CLASS-12 SKC PHYSICS CRUSH Saleem Bhaiya

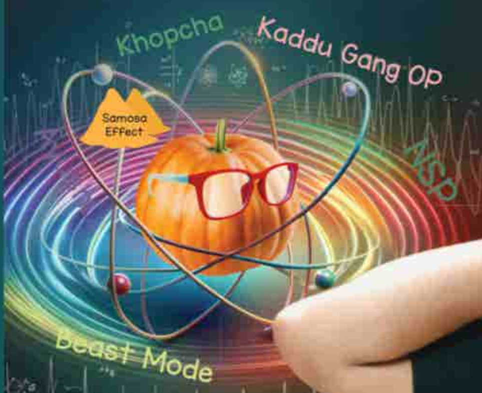
CLASS 12

SKC PHYSICS CRUSH

Class Notes in Handwritten Format

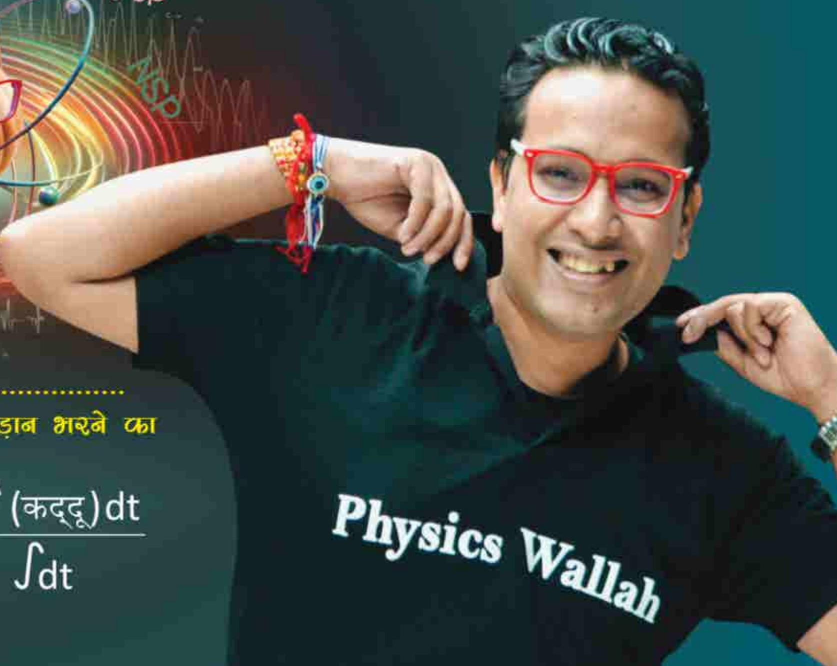
A beautiful journey From basic to JEE advanced via Mains/ NEET

By: Saleem Bhaiya



प्रयास है......................
Lakshya तक उड़ान भरने का

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



SKC

Saleemians Khopcha Concept

PHYSICS CRUSH

Class Notes in Handwritten Format

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

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Preface

Physics Wallah (PW) strongly believes in conceptual and fun-based learning. PW provides highly exam-oriented content to bring quality and clarity to the students.

A plethora of Competitive Exams Books is available in the market but PW professionals are continuously working to provide the supreme book for Competitive Exams to our students.

Books adopt a multi-faceted approach to master and understanding the concepts by having a rich diversity of questions asked in the examination and equip the students with the knowledge for the competitive exam.

The main objective of the book is to provide a large number of quality problems with varying cognitive levels to facilitate teaching-learning of concepts that are presented through the book.

It has become popular among aspirants because of its easy to understand language and clear illustrations with diagrams, mnemonics, flow charts and tables.

Factor in the content that should be checked thoroughly including the quality of language or ease of understanding or comprehension, coverage of topics and chapters from the Competitive Exams latest syllabus by NTA.

Students can benefit themselves by attempting the exercise given in the book for the self-assessment and also mastering the basic techniques of problem-solving.

Mastering the Physics Wallah (PW) study material curated by the PW team, the students can easily qualify for the exam with a Top Rank in the Competitive Exams.

In each chapter, for better understanding, theory and examples are according to the latest syllabus for Competitive Exams.

- To strengthen the concept of the topic at the zenith level

This Book Consists of

Complete class Notes content from basic to advance, SKC box which will help you to remember and visualise the physics, All relevant illustrations which is very important for exams, summery box which is very important for revision with special tips and tricks, concept explained in entertaining way.

A step to make our book even better for our students:

Provide your valuable feedback or Report the Error

View Errata (Error Correction from our end)

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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@SALEEMSIR_PW

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 [$\vec{B} \rightarrow$ 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)

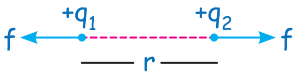
COULOMB LAW

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

$f \propto q_1q_2$

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

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

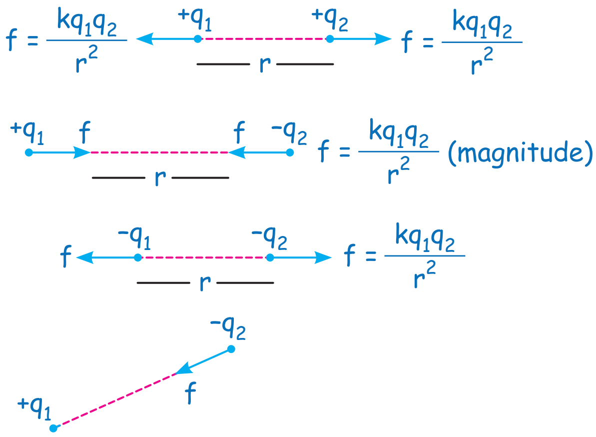


$$\boxed{K = 1/4\pi\varepsilon_0 = 9 \times 10^9\ Nm^2/c^2}$$

ε_0 → Permitivity of free space (ε_0)

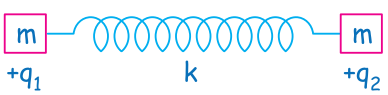
- Two like charge repel each other and unlike charge attract each other.

Ex.:

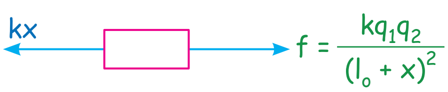


1. This force always act along the line joining two points
2. Central force
3. Electrostatic force b/w two charge particle are action reaction pair
4. Conservative force
5. Force applied by one charge particle on another charge particle is independent on presence or absence of other charge
6. Net force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

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



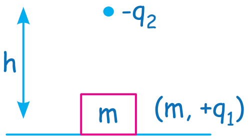
Sol. Let elongation in spring is x



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

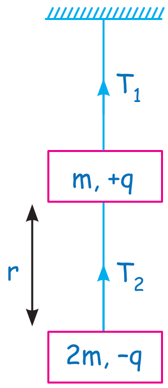
(अबे अब value put करके quadratic eqn. बनाके कर लोगे ना ☺)

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



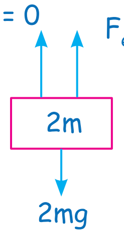
$$mg = \frac{kq_1q_2}{h^2}$$

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



Sol.

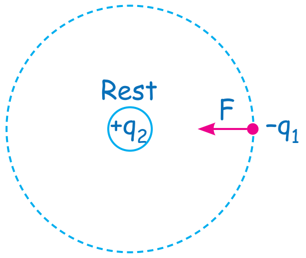
$T_2 = 0$ $\quad F_e = \dfrac{kq_1q_2}{r^2}$



$$\frac{kq^2}{r^2} = 2\,mg$$

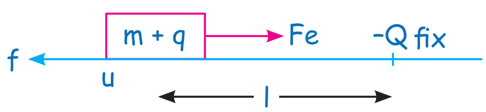
Q. A charge $(-q_1, m)$ is moving in a circular path of radius r around positive charge $+q_2$ with constant speed. Find speed

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



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

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

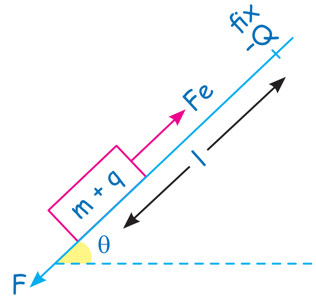


$F_e \geq \mu_s mg$

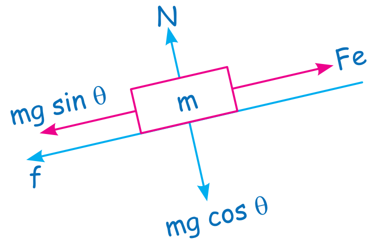
$\dfrac{kqQ}{l^2} \geq \mu_s mg$ $\qquad$ (Assume block is a point mass)

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

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



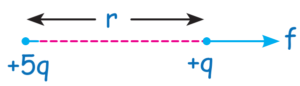
$$Fe \geq mg\sin\theta + (f_s)_{max} \Rightarrow \frac{kQq}{l^2} = mg\sin\theta + \mu_s mg\cos\theta$$



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।

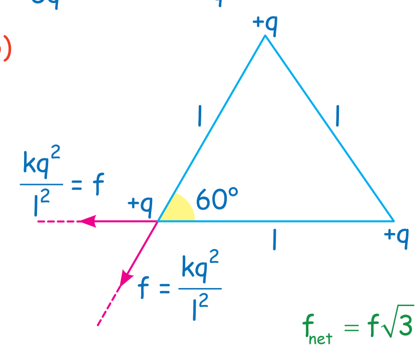
Q. Find the net force on the given charge q

(a)



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

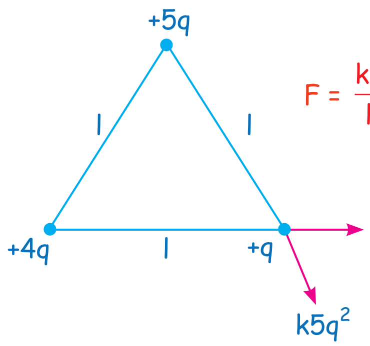
(b)



$\dfrac{kq^2}{l^2} = f$ $\qquad f = \dfrac{kq^2}{l^2}$

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

(c)



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

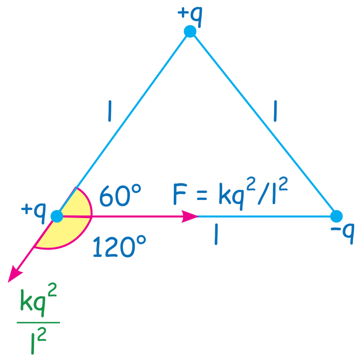
$\dfrac{k4q^2}{l^2} = 4F$

$\dfrac{k5q^2}{l^2} = 5F$

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

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

(d)

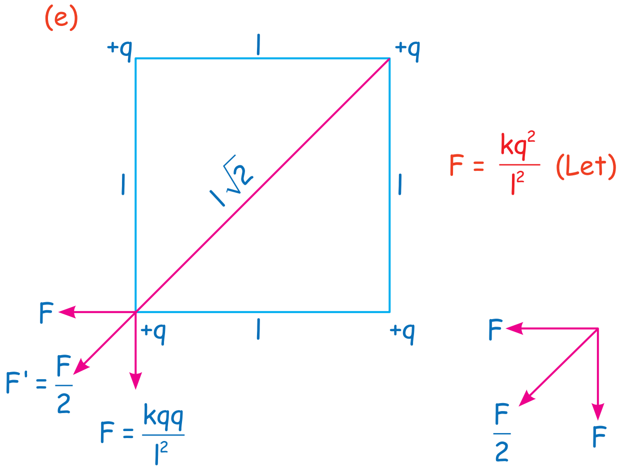


$$F_{net} = \sqrt{F^2 + F^2 + 2F^2 \cos 120^\circ}$$

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

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

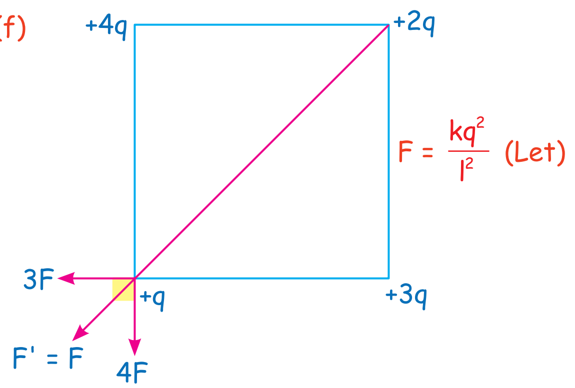
(e)



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

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

(f)



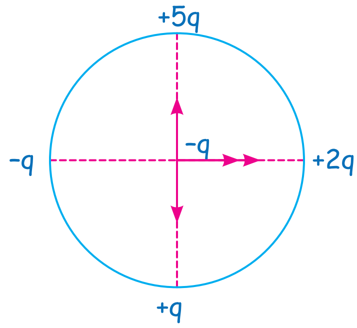
तीनो Force का resultant will be answer. 3F और 4F का resultant 5F आयेगा। So answer = 5F + F = 6F अगर तुमने दिया तो तुम बहुत बड़े गधे हो। Bcz 6F is wrong.

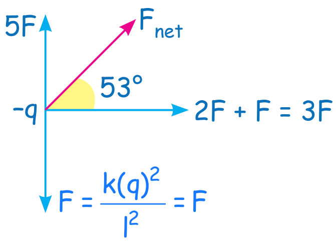
$$F' = \frac{2kq^2}{(l\sqrt{2})^2} = F$$

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

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

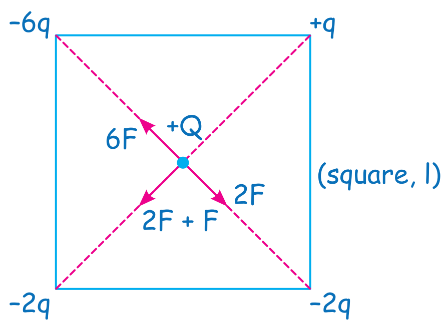
(g) Find F_{net} on the charge -q at centre





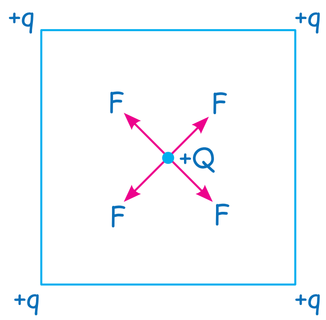
$$F_{net} = 5F = \frac{5kq^2}{r^2}$$

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



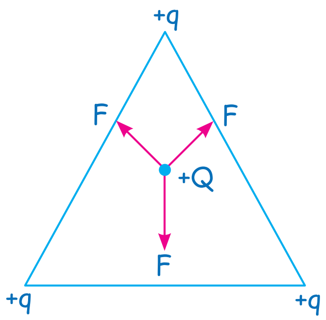
$$F_{net} = 5F = \frac{5kq^2}{(l/\sqrt{2})^2} = \frac{10kq^2}{l^2}$$

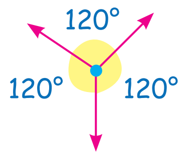
(i) Find F_{net} on + Q at centre of square.



$F_{net} = 0$

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

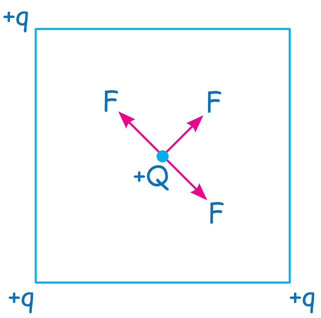




$\Rightarrow 0.$

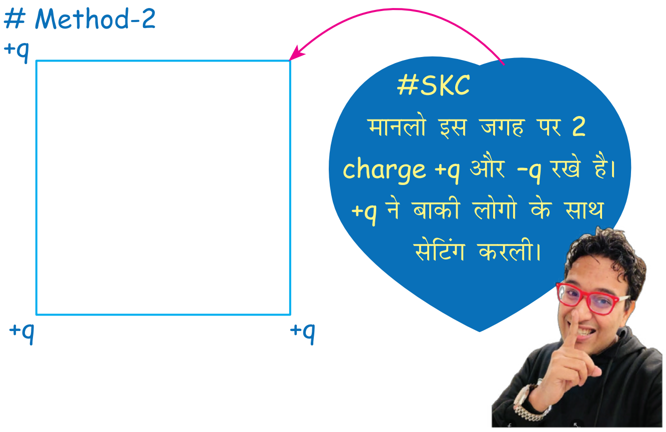
$F_{net} = 0$

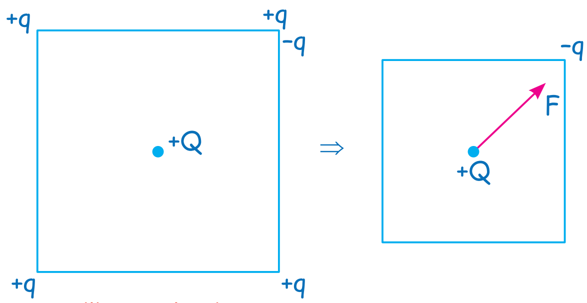
(k)



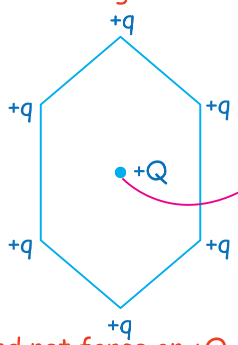
$$F_{net} = F = \frac{kQq}{(l/\sqrt{2})^2}$$

Method-2



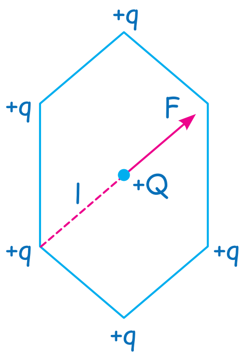


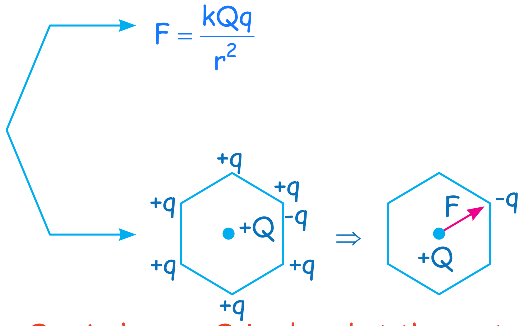
(l) Regular hexagon



$F_{net} = 0$

(m) Find net force on +Q.

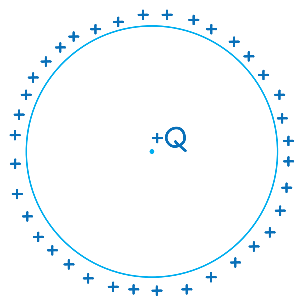




$F = \frac{kQq}{r^2}$

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

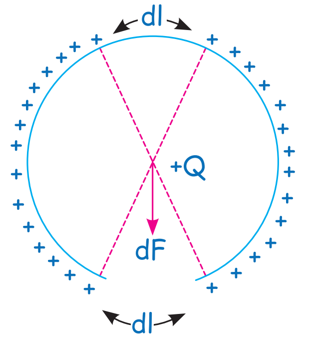
Q. A charge +Q is placed at the centre of ring of uniform charge +q, of radius r. F_{net} on + Q at centre will be



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

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

Sol.



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

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

$1 \longrightarrow q/2\pi r$

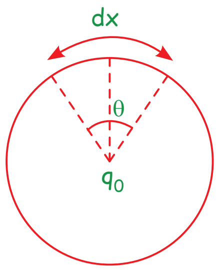
$dl \longrightarrow q/2\pi r \times dl = dq$

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

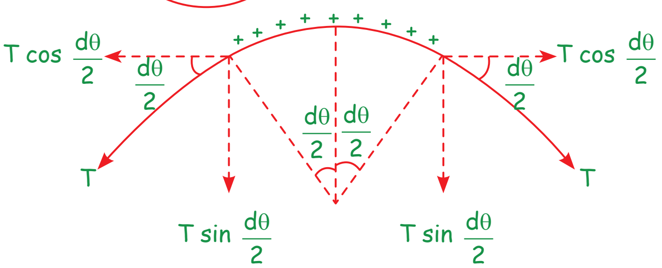
$\Rightarrow F_{net} = k\left(\dfrac{q\,dl}{2\pi r}\right) \times \dfrac{Q}{r^2} = \dfrac{kqQ\,dl}{2\pi r^3}$

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.



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



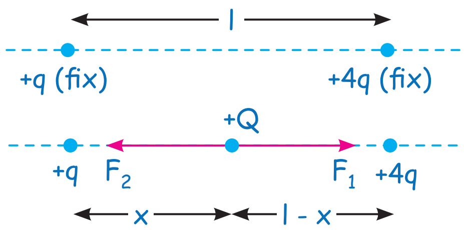
$2T\sin\dfrac{d\theta}{2} = \dfrac{k\,dq.\,q_0}{R^2}$

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

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

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

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



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

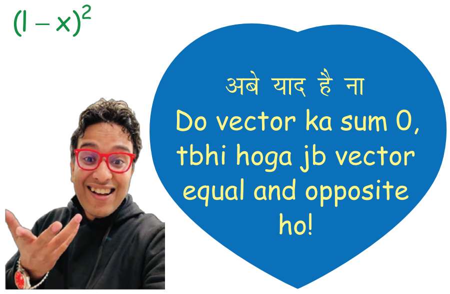
$F_1 = F_2$ [in eqb^m]

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

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

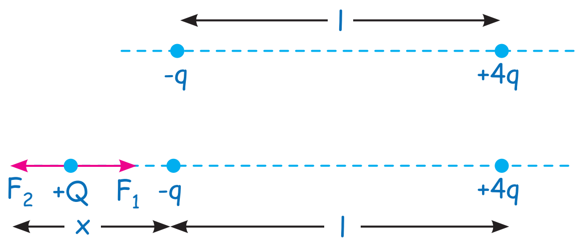
$l - x = 2x$

$x = l/3$ Ans.



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

Sol.



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

$F_1 = F_2$ [in eqb^m]

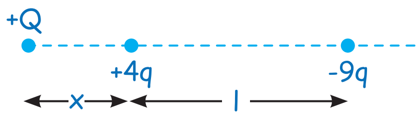
$\dfrac{1}{x^2} = \dfrac{4}{(l+x)^2}$

$l + x = 2x$

$x = l$ 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।



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

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

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

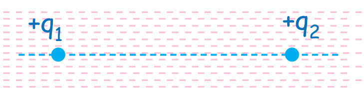
$$2l = x$$

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

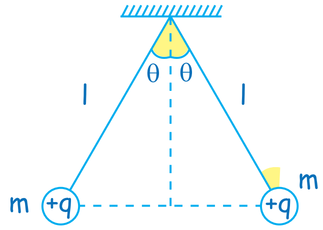
$$\frac{1}{4\pi\varepsilon}\frac{q_1q_2}{r^2} = \frac{1}{4\pi\varepsilon_o k}\frac{q_1q_2}{r^2} = \frac{F_o}{k} \qquad k \to \text{Dieletric const.}$$

Permittivity of that medium

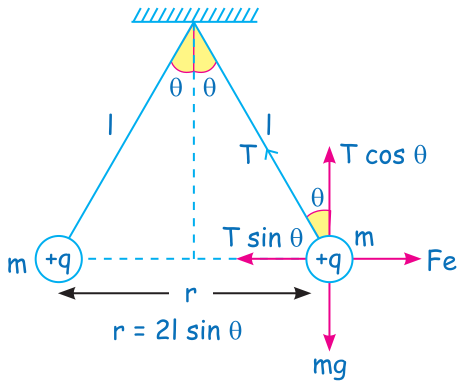
$\varepsilon = \varepsilon_0\, \varepsilon_r$

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

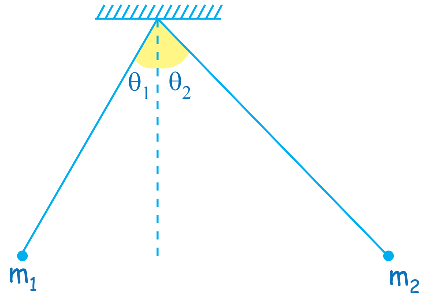
Sol. $\theta_1 = \theta_2$

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

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

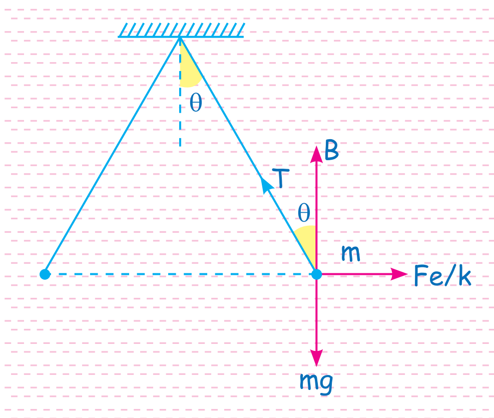
(c) If $q_1 \neq q_2$ and $m_1 > m_2$

Sol. Then, $\theta_1 < \theta_2$



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

Sol.

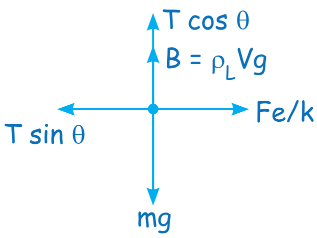


$$\tan\theta = \frac{Fe/k}{mg - B}$$

$T \sin\theta = Fe/k$

$T \cos\theta + B = mg$

B = Buoyant force



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

Sol. Homework

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

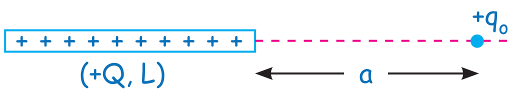
अगर पूरा sol. लिखा तो no. of page बढने की वजह से Book की price बढ़ जाएगी।

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

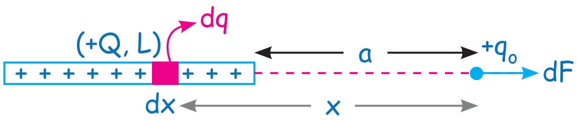
(x very small) $\tan\theta \approx \sin\theta = \frac{x/2}{\ell}$ ...(ii)

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

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



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



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

$L \longrightarrow Q$

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

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

ये चीज बहुत बार use होगी।

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

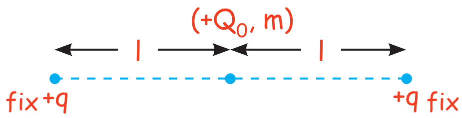
$$= \int_a^{a+L} \frac{kq_o Q dx}{Lx^2}$$

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

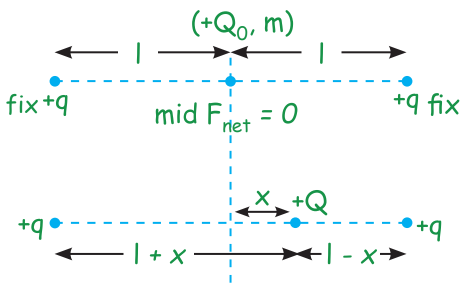
$$= \frac{kqQ}{a(a+L)}$$

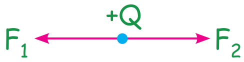
If a >>>> L, $F_{net} \approx \frac{kqQ}{a^2}$ (देखो ये point charge जैसा result आगया)

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



Sol.





$F_{net} = F_2 - F_1$

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

If $x \ll l$

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

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

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

$F_{net} = -kx$

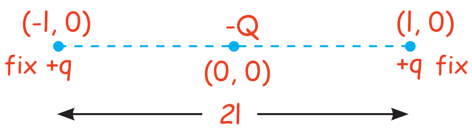
$$T = 2\pi\sqrt{\frac{m}{Qq/\pi\varepsilon_0 l^3}}$$

In SHM

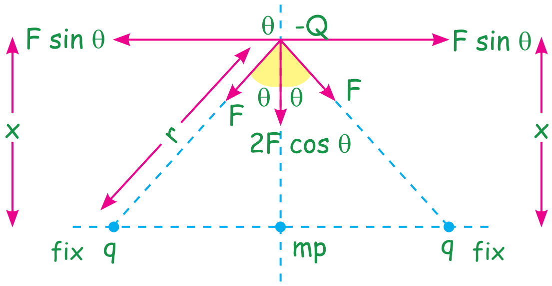
If $\vec{F}_{net} = -k\vec{x}$

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

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



Sol.



$F_{net} = 2F\cos\theta$ (नीचे)

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

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

If $x \ll a$

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

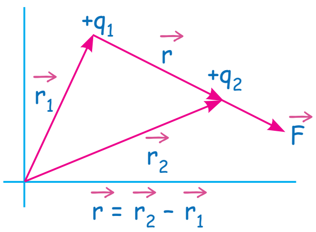
$$T = 2\pi\sqrt{\frac{m}{2kqQ/a^3}}$$

VECTOR FORM OF COULOMB LAW

Force by q_1 on q_2

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

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



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

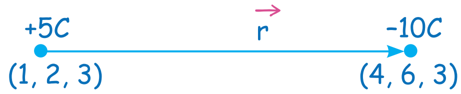
But हम SKC लगा कर सवाल solve करेंगे।

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

##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:

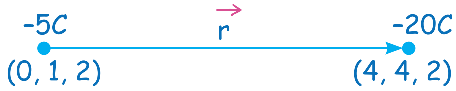


$\vec{r} = 3\hat{i} + 4\hat{j}$

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

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

Q.

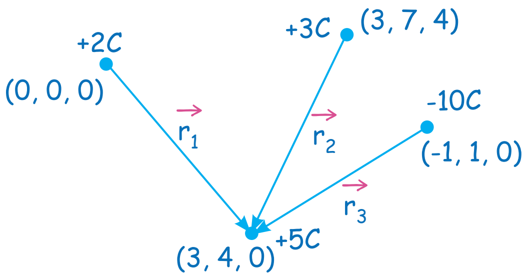


Force applied by -5C on -20C:

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

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

Q. Find net force on +5C.



Find F_{net} on + 5C

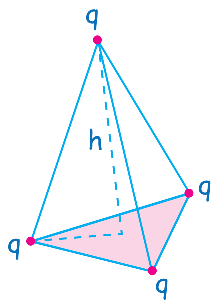
$\vec{r}_1 = 3\hat{i} + 4\hat{j}$

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

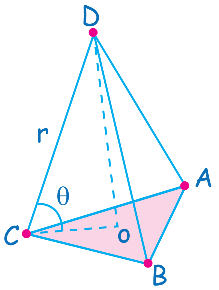
$\vec{r}_3 = 4\hat{i} + 3\hat{j}$

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

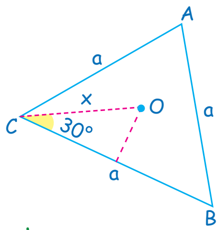
Q. Three charges (+q) are placed on the vertices of a equilateral triangle of side a as shown in diagram. Find net force on 4th identical charge particle at a height h = a above the centroid of Δ.



Sol.

