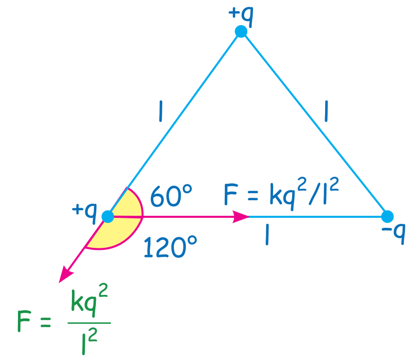


$F = \frac{kq^2}{l^2}$ (Let)

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

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

(d)

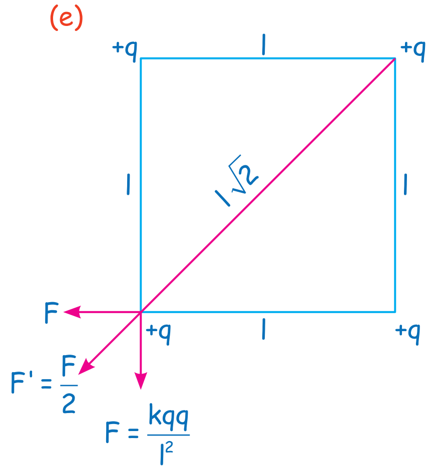


$$F_{net} = \sqrt{F^2 + F^2 + 2F^2 \cos 120^\circ}$$

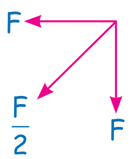
$$= \sqrt{2F^2 + 2F^2 \cos 120^\circ}$$

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

(e)



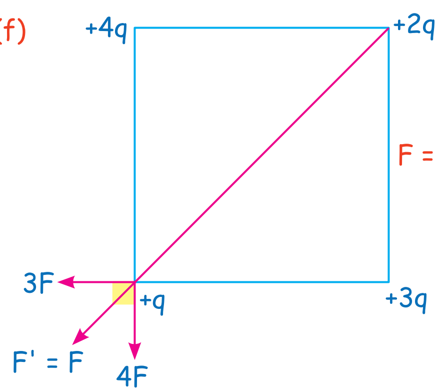
$F = \frac{kq^2}{l^2}$ (Let)



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

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

(f)



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

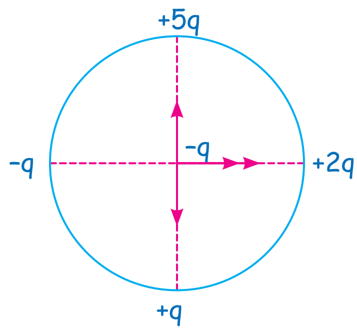
तीनो Force का resultant will be answer. 3F और 4F का resultant 5F आयेगा। So answer = 5F + F = 6F अगर तुमने दिया तो तुम बहुत बड़े गधे हो। Bcz 6F is wrong.

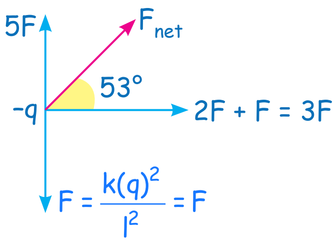
$$F' = \frac{2kq^2}{(l\sqrt{2})^2} = F$$

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

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

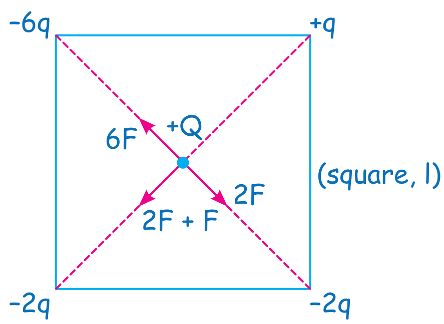
(g) Find F_{net} on the charge $-q$ at centre





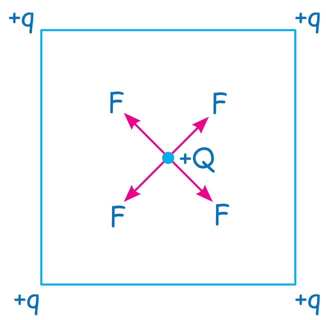
$$F_{net} = 5F = \frac{5kq^2}{r^2}$$

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



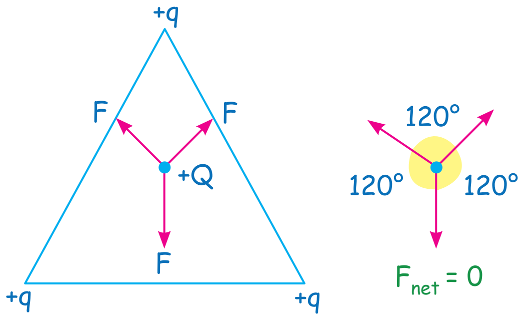
$$F_{net} = 5F = \frac{5kq^2}{(l/\sqrt{2})^2} = \frac{10kq^2}{l^2}$$

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



$F_{net} = 0$

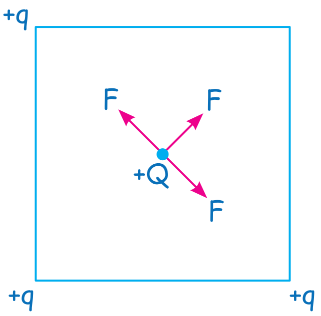
(j) Find F_{net} on + Q at the centroid of equilateral triangle.



$\Rightarrow 0.$

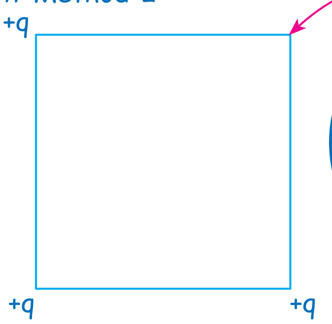
$F_{net} = 0$

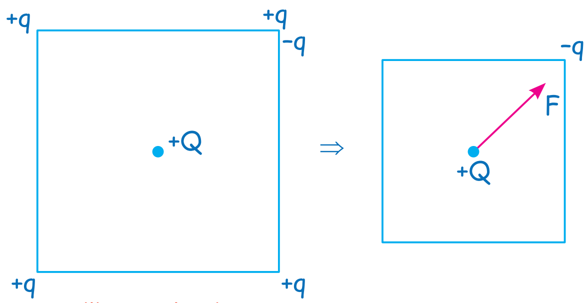
(k)



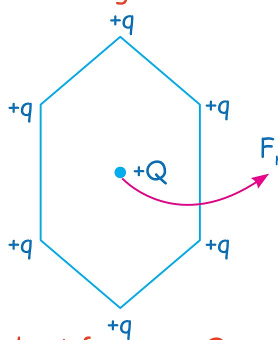
$$F_{net} = F = \frac{kQq}{(l/\sqrt{2})^2}$$

Method-2



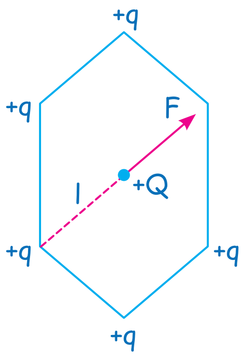


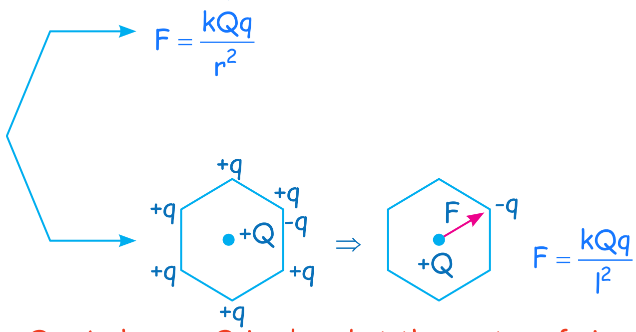
(l) Regular hexagon



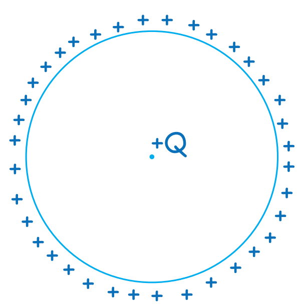
$F_{net} = 0$

(m) Find net force on +Q.





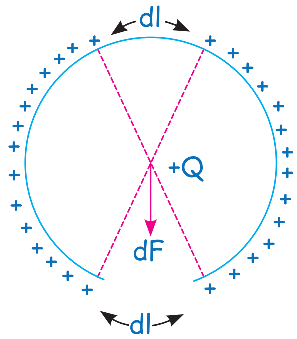
Q. A charge +Q is placed at the centre of ring of uniform charge +q, of radius r. F_{net} on + Q at centre will be



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

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

Sol.



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

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

$1 \longrightarrow q/2\pi r$

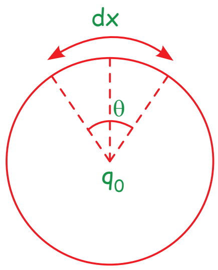
$dl \longrightarrow q/2\pi r \times dl = dq$

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

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

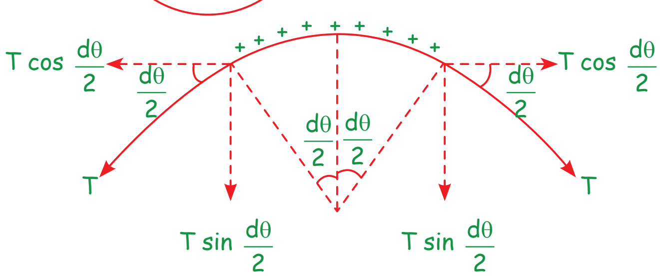
Q. A ring of radius R is made out of a thin wire of cross section A ring has uniform charge Q distributed in it. A charge q_0 is placed at the center of ring. If Y is young's modulus for material of the ring and ΔR is the change in radius of ring then find tension develope in ring and ΔR.

Sol.



dq = λdx (where λ is charge per unit length)

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



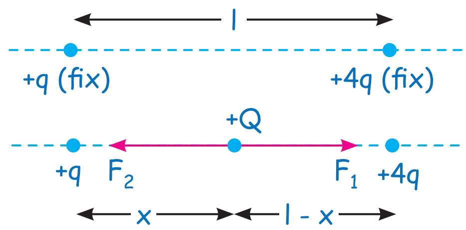
$$2T\sin\frac{d\theta}{2} = \frac{k\,dq.\,q_0}{R^2}$$

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

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

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

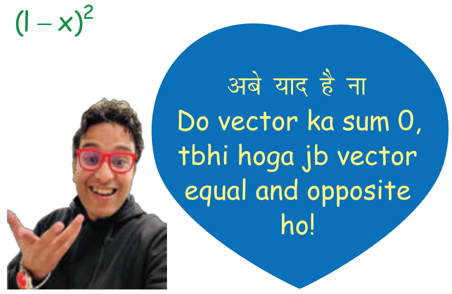
Q. Where we should place a charge Q so that it remains in eqb^m.



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

$F_1 = F_2$ [in eqb^m]

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



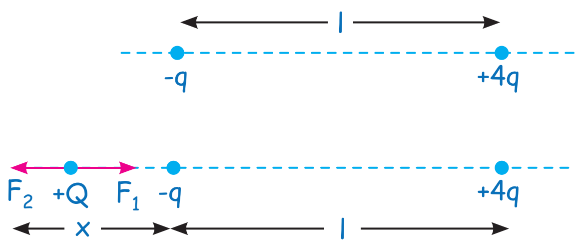
$\frac{1}{x} = \frac{2}{l-x}$

$l - x = 2x$

$x = l/3$ Ans.

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

Sol.



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

$F_1 = F_2$ [in eqb^m]

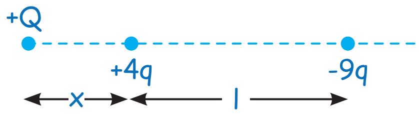
$\frac{1}{x^2} = \frac{4}{(l+x)^2}$

$l + x = 2x$

$x = l$ Ans.

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

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



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

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

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

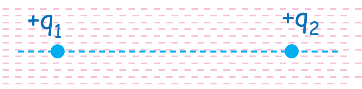
$$2l = x$$

EFFECT OF MEDIUM

In Vaccum

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

In Medium



If medium is upto ∞ then net force on the charge q_2 will be

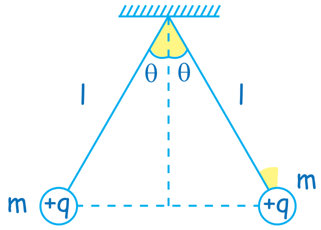
$$\frac{1}{4\pi\varepsilon}\frac{q_1q_2}{r^2} = \frac{1}{4\pi\varepsilon_o k}\frac{q_1q_2}{r^2} = \frac{F_o}{k} \quad k \to \text{Dieletric const.}$$

Permittivity of that medium

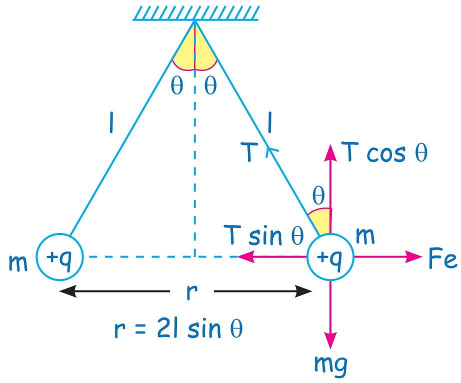
$\varepsilon = \varepsilon_0\,\varepsilon_r$

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

(a) Find θ, tension etc.



Sol.



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

$T\cos\theta = mg$

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

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

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

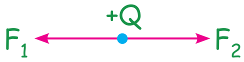
(b) If $q_1 \neq q_2$ and $m_1 = m_2$ repeat above question

Sol. $\theta_1 = \theta_2$

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

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

$F_{net}=F_2-F_1$



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

If $x \ll l$

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

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

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

$F_{net} = -kx$

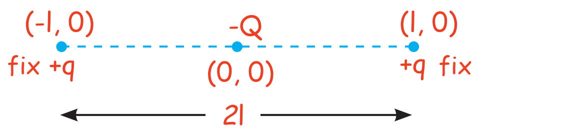
$$T = 2\pi\sqrt{\frac{m}{Qq/\pi\varepsilon_0 l^3}}$$

In SHM

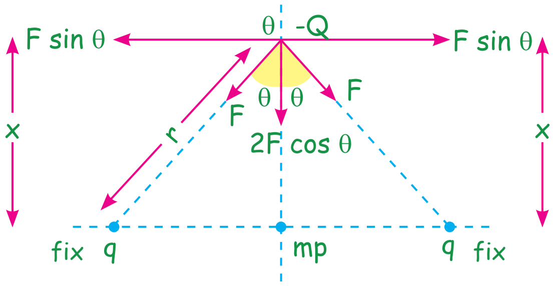
If $\vec{F}_{net} = -k\vec{x}$

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

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



Sol.



$F_{net} = 2F\cos\theta$ (नीचे)

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

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

If $x \ll a$

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

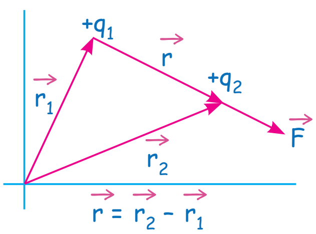
$$T = 2\pi\sqrt{\frac{m}{2kqQ/a^3}}$$

VECTOR FORM OF COULOMB LAW

Force by q_1 on q_2

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

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



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

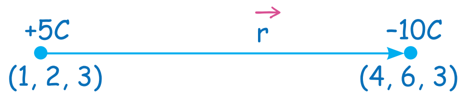
But हम SKC लगा कर सवाल solve करेंगे।

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

##SKC

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

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

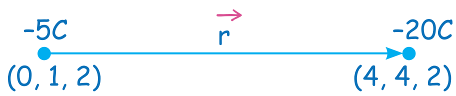


$\vec{r} = 3\hat{i} + 4\hat{j}$

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

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

Q.

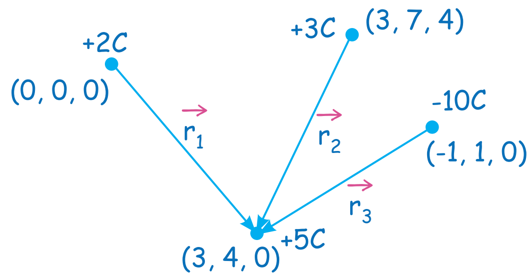


Force applied by -5C on -20C:

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

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

Q. Find net force on +5C.



Find F_{net} on + 5C

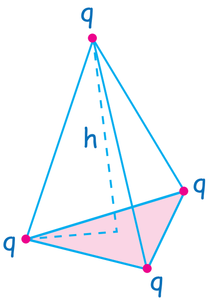
$\vec{r}_1 = 3\hat{i} + 4\hat{j}$

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

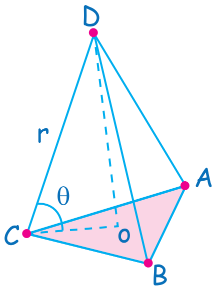
$\vec{r}_3 = 4\hat{i} + 3\hat{j}$

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

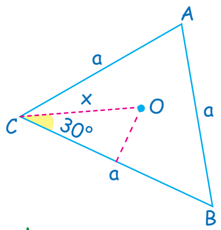
Q. Three charges (+q) are placed on the vertices of a equilateral triangle of side a as shown in diagram. Find net force on 4th identical charge particle at a height h = a above the centroid of Δ.



Sol.

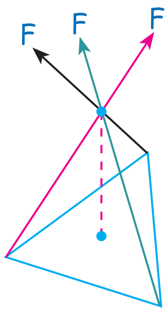


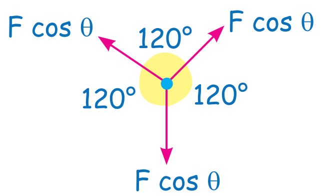
$\tan\theta = \frac{OD}{OC} = \frac{h}{OC}$



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

Hence $\theta = 60°$





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

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

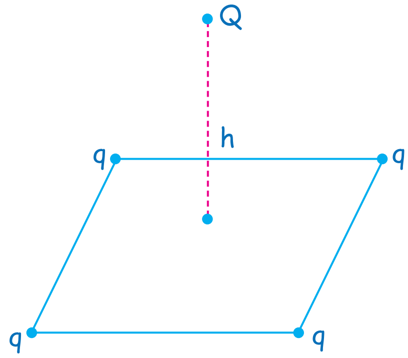
$F\sin\theta + F\sin\theta + F\sin\theta$

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

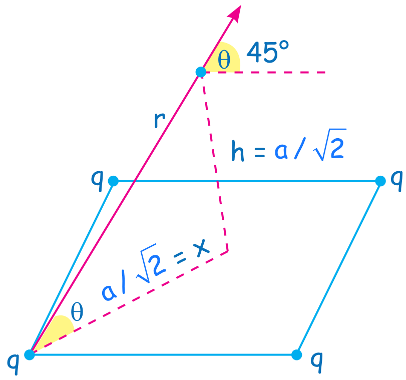
where $F = \frac{kq^2}{r^2}$

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

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



Sol.



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

$\sin\theta = 45°$

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

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

ELECTRIC FIELD

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

$\Rightarrow$ Electric field intensity is defined as force on unit test charge.

Electric Field due to Point Charge

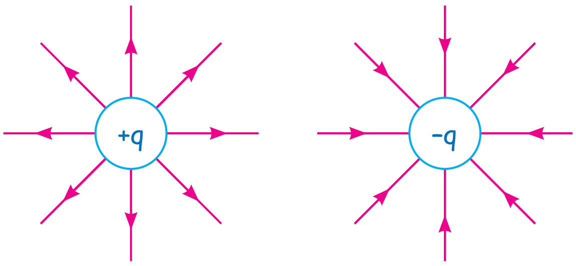
(E.F) at A due to + Q = $\frac{\vec{F}}{q_0}$

Force experimental per unit test charge.

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

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

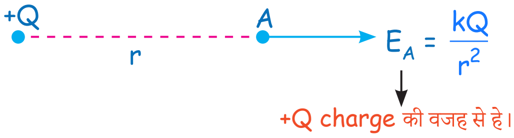
2. EF due to +ve point chare is radially outward and due to –ve point charge its radially inward



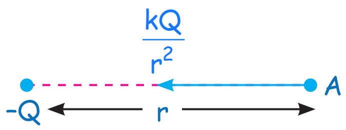
अब हम EF निकालना सीखेंगे सही से देखो तो यह coulomb law जैसे ही question है।

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

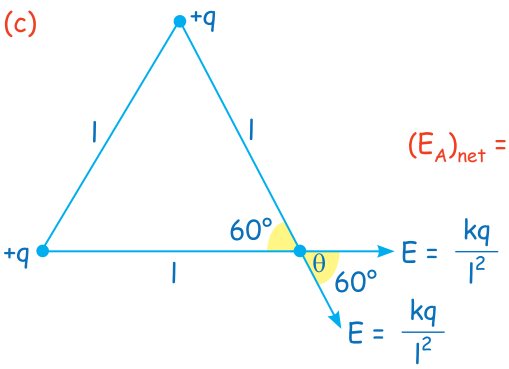
(a)



(b)

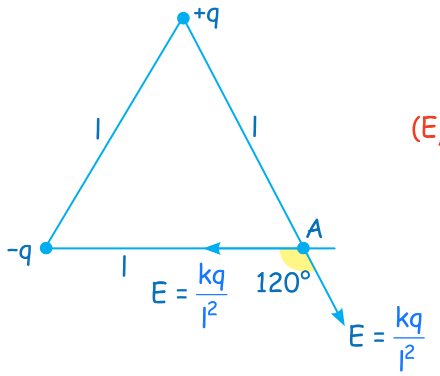


(c)



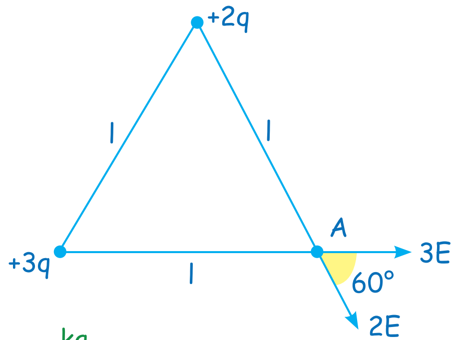
$(E_A)_{net} = E\sqrt{3}$

(d)



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

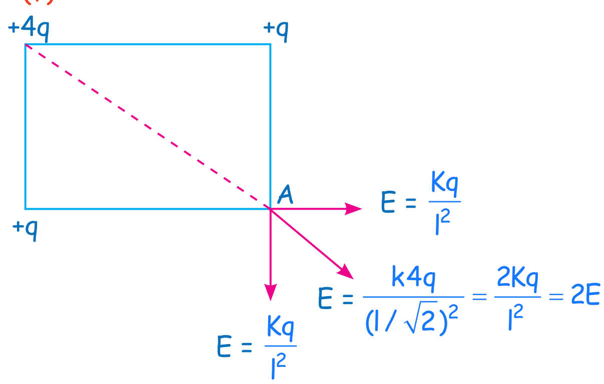
(e)



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

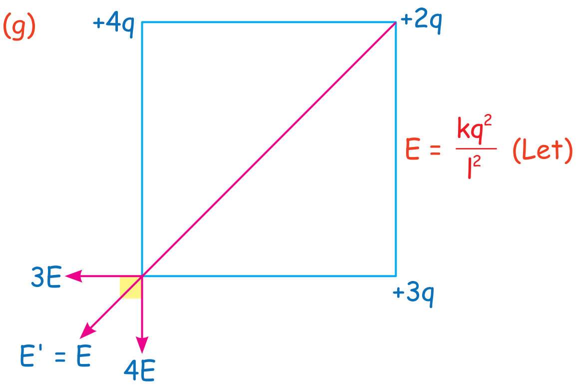
$$E_{net} = \sqrt{(2E)^2 + (3E)^2 + 2 \times 2E \times 3E \times \cos 60°}$$
$$= E\sqrt{19}$$

(f)



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

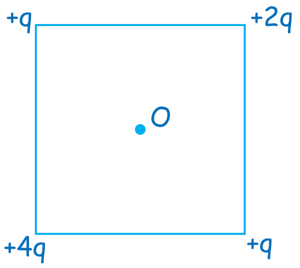
(g)

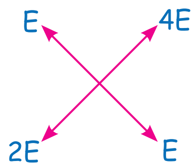


तीनो का resultant will be answer. 3E और 4E का resultant 5E आयेगा। So answer = 5E + E = 6E अगर तुमने दिया तो तुम अब तो और भी बहुत ही ज्यादा बड़े गधे हो। Bcz 6E is wrong.

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

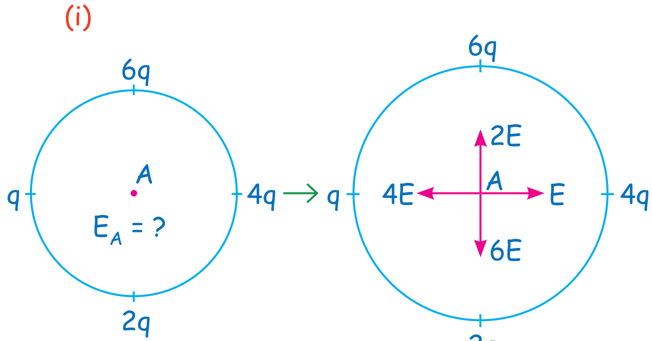
(h) Find electric field at point at centre of square (l) at O.

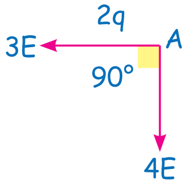




$$= 2E = \frac{2kq}{(l/\sqrt{2})^2}$$

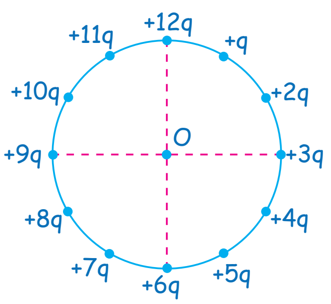
(i)

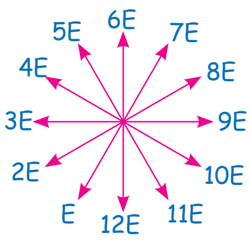


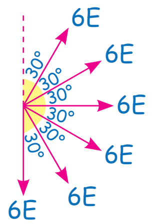


$$(E_{net})_A = 5E = \frac{5kq}{r^2}$$

Q. Find E_{net} at centre 0.







अब component लेकर solve करो जैसे vector में करते थे।

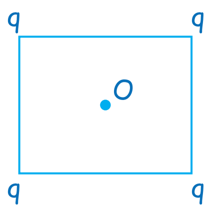
$$\vec{E}_{net} = (12E + 6E\sqrt{3})\hat{i} - 6E\hat{j}$$

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

Sol. $\tan\alpha = \frac{E_y}{E_x} = \frac{6E}{12E + 6E\sqrt{3}} = 2 - \sqrt{3}$

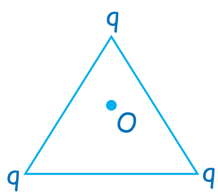
Q. Find net electric field at O.

(a)



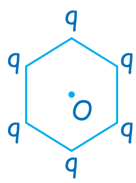
E = 0

(b)



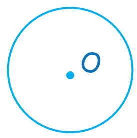
E = 0

(c)



E = 0

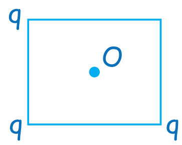
(d)



Uniform (Ring Q, R)

E = 0

(e)



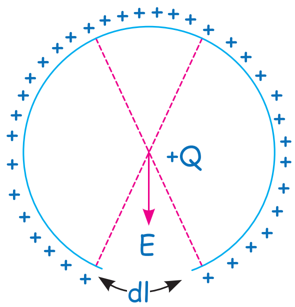
$$E = \frac{kq}{(l/\sqrt{2})^2}$$

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

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

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

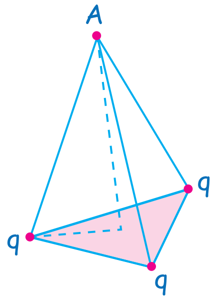
Sol.

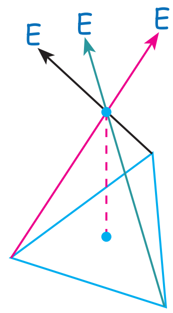


$$E_{net} = \frac{kdq}{R^2} = \frac{kQ}{R^2\,2\pi R}dl$$

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

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





Sol. $E_A = 3E\sin\theta$

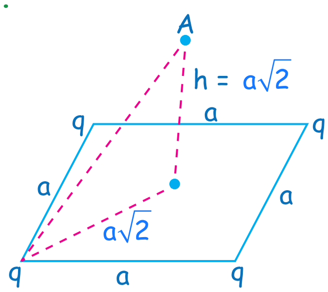
[$\theta = 60^\circ$ already solved]

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

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

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

Sol.



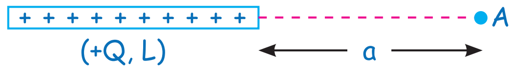
$E_A = 4E\sin\theta$ [$\theta = 45^\circ$]

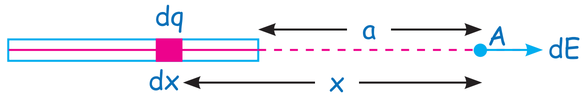
ऐ फिर आ गया रे बाबा

अपने पास इसका भी एक मस्त तरीका है।

chapter के last में बताऊँगा।

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



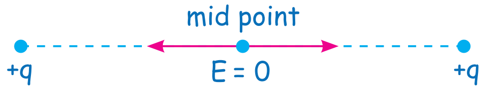


Sol. $\displaystyle\int dE = \int_a^{a+L} \frac{kdq}{x^2} = \int_a^{a+L} \frac{kQ}{L}\frac{dx}{x^2} = \frac{kQ}{a(a+L)}$

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

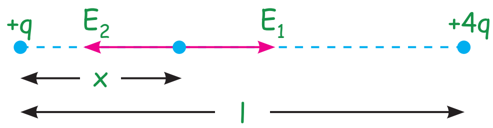
(a)

Sol.



(b)

Sol.



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

$l - x = 2x$

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

Q. Find where electric field is zero.

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

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

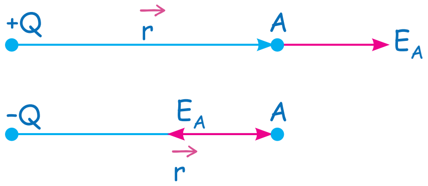
$\dfrac{4}{x^2} = \dfrac{9}{(x+l)^2}$

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

$x = 2l$

ELECTRIC FIELD DUE TO PT. CHARGE IN VECTOR FORM.

$\vec{E}_A = \lim\limits_{q_0 \to 0} \dfrac{\vec{F}}{q_0} = \dfrac{kQq_0}{r^2 q_0}.\hat{r}$



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

→ due to pt. charge

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

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

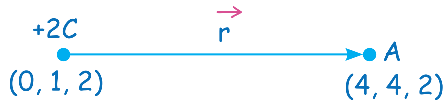
#SKC

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

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

Q. Find net E.F at point A.

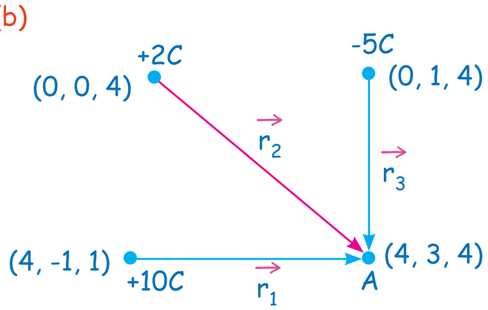
(a)



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

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

(b)



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

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

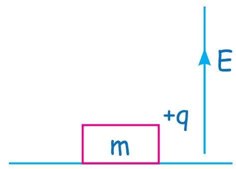
$+ \frac{k(-5)}{20}\left(\frac{4\hat{i} + 2\hat{j}}{\sqrt{20}}\right)$

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

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

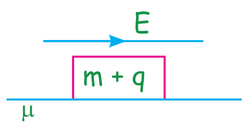


$qE \geq mg$

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

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

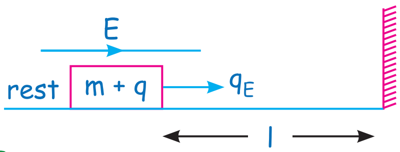
Sol.



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

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

Initially at rest



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

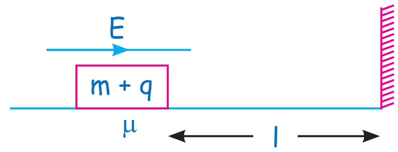
$s = ut + \frac{1}{2}at^2$

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

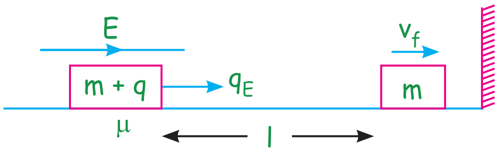
$t_o = \sqrt{\frac{2s}{a}} = \sqrt{\frac{m2s}{qE}}$

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

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



Sol.

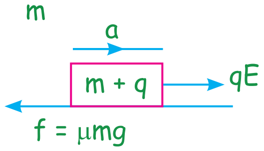


$(WD)_{\text{all force}} = \Delta K.E$

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

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

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



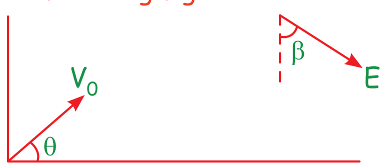
$V^2 = O^2 + 2al$ ...(i)

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

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

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

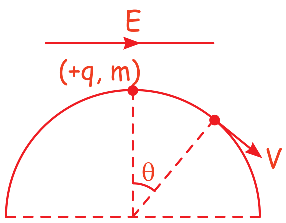
Q. A charge particle (q, m) is projected from ground where electric field is also present along with gravitational field. Find is time period and range in following figure.



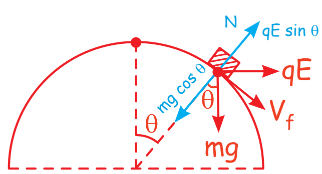
Sol. $T = \frac{2U_y}{a_y} = \frac{2 \times V_0 \sin\theta}{g + \frac{qE\cos\beta}{m}}$

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

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



Sol.



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

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

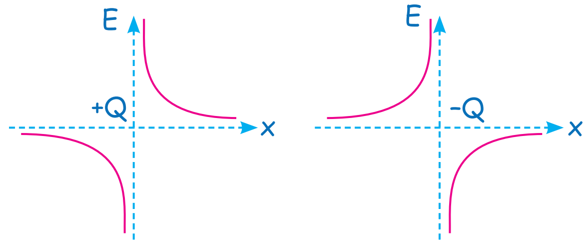
Q. A charge particle of radius 5×10^{-7}m is moving in a horizontal E.F. of intensity $2\pi \times 10^5$ V/m. The surrounding medium is air with coff. of viscosity $\eta = 1.6 \times 10^{-5}$ N.S/m^2. If this particle is moving with a uniform horizontal speed of .02 m/s. Find no. of excess electron on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

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

Ans. $30e^-$

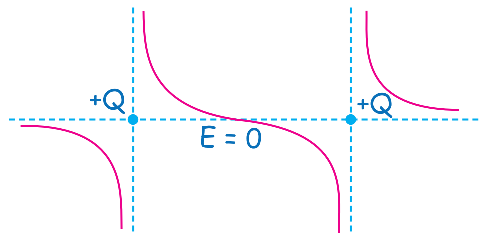
Graph b/w E Vs r

#



[For +ve, (आगे)] [For -ve]

#



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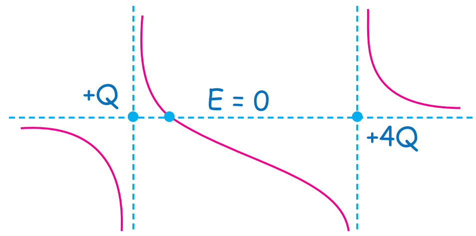

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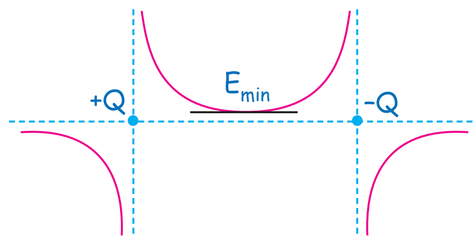

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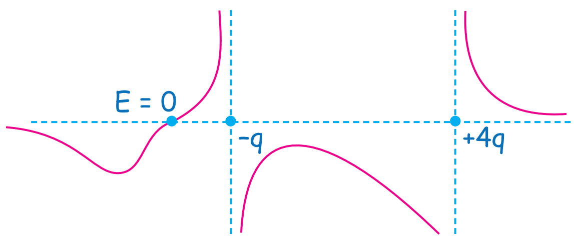
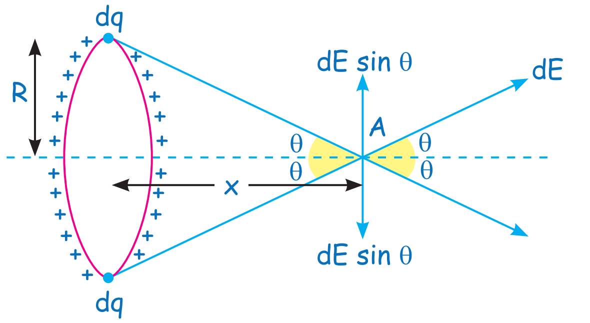


Use

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

ELECTRIC FIELD DUE TO CHARGED UNIFORM RING AT AXIS



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

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

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

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

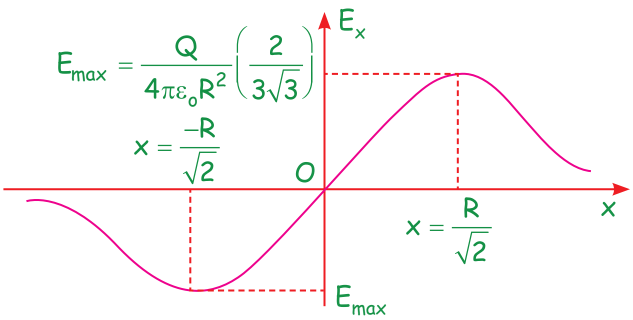
at $x = 0$, $\Rightarrow$ E.F = 0

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

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

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

$E_{max} = \frac{Q}{4\pi\varepsilon_o R^2}\left(\frac{2}{3\sqrt{3}}\right)$



Charge Distribution

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

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

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

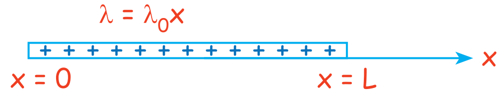
$Q = \int\lambda dx$
$Q = \int\sigma dA$
$Q = \int\rho dV$

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

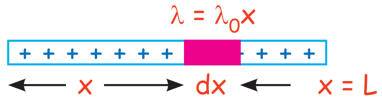
$\rho = \frac{dq}{dV}$ = charge per unit volume.

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

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



Sol.

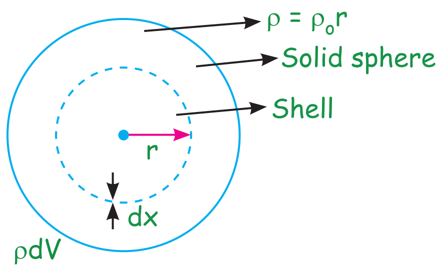


$\int dq = \int \lambda dx$

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

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

Sol.



$dq = \rho dV$

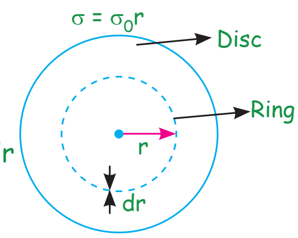
$Q_{total} = \int dq = \int_0^R \rho_0 r.4\pi r^2 dr = \pi\rho_0 R^4$

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

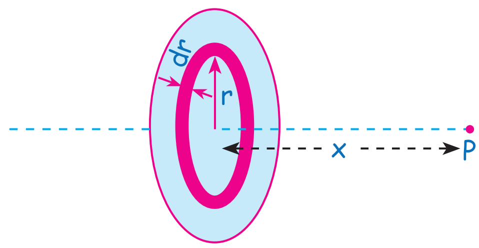
Sol. $dq = \sigma dA$

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

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



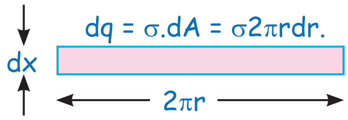
ELECTRIC FIELD DUE TO UNIFORM CHARGED DISC AT A POINT ON AXIS [+Q, σ, R]



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

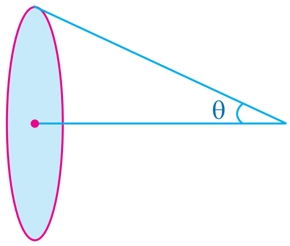
$E_{net} = \int dE$

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



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

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

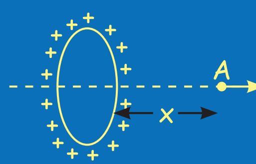


If disc is very large/Infinite sheet......

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

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

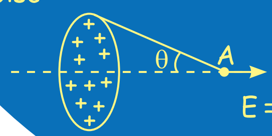
(1) Ring



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

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

(2) Disc



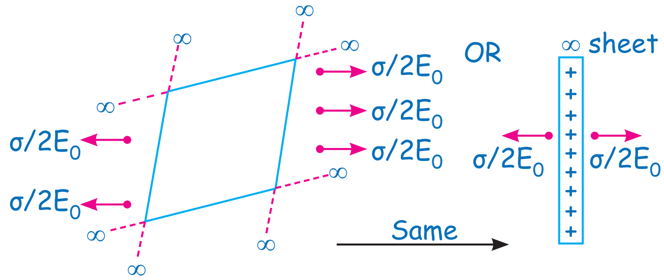
$$E = \frac{\sigma}{2\varepsilon_0}(1 - \cos\theta)$$

#SKC

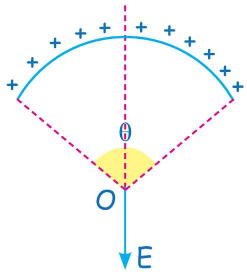
∞ sheet के दो मतलब

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

∞ sheet

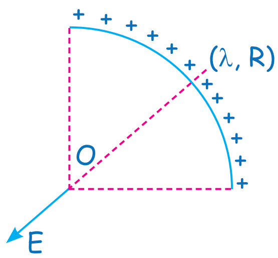


ELECTRIC FIELD DUE TO CHARGED ARC AT CENTER



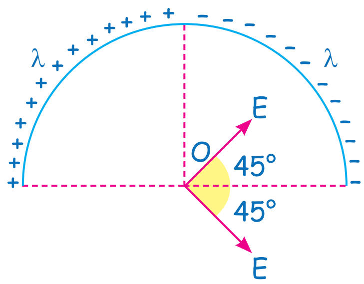
$$E = \frac{2k\lambda}{R}\sin\frac{\theta}{2}$$

1



$$E = \frac{2k\lambda}{R}\sin 45°$$

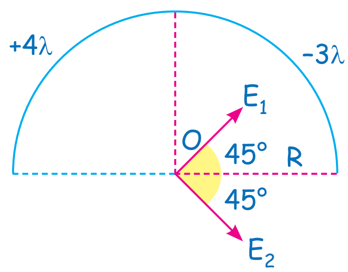
2



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

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

3

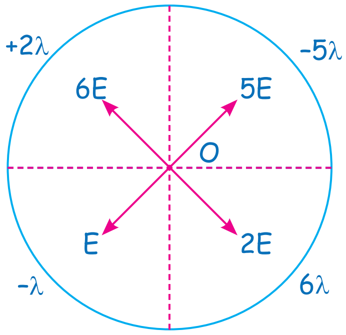


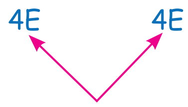
$$E_1 = \frac{2k(3\lambda)}{R}\sin 45^\circ = \frac{3\sqrt{2}\,k\lambda}{R}$$

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

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

4

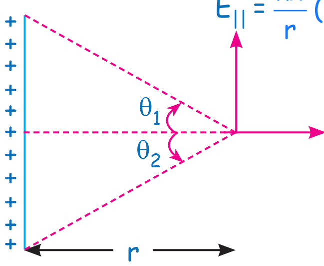




$$E = \frac{2k\lambda}{R}\sin\frac{90}{2} = \frac{k\lambda\sqrt{2}}{R}$$

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

ELECTRIC FIELD DUE STRAIGHT CHARGED WIRE AT A POINT

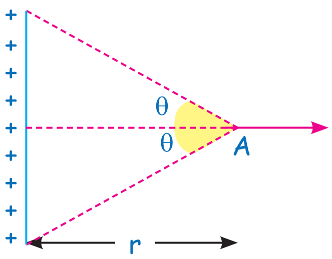


$$E_{||} = \frac{k\lambda}{r}(\cos\theta_1 - \cos\theta_2)$$

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

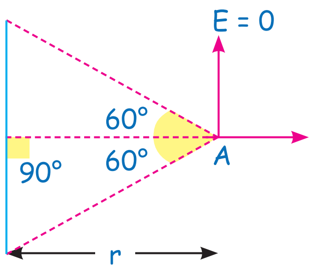
Q. Find electric field at point A in following case.