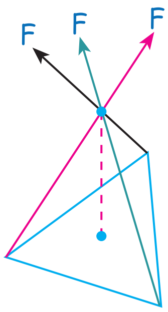


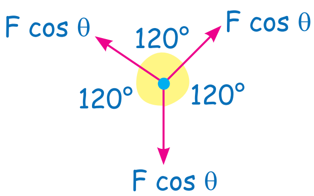
$$\tan\theta = \frac{OD}{OC} = \frac{h}{OC}$$



$OC = \frac{a}{\sqrt{3}}$ 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

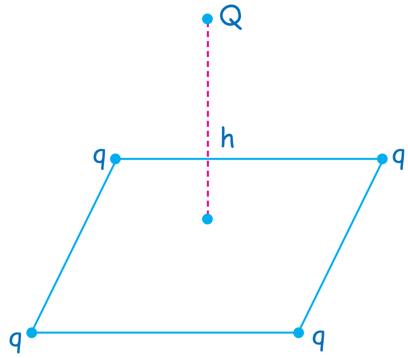
$F\sin\theta + F\sin\theta + F\sin\theta$

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

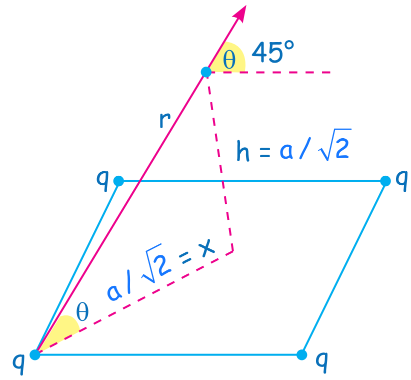
where $F = \frac{kq^2}{r^2}$

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

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.

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

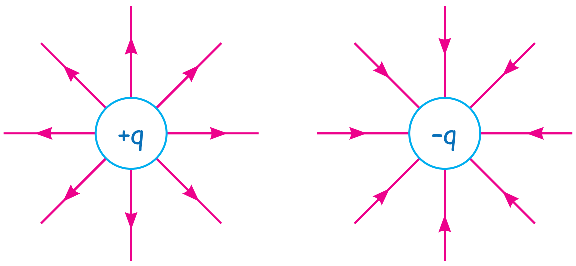
Electric Field due to Point Charge

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

Force experimental per unit test charge.

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

1. $\vec{E} = \frac{\vec{F}}{q_0}$ (unit ⇒ N/coulomb)
2. EF due to +ve point chare is radially outward and due to –ve point charge its radially inward



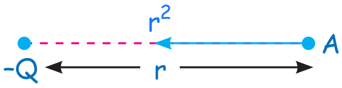
अब हम EF निकालना सीखेंगे सही से देखो तो
यह coulomb law जैसे ही question है।

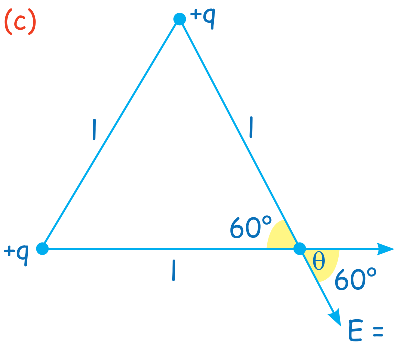
Q. Find E.F (net) at point A.

(a) 

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

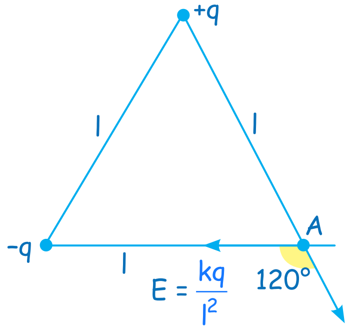
+Q charge की वजह से हे।

(b) 

(c) 

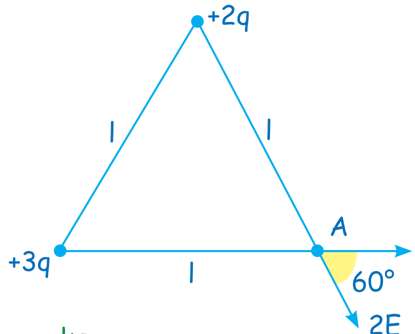
$E = \frac{kq}{l^2}$, $E = \frac{kq}{l^2}$

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

(d) 

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

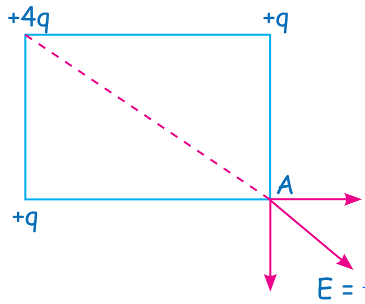
$(E_A)_{net} = E = \frac{kq}{l^2}$

(e) 

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

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

$= E\sqrt{19}$

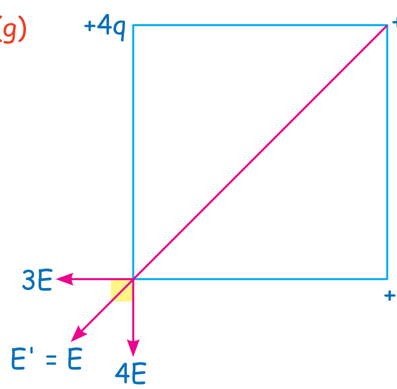
(f) 

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

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

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

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

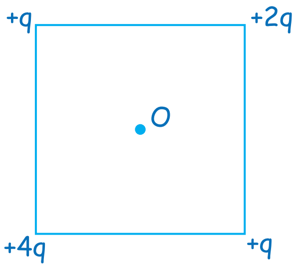
(g) 

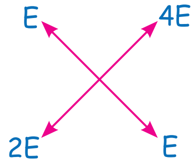
$E = \frac{kq^2}{l^2}$ (Let)

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.

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

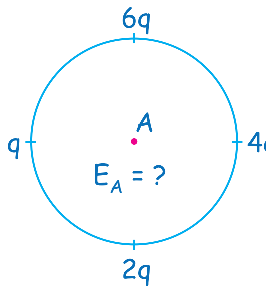
(h) Find electric field at point at centre of square (l) at O.





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

(i)



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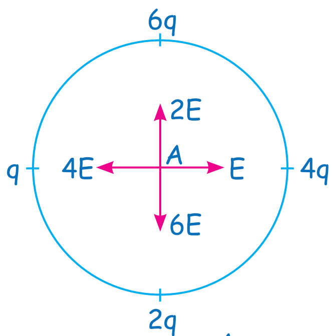
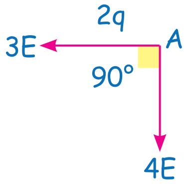
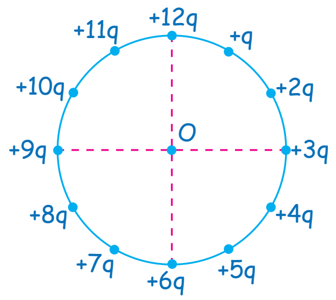
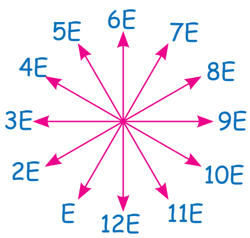


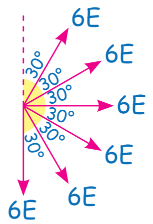


$$(E_{net})_A = 5E = \frac{5kq}{r^2}$$

Q. Find E_{net} at centre O.







अब component लेकर solve करो जैसे vector में करते थे।

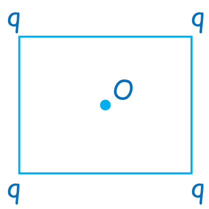
$$\vec{E}_{net} = (12E + 6E\sqrt{3})\hat{i} - 6E\hat{j}$$

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

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

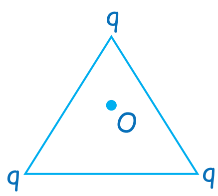
Q. Find net electric field at O.

(a)



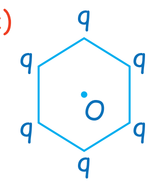
E = 0

(b)



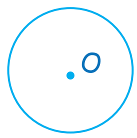
E = 0

(c)



E = 0

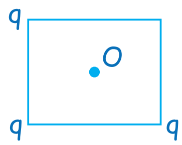
(d)



Uniform (Ring Q, R)

E = 0

(e)



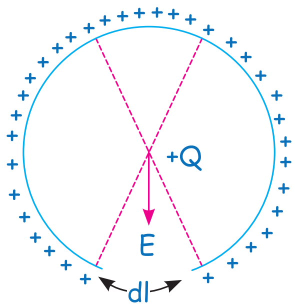
$$E = \frac{kq}{(l/\sqrt{2})^2}$$

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.

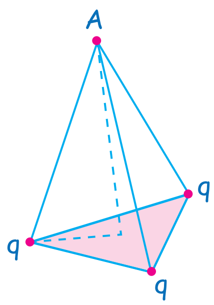
Sol.

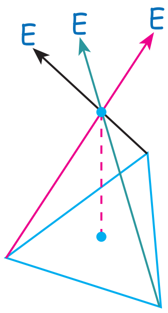


$$E_{net} = \frac{kdq}{R^2} = \frac{kQ}{R^2\, 2\pi R} dl$$

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

(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.





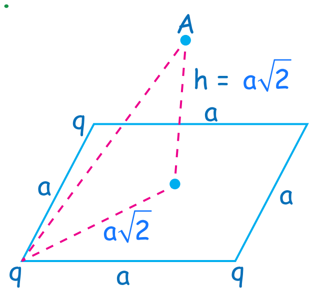
Sol. $E_A = 3E\sin\theta$
[$\theta = 60°$ already solved]

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.



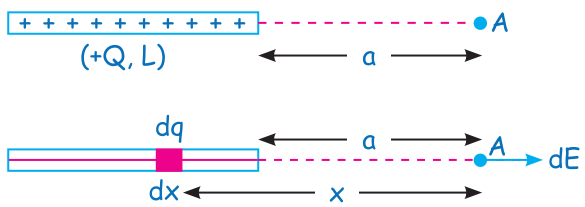
$E_A = 4E\sin\theta$ [$\theta = 45°$]

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.

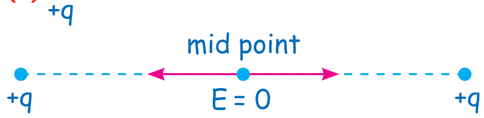


Sol. $\displaystyle\int dE = \int_a^{a+L} \frac{kdq}{x^2} = \int_a^{a+L} \frac{kQ}{L}\frac{dx}{x^2} = \frac{kQ}{a(a+L)}$

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

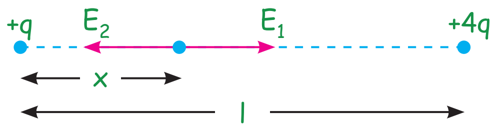
(a)

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

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

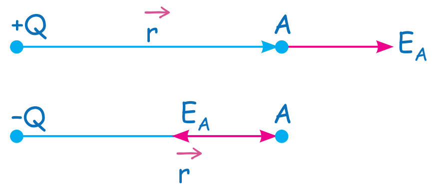
$\dfrac{4}{x^2} = \dfrac{9}{(x+l)^2}$

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

$x = 2l$

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 $\hat{r}$

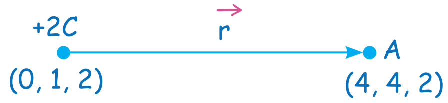
#SKC

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

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

Q. Find net E.F at point A.

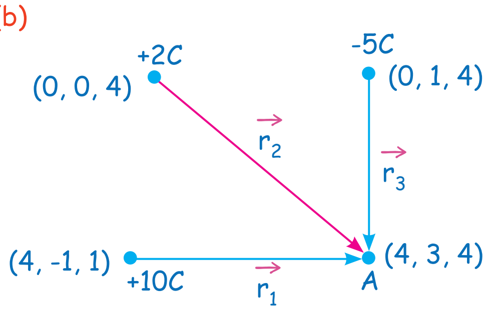
(a)



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

$$\vec{E}_A = \frac{9\times10^9\times(+2)}{5^2}\left(\frac{4\hat{i}+3\hat{j}}{5}\right)$$

(b)



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

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

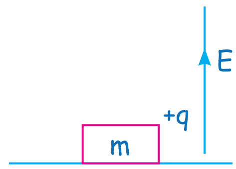
$$+\frac{k(-5)}{20}\left(\frac{4\hat{i}+2\hat{j}}{\sqrt{20}}\right)$$

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

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

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

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

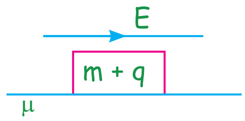


$qE \geq mg$

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

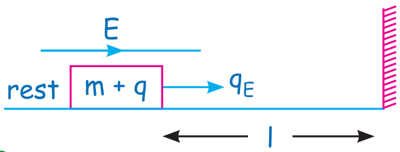
Q. Find min. value of E so that block start moving

Sol.



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

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



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

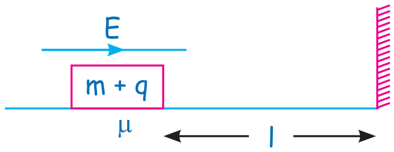
$s = ut + \frac{1}{2}at^2$

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

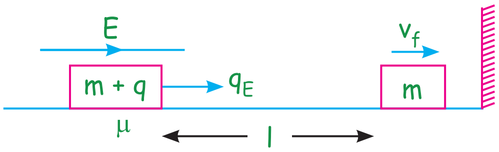
$t_o = \sqrt{\frac{2s}{a}} = \sqrt{\frac{m2s}{qE}}$

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.

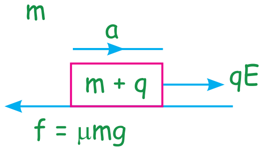


$(WD)_{\text{all force}} = \Delta K.E$

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

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

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



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

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

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

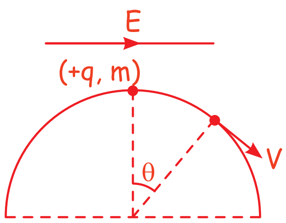
eq(1)- $V = \sqrt{2 \times \left(\frac{qE - \mu mg}{m}\right)l}$

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.

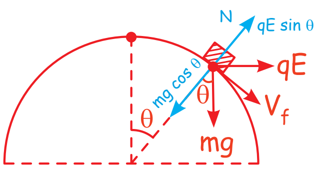
Sol. $T = \frac{2U_y}{a_y} = \frac{2 \times V_0 \sin\theta}{g + \frac{qE\cos\beta}{m}}$

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

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

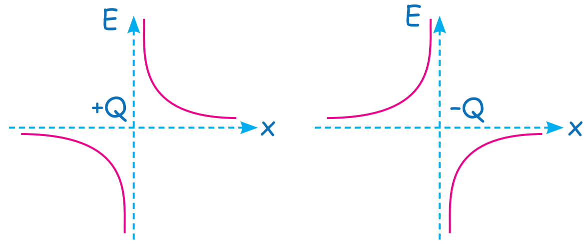
Q. A charge particle of radius 5×10^{-7}m is moving in a horizontal E.F. of intensity $2\pi \times 10^5$ V/m. The surrounding medium is air with coff. of viscosity $\eta = 1.6 \times 10^{-5}$ N.S/m^2. If this particle is moving with a uniform horizontal speed of .02 m/s. Find no. of excess electron on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

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

Ans. $30e^-$

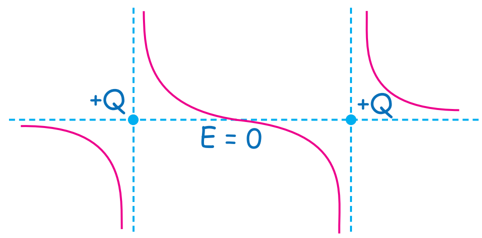
Graph b/w E Vs r

#



[For +ve, (आगे)] [For -ve]

#



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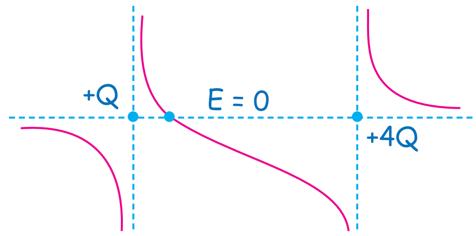

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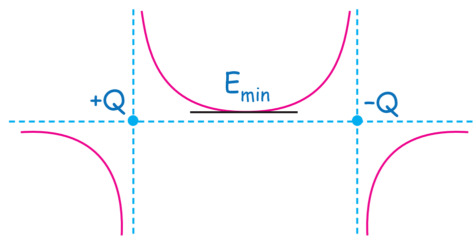

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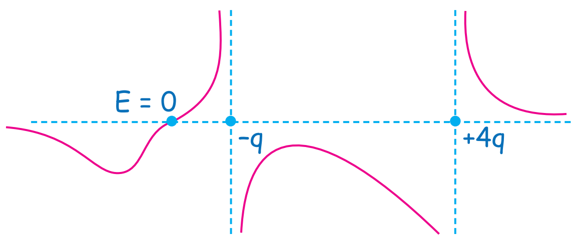
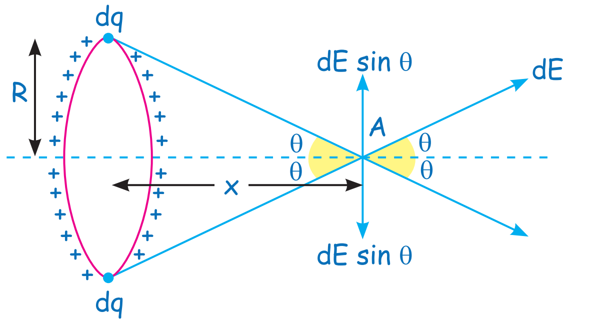


Use

ELECTRIC FIELD DUE TO CHARGED UNIFORM RING AT AXIS



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

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

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

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

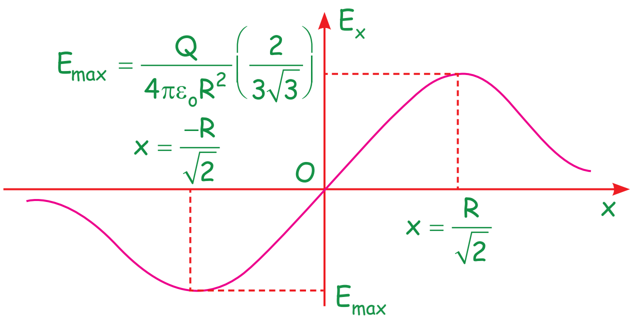
at $x = 0$, $\Rightarrow$ E.F = 0

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

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

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

$E_{max} = \frac{Q}{4\pi\varepsilon_0 R^2}\left(\frac{2}{3\sqrt{3}}\right)$



Charge Distribution

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

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

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

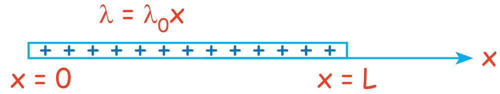
$$\boxed{\begin{array}{l} Q = \int \lambda dx \\ Q = \int \sigma dA \\ Q = \int \rho dV \end{array}}$$

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

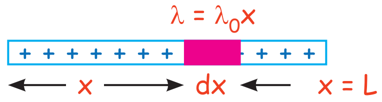
$\rho = \frac{dq}{dV}$ = charge per unit volume.

$dq = \rho dV$ [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.

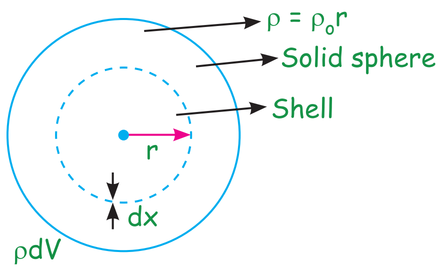


$\int dq = \int \lambda dx$

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

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.



$dq = \rho dV$

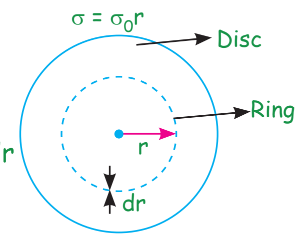
$Q_{total} = \int dq = \int_0^R \rho_0 r.4\pi r^2 dr = \pi\rho_0 R^4$

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

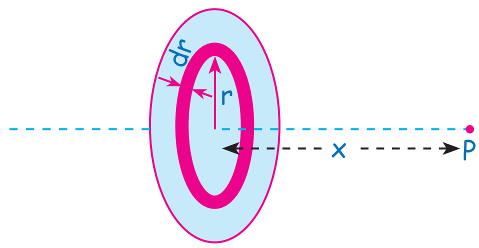
Sol. $dq = \sigma dA$

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

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

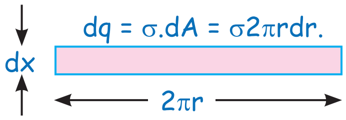


ELECTRIC FIELD DUE TO UNIFORM CHARGED DISC AT A POINT ON AXIS [+Q, σ, R]



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

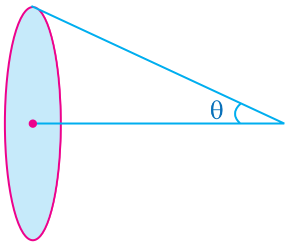
$E_{net} = \int dE$



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

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

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

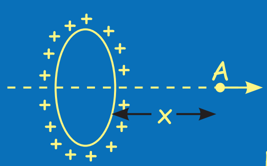


If disc is very large/Infinite sheet......

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

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

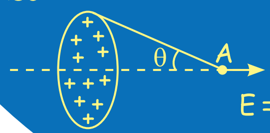
(1) Ring



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

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

(2) Disc



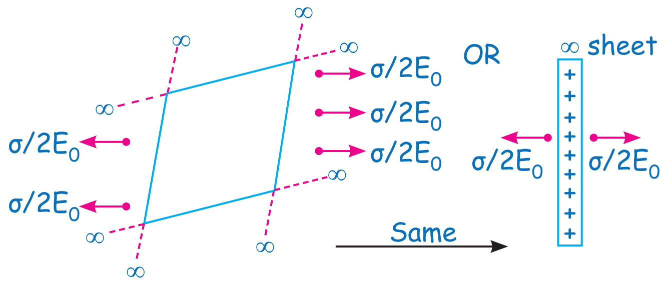
$$E = \frac{\sigma}{2\varepsilon_0}(1 - \cos\theta)$$

#SKC

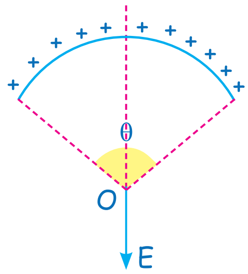
∞ sheet के दो मतलब

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

∞ sheet

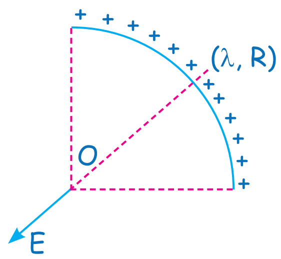


ELECTRIC FIELD DUE TO CHARGED ARC AT CENTER



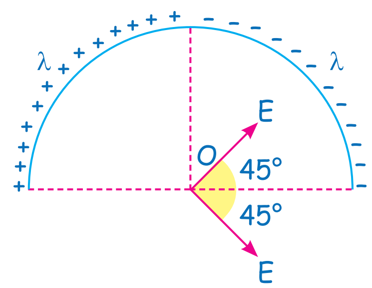
$$E = \frac{2k\lambda}{R}\sin\frac{\theta}{2}$$

1



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

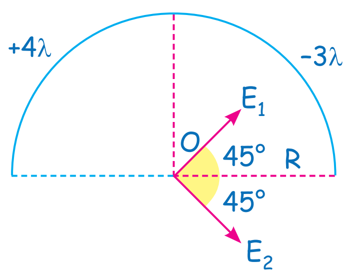
2



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

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

3

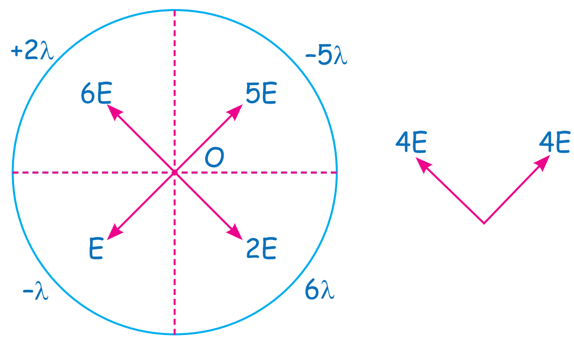


$$E_1 = \frac{2k(3\lambda)}{R}\sin 45^\circ = \frac{3\sqrt{2}\,k\lambda}{R}$$

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

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

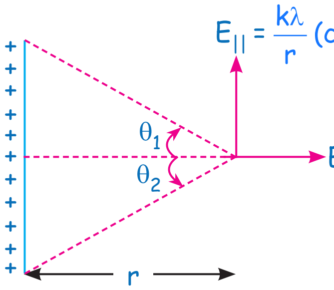
4



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

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

ELECTRIC FIELD DUE STRAIGHT CHARGED WIRE AT A POINT

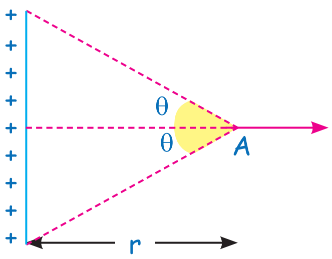


$$E_{||} = \frac{k\lambda}{r}(\cos\theta_1 - \cos\theta_2)$$

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

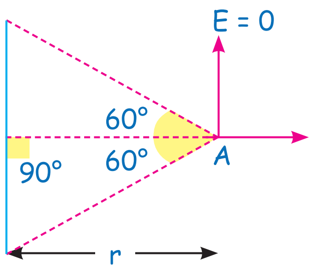
Q. Find electric field at point A in following case.

1



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

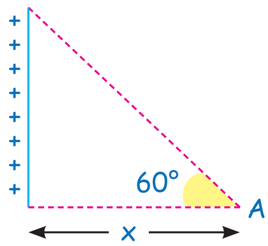
2



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

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

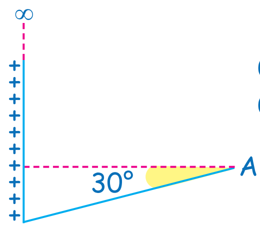
3



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

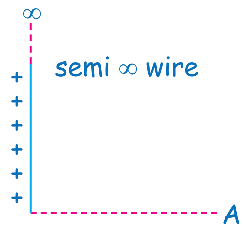
Now put the value in formula and get ans. अबे ये भी मै ही करू क्या बच्चे की जान लेगा।

4



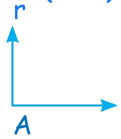
$\theta_1 = 90^\circ$
$\theta_2 = 30^\circ$

5



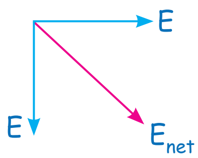
$\theta_1 = 90^\circ$
$\theta_2 = 0^\circ$

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



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

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

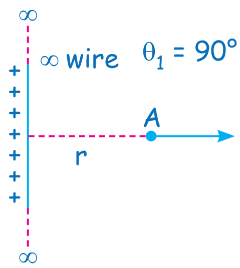


Here

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

इसे याद करलो

6

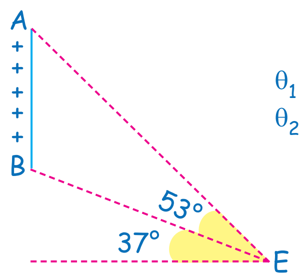


$\theta_1 = 90^\circ$ & $\theta_2 = 90^\circ$

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

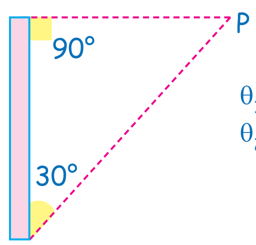
∞ wire ki वजह से $EF = \frac{2k\lambda}{r}$ होती है

7



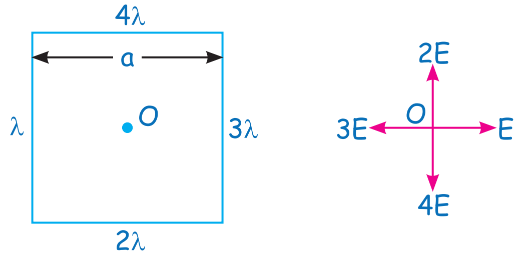
$\theta_1 = 53^\circ$
$\theta_2 = -37^\circ$

8

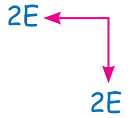


$\theta_1 = 0$
$\theta_2 = 60^\circ$

9 Find electric field at O.

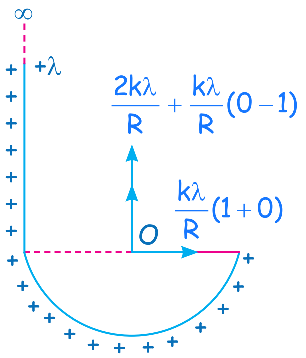


⇒



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

10



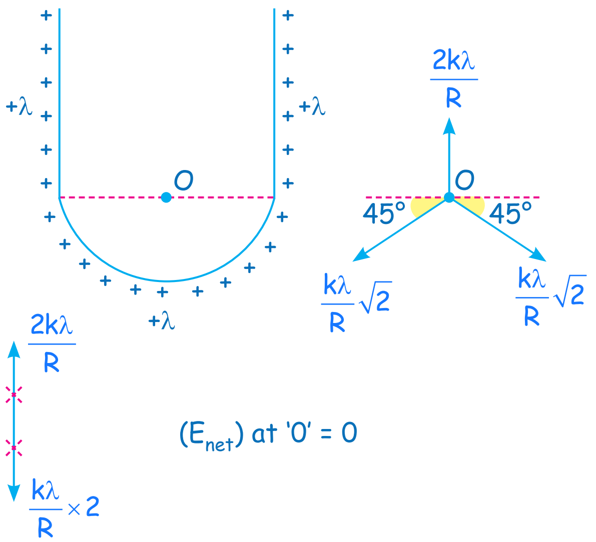
$\theta_1 = 90^\circ$

$\theta_2 = 0$

Solve and get

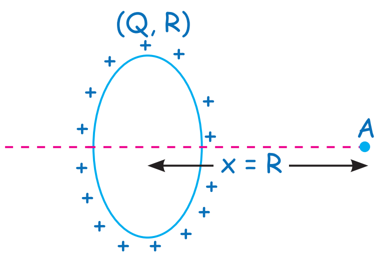
$$E_0 = \frac{k\lambda}{R}\sqrt{2}$$

11 Find electric field at O.



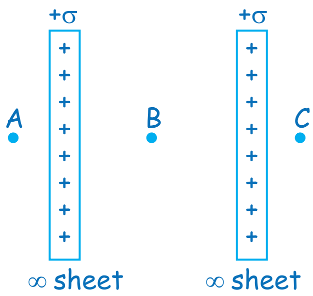
(E_{net}) at 'O' = 0

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

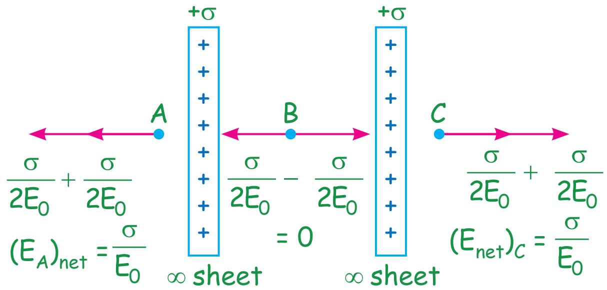


$$E_A = \frac{kQR}{(R^2 + R^2)^{3/2}} = \frac{kQ}{2\sqrt{2}R^2}$$

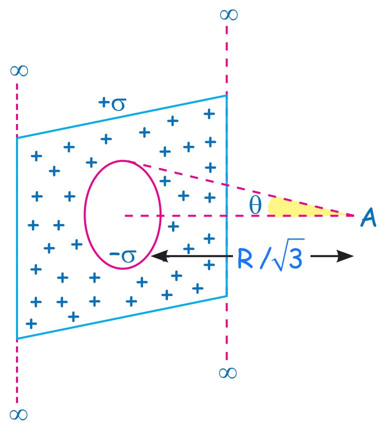
13 Find electric field at A, B, C



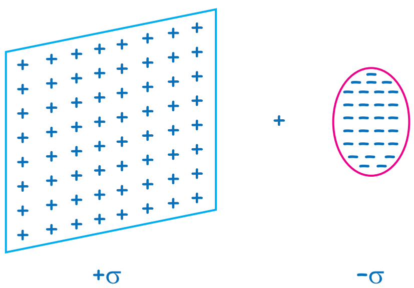
Sol.