1



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

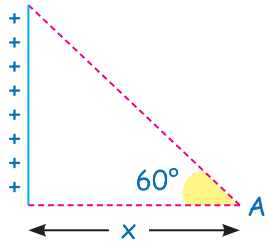
2



$$\frac{k\lambda}{r}(\sin 60^\circ + \sin 60^\circ)$$

$$= \frac{k\lambda}{r}\sqrt{3}$$

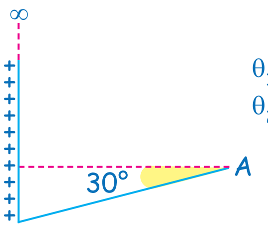
3



$\theta_1 = 60^\circ$
$\theta_2 = 0^\circ$

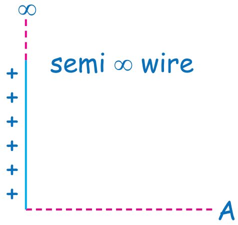
Now put the value in formula and get ans. अबे ये भी मै ही करू क्या बच्चे की जान लेगा।

4



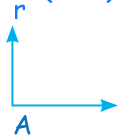
$\theta_1 = 90^\circ$
$\theta_2 = 30^\circ$

5



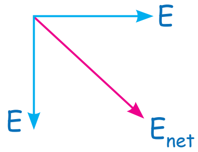
$\theta_1 = 90^\circ$
$\theta_2 = 0^\circ$

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



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

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

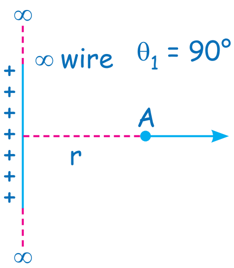


Here

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

इसे याद करलो

6

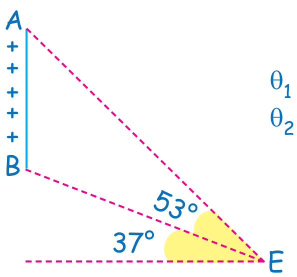


$\theta_1 = 90^\circ$ & $\theta_2 = 90^\circ$

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

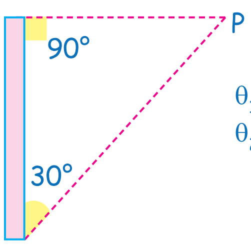
∞ wire ki वजह से $EF = \frac{2k\lambda}{r}$ होती है

7



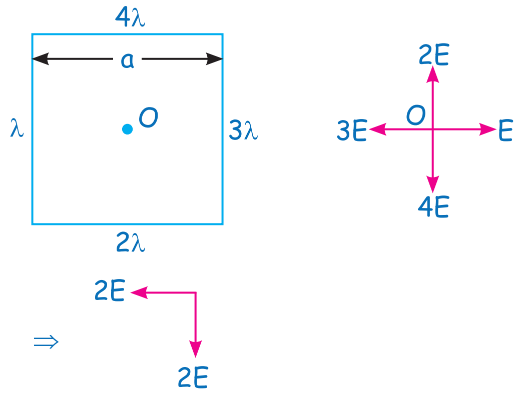
$\theta_1 = 53^\circ$
$\theta_2 = -37^\circ$

8



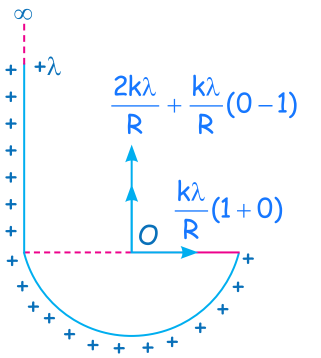
$\theta_1 = 0$
$\theta_2 = 60^\circ$

9. Find electric field at O.



$$E_{net} = 2E\sqrt{2} = 2 \times \frac{2k\lambda}{l/2}(\sin 45^\circ)\sqrt{2}$$

10.



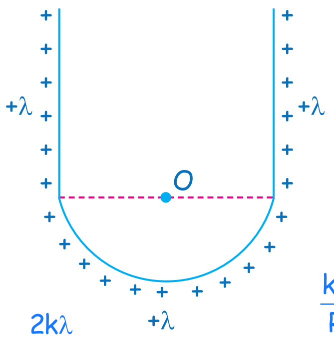
$\theta_1 = 90^\circ$

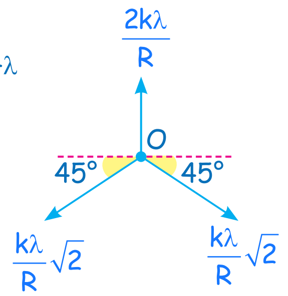
$\theta_2 = 0$

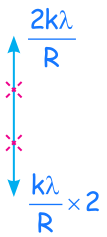
Solve and get

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

11. Find electric field at O.

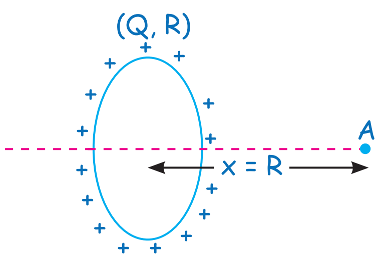






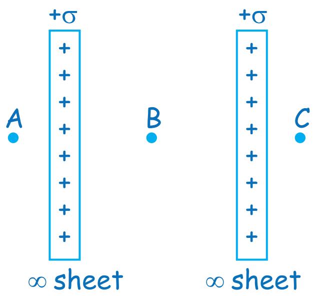
(E_{net}) at 'O' = 0

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

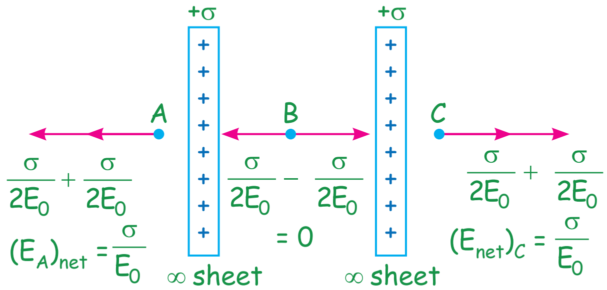


$$E_A = \frac{kQR}{(R^2 + R^2)^{3/2}} = \frac{kQ}{2\sqrt{2}R^2}$$

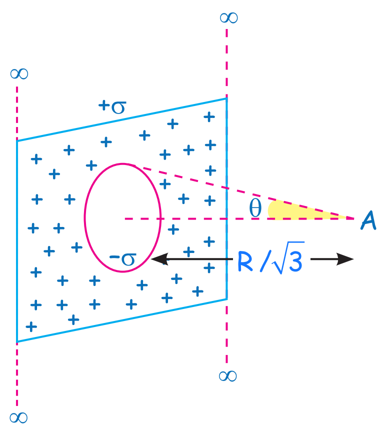
13. Find electric field at A, B, C



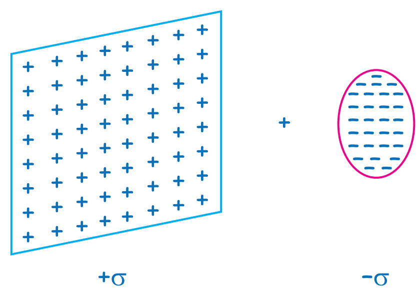
Sol.



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



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



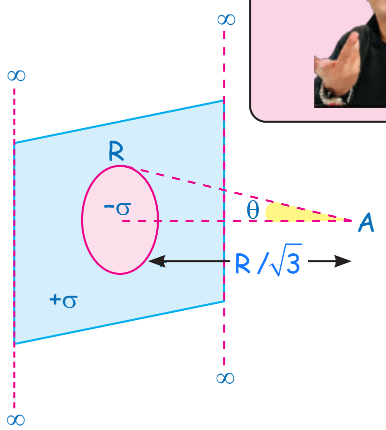
$(Ef)_{at}$ Point A = $\underbrace{\frac{\sigma}{2E_0}}_{\vec{E}\text{ due to }\infty\text{ sheet}} - \underbrace{\frac{\sigma}{2E_0}(1-\cos\theta)}_{\vec{E}\text{ due to -ve disc}}$

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

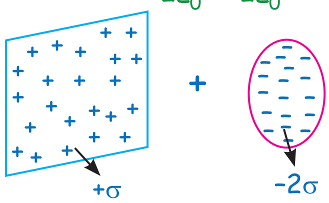
$= \frac{\sigma}{2E_0} - \frac{\sigma}{4E_0} = \frac{\sigma}{4E_0}$

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

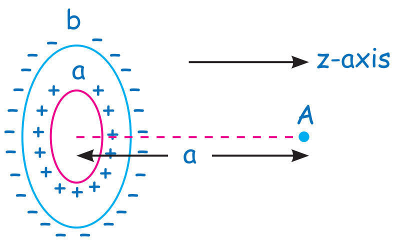
Q. Find electric field at A.



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



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



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

$(E_A)_{net} = 0$

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

$$\frac{kq_1x}{(R_1^2 + x)^{3/2}} = \frac{kq_2x}{(R_2^2 + x)^{3/2}}$$

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

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

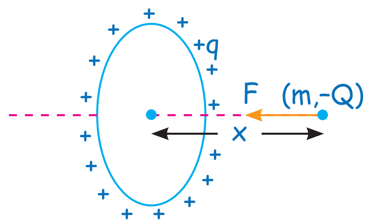
$b^2 = 4a^2$

$b = 2a$

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

Q. A particle of mass m, charge -Q is constrained to move along the axis of radius a. The ring carries a uniform charge density $+\lambda$ 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^m position is

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



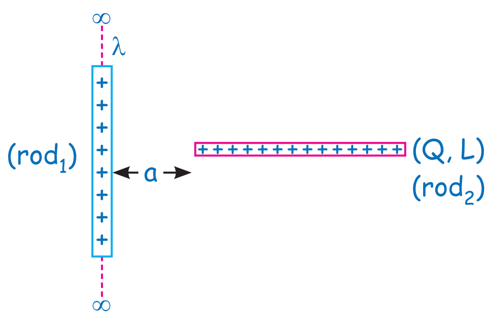
$F_{net} = QE$ (पीछे)

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

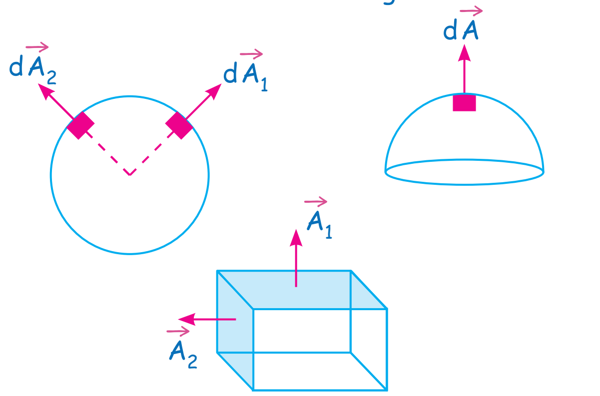
$F_{ent} = \frac{kqQ}{R^3}\vec{x}$

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

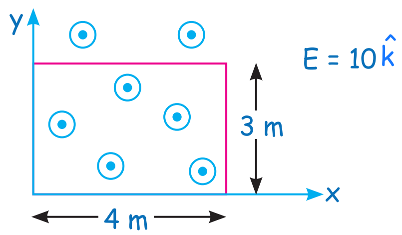
Q. Find the force applied by infinite (rod_1) to (rod_2) of length l and charge Q in given figure.



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



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



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

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

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

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

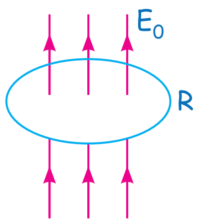
$\phi = \vec{E}.\vec{A} = 0 + 0 + 10 \times 12 = 120$

Area = 4 × 3 = 12

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

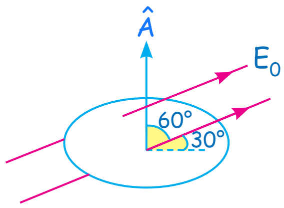
Q. Find flux through given area in following question.

1



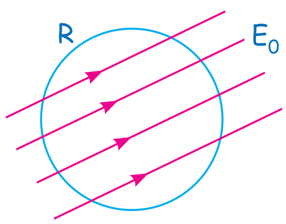
$\Rightarrow \phi = E_0 \cdot \pi R^2$

2



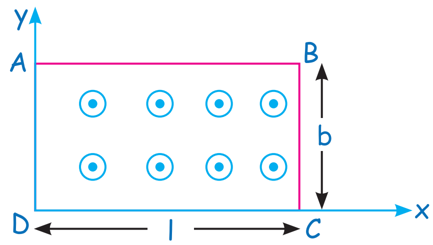
$\Rightarrow E\pi R^2 \cos 60°$

3



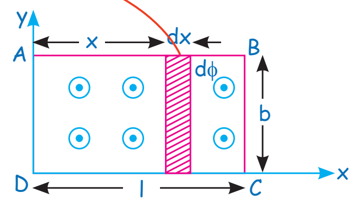
$\Rightarrow \phi = 0$

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



Sol.

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



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

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

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

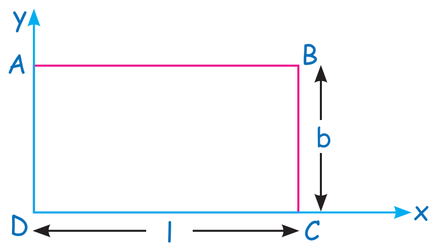
Q. In above part $\vec{E} = 5\hat{i} + 10\hat{j} + 10x\hat{k}$

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

Last part

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

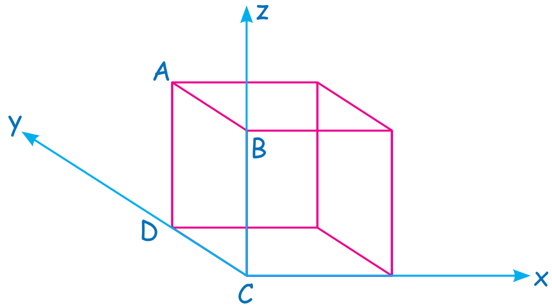
Q. Find flux through the rectangle if $\vec{E} = 3x^2y\hat{i} + 4y^3x\hat{j} + 3x^2\hat{k}$ in given diagram



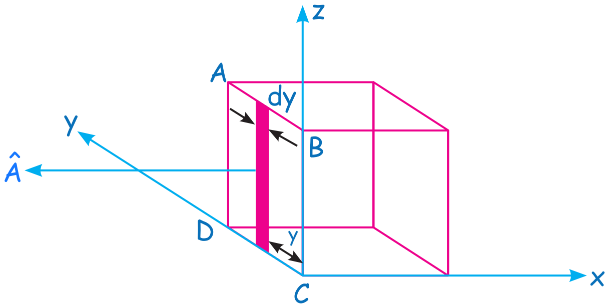
Sol. $d\phi = \vec{E}.d\vec{A}$

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

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



Sol.



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

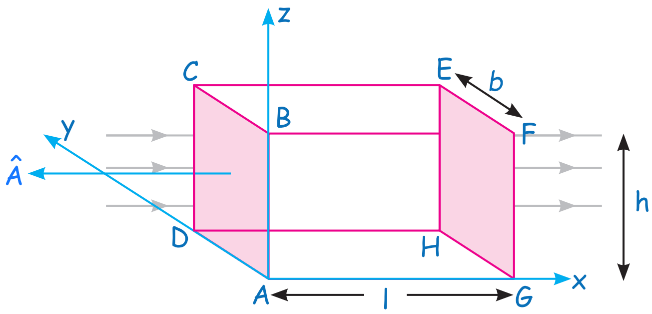
$\phi_{ABCD} = \int_0^A 10y.\, L dy$ (magnitude) $= 5L^3$ (magnitude)

net flux through cube = 0

☆ ϕ Through Body/closed area

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

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



$\phi = EA \cos\theta$

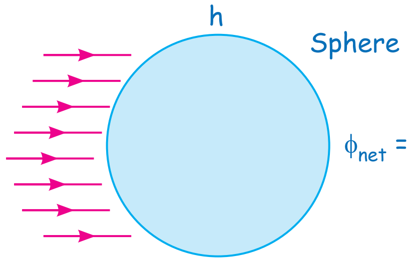
$\phi_{ABCD} = 10bh \cos 180° = -10bh = \phi_{in}$

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

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

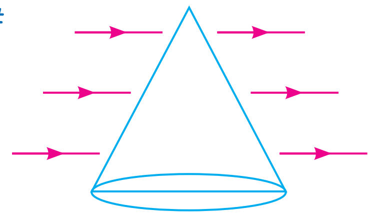
- $\phi_{in} = \phi_{body}$ में आने वाला flux
  $\rightarrow$ Negative
- $\phi_{out} = \phi_{body}$ से जाने वाला flux
  $\rightarrow$ Positive
- अगर आने वाली = जाने वाली तो body से net flux = 0

Sphere



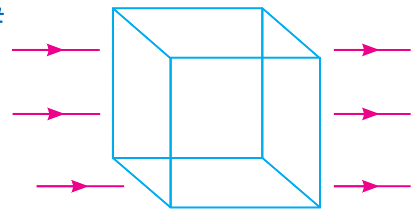
$\phi_{net} = 0$

#



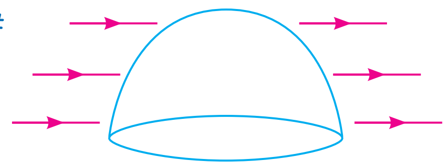
$\phi_{net} = 0$

#



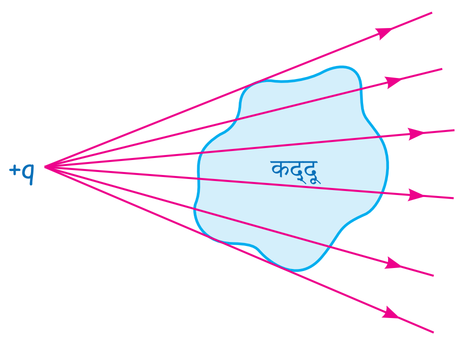
$\phi_{net} = 0$

#



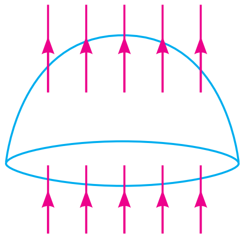
$\phi_{net} = 0$

#



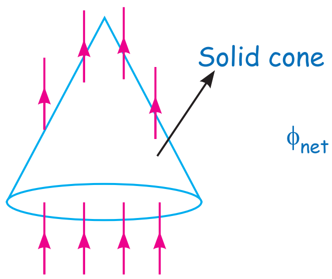
$\phi_{net} = 0$

#



$\phi_{net} = 0$

#

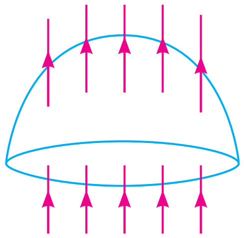


$\phi_{net} = 0$

#

$\phi_{net} = 0$

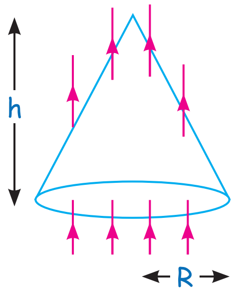
Q. Find flux through the curve surface of in hemisphere in following figure.



Sol. $\phi_{net} = 0$

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

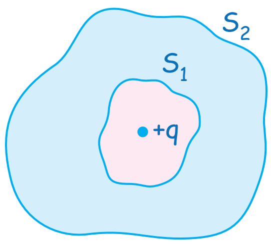
#



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

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

#



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

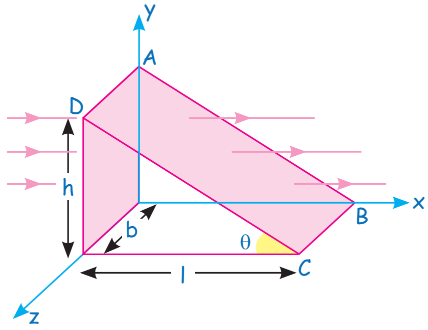
$\phi_{S_1} = \phi_{S_2}$

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

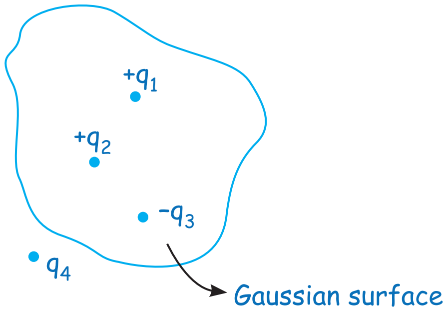
Sol. $\phi_{in} = -E_0hb$

$\phi_{out} = E_0hb$

$\phi_{net} = 0$



GAUSS LAW



$$\phi_{net} = \underbrace{\oint \vec{E}\cdot d\vec{A} = \frac{q_{in}}{\varepsilon_0}}_{\text{Gauss Law}} = \frac{q_1+q_2-q_3}{\varepsilon_0}$$

due to all the charge

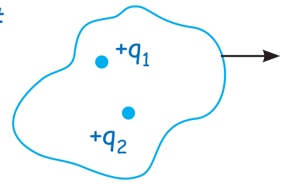
अंदर वाला charge

$$\phi_{net(\text{close surface area})} = \underbrace{\oint \vec{E}\cdot d\vec{A} = \frac{q_{in}}{\varepsilon_0}}_{\text{Gauss Law}} = \frac{q_1+q_2-q_3}{\varepsilon_0}$$

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

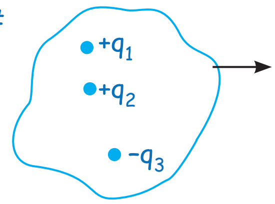
- $\oint \vec{E}\cdot d\vec{A} = \frac{q_{in}}{\varepsilon_0}$
- $\phi_{net} = \frac{q_{in}}{\varepsilon_0}$

#



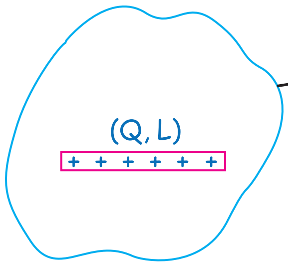
$\phi_{net} = \frac{q_1+q_2}{\varepsilon_0}$

#



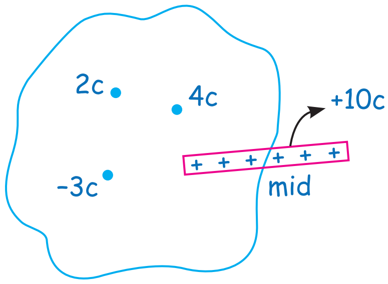
$\phi_{net} = \frac{q_1+q_2-q_3}{\varepsilon_0}$

#



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

#



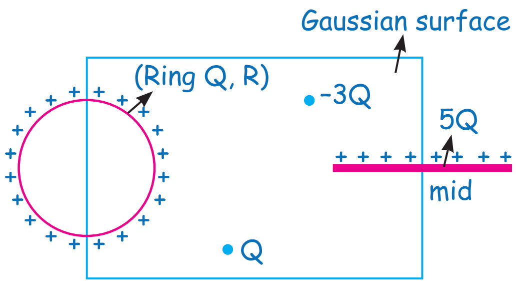
$\phi_{net} = \dfrac{2+4-3+5}{\varepsilon_0} = \dfrac{8}{\varepsilon_0}$

भाई आगे ε_o की जगह E_o type हो गया है इसलिए बुरा मत मानना।

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

चलो अब पढ़ाई करते है।

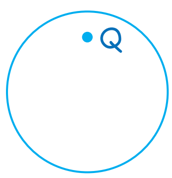
Q. Find flux through the Gaussian surface



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

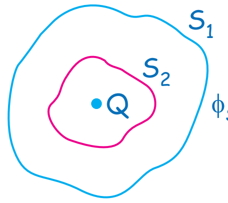
#

$\phi_{net} = \dfrac{Q}{E_0}$



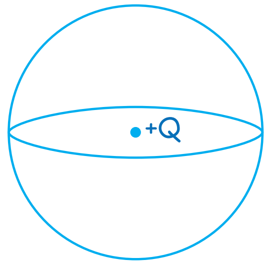
$\phi_{net} = \dfrac{Q}{E_0}$

#



$\phi_{S_1} = \phi_{S_2}$ $[\phi_{S_2} = Q/_{E_0} \cdot \phi_{S_1} = Q/_{E_0}]$

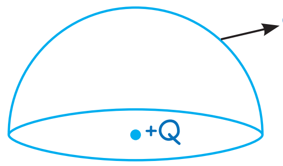
#



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

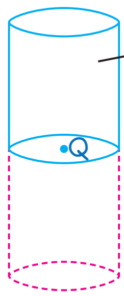
$(\phi)_{\text{upper half hemisphere}} = \dfrac{Q}{2E_0} = \phi_{\text{lower half hemispheres}}$

#



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

#



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

 # काम का डब्बा

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

- $\phi_{net} = \oint \vec{E} \cdot d\vec{A} = \dfrac{q_{in}}{E_0}$
- यहां Electric field due to all charges hai. [अंदर वाले भी बाहर वाले भी]
- $q_{in} \rightarrow$ Gausian surface के अंदर वाले charge.
- बाहर वाला charge net flux में participate नही करता [through closed Gausian surface]
- Gauss Law की मदद से हम हर जगह E.F नही निकाल सकते, कुछ selected symmetrical cases में निकाल सकते है।

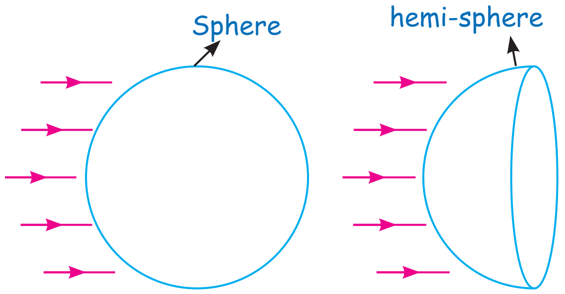
- Gaussian surface smartly मानना है, वर्ना कद्दू मिलेगा, और Gaussian surface ऐसे मानो की हर जगह पर θ की value 0°, 90°, 180° मिले

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

1. Flux calculation based
2. EF calculation based

पहले हम flux calculation based questions करेंगे

#



$\phi_{net} = 0$

$\phi_{entering} = \phi_{in}$

$= -E_0\pi R^2$

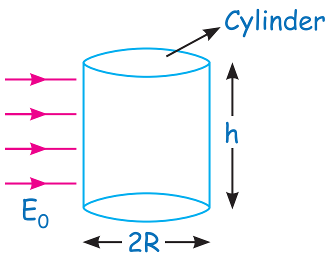
$\phi_{out} = E_0\pi R^2$

$\phi_{net} = 0$

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

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

#

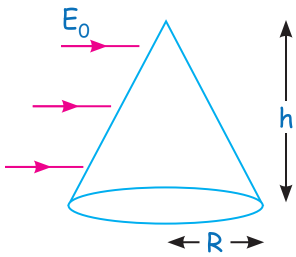


$\phi_{net} = 0$

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

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

#

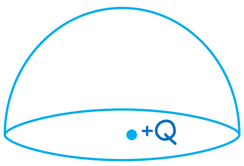


$\phi_{net} = 0$

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

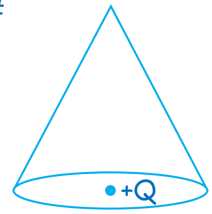
$\phi_{out} = E_0 \frac{1}{2} 2Rh$

#



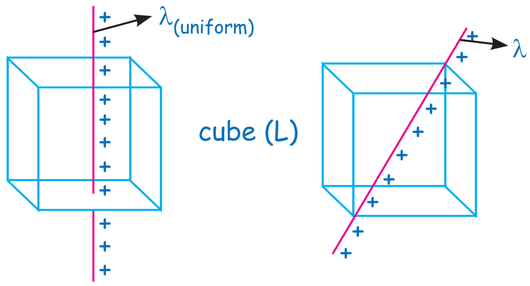
$\phi_{semi\text{-}sphere} = \frac{Q}{2E_0}$

#



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

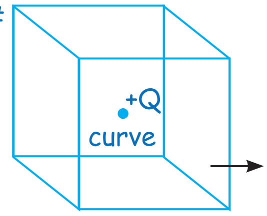
#



$\phi_{cube} = \frac{q_{in}}{E_0} = \frac{\lambda L}{E_0}$

$\phi_{cube} = \frac{q_{in}}{E_0} = \frac{\lambda L\sqrt{3}}{E_0}$

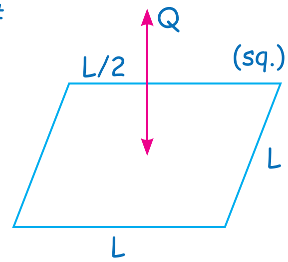
#



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

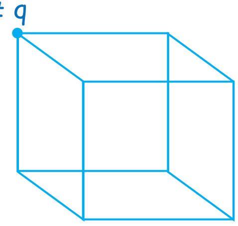
$\phi_{face} = \frac{Q}{6E_0}$

#



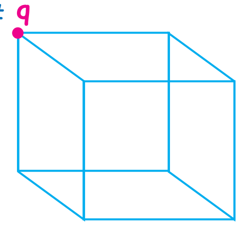
$\phi_{sq.face} = \frac{Q}{6\,E_0}$

q



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

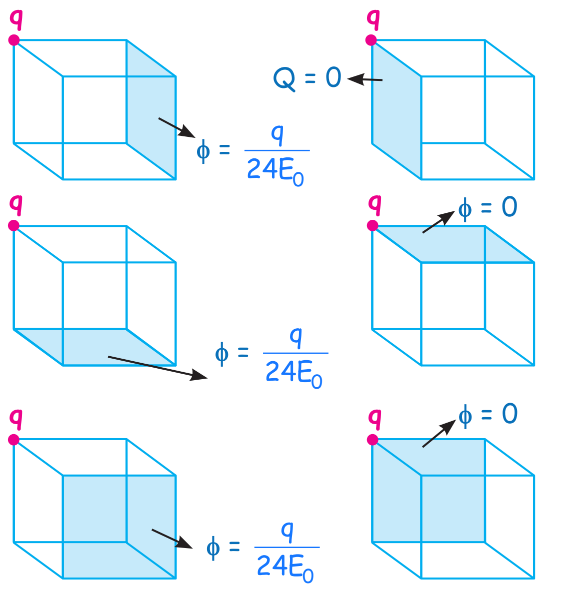
q



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

$\phi_{3faces} = 0$

$\phi_{samne\ bala} = \frac{q}{24E_0}$



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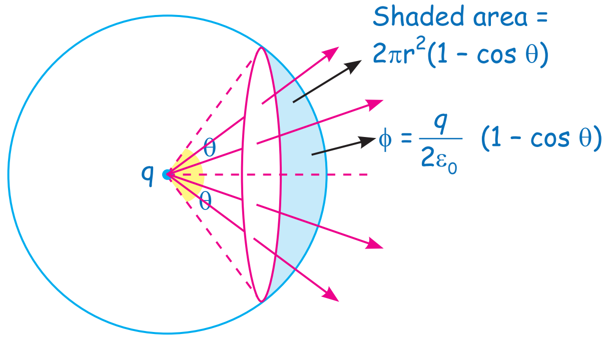
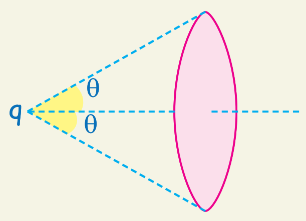


बहुत important formula ये मत भूलना

Flux through the disc ϕ

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



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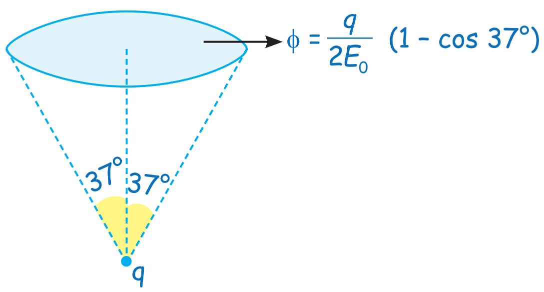

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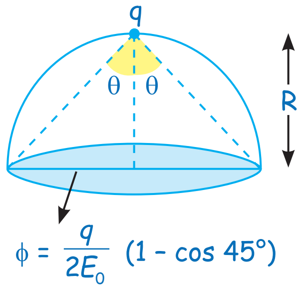
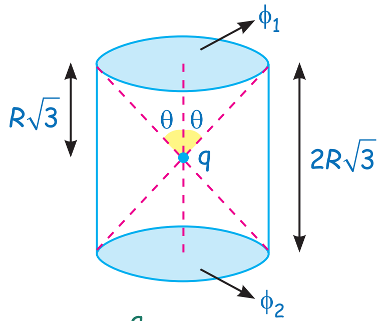


Q. Inside a cylinder a charge q is placed as shown in figure. Find flux through the circular area and curve surface area of cylinder.



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

$$\phi_1 = \frac{q}{2E_0}(1 - \cos\theta) \qquad \left[\tan\theta = \frac{R}{R\sqrt{3}} \Rightarrow \theta = 30°\right]$$

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

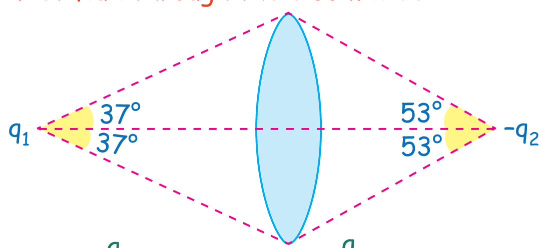
$\phi_1 \rightarrow$ flux through upper circular area
$\phi_2 \rightarrow$ flux through lower circular area

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

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

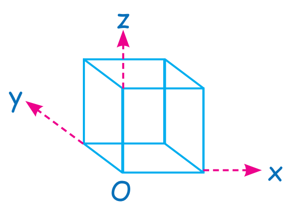
$$= \frac{q}{E_0}\frac{\sqrt{3}}{2}$$

Q. Net flux through the disc will be

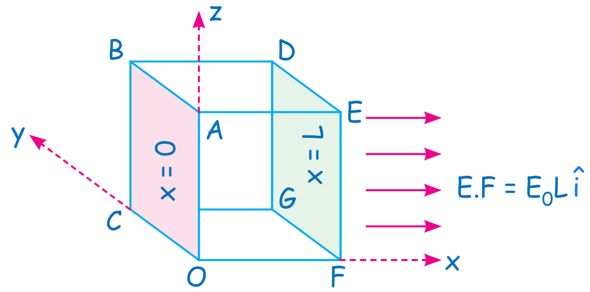


$$\phi_{net} = \frac{q_1}{2E_0}(1 - \cos 37°) + \frac{q_2}{2E_0}(1 - \cos 53°)$$

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



Sol.



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

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

Net flux through cube = $E_0 L^3 - 0$

$(\phi_{cube})_{net} = q_{in}/E_0$

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

$q_{in} = \varepsilon_o E_o L^3$

#SKC

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

$$\boxed{\oint \vec{E}.d\vec{A} = \frac{q_{in}}{E_0}}$$

→ Gaussian surface area

VERIFICATION OF GAUSS LAW

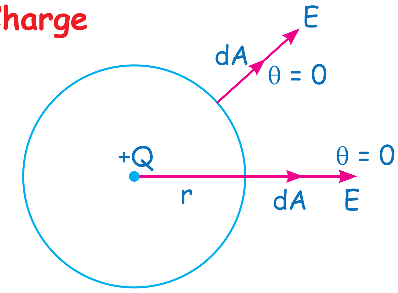
E.F Due to Pt. Charge

$$\oint \vec{E}.d\vec{A} = \frac{q_{in}}{E_0}$$

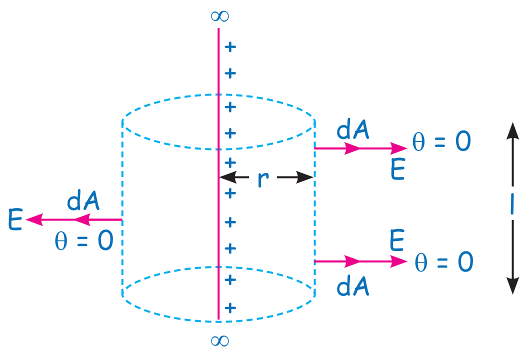
$$E\int dA = \frac{Q}{E_0}$$

$$E4\pi r^2 = \frac{Q}{E_0}$$

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



E.F DUE TO ∞ LINE-WIRE



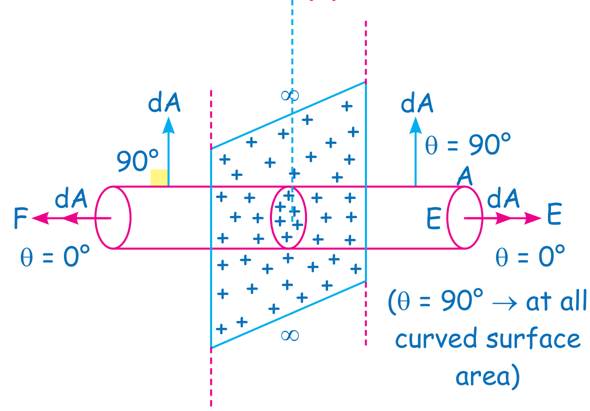
$$\oint \vec{E}.d\vec{A} = \frac{q_{in}}{\varepsilon_0}$$

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

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

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

E.F Due to ∞ Sheet (σ)



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

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

↓

Curved Surface area

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

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

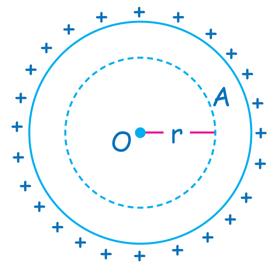
(a) E.F inside the hollow sphere

For r < R

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

$q_{in} = 0$

E = 0



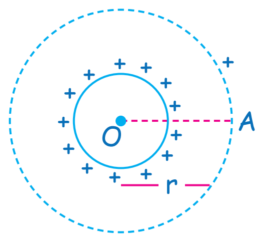
(Q, R)

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

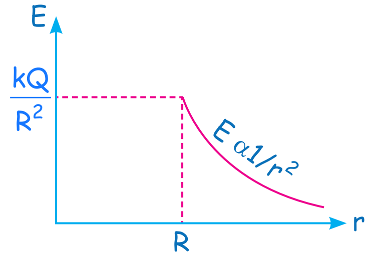
$$\oint \vec{E}.d\vec{A} = \frac{q_{in}}{\varepsilon_0}$$

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

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

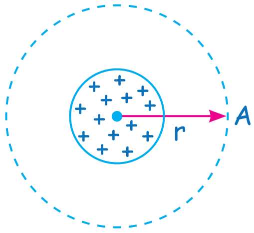


$$E = \frac{Q}{4\pi r^2 \varepsilon_0} = \frac{kQ}{r^2}$$



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

1 Outside (r > R)



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

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

$$E = \frac{Q}{4\pi r^2 \varepsilon_0} = \frac{kQ}{r^2} \qquad \rho = \frac{Q}{\frac{4}{3}\pi R^2}$$

2 Inside (r < R)

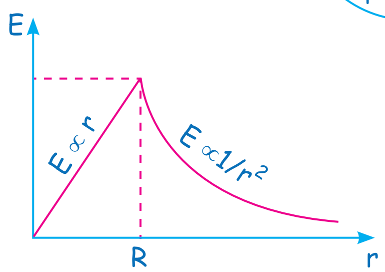
हमें यहाँ O से r radius तक के गोले के अंदर का charge चाहिए।

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

$$E.\ 4\pi r^2 = \frac{\rho\ .\ 4/3\,\pi r^3}{E_0}$$

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

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



Very Important Result

[Solid sphere uniform Q, R, ρ]

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

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

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 $\rho = \rho_0 r$ ... $(r \le R)$ find

(1) Total charge of this sphere

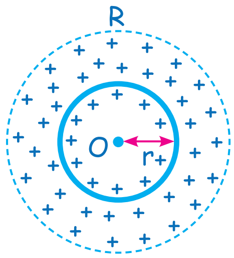
(2) Total charge of vol^n from r = 0 to r = R/2

(3) Electric field outside the sphere

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

Sol.

1 Total charge of this sphere



$dq = \rho dV$

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

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

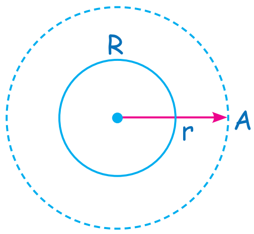
dV = $4\pi r^2 dr$ [learn it]

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

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

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

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



$$E.\oint dA = \frac{q_{in}}{E_0}$$

$$E4\pi r^2 = \frac{Q_{total}}{E_0}$$

$$E = \frac{kQ_{total}}{E_0}$$

4 For E.F at r = R/2

$E.4\pi r^2 = \frac{q_{in}}{E_0}$ Gaussian surface ke andr ka charge

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

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

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

$$E = \frac{\rho_o R^2}{4\varepsilon_o}$$

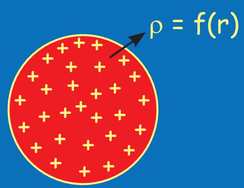
#SKC

*Very very important

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

$\rightarrow$ Inside E.F $= E.4\pi r^2$

$$= \frac{\int_0^r \rho 4\pi r^2 dr}{\varepsilon_0}$$



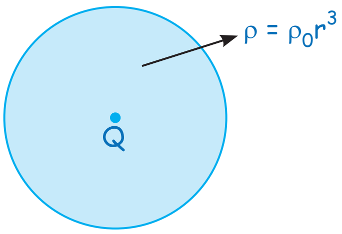
$\rightarrow$ Outside E.F. $= E.4\pi r^2$

$$= \frac{\int_0^R \rho 4\pi r^2 dr}{\varepsilon_0}$$

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

****

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



Sol. Hint:

1. Outside E.F

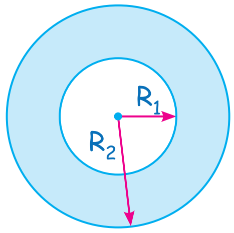
$$E = \frac{kq_{in}}{r^2}$$

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

2. Inside E.F [r < R]

$$E.4\pi r^2 = \frac{\left[\int_0^r \rho_0 r^3 . 4\pi r^2 dr\right] + Q'}{E_0}$$

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



Sol.