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)



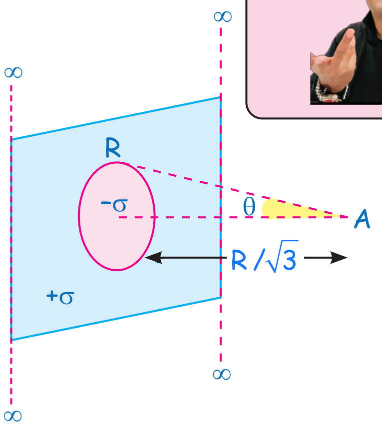
$(Ef)_{at}$ Point A = $\underbrace{\dfrac{\sigma}{2E_0}}_{\vec{E}\text{ due to }\infty\text{ sheet}} - \underbrace{\dfrac{\sigma}{2E_0}}_{\vec{E}\text{ due to -ve disc}}(1-\cos\theta)$

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

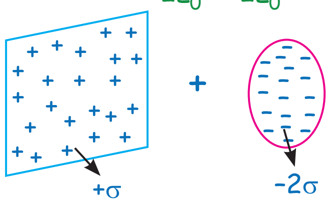
$= \dfrac{\sigma}{2E_0} - \dfrac{\sigma}{4E_0} = \dfrac{\sigma}{4E_0}$

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

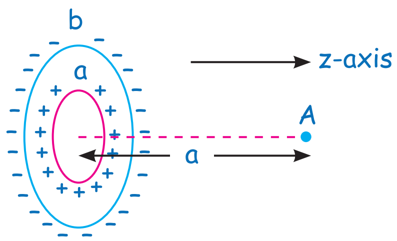
Q. Find electric field at A.



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



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



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

$(E_A)_{net} = 0$

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

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

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

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

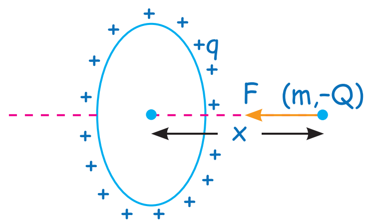
$b^2 = 4a^2$

$b = 2a$

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

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 $F = q \times E$



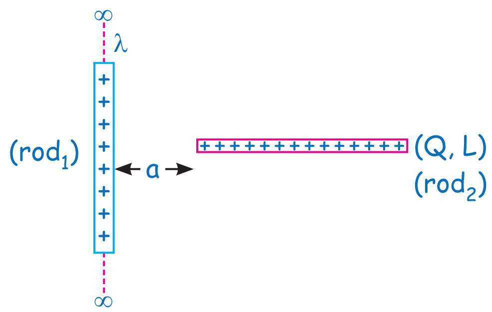
$F_{net} = QE$ (पीछे)

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

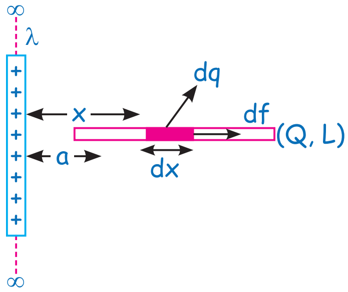
$F_{ent} = \dfrac{kqQ}{R^3}\vec{x}$

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

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



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



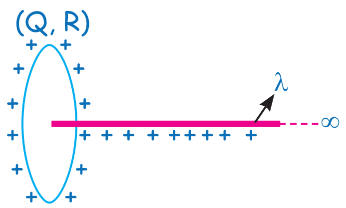
$$dF = dq.E$$

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

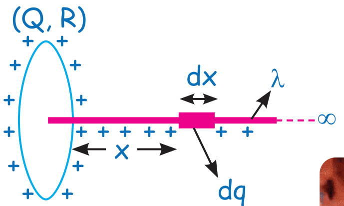
$$\int dF = \int_a^{a+L} \frac{Qdx}{L} \times \frac{2k\lambda}{x}$$

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

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



Sol.



$$dF = dq.\ E$$

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

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

$0 + 2xdx = dt$

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

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

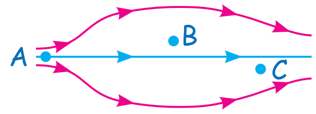
$$F_{net} = \lambda kQ \int_0^\infty \frac{xdx}{(R^2+x^2)^{3/2}} = \lambda kQ \int \frac{dt}{2t^{3/2}}$$

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

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

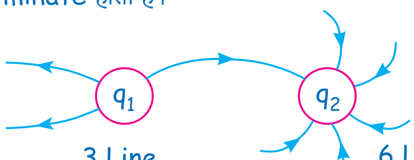
ELECTRIC FIELD LINE (EFL)

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



$E_A > E_C > E_B$

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



3 Line — 6 Line

$q_1 > 0$ — $q_1 = q(\text{let})$

$q_2 < 0$ — $q_2 = -2q$

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

न उसे हुई मेरे प्यार की कदर
न मुझे हुई उसके प्यार की कदर
फिर मुझे याद आई सलीम भईया
की वो line

Two electric field line never intersect each other.

ELECTRIC FLUX [ϕ]

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

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

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

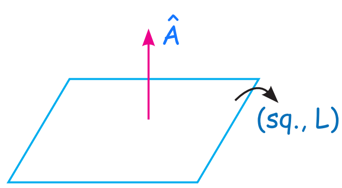
$$\boxed{\phi_{net} = \int \vec{E}.d\vec{A}}$$

If E.F is uniform

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

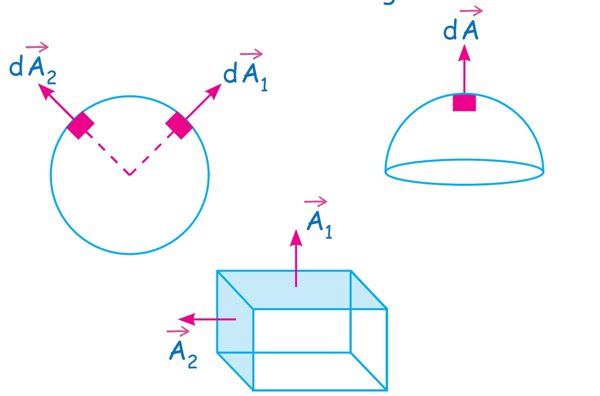
#SKC
Uniform = हर जगह same होना।
Constant = हर वक्त same होना।

AREA VECTOR [$\vec{A}$]

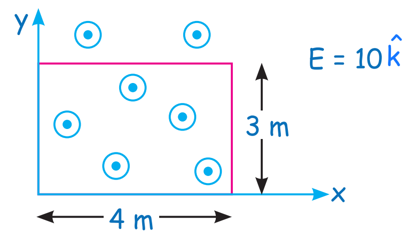


For closed body/surface

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



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



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

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

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

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

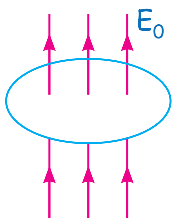
$\phi = \vec{E}\cdot\vec{A} = 0 + 0 + 10 \times 12 = 120$

Area = $4 \times 3 = 12$

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

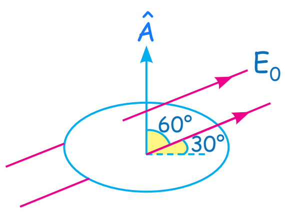
Q. Find flux through given area in following question.

1



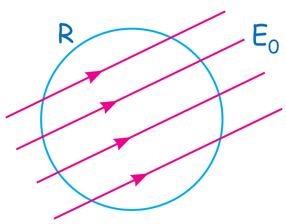
$\Rightarrow \phi = E_0 \cdot \pi R^2$

2



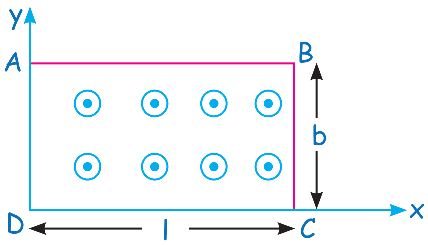
$\Rightarrow E\pi R^2 \cos 60°$

3



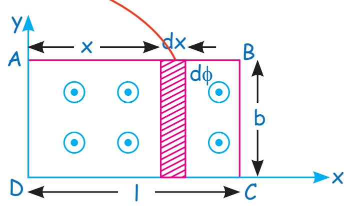
$\Rightarrow \phi = 0$

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



Sol.

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



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

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

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

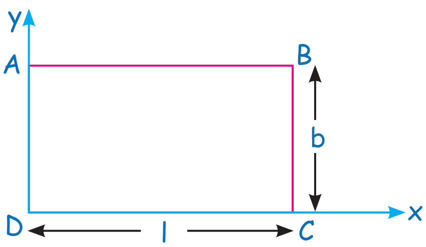
Q. In above part $\vec{E} = 5\hat{i} + 10\hat{j} + 10x\hat{k}$

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

Last part

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

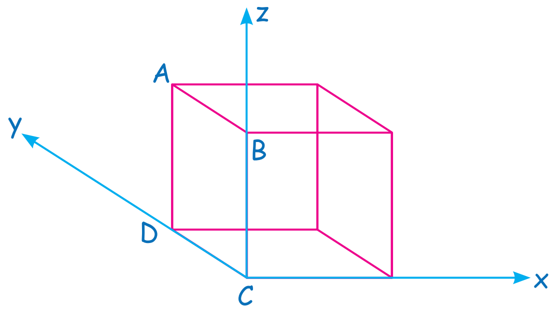
Q. Find flux through the rectangle if $\vec{E} = 3x^2y\hat{i} + 4y^3x\hat{j} + 3x^2\hat{k}$ in given diagram



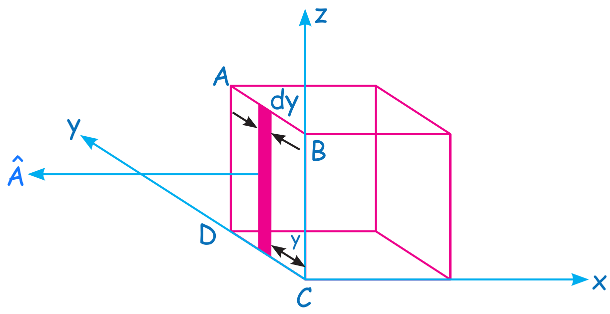
Sol. $d\phi = \vec{E}.d\vec{A}$

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

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



Sol.



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

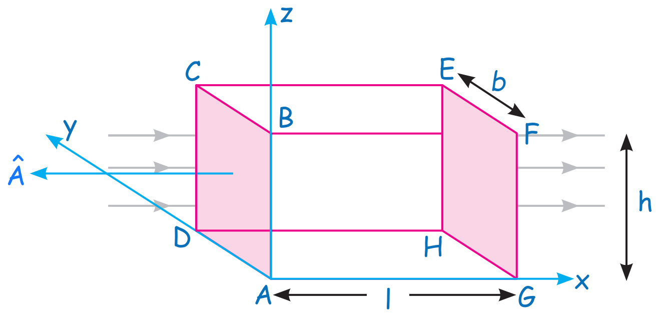
$\phi_{ABCD} = \int_0^A 10y.\, Ldy$ (magnitude) $= 5L^3$ (magnitude)

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 ($l \times b \times h$)



$\phi = EA \cos\theta$

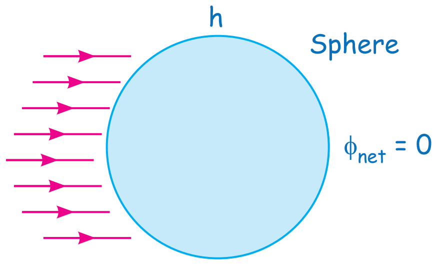
$\phi_{ABCD} = 10bh \cos 180° = -10bh = \phi_{in}$

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

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

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

Sphere



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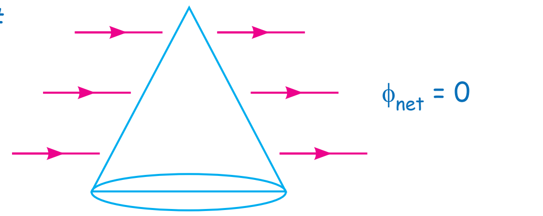

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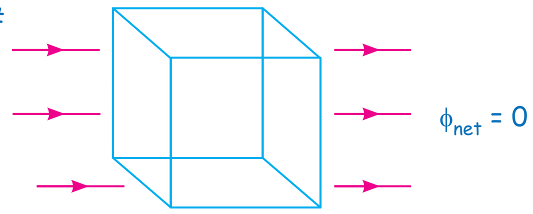

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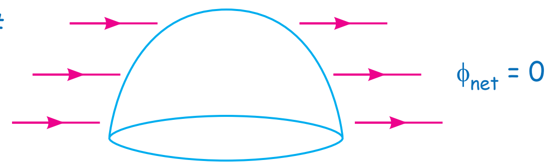

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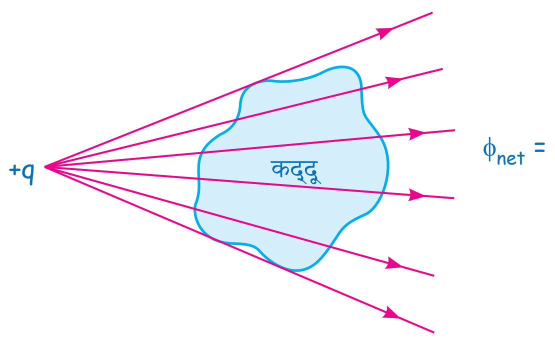

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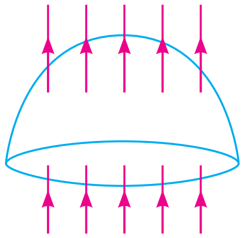
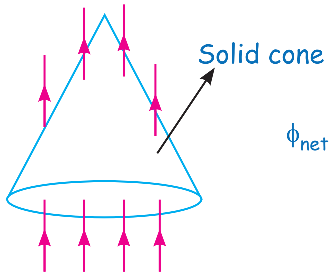


$\phi_{net} = 0$

#

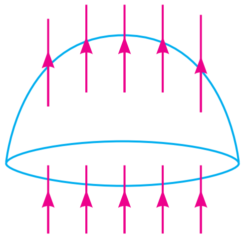


$\phi_{net} = 0$

#

$\phi_{net} = 0$

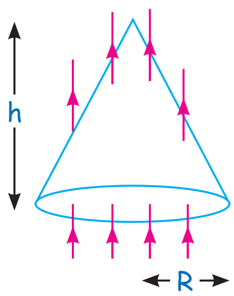
Q. Find flux through the curve surface of in hemisphere in following figure.



Sol. $\phi_{net} = 0$

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

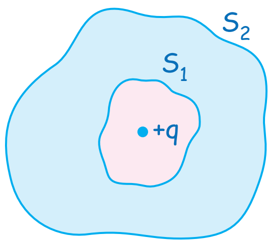
#



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

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

#



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

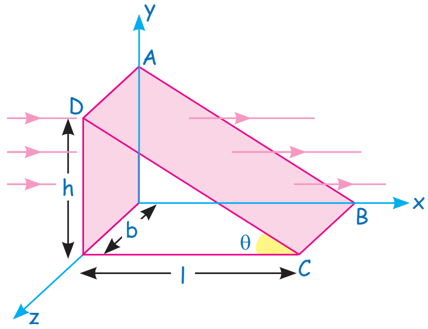
$\phi_{S_1} = \phi_{S_2}$

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

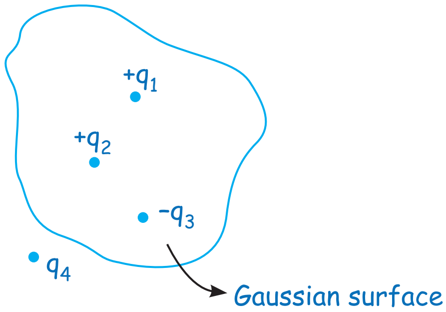
Sol. $\phi_{in} = -E_0hb$

$\phi_{out} = E_0hb$

$\phi_{net} = 0$



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

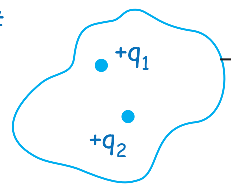
अंदर वाला charge

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

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

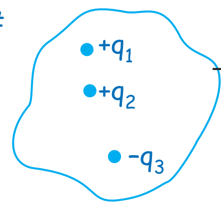
- $\oint \vec{E}\cdot d\vec{A} = \frac{q_{in}}{\varepsilon_0}$ • $\phi_{net} = \frac{q_{in}}{\varepsilon_0}$

#



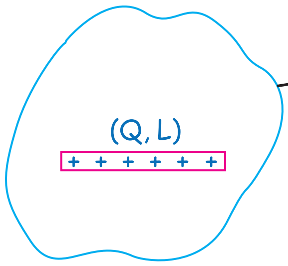
$\phi_{net} = \frac{q_1 + q_2}{\varepsilon_0}$

#



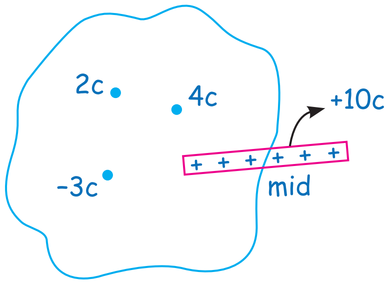
$\phi_{net} = \frac{q_1 + q_2 - q_3}{\varepsilon_0}$

#



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

#



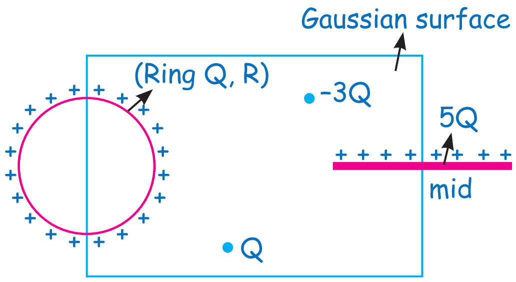
$$\phi_{net} = \frac{2+4-3+5}{\varepsilon_0} = \frac{8}{\varepsilon_0}$$

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।

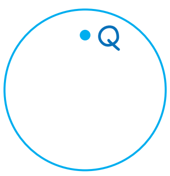
Q. Find flux through the Gaussian surface



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

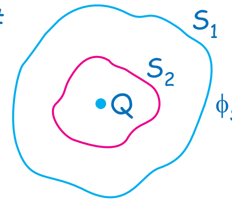
#

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



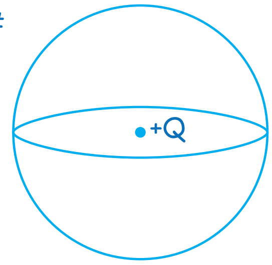
$\phi_{net} = \dfrac{Q}{E_0}$

#



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

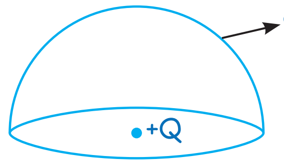
#



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

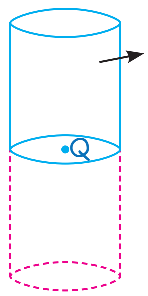
$(\phi)_{\text{upper half hemisphere}} = \dfrac{Q}{2E_0} = \phi_{\text{lower half hemispheres}}$

#



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

#



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

काम का डब्बा

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

- $\phi_{net} = \oint \vec{E} . d\vec{A} = \dfrac{q_{in}}{E_0}$
- यहां Electric field due to all charges hai. [अंदर वाले भी बाहर वाले भी]
- q_{in} → 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।

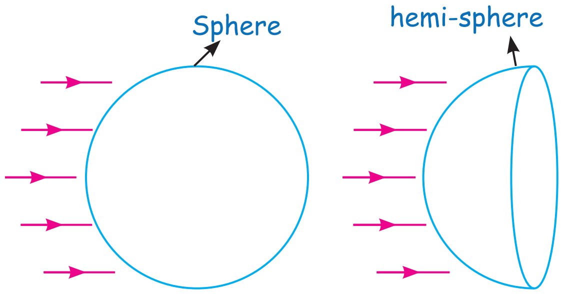
- Gaussian surface smartly मानना है, वर्ना कद्दू मिलेगा, और Gaussian surface ऐसे मानो की हर जगह पर θ की value 0°, 90°, 180° मिले

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

#



Sphere:

$\phi_{net} = 0$

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

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

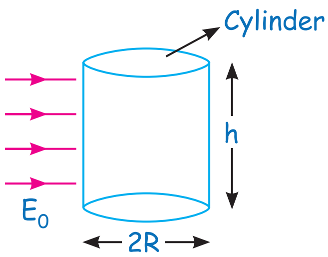
Hemi-sphere:

$\phi_{net} = 0$

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

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

#

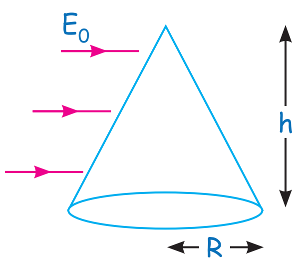


$\phi_{net} = 0$

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

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

#

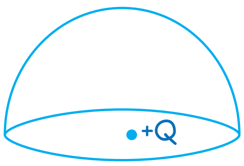


$\phi_{net} = 0$

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

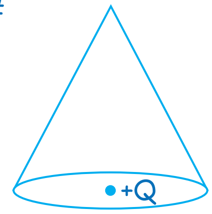
$\phi_{out} = E_0 \frac{1}{2} 2Rh$

#



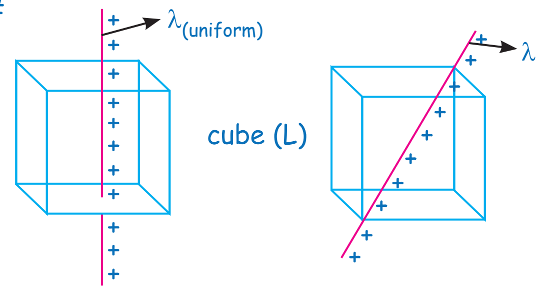
$\phi_{semi\text{-}sphere} = \frac{Q}{2E_0}$

#



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

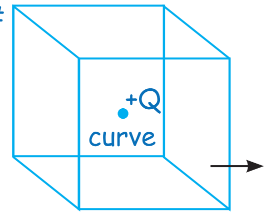
#



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

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

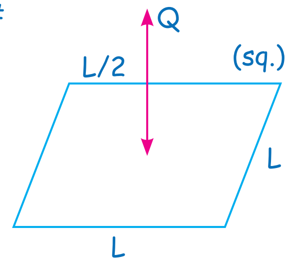
#



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

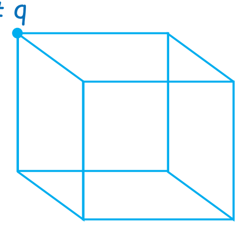
$\phi_{face} = \frac{Q}{6E_0}$

#



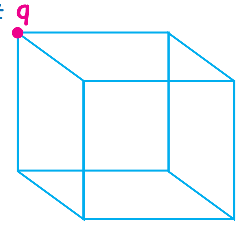
$\phi_{sq.face} = \frac{Q}{6\,E_0}$

q



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

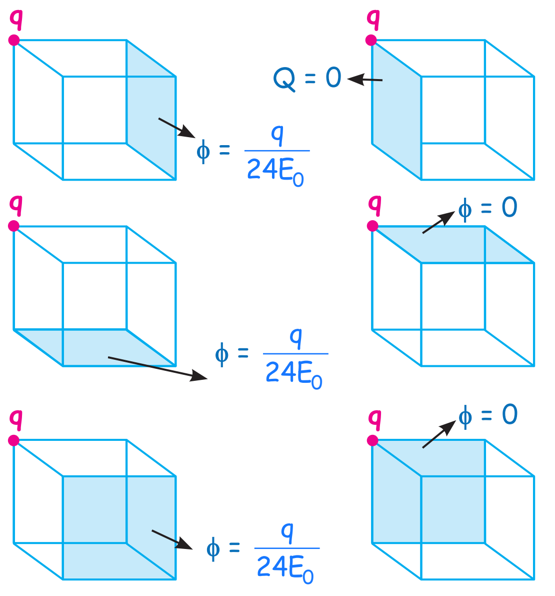
q



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

$\phi_{3faces} = 0$

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



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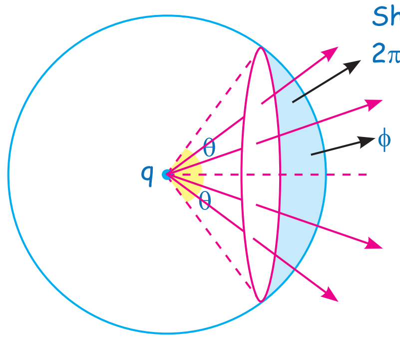


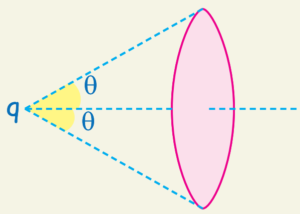
Shaded area = $2\pi r^2(1 - \cos\theta)$

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

बहुत important formula ये मत भूलना

Flux through the disc ϕ

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



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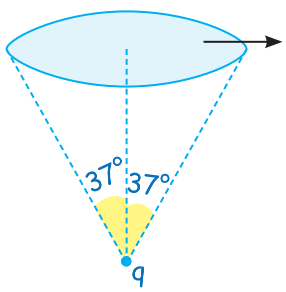
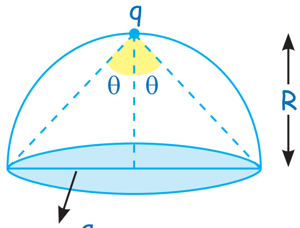


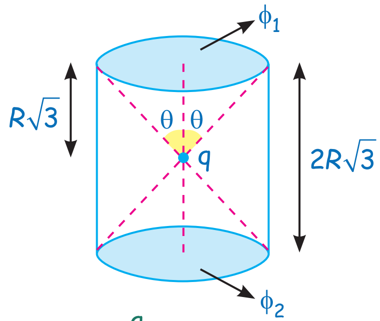
$\phi = \frac{q}{2E_0}(1 - \cos 37°)$

#



$\phi = \frac{q}{2E_0}(1 - \cos 45°)$

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



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

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

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

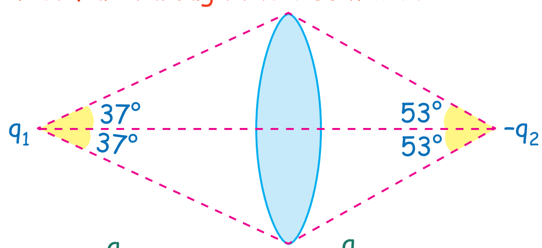
$\phi_1 \rightarrow$ flux through upper circular area
$\phi_2 \rightarrow$ flux through lower circular area

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

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

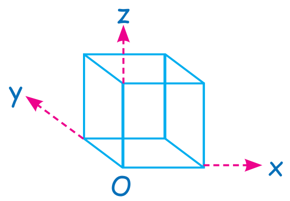
$$= \frac{q}{E_0}\frac{\sqrt{3}}{2}$$

Q. Net flux through the disc will be

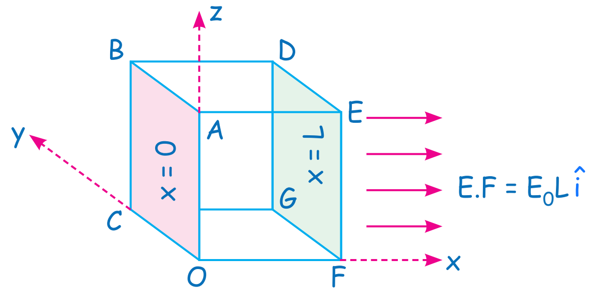


$$\phi_{net} = \frac{q_1}{2E_0}(1 - \cos 37°) + \frac{q_2}{2E_0}(1 - \cos 53°)$$

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

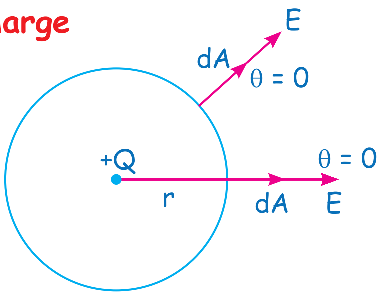
जब भी कभी मुझसे charge enclose पूछेगा, मैं $\phi_{net} = q_{in}/\varepsilon_0$ सबसे पहले सोचूंगी

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

Gaussian surface area

VERIFICATION OF GAUSS LAW

E.F Due to Pt. Charge



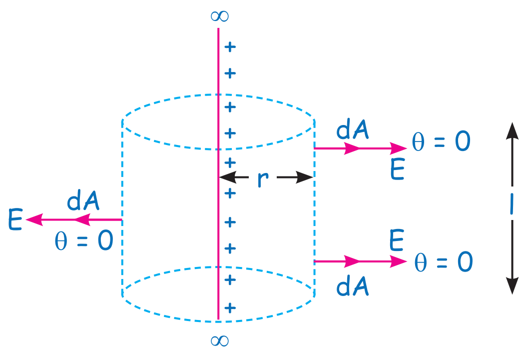
$$\oint \vec{E}\,.\,d\vec{A} = \frac{q_{in}}{E_0}$$

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

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

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

E.F DUE TO ∞ LINE-WIRE



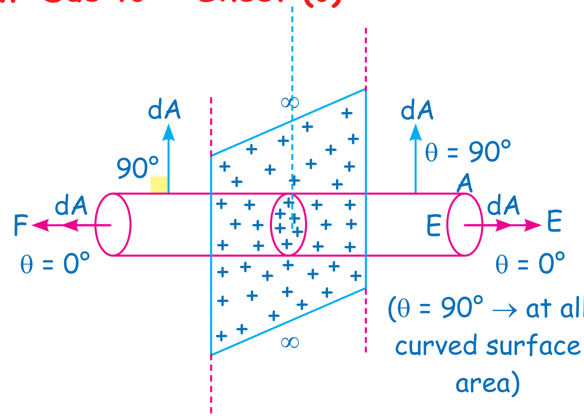
$$\oint \vec{E}\,.\,d\vec{A} = \frac{q_{in}}{\varepsilon_0}$$

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

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

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

E.F Due to ∞ Sheet (σ)



(θ = 90° → at all curved surface area)