1. For $r > R_2$ outside

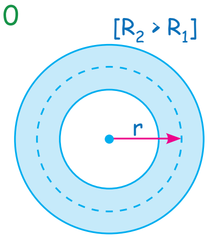
$$E.4\pi r^2 = \frac{q_{in}}{E_0} = \frac{Q}{E_0}$$

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

2. Inside $r < R_1$

$$E.4\pi r^2 = \frac{q_{in}}{E_0} = 0$$

$$E = 0$$



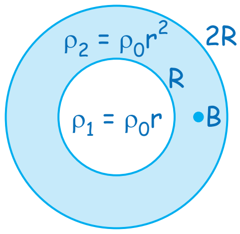
3. For $R_1 < r < R_2$

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

$$E.4\pi r^2 = \frac{\frac{Q}{4/3\pi(R_2^3 - R_1^3)} \times \frac{4}{3}\pi(r^3 - R_1)^3}{E_0}$$

E = ______ solve and get

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



$\rho_1 = \rho_0 r \qquad 0 < r \le R$

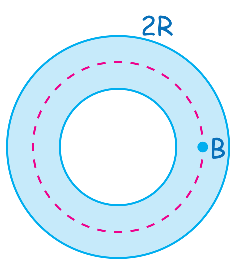
$\rho_2 = \rho_0 r^2 \qquad R < r \le 2R$

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

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

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

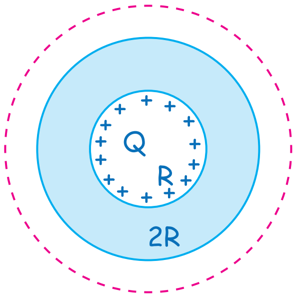
2. Find E.F at $\quad r = 1.5$ R



$$E4\pi r^2 = \frac{q_{in}}{E_0} = \int_0^{1.5R} \frac{\rho 4\pi r^2 dr}{E_0}$$

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

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



$$E4\pi r^2 = \frac{q_{in}}{E_0} = \frac{Q + \int_R^r \rho 4\pi r^2 dr}{E_0}$$

$$E4\pi r^2 = \frac{Q + \int_R^r \alpha / r\ 4\pi r^2 dr}{E_0}$$

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

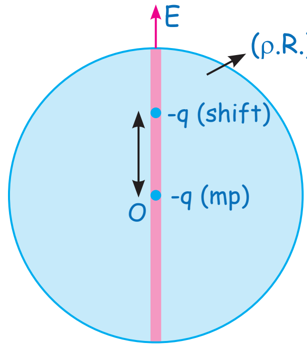
$$E = \frac{(Q - \alpha 2\pi R^2) + 2\pi r^2 \alpha}{4\pi r^2\ E_0}$$

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

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

then, E will independent of r.

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



Sol. mp → centre

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

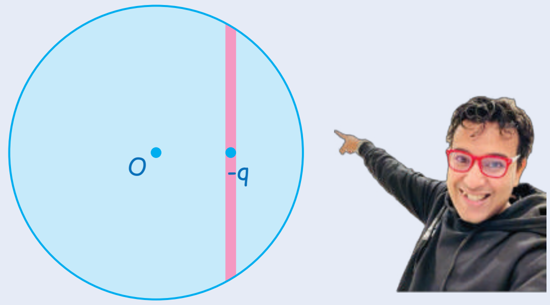
$\vec{F}_{net} = -q\dfrac{\rho \vec{x}}{3E_0} = -K\vec{x}$ (SHM)

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

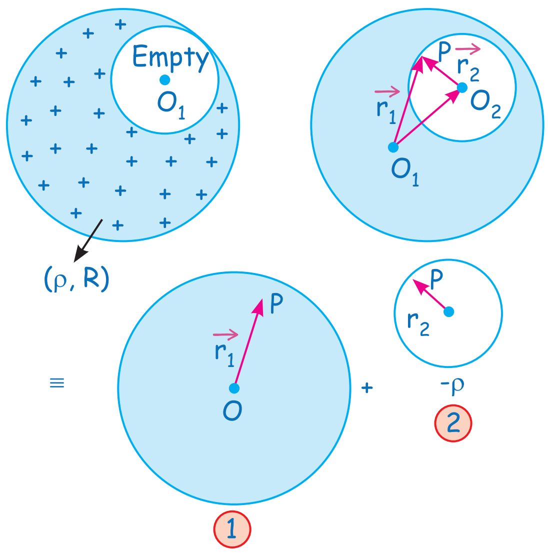
in SHM if F = – k x

then time period $T = 2\pi\sqrt{\dfrac{m}{k}} = 2\pi\sqrt{\dfrac{m}{q\rho/3E_0}}$

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

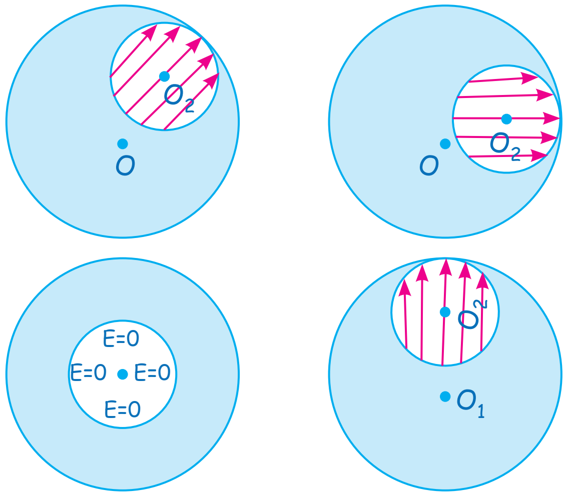


$$(\vec{E}_{at\ P}) = \vec{E}_1 + \vec{E}_2 = \frac{\rho\vec{r}_1}{3E_0} + \left(\frac{-\rho\vec{r}_2}{3E_0}\right) = \frac{\rho}{3E_0}[\vec{r}_1 - \vec{r}_2]$$

$$= \frac{\rho}{3E_0}\overrightarrow{O_1O_2}$$

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

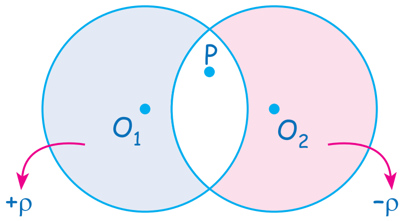
#



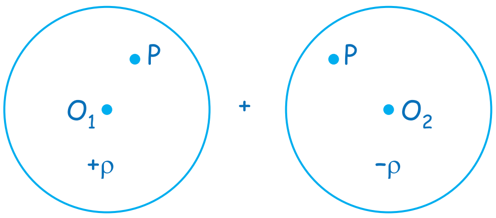
$\overrightarrow{O_1\,O_2} = 0$

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.



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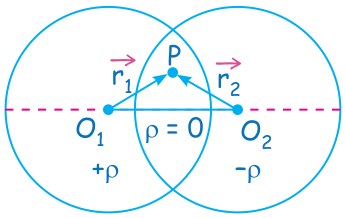
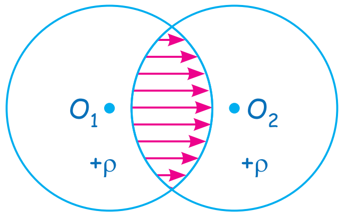


$$\vec{E}_P = \vec{E}_1 + \vec{E}_2$$

$$\vec{E}_P = \rho\frac{O_1\vec{P}}{3E_0} + \left(\frac{-\rho O_2\vec{P}}{3E_0}\right) = \frac{\rho\vec{r}_1}{3E_0} - \frac{\rho\vec{r}_2}{3E_0}$$

$$= \frac{\rho}{3E_0}[\vec{r}_1 - \vec{r}_2] = \frac{\rho}{3E_0}\overrightarrow{O_1O_2}$$

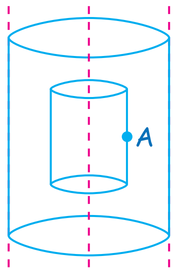
#



$\Rightarrow \frac{\rho}{3E_0}(O_1O_2)$

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

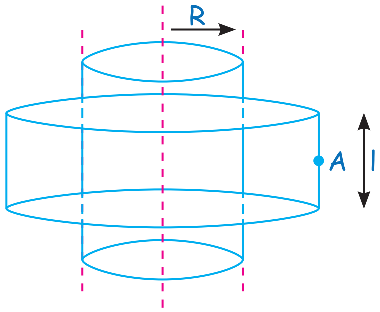
1. E.F inside r < R



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

$$E = 0$$

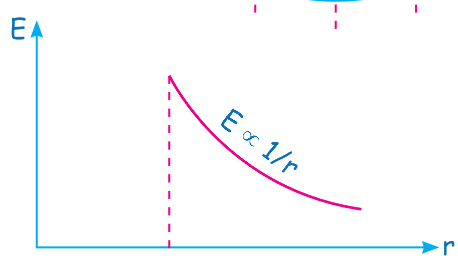
2. E.F Outside r > R



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

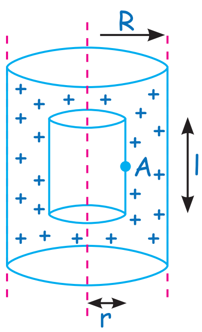
$$E.2\pi rl = \frac{\sigma 2\pi Rl}{E_0}$$

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



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

1. E.F inside r < R



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

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

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

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

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

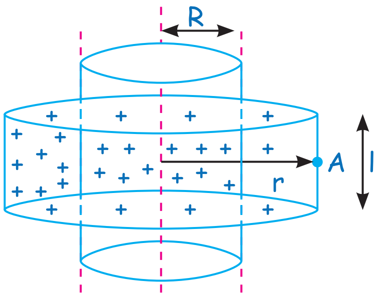
2 E.F outside $r > R$

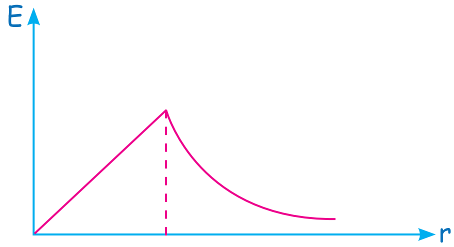
$E\int dA = \frac{q_{in}}{E_0}$

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

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

$$\boxed{E = \rho\frac{R^2}{2\varepsilon_0 r}}$$





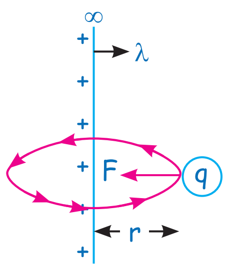
Circular motion वाले सवाल

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

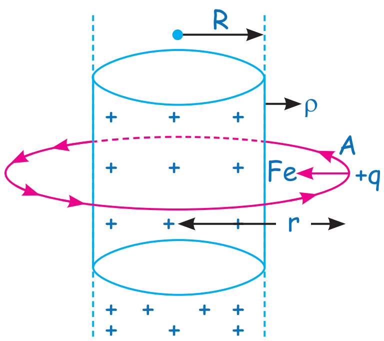
Sol. $q\frac{2k\lambda}{r} = \frac{mv^2}{r}$

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

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



Q. Repeat the above question if infinite wire is replace by solid cylinder (ρ, R)



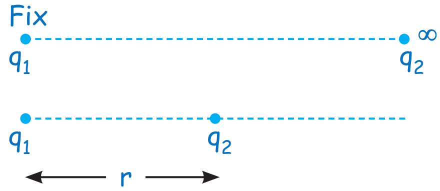
$E_A = \frac{\rho R^2}{2E_0 r}$

$q\frac{\rho R^2}{2E_0 r} = \frac{mv^2}{r}$

$v \propto r^0$

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 ∞ to separation 'r' slowly, slowly (without change in K.E without acc.)



$dU = dw$

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

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

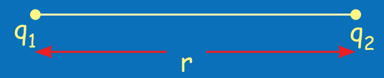
$\boxed{U - U_\infty = \frac{kq_1q_2}{r}} \Rightarrow \boxed{\text{If } U_\infty = 0 \;\Rightarrow\; U = \frac{kq_1q_2}{r}}$

Find P.E of system

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

#SKC

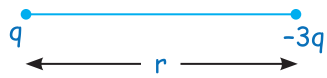
- $U = \frac{kq_1q_2}{r}$, $(U_\infty = 0)$ [$q_1q_2 \rightarrow$ with sign.]



- इसका मतलब है ये set up बनाने में मुझे इतना WD करना पड़ेगा।
- P.E is the energy due to interaction. Hence it is define for system of particles.
  - 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.

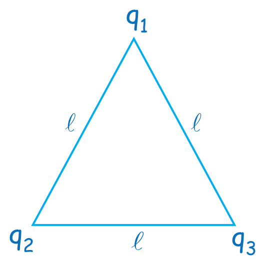
Q. Find P.E of system

1



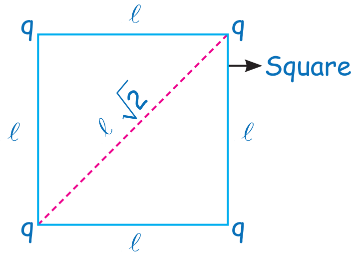
$\Rightarrow U = \frac{kq(-3q)}{r}$

2



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

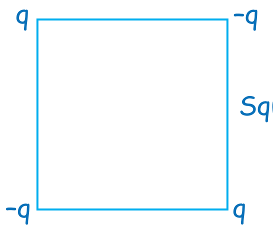
3



${}^{n}C_2 \Rightarrow$ Total no. of sets.

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

4

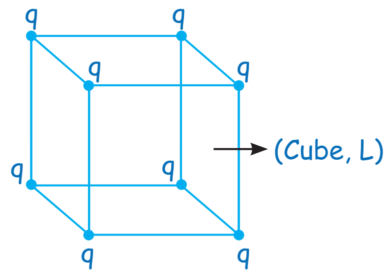


Square (L)

${}^{4}C_2 = 6$ (terms आएंगे)

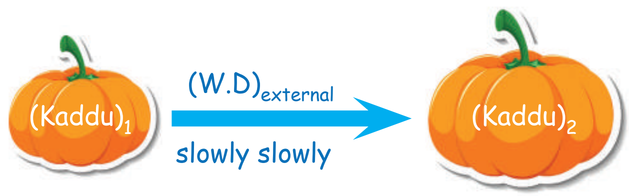
$$U = -\frac{kqq}{\ell} \times 4 + \frac{kqq}{\ell\sqrt{2}} \times 2$$

5



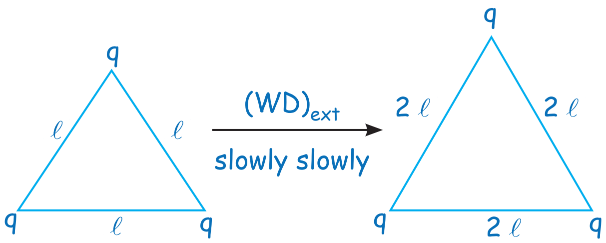
${}^{8}C_2 = 28$ terms

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



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

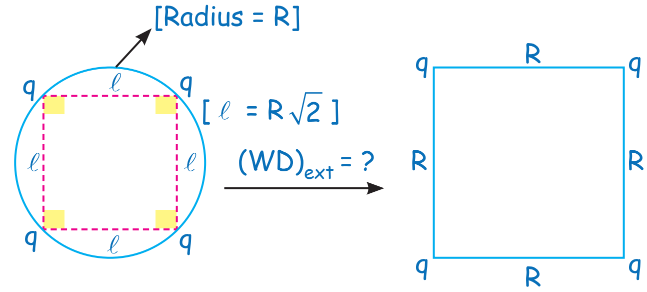
Q. Find WD ext.



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

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

#



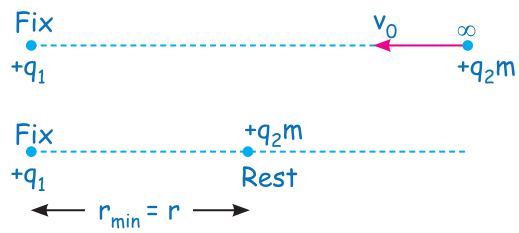
$$U_i = \frac{kq^2}{R\sqrt{2}} \times 4 + \frac{kq^2}{2R} \times 2 \qquad U_f = \frac{kq^2}{R} \times 4 + \frac{kq^2}{R\sqrt{2}} \times 2$$

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

THANOS WALE SAWAL (CONSERVATION OF MECH. ENERGY)

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

Sol.



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

M.E $\rightarrow$ conserve

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

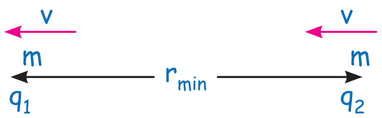
$K_i + U_i = k_f + U_f$

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

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

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

Sol.



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

$P_i = P_f$

$0 + mv_0 = mv + mv$

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

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

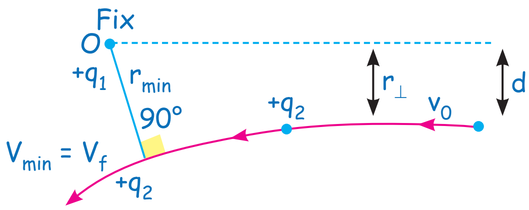
$0 + \frac{1}{2}mv_0^2 + 0 = \left(\frac{1}{2}mv^2 + \frac{1}{2}mv^2\right) + \frac{kq_1q_2}{r_{min}}$

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

Solve (i) and (ii).

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

Q. Find min. separation for the given diagram.



1. $k_i + U_i = k_f + U_f$

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

2. abt point 'O' angular momentum will conserve

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

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

Solve (1) and (2)

ELECTRIC POTENTIAL

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

2. $\boxed{(WD)_{ext.} = \Delta U = -(WD)_{E.F}}$ [without acc.]

3. Pot difference is defined as change in P.E per unit charge

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

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

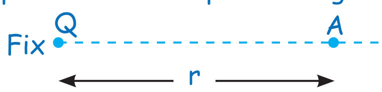
4. Electric potential $\Rightarrow$ interaction energy of unit +ve charge.

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

काम का डब्बा

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

Electric potential due to point charge Q at a pint



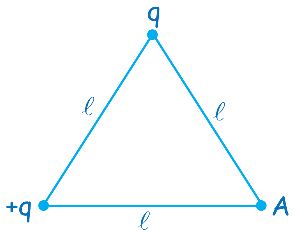
$\Rightarrow v_A = \frac{kQ}{r}$ (scaler)

with sign

Find electric potential at Pt. 'A'.

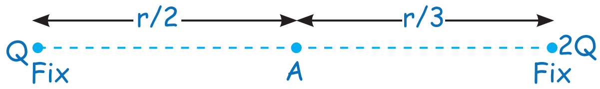
1. -Q - - - - r - - - - A $V_A = \frac{k(-Q)}{r}$

2



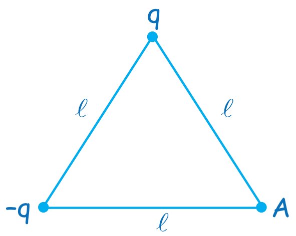
$V_A = \frac{kq}{\ell} + \frac{kq}{\ell}$

3



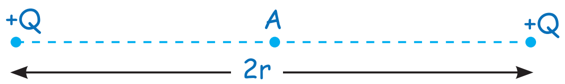
$\Rightarrow V_A = \frac{kQ}{r/2} + \frac{k2Q}{r/3}$

4



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

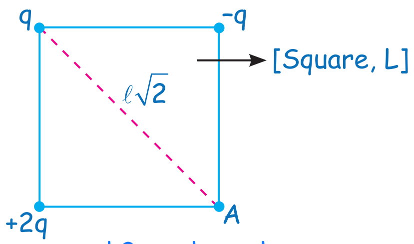
5



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

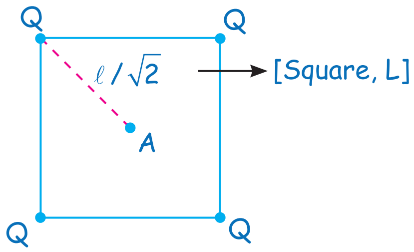
$E_A = 0.$

6



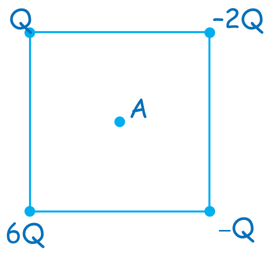
$\Rightarrow V_A = \frac{k2q}{\ell} + \frac{kq}{\ell\sqrt{2}} - \frac{kq}{\ell}$

7



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

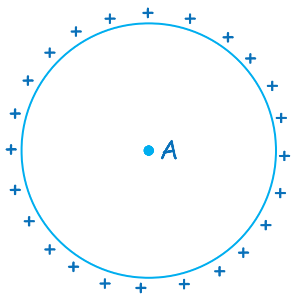
8



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

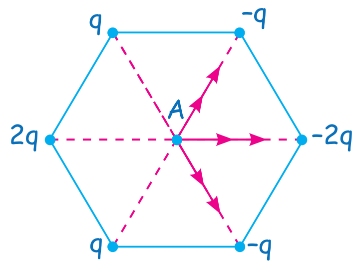
$V_A = \frac{4kQ}{\ell/\sqrt{2}}$

9 ring (Q, R)



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

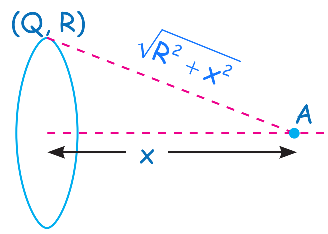
10



$\Rightarrow V_A = 0$

$\Rightarrow E \rightarrow +x$ Ans.

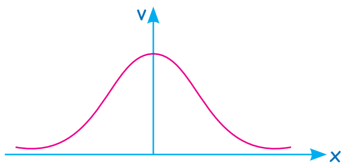
Potential at a point x from center of charged ring



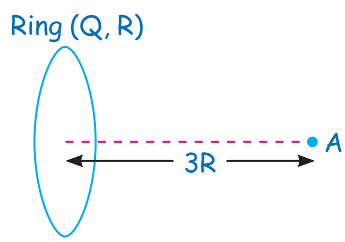
$V_A = \frac{kQ}{\sqrt{R^2 + x^2}}$

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

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

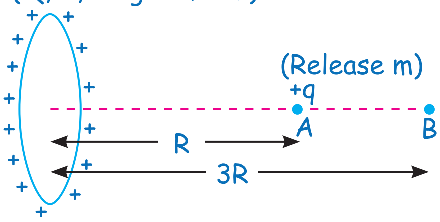


Q. Find potential at A due to charge ring (Q, R).



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

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



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

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

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

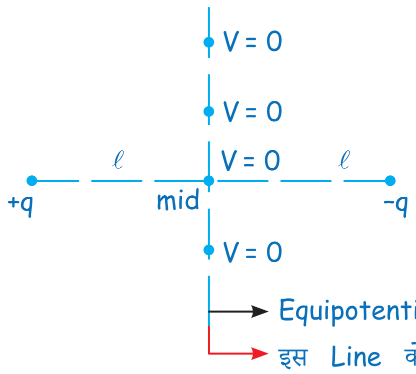
Q. Repeat the above problem when charge reaches at infinity.

Sol. $k_A + U_A = k_B + U_B$

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

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

#



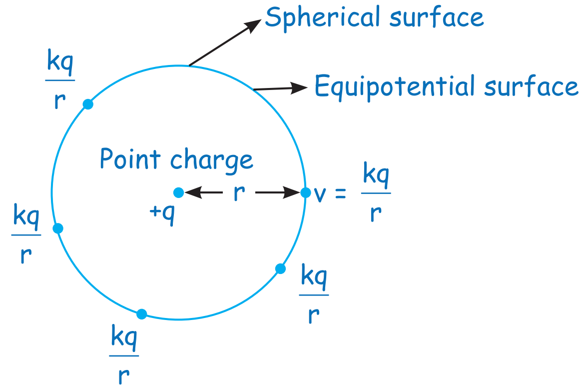
Equipotential line

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

#SKC

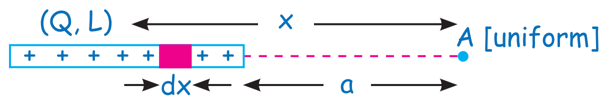
Equipotential line ka मतलब उस line Ke hr point ka potential 0 hai, aur equipotential surface ka मतलब उस surface k hr point ka potential same hoga.

#



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

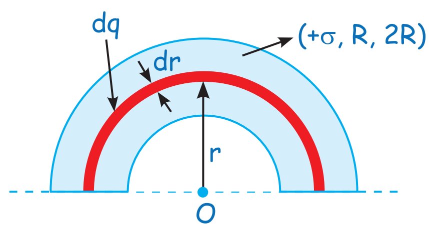
Sol.



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

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

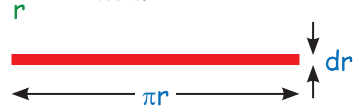
SSSQ. Find the potential at 'O' due to given part of disc.



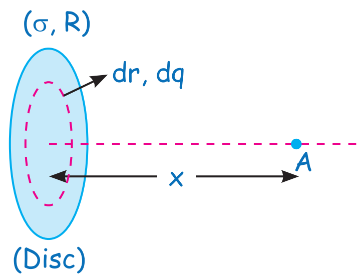
$$\int dv = \int\frac{kdq}{r} = \int_R^{2R}\frac{k\sigma\,\pi r dr}{r} = k\sigma\pi r$$

$dq = \sigma dA$

$dq = \sigma\pi r dr$



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



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

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

⋮

Solve and get and याद करलो

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

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

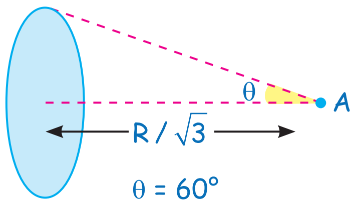
$V_{\text{near center}} = \dfrac{\sigma}{2\varepsilon_0}R$ (just bahar)

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

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

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

\# (σ, R, Disc)

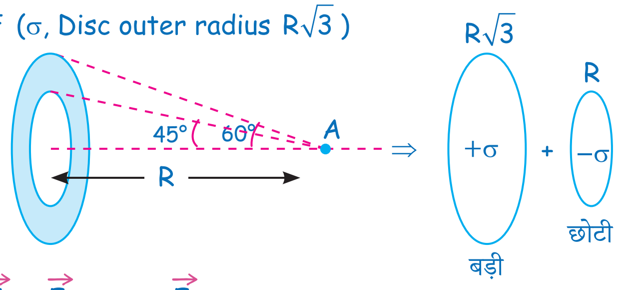


$\theta = 60°$

$E_A = \dfrac{\sigma}{2E_0}(1 - \cos 60°)$

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

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



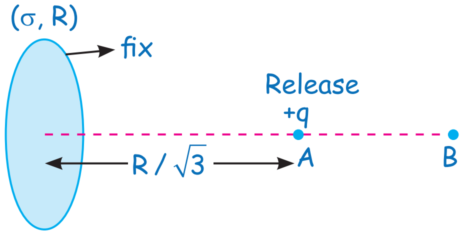
$\vec{E}_A = \vec{E}_{\text{बड़ी Disc}} + \vec{E}_{\text{छोटी Disc}(-\sigma)}$

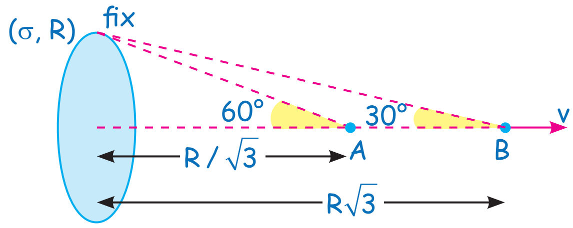
$\rightarrow E_A = \dfrac{\sigma}{2E_0}$ $(1\text{-}\cos 60°) + \dfrac{-\sigma}{2E_0}(1 - \cos 45°)$

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

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

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





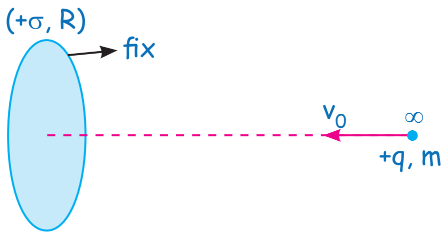
$k_A + U_A = k_B + U_B$

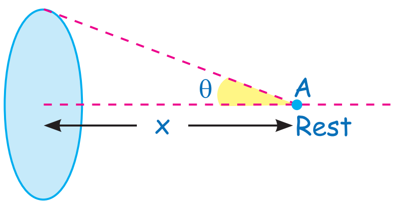
$k_A + qv_A = k_B + qv_B$

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

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

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





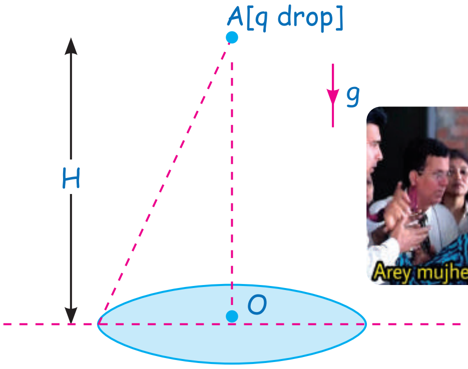
$k_i + U_i = k_f + U_f$

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

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

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

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



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

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

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

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

RELATION BETWEEN ELECTRIC POTENTIAL AND ELECTRIC FIELD

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

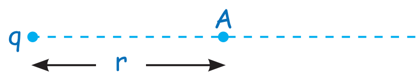
$q\Delta V = -\int q\vec{E}.d\vec{r}$

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

Potential Due to Point Charge

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

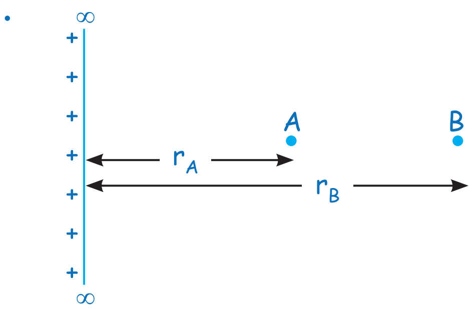
$$\int_0^v dv = -\int_\infty^r \frac{kq}{r^2}dr$$



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

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

Potential Difference Between Two Point Due to Infinite Line Charge Wire



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

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

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

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

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

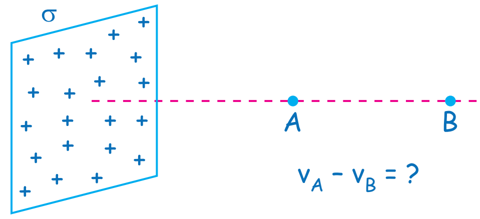
#SKC

$V_{बड़ा} - V_{छोटा}$

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

वैसे r_A and r_B shortest perpendicular distance है।

Potential Difference Between Two Point Due to ∝ Sheet



$v_A - v_B = ?$

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

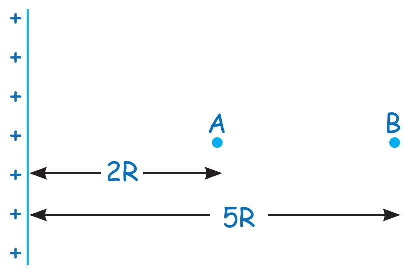
$$\int_A^B dv = -\int_{r_A}^{r_B} \frac{\sigma}{2E_0}dr$$

वैसे r_A and r_B shortest perpendicular distance है।

$$v_B - v_A = \frac{-\sigma}{2E_0}\int_{r_A}^{r_B} dr$$

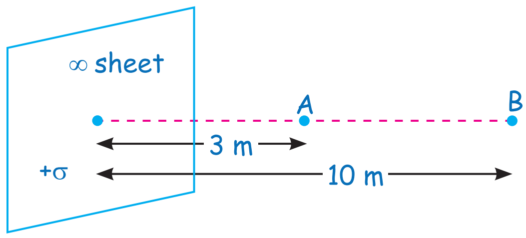
$$v_A - v_B = \frac{\sigma}{2E_0}(r_B - r_A)$$

Q. Find potential difference between A and B.



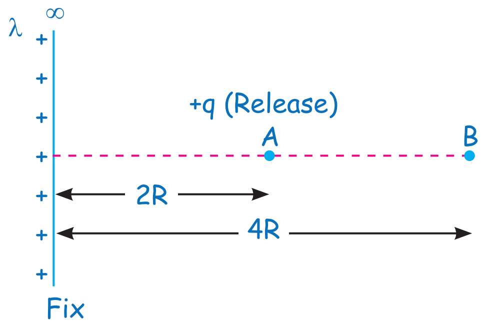
$$v_A - v_B = 2k\lambda\ \ell n\left(\frac{5R}{2R}\right)$$

Q.



$$v_A - v_B = \frac{\sigma}{2E_0} \times (10 - 3)$$

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



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

$$k_A + U_A = k_B + U_B$$

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

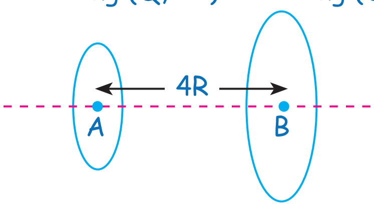
$$q(v_A - v_B) = \frac{1}{2}mv_B^2$$

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

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

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

Ring (Q, 2R) Ring (Q, 3R)



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

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

Now find $V_A - V_B$

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

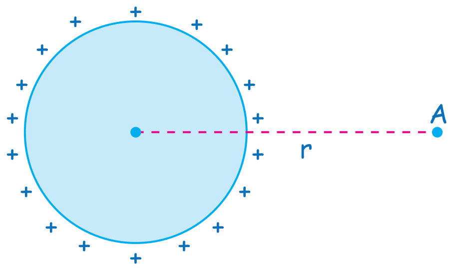
$$= -\int \frac{q\vec{E} \cdot d\vec{r}}{q} = -\int \vec{E} \cdot d\vec{r}$$

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

If $E = 0 \Rightarrow \Delta V = 0 \Rightarrow V \rightarrow$ const.

ELECTRIC POTENTIAL DUE TO HOLLOW SPHERE/SHELL/SPHERICAL CONDUCTOR

1. r > R [outside]



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

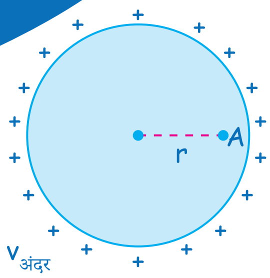
$$\int_0^v dv = -\int_\infty^r \frac{kQ}{r^2} dr$$

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

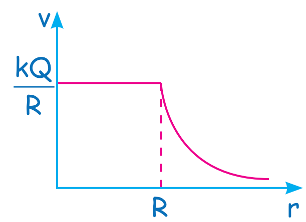
$\Rightarrow \boxed{v = \frac{kQ}{r} \Rightarrow V_{outside}}$ $\Rightarrow \boxed{V_{surface} = \frac{kQ}{R}}$

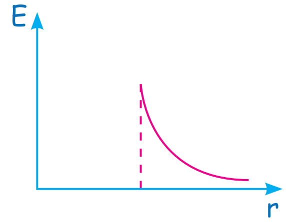
- $v = \frac{kQ}{R}$ [अंदर]
  R ⟶ Radius
- $v = \frac{kQ}{r}$ [बाहर]
  r ⟶ Distance

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

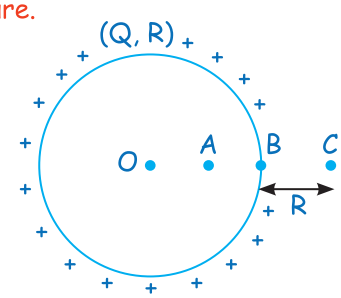


$$v = \frac{kQ}{R} = V_{surface} = V_{centre} = V_{\text{अंदर}}$$





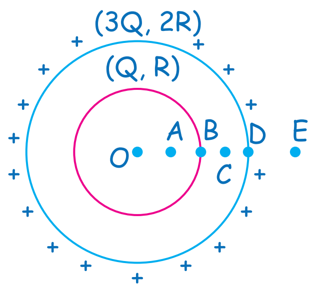
Q. Find potential at O, A, B, C due to shell as shown in figure.



$$V_O = \frac{kQ}{R},\ V_A = \frac{kQ}{R},\ V_B = \frac{kQ}{R},\ V_C = \frac{kQ}{2R}$$

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

Sol.



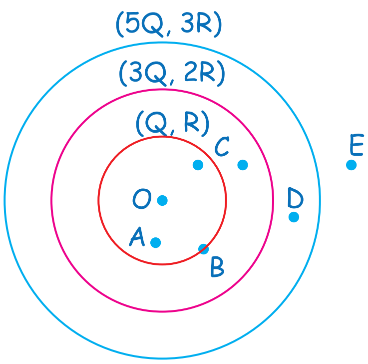
$$V_O = \frac{kQ}{R} + \frac{k3Q}{2R} = V_A = V_B$$

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

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

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

Q. Find potential at given point.



$$V_O = \frac{kQ}{R} + \frac{k3Q}{2R} + \frac{k5Q}{2R} = V_A = V_B$$

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

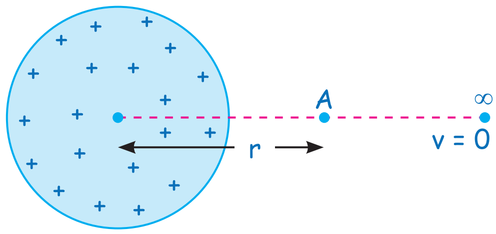
$$V_D = \frac{kQ}{OD} + \frac{k3Q}{OD} + \frac{k5Q}{3R}$$

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

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

Electric Potential Due to Solid Sphere

1. Outside [R > r]

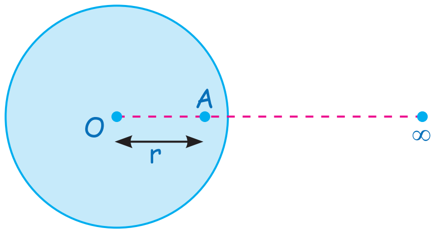


$$\int_0^{v} dv = -\int_{\infty}^{r} \vec{E}\cdot d\vec{r}$$

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

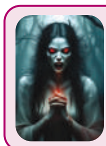
$$v = \frac{kQ}{r}$$

2. Inside [r < R]



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

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

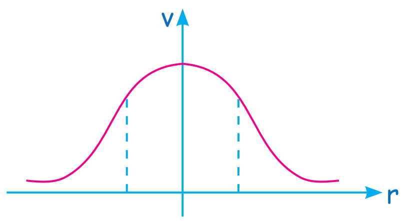


$$v_A = v_{inside} = \frac{kQ}{2R^3}(3R^2 - r^2)$$

चुड़ैल वाला formula

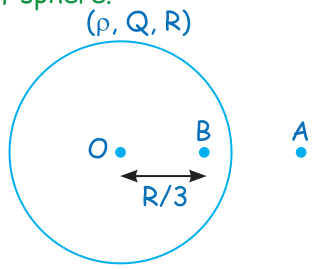
3. $v_{surface} = \dfrac{kQ}{R}$

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



Q. We have a solid charge sphere uniform density ρ total charge Q and radius R.

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



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

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

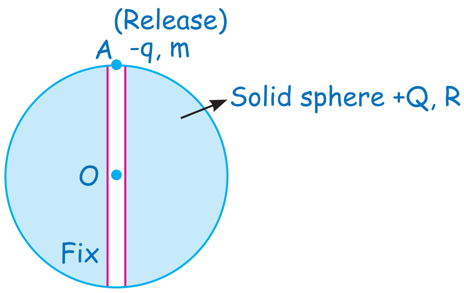
$E_0 = 0, V_0 = \frac{3}{2}\frac{kQ}{R}$

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

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

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

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



Sol. $k_A + U_A = k_0 + U_0$

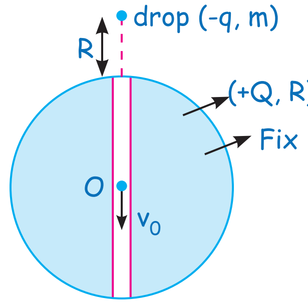
$0 + (-qV_A) = \frac{1}{2}mv_0^2 + (-q\ V_{centre})$

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

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

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

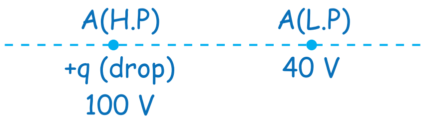
Q. Find speed of charge -q where reaches at centre



$k_i + U_i = k_f + U_f$

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

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



$k_i + U_i = k_f + U_f$

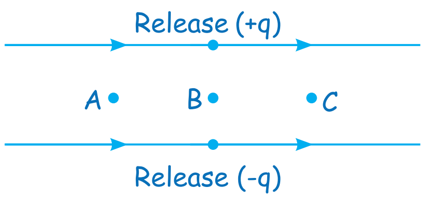
$0 + qv_A = \frac{1}{2}mv_B^2 + q \times 40$

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

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

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

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



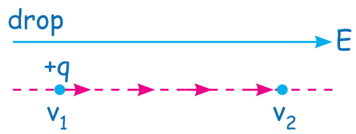
$\Rightarrow V_A > V_B > V_C$ (potential)

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

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

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

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



$$k_i + U_i = k_f + U_f$$
$$0 + qU_1 = k_f + qU_2$$
$$q(v_1 - v_2) = kf$$
$$q\Delta v = k_f$$

EQUIPOTENTIAL SURFACE

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

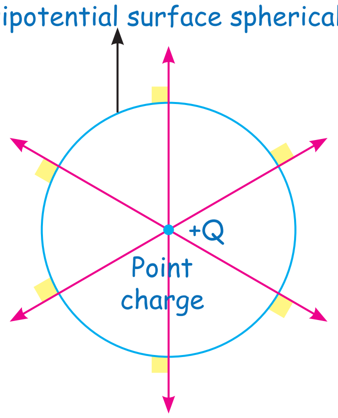
   $dv = -\vec{E} \cdot d\vec{r} = -Edr\cos\theta$

   $v \rightarrow$ same

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

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

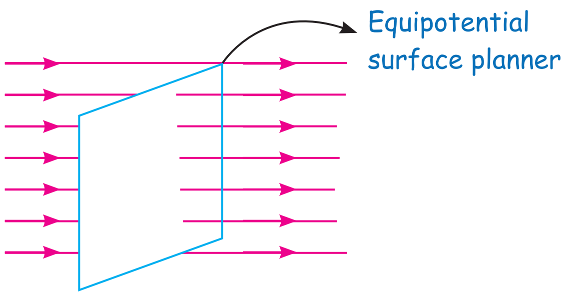
Equipotential surface spherical

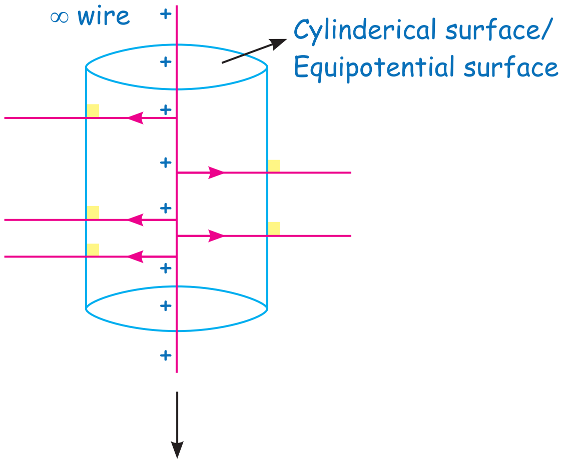


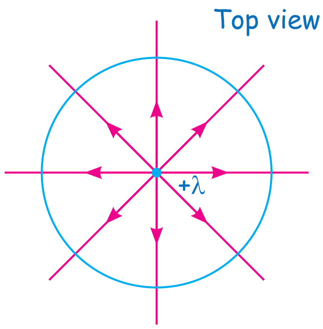
2. If a charge is moved from one point to the over an equipotential surface

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

3. Equipotential surfaces can never cross each other.

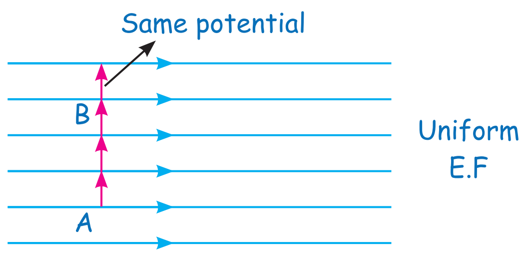






4. E.F.L ki trf chaloge to H.P to low potential jaoge

5. E.FL ke $\perp^{ar}$ jaoge to no charge in potential

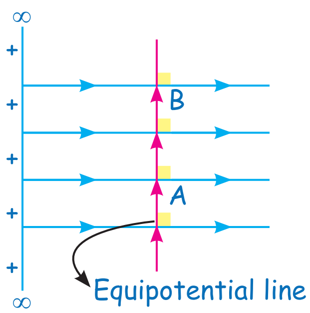


$dv = \vec{E} \cdot d\vec{r}$

$dv = -Edr\cos\theta$

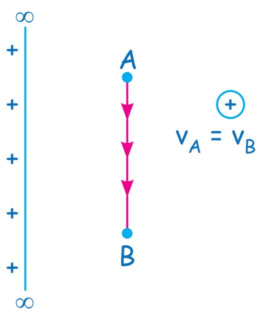
$\theta = 90° \Rightarrow dv = 0$

$v \rightarrow$ const.