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

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

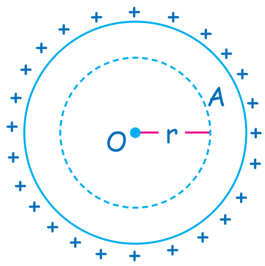
Curved Surface area

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

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

(a) E.F inside the hollow sphere

For r < R



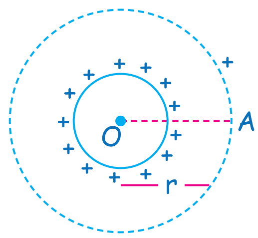
(Q, R)

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

$q_{in} = 0$

E = 0

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

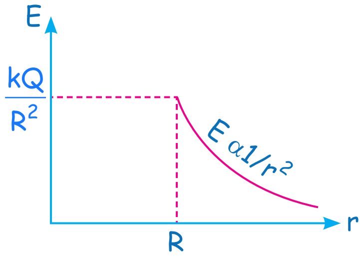


$$\oint \vec{E}\,.\,d\vec{A} = \frac{q_{in}}{\varepsilon_0}$$

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

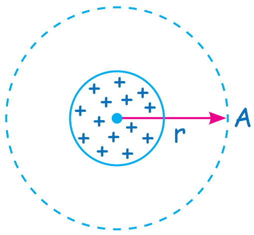
$$E4\pi r^2 = \frac{Q}{\varepsilon_0}$$

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



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

1. Outside (r > R)



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

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

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

$$\rho = \frac{Q}{\frac{4}{3}\pi R^2}$$

2. Inside (r < R)

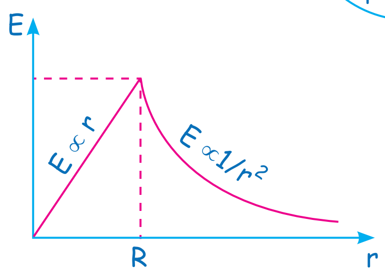
$$E.4\pi r^2 = \frac{q_{in}}{E_0}$$

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

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

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

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



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

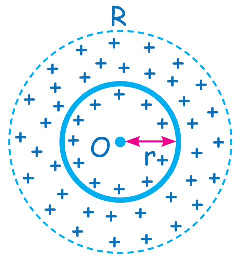
(2) Total charge of vol^n from r = 0 to r = R/2

(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]

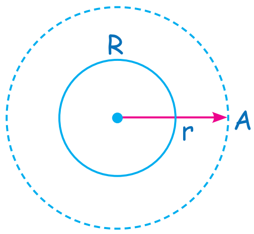
$$Q_0 = \rho_0 \frac{4\pi R^4}{4} = \rho\pi R^4$$

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

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

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

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

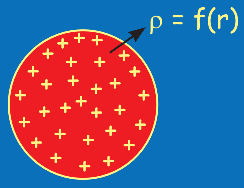
#SKC

*Very very important

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

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

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



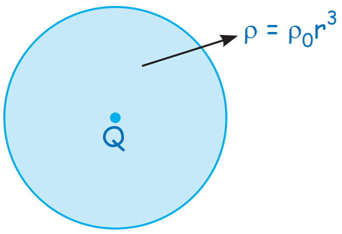
$\rightarrow$ Outside E.F. $= E.4\pi r^2$

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

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

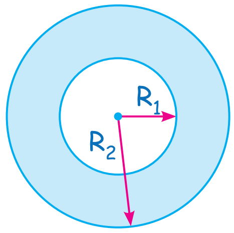
$$E = \frac{kq_{in}}{r^2}$$

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

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

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

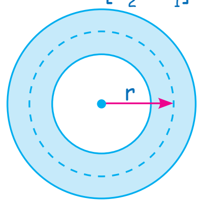
$$E = \frac{kQ}{r^2}$$

2. Inside $r < R_1$

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

$E = 0$

$[R_2 > R_1]$



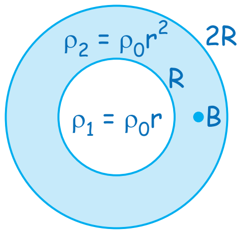
3. For $R_1 < r < R_2$

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

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

E = _____ solve and get

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



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

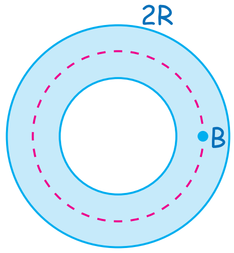
$\rho_2 = \rho_0 r^2 \quad R < r \le 2R$

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

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

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

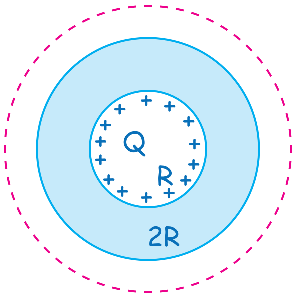
2. Find E.F at $r = 1.5$ R



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

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

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:



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

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

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

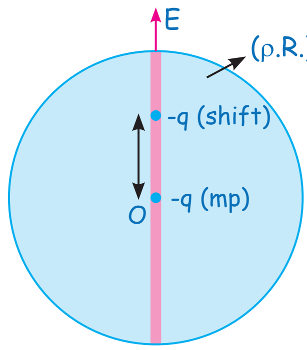
$$E = \frac{(Q - \alpha 2\pi R^2) + 2\pi r^2 \alpha}{4\pi r^2\ E_0}$$

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

$\therefore$ 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

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

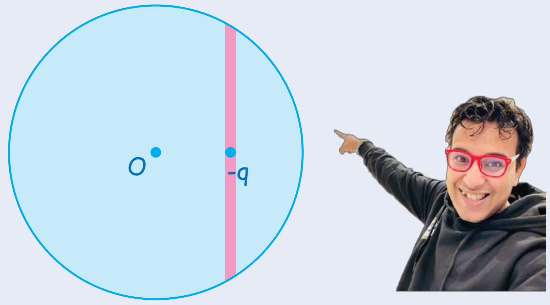
$$\vec{F}_{net} = -q\frac{\rho \vec{x}}{3E_0} = -K\vec{x}\ \text{(SHM)}$$

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

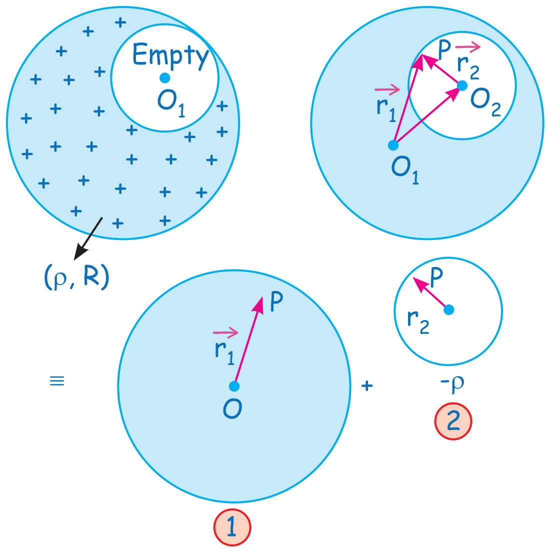
in SHM if F = – k x

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

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

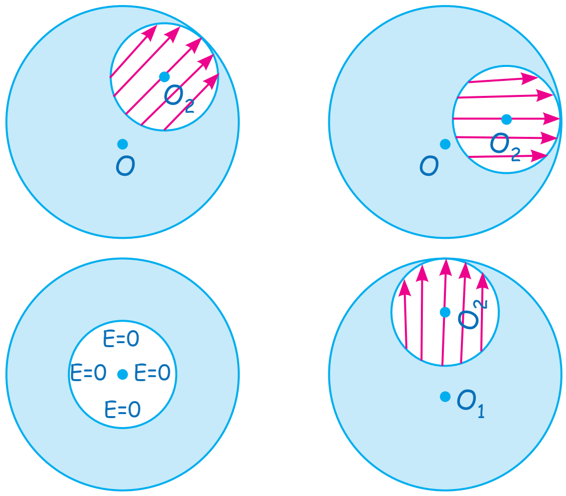


$$(\vec{E}_{at\ P}) = \vec{E}_1 + \vec{E}_2 = \frac{\rho\vec{r}_1}{3E_0} + \left(\frac{-\rho\vec{r}_2}{3E_0}\right) = \frac{\rho}{3E_0}[\vec{r}_1 - \vec{r}_2]$$

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

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

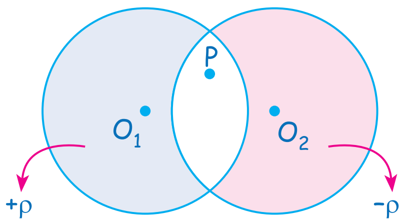
#



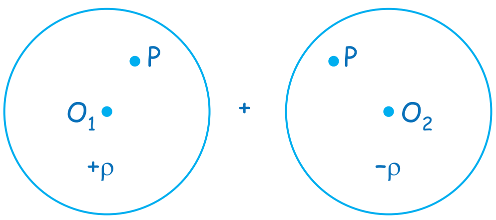
$\overrightarrow{O_1\,O_2} = 0$

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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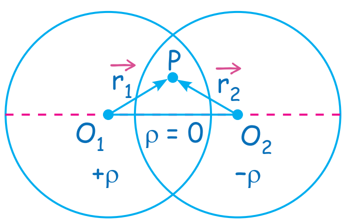
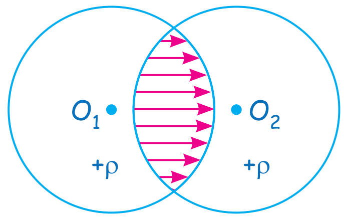


$$\vec{E}_P = \vec{E}_1 + \vec{E}_2$$

$$\vec{E}_P = \rho\frac{\vec{O_1P}}{3E_0} + \left(\frac{-\rho\vec{O_2P}}{3E_0}\right) = \frac{\rho\vec{r}_1}{3E_0} - \frac{\rho\vec{r}_2}{3E_0}$$

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

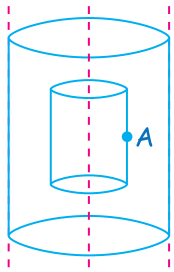
#



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

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

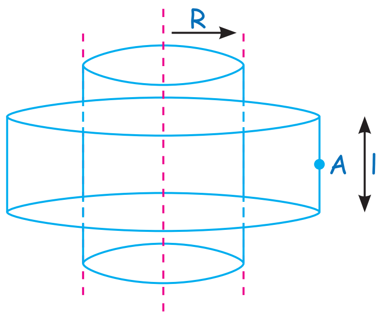
1. E.F inside r < R



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

$$E = 0$$

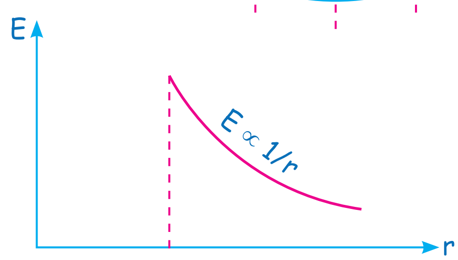
2. E.F Outside r > R



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

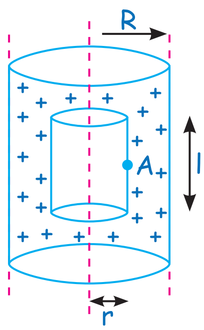
$$E.2\pi rl = \frac{\sigma 2\pi Rl}{E_0}$$

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



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

1. E.F inside r < R



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

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

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

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

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

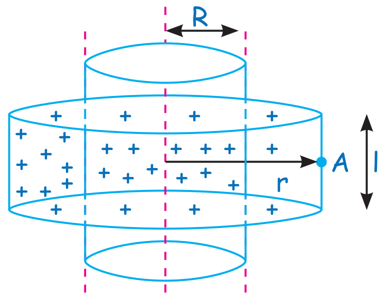
② E.F outside r > R

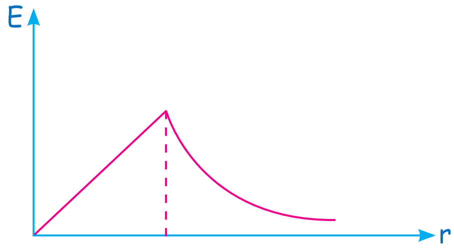
$E\int dA = \frac{q_{in}}{E_0}$

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

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

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





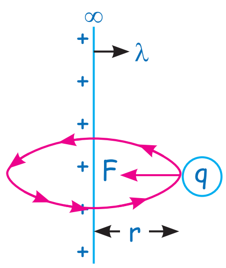
Circular motion वाले सवाल

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

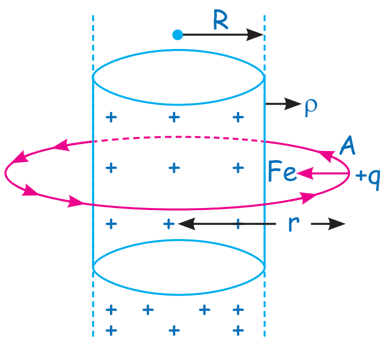
Sol. $q\frac{2k\lambda}{r} = \frac{mv^2}{r}$

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

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



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



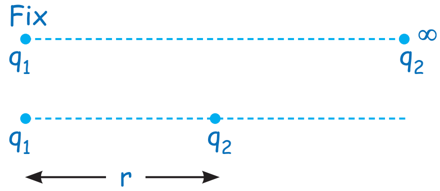
$E_A = \frac{\rho R^2}{2E_0 r}$

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

$v \propto r^0$

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

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

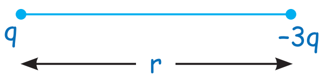
#SKC

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

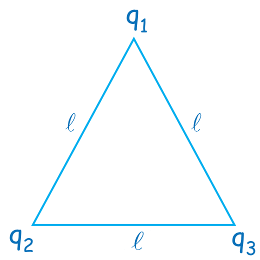
Q. Find P.E of system

①



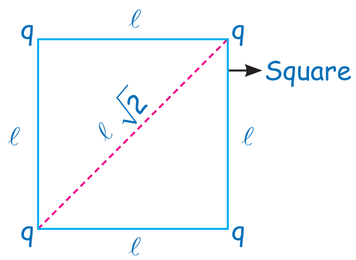
$\Rightarrow U = \frac{kq(-3q)}{r}$

②



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

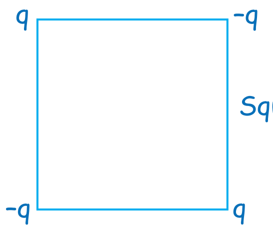
3



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

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

4

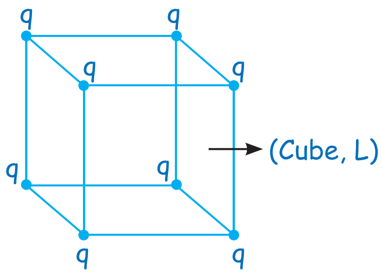


Square (L)

${}^4C_2 = 6$ (terms आएंगे)

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

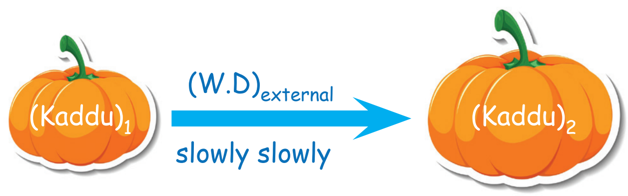
5



(Cube, L)

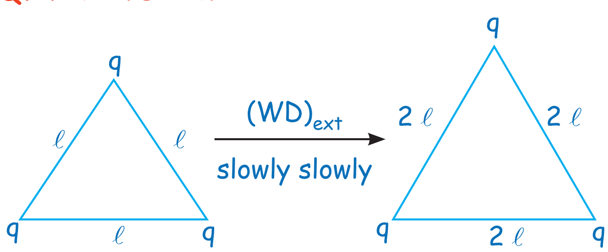
${}^8C_2 = 28$ terms

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



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

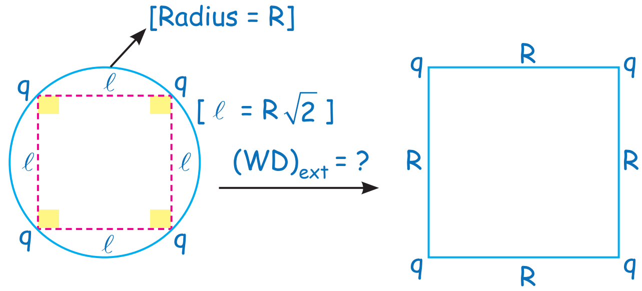
Q. Find WD ext.



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

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

#



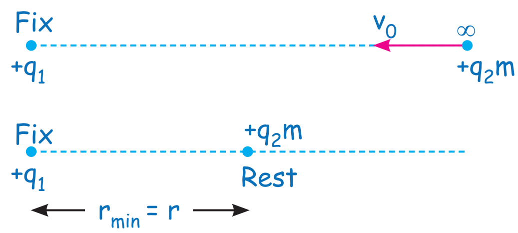
$$U_i = \frac{kq^2}{R\sqrt{2}} \times 4 + \frac{kq^2}{2R} \times 2 \qquad U_f = \frac{kq^2}{R} \times 4 + \frac{kq^2}{R\sqrt{2}} \times 2$$

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

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 $\to$ conserve

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

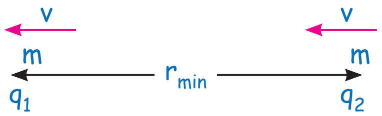
$K_i + U_i = k_f + U_f$

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

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

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

Sol.



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

$P_i = P_f$

$0 + mv_0 = mv + mv$

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

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

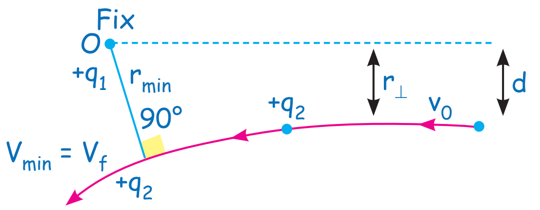
$k_i + U_i = k_f + U_f$ (apply thanos MEC)

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

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

Solve (i) and (ii).

Q. Find min. separation for the given diagram.



1. $k_i + U_i = k_f + U_f$

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

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 ⇒ interaction energy of unit +ve charge.

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

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

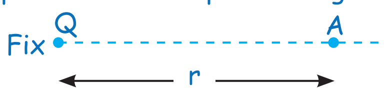
  $(WD)_{electric\ feild} = -\Delta U$

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

 # काम का डब्बा

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



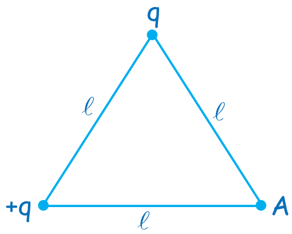
$\Rightarrow v_A = \frac{kQ}{r}$ (scaler)

with sign

Find electric potential at Pt. 'A'.

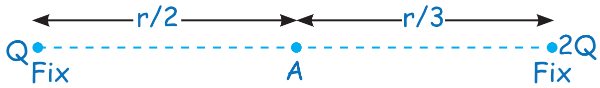
1. -Q ---------------- A (r) $V_A = \frac{k(-Q)}{r}$

2



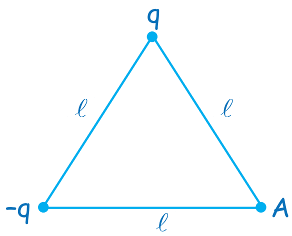
$$V_A = \frac{kq}{\ell} + \frac{kq}{\ell}$$

3



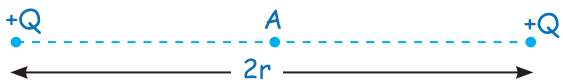
$$\Rightarrow V_A = \frac{kQ}{r/2} + \frac{k2Q}{r/3}$$

4



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

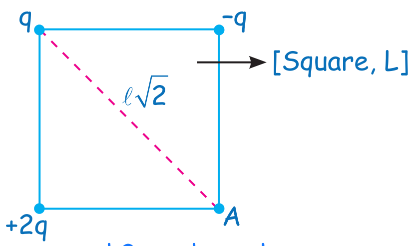
5



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

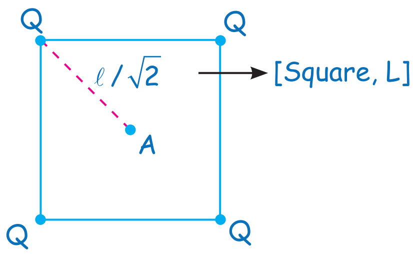
$E_A = 0.$

6



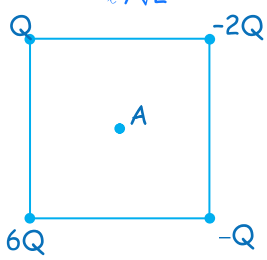
$$\Rightarrow V_A = \frac{k2q}{\ell} + \frac{kq}{\ell\sqrt{2}} - \frac{kq}{\ell}$$

7



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

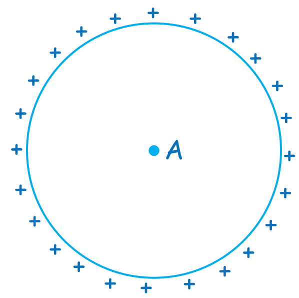
8



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

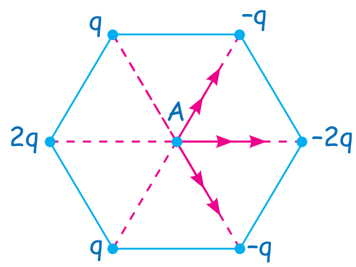
$$V_A = \frac{4kQ}{\ell/\sqrt{2}}$$

9 ring (Q, R)



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

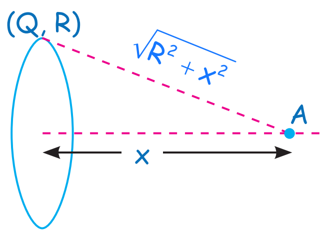
10



$\Rightarrow V_A = 0$

$\Rightarrow E \rightarrow +x$ Ans.

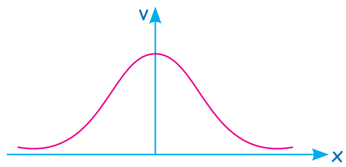
Potential at a point x from center of charged ring



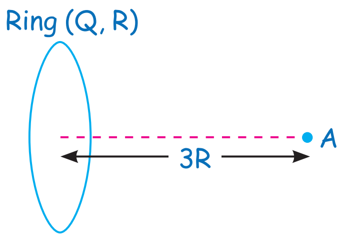
$$V_A = \frac{kQ}{\sqrt{R^2 + x^2}}$$

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

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

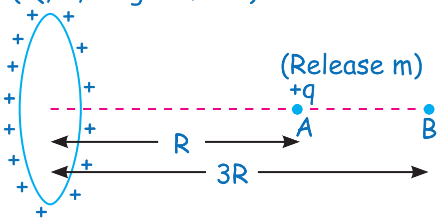


Q. Find potential at A due to charge ring (Q, R).



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

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)

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

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

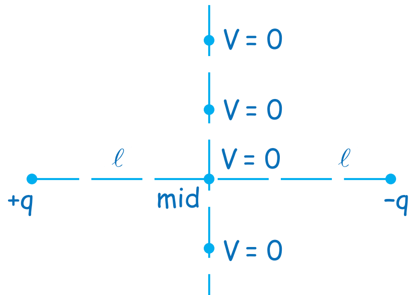
Q. Repeat the above problem when charge reaches at infinity.

Sol. $k_A + U_A = k_B + U_B$

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

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

#



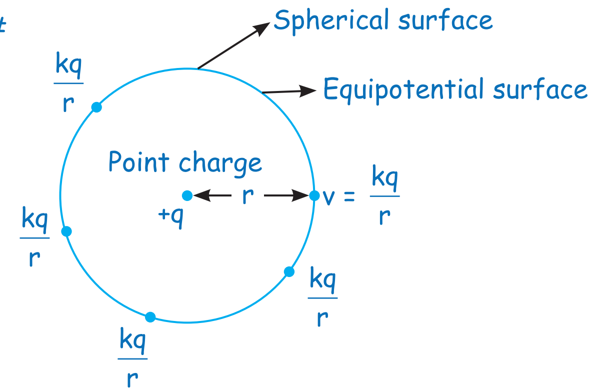
Equipotential line

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

#SKC

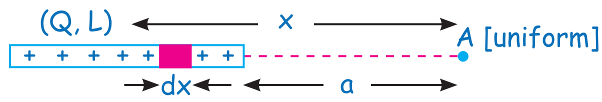
Equipotential line ka मतलब उस line Ke hr point ka potential 0 hai, aur equipotential surface ka मतलब उस surface k hr point ka potential same hoga.

#



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

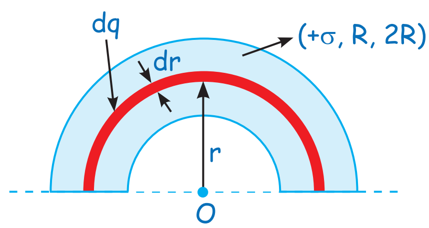
Sol.



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

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

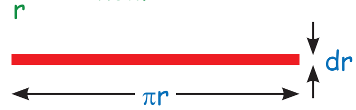
SSSQ. Find the potential at 'O' due to given part of disc.



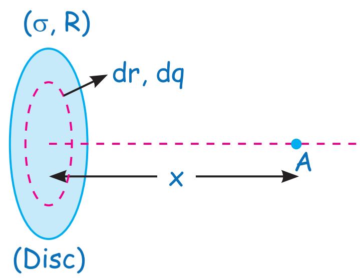
$$\int dv = \int\frac{kdq}{r} = \int_R^{2R}\frac{k\sigma\,\pi r dr}{r} = k\sigma\pi r$$

$dq = \sigma dA$

$dq = \sigma\pi r dr$



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



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

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

Solve and get and याद करलो

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

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

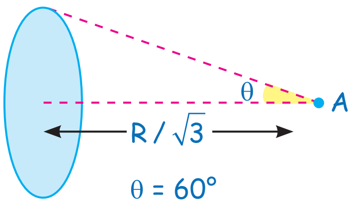
$$V_{\text{near center}} = \frac{\sigma}{2\varepsilon_0}R \text{ (just bahar)}$$

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

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

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

(σ, R, Disc)

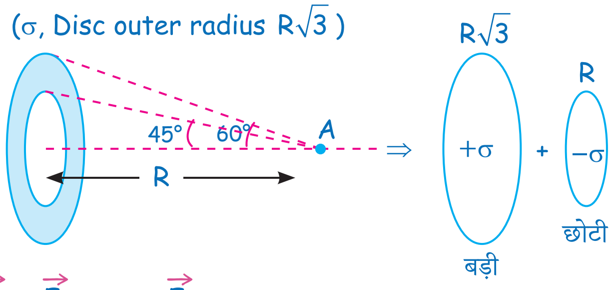


$\theta = 60°$

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

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

(σ, Disc outer radius $R\sqrt{3}$)



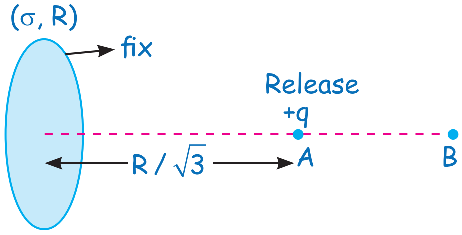
$$\vec{E}_A = \vec{E}_{\text{बड़ी Disc}} + \vec{E}_{\text{छोटी Disc}(-\sigma)}$$

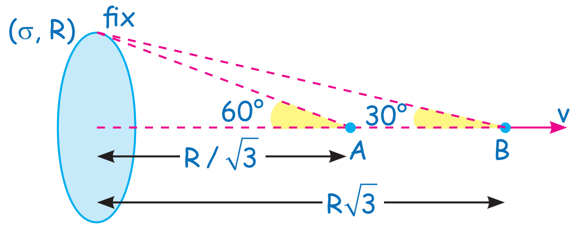
$$\rightarrow E_A = \frac{\sigma}{2E_0}(1-\cos 60°) + \frac{-\sigma}{2E_0}(1-\cos 45°)$$

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

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

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





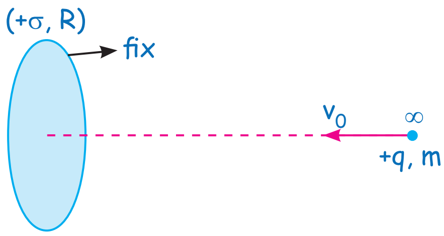
$$k_A + U_A = k_B + U_B$$

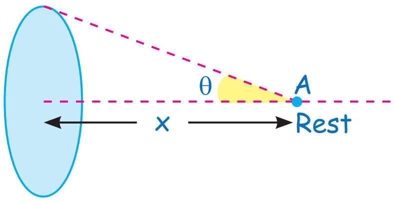
$$k_A + qv_A = k_B + qv_B$$

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

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

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





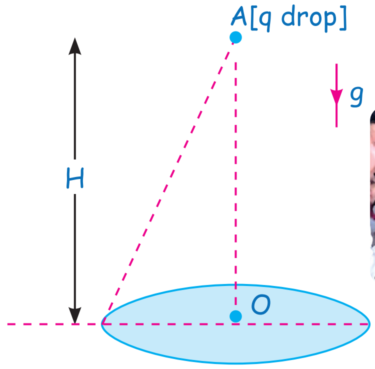
$$k_i + U_i = k_f + U_f$$

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

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

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.



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

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

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

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

RELATION BETWEEN ELECTRIC POTENTIAL AND ELECTRIC FIELD

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

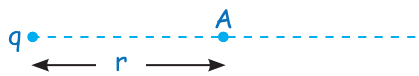
$q\Delta V = -\int q\vec{E}.d\vec{r}$

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

Potential Due to Point Charge

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

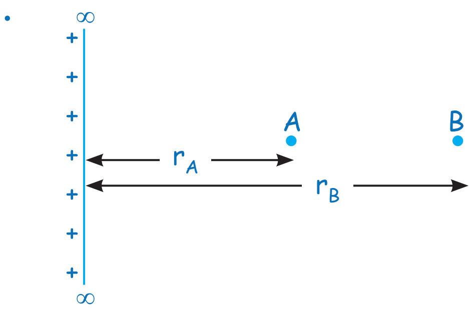
$\int_0^v dv = -\int_\infty^r \dfrac{kq}{r^2} dr$



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

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

Potential Difference Between Two Point Due to Infinite Line Charge Wire



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

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

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

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

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

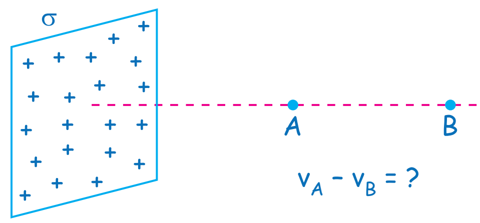
#SKC

$V_{\text{बड़ा}} - V_{\text{छोटा}}$

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

वैसे r_A and r_B shortest perpendicular distance है।

Potential Difference Between Two Point Due to ∝ Sheet



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

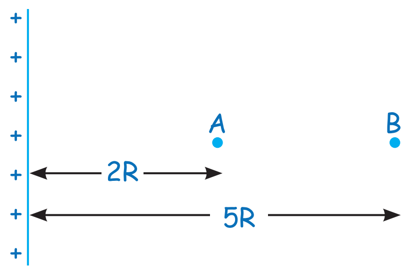
$\int_A^B dv = -\int_{r_A}^{r_B} \dfrac{\sigma}{2E_0} dr$

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

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

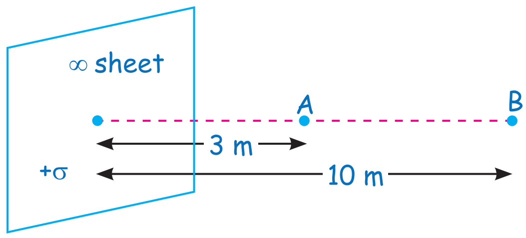
वैसे r_A and r_B shortest perpendicular distance है।

Q. Find potential difference between A and B.



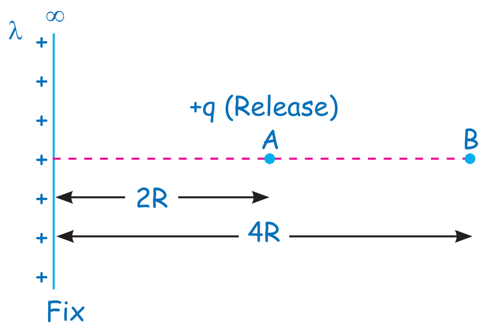
$v_A - v_B = 2k\lambda \; \ell n\left(\dfrac{5R}{2R}\right)$

Q.



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

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



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

$k_A + U_A = k_B + U_B$

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

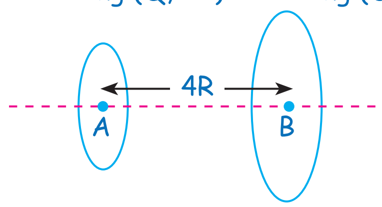
$q(V_A - V_B) = \frac{1}{2}mv_B^2$

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

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 $V_A - V_B$

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

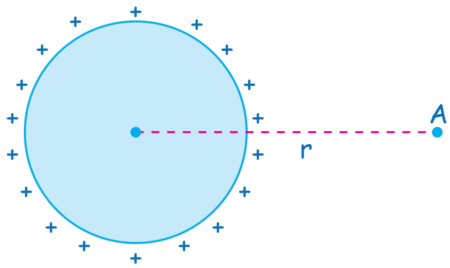
$= -\int \frac{q\vec{E}\cdot d\vec{r}}{q} = -\int \vec{E}\cdot d\vec{r}$

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

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

ELECTRIC POTENTIAL DUE TO HOLLOW SPHERE/SHELL/SPHERICAL CONDUCTOR

1. r > R [outside]



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

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

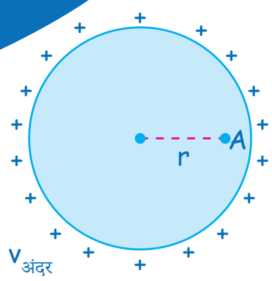
$v - 0 = \frac{kQ}{r}\Big|_\infty^r$

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

• $v = \frac{kQ}{R}$ [अंदर]
R → Radius

• $v = \frac{kQ}{r}$ [बाहर]
r → Distance

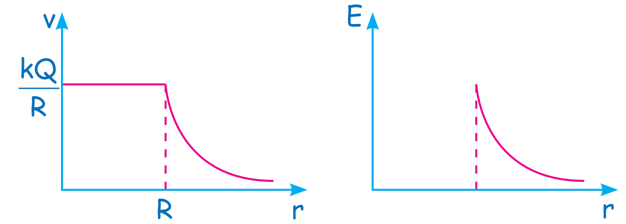
2. r < R [inside]



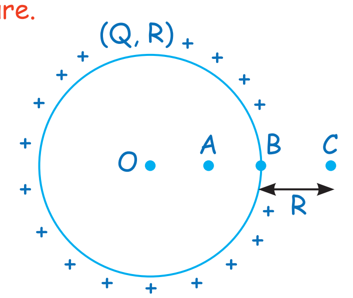
E = 0

v = const.

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



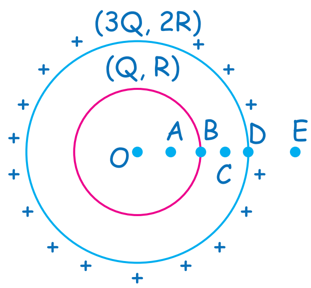
Q. Find potential at O, A, B, C due to shell as shown in figure.



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

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.



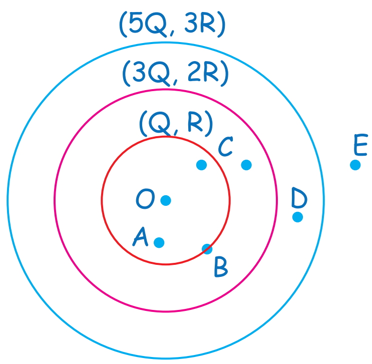
$$V_O = \frac{kQ}{R} + \frac{k3Q}{2R} = V_A = V_B$$

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

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

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

Q. Find potential at given point.



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

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

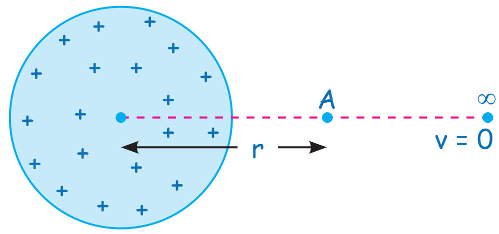
$$V_D = \frac{kQ}{OD} + \frac{k3Q}{OD} + \frac{k5Q}{3R}$$

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

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]

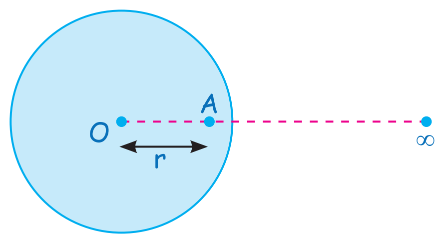


$$\int_0^V dv = -\int_\infty^r \vec{E} \cdot d\vec{r}$$

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

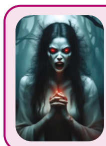
$$V = \frac{kQ}{r}$$

2. Inside [r < R]



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

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

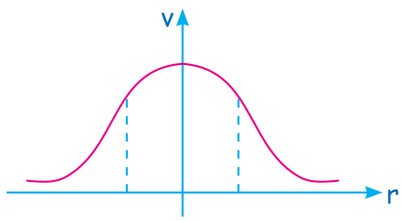


$$V_A = V_{inside} = \frac{kQ}{2R^3}(3R^2 - r^2)$$

चुड़ैल वाला formula

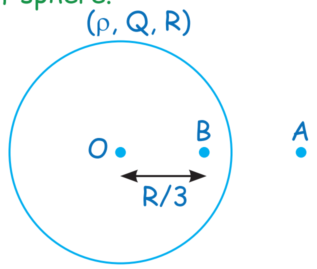
3. $V_{surface} = \frac{kQ}{R}$

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



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

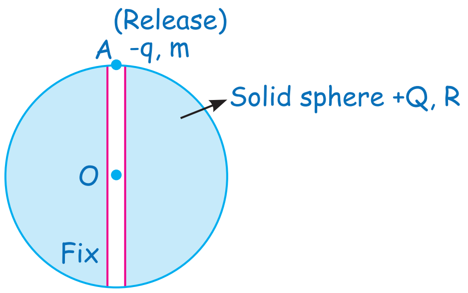
$E_0 = 0, v_0 = \frac{3}{2}\frac{kQ}{R}$

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. $k_A + U_A = k_0 + U_0$

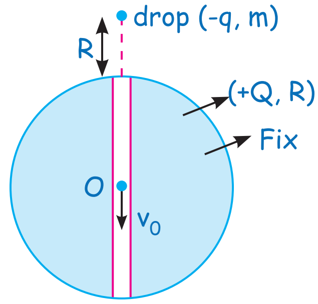
$0 + (-qv_A) = \frac{1}{2}mv_0^2 + (-q\ v_{centre})$

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

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

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

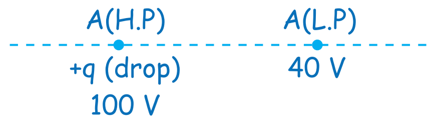
Q. Find speed of charge –q where reaches at centre



$k_i + U_i = k_f + U_f$

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

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



$k_i + U_i = k_f + U_f$

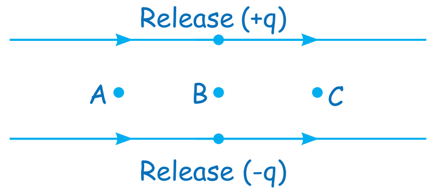
$0 + qv_A = \frac{1}{2}mv_B^2 + q \times 40$

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

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

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.



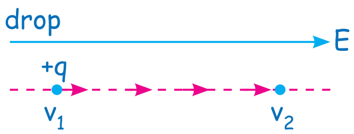
$\Rightarrow v_A > v_B > v_C$ (potential)

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

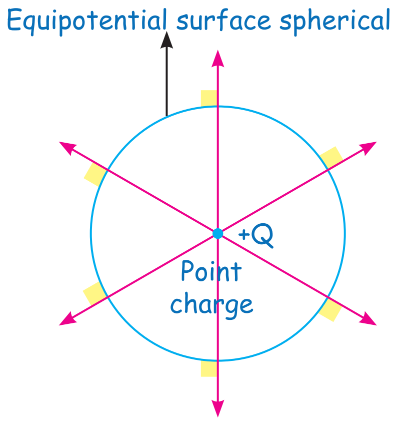
1. Locus of all point havig same potential. Surface of all point of which potential is ame.

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

   $v \rightarrow$ same

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

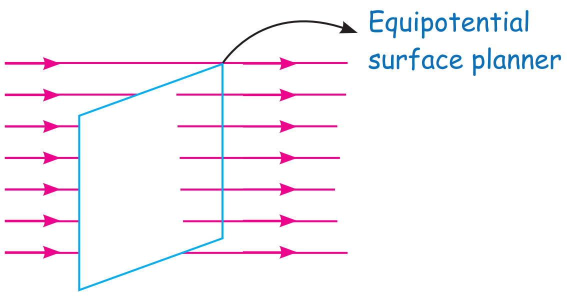
   i.e., E.F is $\perp^{ar}$ to equipotential surface.

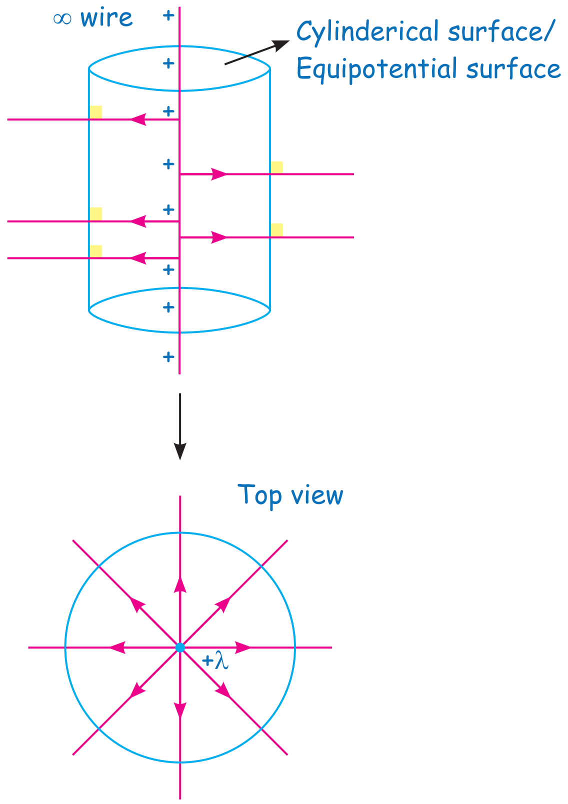


2. If a charge is moved from one point to the over an equipotential surface

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

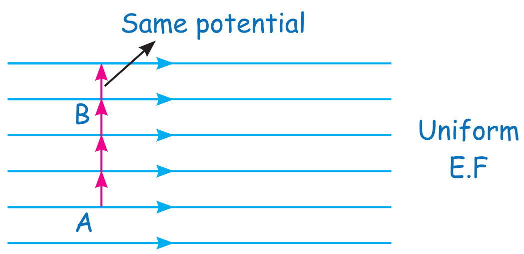
3. Equipotential surfaces can never cross each other.





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

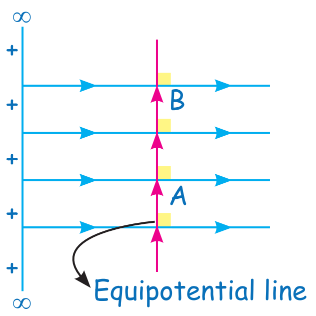


$dv = \vec{E} \cdot d\vec{r}$

$dv = -Edr \cos\theta$

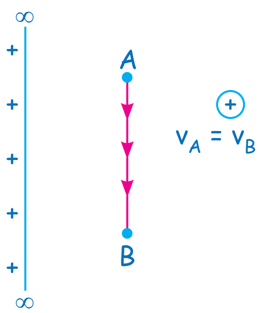
$\theta = 90° \Rightarrow dv = 0$

$v \rightarrow$ const.

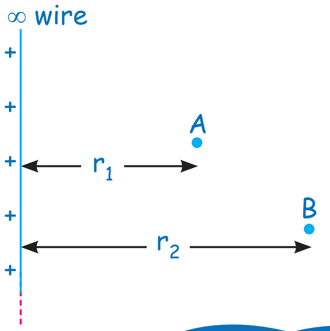


$\Delta v = 0$

$v_A - v_B = 0$



(Same for ∞-sheet)



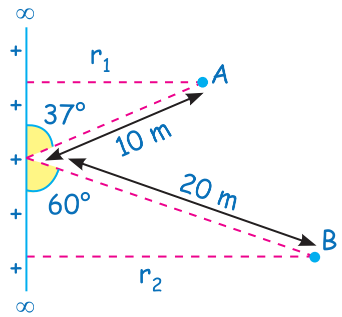
$V_A - V_B = 2k\lambda \ \ell n \dfrac{r_B}{r_A}$

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

#SKC

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

Q. Find potential different A and B.

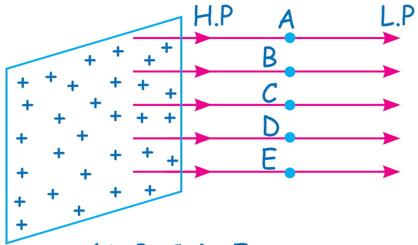


$V_A - V_B = 2k\lambda \ \ell n \left(\dfrac{r_2}{r_1}\right)$

$r_1 = 10 \sin 37°$

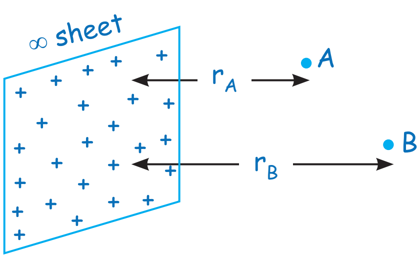
$r_2 = 20 \sin 60°$

#



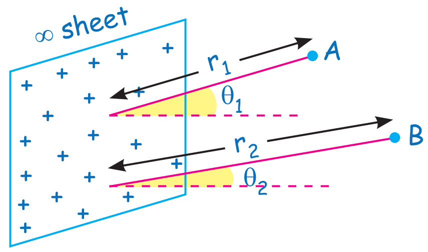
(A, B, C, D, E → same potential)

☆



$V_A - V_B = \dfrac{\sigma}{2E_0}(r_B - r_A)$

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)

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

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

$v = 10 - 90 = -80$

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

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

$v = -7$ 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 → uniform

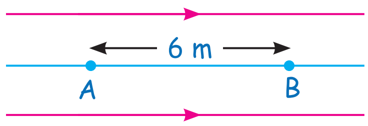
$\int dv = -\vec{E} \cdot \vec{dr}$ $\qquad \Delta\vec{r} = 2\hat{i} + 2\hat{j} + 2\hat{k}$

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

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

$v_f = -14$

☆



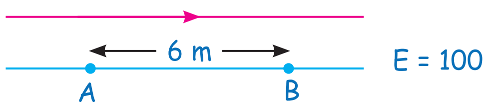
E = 100 volt / m

H.P → A

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

$V_B - V_A = -\,600$

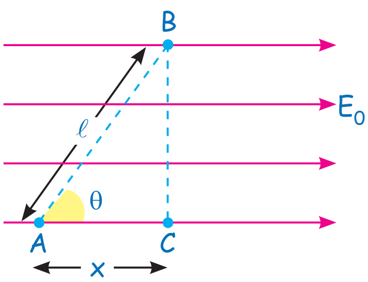
$V_A - V_B = 600$



A → B चलोगे तो pot. कम 100 × 6 = 600

$V_A - V_B = 600$

Q. Find $V_A - V_B$



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

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

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

$v_B - v_A = -\,E_0 x.$

Pot. at B = pot at C

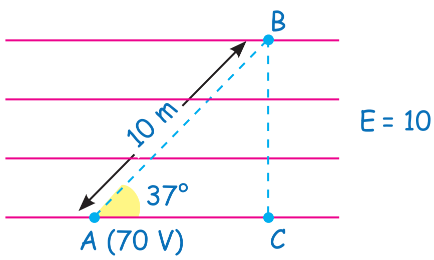
$v_A - v_C = Ex$

$v_A - v_B = Ex$

$v_C - v_A = -E_0 x$

$\therefore\ v_B - v_A = -E_0 x$

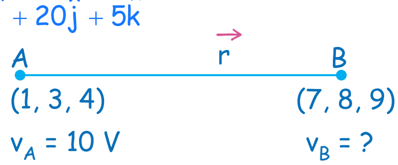
#



$\Rightarrow\ V_B = V_C$

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

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



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

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

$v_B = -\,175$

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.

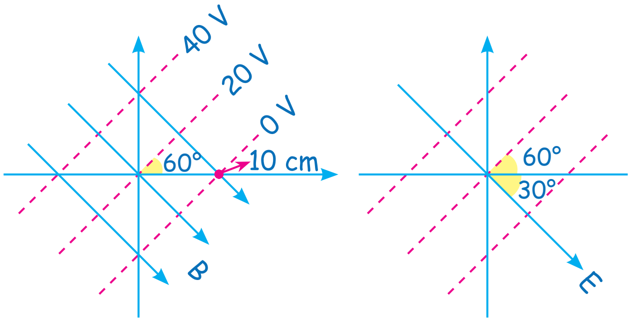
Q. If $v = x^2yz$ find E.F at (1, 2, 3)

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

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

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

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



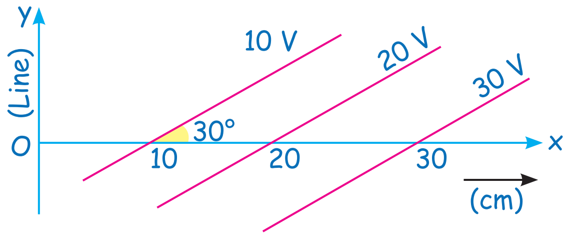
$20 = Ed$

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

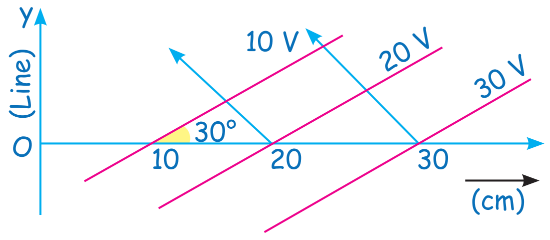
$E = \dfrac{400}{\sqrt{3}}$

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

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



Sol.



$d = 10 \sin 30$ cm $= 5$ cm

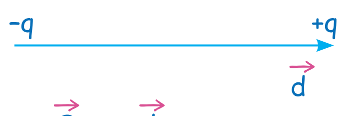
$10 = Ed$

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

$E = 200$ v/m

DIPOLE

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



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

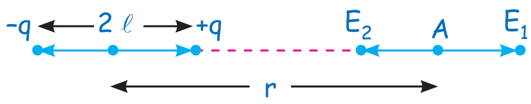
Direx^n is -ve

+ve charge

magnitude = qd

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

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



$E_A = E_1 - E_2$

[$P = q2\ell$ 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 $\ell <<< r$

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

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

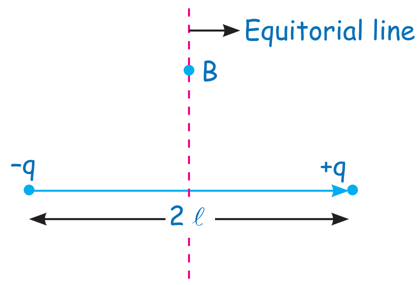
Potential at A

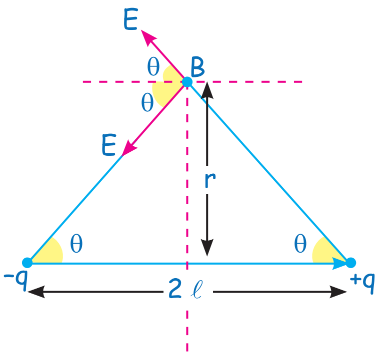
$$V_A = \frac{kq}{(r-\ell)} + \frac{k(-q)}{(r+\ell)} = kq\,\frac{(r+\ell)-(r-\ell)}{(r^2-\ell^2)}$$

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

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

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



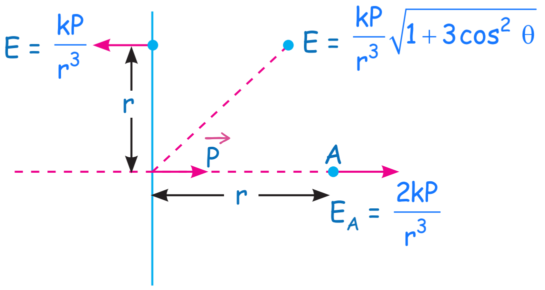


$E_{at\ B} = 2E\cos\theta$ (पीछे)

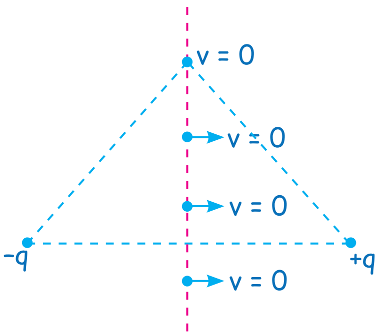
$$= \frac{2kq}{(\sqrt{r^2+\ell^2})^2}\ \frac{l}{\sqrt{r^2+\ell^2}} = \frac{kq2\ell}{(r^2+\ell^2)^{3/2}}$$

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

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



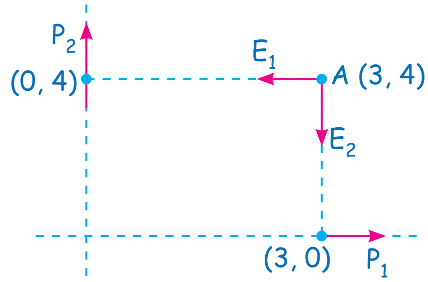
Electric Potential due to Short Dipole at Equitorial line = zero.



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

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

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

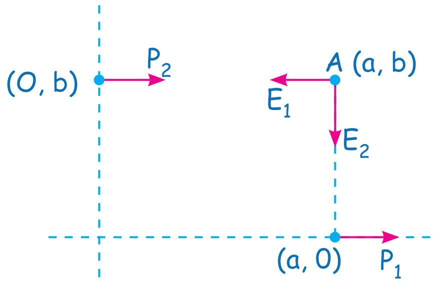


E.F at A due to $P_1 = \frac{kP_1}{4^3}(-\hat{i})$

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

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

Q. Find E.F at A.



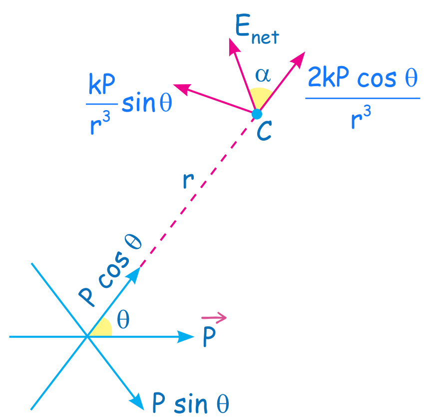
Pot at A = $0 + \frac{kP_2}{a^2}$

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

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

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

E.F at a general point due to short Dipole



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

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

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

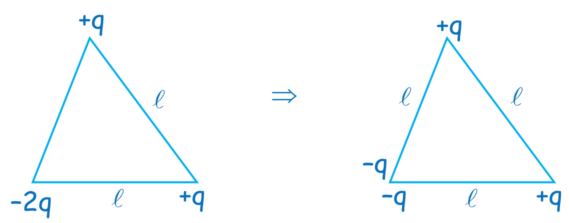
$E = \frac{kP}{r^3}\sqrt{1+3\cos^2\theta}$ $\Rightarrow$ E.F kabhi zero nhi hogi

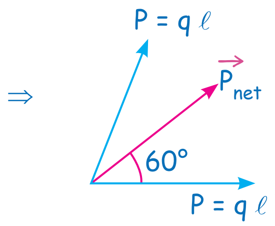
$E_{max} \Rightarrow \theta = 0° \Rightarrow E = \frac{2kP}{r^3}$ (Axis)

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

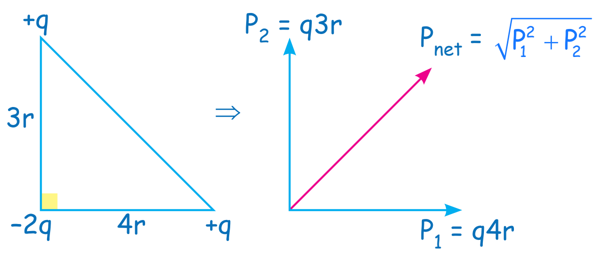
Find dipole moment of following cases

1

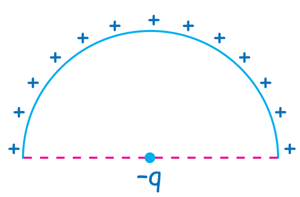




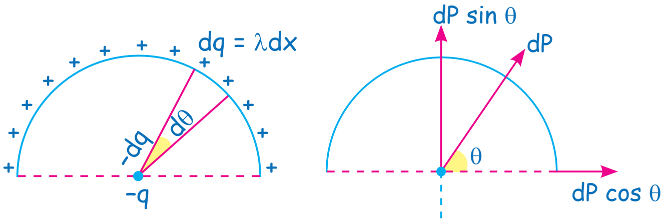
2



3



Sol.

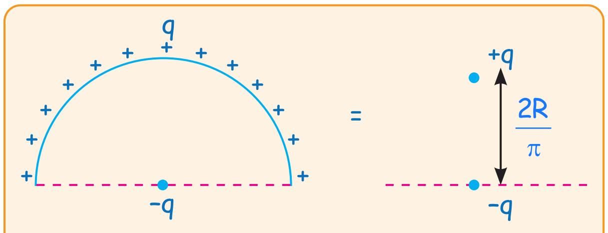


$$P_{net} = \int dP\sin\theta = \int dq\cdot R\cdot\sin\theta$$

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

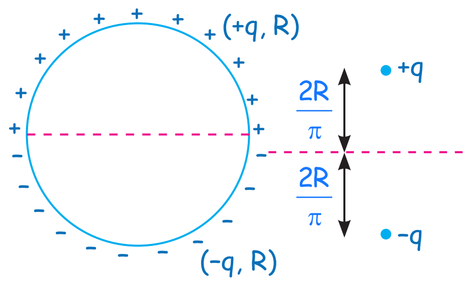
$$= \lambda R^2\cdot 2 = \frac{q}{\pi R}R^2\cdot 2$$

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



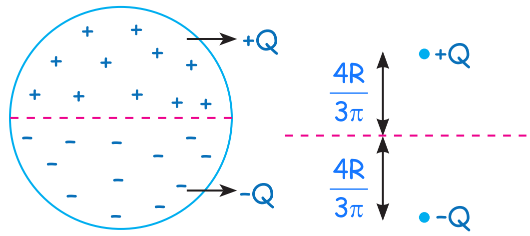
$$\vec{P} = q\frac{2R}{\pi}\hat{j}$$

4

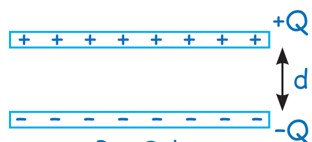


$$\vec{P} = q\frac{4R}{\pi}\hat{j}$$

5



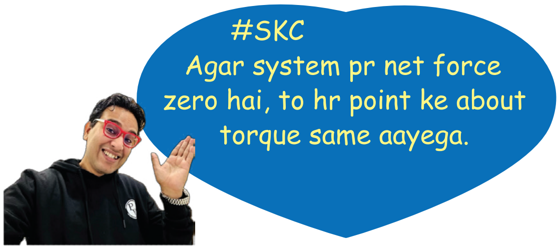
6

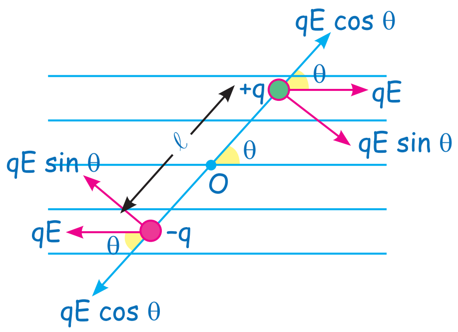


P = Qd

DIPOLE IN UNIFORM E.F

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





$F_{net} = 0$

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

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

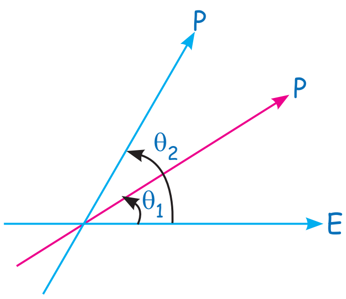
$\boxed{\begin{array}{c} \tau = PE\sin\theta \\ \vec{\tau} = \vec{P}\times\vec{E} \end{array}}$

#SKC
Uniform electric field
चाहती है की, $\vec{P}$ electric field के parallel rhe

If $\theta = 0, \tau = 0$ $\qquad$ $\theta = 180°, \tau = 0$

Potential Energy of Dipole in Uniform E.F

$(WD)_{ext.}$ to rotate dipole from θ_1 to θ_2 [slowly - slowly]



$dW = \int \tau d\theta$

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

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

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

$= U_f - U_i$

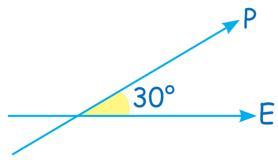
$U_f = -PE\cos\theta_2$

$U_i = -PE\cos\theta_1$

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

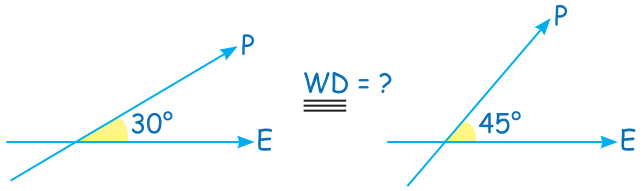
$$\boxed{U_f = -\vec{P}\cdot\vec{E}}$$

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°



$U_i = -PE\cos 30°$ $\qquad$ $U_f = -PE\cos 45°$

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

VV Imp हर साल JEE Mains मे यह आता है।

$(WD)_{by\ ext.}$ agent to rotate a dipole from 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