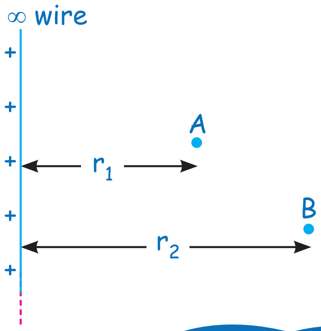


$\Delta v = 0$

$V_A - V_B = 0$



(Same for ∞-sheet)

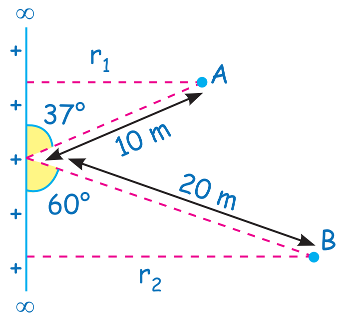


$v_A - v_B = 2k\lambda \; \ell n \dfrac{r_B}{r_A}$

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

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

Q. Find potential different A and B.

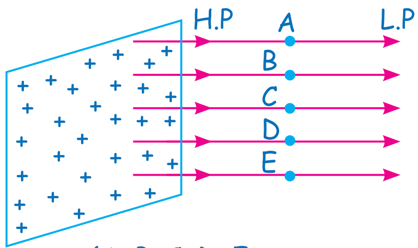


$v_A - v_B = 2k\lambda \; \ell n \left(\dfrac{r_2}{r_1}\right)$

$r_1 = 10 \sin 37°$

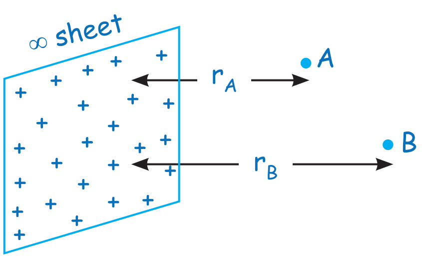
$r_2 = 20 \sin 60°$

#



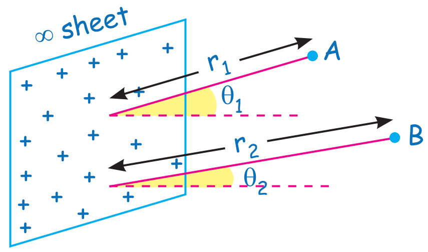
(A, B, C, D, E $\rightarrow$ same potential)

☆



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

perpendicular distance



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

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

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

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

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

$v = 10 - 90 = -80$

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)

$$\int_{20}^{v} dv = -\left[\int_1^2 2xdx + \int_2^3 10ydy + \int_3^4 4zdz\right]$$

$v = -7$ solve and get

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

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

$v = -14$ solve and get

or

$E \rightarrow$ uniform

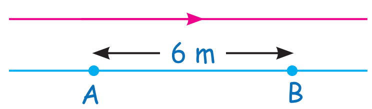
$\int dv = -\vec{E}\cdot d\vec{r}$ $\qquad \Delta\vec{r} = 2\hat{i} + 2\hat{j} + 2\hat{k}$

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

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

$v_f = -14$

☆



E = 100 volt / m

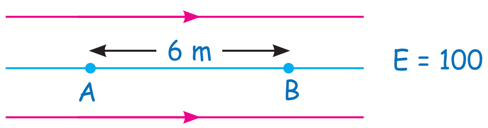
#SKC
अगर uniform E.F है और E.F की दिशा मे हम d चले तो pot. में Ed का drop aa jayega $\Rightarrow$ pot. Ed कम हो जायेगा

H.P $\rightarrow$ A

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

$V_B - V_A = -600$

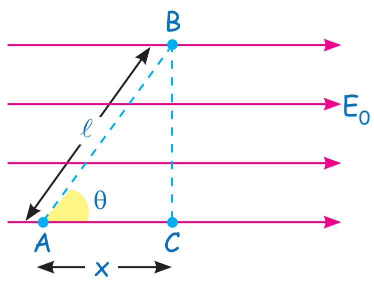
$V_A - V_B = 600$



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

$V_A - V_B = 600$

Q. Find $V_A - V_B$



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

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

$\Delta v = -\vec{E}.\vec{d} = -E_0\ \ell\cos\theta + 0$

$v_B - v_A = -E_0x.$

Pot. at B = pot at C

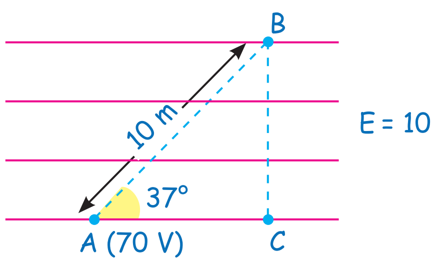
$v_A - v_C = Ex$

$v_A - v_B = Ex$

$v_C - v_A = -E_0x$

$\therefore\ v_B - v_A = -E_0x$

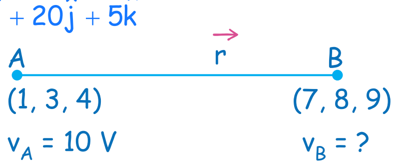
#



$\Rightarrow\ V_B = V_C$

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

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



$\Delta v = -\vec{E}\,.\,\vec{d}$ $\qquad$ $\vec{d} = 6\hat{i} + 5\hat{j} + 5\hat{k}$

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

$v_B = -175$

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

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

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

Q. If $v = 4x^2y^3z$ (let) find E.F at and E.F at (1, 1, 1)

$\vec{E}_x = -\dfrac{\partial v}{\partial x}\hat{i} = -[4\times 2xy^3z]\hat{i}$

$\vec{E}_x = 8xy^3z\hat{i}$

$\vec{E}_y = -\dfrac{\partial v}{\partial y}\hat{j} = -[4x^2z\,3y^2] = -[12x^2y^2z]\hat{j}$

$\vec{E}_k = -4x^2y^3\hat{k}$

$\vec{E} = -8xy^2z\hat{i} - 12x^2y^2z\hat{j} - 4x^2y^3\hat{k}$

at (1, 1, 1) = $-8\hat{i} - 12\hat{j} - 4\hat{k}$

#SKC#

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

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

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

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

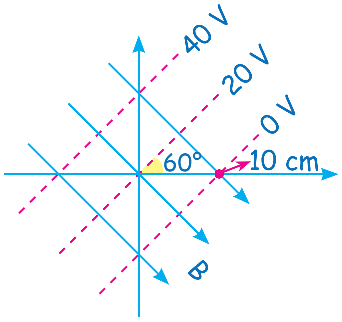
Q. If $v = x^2yz$ find E.F at (1, 2, 3)

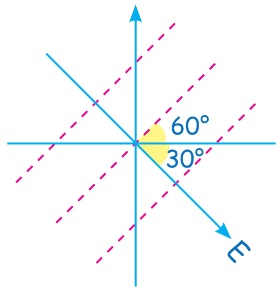
$\vec{E} = -\left[\dfrac{\partial v}{\partial x}\hat{i} + \dfrac{\partial v}{\partial y}\hat{j} + \dfrac{\partial v}{\partial z}\hat{k}\right] = -\left[2xyz\hat{i} + x^2z\hat{j} + x^2y\hat{k}\right]$

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

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

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





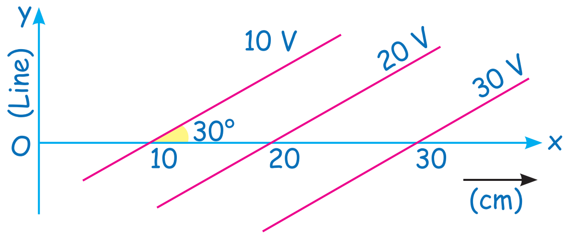
$20 = Ed$

$20 = \frac{E\,10\sin 60^\circ}{100}$

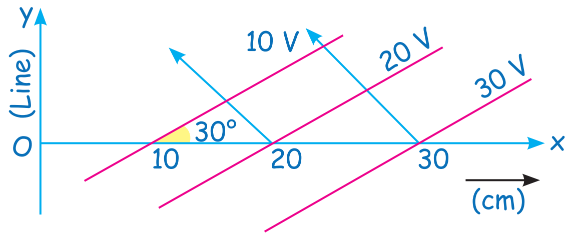
$E = \frac{400}{\sqrt{3}}$

$\vec{E} = E(\cos 30\hat{i} - E\sin 30\hat{j})$

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



Sol.



$d = 10\sin 30\text{ cm} = 5\text{ cm}$

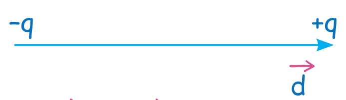
$10 = Ed$

$10 = E \times \frac{5}{100}$

$E = 200\text{ v/m}$

DIPOLE

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



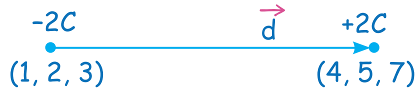
Dirx^n moment = $\vec{Q} = q\vec{d}$

$\vec{d}$ → Direx^n is -ve

q → +ve charge

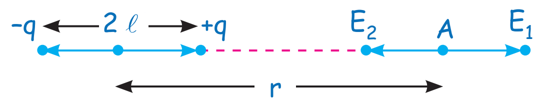
magnitude = qd

#



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

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



$E_A = E_1 - E_2$

[$P = q2\ell$ magnitude]

$E_A = E_1 - E_2 = \frac{kq}{(r-\ell)^2} - \frac{kq}{(r+\ell)^2}$

$= kq\left[\frac{(r+\ell)^2 - (r-\ell)^2}{(r-\ell)^2(r+\ell)^2}\right]$

$= \frac{kq.\,2r\,2\ell}{(r^2-\ell^2)^2} = \frac{2kq\,2\ell r}{(r^2-\ell^2)^2}$

If $\ell <<< r$

$E_A = \frac{2kq\,2\ell r}{r^4} = \frac{2k\,(q2\ell)}{r} = \frac{2kP}{r^3}$

$\vec{E}_{axis} = \frac{2k\vec{P}}{r^3}$

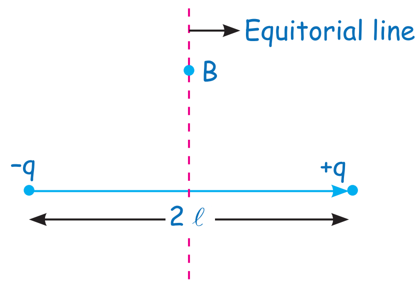
Potential at A

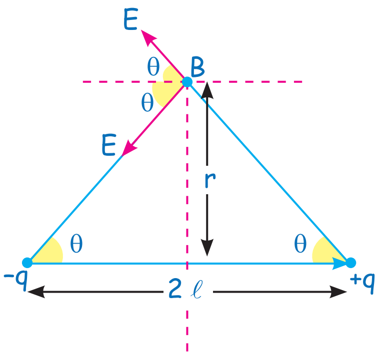
$v_A = \frac{kq}{(r-\ell)} + \frac{k(-q)}{(r+\ell)} = kq\frac{(r+\ell)-(r-\ell)}{(r^2-\ell^2)}$

$v_A = \frac{kq2\ell}{r^2-\ell^2}$ [$\ell <<< r$]

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

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



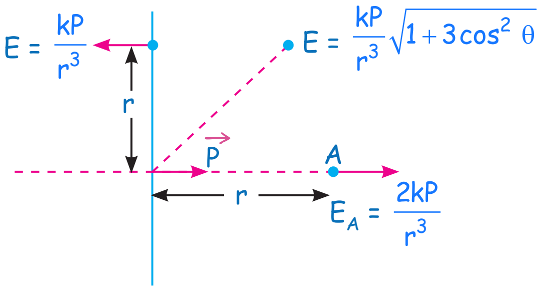


$E_{at\ B} = 2E\cos\theta$ (पीछे)

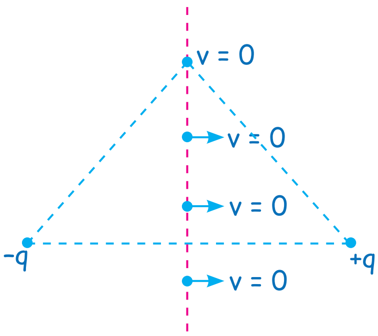
$$= \frac{2kq}{(\sqrt{r^2+\ell^2})^2}\,\frac{l}{\sqrt{r^2+\ell^2}} = \frac{kq2\ell}{(r^2+\ell^2)^{3/2}}$$

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

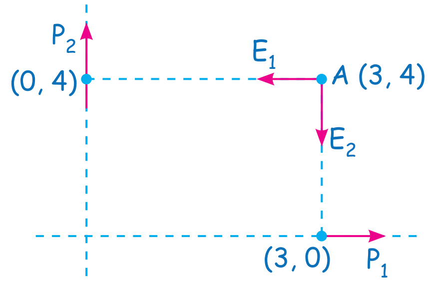
$$\vec{E}_{equit} = -\frac{k\vec{P}}{r^3}$$



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



Q. Two short dipole P_1 and P_2 at (3, 0) and (0, 4) respectively are placed along + x-axis and + y-axis as shown in figure find net electric field at (3, 4).

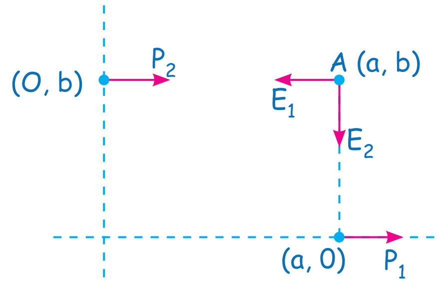


E.F at A due to $P_1 = \frac{kP_1}{4^3}(-\hat{i})$

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

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

Q. Find E.F at A.



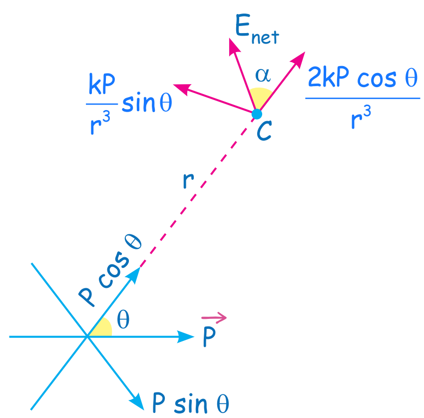
Pot at A = $0 + \frac{kP_2}{a^2}$

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

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

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

E.F at a general point due to short Dipole



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

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

$$= \frac{kP}{r^3}\sqrt{4\cos^2\theta + \sin^2\theta}$$

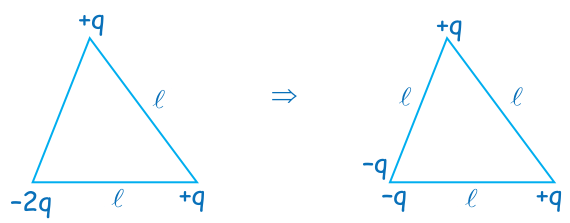
$E = \dfrac{kP}{r^3}\sqrt{1+3\cos^2\theta}$ $\Rightarrow$ E.F kabhi zero nhi hogi

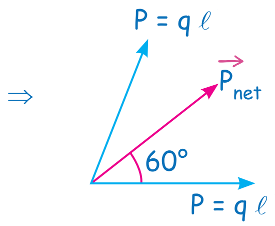
$E_{max} \Rightarrow \theta = 0° \Rightarrow E = \dfrac{2kP}{r^3}$ (Axis)

$E_{max} \Rightarrow \theta = 90° \Rightarrow E = \dfrac{kP}{r^3}$ (Equitorial)

Find dipole moment of following cases

1





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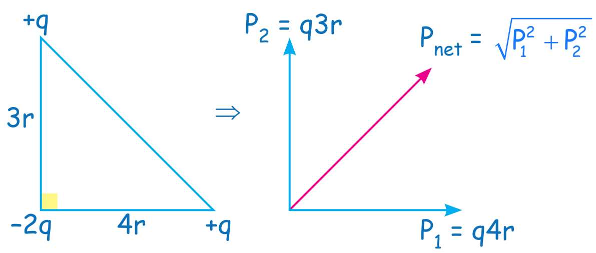

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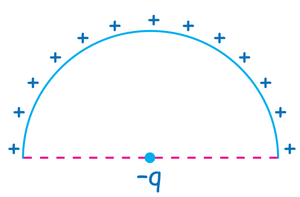
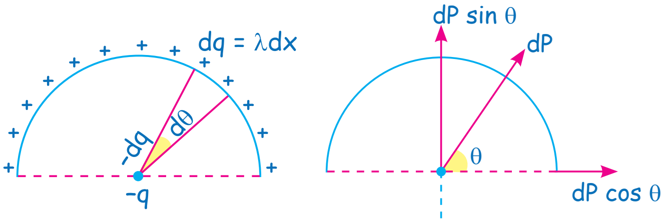


Sol.

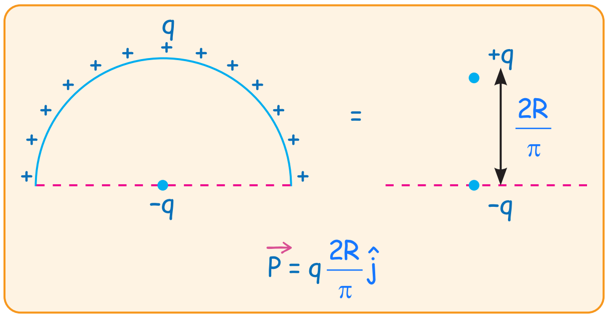


$P_{net} = \int dP\sin\theta = \int dq\cdot R\cdot\sin\theta$

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

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

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



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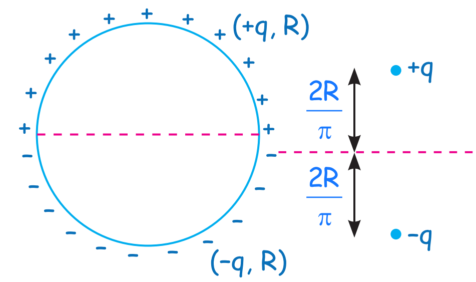
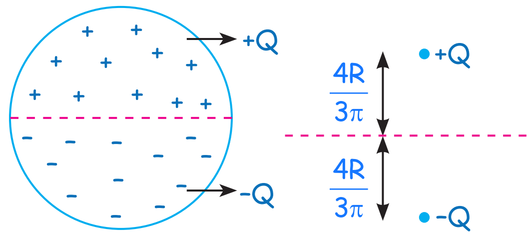


$\vec{P} = q\dfrac{4R}{\pi}\hat{j}$

5



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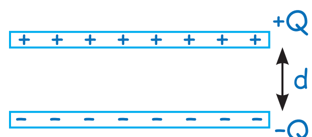
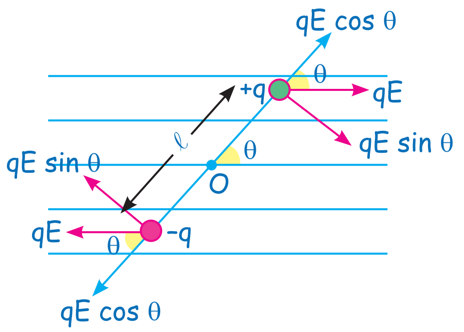


P = Qd

DIPOLE IN UNIFORM E.F

$\boxed{\vec{\tau} = \vec{P} \times \vec{E}}$ $\boxed{U = -\vec{P}\cdot\vec{E}}$ $\boxed{F_{net} = 0}$

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



$F_{net} = 0$

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

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

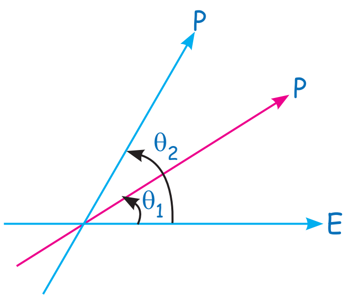
$\boxed{\begin{array}{c}\tau = PE\sin\theta \\ \vec{\tau} = \vec{P}\times\vec{E}\end{array}}$

#SKC
Uniform electric field चाहती है की, $\vec{P}$ electric field के parallel rhe

If $\theta = 0, \tau = 0$ $\quad\quad$ $\theta = 180°, \tau = 0$

Potential Energy of Dipole in Uniform E.F

$(WD)_{ext.}$ to rotate dipole from θ_1 to θ_2 [slowly - slowly]



$dW = \int \tau d\theta$

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

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

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

$= U_f - U_i$

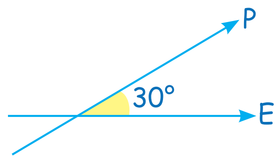
$U_f = -PE\cos\theta_2$

$U_i = -PE\cos\theta_1$

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

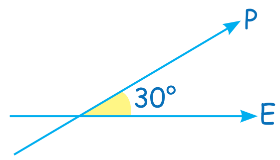
$\boxed{U_f = -\vec{P}\cdot\vec{E}}$

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

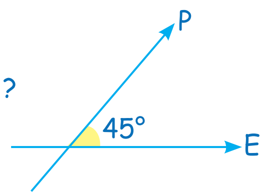


Sol.

1. $\tau = PE\sin\theta = PE\sin 30° = \frac{PE}{2}$
2. $P.E = -\vec{P}\cdot\vec{E} = -PE\cos\theta = -PE\cos 30°$
3. Find $(WD)_{ext.}$ agent to rotate dipole so that angle b/w dipole and E.F become 45°



WD = ?



$U_i = -PE\cos 30°$ $\quad\quad$ $U_f = -PE\cos 45°$

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

VV Imp हर साल JEE Mains मे यह आता है।

$(WD)_{by\ ext.}$ agent to rotate a dipole from θ_1 to θ_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, τ, U

F = 0

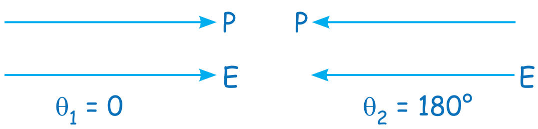
$\tau = 0\ [\tau = PE\sin 0 = 0]$

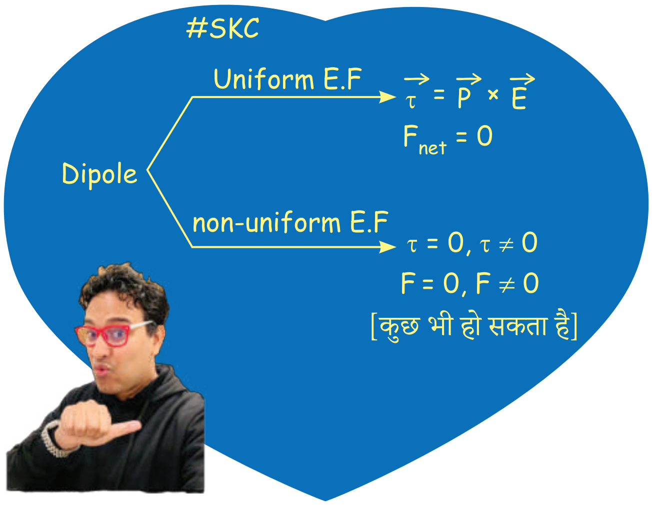
$U_i = -PE\cos 0° = -PE$

(b) (WD)ext. required to rotate st dipole become $\perp^{ar}$ to E.F = – PE (cos 90° – cos 0°) = + PE

(c) $(WD)_{ext.}$ require to totate st dipole become antiparallel to E.F [from $\theta_1 = 0$]

= – PE [cos 180° – cos 0°] = 2PE





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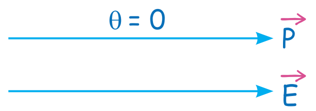


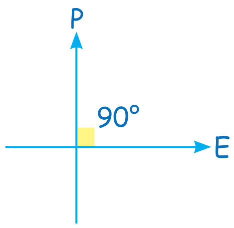
$\vec{\tau} = 0$

U = – PE

U → min

Eqb^m stable

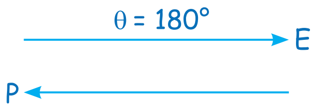
☆



τ = PE

U = 0

☆



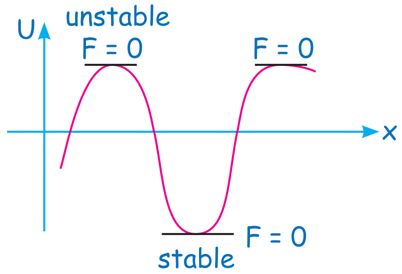
τ = 0

P.E = + PE

U → max

unstable equilibrium

☆ 11^{th} class



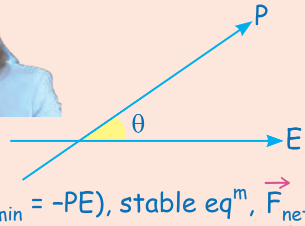
काम का डब्बा

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

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

τ = PE sin θ

U = – PE cos θ

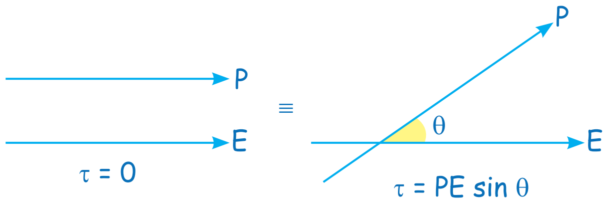


- θ = 0°, τ = 0, U_{min}, (U_{min} = –PE), stable eq^m, $\vec{F}_{net} = 0$
- θ = 180°, τ = 0, U_{max}, (U_{max} = +PE), unstable eq^m, $\vec{F}_{net} = 0$
- θ = 90°, τ_{max} U = 0 No equillibrium

Initially a dipole is in eqb^m st it is parallel to E.F E (uniform). Time period of oscillation if it rotated by small angle θ is:

Sol. If θ is very small

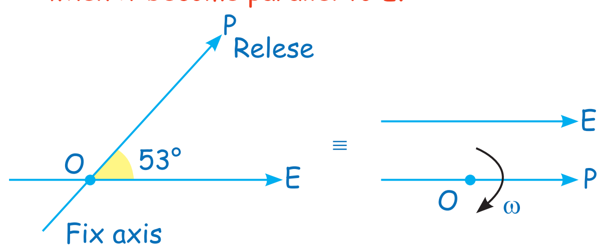
$\vec{\tau} = -PE \cdot \vec{\theta}$



τ = PE sin θ = PE θ (Approx because θ is very small) Hence

$\boxed{T = 2\pi\sqrt{\frac{I}{PE}}}$ I = moment of inertia

Q. Initially dipole makes angle 53° with E.f as shown is diagram and release. Find K.E of dipole when it become parallel to E.



$K_i + U_i = K_f + U_f$

$0 - PE\cos 53° = K_f - PE\cos 0°$

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

Q. If a Dipole $\vec{P} = 2\hat{i} + 3\hat{j}$ is placed at (1, 2) and electric field in non uniform $\vec{E} = 3x\hat{i} + 4y\hat{j}$. Find force on the dipole

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

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

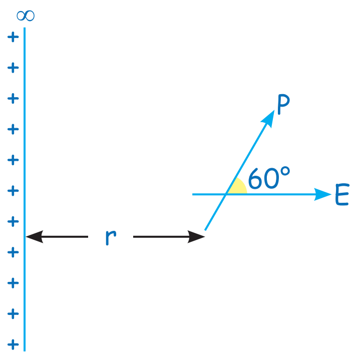
$$f_y = -\frac{\partial U}{\partial y} = -\left[0 + 12\right] = -12$$

Q. If a short dipole $\vec{p} = \rho_0\hat{r}$ is placed in non-uniform E.f. $\vec{E} = E_0 r^2\ (\hat{r})$ find force on dipole

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

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

Q. Force by ∞-wire on short dipole



Sol. $U = -\vec{P}\cdot\vec{E} = -P\cdot\vec{E}\cos 60^\circ$

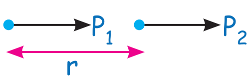
$$U = -\frac{P2k\lambda}{r}\text{Cos}60^\circ$$

$$F = -\frac{du}{dr} = -\frac{P2k\lambda\cos 60}{r^2}$$

$$\vec{F} = -\frac{P2K\lambda\cos 60}{r^2}\hat{r}$$

अबे infinite wire की जगह अगर ring दे दूँ तो उसकी EF का formula तूम्हें याद है ही तो dipole पर force निकाल लोगे ना।

Q. Force b/w them [short dipole]



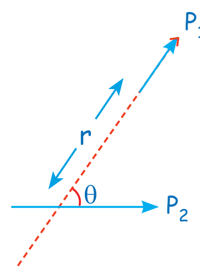
Sol. $U = -\vec{P}_2.\,(Ef)_{\text{due}}$ to P, on P_2

$$= -\vec{P}_2\cdot\frac{2K\vec{P}_1}{r^3}$$

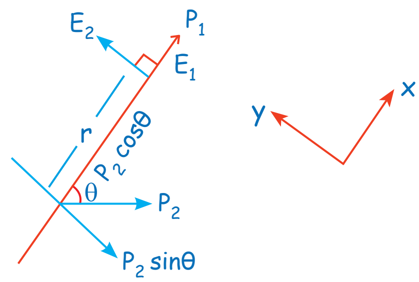
$$U = -\frac{2kP_1P_2}{r^3}$$

$$f = -\frac{dU}{dr} = -\frac{6KP_1P_2}{r^4}$$

Q. Two short dipole are placed as shown. The energy of electric field interaction b/w these dipoles will be:-



Sol.



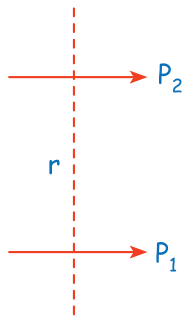
$$U = -\vec{P}_1\vec{E}$$

$$U = -\vec{P}_1\hat{i}\,(E_1\hat{i} + E_2\hat{j})$$

$$U = -P_1E_1$$

$$U = -P_1\frac{2KP_2\cos\theta}{r^3}$$

Q. Find force of interaction b/w P_1 & P_2 or find force P_1 on P_2 [short dipole



$$U = -\vec{P}_2\cdot\vec{E} = -P_2E\ \text{Cos}180^\circ$$

$$U = -P_2 \frac{KP_1}{r^3} \times (-1)$$

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

$$f = -\frac{dU}{dr} = -KP_1P_2 \frac{(-3)}{r^4}$$

$$f = \frac{3KP_1P_2}{r^4}$$

- Conductor → Free e^- bahut saare.
- Semi-Conductor → Bahut Kam free e^- [12th last]
- Insulator → No free e^-

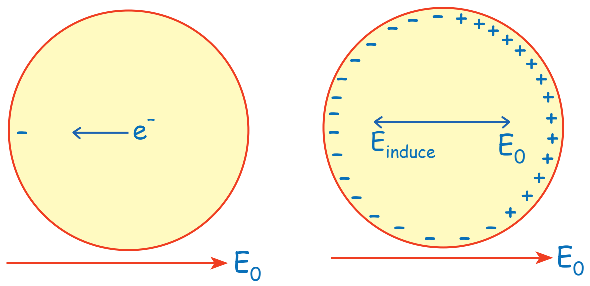
CONDUCTOR

→ They have free e^-. Which are free to move inside conductor.

→ Inside the conductor, E.F = 0 [jha jha maal bhra hua h] [In Electrostatic]

→ Metals are good conductor

→ Agar m kisi conductor ko E.F mein rakh du to, conductor Ke ander free e– ke motion ki vajah se charge seprate ho jayenge, mtlb induce ho jayenge, or ye to tab tak hota rahega, jab tak ander net electric field zero na ho jaye. Mtlb, jitne External E.F ho utni hi opposite dirx^n me charge sepr^n ki vajah se induce ho gyi.



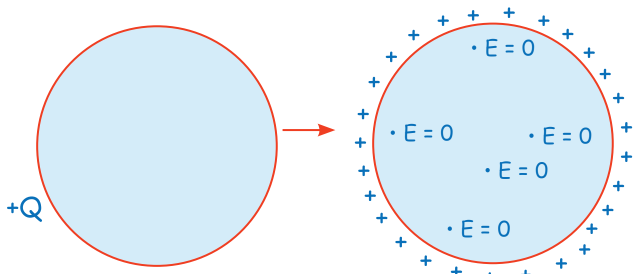
$E_{net} = E_0 - E_{induce}$

⇓

0 $\quad E_{induce} = E_0$

→ Agr kisi conductor ko charge dedu to,

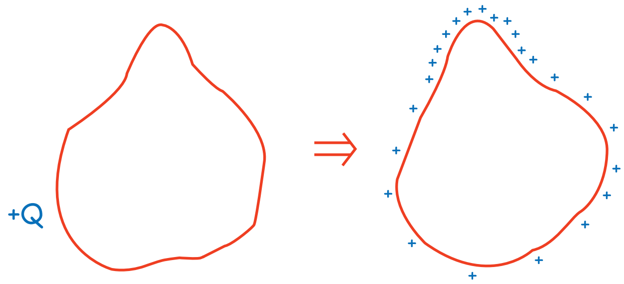
$$\sigma \propto \frac{1}{r}, r\downarrow, \sigma\uparrow$$



Perfect गोला

R → same

σ → same uniform



σ ∝ 1/r

r↓, σ↑

→ Potential of every point of conductor are same.

→ Hence, we can say that surface of conductor is Equipotential surface

→ Since E.F is always $\perp^{ar}$ to Equipotential surface
Hence E.F is always $\perp^{ar}$ to conducting surface

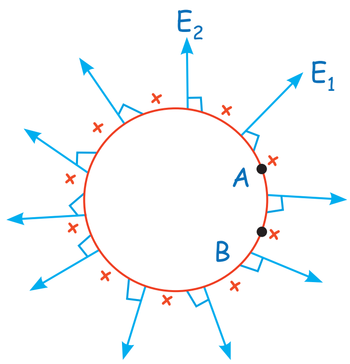
$dv = -\vec{E}\cdot d\vec{r} = -Edr\cos\theta$

V → same

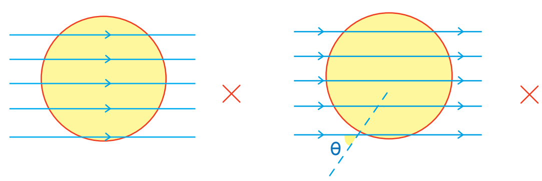
$dv = 0 \Rightarrow E = 0$ or

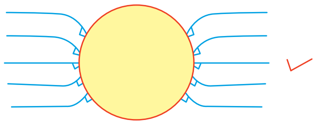
$\theta = 90°$

$\vec{E} \perp d\vec{r}$



Q. Which of the following diagram is not possible for a conductor?



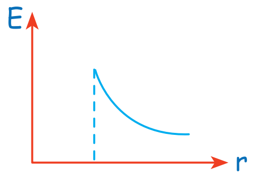


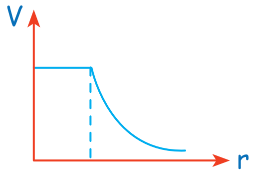
SPHERICAL CONDUCTOR OF 'R', +Q.

$\rightarrow E_{inside} = 0$ $\qquad$ $\rightarrow E_{outside} = \frac{KQ}{r^2}$

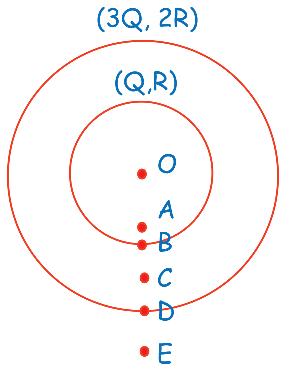
$V_{inside} = \frac{KQ}{R}$ $\qquad$ $V_{outside} = \frac{KQ}{r}$

Results are same as non conducting shell.





Q. In following diagram we have two conducting sphere. Find potential at A, B, C, D, E.



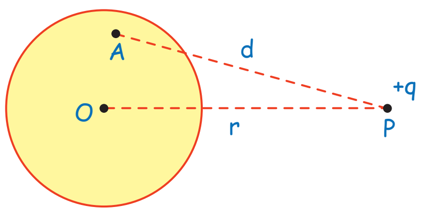
$$V_O = \frac{KQ}{R} + \frac{K3Q}{2R} = V_A = V_B$$

$$V_C = \frac{KQ}{OC} + \frac{K3Q}{2R}$$

$$V_D = \frac{KQ}{2R} + \frac{K3Q}{2R}$$

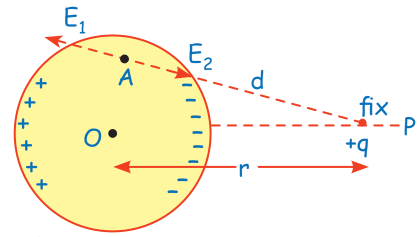
$$V_E = \frac{KQ}{OE} + \frac{K3Q}{OE}$$

Q. A charge q is placed at P outside at a distance r from the center of a conducting neutral sphere of radius R (r > R). Find EF and EP at A due to induce charge.



Conducting
[Neutral R]

Sol.



Conducting
[Neutral R]

E.F at Pt. A = 0

E.F at pt. A due to pt. charge q = $\frac{Kq}{d^2} = E_1$

E.F at pt. A due to induce charge = E_2

$E_2 = \frac{Kq}{d^2}$ (opposite to E_1)

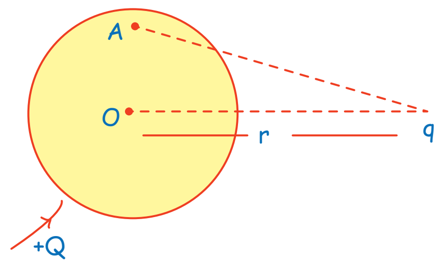
$V_A = V_O$

$V_A = V_{\text{at A due to q}} + V_{\text{at A due to induce charge}}$

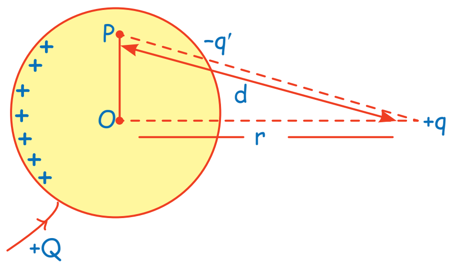
$\frac{Kq}{r} = \frac{Kq}{d} + V_{\text{at A due to induce charge}}$

$V_{\text{at A due to induce charge}} = \frac{Kq}{r} - \frac{Kq}{d}$

Q. Repeat the last all parts if conducting sphere is given + Q charge. Find potential at A due to induce charge.



Sol.



$V_p = V_0 = \frac{Kq}{r} + \frac{K(Q + q' - q')}{R}$

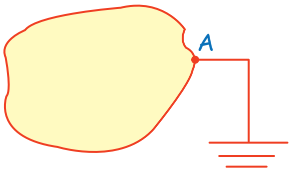
$V_p = V_0 = \frac{Kq}{r} + \frac{KQ}{R}$

Pot. at 'P' due to induce charge = कद्दू

$V_p = V_{\text{due to 'q'}} + V_{\text{induce charge}}$

$\frac{Kq}{r} + \frac{KQ}{R} = \frac{Kq}{d} + V_{\text{due to induce charge}}$

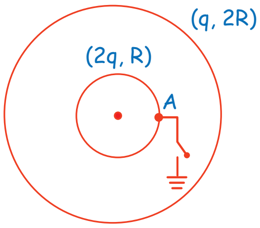
IDEA OF EARTHING



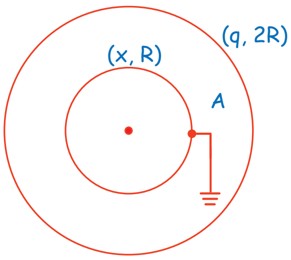
$V_A = 0$ कर दिया

#SKC
जिसको Earth Kiya hai, uska potential zero Krna. hai.

Q. Suppose we have two concentric conductor as shown in figure. Find the charge on inner conducting sphere after switch close.



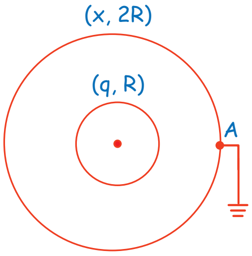
Sol.



$$V_A = \frac{Kx}{R} + \frac{Kq}{2R} = 0$$

$x = -q/2$

Q. Find the charge on outer sphere

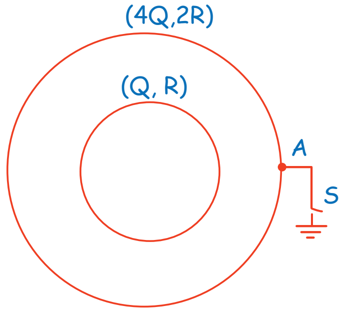


#SKC
जिसको Earth Kiya hai, uska potential zero Krna. hai.

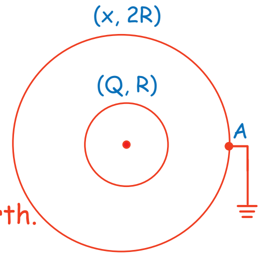
$$V_A = \frac{kq}{2R} + \frac{kx}{2R} = 0$$

$x = -q$

Q.



→ Find charge flow through switch after switch closed



$V_A = 0$

$$\frac{Kx}{2R} + \frac{KQ}{2R} = 0$$

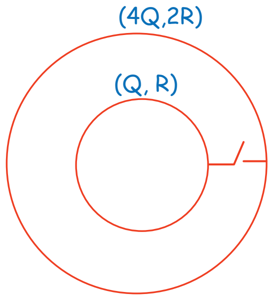
$x = -Q$

$\therefore$ + 5Q charge flow.

→ find no. of e^- supply by earth.