$F = 0$

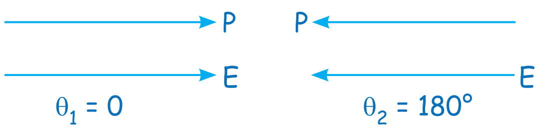
$\tau = 0\ [\tau = PE\sin 0 = 0]$

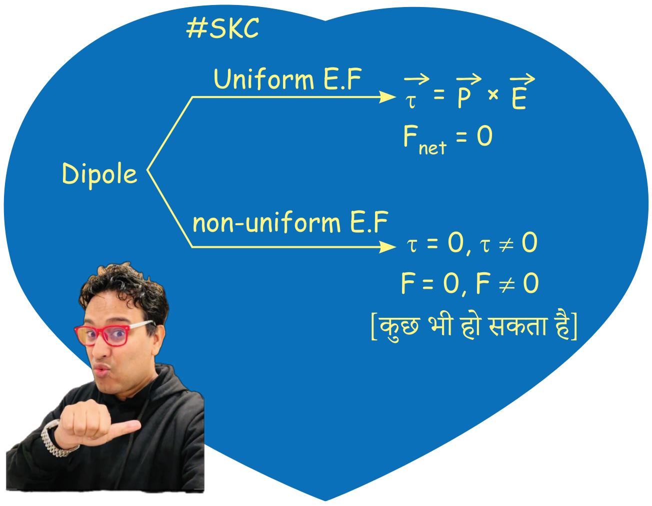
$U_i = -PE\cos 0° = -PE$

(b) $(WD)_{ext.}$ required to rotate st dipole become $\perp^{ar}$ to E.F = – PE (cos 90° – cos 0°) = + PE

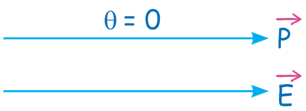
(c) $(WD)_{ext.}$ require to totate st dipole become antiparallel to E.F [from θ_1 = 0]

= – PE [cos 180° – cos 0°] = 2PE





☆



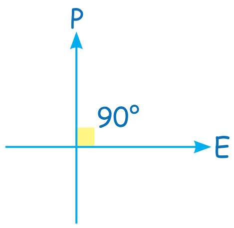
$\vec{\tau} = 0$

U = – PE

U → min

Eqb^m stable

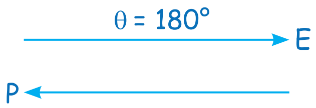
☆



τ = PE

U = 0

☆



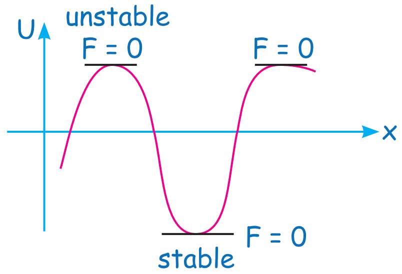
τ = 0

P.E = + PE

U → max

unstable equilibrium

☆ 11^{th} class



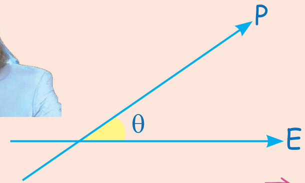
काम का डब्बा

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

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

τ = PE sin θ

U = – PE cos θ

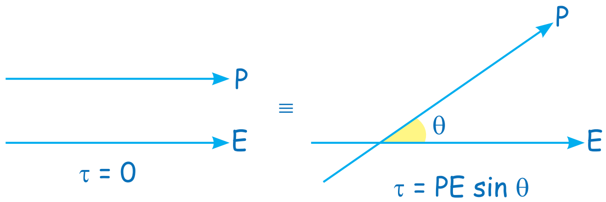


- θ = 0°, τ = 0, U_{min}, (U_{min} = –PE), stable eq^m, $\vec{F}_{net} = 0$
- θ = 180°, τ = 0, U_{max}, (U_{max} = +PE), unstable eq^m, $\vec{F}_{net} = 0$
- θ = 90°, τ_{max} U = 0 No equillibrium

\# 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

$\vec{\tau} = -PE \cdot \vec{\theta}$

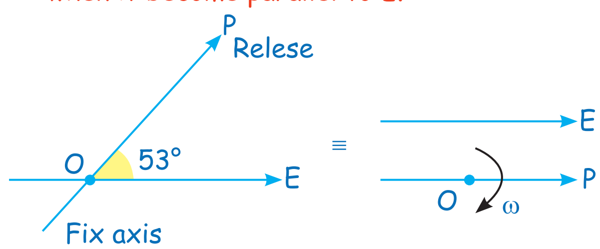


τ = PE sin θ = PE θ (Approx because θ is very small) Hence

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

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

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

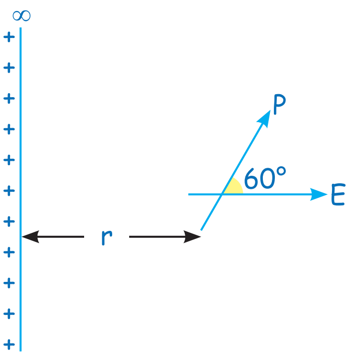
$$f_y = -\frac{\partial U}{\partial y} = -\left[0 + 12\right] = -12$$

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. $U = -\vec{P}\cdot\vec{E} = -[P_0E_0r^2\,\hat{r}\cdot\hat{r}] = -P_0E_0r^2$

$$F = -\frac{dU}{dr} = -[-P_0E_0 2r] = P_0E_0 2r$$

Q. Force by ∞-wire on short dipole



Sol. $U = -\vec{P}\cdot\vec{E} = -P\cdot\vec{E}\cos 60^\circ$

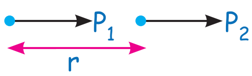
$$U = -\frac{P2k\lambda}{r}\cos 60^\circ$$

$$F = -\frac{du}{dr} = -\frac{P2k\lambda\cos 60}{r^2}$$

$$\vec{F} = -\frac{P2K\lambda\cos 60}{r^2}\hat{r}$$

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]



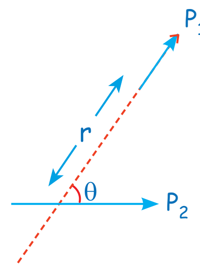
Sol. $U = -\vec{P}_2.(Ef)_{due}$ to P, on P_2

$$= -\vec{P}_2 \cdot \frac{2K\vec{P}_1}{r^3}$$

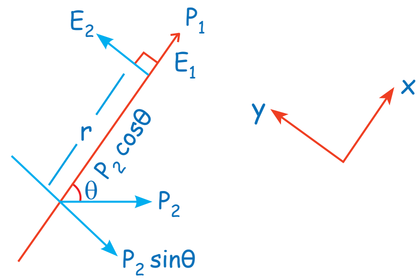
$$U = -\frac{2kP_1P_2}{r^3}$$

$$f = -\frac{dU}{dr} = -\frac{6KP_1P_2}{r^4}$$

Q. Two short dipole are placed as shown. The energy of electric field interaction b/w these dipoles will be:-



Sol.



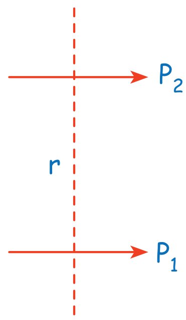
$U = -\vec{P}_1\vec{E}$

$U = -P_1\hat{i}\,(E_1\hat{i} + E_2\hat{j})$

$U = -P_1E_1$

$$U = -P_1\frac{2KP_2\cos\theta}{r^3}$$

Q. Find force of interaction b/w P_1 & P_2 or find force P_1 on P_2 [short dipole



$U = -\vec{P}_2\cdot\vec{E} = -P_2E\ \cos 180^\circ$

$$U = -P_2 \frac{KP_1}{r^3} \times (-1)$$

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

$$f = -\frac{dU}{dr} = -KP_1P_2 \frac{(-3)}{r^4}$$

$$f = \frac{3KP_1P_2}{r^4}$$

→ Conductor → Free e^- bahut saare.

→ Semi-Conductor → Bahut Kam free e^- [12^{th} last]

→ Insulator → No free e^-

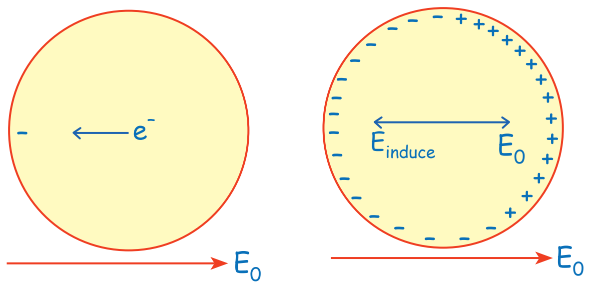
CONDUCTOR

→ They have free e^-. Which are free to move inside conductor.

→ Inside the conductor, E.F = 0 [jha jha maal bhra hua h] [In Electrostatic]

→ Metals are good conductor

→ Agar m kisi conductor ko E.F mein rakh du to, conductor Ke ander free e– ke motion ki vajah se charge seprate ho jayenge, mtlb induce ho jayenge, or ye to tab tak hota rahega, jab tak ander net electric field zero na ho jaye. Mtlb, jitne External E.F ho utni hi opposite $dirx^n$ me charge $sepr^n$ ki vajah se induce ho gyi.



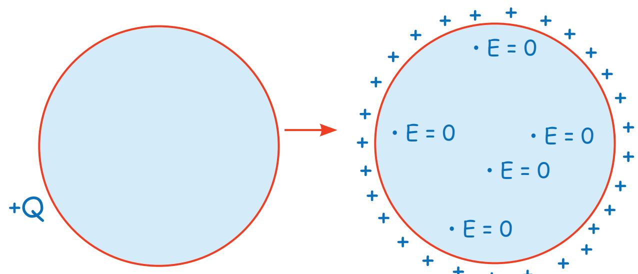
$$E_{net} = E_0 - E_{induce}$$

$\Downarrow$

$0 \qquad E_{induce} = E_0$

→ Agr kisi conductor ko charge dedu to,

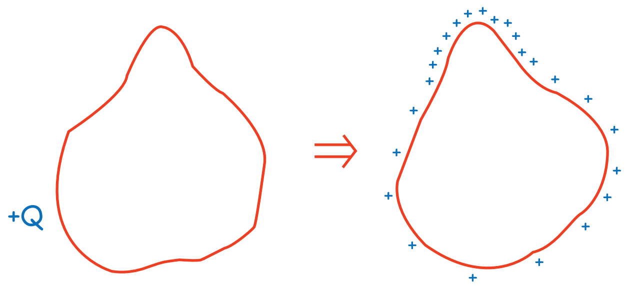
$$\sigma \propto \frac{1}{r}, r\downarrow, \sigma\uparrow$$



Perfect गोला

R → same

σ → same uniform



$\sigma \propto 1/r$

$r\downarrow,\ \sigma\uparrow$

→ Potential of every point of conductor are same.

→ Hence, we can say that surface of conductor is Equipotential surface

→ Since E.F is always $\perp^{ar}$ to Equipotential surface Hence E.F is always $\perp^{ar}$ to conducting surface

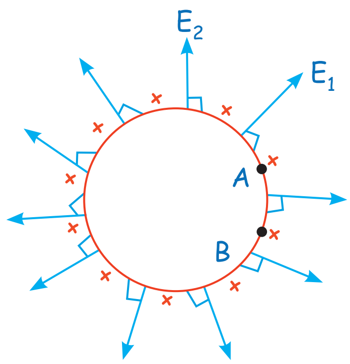
$$dv = -\vec{E}\cdot d\vec{r} = -Edr\cos\theta$$

V → same

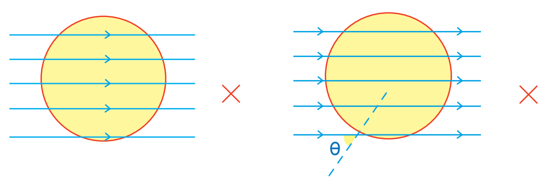
$dv = 0 \Rightarrow E = 0$ or

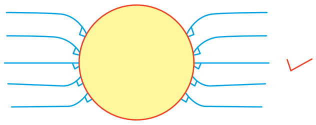
$\theta = 90°$

$\vec{E} \perp d\vec{r}$



Q. Which of the following diagram is not possible for a conductor?



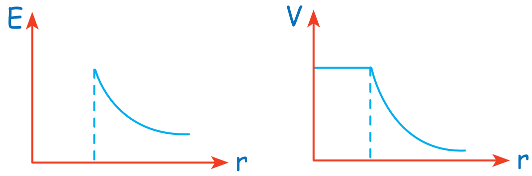


SPHERICAL CONDUCTOR OF 'R', +Q.

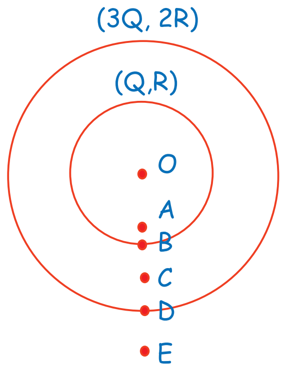
→ $E_{inside} = 0$ → $E_{outside} = \frac{KQ}{r^2}$

$V_{inside} = \frac{KQ}{R}$ $V_{outside} = \frac{KQ}{r}$

Results are same as non conducting shell.



Q. In following diagram we have two conducting sphere. Find potential at A, B, C, D, E.



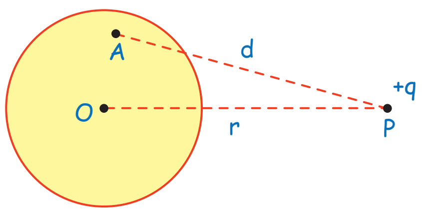
$$V_O = \frac{KQ}{R} + \frac{K3Q}{2R} = V_A = V_B$$

$$V_C = \frac{KQ}{OC} + \frac{K3Q}{2R}$$

$$V_D = \frac{KQ}{2R} + \frac{K3Q}{2R}$$

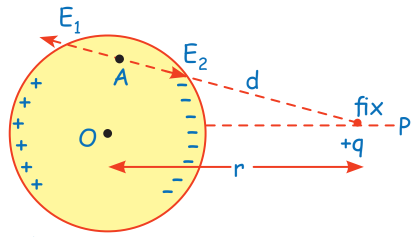
$$V_E = \frac{KQ}{OE} + \frac{K3Q}{OE}$$

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)

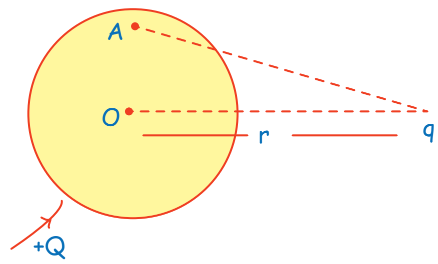
$V_A = V_O$

$V_A = V_{\text{at A due to q}} + V_{\text{at A due to induce charge}}$

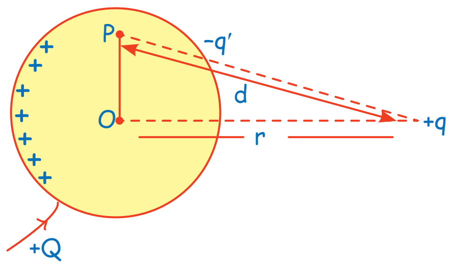
$\frac{Kq}{r} = \frac{Kq}{d} + V_{\text{at A due to induce charge}}$

$V_{\text{at A due to induce charge}} = \frac{Kq}{r} - \frac{Kq}{d}$

Q. Repeat the last all parts if conducting sphere is given + Q charge. Find potential at A due to induce charge.



Sol.



$V_p = V_O = \frac{Kq}{r} + \frac{K(Q + q' - q')}{R}$

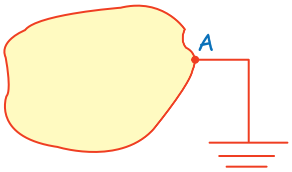
$V_p = V_O = \frac{Kq}{r} + \frac{KQ}{R}$

Pot. at 'P' due to induce charge = कद्दू

$V_p = V_{\text{due to 'q'}} + V_{\text{induce charge}}$

$\frac{Kq}{r} + \frac{KQ}{R} = \frac{Kq}{d} + V_{\text{due to induce charge}}$

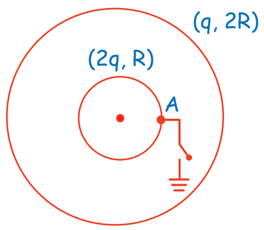
IDEA OF EARTHING



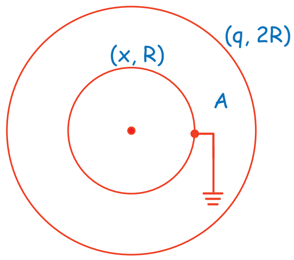
$V_A = 0$ कर दिया

#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.



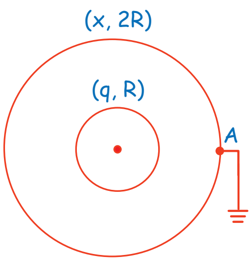
Sol.



$$V_A = \frac{Kx}{R} + \frac{Kq}{2R} = 0$$

$x = -q/2$

Q. Find the charge on outer sphere

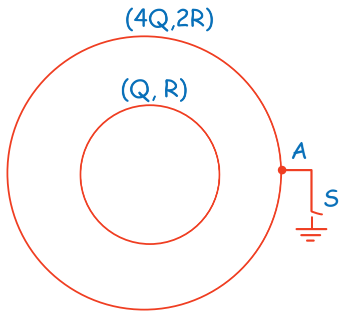


#SKC
जिसको Earth Kiya hai, uska potential zero Krna. hai.

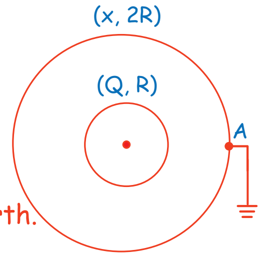
$$V_A = \frac{kq}{2R} + \frac{kx}{2R} = 0$$

$x = -q$

Q.



→ Find charge flow through switch after switch closed



$V_A = 0$

$$\frac{Kx}{2R} + \frac{KQ}{2R} = 0$$

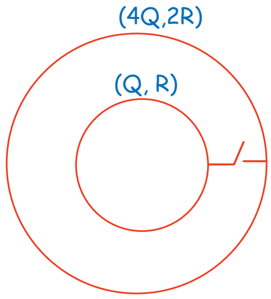
$x = -Q$

$\therefore$ + 5Q charge flow.

→ find no. of e^- supply by earth.

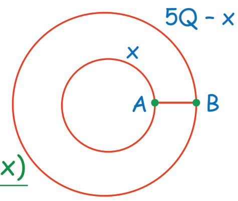
$5Q = ne$

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



$V_A = V_B$

$$\frac{Kx}{R} + \cancel{\frac{K(5Q-x)}{R}} = \frac{Kx}{2R} + \cancel{\frac{K(5Q-x)}{2R}}$$

$$\frac{Kx}{R} = \frac{Kx}{2R}$$

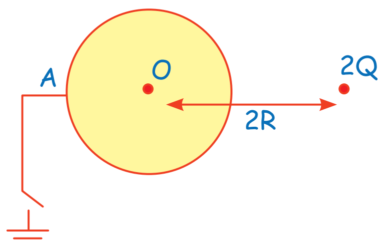
$$x = \frac{x}{2}$$

$$x - \frac{x}{2} = 0$$

[inner] $x = 0$

सारा का सारा charge बाहर चला गया
Sorry Shubham* Bhaiya

Q. Find net charge on conductor after switch is closed.



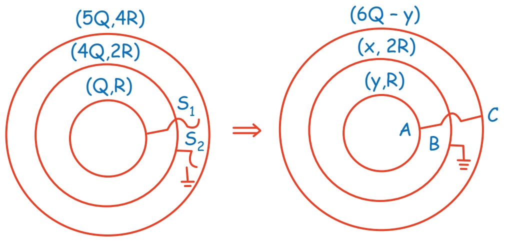
Sol. Let charge on the sphere is x after switches close

$V_A = 0 = V_0$

$$\frac{K2Q}{2R} + \frac{Kx}{R} = 0$$

$x = -Q$

Q. Find charge on each sphere after S_1 and S_2 closed [conducting]



Sol. $V_B = 0$

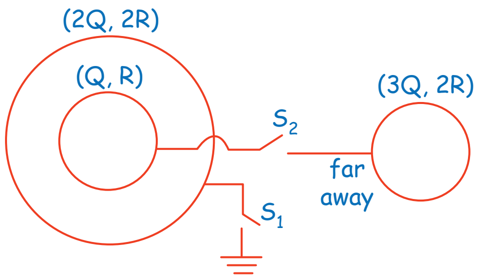
$$\frac{Ky}{2R} + \frac{Kx}{2R} + \frac{K(6Q-y)}{4R} = 0 \qquad ...(1)$$

$V_A = V_C$

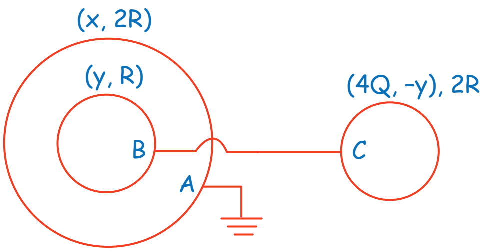
$$\frac{Ky}{R} + \frac{Kx}{R} + \frac{K(6Q-y)}{4R} = \frac{Ky}{4R} + \frac{Kx}{4R} + \frac{K(6Q-y)}{4R} \qquad ...(2)$$

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.



$V_A = 0$

$$\frac{Ky}{2R} + \frac{Kx}{2R} + 0 = 0$$

$x + y = 0 \qquad ....(1)$

$V_B = V_C$

$$\frac{Ky}{R} + \frac{Kx}{2R} + 0 = \frac{K(4Q-y)}{2R}$$

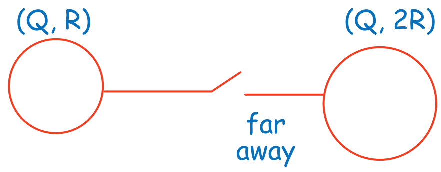
$x + 3y = 4Q \qquad ....(2)$

Solve (1) and (2)

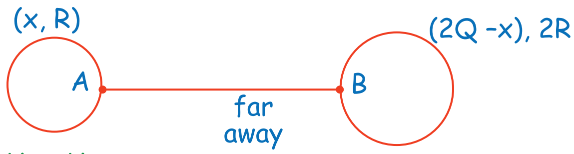
$\therefore y = +2Q$

$x = -2Q$

Q. Find charge on small sphere after switch close



Sol.



$V_A = V_B$

$$\frac{Kx}{R} + 0 = 0 + \frac{K(2Q-x)}{2R}$$

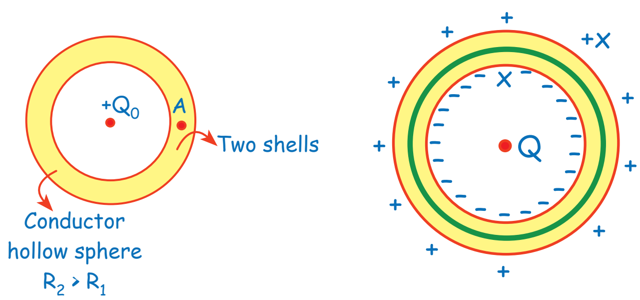
$$x = \frac{2Q}{3}$$

$q_1 = 2Q/3$

$$q_2 = 2Q - \frac{2Q}{3} = \frac{4Q}{3}$$

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.

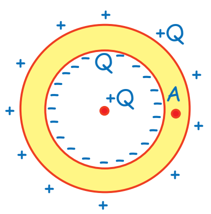


$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{in}}{E_0}$$

$$0 = \frac{Q-x}{E_0}$$

$Q = x$

$$\sigma_{inner} = \frac{-Q}{4\pi R_1^2}$$



$$\sigma_{outer} = \frac{Q}{4\pi R_2^2}$$

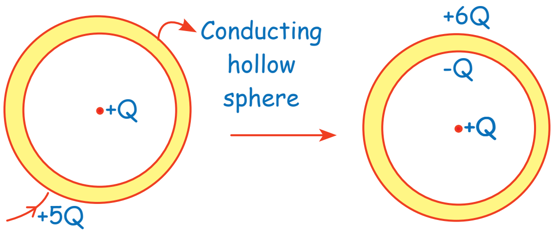
Inner surface pr charge -x h, mtlb -Q h

#SKC
इसमें 2 shell है
$\rightarrow -Q \,.\, R_1$
$\rightarrow +Q \,.\, R_2$

→Last Quesn में

#SKC
Chore Ka samne. barabar Ki age ki chori Ko bitha K setting Kr do and उसी प्रकार अगर छोरी है तो सामने बराबर age का छोरा बैठा दो। उसके बाद क्या होगा अपको पता ही है।

Q. Find charges & σ on inner and Outer surface after proper induction

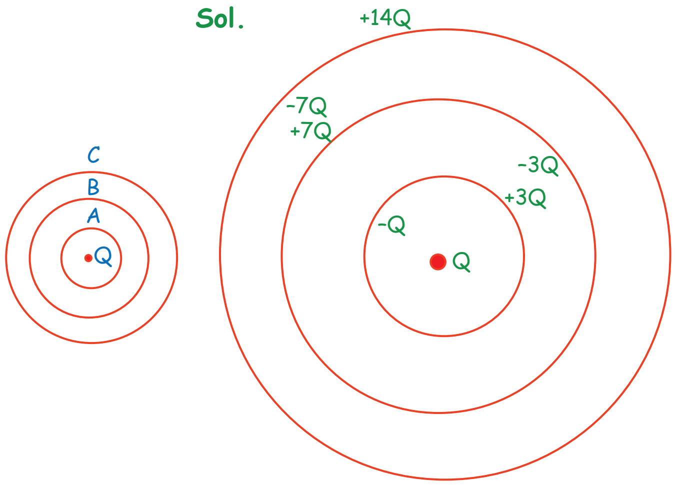


$$\sigma_{inner} = \frac{-Q}{4\pi R_1^2}$$

$$\sigma_{outer} = \frac{+6Q}{4\pi R_2^2}$$

Q. If 2Q, 4Q, 7Q charge is given to A, B, C respectively. Find charges & σ on inner and Outer surface after proper induction.

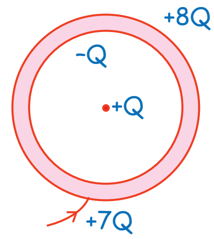
Sol.



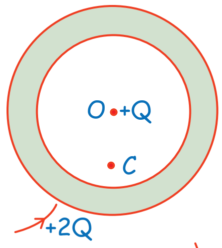
Q. Suppose we have a thin conductor of inner radius R and thickness t and charge +7Q. If +Q charge is placed at center. Find σ_{inner} and σ_{outer}.

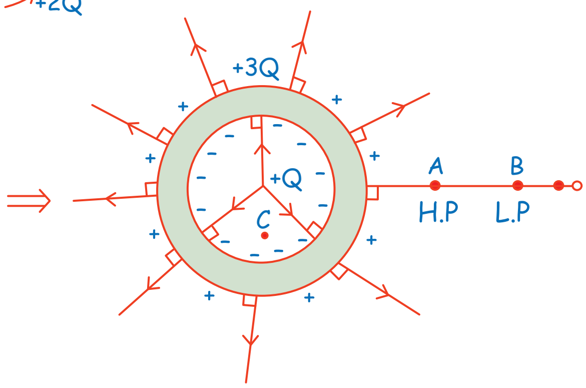
Sol. $\sigma_{inside} = \dfrac{-Q}{4\pi R^2}$

$\sigma_{outside} = \dfrac{8Q}{4\pi (R+t)^2}$



☆ 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 -

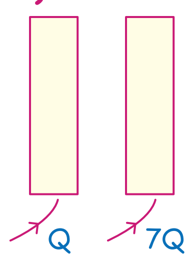
$$\vec{E}_C = \vec{E}_{\text{due to point charge}} + \vec{E}_{\text{inner shell}} + \vec{E}_{\text{outer shell}}$$

$$= \frac{KQ}{(OC)^2} + 0 + 0$$

$$E_c = \frac{KQ}{(OC)^2}$$

CONDUCTING PLATE VERY CLOSE TO EACH OTHER / (LIKE ∞ PLATE)

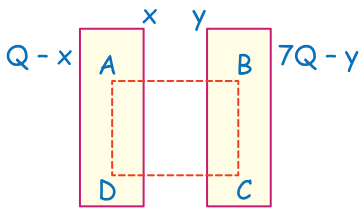
Q. Suppose we have two conducting plate very close to each other and charge +Q, +7Q is given to both the plate as shown in figure. Find charge on every surface of both plates.

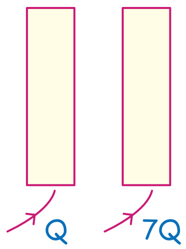


Sol. ABCD के लिए gauss law लगाकर और

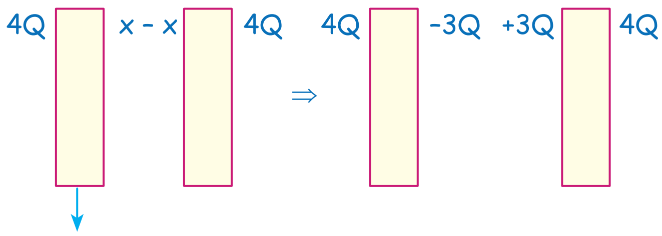
$E_A = 0$ करके we found

Plate के आमने सामने equal & opposite charge होगा और दोनो outer surface पर total का half charge होगा।





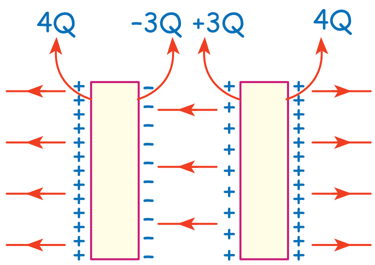
$$Q_{outer} = \frac{Q_{total}}{2} = \frac{Q+7Q}{2} = 4Q$$



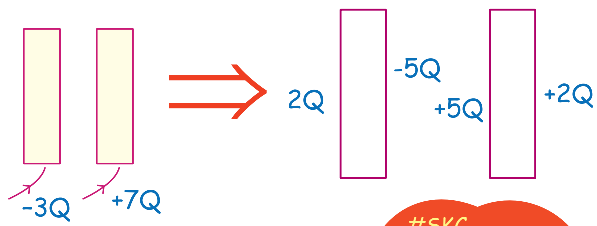
Total charge on this plate = Q

So x = -3Q

So final charge distribution and E.F pattern will be

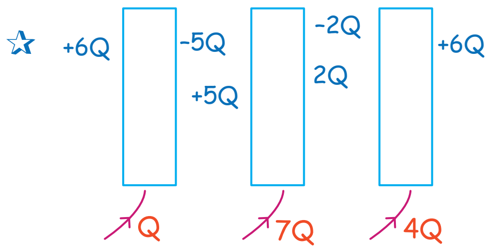


Q.

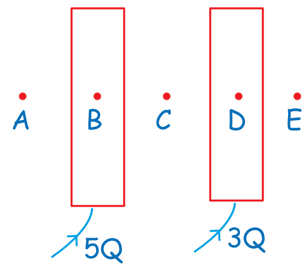


$$Q_{outer} = \frac{Q_{total}}{2} = \frac{-3Q+7Q}{2} = 2Q$$

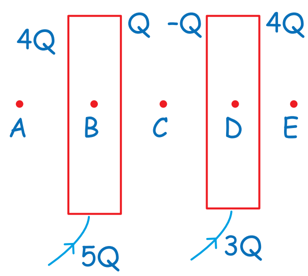
#SKC
Total charge ko आधा आधा करके outer suface ko de do, fir setting kr do.



Q. Charge 5Q and 3Q are given to two conducting plate very close to each other find charge on each face and Find E.F at A, B, C, D, E.



Sol.



$E_B = E_D = 0$

$$E_c = \frac{4Q/A}{2E_0} - \frac{4Q/A}{2E_0} + \frac{Q/A}{2E_0} + \frac{Q/A}{2E_0}$$

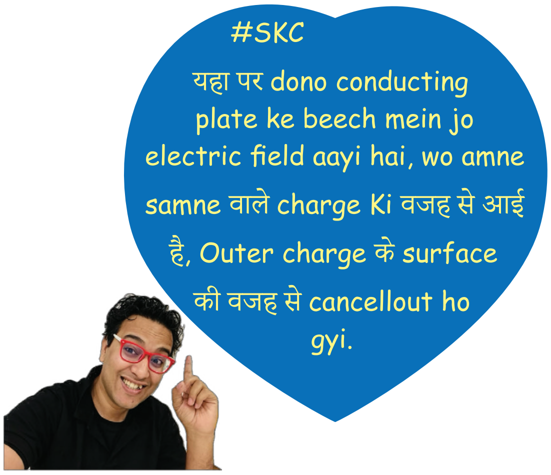
$$E_C = E_{\text{बीच में}} = \frac{Q}{AE_0} = \frac{Q_{\text{अंदर वाला}}}{AE_0}$$

$$= \frac{\sigma_{\text{अंदर वाला}}}{E_0}$$

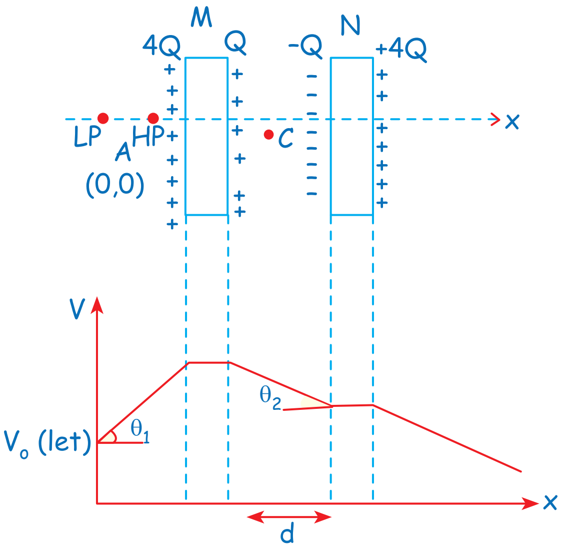
$$E_A = \frac{-4Q/A}{2E_0} - \frac{Q/A}{2E_0} + \frac{Q/A}{2E_0} - \frac{4Q/A}{2E_0}$$

$$= \frac{-8Q/A}{2E_0} = \frac{-4Q/A}{E_0}$$

$$E_E = \frac{4Q/A}{2E_0} \times 2 = \frac{4Q/A}{E_0}$$



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.

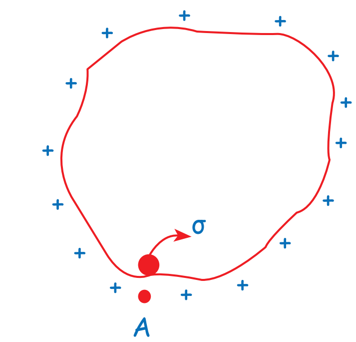
> → S.P.E of a pt. charge = 0
>
> → S.P.E of a shell, conducting sphere $= \dfrac{KQ^2}{2R}$
>
> → S.P. E of a solid sphere $= \dfrac{3}{5}\dfrac{KQ^2}{R}$

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. $(WD) = U_f - U_i$

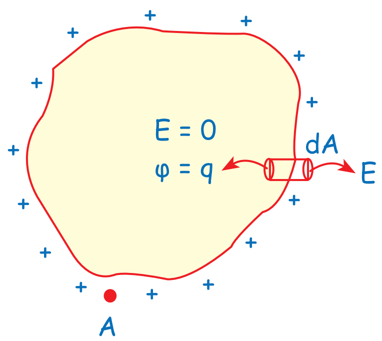
$$= \frac{Kq^2}{2R_2} - \frac{Kq^2}{2R_1}$$

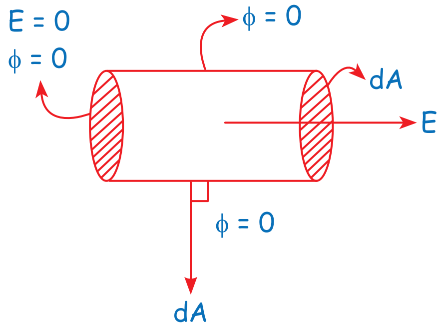
E.F IN THE VICINITY OF CONDUCTOR



$\boxed{E_A = \sigma/\varepsilon_0}$

Proof:

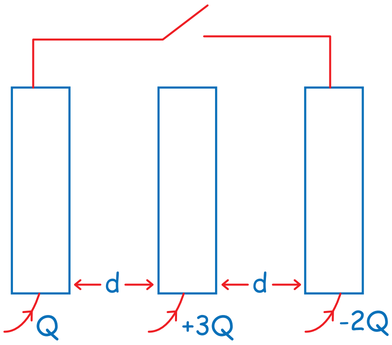


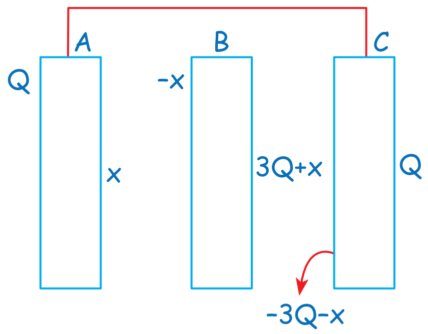


$$EdA + 0 + 0 + 0 = \frac{q_{in}}{\varepsilon_0} = \frac{\sigma dA}{\varepsilon_0}$$

$\boxed{E = \sigma/\varepsilon_0}$

Q. Find charge on each surface after switch closed.





$Q_{total} = Q + 3Q - 2Q$

$V_A = V_C$

$(V_A - V_B) + (V_B - V_C) = 0$

$E_1 d + E_2 d = 0$

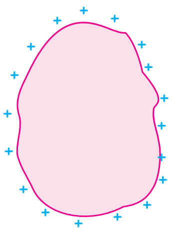
$$\left(\frac{x/A}{2E_0}\right) + \frac{(3Q+x)/A}{2E_0} = 0$$

$x + 3Q + x = 0$

$$x = \frac{-3Q}{2}$$

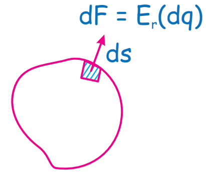
ELECTROSTATIC PRESSURE

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.

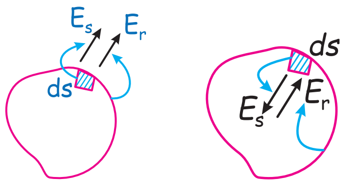
Force on this element due to the remaining charges:



$$dF = \begin{pmatrix} \text{electric field at} \\ \text{that place due to} \\ \text{remaining charges} \end{pmatrix} \begin{pmatrix} \text{charge of} \\ \text{the small} \\ \text{element} \end{pmatrix}$$

$dF = E_2 \times dq$ ...(*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 $= \dfrac{\sigma}{\varepsilon_0}$

$$\Rightarrow E_s + E_r = \frac{\sigma}{\varepsilon_0} \qquad ...(ii)$$

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)

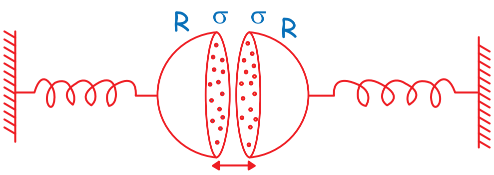
From eqn. (ii) and eqn. (iii), we can say that:

$$2E_r = \frac{\sigma}{\varepsilon_0} \Rightarrow E_r = \frac{\sigma}{2\varepsilon_0}$$

$$P = \frac{dF}{dA} = \frac{dq.E_r}{dA} = \frac{\sigma.\sigma}{2E_0}$$

Electrost. Pressure = $\dfrac{\sigma^2}{2E_0}$

Q. Hemisphere are in equillibrium find compression in string.



Equilibrium

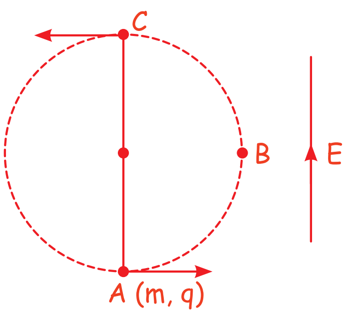
$$\frac{\sigma^2}{2E_0} \times \pi R^2 = Kx$$

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

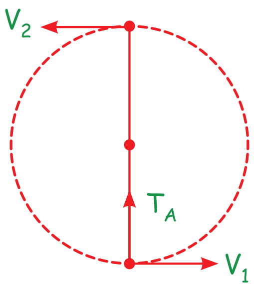
What should be velocity at C



OR

What horizontal velocity must be impart to ball at C so that tension at A become 15 times of weight.

Sol.

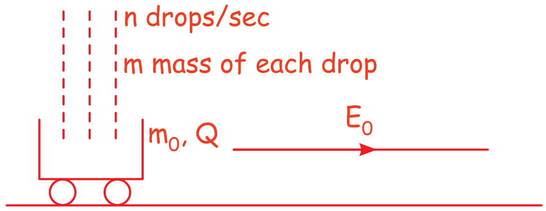


(1) $T_A + qE - mg = \dfrac{mV_A^2}{R}$

$15mg + qE - mg = \dfrac{mV_A^2}{R}$

(2) $-mg\,2R + 0 + qE\,2R = \dfrac{1}{2}mV_2^2 - \dfrac{1}{2}mV_1^2$

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 = $M_0 + n\,t\,m$

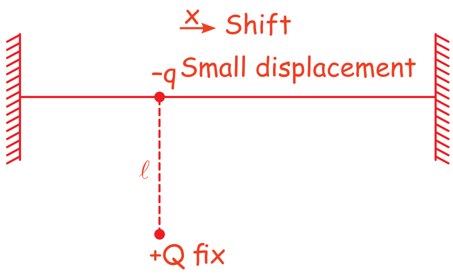
Impulse momentum theorem $\boxed{J = \Delta P}$

$QE_0t = (M_0 + n\,t\,m)V_f - 0$

$$V_f = \frac{QE_0t}{M_0 + mnt}$$

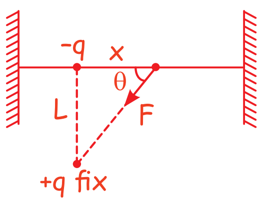
Q. Find time period of SHM

if –q charge is slightly displaced in following figure along x-axis.

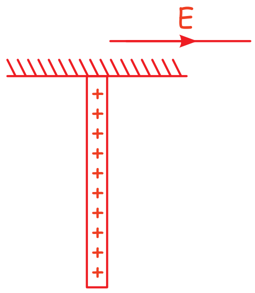


Sol. $F_{net} = F\cos\theta$

$$= \frac{Kq\theta}{(L^2 + x^2)}\,\frac{x}{\sqrt{L^2 + x^2}}$$



Q. Suddenly E_0 apply St. rod rotated max angle 90°. E = ?



Rod AB of length (L, Q, m)

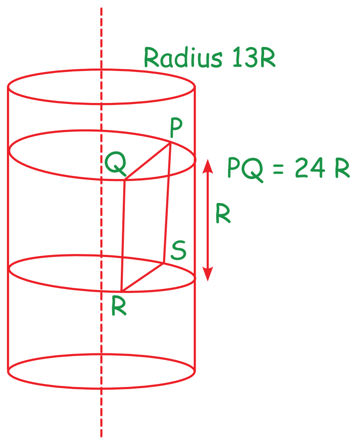
Sol. WET

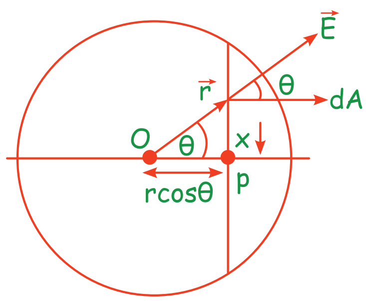
$W_g + W_{EF} = \Delta K.E.$

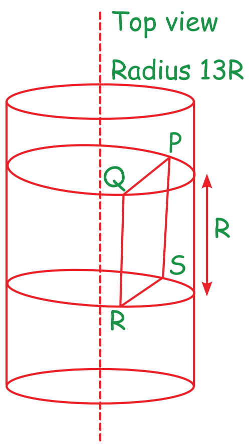
$-mg\frac{L}{2} + qE\frac{L}{2} = 0\text{-}0$

$$\boxed{E = \frac{mg}{q}}$$

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)

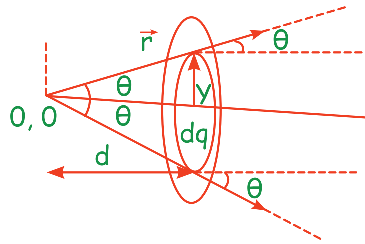
$= \left(\frac{\rho}{2\varepsilon_0}\right)(op)\int dA = \frac{\rho}{2\varepsilon_0}.5R(24R.R)$

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. $F_{net} = \int dF\cos\theta$

$= \int (dq)\, E\cos\theta$

$= \int (\rho 2\pi y dy t) kr\cos\theta$



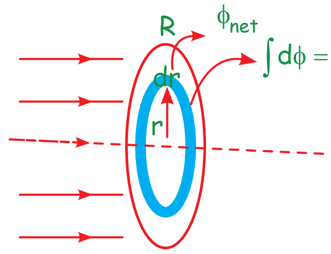
$F_{net} = \rho 2\pi tk\int r\cos\theta.y\, dy$

$F_{net} = \rho 2\pi tkd\int_0^R y dy$

$F_{net} = \rho 2\pi tkd\frac{R^2}{2}$

Q. E.F is normal to Disc $\vec{E} = E_0\left(1-\frac{r}{R}\right)\hat{i}$ Where r is distance from center of Disc, Find $\phi_{disc} = ?$

Sol.



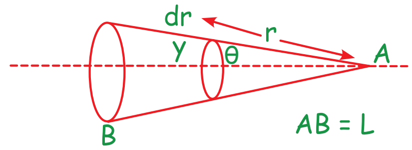
$\int d\phi = \int E.dA\cos o$

$\phi_{net} = \int_0^R E_0\left(1-\frac{r}{R}\right)2\pi r dr$

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. $dv = \frac{kdq}{\sqrt{y^2+x^2}} = \frac{kdq}{r}$

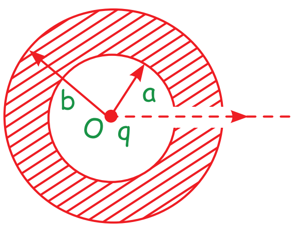
$\sin\theta = \frac{y}{r} = \frac{R}{L}, y = \frac{Rr}{L}$



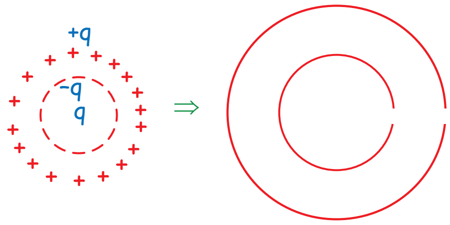
$$\int dv = \int_0^L \frac{k\sigma 2\pi y dr}{r} = k\sigma 2\pi \int_0^L \frac{R\cancel{r}}{L}\frac{dr}{\cancel{r}} = k\frac{\theta}{\pi RL} 2\pi \frac{R}{L}.L$$

$$= \frac{2K\theta}{L}$$

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.

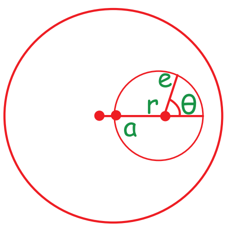


T.P.E = $(SPE)_1 + (SPE)_2 + (SPE)_3 + U_{12} + U_{31} + U_{23}$

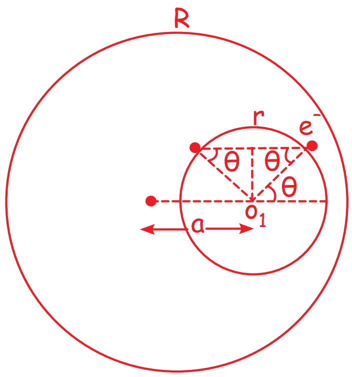
$$U_i = O + \frac{k(-q)^2}{2a} + \frac{kq^2}{2b} + \left(\frac{-kq}{a}.q\right) + \left(\frac{kq}{b}.q\right) + \frac{kq}{b}(-q)$$

$U_f = 0$. 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.

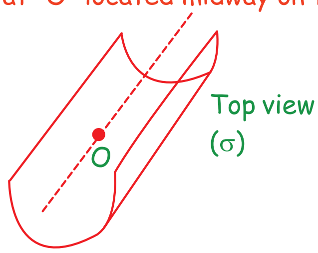


$$2r\cos\theta = 0 + \frac{1}{2}\frac{eE}{m}.t^2$$

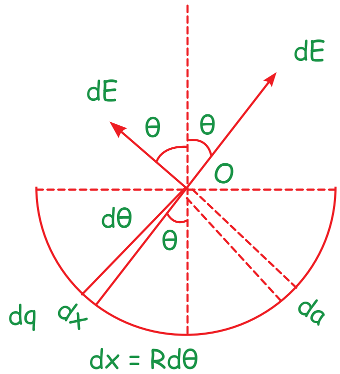
$$2r\cos\theta = \frac{1}{2}\frac{e\rho a}{3\varepsilon_0 m}t^2$$

$$t = \sqrt{\frac{12\varepsilon_0 m\, r\cos\theta}{e\rho a}}, \theta = 45^\circ$$

Q. Thin long strip whose cross-section is a semicircle find EF at 'O' located midway on the axis



Sol. $E_0 = \int_0^{\pi/2} 2dE\cos\theta$



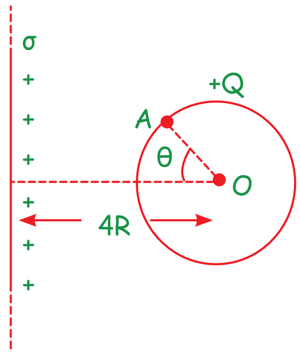
$$= \int_0^{\pi/2} 2.\frac{2k\sigma R d\theta \cos\theta}{R}$$

$$= 4k\sigma \int_0^{\pi/2} \cos\theta d\theta$$

$$= \frac{\sigma}{\pi\varepsilon_0}$$

Q. A conducting sphere of radius R and charge Q is placed near a uniformly charged nonconducting infinitely large thin plate having surface charge density σ. Then find the potential at point A (on the surface of sphere) due to charge on sphere

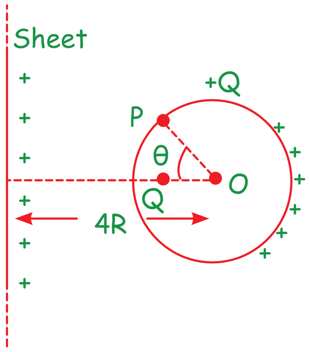
(here $K = \frac{1}{4\pi \in}, \theta_0 = \frac{\pi}{3}$)



Sol. $V_p = V_O$

$$(V_p)_{\text{due to sheet}} + (V_p)_{gola} = (V_o)_{Sheet} + (V_o)_{Gola}$$

$$(V_Q)_{\text{due to sheet}} - (V_o)_{sheet} + (V_p)_{gola} = (V_o)_{Gola}$$



$$\frac{\sigma}{2\varepsilon_0}\left(4R - (4R - R\cos\theta)\right) + \left(V_p\right)_{gola} = \frac{kQ}{R}$$

$$(V_p)_{Gola} = \frac{kQ}{R} = \frac{\sigma R\cos\theta}{2\varepsilon_0}$$

Q. The electric potential in a region is given by $V(x, y, z) = ax^2 + ay^2 + abz^2$ 'a' is a positive constant of appropriate dimensions and b, a positive constant such that V is volts when x, y, z are in m Let b = 2 The work done by the electric field when a point charge +4μC moves from the point (0, 0, 0.1m) to the origin is 50 μJ. The radius of the circle of the equipotential curve corresponding to V = 6250 volts and $z = \sqrt{2}$ m is α m. Fill α^2 in OMR sheet.

Sol. $(WD)_{ext} = -\Delta V = -q\Delta V = -q\left(0 - \frac{a}{50}\right) = \frac{aq}{50}$

$$50 \times 10^{-6} = \frac{a \times 4 \times 10^{-6}}{50}$$

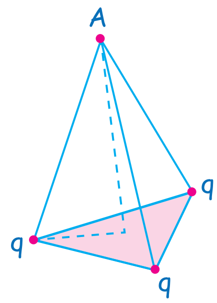
$$a = \frac{50 \times 50}{4} = 625$$

$$V = 6250 = 625x^2 + 625y^2 + 625 \times 2 \times 2$$

$$10 = x^2 + y^2 + 4$$

$$x^2 + y^2 = (\sqrt{6})^2$$

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.

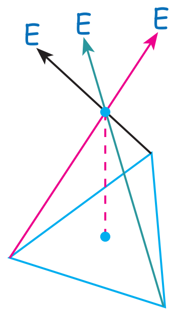


Sol. E_A = 3E sin θ

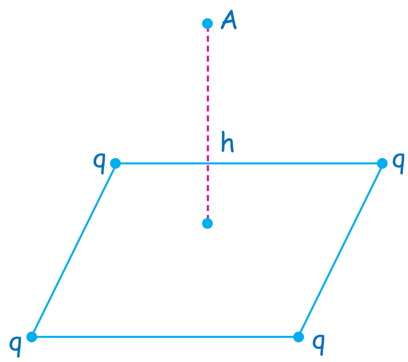
[θ = 60° already solved]

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

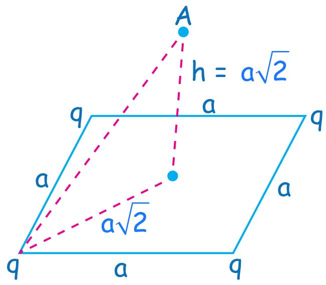
$$r^2 = h^2 + \left(\frac{a}{\sqrt{3}}\right)^2$$



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.

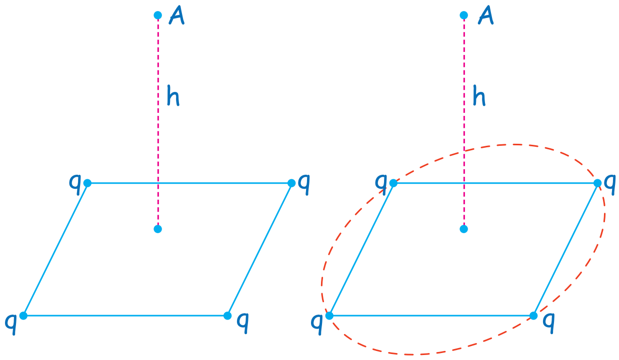


Sol.



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

ऐ फिर आ गया रे बाबा

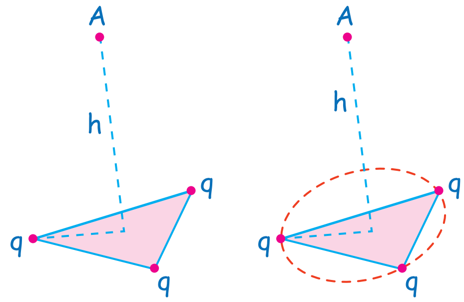


ऐसे symmetric सवालो मे हम 4q charge की एक ring मान सकते है जिसकी radius center से किसी भी एक charge के बीच की दूरी होगी यहाँ पर

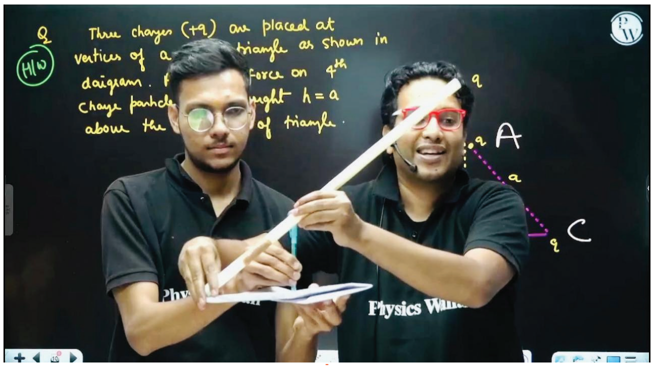
$R = \left(\dfrac{A}{\sqrt{2}}\right)$ और $x = h$.

$$E = \frac{KQx}{\left(R^2 + x^2\right)^{3/2}} = \frac{K(4q)h}{\left[\left(\dfrac{a}{\sqrt{2}}\right)^2 + h^2\right]^{3/2}}$$

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 = $\frac{\int v dt}{\int dt}$

$\langle कददू \rangle = \frac{\int कददू\ dt}{\int dt}$

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

$t = 0 \to t = 2sec$

$$\Delta q = \int i dt = \int_0^2 3t^2 dt = 8$$

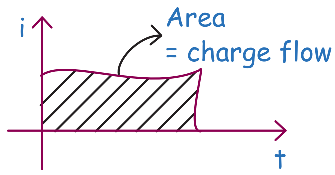
☆ $\boxed{i = \frac{dq}{dt}}$

$\int dq = \int i dt$

$\Delta q = \int i dt$ = Area

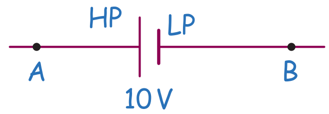
↓

charge flow

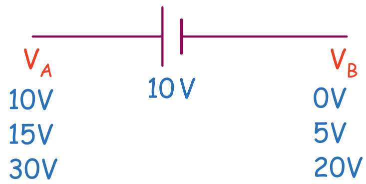


अबे सुनो Current electricity में सबसे जरूरी होता है circuit analysis तो sequence change करके saleem bhaiya के sequence में पढ़ते है from basic to advance.

☆ Ideal battery

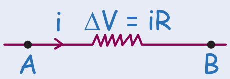


$V_A - V_B = 10$



☆ Ohm's Law (derivation बाद में देखेंगे)

CE में बहुत जरूरी है V = iR लगाना सीखना let's start it.



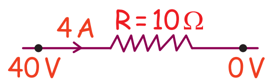
$V_A - V_B = iR$ or $V = iR$

V → pot. diff.

i → Resist मे H.P to L.P

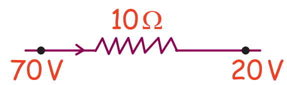
Q. Find current in the resistance in following cases.

(a)



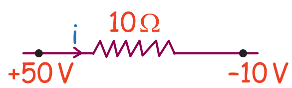
Sol. $i = \frac{40 - 0}{10} = 4$

(b)



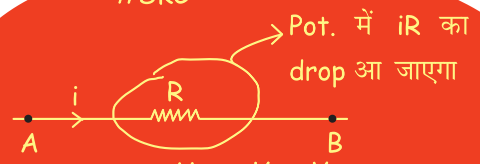
Sol. $i = \frac{50}{10} = 5$

(c)



Sol. $i = \frac{50 - (-10)}{10} = \frac{60}{10} = 6$

#SKC

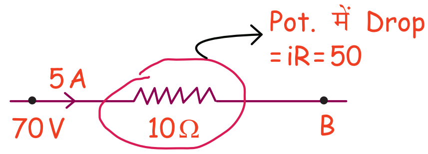


$i = \frac{V}{R} = \frac{V_A - V_B}{R}$

direction of current

$\Rightarrow$ HP to LP (Resistance)

(d) Find V_B.

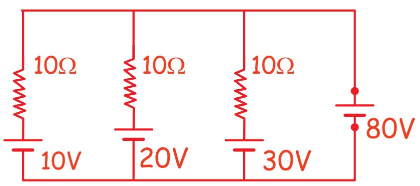


Sol. $V_B = 70 - 50 = 20\,V$

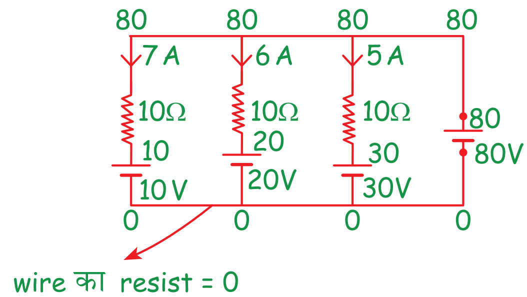
#SKC

Resistance मे current H.P to L.P flow करेगा but Battery मे कैसे भी कर सकता है

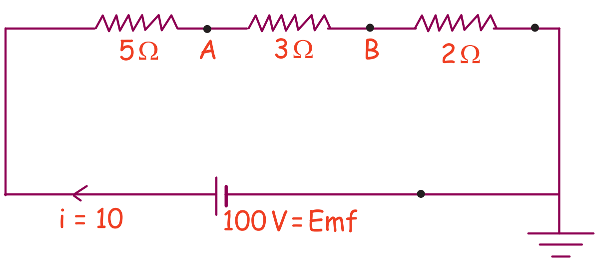
Q. Find current through each resistors.



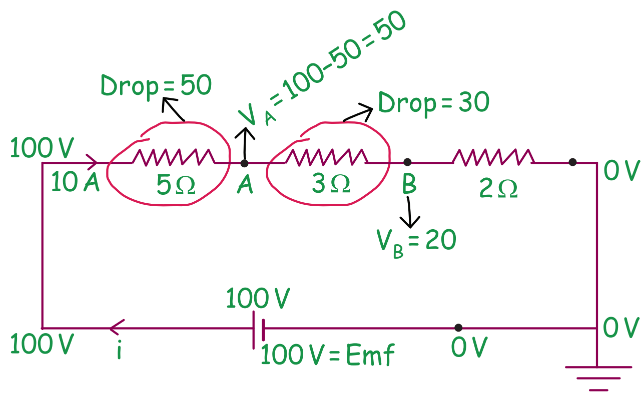
Sol.



Q. Find current and potential at A & B.



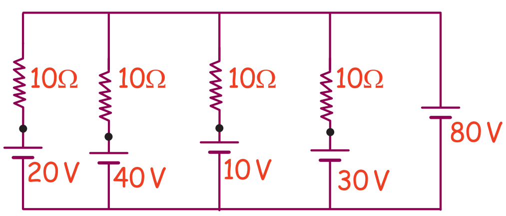
Sol.