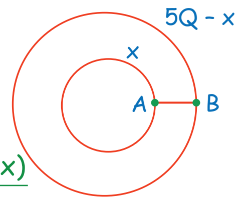
$5Q = ne$

Q. Find charge on inner sphere & outer sphere after switch closed



#SKC
जिन दो conducting surface को तारो से जोड़ा है उनका potential बराबर करदो

Sol. Suppose inner sphere has charge x



$V_A = V_B$

$$\frac{Kx}{R} + \frac{K(\cancel{5Q - x})}{R} = \frac{Kx}{2R} + \frac{K(\cancel{5Q - x})}{2R}$$

$$\frac{Kx}{R} = \frac{Kx}{2R}$$

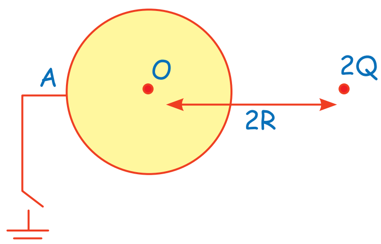
$$x = \frac{x}{2}$$

$$x - \frac{x}{2} = 0$$

[inner] $x = 0$

सारा का सारा charge बाहर चला गया
Sorry Shubham* Bhaiya

Q. Find net charge on conductor after switch is closed.



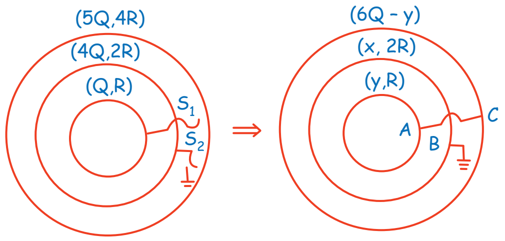
Sol. Let charge on the sphere is x after switches close

$V_A = 0 = V_0$

$$\frac{K2Q}{2R} + \frac{Kx}{R} = 0$$

$x = -Q$

Q. Find charge on each sphere after S_1 and S_2 closed [conducting]



Sol. $V_B = 0$

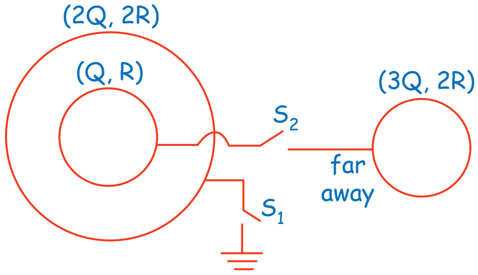
$$\frac{Ky}{2R} + \frac{Kx}{2R} + \frac{K(6Q-y)}{4R} = 0 \quad ...(1)$$

$V_A = V_C$

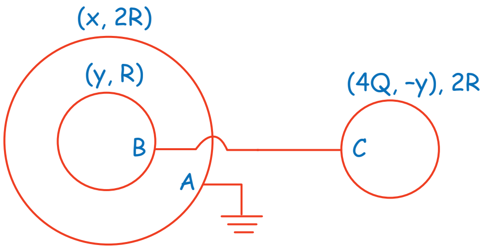
$$\frac{Ky}{R} + \frac{Kx}{R} + \frac{K(6Q-y)}{4R} = \frac{Ky}{4R} + \frac{Kx}{4R} + \frac{K(6Q-y)}{4R} \quad ...(2)$$

By Solving (1) and (2) we can get the answer focus on concept.

Q. Find charge on each sphere after S_1, S_2 is closed.



Sol.



$V_A = 0$

$$\frac{Ky}{2R} + \frac{Kx}{2R} + 0 = 0$$

$x + y = 0 \quad ....(1)$

$V_B = V_C$

$$\frac{Ky}{R} + \frac{Kx}{2R} + 0 = \frac{K(4Q-y)}{2R}$$

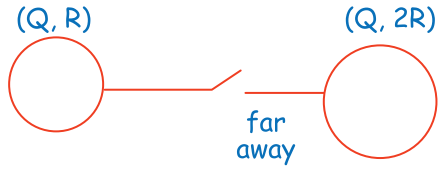
$x + 3y = 4Q \quad ....(2)$

Solve (1) and (2)

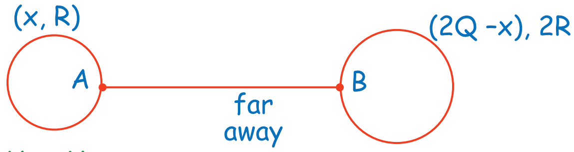
$\therefore y = +2Q$

$x = -2Q$

Q. Find charge on small sphere after switch close



Sol.



$V_A = V_B$

$$\frac{Kx}{R} + 0 = 0 + \frac{K(2Q-x)}{2R}$$

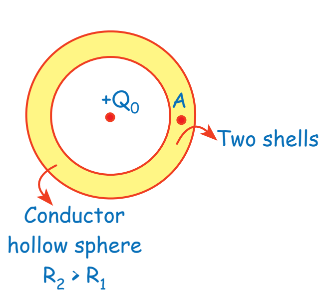
$$x = \frac{2Q}{3}$$

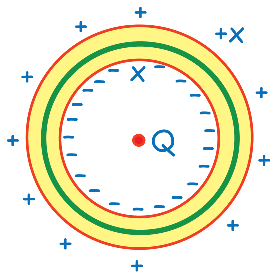
$q_1 = 2Q/3$

$$q_2 = 2Q - \frac{2Q}{3} = \frac{4Q}{3}$$

Q. Suppose we have a neutral hollow conducting sphere of inner radius R_1 and outer radius R_2. A point charge $+Q_o$ is placed at center. Find charge density inner and outer surface

Sol.



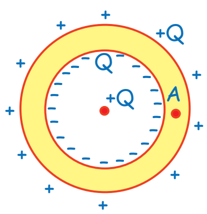


$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{in}}{E_0}$$

$$0 = \frac{Q - x}{E_0}$$

$Q = x$

$$\sigma_{inner} = \frac{-Q}{4\pi R_1^2}$$



$\sigma_{outer} = \dfrac{Q}{4\pi R_2^2}$

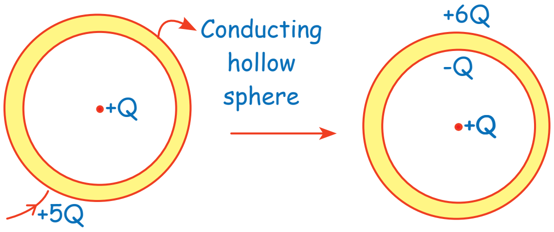
Inner surface pr charge -x h, mtlb -Q h

#SKC
इसमें 2 shell है
→ -Q . R_1
→ +Q . R_2

→Last Quesn में

#SKC
Chore Ka samne. barabar Ki age ki chori Ko bitha K setting Kr do and उसी प्रकार अगर छोरी है तो सामने बराबर age का छोरा बैठा दो। उसके बाद क्या होगा अपको पता ही है।

Q. Find charges & σ on inner and Outer surface after proper induction

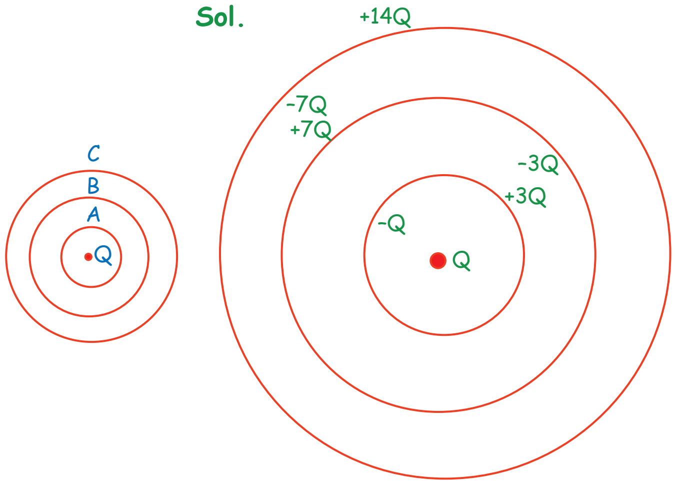


$\sigma_{inner} = \dfrac{-Q}{4\pi R_1^2}$

$\sigma_{outer} = \dfrac{+6Q}{4\pi R_2^2}$

Q. If 2Q, 4Q, 7Q charge is given to A, B, C respectively. Find charges & σ on inner and Outer surface after proper induction.

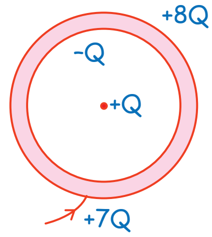
Sol.



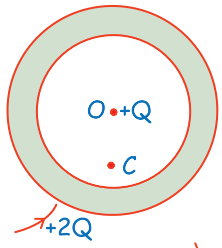
Q. Suppose we have a thin conductor of inner radius R and thickness t and charge +7Q. If +Q charge is placed at center. Find σ_{inner} and σ_{outer}.

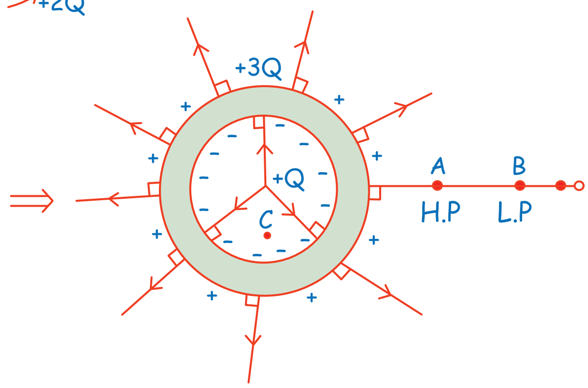
Sol. $\sigma_{inside} = \dfrac{-Q}{4\pi R^2}$

$\sigma_{outside} = \dfrac{8Q}{4\pi(R+t)^2}$



☆ Draw E.F pattern.





→ Electric field and potential at A.

$$\vec{E}_A = \frac{KQ}{(OA)^2} + \frac{K(-Q)}{(OA)^2} + \frac{K3Q}{(OA)^2}$$

$$V_A = \frac{KQ}{OA} + \frac{K(-Q)}{OA} + \frac{K3Q}{OA}$$

→ E.F at point C inside खाली जगाह -

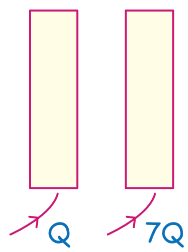
$$\vec{E}_C = \vec{E}_{\text{due to point charge}} + \vec{E}_{\text{inner shell}} + \vec{E}_{\text{outer shell}}$$

$$= \frac{KQ}{(OC)^2} + 0 + 0$$

$$E_c = \frac{KQ}{(OC)^2}$$

CONDUCTING PLATE VERY CLOSE TO EACH OTHER / (LIKE ∞ PLATE)

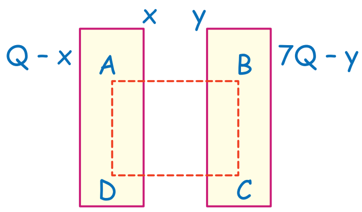
Q. Suppose we have two conducting plate very close to each other and charge +Q, +7Q is given to both the plate as shown in figure. Find charge on every surface of both plates.

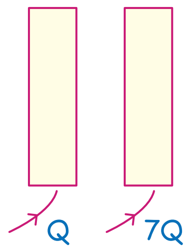


Sol. ABCD के लिए gauss law लगाकर और

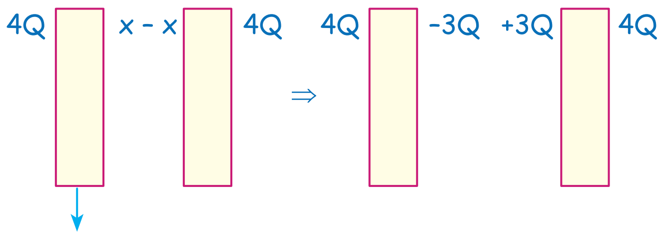
$E_A = 0$ करके we found

Plate के आमने सामने equal & opposite charge होगा और दोनों outer surface पर total का half charge होगा।





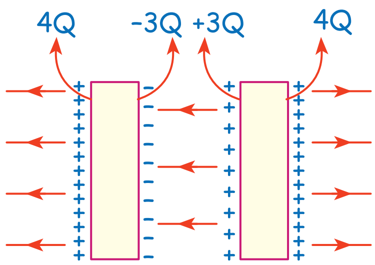
$$Q_{outer} = \frac{Q_{total}}{2} = \frac{Q+7Q}{2} = 4Q$$



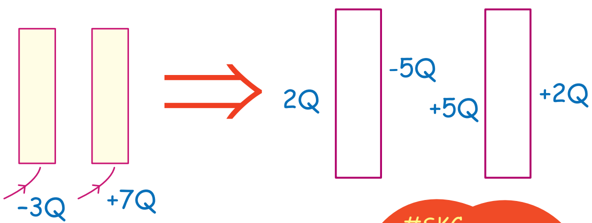
Total charge on this plate = Q

So x = -3Q

So final charge distribution and E.F pattern will be

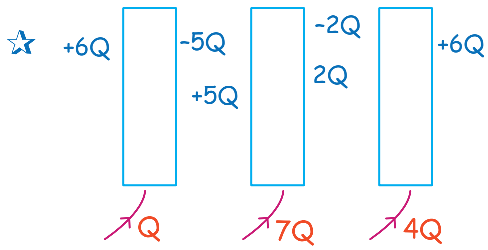


Q.

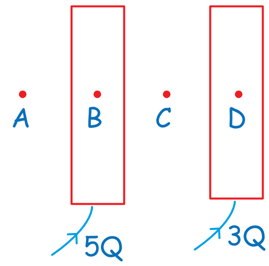


$$Q_{outer} = \frac{Q_{total}}{2} = \frac{-3Q+7Q}{2} = 2Q$$

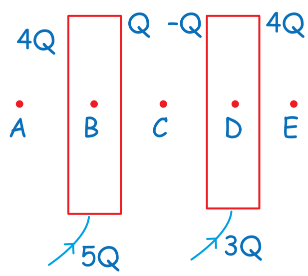
#SKC
Total charge ko आधा आधा करके outer suface ko de do, fir setting kr do.



Q. Charge 5Q and 3Q are given to two conducting plate very close to each other find charge on each face and Find E.F at A, B, C, D, E.



Sol.



$E_B = E_D = 0$

$$E_C = \frac{4Q/A}{2E_0} - \frac{4Q/A}{2E_0} + \frac{Q/A}{2E_0} + \frac{Q/A}{2E_0}$$

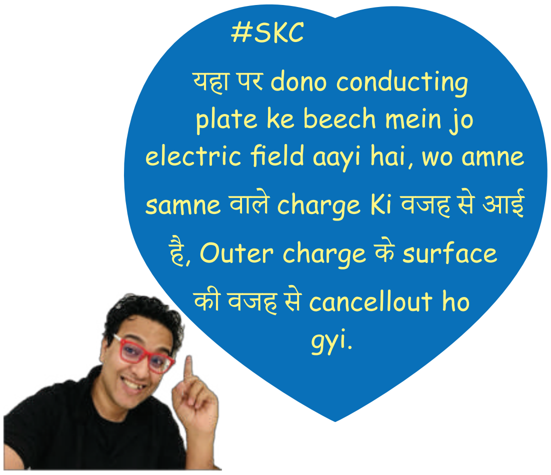
$$E_C = E_{\text{बीच में}} = \frac{Q}{AE_0} = \frac{Q_{\text{अंदर वाला}}}{AE_0}$$

$$= \frac{\sigma_{\text{अंदर वाला}}}{E_0}$$

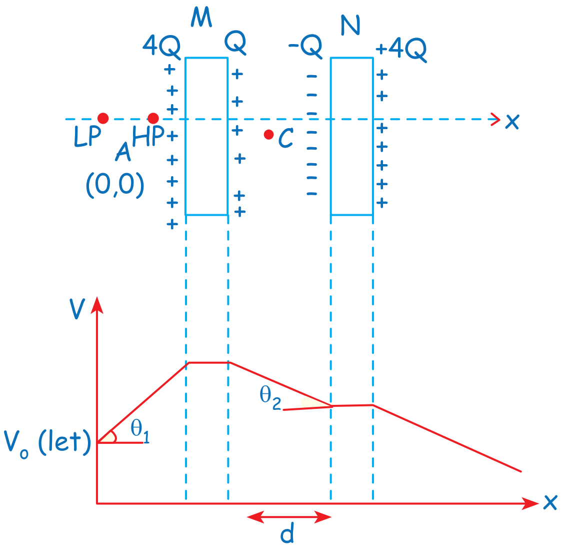
$$E_A = \frac{-4Q/A}{2E_0} - \frac{Q/A}{2E_0} + \frac{Q/A}{2E_0} - \frac{4Q/A}{2E_0}$$

$$= \frac{-8Q/A}{2E_0} = \frac{-4Q/A}{E_0}$$

$$E_E = \frac{4Q/A}{2E_0} \times 2 = \frac{4Q/A}{E_0}$$



GRAPH-



$\tan\theta_1 = E_A$ (magn.)

$\tan\theta_2 = E_C$ (magn.)

SELF-POTENTIAL ENERGY

- Self-potential energy of a charge system is the total electrostatic potential energy due to interactions between the charges in the system.
- For a system of point charges, it is the sum of the potential energies of all distinct pairs of charges.

→ S.P.E of a pt. charge = 0

→ S.P.E of a shell, conducting sphere $= \dfrac{KQ^2}{2R}$

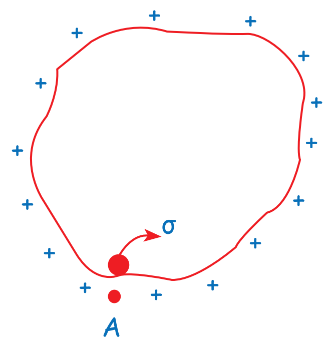
→ S.P. E of a solid sphere $= \dfrac{3}{5}\dfrac{KQ^2}{R}$

Q. A spherical shell of radius R_1 with uniform charge q is expanded to a radius R_2. Find the work performed by the electric forces in this process.

Sol. $(WD) = U_f - U_i$

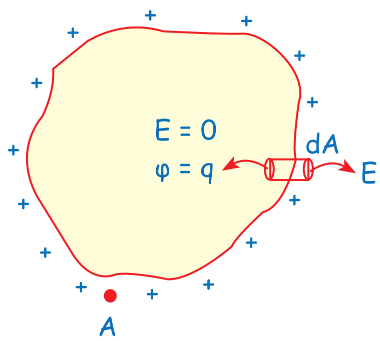
$$= \frac{Kq^2}{2R_2} - \frac{Kq^2}{2R_1}$$

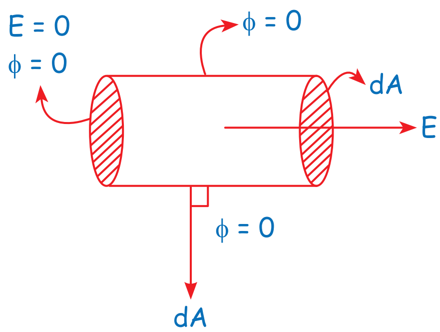
E.F IN THE VICINITY OF CONDUCTOR



$\boxed{E_A = \sigma/\varepsilon_0}$

Proof:

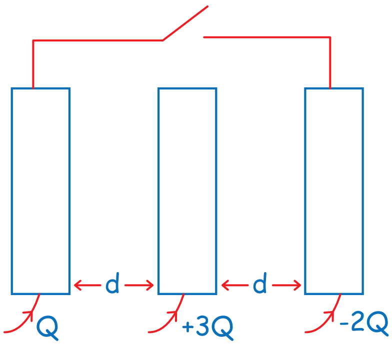


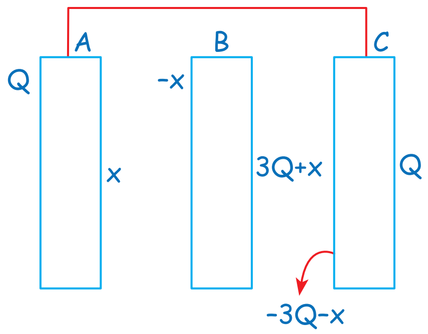


$$EdA + 0 + 0 + 0 = \frac{q_{in}}{\varepsilon_0} = \frac{\sigma dA}{\varepsilon_0}$$

$\boxed{E = \sigma/\varepsilon_0}$

Q. Find charge on each surface after switch closed.





$Q_{total} = Q + 3Q - 2Q$

$V_A = V_C$

$(V_A - V_B) + (V_B - V_C) = 0$

$E_1 d + E_2 d = 0$

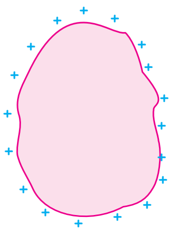
$$\left(\frac{x/A}{2E_0}\right) + \frac{(3Q+x)/A}{2E_0} = 0$$

$x + 3Q + x = 0$

$$x = \frac{-3Q}{2}$$

ELECTROSTATIC PRESSURE

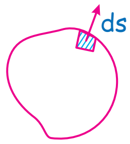
Suppose a conductor is given some charge. Due to repulsion, all the charges will reach the surface of the conductor. But the charges will still repel each other. So an outward force will be felt by each charge due to others. Due to this force, there will be some pressure at the surface, which is called electrostatic pressure.



To find the electrostatic pressure, lets take a small surface element having area '*ds*' and elemental charge dq.

Force on this element due to the remaining charges:

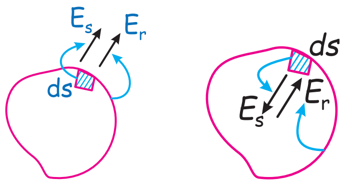
$dF = E_r(dq)$



$$dF = \begin{pmatrix}\text{electric field at}\\ \text{that place due to}\\ \text{remaining charges}\end{pmatrix}\begin{pmatrix}\text{charge of}\\ \text{the small}\\ \text{element}\end{pmatrix}$$

$dF = E_2 \times dq$ ...(*i*)

At a point just outside the surface, electric field due to the small element (E_s) will be normally outwards, and electric field due to the remaining part (E_r) will also be normally outwards.



So net electric field just outside the surface = $E_s + E_r$. We have already proved that electric field just outside

the conductor surface $= \frac{\sigma}{\varepsilon_0}$

$$\Rightarrow E_s + E_r = \frac{\sigma}{\varepsilon_0} \qquad ...(ii)$$

Electric field just inside the metal surface. Due to the remaining charges (E_r) will be in the same direction (normally outward), but the electric field due to the small element will be in opposite direction (normally inward)

So net electric field just inside the metal surface = $E_r - E_s$ and electric field inside a conductor = 0

So, $E_r - E_s = 0 \Rightarrow E_r = E_s$ ...(iii)

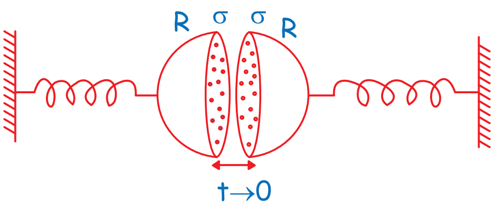
From eqn. (ii) and eqn. (iii), we can say that:

$$2E_r = \frac{\sigma}{\varepsilon_0} \Rightarrow E_r = \frac{\sigma}{2\varepsilon_0}$$

$$P = \frac{dF}{dA} = \frac{dq.E_r}{dA} = \frac{\sigma.\sigma}{2E_0}$$

$$\boxed{\text{Electrost. Pressure} = \frac{\sigma^2}{2E_0}}$$

Q. Hemisphere are in equillibrium find compression in string.



Equilibrium

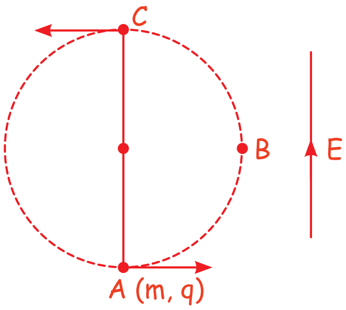
$$\frac{\sigma^2}{2E_0} \times \pi R^2 = Kx$$

IMPORTANT QUESTIONS

q charge को EF मे रखने पर उसके force qE लगता है इस concept को पूरी mechanics मे use करके सवाल बनाए जा सकते है।

Q. If $T_A = 15$ mg

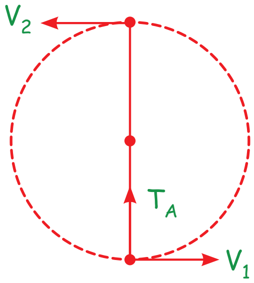
What should be velocity at C



OR

What horizontal velocity must be impart to ball at C so that tension at A become 15 times of weight.

Sol.

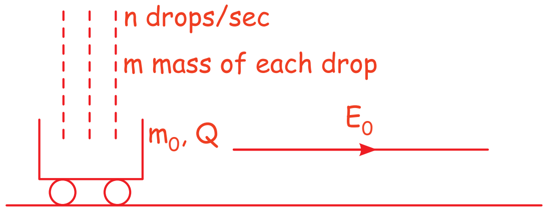


(1) $T_A + qE - mg = \frac{mV_A^2}{R}$

$15mg + qE - mg = \frac{mV_A^2}{R}$

(2) $-mg\ 2R + 0 + qE\ 2R = \frac{1}{2}mV_2^2 - \frac{1}{2}mV_1^2$

Q. n droper second m → mass of each drop.



Find velocity of car/tank as fx_n of time.

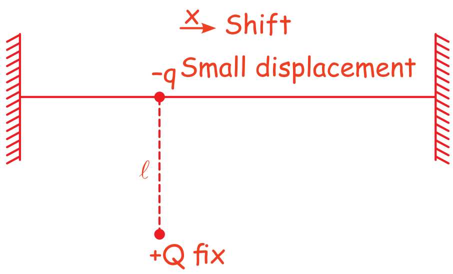
Sol. At any time 't' mass of car = $M_0 + n\,t\,m$

Impulse momentum theorem $\boxed{J = \Delta P}$

$QE_0 t = (M_0 + n\,t\,m)V_f - 0$

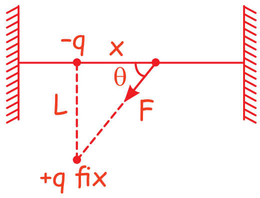
$V_f = \frac{QE_0 t}{M_0 + mnt}$

Q. Find time period of SHM if $-q$ charge is slightly displaced in following figure along x-axis.

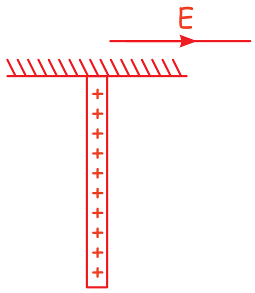


Sol. $F_{net} = F\cos\theta$

$$= \frac{Kq\theta}{(L^2 + x^2)} \frac{x}{\sqrt{L^2 + x^2}}$$



Q. Suddenly E_0 apply St. rod rotated max angle $90°$. E = ?



Rod AB of length (L, Q, m)

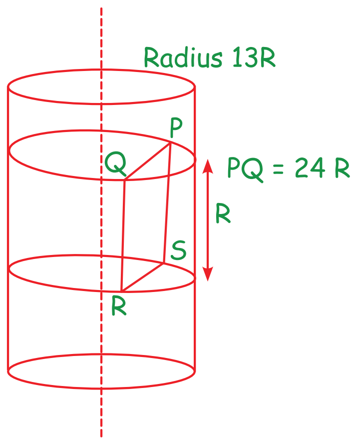
Sol. WET

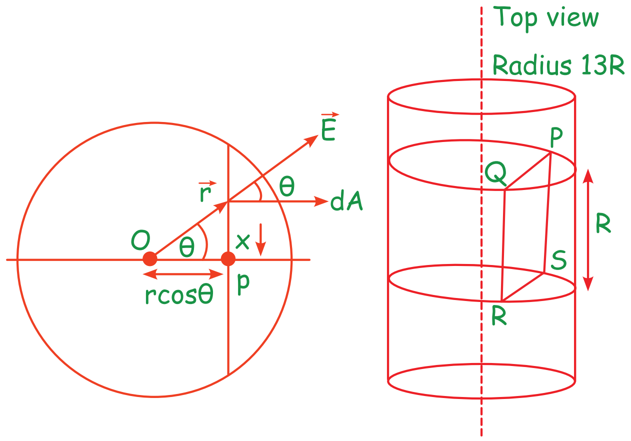
$W_g + W_{EF} = \Delta K.E.$

$-mg\frac{L}{2} + qE\frac{L}{2} = 0\text{-}0$

$$\boxed{E = \frac{mg}{q}}$$

SSSQ. A long non conducting solid cylinder of radius 13R has charge density s. Find flux through shaded ractangle. PQRS





Sol. $\phi_{net} = \int d\phi = \int \vec{E}.d\vec{A} = \int E\,dA\cos\theta = \int \frac{\rho r}{2\varepsilon_0} dA\cos\theta$

$= \frac{\rho}{2\varepsilon_0}\int r\cos\theta\,dA$ (OP = 5R after solving)

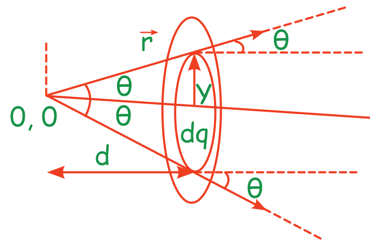
$= \left(\frac{\rho}{2\varepsilon_0}\right)(op)\int dA = \frac{\rho}{2\varepsilon_0}.5R(24R.R)$

Q. A disc of radius R is kept such that its axis coincide with the x-axis and its centre is at (d,0,0). The thickness of disc is t and it carries a uniform volume charge density ρ. The external electric field in the space is given by $\vec{E} = K\vec{r}$ where K = Constant and $\vec{r}$ is position vector of any point in space with respect to the origin of the coordinate system. Find the electric force on the disc.

Sol. $F_{net} = \int dF\cos\theta$

$= \int (dq)\,E\cos\theta$

$= \int (\rho 2\pi y d y t) kr\cos\theta$



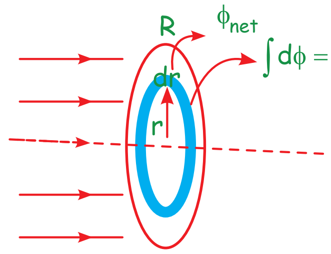
$F_{net} = \rho 2\pi tk\int r\cos\theta.y\,dy$

$F_{net} = \rho 2\pi tkd\int_0^R y\,dy$

$F_{net} = \rho 2\pi tkd\frac{R^2}{2}$

Q. E.F is normal to Disc $\vec{E} = E_0\left(1-\frac{r}{R}\right)\hat{i}$ Where r is distance from center of Disc, Find $\phi_{disc} = ?$

Sol.



ϕ_{net}

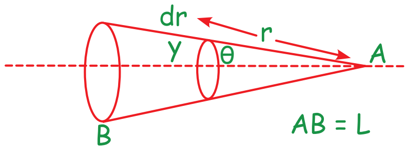
$\int d\phi = \int E.dA\cos o$

$\phi_{net} = \int_0^R E_0\left(1-\frac{r}{R}\right)2\pi r dr$

Q. A cone made of insulating material has a total charge Q spread uniformly over its sloping surface. Calculate the energy required to take a test charge q from infinity to apex A of cone. The slant length is L.

Sol. $dv = \frac{kdq}{\sqrt{y^2+x^2}} = \frac{kdq}{r}$

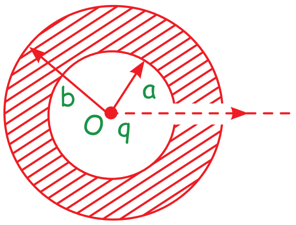
$\sin\theta = \frac{y}{r} = \frac{R}{L}, y = \frac{Rr}{L}$



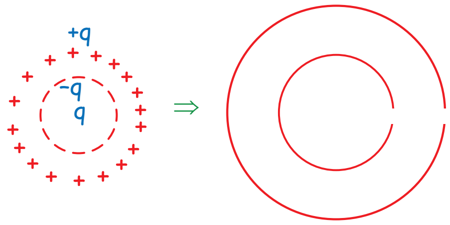
$$\int dv = \int_0^L \frac{k\sigma 2\pi y dr}{r} = k\sigma 2\pi \int_0^L \frac{R\cancel{r}}{L}\frac{dr}{\cancel{r}} = k\frac{\theta}{\pi RL}2\pi\frac{R}{L}.L$$

$$= \frac{2K\theta}{L}$$

Q. A point charge q is located at the centre O of a spherical uncharged conducting layer provided with a small orifice. The inside and outside radii of the layer are equal to a and b respectively. What amount of work has to be performed to slowly transfer the charge q from the point O through the orifice and into infinity?



Sol.

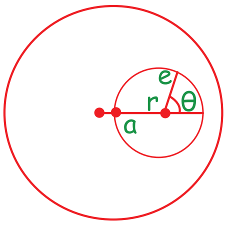


T.P.E = $(SPE)_1 + (SPE)_2 + (SPE)_3 + U_{12} + U_{31} + U_{23}$

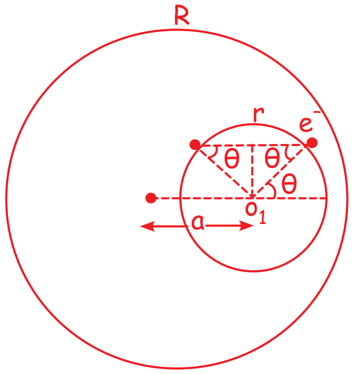
$$U_i = O + \frac{k(-q)^2}{2a} + \frac{kq^2}{2b} + \left(\frac{-kq}{a}.q\right) + \left(\frac{kq}{b}.q\right) + \frac{kq}{b}(-q)$$

$U_f = 0$. Ans. $= U_f - U_i$

Q. A cavity of radius r is present inside a solid dielectric sphere of radius R, having a volume charge density of ρ. The distance between the centres of the sphere and the cavity is a. An electron e is kept inside the cavity at an angle thet θ = 45° as shown. How long will it take to touch the sphere again?



Sol.

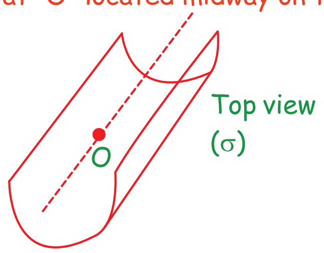


$$2r\cos\theta = 0 + \frac{1}{2}\frac{eE}{m}.t^2$$

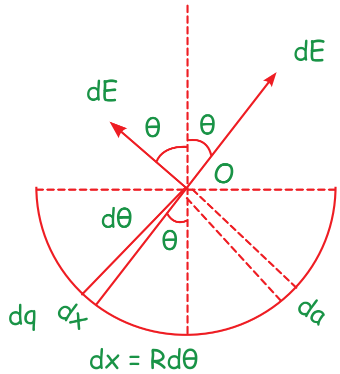
$$2r\cos\theta = \frac{1}{2}\frac{e\rho a}{3\varepsilon_0 m}t^2$$

$$t = \sqrt{\frac{12\varepsilon_0 m\, r\cos\theta}{e\rho a}}, \theta = 45^\circ$$

Q. Thin long strip whose cross-section is a semicircle find EF at 'O' located midway on the axis



Sol. $E_0 = \int_0^{\pi/2} 2dE\cos\theta$



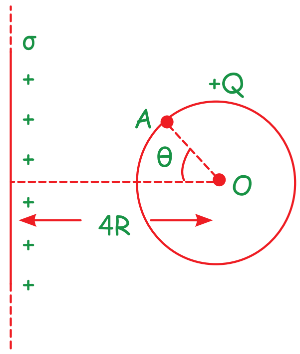
$$= \int_0^{\pi/2} 2.\frac{2k\sigma Rd\theta\cos\theta}{R}$$

$$= 4k\sigma\int_0^{\pi/2}\cos\theta d\theta$$

$$= \frac{\sigma}{\pi\varepsilon_0}$$

Q. A conducting sphere of radius R and charge Q is placed near a uniformly charged nonconducting infinitely large thin plate having surface charge density σ. Then find the potential at point A (on the surface of sphere) due to charge on sphere

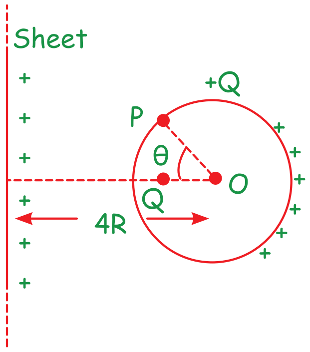
(here $K = \frac{1}{4\pi \in}, \theta_0 = \frac{\pi}{3}$)



Sol. $V_p = V_O$

$$(V_p)_{\text{due to sheet}} + (V_p)_{\text{gola}} = (V_o)_{\text{Sheet}} + (V_o)_{\text{Gola}}$$

$$(V_Q)_{\text{due to sheet}} - (V_o)_{\text{sheet}} + (V_p)_{\text{gola}} = (V_o)_{\text{Gola}}$$



$$\frac{\sigma}{2\varepsilon_0}\left(4R - (4R - R\cos\theta)\right) + \left(V_p\right)_{\text{gola}} = \frac{kQ}{R}$$

$$(V_p)_{\text{Gola}} = \frac{kQ}{R} = \frac{\sigma R\cos\theta}{2\varepsilon_0}$$

Q. The electric potential in a region is given by $V(x, y, z) = ax^2 + ay^2 + abz^2$ 'a' is a positive constant of appropriate dimensions and b, a positive constant such that V is volts when x, y, z are in m Let b = 2 The work done by the electric field when a point charge +4μC moves from the point (0, 0, 0.1m) to the origin is 50 μJ. The radius of the circle of the equipotential curve corresponding to V = 6250 volts and $z = \sqrt{2}$ m is α m. Fill α^2 in OMR sheet.

Sol. $(WD)_{ext} = -\Delta V = -q\Delta V = -q\left(0 - \frac{a}{50}\right) = \frac{aq}{50}$

$$50 \times 10^{-6} = \frac{a \times 4 \times 10^{-6}}{50}$$

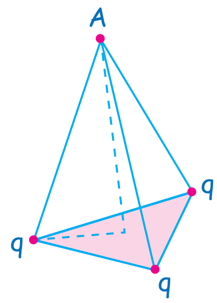
$$a = \frac{50 \times 50}{4} = 625$$

$$V = 6250 = 625x^2 + 625y^2 + 625 \times 2 \times 2$$

$$10 = x^2 + y^2 + 4$$

$$x^2 + y^2 = (\sqrt{6})^2$$

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

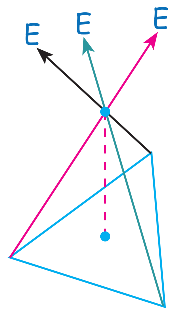


Sol. $E_A = 3E\sin\theta$

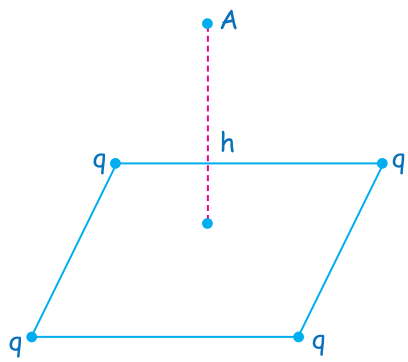
[θ = 60° already solved]

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

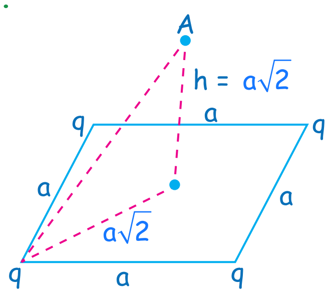
$$r^2 = h^2 + \left(\frac{a}{\sqrt{3}}\right)^2$$



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

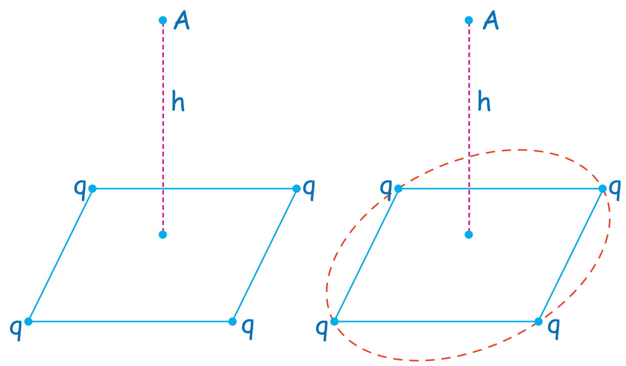


Sol.



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

ऐ फिर आ गया रे बाबा

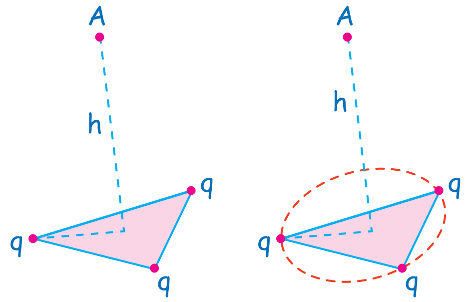


ऐसे symmetric सवालो मे हम 4q charge की एक ring मान सकते है जिसकी radius center से किसी भी एक charge के बीच की दूरी होगी यहाँ पर

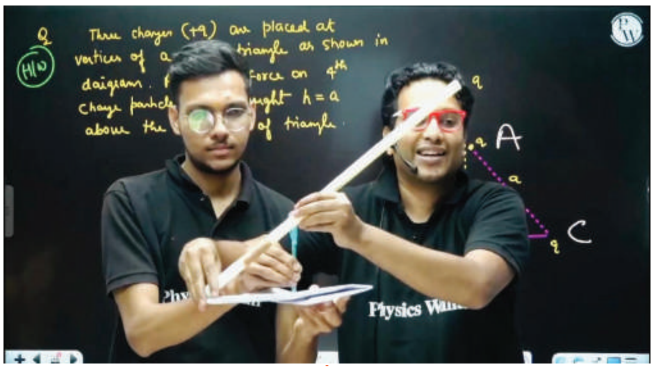
$R = \left(\dfrac{A}{\sqrt{2}}\right)$ और $x = h$.

$$E = \frac{KQx}{\left(R^2+x^2\right)^{3/2}} = \frac{K(4q)h}{\left[\left(\dfrac{a}{\sqrt{2}}\right)^2+h^2\right]^{3/2}}$$

अब ये मत बोलना की ये पहले क्यों नही बताया अगर पहले बता देता तो तुम्हारी physics and visualisation develop नही हो पाता अब बोलो thank you saleem भईया।



इसको भी 3q charge का ring मानकर जिसकी radius $\frac{a}{\sqrt{3}}$ है, A पर EF निकाल सकते है। It's your homework verify the result. जब verify हो जाए तो मुझे insta पर खुशी खुशी बताना। (Saleem.nitt) अगर आप insta पर नही हो तो account मत बनाना।



2 Current Electricity

✦ Current (i) ⇒ Rate of flow of charge, scalar quantity

$$i = \frac{dq}{dt}$$

✦ Inst Current = $i = \frac{dq}{dt}$

✦ Average Current = $\langle i \rangle = \frac{\int i.dt}{\int dt} = \frac{\Delta q}{\Delta t}$

✦ $\langle \vec{V} \rangle$ = Average velocity = $\frac{\int v dt}{\int dt}$

$\langle \text{कदद्} \rangle = \frac{\int \text{कदद्}\, dt}{\int dt}$

Q. Given $i = 3t^2$

(a) Find current at t = 2 sec

Sol. $i = 3 \times 2^2 = 12$

(b) Finds average current from $t = 0 \to t = 2$

$$\langle i \rangle = \frac{\int_0^2 i dt}{\int_0^2 dt} = \frac{\int_0^2 3t^2 dt}{\int_0^2 dt} = \frac{8}{2} = 4$$

(c) $i = 3t^2$ Find the charge flow from

$t = 0 \to t = 2sec$

$$\Delta q = \int i dt = \int_0^2 3t^2 dt = 8$$

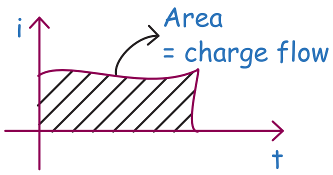
✩ $\boxed{i = \frac{dq}{dt}}$

$\int dq = \int i dt$

$\Delta q = \int i dt$ = Area

↓

charge flow



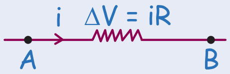

अबे सुनो Current electricity में सबसे जरूरी होता है circuit analysis तो sequence change करके saleem bhaiya के sequence में पढ़ते है from basic to advance.

✩ 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.



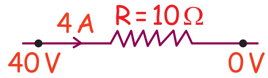
$V_A - V_B = iR$ or $V = iR$

pot. diff.

i → Resist मे H.P to L.P

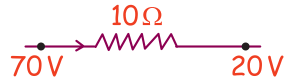
Q. Find current in the resistance in following cases.

(a)



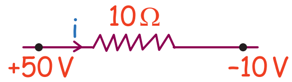
Sol. $i = \frac{40 - 0}{10} = 4$

(b)



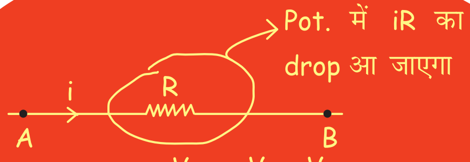
Sol. $i = \frac{50}{10} = 5$

(c)



Sol. $i = \frac{50 - (-10)}{10} = \frac{60}{10} = 6$

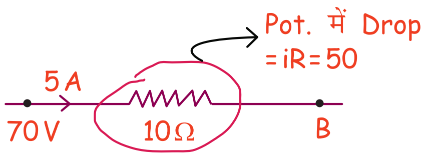
#SKC



$i = \frac{V}{R} = \frac{V_A - V_B}{R}$

direction of current
⇒ HP to LP (Resistance)

(d) Find V_B.

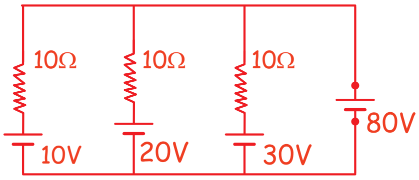


Sol. $V_B = 70 - 50 = 20\,V$

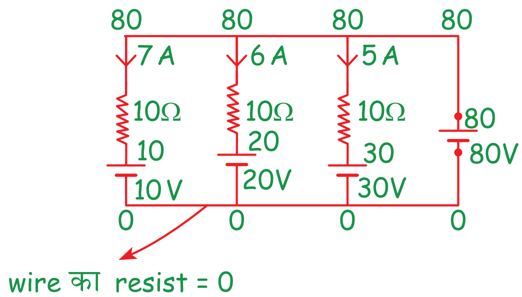
#SKC

Resistance मे current H.P to L.P flow करेगा but Battery मे कैसे भी कर सकता है

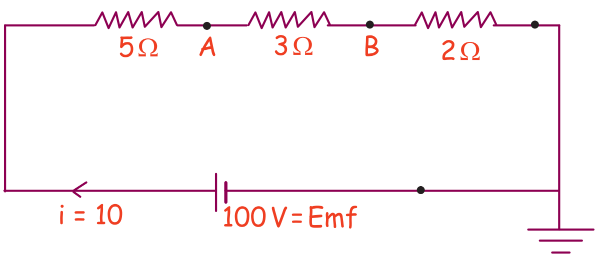
Q. Find current through each resistors.



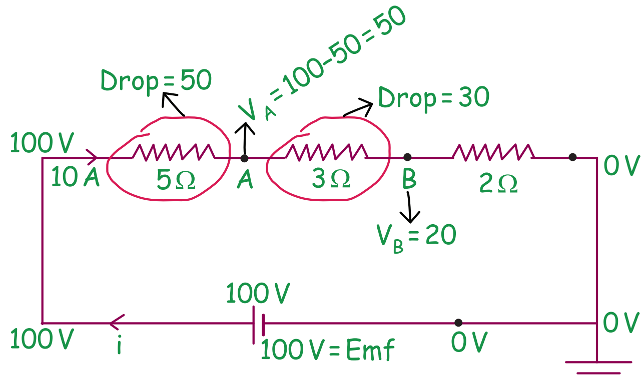
Sol.



Q. Find current and potential at A & B.



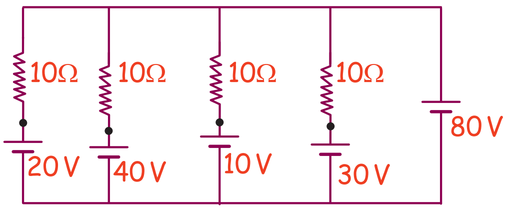
Sol.



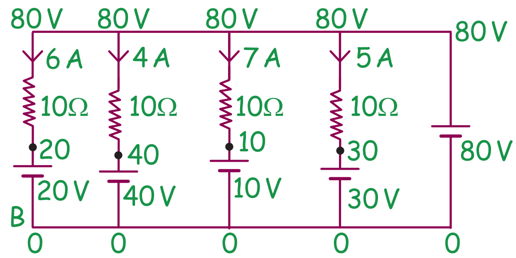
$$i = \frac{E}{R_{eq}} = \frac{100}{10} = 10A$$

$$R_{eq} = 5 + 3 + 2 = 10\Omega$$

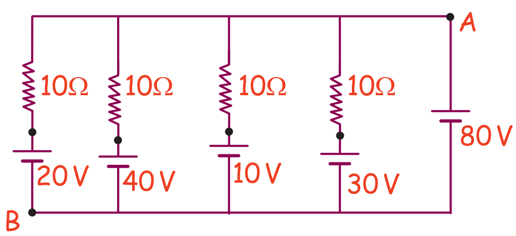
Q. Find current through each resistors (R = 10Ω each)



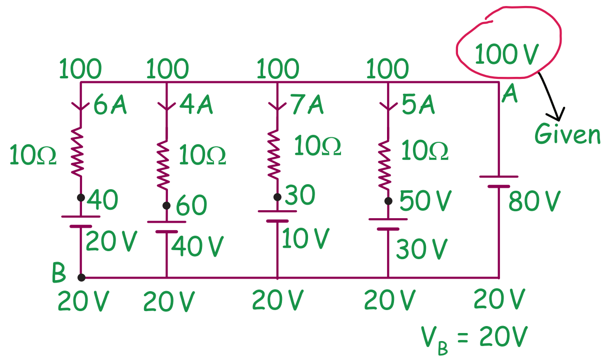
Sol.



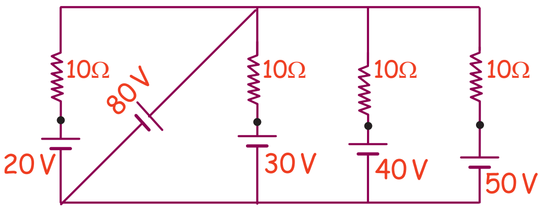
Q. If pot. at A is 100V, find V_B & Current. (R = 10Ω each)



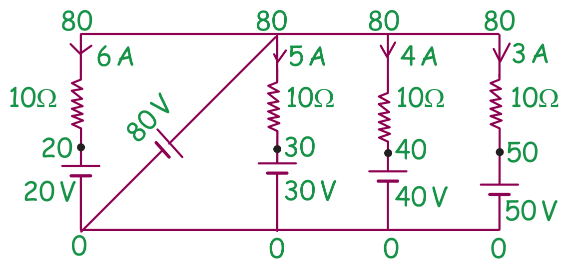
Sol.

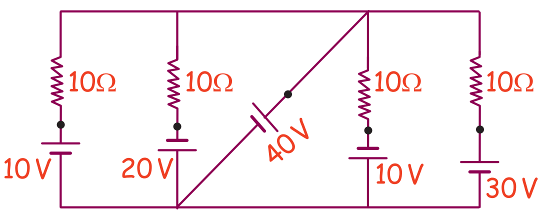


Q. Find i in each resistance

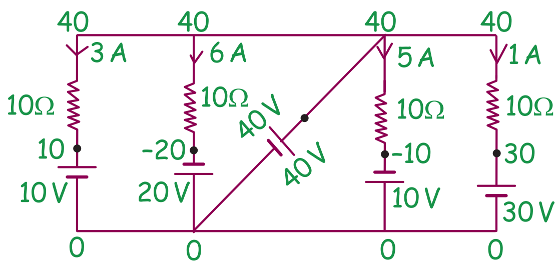


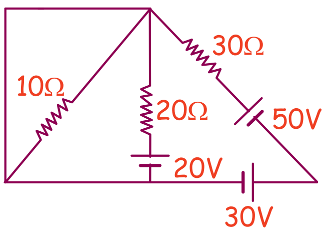
Sol.



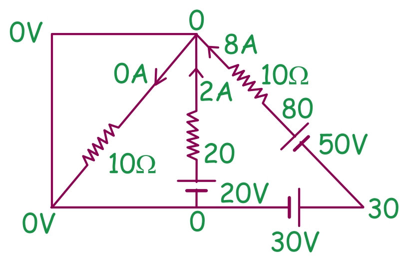


Sol.



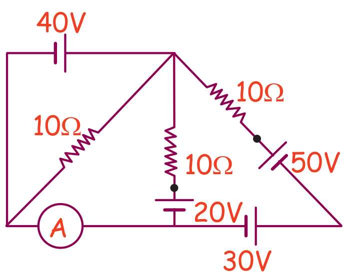


Sol.

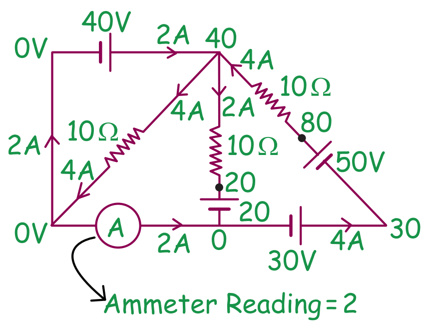


यहाँ 10 Ω short circuit हो गया

Q. What is ammeter reading?



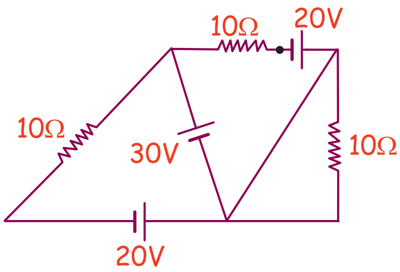
Sol.



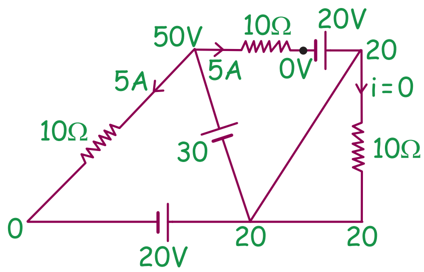
माना की no. of pages of book को कम से कम रखने का pressure है to minimise the MRP/- लेकिन circuit analysis के सवाल हम भर-भर कर practice करेंगे। (Bcz it's vry imp)

अबे ready हो ना मुझे ऐसा लग रहा है ये तुमी 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)

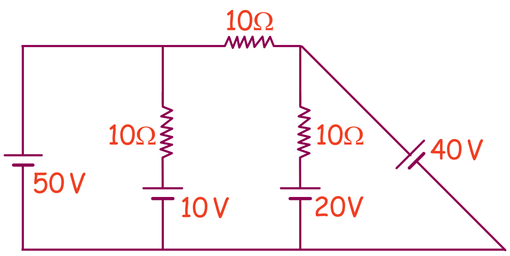
Q. Find current in each resistors.



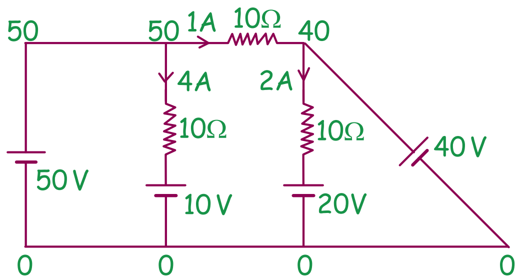
Sol.



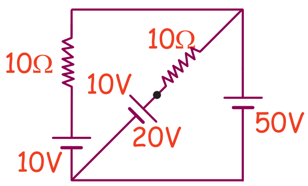
Q. Find current in each resistors.



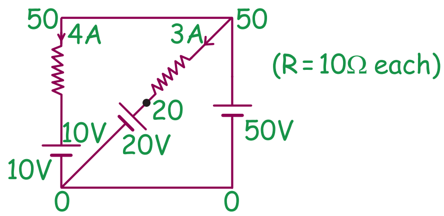
Sol.



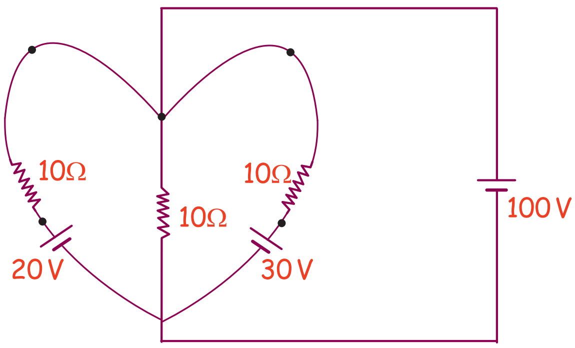
Q. Find current in each resistors.



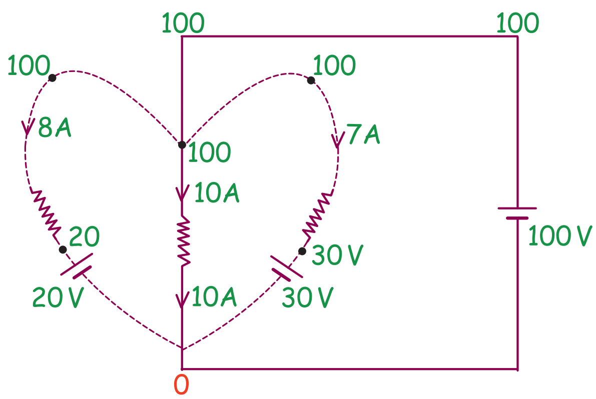
Sol.

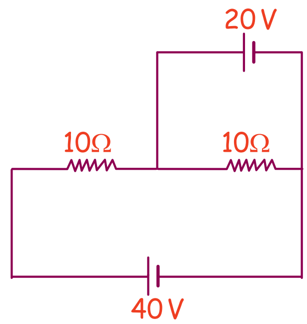


Q. Find current in each resistors.

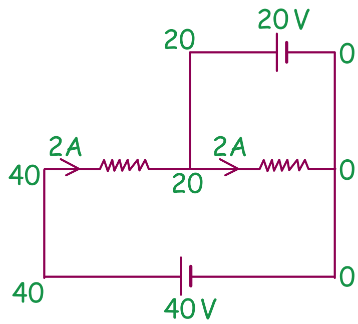


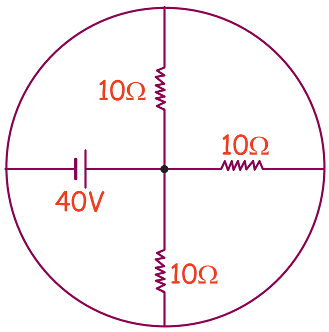
Sol.



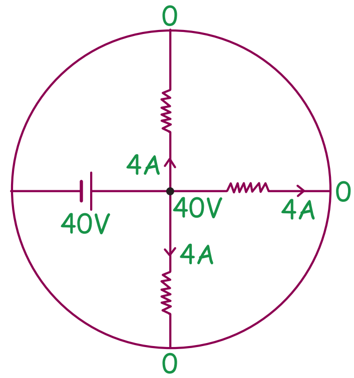


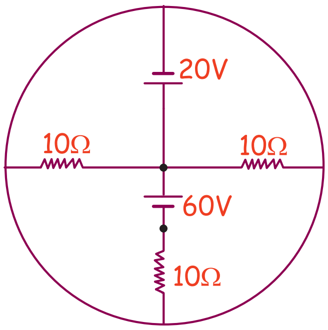
Sol.



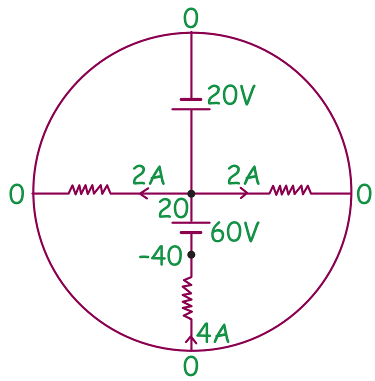


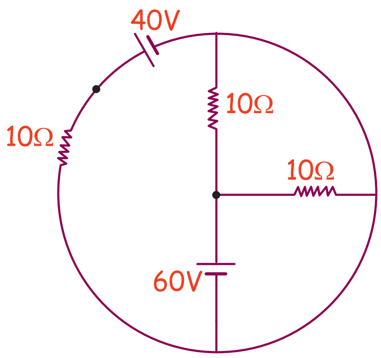
Sol.



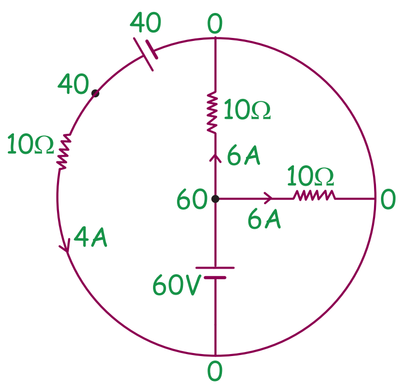


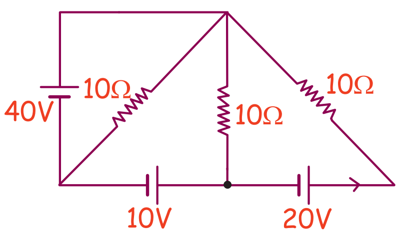
Sol.



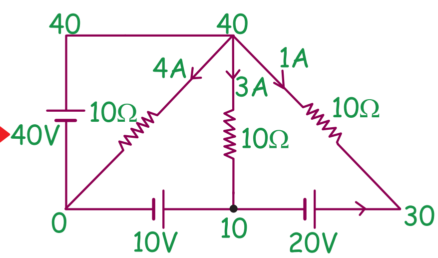


Sol.

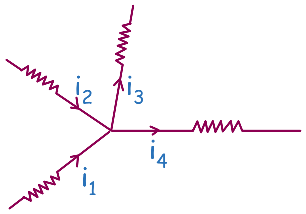




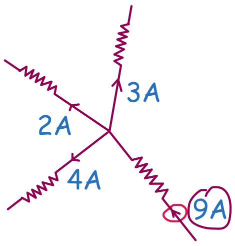
Sol.



JUNCTION LAW



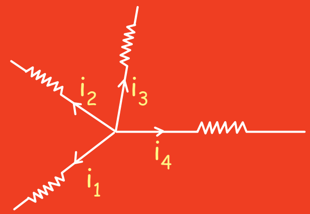
$i_1 + i_2 = i_3 + i_4$ (आने वाली = जाने वाली)



OR

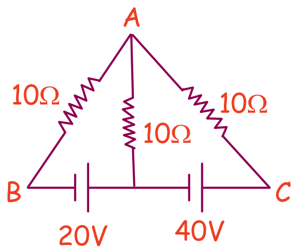
#SKC

किसी भी junction से total जाने वाला current का sum = 0

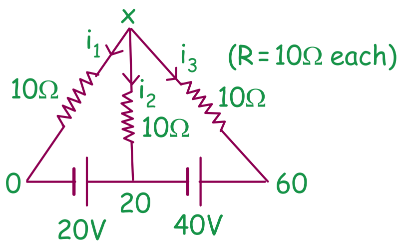


$i_1 + i_2 + i_3 + i_4 = 0$ (junction law)

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 नही बता सकते, हम फँस गए.......

जहाँ फँस जाओ वहाँ EX को याद करो.......

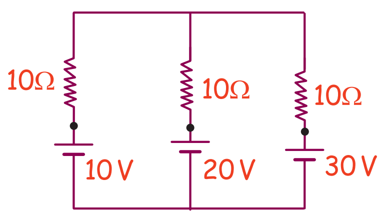
अबे emotional मत हो I mean जहाँ फँसे वहाँ potential X मान लो और junction law लगादो

$i_1 + i_2 + i_3 = 0$

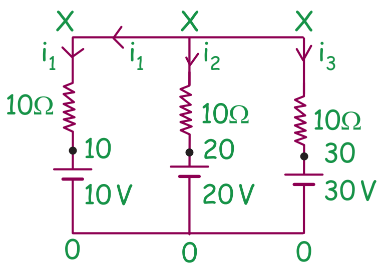
$$\frac{x-0}{10} + \frac{x-20}{10} + \frac{x-60}{10} = 0$$

$$x = \boxed{\frac{80}{3}}$$

Q. Find current through each resistance.



Sol.



$i_1 + i_2 + i_3 = 0$

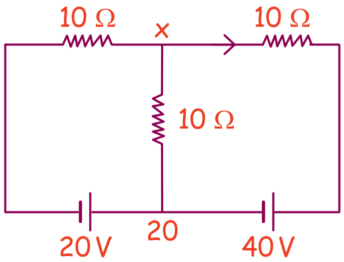
$$\frac{x-10}{10} + \frac{x-20}{10} + \frac{x-30}{10} = 0$$

$x = 20$

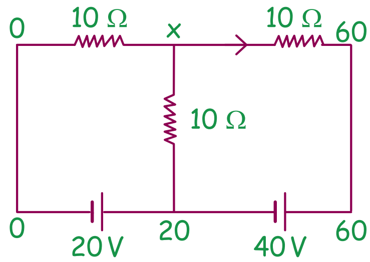
now we can find current though any wire

$$i_1 = \frac{x-10}{10} = 1A \text{ and } i_2 = \frac{x-20}{10} = 0$$

Q. Find current through each resistors.



Sol.

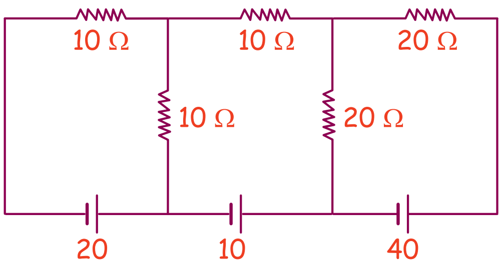


$i_1 + i_2 + i_3 = 0$

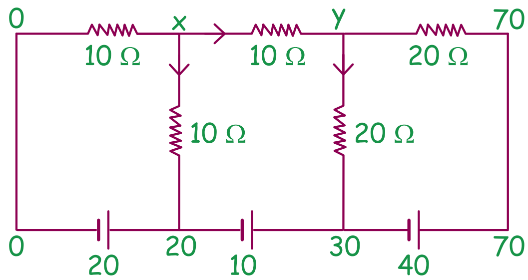
$$\frac{x-0}{10} + \frac{x-20}{10} + \frac{x-60}{10}$$

$$x = \frac{80}{3}$$

Q. Find potential (x).



Sol.



$$\frac{x-0}{10} + \frac{x-20}{10} + \frac{x-y}{10} = 0$$

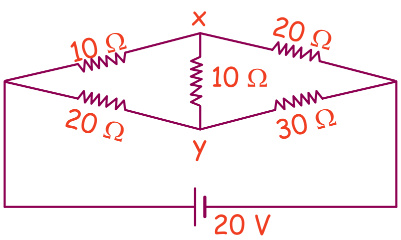
$3x - y = 20$ ...(1)

$$\frac{y-x}{10} + \frac{y-30}{20} + \frac{y-70}{20} = 0$$

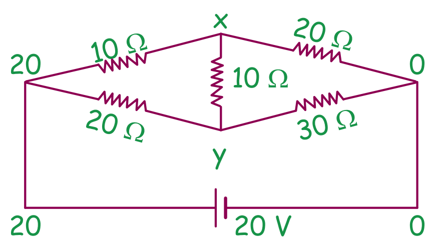
$4y - 2x = 100$ ...(2)

Now we solve both eqn. and get answer

Q. Find $V_x - V_y = ?$



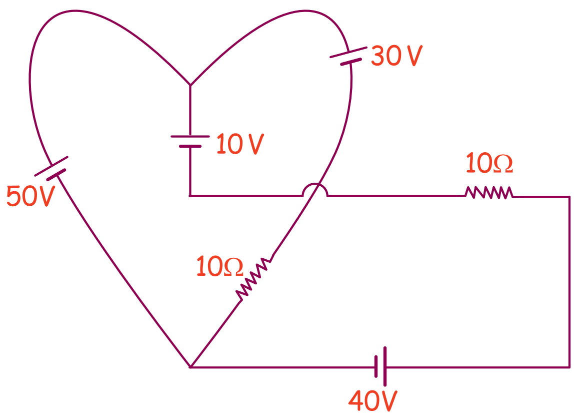
Sol.



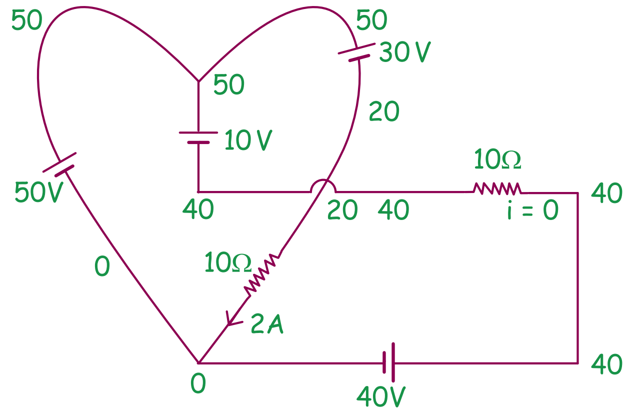
$$\frac{x-20}{10} + \frac{x-y}{10} + \frac{x-0}{20} = 0$$

$$\frac{y-20}{20} + \frac{y-x}{10} + \frac{y-0}{30} = 0$$

Q. Find current through each resistors.

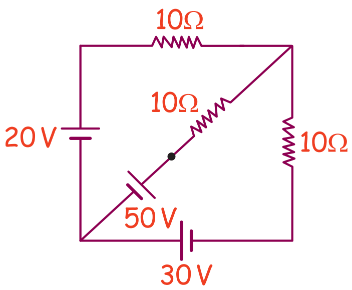


Sol.

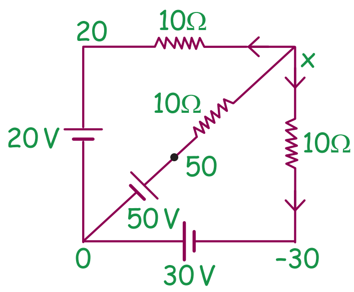


v = iR

Q. Find current through each resistors.



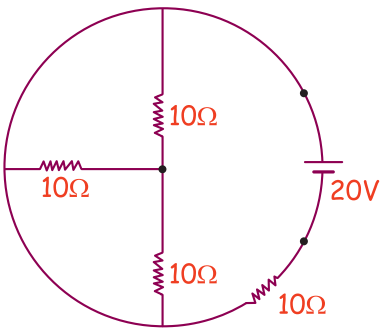
Sol.



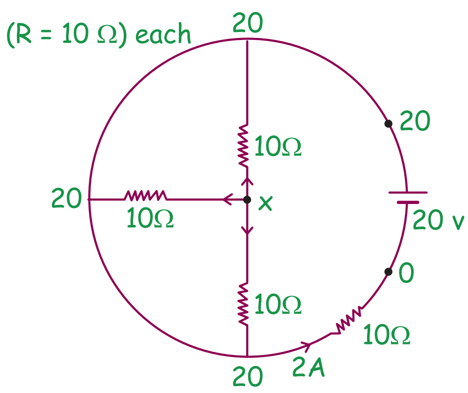
$$\frac{x-20}{10}+\frac{x-50}{10}+\frac{x+30}{10}=0$$

$$x=\frac{40}{3}$$

Q. Find current through each resistors.



Sol.

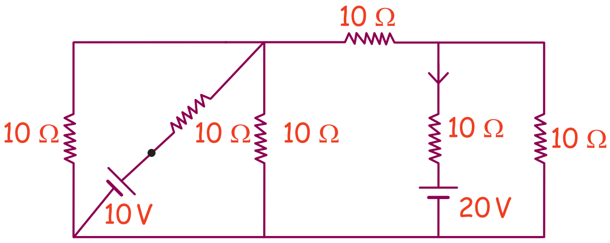


$$\frac{x-20}{10}+\frac{x-20}{10}+\frac{x-20}{10}=0$$

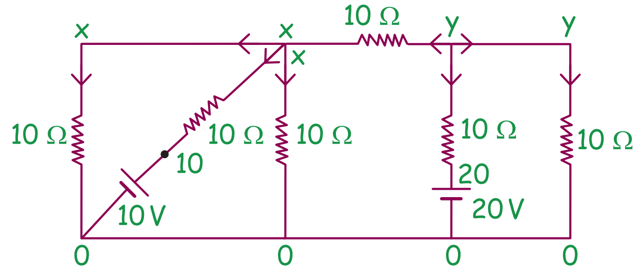
$x = 20$

$i_1 = i_2 = i_3 = 0$

Q. Find current through each resistors.



Sol.



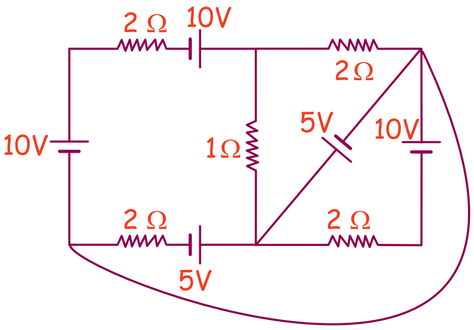
Apply junction law at x

$$\frac{x-0}{10}+\frac{x-10}{10}+\frac{x-0}{10}+\frac{x-y}{10}=0$$

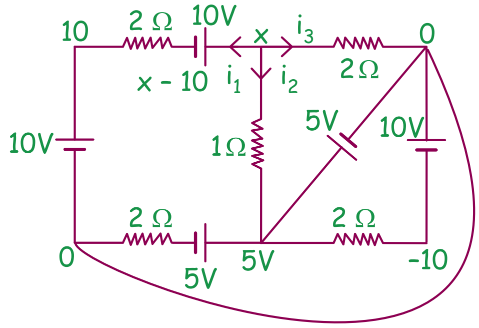
Apply junction law at y

$$\frac{y-x}{10}+\frac{y-20}{10}+\frac{y-0}{10}=0$$

Q. Find current through each resistors.



Sol.



$$\frac{x-10-10}{2}+\frac{x-5}{1}+\frac{x-0}{2}=0$$

$x - 20 + 2x - 10 + x = 0$

$4x = 30 = 7.5$

$$i_2=\frac{x-5}{1}=7.5-5=2.5$$

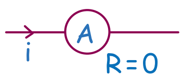
#SKC

ideal Amm का Resistance
⇒ Zero

ideal Voltmeter का Resistance ⇒ ∞

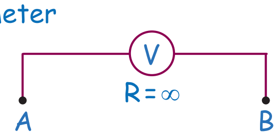
क्योंकी हम चहते है A V का
इस्तेमाल करते वक्त circuit
ना बदले

+ Ideal Ammeter



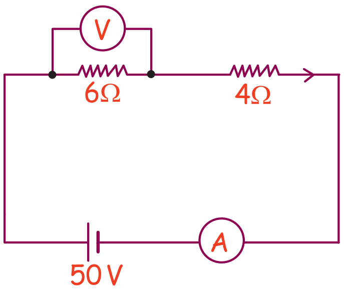
Reading = i

+ Ideal Voltmeter

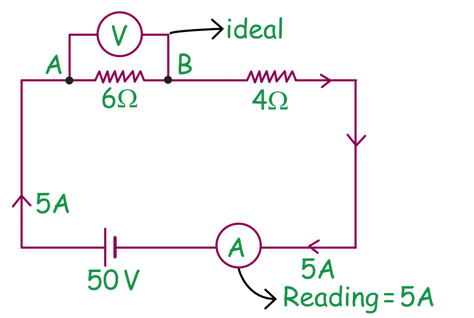


$|V_A - V_B| = \text{Reading}$

Q. Find the reading of ideal V & A

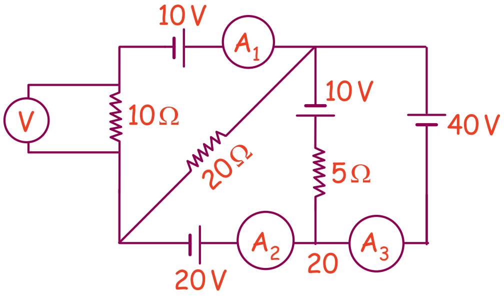


Sol.

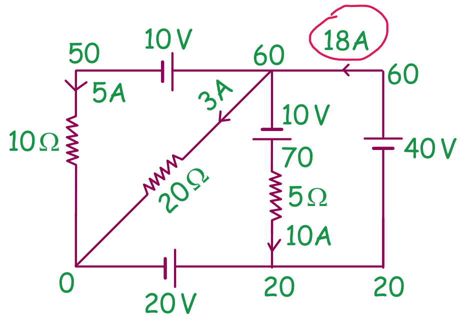


$V_A - V_B = 5 \times 6 = \text{Reading of voltmeter}$

Q. Find the reading of (A) & (V)



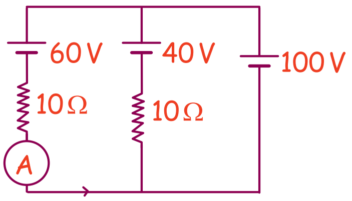
Sol.



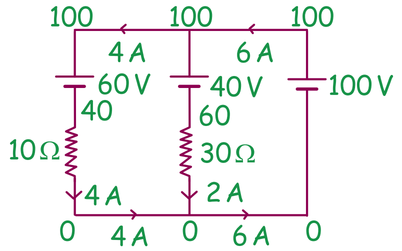
> Ammeter की reading मतलब उससे कितना current pass कर रहा है अगर ammeter ideal है तो उसे wire मान लो। voltmeter की reading मतलब जिन दो point के बीच उसे connect किया है उनके बीच potential difference अगर voltmeter ideal है तो उसके through i = 0

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)

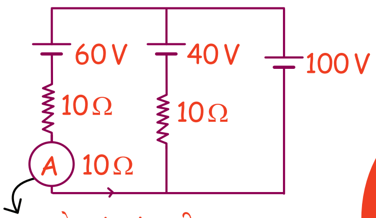


Sol.



Ans. 4 A

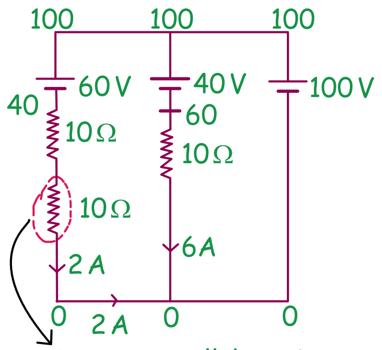
Q. What is the reading of non-ideal ammeter?



अब ये ideal नही रहा

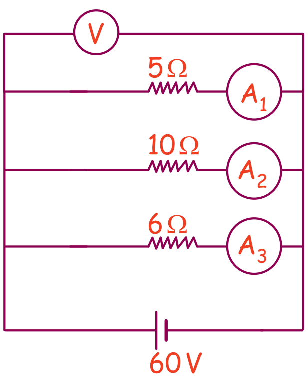
> #SKC
> अगर —(A)— —(V)— का Resistance given हो तो ये Non-ideal है।
> तो —(A)— —(V)— को हटाओ और Resistance रखदो

Sol.

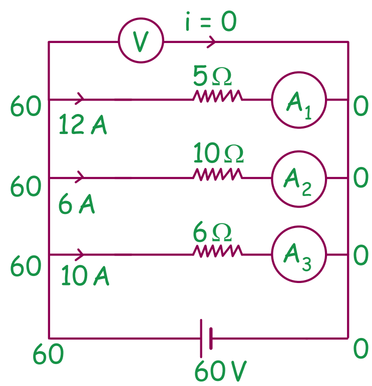


Ammeter wallah resistance

Q. What will be the readings?



Sol.

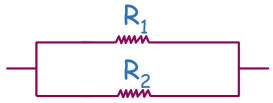


All are ideal:
Reading of (V) = 60V
Reading of (A_1) = 12A
Reading of (A_2) = 6A
Reading of (A_3) = 10A

If two resistance R_1 and R_2 are in parallel then

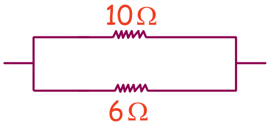
Parallel

$\Delta V \rightarrow$ same



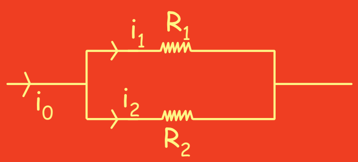
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{R_2 + R_1}{R_1 R_2}$$

$$R_{eq} = \frac{R_1 R_2}{R_2 + R_2} = \frac{\text{multiply}}{\text{sum}}$$

Q. 

Sol. $R_{eq} = \dfrac{10 \times 6}{10 + 6} = \dfrac{60}{16}$

#SKC



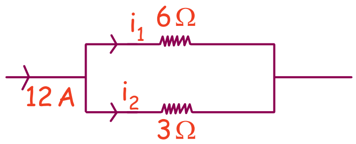
IMP

i_1 = सामने वाला 'R' × total current/total R

$$i_1 = \frac{R_2}{R_1 + R_2} \times i_0$$

$$i_2 = \frac{R_1}{R_1 + R_2} \times i_0$$

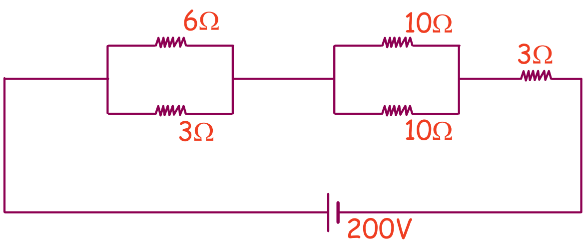
Q. Find i_1 and i_2



$$i_1 = \frac{3}{9} \times 12 = 4A$$

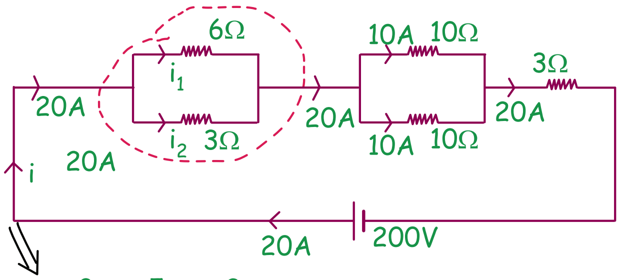
$$i_2 = \frac{6}{9} \times 12 = 8A$$

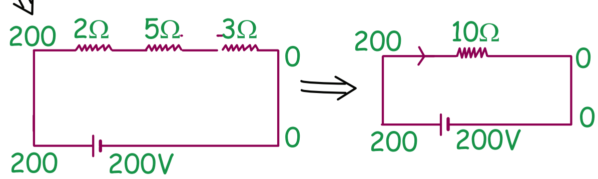
Q. Find current through each resistors.



Sol.

$$R_{eq} = \frac{\text{Multiply}}{\text{sum}}$$





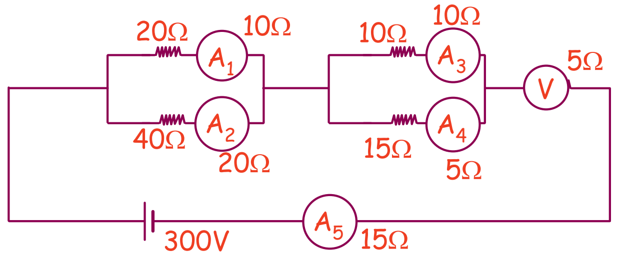
$R_{eq} = 2 + 5 + 3 = 10\Omega$

$$i = \frac{V}{R_{eq}} = \frac{200}{10} = 20A$$

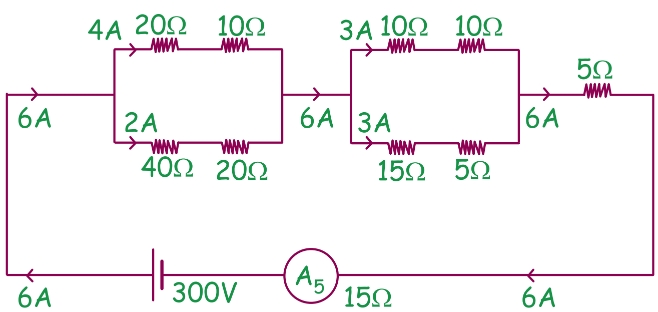
$$i_1 = \frac{3}{3+6} \times 20 = \frac{20}{3}$$

$$i_2 = \frac{6}{3+6} \times 20 = \frac{120}{9}$$

SSSQ. What will be reading of A_1 A_2 A_3 A_4 and V?



Sol.



Reading of $A_1 \rightarrow 4A$

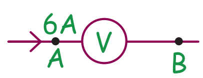
Reading of $A_2 \rightarrow 2A$

Reading of $A_3 \rightarrow 3A$

Reading of $A_4 \rightarrow 3A$

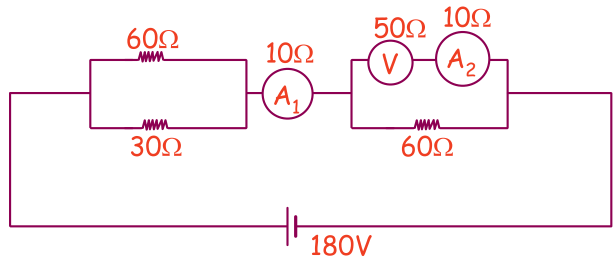
Reading of $A_5 \rightarrow 6A$

Reading of voltmeter = 6 × 5 = 30



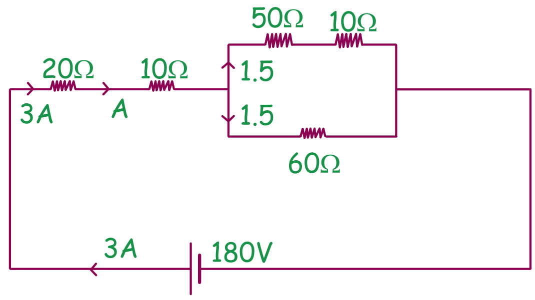
SSSQ. Saleem Sir Special Question

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 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

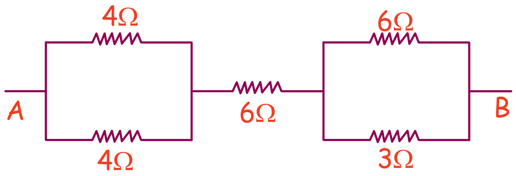
  $R_{eq} = R_1 + R_2 + R_3 + \ldots\ldots..$

- If resistance in parallel

  $R_{eq} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots\ldots$

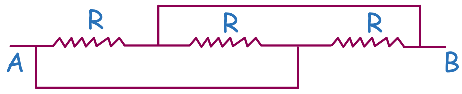
- If R_1 and R_2 are in parallel then $R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$

Q. Find R_{eq}

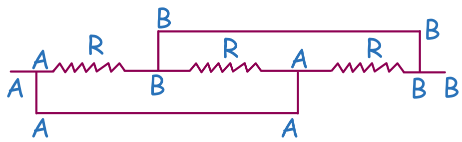


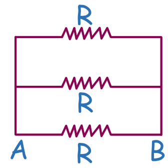
$R_{eq} = 2 + 6 + 2 = 10\Omega$

Q. Find R_{eq} between A and B.



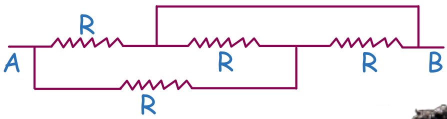
Sol.



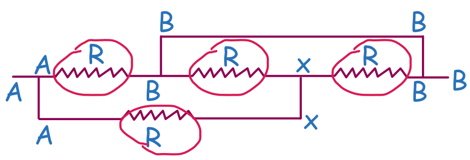


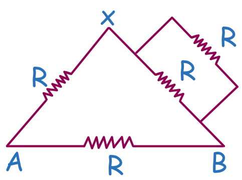
$$\frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} = \frac{3}{R} \qquad R_{eq} = R/3$$

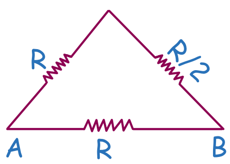
Q. Find R_{eq} between A and B.

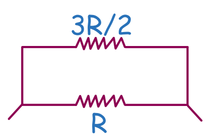


Sol. जहाँ फसो वहाँ x को याद करो और उसके खराब, बेकार, डरावनी सूरत को सूधार लो........ अबे मतलब नया circuit diagram बनाओ।



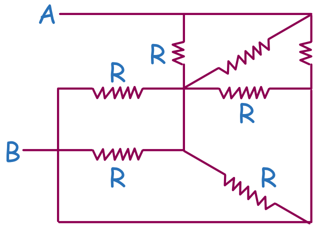






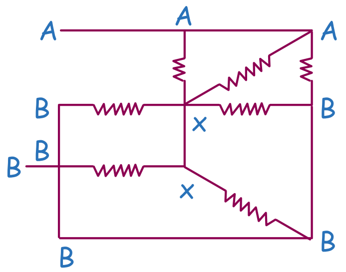
Ans. $R_{eq} = 0.6R$

Q. Find the R_{eq} between A and B.



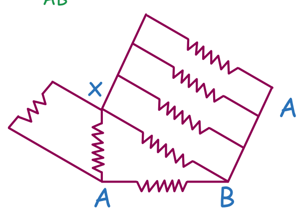
Sol.

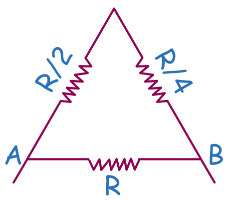
Resistance $R\Omega$ each



All resistance are equal $(R\Omega)$

$R_{AB} = ?$

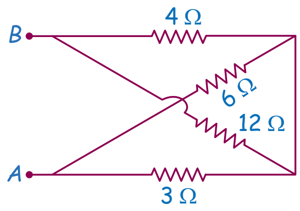




$$R_{eq} = \frac{\frac{3R}{4} \times R}{\frac{3R}{4} + R} = \frac{3}{7}R$$

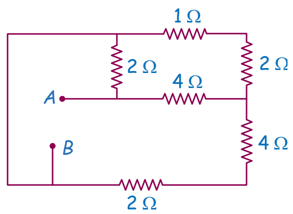
Homework

Q. In the given network, the equivalent resistance between A and B is



Ans. 5

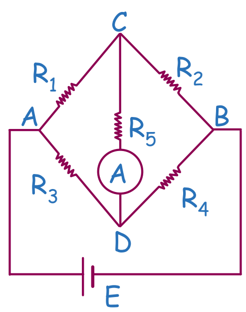
Q. In the circuit shown in figure, equivalent resistance between A and B is



Ans. 1.5

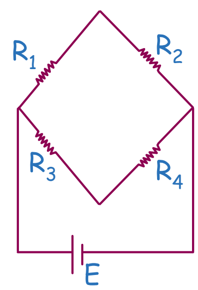
Wheatstone Bridge

☆ In following circuit

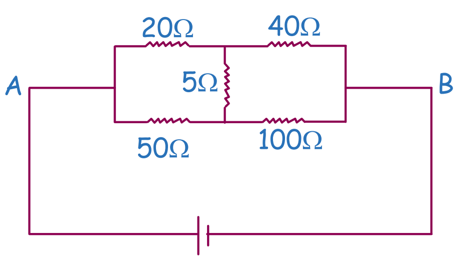


If $\frac{R_1}{R_2} = \frac{R_3}{R_4}$ then be observed that $V_C = V_D$ and current through R_5 is zero तो R_5 को circuit से उड़ा दो such type of circuit called balance wheatstone bridge

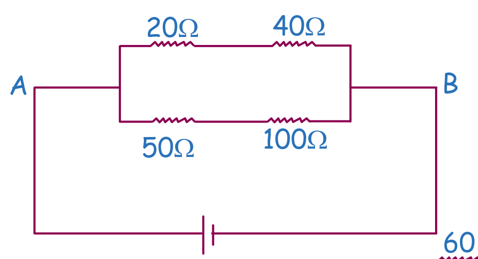
⇒

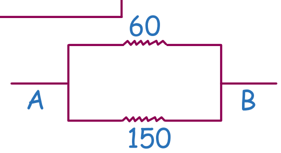


Q. Find R_{eq} between A & B



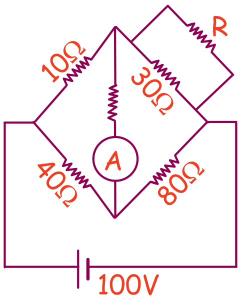
Sol.





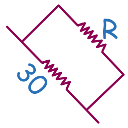
$$R_{AB} = \frac{60 \times 150}{210}$$

Q. Find value of R for which ammeter reading is zero



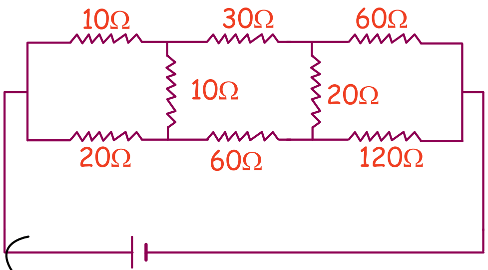
Sol. →

R = 60



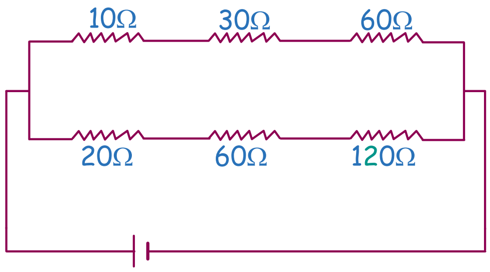
$\Rightarrow$ 20 Ω होना चाहिए

Q. Find equivalent resistance.

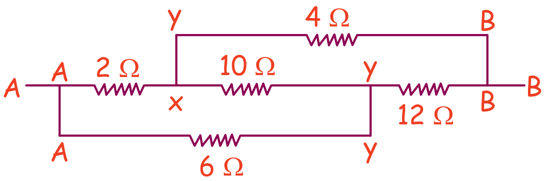


इसमे wheatstone Bridge छुपा है

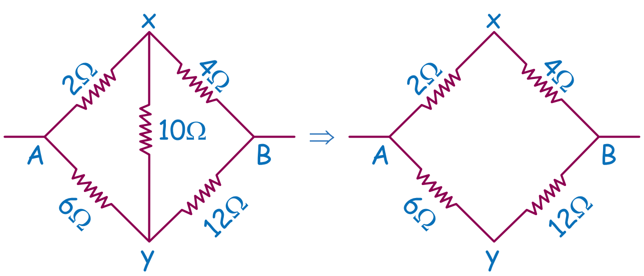
Sol. →



Q. find R_{AB} = ?



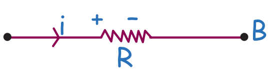
Sol.



$$R_{eq} = \frac{6 \times 18}{6 + 18} = \frac{6 \times 18}{24} = 4.5$$

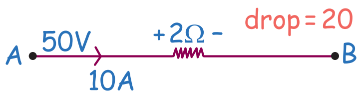
Kirchhoff Voltage Law (KVL)

$V_A - V_B = 10$



$V_A - V_B = iR$

$V_A - iR = V_B$



$V_A - iR = V_B$

$50 - 10 \times 2 = V_B$

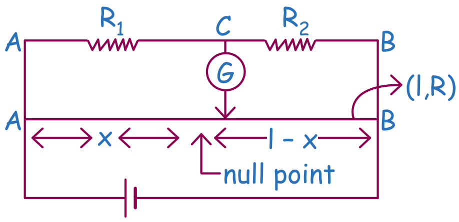
$V_B = 30$

Meter Bridge

- It is used to find unknown resistance.
- Its concept based on balance wheat stone bridge.
- When current through galvanometer is Zero.

$$\frac{R_1}{R_2} = \frac{R_{AD}}{R_{DB}} = \frac{x}{l - x} \qquad (l = 100 \text{ cm})$$

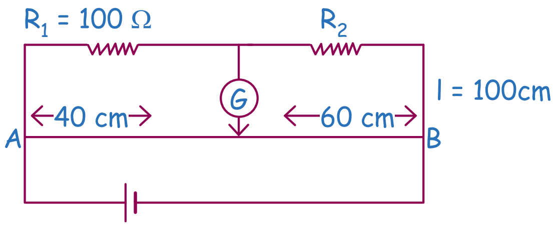
$$\boxed{\frac{R_1}{R_2} = \frac{x}{l - x}}$$



$$R = \frac{\rho l}{A}$$

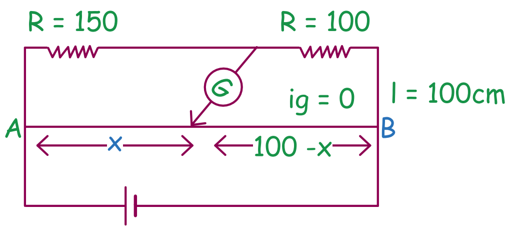
$R \propto$ length

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



Sol. $\dfrac{R_1}{R_2} = \dfrac{40}{60}$

$\dfrac{100}{R_2} = \dfrac{40}{60} \Rightarrow \boxed{R_2 = 150}$



$\dfrac{150}{100} = \dfrac{x}{100 - x}$

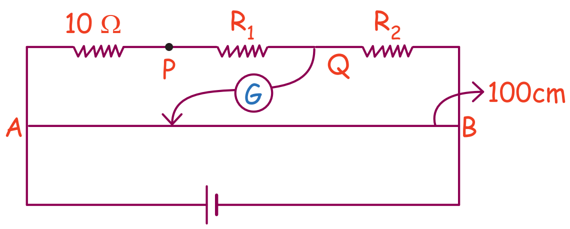
$\dfrac{3}{2} = \dfrac{x}{100 - x}$

$300 - 3x = 2x$

$x = 60$

Ans. shift = 60 – 40 = 20cm

Q. When galvanometer is connected to point P, null point at a distance 40cm. From point A when galvanometer is connected to point Q, null point is found at a distance 30cm from end B. Find R_1&R_2.



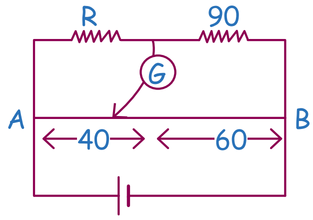
Sol. $\dfrac{10}{R_1 + R_2} = \dfrac{40}{60}$ ...(1)

$\dfrac{10 + R_1}{R_2} = \dfrac{70}{30}$ ...(2)

Solve and get $\boxed{R_1 = R_2 = 7.5\Omega}$

Q. In a meter Bridge find value of R if end correction are 1cm & 3cm at end A & end B

Sol.



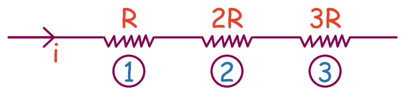
$\dfrac{R}{90} = \dfrac{40 + 1}{60 + 3}$

POWER DISSIPATED ACROSS RESISTANCE

- Power dissipated across the resistance = i^2R
- $P = V.i = iR.i = i^2R = \dfrac{V^2}{R}$
- $H = \int_0^t i^2R\,dt$
- If current is constant heat = i^2Rt

Q. Find the order of power dissipated across the resistance in following question.

(a)

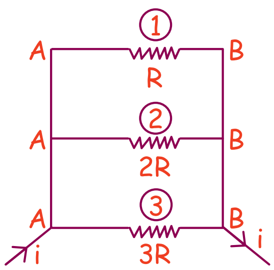


Sol. $P = i^2R$

R↑ = P↑ Power loss↑

$P_3 > P_2 > P_1$

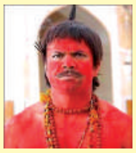
(b)



Sol. V → same

$P = \dfrac{V^2}{R}$ R↑ = P↓

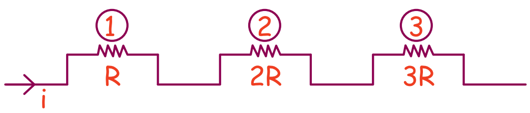
$P_3 < P_2 < P_1$



Student: sir ये बताओ कि कब $P = i^2R$ लगाना है कब $P = v^2/R$ लगाना है।

फिर भी अगर resistance series में है तो $P = i^2R$ 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.



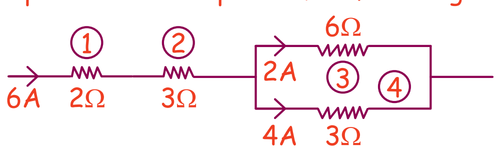
Sol. $i \rightarrow$ same $\qquad P = i^2R$

$P \rightarrow P_3 > P_2 > P_1$

Brig $\rightarrow B_3 > B_2 > B_1$

Bulb के case मे जिसके across power ↑ तो Brightness ↑

Q. Repeat the above problem in following case.



Sol. $P_1 = 6^2 \times 2 = 72$

$P_2 = 6^2 \times 3 = 108$

$P_3 = 2^2 \times 6 = 24$

$P_4 = 4^2 \times 3 = 48$

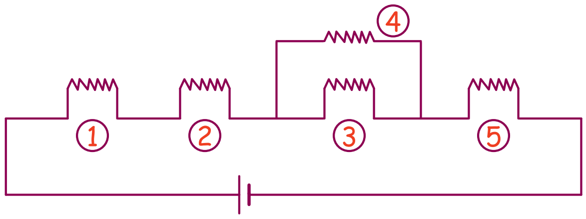
$P_2 > P_1 > P_4 > P_3$

Brightness $B_2 > B_1 > B_4 > B_3$

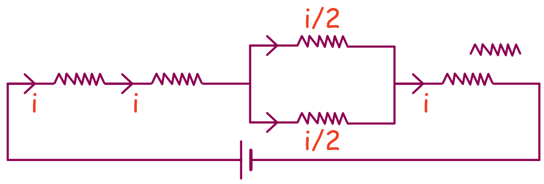
Q. Compare brighten of bulb

All are identical bulb

$R \rightarrow$ same

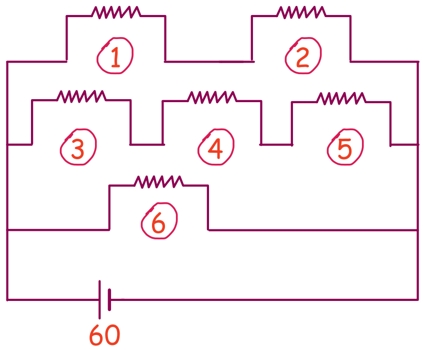


Sol.

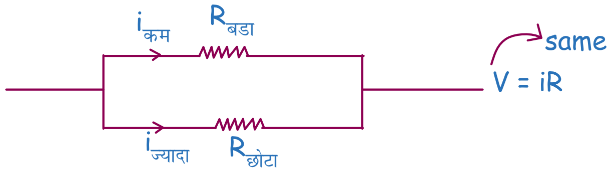


$B_1 = B_2 = B_5 > B_4 = B_3$

Q. All bulbs are indentical having same resistance 10Ω. Find order of brightness

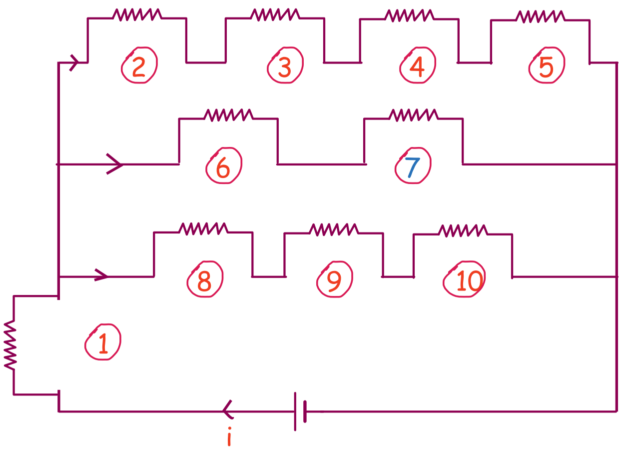


Sol. $B_6 > B_1 = B_2 > B_3 = B_4 = B_5$



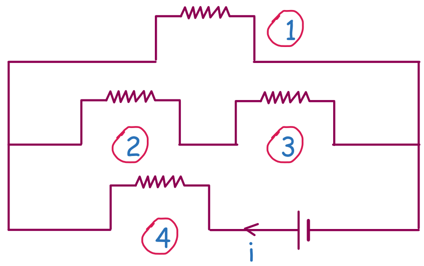
Q. All are identical

(a)



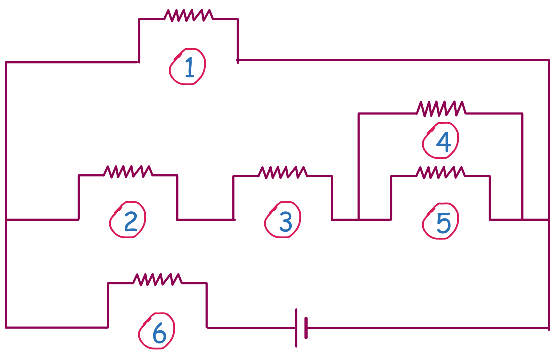
Sol. $B_1 > B_6 = B_7 > B_8 = B_9 = B_{10} > B_2 = B_3 = B_4 = B_5$

(b) All bulbs are identical



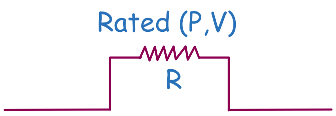
Sol. $B_4 > B_1 > B_2 = B_3$

(c)



Sol. $B_6 > B_1 > B_2 = B_3 > B_4 = B_5$

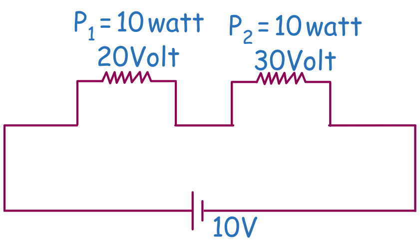
Bulb



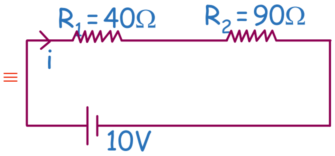
Suppose it's given that rated voltage of bulb is V and rated power is P it means यह bulb का resistance देने का तरीका है

Resistance of bulb = $\frac{V^2}{P}$

Q. Compare brighter of bulbs.



≡



Sol. $R = \frac{V^2}{P} \Rightarrow R_1 = \frac{(20)^2}{10} = 40\Omega$

$i = \frac{10}{130}$

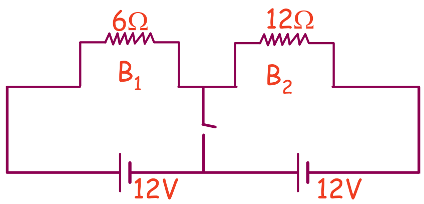
$R_2 = \frac{(30)^2}{10} = 90\Omega$

Power across $B_1 = i^2R_1 = (1/13)^2 \times 40$

$B_2 = i^2R_2 = (1/13)^2 \times 90$

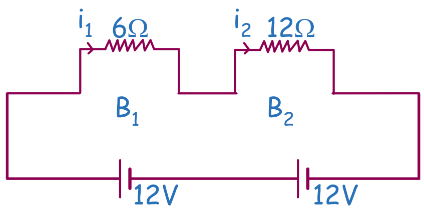
$B_2 > B_1$ (or $i \to$ same $\Rightarrow$ जिसका R↑ उसकी P↑B↑).

Q. B_1 and B_2 are bulbs. What happens to brightness of bulbs after switch close?



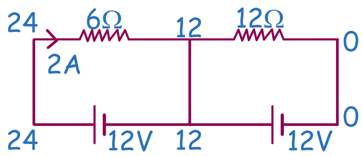
1. Brightness of B_1 inc
2. Brightness of B_1 dec
3. Brightness of B_2 inc
4. Brightness of B_2 dec

Sol. Before switch is close



$i_1 = i_2 = 1.33$

Now after switch is closed.



$i_1 = 2$ 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 decrease. Hence power across bulb 2 decrease.

Ans: 1 & 4

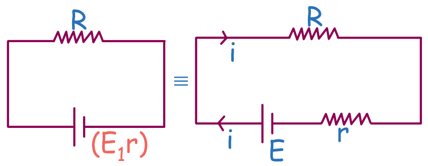
- When connected voltage and rated voltage are same then total power dissipated for n number of bulbs in series,

$$\frac{1}{P_T}=\frac{1}{P_1}+\frac{1}{P_2}+\frac{1}{P_3}+.....+\frac{1}{P_n}$$

- When connected voltage and rated voltage are same then total power dissipated for n number of bulbs in parallel,

$$P_T=P_1+P_2+P_3+......+P_n$$

Max Power Theorem



Power dessipited across R = $i^2R=\left(\frac{E}{R+r}\right)^2R$

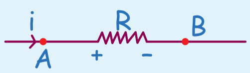
$$P=\frac{E^2R}{(R+r)^2}$$

At what condition $P\rightarrow$ max

Do $\frac{dP}{dR}=0$ $\Rightarrow$ 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 मे iR का drop)

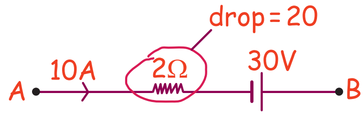
$V_A - V_B = E$

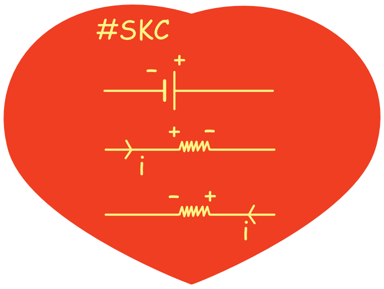
(irrespective of dir^n of current)

$V_B - V_A = E$

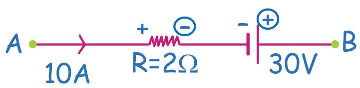
(चाहे current हो या ना हो या कही भी हो)

Q. Find $V_A - V_B$

(a)


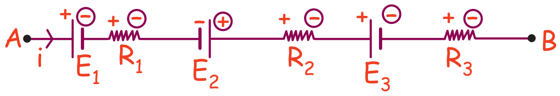


Sol.



$$\boxed{V_A - iR + E = V_B}$$

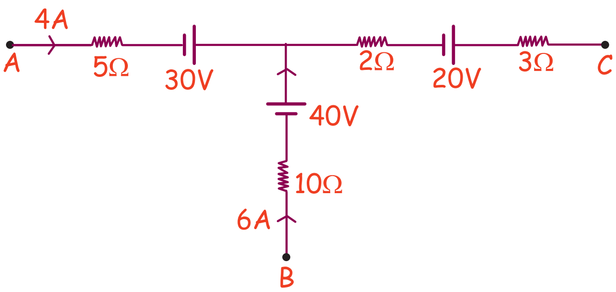
$$V_A - 20 + 30 = V_B$$
$$V_A - V_B = -10$$

(b)


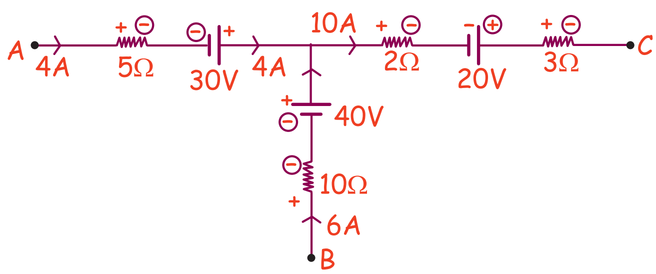
Sol. $V_A - E_1 - iR_1 + E_2 - iR_2 - E_3 - iR_3 = V_B$

$V_A - V_B = \checkmark$

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) $V_A - V_B = ?$

$V_A - 20 + 30 - 40 + 6 \times 10 = V_B$

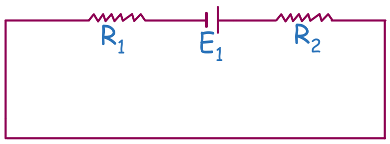
$V_A - V_B = -30$

(3) $V_B - V_C = ?$

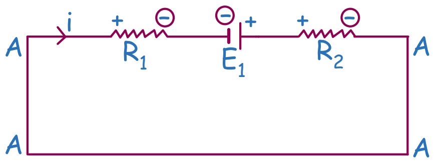
$V_B - 60 + 40 - 20 + 20 - 30 = V_C$

$V_B - V_C = 50$

Q. Find current in the circuit.



Sol.

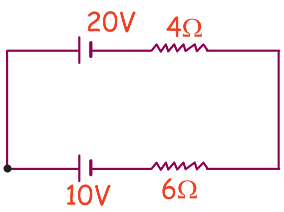


$V_A - iR_1 + E_1 - iR_2 = V_A$

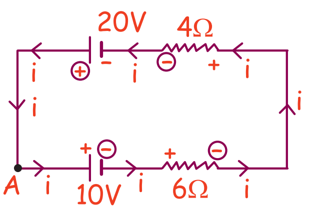
$E_1 = iR_1 + iR_2$

$$\boxed{i = \frac{E_1}{R_1 + R_2}}$$

Q. Find current in the circuit.



Sol.



थोड़ी देर के बाद हम देखेंगे 20 V battery is discharging and 10 V batter is charging in this case.

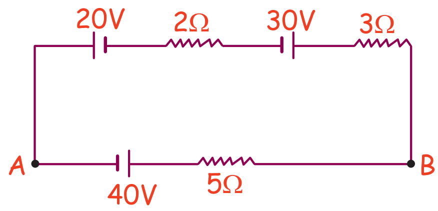
$V_A - 10 - 6i - i \times 4 + 20 = V_A$

$-10 - 10i + 20 = 0$

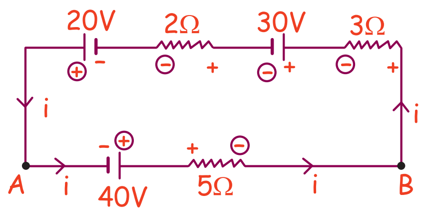
$i = 1A$

Q. (1) Find current in circuit

(2) $V_A - V_B = ?$



Sol.



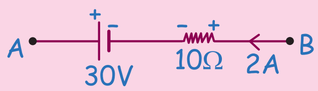
(1) i→ Acw मान लो (let)

$V_A + 40 - 5i - 3i - 30 - 2i + 20 = V_A$

$i = 3A$

(2) $V_A + 40 - 3 \times 5 = V_B$

$\boxed{V_A - V_B = -25}$

✦ 

1. A से B चलते है

$V_A - 30 + 2 \times 10 = V_B$

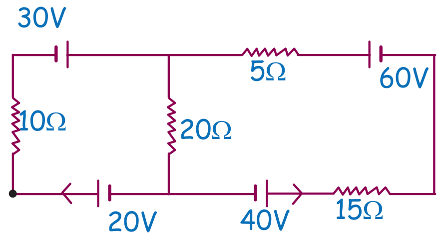
$V_A - V_B = 10V$

2. B से A चलते है

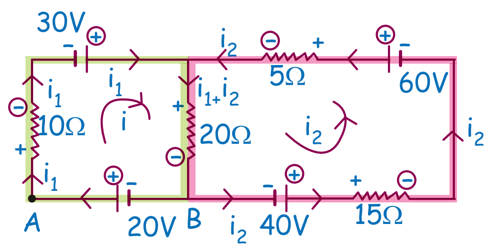
$V_B - 2 \times 10 + 30 = V_A$

$V_A - V_B = 10$

Q. Find current in each in each resistors



Sol.



$V_A - 10i + 30 - (i_1 + i_2) \times 20 + 20 = V_A$

$-10i_1 + 30 - (i_1 + i_2) \times 20 + 20 = 0$ ...(1)

$VB + 40 - 15i_2 + 60 - 5i_2 - (i_1 + i_2) \times 20 = VB$

$40 - 15i_2 + 60 - 5i_2 - (i_1 + i_2) \times 20 = 0$ ...(2)

Solve (1) & (2) And get Ans:

Charging & Discharging of Batteries

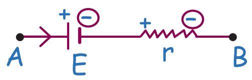
#SKC

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

Discharge of battery

Charging of battery

Charging of battery



$V_A - E - ir = V_B$

$V_A - V_B = E + ir$

(Pot diff across battery, terminal voltage)

Discharging of battery

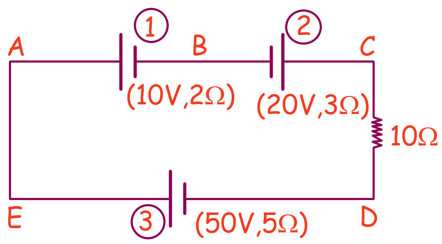
$V_A - E + ir = V_B$

$V_A - V_B = E - ir$

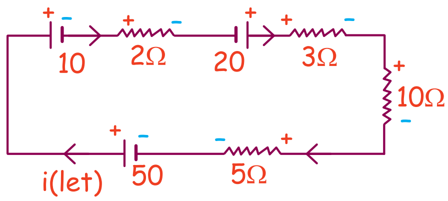
(Pot diff across battery, terminal voltage)

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



Sol.



$V_A - 10 - 2i + 20V - 3i - 10i - 5i + 50 = V_A$

$60 = 2i$

$\boxed{i = 3A}$

(1) → Charging 2, 3 → discharge

Potential diff across each battery

$|V_{AB}| = E + ir = 10 + 3 \times 2 = 16V$

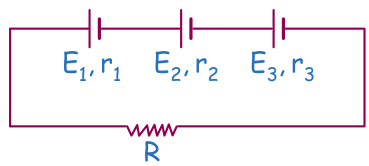
$|V_{BC}| = |E - ir| = |20 - 3 \times 3| = 11V$

$|V_{ED}| = |50 - 3 \times 5| = 35$

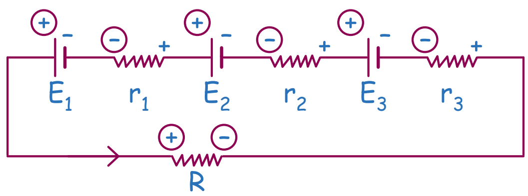
#SKC

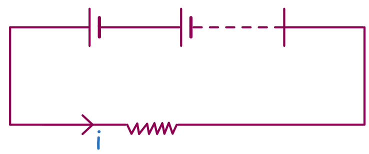
Battery के internal resistance से बिलकुल नही डरना है बस battery के बाजू मे उतना resistance लगा देना है

Q. Find current in circuit



Sol.



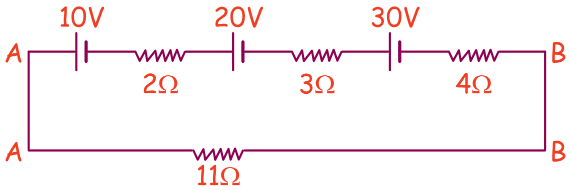


$-iR - iR_3 + E_3 - iR_2 + E_2 - iR_1 + E_1 = 0$

$$i = \frac{E_1 + E_2 + E_3}{r_1 + r_2 + r_3 + R}$$

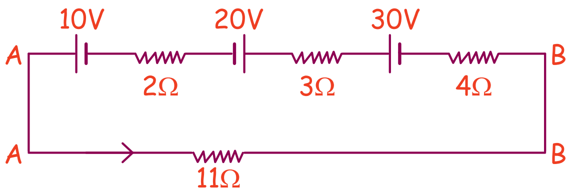
$$i = \frac{E_1 + E_2 + \ldots}{(r_1 + r_2 + \ldots) + R}$$

Q. Find current in circuit



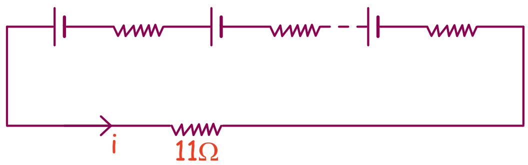
Sol. $i = \dfrac{10+20+30}{2+3+4+11}$ $\quad V_{AB} = \checkmark$

Q. Find current in circuit



Sol. $i = \dfrac{10-20+30}{2+3+4+11}$

Q. (a) n indentical cells are connected in series as shown in diagram. Find i through R



Sol. $i = \dfrac{E+E+\ldots}{(r+r+r\ldots)R} = \dfrac{nE}{nr+R}$

(b) If one cell is reversed find current in R

Sol. $\boxed{i = \dfrac{nE-2E}{nr+R}}$

(c) If m battery reversed

Sol. $i = \dfrac{nE-2mE}{nr+R} = \dfrac{(n-2m)E}{nr+R}$

Results

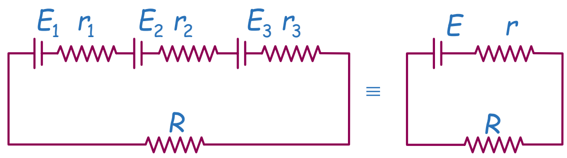
(i) Series Combination

If n sources of emf are connected in series with same polarity, then the equivalent emf is given by

$E = E_1 + E_2 + E_3 + \ldots\ldots + E_n$

And, total internal resistance is

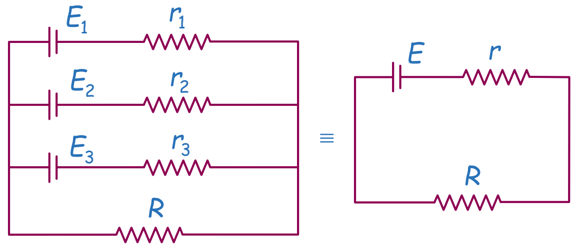
$r = r_1 + r_2 + r_3 + \ldots\ldots\ldots + r_n$



- 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,

$E_{net} = (n-2p)E$ and $r_{net} = nr$

(ii) Parallel Combination



The emf and internal resistance of the equivalent battery are given by

$$E = \dfrac{\dfrac{E_1}{r_1}+\dfrac{E_2}{r_2}+\dfrac{E_3}{r_3}}{\dfrac{1}{r_1}+\dfrac{1}{r_2}+\dfrac{1}{r_3}}$$

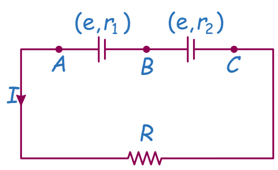
and $\dfrac{1}{r} = \dfrac{1}{r_1}+\dfrac{1}{r_2}+\dfrac{1}{r_3}$

मेरे सपने में आई सुन्दर परी..........

And नीचे वाला questions is compulsory

Q. Two batteries having the same emf ε 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

$I = \dfrac{2\varepsilon}{(r_1 + r_2 + R)}$

The potential difference between the terminals of first battery is $(V_A - V_B)$. Terminal potential difference is given by

$(V_A - V_B) = \varepsilon - Ir_1$

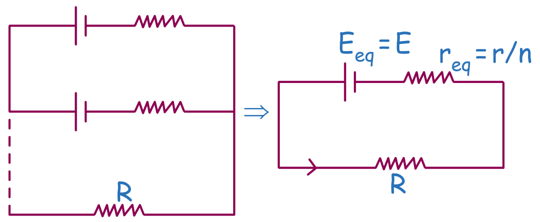
$$V_A - V_B = \varepsilon - \frac{2\varepsilon r_1}{r_1 + r_2 + R} = \varepsilon\frac{(R + r_2 - r_1)}{(R + r_2 + r_1)}$$

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



$$i = \frac{E}{\frac{r}{n} + R}$$

$$E_{eq} = \frac{E/r + E/r + \dots \text{ n times}}{1/r + 1/r + \dots \text{ n times}}$$

$\boxed{E_{eq} = E}$

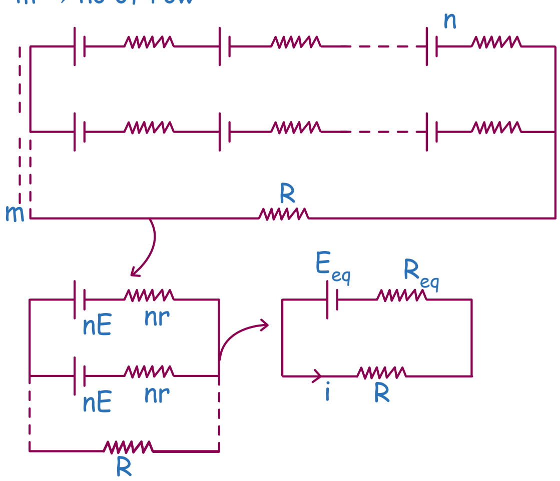
$$\frac{1}{Req} = \frac{1}{r} + \frac{1}{r} + \dots \text{ n times}$$

$\boxed{req = \frac{r}{n}}$

✦ Mixed Grouping

n identical cell in row in series

m → no of row



net emf = nE

Total internal resistance = $\frac{nr}{m}$

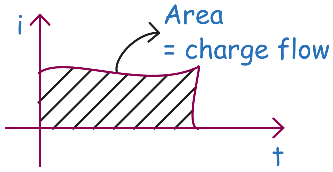
$$i = \frac{nE}{\frac{nr}{m} + R}$$

अब हम पढ़ेंगे वो चीज जो सारी दुनिया इस chapter मे सबसे पहले पढ़ती है।

Current Electricity

Current = $i = \frac{dq}{dt}$ = Rate of flow of charge

$\Delta q = \int i dt$



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.

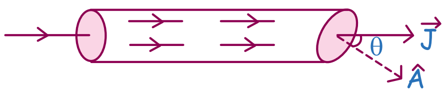
Current Density

✦ 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

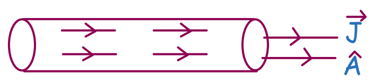


$i = \vec{J}.\vec{A} = JA\cos\theta$

$\Rightarrow \quad J = \frac{i}{A\cos\theta}$

For special case

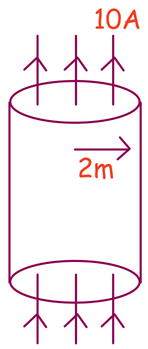
$\theta = 0$



$i = JA \Rightarrow \boxed{J = \frac{i}{A}}$

$i = \int \vec{J} . d\vec{A}$ अगर J बदला तो we will use this

Q.

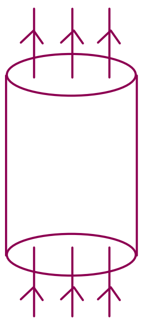


Sol. $\vec{J} = \frac{10}{\pi 2^2}\hat{i}$

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

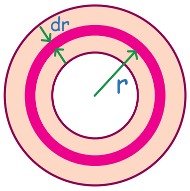
$\boxed{\text{Current density का flux} = \int \vec{J} \cdot d\vec{A} = i}$

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।

Top view



$di = \vec{J} \cdot d\vec{A}$

$\int di = \int_0^R J_0 r 2\pi r . dr$

$i = J_0 2\pi \frac{R^3}{3}$

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 λ.

Mean free path $\lambda = \frac{\text{total distance travelled}}{\text{number of collisions}}$

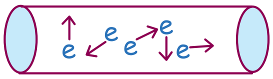
Relaxation Time

The time taken by an electron between two successive collisions is called as relaxation time τ. ($\tau \sim 10^{-14}$ 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



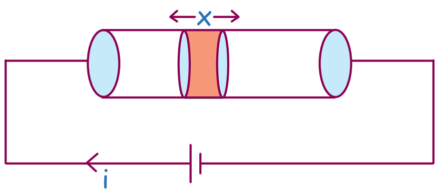
$\vec{u}_1 + \vec{u}_2 + \vec{u}_3 + \ldots \vec{u}_A = 0$

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 carries 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^m



$i = \frac{\Delta q}{\Delta t}$ $\quad \Delta q = nAxe$

$i = \frac{nAxe}{x/v_d} = nAev_d$

Charge on electron

$i = neAV_d \rightarrow$ Drift velocity

Area of cross section

No. of free e^- per unit vol^m

Derivation for Drift Velocity, J

$$\vec{v}_1 = \vec{u}_1 + \vec{a}\tau_1$$

where, $\vec{a}$ = acceleration of electron = $\dfrac{-e\vec{E}}{m_e}$

τ = 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.

$$\vec{v}_d = \frac{\vec{v}_1 + \vec{v}_2 + \vec{v}_3 \ldots\ldots\ldots \vec{v}_n}{n}$$

$$= \frac{(\vec{u}_1 + \vec{a}\tau_1) + (\vec{u}_2 + \vec{a}\tau_2) + \ldots\ldots(\vec{u}_n + \vec{a}\tau_n)}{n}$$

$$= \left(\frac{\vec{u}_1 + \vec{u}_2 + \vec{u}_3 + \ldots \vec{u}_n}{n}\right) + \vec{a}\left(\frac{\tau_1 + \tau_2 + \tau_3 + \ldots \tau_n}{n}\right)$$

Since average thermal speed = 0

So, $\dfrac{\vec{u}_1 + \vec{u}_2 + \vec{u}_3 + \ldots \vec{u}_n}{n} = 0$ and

$\dfrac{\tau_1 + \tau_2 + \tau_3 + \ldots \tau_n}{n} = \tau =$ average relaxation time.

So, $\vec{v}_d = \vec{a}\tau \quad \Rightarrow \quad \vec{v}_d = \dfrac{-e\vec{E}}{m_e}(\tau)$

Where,

$\vec{v}_d$ = Drift velocity of electrons

$\vec{E}$ = Electric field applied

m_e = Mass of electron

τ = Average relaxation time

The direction of drift velocity for electrons in a metal is opposite to that of applied field $\vec{E}$.

$$i = V_d enA = \left(\frac{eE}{m}\right)\tau\, enA = \frac{eV}{ml}\tau\, enA$$

$$i = \frac{e^2\tau nvA}{ml} = \frac{v}{\left(\dfrac{ml}{\tau e^2 nA}\right)} = \frac{V}{R} = \frac{\Delta V}{R}$$

$$E = \frac{V}{l} = \frac{\text{Pot. diff}}{\text{length}}$$

$\Delta V = iR$
Ohm's Law

and

$$i = V_d enA$$

$$\frac{i}{A} = V_d en = \frac{eE}{m}\tau en$$

$$J = \frac{e^2\tau n}{m}E = \sigma E$$

$$\vec{J} = \sigma\vec{E}$$

$$\text{mobility} = \mu = \frac{\text{Drift velocity}}{\text{E.F}}$$

$$\mu = \frac{V_d}{E}$$

$\Delta V = iR$ (ohm's law)

substance which follow ohm's law called ohmic structure.

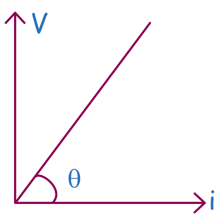
$$\frac{1}{\rho} = \sigma = \frac{\tau e^2 n}{m} = \text{conductivity}$$

$$R = \frac{\rho l}{A} = \frac{l}{\sigma A}$$

- $V = iR$
- $i = V_d enA$
- $v_d = \dfrac{eE}{m}\tau$
- $\vec{J} = \sigma\vec{E}$
- $R = \rho\dfrac{l}{A} = \dfrac{l}{\sigma A}$ (ρ = resistivity, σ = conductivity)
- $\dfrac{1}{\rho} = \sigma = \dfrac{\tau e^2 n}{m}$ = conductivity
- mobility = $\mu = \dfrac{\text{Drift velocity}}{\text{E.F}} = \dfrac{V_d}{E}$

सवाल आएगा तो इसी BOX से आऐगा।

- Ohm's law $i \propto V$



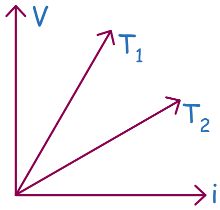
V = iR
y = mn

$i = \frac{V}{R}$ Electric Resistance

$\tan\theta = \frac{V}{i}$ = Resistance

As $T\uparrow \Rightarrow \; R\uparrow \Rightarrow$ slope$\uparrow$

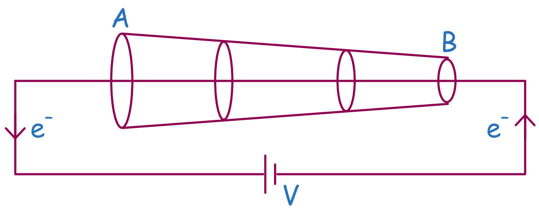
For a given material graph between ΔV & i is plotted at diff temp T_1&T_2



$(\text{Slope})_1 > (\text{Slope})_2$

$(T\uparrow, R\uparrow, \text{slope}\uparrow) \Rightarrow \; T_1 > T_2$

Q. As we move from right to left A to B analyse the question.



Sol. A to B $\Rightarrow$ Area of cross section decrease

$i = V_d enA$

1. Current $\rightarrow$ same
2. Current density $= \frac{i}{A} = J\uparrow$ (increase)
3. Electric field $= E\uparrow$ (increase bcz $\vec{J} = \sigma\vec{E}$)
4. Drift velocity $V_d\uparrow$ (increase bcz $V_d = \frac{i}{enA}$)

TEMP DEPENDENCY OF ρ & R

- $\rho = \rho_0(1 + \alpha\Delta T)$
- $R = R_0(1 + \alpha\Delta T)$
- $R = R_0[1 + \alpha(T - Ti)]$
- R_0 is the resistance at Temp T_1
- $T_1 = 0°C \Rightarrow R_0$ is resistance at 0°C
- For metal/conductor $\Rightarrow \alpha > 0$ $\quad T\uparrow, R\uparrow$
- For semi conductor $\Rightarrow \alpha < 0$ $\quad T\uparrow, R\downarrow$

Q. Value of resistance at 10° c is 50Ω and at 30°c is 60Ω Find resistance at 50°c

Sol. $R = R_0(1 + \alpha\Delta T)$

$50 = R_0[(1 + \alpha(10 - 0)]$

$60 = R_0[(1 + \alpha(30 - 0)]$

$60 + 600\alpha = 50 + 1500\alpha$

$\alpha = \frac{1}{90}$

$50 = R_0(1 + 1/90 \times 10)$

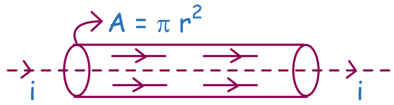
$R_0 = 45$

$R_f = R_0(1 + \alpha\Delta T)$

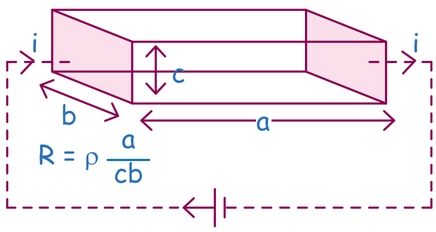
$= 45(1 + 1/90 \times (50 - 0))$

$= 45(1 + 5/9) = \frac{45 \times 14}{9}$

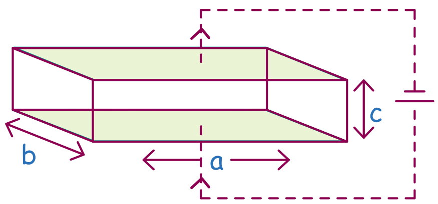
अब in following case में R_{eq} की अच्छे से practice करलो (apply smartly $R = \rho l/A$)

1. 

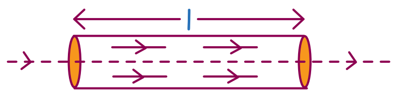
Solid Cylinder $R = \rho\frac{l}{\pi r^2}$

2. 

$R = \rho\frac{a}{cb}$

3. 

$R = \rho\frac{c}{ab}$

4. 

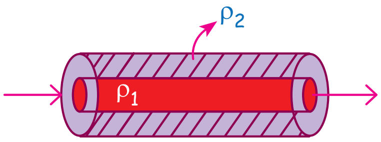
$R = \rho\frac{l}{A} = \rho\frac{l}{\pi r^2}$

5. 

$R = \rho\frac{l}{\pi(R_2^2 - R_1^2)}$

(R_1 is inner radius R_2 is outer radius)

6.

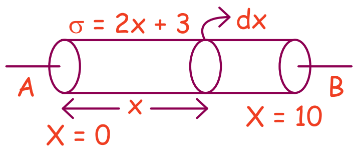


R_1 = R अदर = $\rho_1 \frac{l}{\pi R_1^2}$

R_2 = R 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



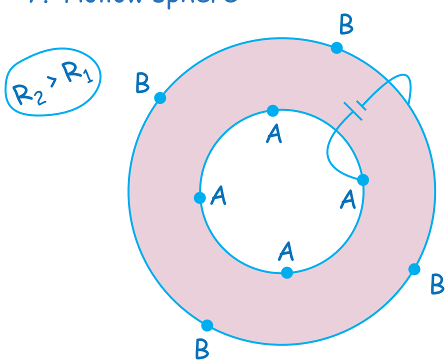
Sol. $= dR = \rho \frac{dx}{\pi r^2} = \frac{l}{\sigma} \frac{dx}{\pi r^2}$

$\int dR = \int \frac{1}{2x+3} \times \frac{dx}{\pi r^2}$

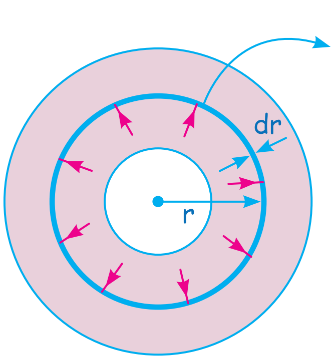
$R_{eq} = \frac{1}{\pi r^2} \int_0^{10} \frac{dx}{2x+3}$

Ans: $R = \frac{1}{\pi r^2 \times 2} \ln\left(\frac{23}{3}\right)$

7. Hollow sphere



$R_{eq} = \rho \frac{(R_2 - R_1)}{4\pi(R_1 R_2)}$



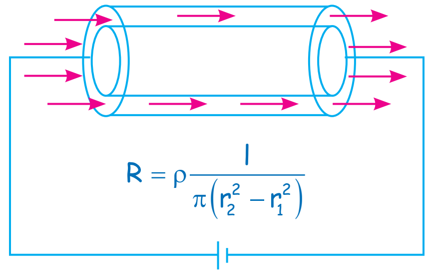
$\int dR = \int_{R_1}^{R_2} \rho \frac{dr}{4\pi r^2}$

$R_{net} = \frac{\rho}{4\pi}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$R_{net} = \frac{\rho(R_2 - R_1)}{4\pi R_1 R_2}$

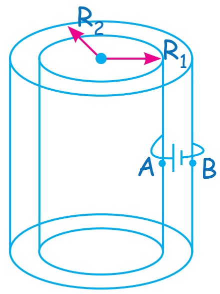
8. Hollow cylinder

(a)



$R = \rho \frac{l}{\pi\left(r_2^2 - r_1^2\right)}$

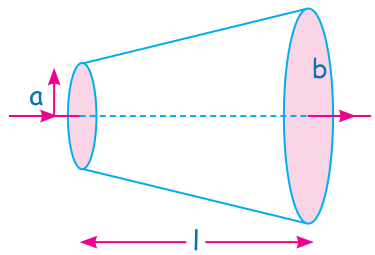
(b) $R_2 > R_1$



$\int dR = \int_{R_1}^{R_2} \rho \frac{dr}{2\pi r l}$

$\boxed{R_{eq} = \frac{\rho}{2\pi l} \ln\left(\frac{R_2}{R_1}\right)}$

9.



$R = \rho \frac{l}{\pi . ab}$

Q. If length of resistance is increase by 5% Find % increase in resistance.

Sol. $R = \rho \frac{l}{A} = \rho \frac{l^2}{Al}$ (V → const)

$R \propto l^2$ $\frac{\Delta l}{l} \times 100 = 5$

$\frac{\Delta R}{R} = \frac{2\Delta l}{l}$

$\frac{\Delta R}{R} \times 100 = 2\left(\frac{\Delta l \times 100}{l}\right)$

= 2 × 5 = 10%

Q. A cylindrical wire is increased double its original length the % increase in the Resistance of wire

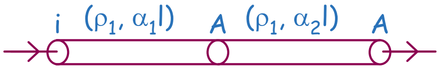
Sol. $R = \frac{\rho l}{A} = \frac{\rho l^2}{Al} = \frac{2l^2}{vol^n}$

$R \propto l^2$ $l \to$ double

$R \to 4$ times

$\% \frac{\Delta R}{R} = \frac{R_f - Ri}{R} \times 100$

Ans. 300%

Q. 

Find the condition for which this combination R_{eq} is independent on the Temp

Sol. $Ri = R_1 + R_2 = \rho_1 \frac{l}{A} + \rho_2 \frac{l}{A}$

$R_f = (R_1\text{नया}) + (R_2\text{नया}) = R_1(1 + \alpha_1\Delta T) + R_2(1 + \alpha_2\Delta T)$

$R_i = R_f$

$\rho_1 \frac{l}{A} + \rho_2 \frac{l}{A} = \rho_1 \frac{l}{A}(1 + \alpha_1\Delta T) + \rho_2 \frac{l}{A}(1 + \alpha_2\Delta T)$

Solve and get $\rho_1 \alpha_1 + \rho_2 \alpha_2 = 0$

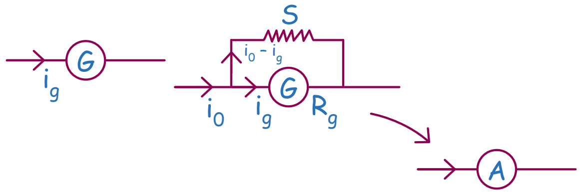
(अब यह मत सोचना ऐसा कैसे हुआ इसका मतलब है कोई एक α negative है)

CONVERSION OF GALVANOMETER INTO AMMETER/VOLTMETER.

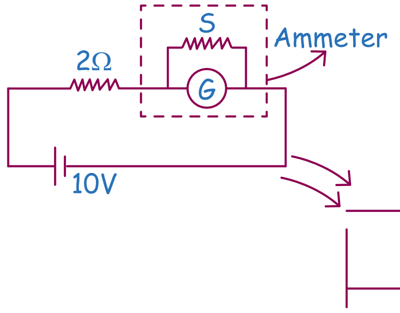
तीनो दिखने में एक जैसे ही होते है बस labelling का अंतर है यकीन नही आता ऊपर के image को ठीक से देखा। बस इतना याद रखो galvanometer के parallel में छोटा सा resistance लगाने पर यह ammeter बन जाता है और galvaometer के बाजू में बहुत बड़ा resistance लगाने पर ये voltmeter बन जाता है।

Ideal ammeter का resistance zero or ideal voltmeter का resistance infinity होता है।

Conversion of Galvanometer into Ammeter

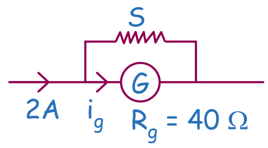


$R\text{ डब्बा} = \frac{S.\,R_g}{S + R_g}$



$\boxed{i_g = \frac{S}{S + R_g} \times i_0}$

Q. A Galvanometer of resistance 40Ω can read max current of 50mA. Find the resistance require to that it converted into ammeter which can measure the current upto 2A.



Sol. $i_g = \frac{S}{S + G} \times i \text{ total}$

$50 \times 10^{-3} = \frac{S}{S + 40} \times 2$

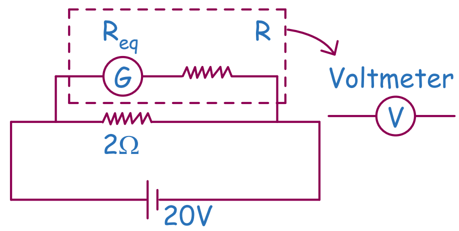
$50\,(S + 40) = 2000S$

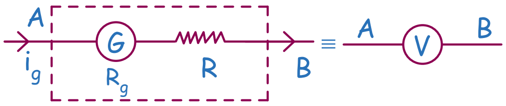
$50S + 2000 = 2000S$

$2000 = 1950S$

$S = \frac{2000}{1950}$

Conversion of Galvanometer into Voltmeter



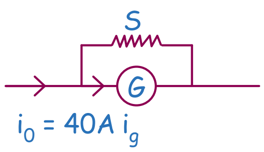


$V_{AB} = i_g(R + R_g)$ (ideally V Resist infinity)

Q. A galvanometer has coil of resistance 40Ω showing full scale deflection of 80mA what resistance should be added and how so that

1. It become Ammeter of range 40A

Sol.



$$i = \frac{S}{S+g} \times i_0$$

$$80 \times 10^{-3} = \frac{S}{S+40} \times 40$$

$$80S + 3200 = 40000\ 'S'$$

$$S = \frac{3200}{39920}$$

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 sincerly

Q. In following case find r_{eq} & ρ_{eq} if rods A & B are connected in series of length $3l_0$.

Rod A: ρ_0, l_0, 3α, A

Rod B $\Rightarrow$ $2\rho_0$, $2l_0$, 2α, A

Sol.

$$R_1 = \rho_0(1 + 3\alpha\Delta T)\frac{l_0}{A}$$

at only temp

$$R_2 = 2\rho_0(1 + 2\alpha\Delta T)\frac{2l_0}{A}$$

$$R_{eq} = R_1 + R_2 = \rho_0\frac{l}{A}(1 + 3\alpha\Delta T) + 4\rho_0\frac{l}{A}(1 + 2\alpha\Delta T)$$

$$\rho_{eq}(1 + \alpha_{eq}\Delta T)\frac{3l_0}{A} = R_{eq} = \rho_0\frac{l_0}{A}(1 + 3\alpha\Delta T) + 4\rho_0\frac{l}{A}(1 + 2\alpha\Delta T)$$

$$3\rho_{eq}(1 + \alpha_{eq}\Delta T) = \rho_0 + 3\alpha\rho_0\Delta T + 4\rho_0 + 8\alpha\rho_0\alpha\Delta T$$

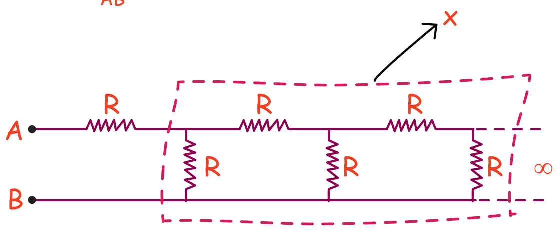
$$3\rho_{eq} + (3\rho_{eq}\alpha_{eq})\Delta T = 5\rho_0 + 11\alpha\rho_0\Delta T$$

$$3\rho_{eq} = 5\rho_0 \quad \boxed{\rho_{eq} = 5/3\rho_0}$$

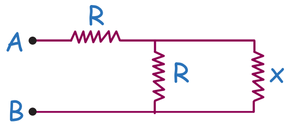
$$3\rho_{eq}\alpha_{eq} = 11\alpha\rho_0 \quad 5\rho_0\alpha_{eq} = 11\alpha\rho_0 \quad \boxed{\alpha_{eq} = \frac{11}{5}\alpha}$$

✦ ∞ ladder question

Q. Find R_{AB} ?



Sol.



Circuit को शुरु मे कितना मिटा दू की उसकी शक्ल सूरत वैसी की वैसी ही रहे

$$R_{AB} = x$$

$$R_{AB} = x = R + \frac{Rx}{R+x}$$

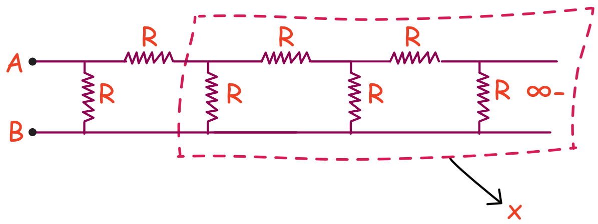
$$x = \frac{R(R+x) + Rx}{R+x}$$

$$xR + x^2 = R^2 + Rx + Rx$$

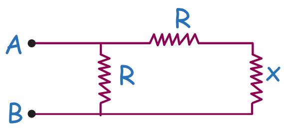
$$x^2 - Rx - R^2 = 0$$

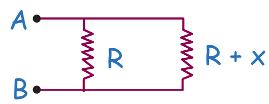
$$x = \text{solve \& get, } x = \frac{R + \sqrt{5}R}{2}$$

Q. $R_{AB} = ?$



Sol.





$$R_{AB} = \frac{R(R+x)}{R+R+x} = x = \frac{R^2 + Rx}{2R + x} = x$$

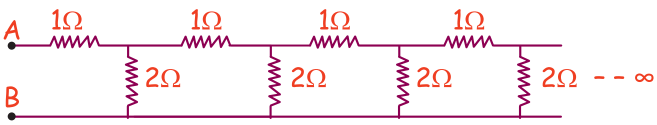
$$R^2 + Rx = 2Rx + x^2$$

$$x^2 - Rx - R^2 = 0$$

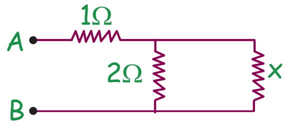
$$x = \frac{-R + \sqrt{R^2 + 4R^2}}{2}$$

$$x = R\left(\frac{\sqrt{5} - 1}{2}\right)$$

Q. $R_{AB} = ?$



Sol.



$$R_{AB} = x = 1 + \frac{2x}{x+2}$$

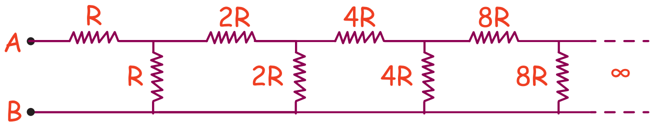
$$x - 1 = \frac{2x}{x+2}$$

$$(x - 1)(x + 2) = 2x$$

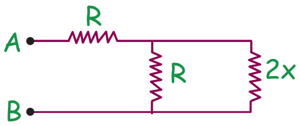
$$\cancel{x^2} + 2x - x - 2 = 2\cancel{x}$$

$$x = \frac{1 - \sqrt{1+8}}{2} = 2$$

Q. Find R_{AB} = ?



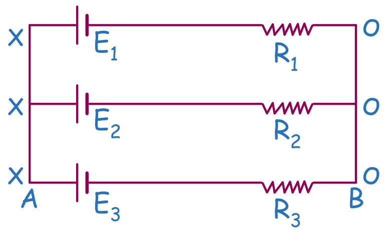
Sol.



$$R_{AB} = x = \frac{R\,2x}{R + 2x} + R$$

Solve & get

Grouping of Cell

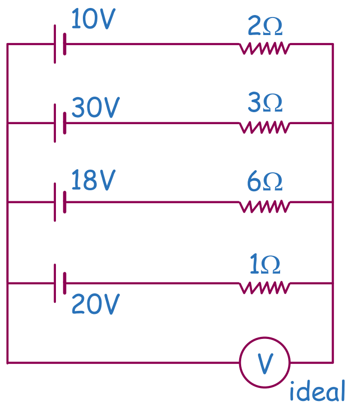


#SKC

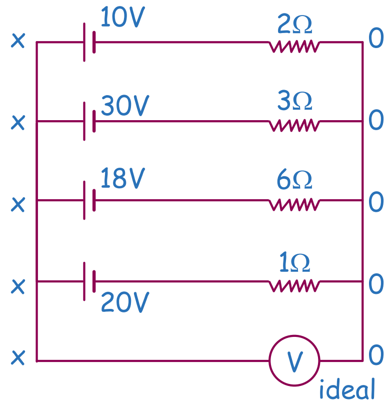
$$x = V_{AB} = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2} + \frac{E_3}{r_3}}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}}$$

अगर इस तरह के सवाल में direct x पुछे तो बिंदास SKC लगाओ।

Q. Find reading of ideal voltmeter.



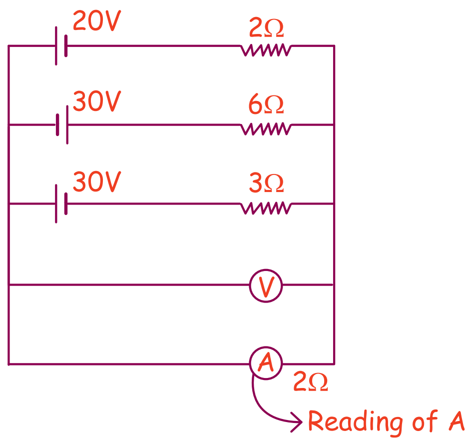
Sol.



$$x = \frac{10/2 + 30/3 + 18/6 + 20/1}{1/2 + 1/3 + 1/6 + 1/1} = \frac{5 + 10 + 3 + 20}{2}$$

$$x = V_{AB} = 19$$

SSSQ. Find volt meter and ammeter reading

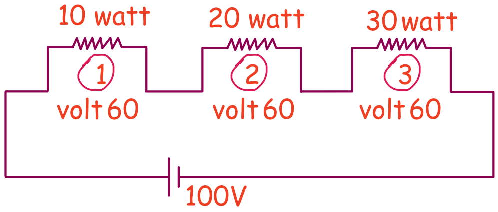


Sol. $x = \dfrac{20/2 - 30/6 + 30/3 + 0/2}{1/2 + 1/6 + 1/3 + 1/2} = 10$

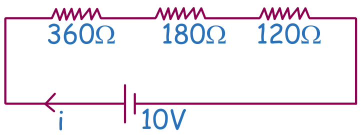
$= 10$ V (Voltmeter Reading)

$$i = \frac{x - 0}{2} = \frac{10 - 0}{2} = 5 = \text{Ammeter reading}$$

Q. Compare brighter of bulbs.



Sol. $R = \dfrac{V^2}{P} = \dfrac{60 \times 60}{10} = 360$



$B_1 > B_2 > B_3$

$$i = \frac{10}{360 + 180 + 120}$$

Q. Find the total average momentum of electrons in a straight wire of length $l = 1000$ m carrying current $I = 704$ A.

Sol. Let n be no. of electrons per unit volume.

No. of electrons in length l

$N = nSl$ (S is cross-sectional area)

Momentum of one electron $= mv_d$

Total momentum $P = (nSl)mv_d$

As $v_d = \dfrac{I}{neS}$

$$P = (nSl)m\frac{I}{(neS)} = \frac{mlI}{e}$$

On substituting numerical values, we get

$P = 4\mu$ Ns

Q. The temperature coefficient of resistivity α is given by $\alpha = \left(\dfrac{1}{\rho}\right)\dfrac{d\rho}{dT}$, where ρ is the resistivity at temperature T. Assume that α is not constant and follows the relation $\alpha = -\dfrac{a}{T}$, where T is the absolute temperature and a is a constant. Show that the resistivity ρ is given by $\rho = \dfrac{b}{T^a}$, where b is another constant.

Sol. $\alpha = \dfrac{1}{\rho}\dfrac{d\rho}{dT} \Rightarrow \dfrac{d\rho}{\rho} = \alpha dT = -a\dfrac{dT}{T}$

Let $\rho = \rho_0$ at $T = T_0$, then

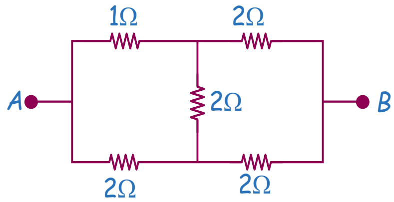
$$\int_{\rho_0}^{\rho}\frac{d\rho}{\rho} = -a\int_{T_0}^{T}\frac{dT}{T}$$

$$\Rightarrow \log_e\left(\frac{\rho}{\rho_0}\right) = -a\log_e\left(\frac{T}{T_0}\right) = \log_e\left(\frac{T_0}{T}\right)^a$$

$$\Rightarrow \rho = (\rho_0 T_0^a)\frac{1}{T^a} = \frac{b}{T^a}$$

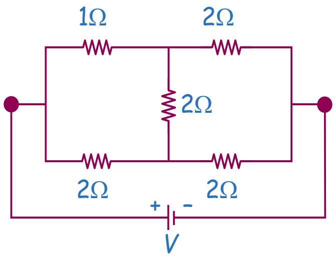
Here, $b = \rho_0 T_0^a$

Q. Find the equivalent resistance across terminals A and B.

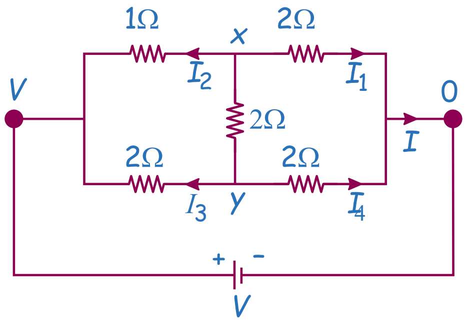


Sol. This is a case of unbalanced Wheatstone bridge.

Step 1: Connect a battery across the terminal.



Step 2: Mark the voltages of nodes.



Step 3: Calculate $R_{eq} = \dfrac{V}{I}$

Apply KCL at node 'x'

$$\Rightarrow \frac{x-V}{1} + \frac{x-0}{2} + \frac{x-y}{2} = 0$$

$\Rightarrow 2x - 2V + x + x - y = 0 \quad \Rightarrow 4x - 2V = y \quad \ldots (i)$

Apply KCL at node 'y'

$\dfrac{y-x}{2} + \dfrac{y-V}{2} + \dfrac{y}{2} = 0 \quad \Rightarrow 3y - V = x \quad \ldots (ii)$

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

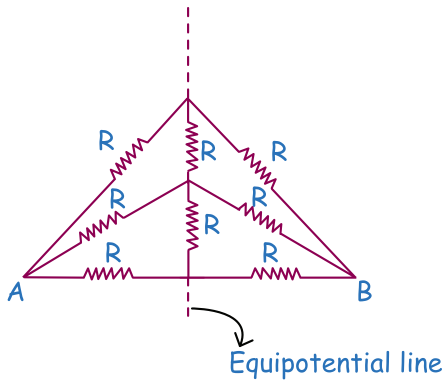
$$R_{eq} = \frac{V}{I} = \frac{V}{I_1 + I_2} = \frac{V}{\frac{7V}{22} + \frac{6V}{22}} = \frac{V}{\frac{13V}{22}} \Rightarrow R_{eq} = \frac{22}{13}\Omega$$

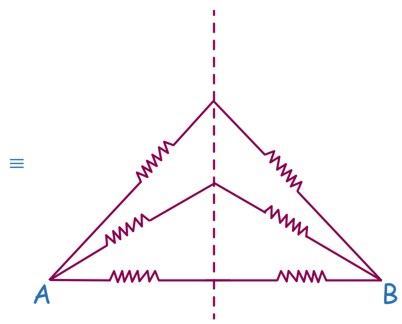
SYMMETRY (Not much important for jee mains)

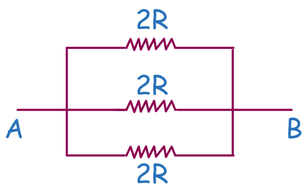
- Perpendicular Bisector symm
- Folding symm
- input output symm

Perpendicular Bisector symmetry

example







#SKC

A को B से connect करो और AB के

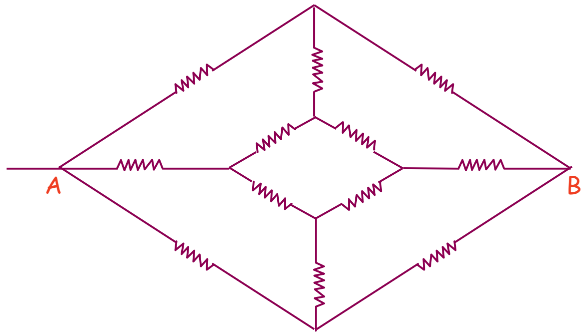
$\perp^{ar}$ Bisector लो

उसके आजू-बाजू अगर circuit mirror

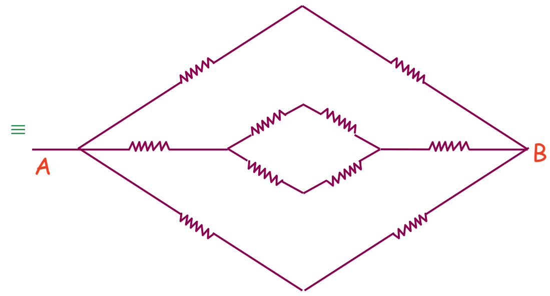
image है तो bisector line के

resistance उड़ा दो

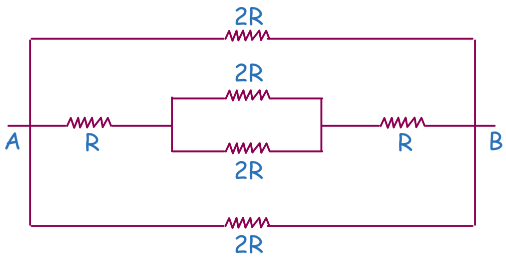
Q. All resisters have same value 'R'. Find R_{AB}

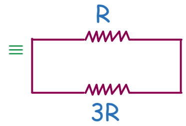


Sol.



All resistance have same 'R'





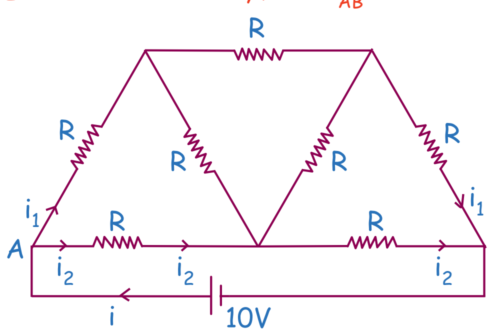
$\frac{3R}{4} = R_{AB}$

✦ Input output symmetry

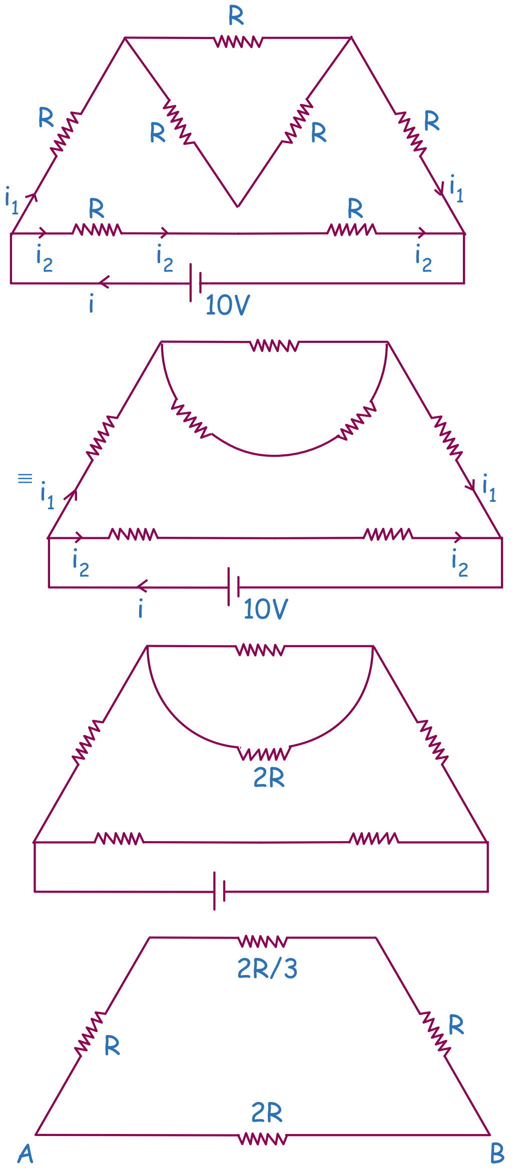
If current has similar path in entering side to exit & vice versa then circuit is said to be input output symmetry.

Under such condition for entry side & exit side are same

Q. Each resistance = R, Find R_{AB}



Sol.

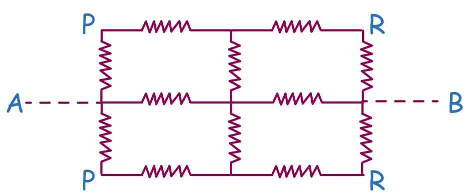


Folding Symmetry

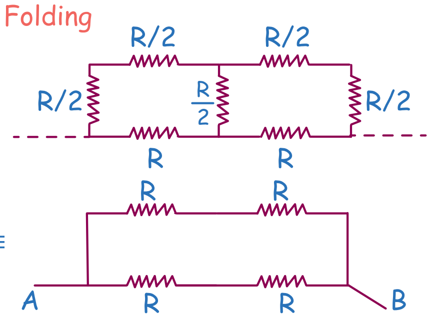
#SKC

अगर AB line के उपर नीचे circuit ek जैसा हो तो नीचे वाले को उपर वाले पर fold करदो मतलब ऊपर के सारे **resistance** आधे करदा

Q. Each resistance = R, Find R_{AB}

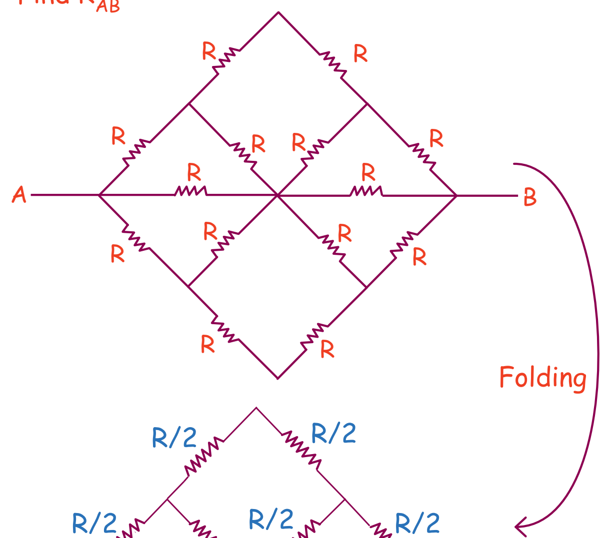


By Folding

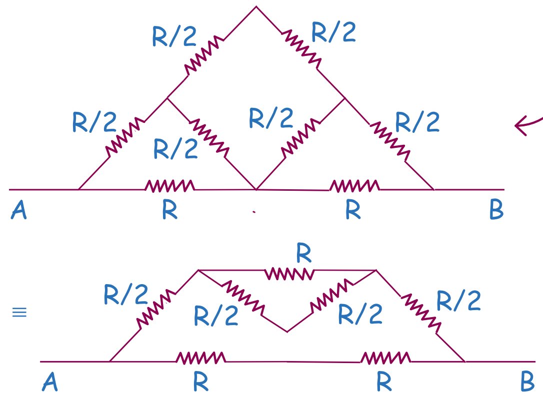


$R_{AB} = R$

Q. Find R_{AB}

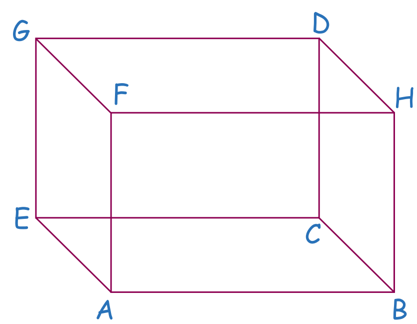


Sol.



Now you can solve.

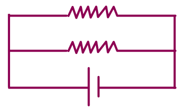
✦ Cube each of length l, Resistance R(each)



$\frac{7R}{12}$	$\frac{3R}{4}$	$\frac{5R}{6}$
R_{AB}	R_{AC}	R_{AD}
पास-पास	थोडा-दूर	दूर-दूर

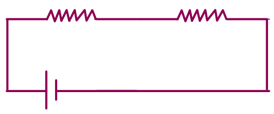
✦ If two appliances with rating (W_1, v)& (W_1, v) are connected to V.

1. In Parallel



Total power dissipated = $\omega_1 + \omega_2$

2. In series



Total power dissipated = ω_{net}

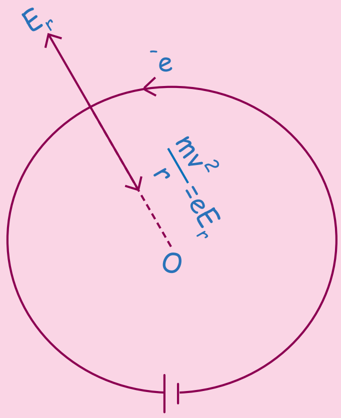
$$\frac{1}{\omega_{net}} = \frac{1}{\omega_1} + \frac{1}{\omega_2}$$

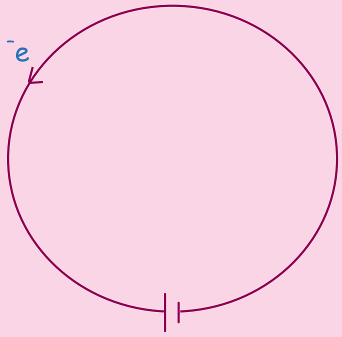
Q. A wire is in a circular shape connected to a battery as shown in figure. Find value of radial electric field.

$eE_t = \frac{mv_d^2}{r}$

↓ Very law value

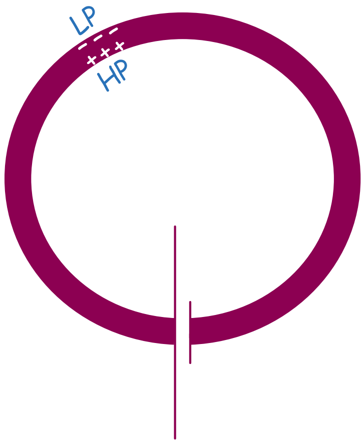
(अक्सर neglect कर देते है)



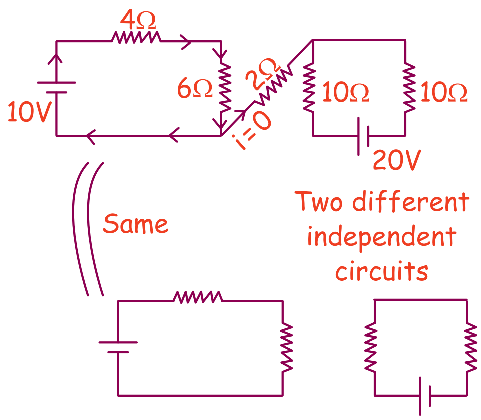


#SKC

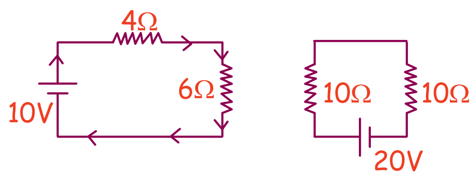
यह ध्यान से देखना Current किसकी वजह से आया? e^- की वजह या +ve charge के motion की वजह से



Q.



Now solve and get

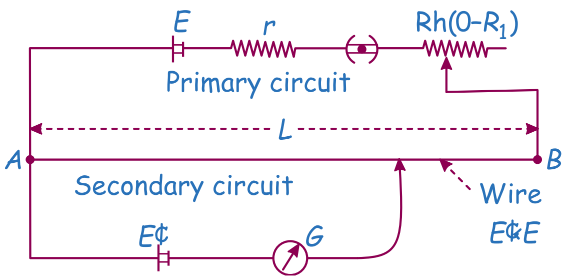


POTENTIOMETER (Not in Jee Mains 2025)

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.

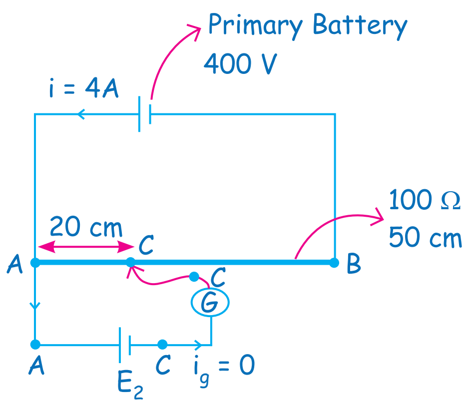
Circuit of Potentiometer



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.



$V_{AB} = 400$ V

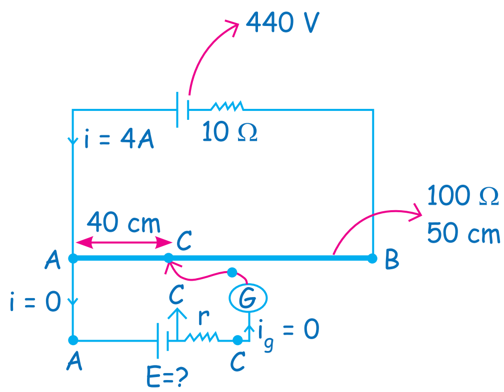
50 cm $\longrightarrow$ 400 V

1 cm $\longrightarrow \dfrac{400}{50}$

20 cm $\longrightarrow \dfrac{400}{50} \times 20$

$= 160 = V_{AC} = E_2$

Q. Find emf of the battery if galvanometer show null deflection at C.

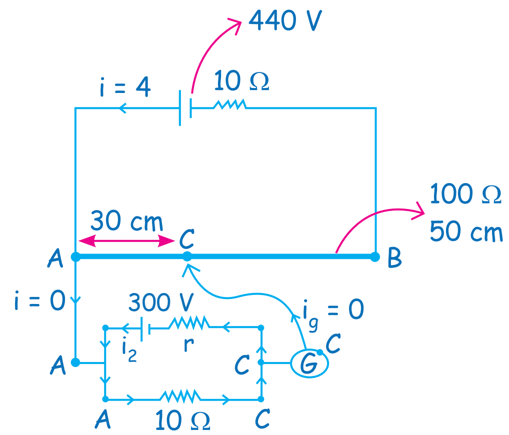


$V_{AB} = 400$ V

50 cm $\longrightarrow$ 400 V

40 cm $\longrightarrow \dfrac{400}{50} \times 40 = 320$ V

Q. Find internal resistance of the battery if galvanometer show null deflection at C.



$$i_2 = \frac{300}{10+r}$$

$V_{AB} = 400$

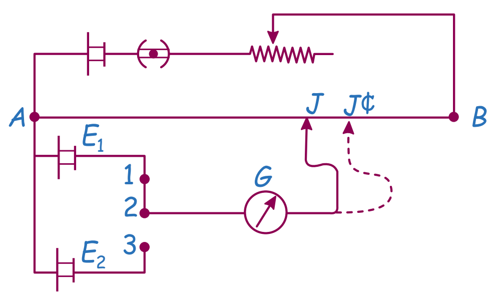
$V_{AC} = \dfrac{400}{50} \times 30 = 240$

$V_{AC} = \dfrac{300}{10+r} \times 10$

$240 = \dfrac{3000}{10+r}$

$r = 2.5\ \Omega$

☆ Comparison of emf of two cells



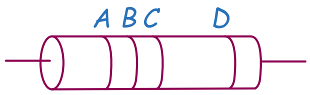
Plug only in (1– 2): Balance length $AJ = \ell_1$

Plug only in (2 – 3): Balance length $AJ' = \ell_2$

$E_1 = x\ell_1$ and $E_2 = x\ell_2$

$$\Rightarrow \frac{E_1}{E_2} = \frac{\ell_1}{\ell_2}$$

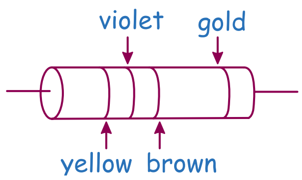
COLOUR CODE FOR CARBON RESISTORS (Removed from Mains 2025 and in Advance also)



	Strip A	Strip B	Strip C	Strip D
Colour	(digit 1)	(digit 2)	(Multiplier)	(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}	±5%
Silver	-	-	10^{-2}	±10%
No Colour	-	-	-	±20%

- Aid to memory **BBROY** of **G**reat **B**ritain does a **V**ery **G**ood **W**ork.

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 ± 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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