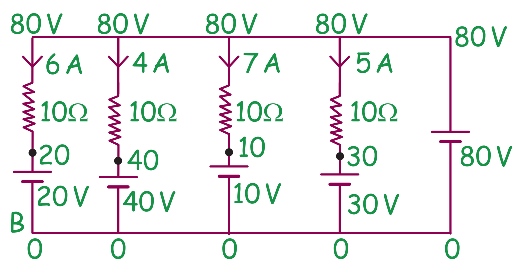
$$i = \frac{E}{R_{eq}} = \frac{100}{10} = 10A$$

$$R_{eq} = 5 + 3 + 2 = 10\Omega$$

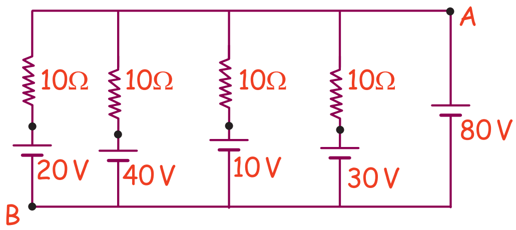
Q. Find current through each resistors (R = 10Ω each)



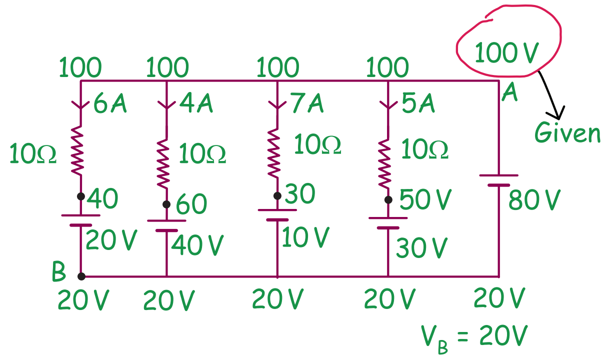
Sol.



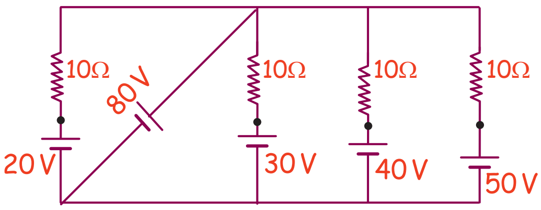
Q. If pot. at A is 100V, find V_B & Current. (R = 10Ω each)



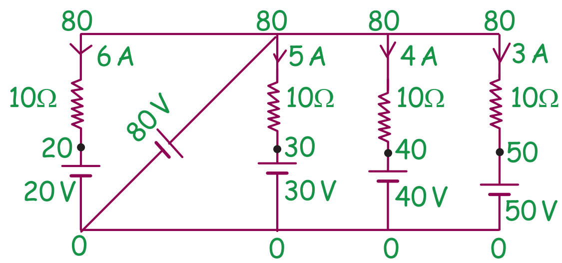
Sol.

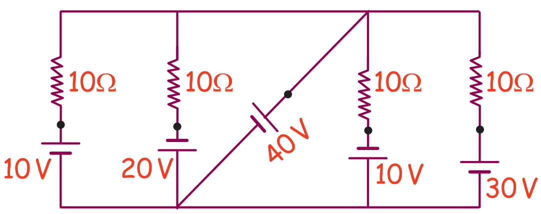


Q. Find i in each resistance

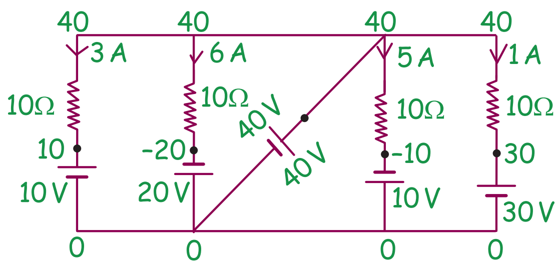


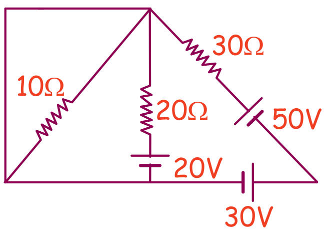
Sol.



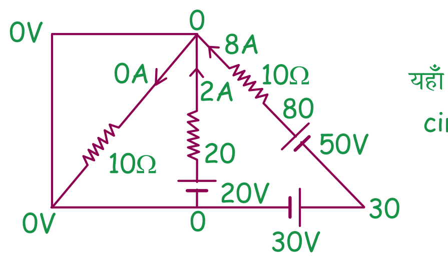


Sol.



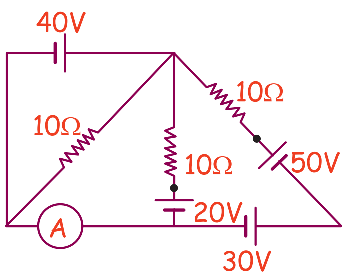


Sol.

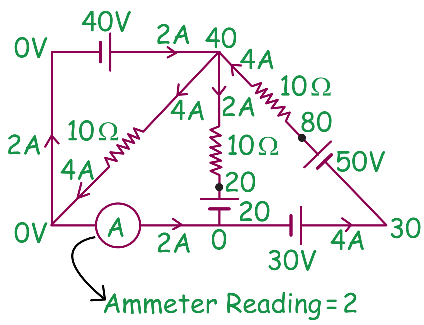


यहाँ 10 Ω short circuit हो गया

Q. What is ammeter reading?



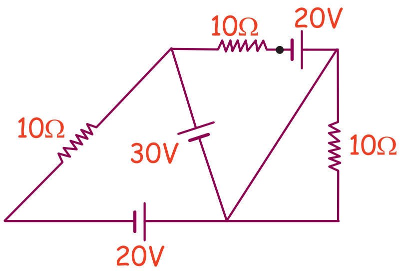
Sol.



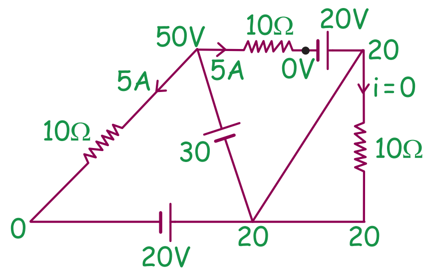
मान की no. of pages of book को कम से कम रखने का pressure है to minimise the MRP/- लेकिन circuit analysis के सवाल हम भर-भर कर practice करेंगे। (Bcz it's vry imp)

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)

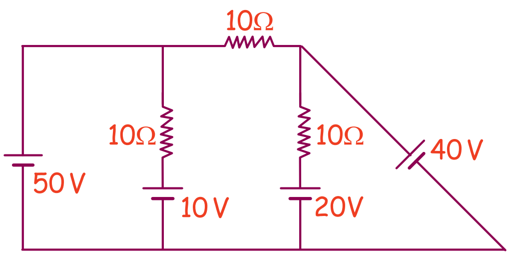
Q. Find current in each resistors.



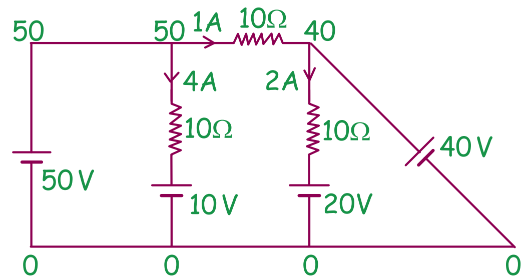
Sol.



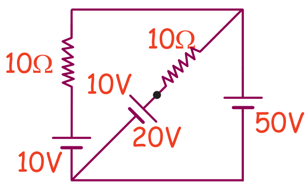
Q. Find current in each resistors.



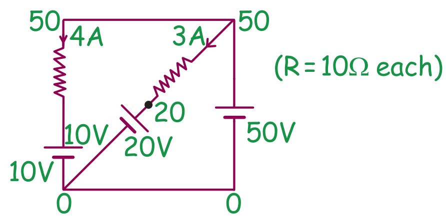
Sol.



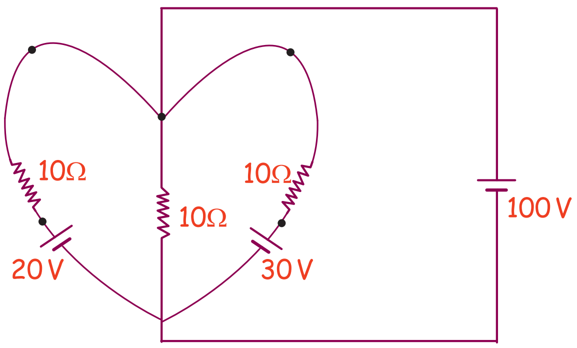
Q. Find current in each resistors.



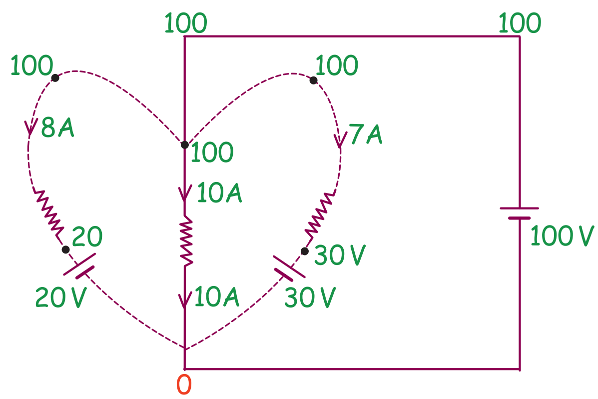
Sol.

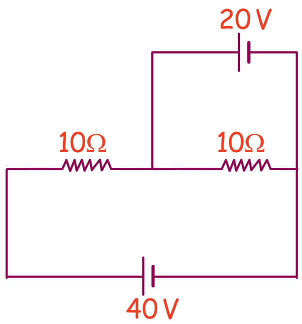


Q. Find current in each resistors.

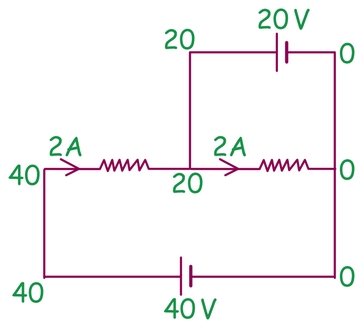


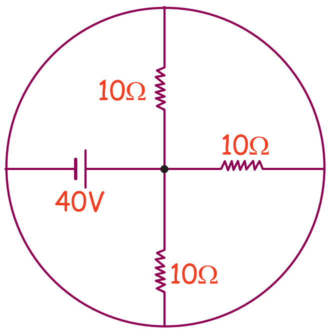
Sol.



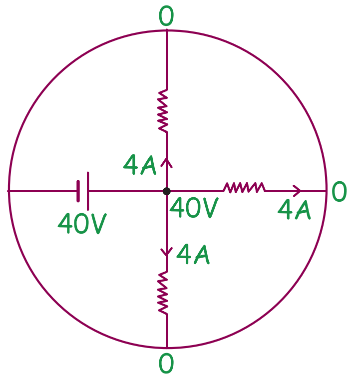


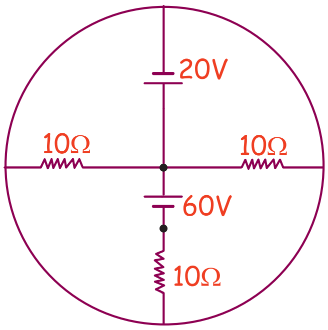
Sol.



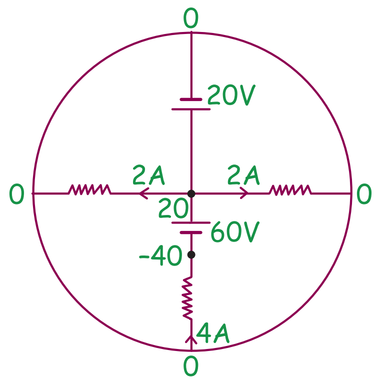


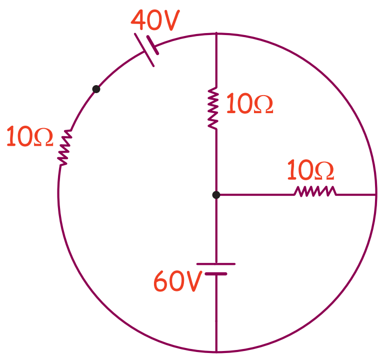
Sol.



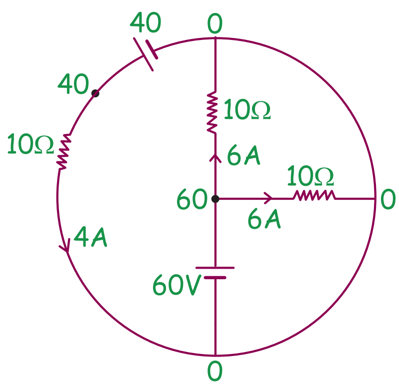


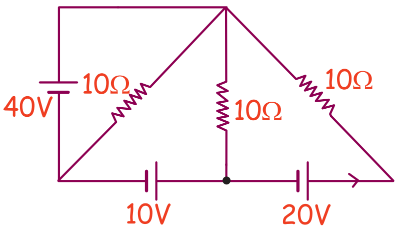
Sol.



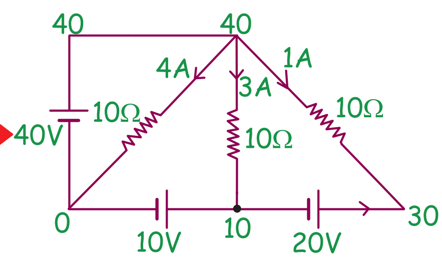


Sol.

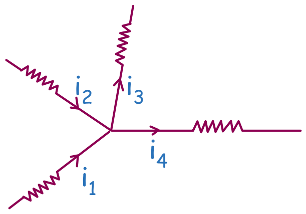




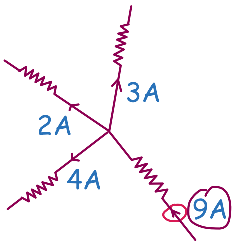
Sol.



JUNCTION LAW



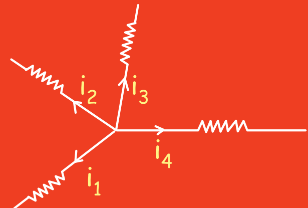
$i_1 + i_2 = i_3 + i_4$ (आने वाली = जाने वाली)



OR

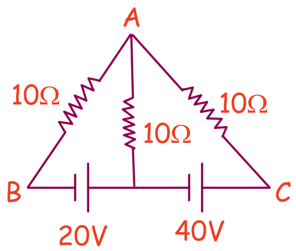
#SKC

किसी भी junction से total जाने वाला current का sum = 0

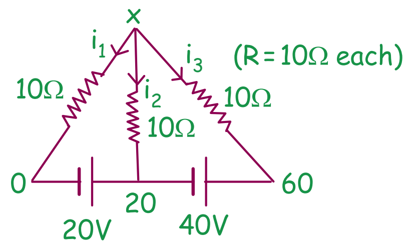


$i_1 + i_2 + i_3 + i_4 = 0$ (junction law)

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.......

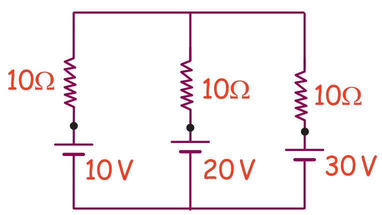
अबे emotional मत हो I mean जहाँ फँसे वहाँ potential X मान लो और junction law लगादो

$i_1 + i_2 + i_3 = 0$

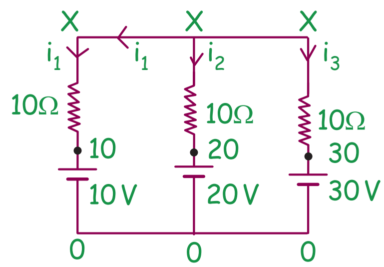
$$\frac{x-0}{10} + \frac{x-20}{10} + \frac{x-60}{10} = 0$$

$$x = \boxed{\frac{80}{3}}$$

Q. Find current through each resistance.



Sol.



$i_1 + i_2 + i_3 = 0$

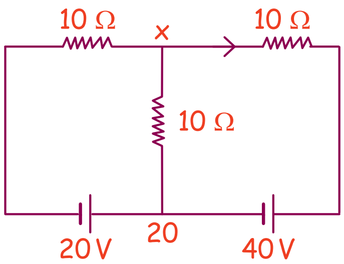
$$\frac{x-10}{10} + \frac{x-20}{10} + \frac{x-30}{10} = 0$$

$x = 20$

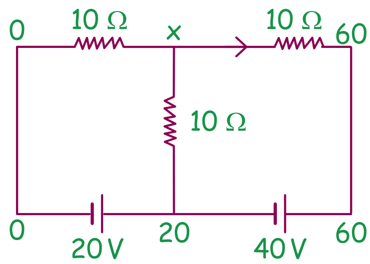
now we can find current though any wire

$$i_1 = \frac{x-10}{10} = 1A \text{ and } i_2 = \frac{x-20}{10} = 0$$

Q. Find current through each resistors.



Sol.

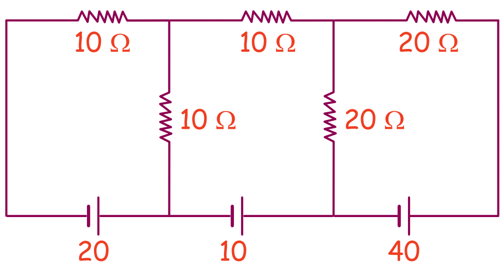


$i_1 + i_2 + i_3 = 0$

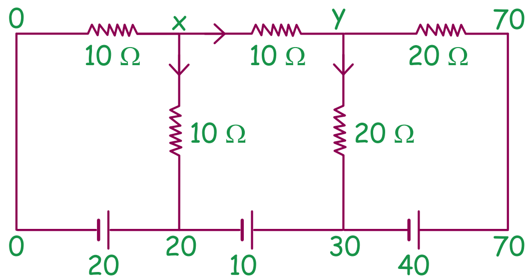
$$\frac{x-0}{10} + \frac{x-20}{10} + \frac{x-60}{10}$$

$$x = \frac{80}{3}$$

Q. Find potential (x).



Sol.



$$\frac{x-0}{10} + \frac{x-20}{10} + \frac{x-y}{10} = 0$$

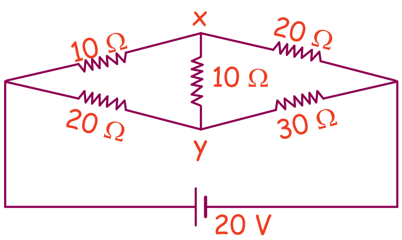
$3x - y = 20$ ...(1)

$$\frac{y-x}{10} + \frac{y-30}{20} + \frac{y-70}{20} = 0$$

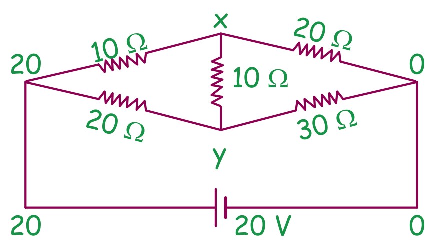
$4y - 2x = 100$ ...(2)

Now we solve both eqn. and get answer

Q. Find $V_x - V_y = ?$



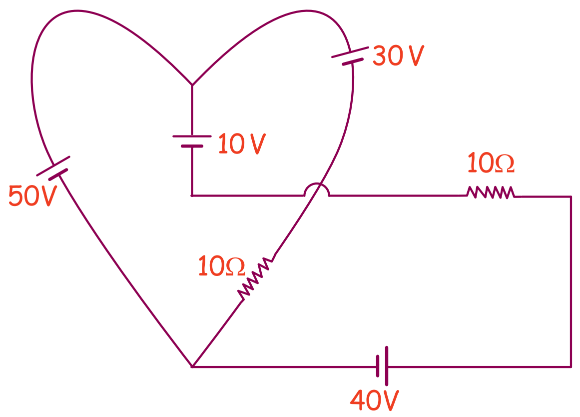
Sol.



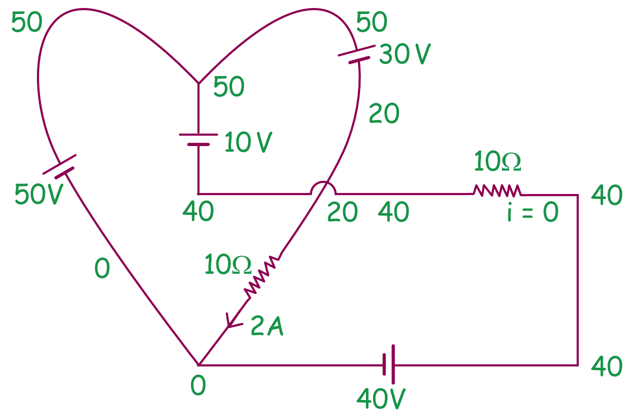
$$\frac{x-20}{10} + \frac{x-y}{10} + \frac{x-0}{20} = 0$$

$$\frac{y-20}{20} + \frac{y-x}{10} + \frac{y-0}{30} = 0$$

Q. Find current through each resistors.

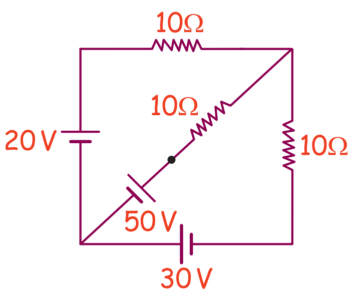


Sol.

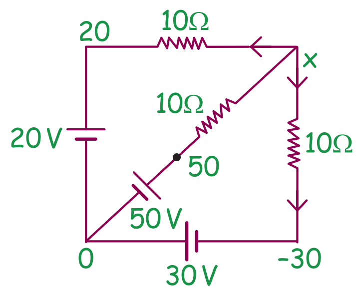


$v = iR$

Q. Find current through each resistors.



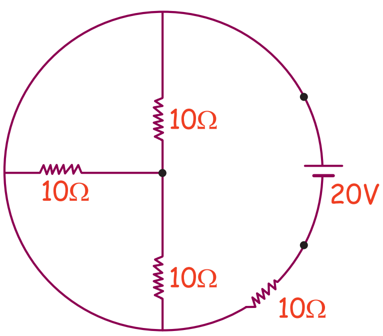
Sol.



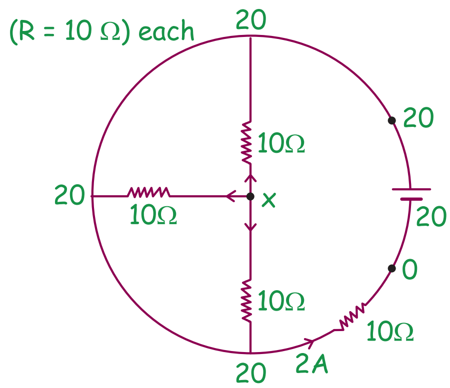
$$\frac{x-20}{10} + \frac{x-50}{10} + \frac{x+30}{10} = 0$$

$$x = \frac{40}{3}$$

Q. Find current through each resistors.



Sol.

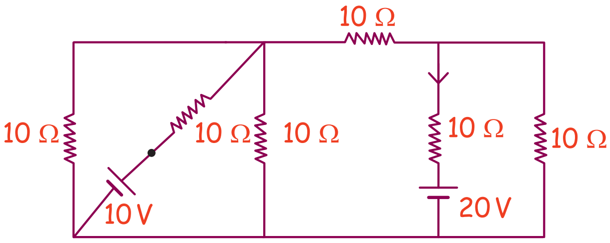


$$\frac{x-20}{10} + \frac{x-20}{10} + \frac{x-20}{10} = 0$$

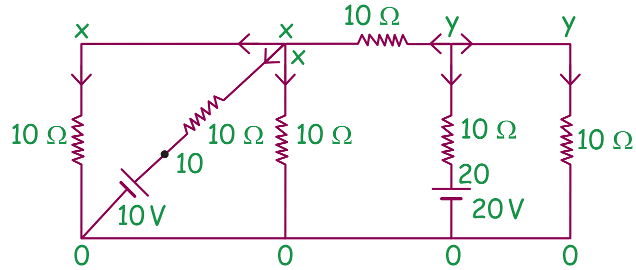
$x = 20$

$i_1 = i_2 = i_3 = 0$

Q. Find current through each resistors.



Sol.



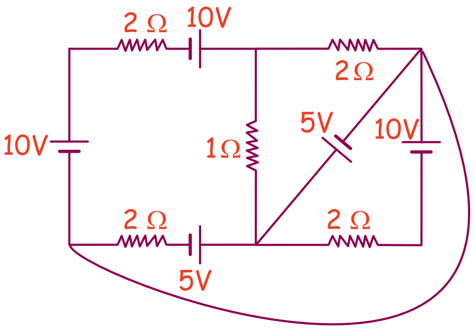
Apply junction law at x

$$\frac{x-0}{10}+\frac{x-10}{10}+\frac{x-0}{10}+\frac{x-y}{10}=0$$

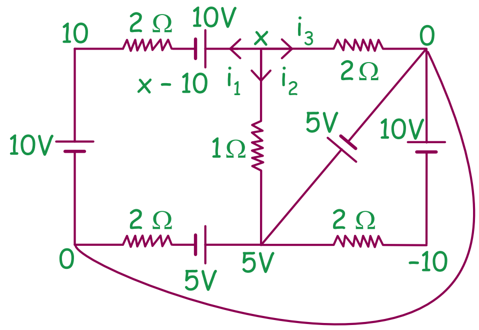
Apply junction law at y

$$\frac{y-x}{10}+\frac{y-20}{10}+\frac{y-0}{10}=0$$

Q. Find current through each resistors.



Sol.



$$\frac{x-10-10}{2}+\frac{x-5}{1}+\frac{x-0}{2}=0$$

$$x-20+2x-10+x=0$$

$$4x=30=7.5$$

$$i_2=\frac{x-5}{1}=7.5-5=2.5$$

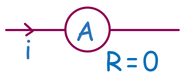
#SKC

ideal Amm का Resistance ⇒ Zero

ideal Voltmeter का Resistance ⇒ ∞

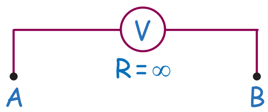
क्योंकी हम चहते है (A) (V) का इस्तेमाल करते वक्त circuit ना बदले

✦ Ideal Ammeter



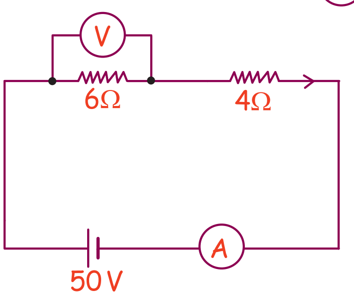
Reading = i

✦ Ideal Voltmeter

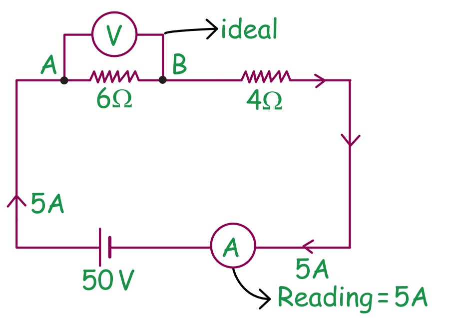


$|V_A - V_B|$ = Reading

Q. Find the reading of ideal (V) & (A)

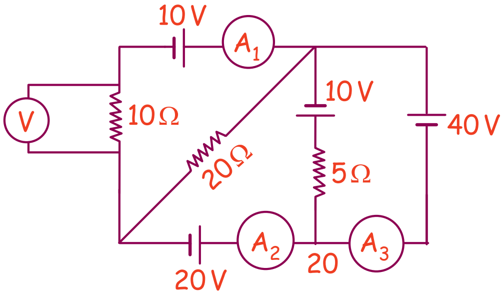


Sol.

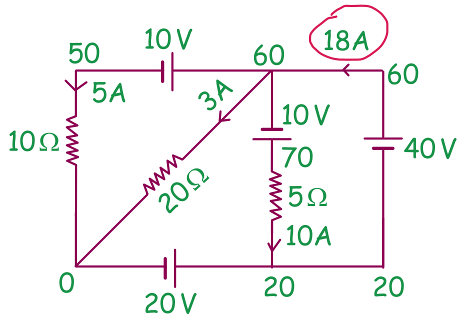


$V_A - V_B = 5 \times 6$ = Reading of voltmeter

Q. Find the reading of (A) & (V)



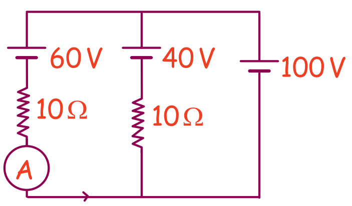
Sol.



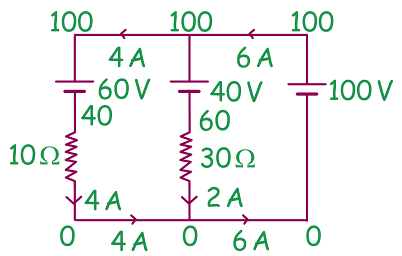
Ammeter की reading मतलब उससे कितना current pass कर रहा है अगर ammeter ideal है तो उसे wire मान लो।
voltmeter की reading मतलब जिन दो point के बीच उसे connect किया है उनके बीच potential difference अगर voltmeter ideal है तो उसके through i = 0

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)

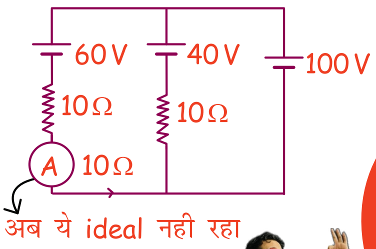


Sol.

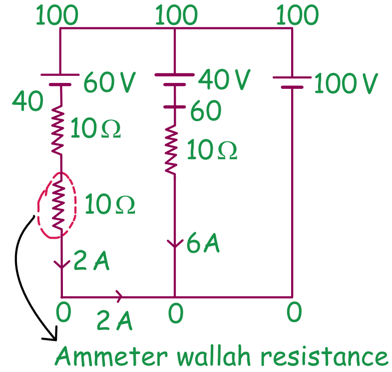


Ans. 4 A

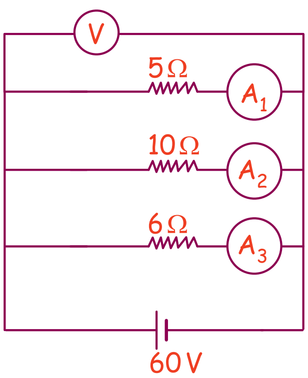
Q. What is the reading of non-ideal ammeter?



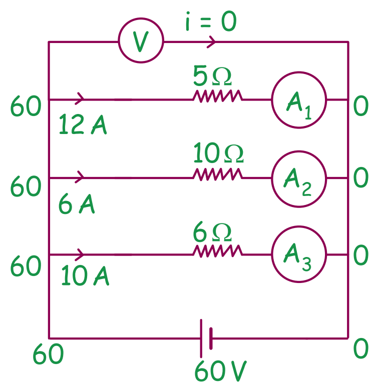
Sol.



Q. What will be the readings?



Sol.

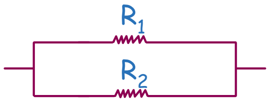


All are ideal:
Reading of (V) = 60V
Reading of (A_1) = 12A
Reading of (A_2) = 6A
Reading of (A_3) = 10A

If two resistance R_1 and R_2 are in parallel then

Parallel

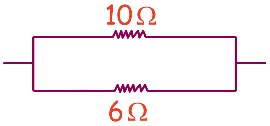
$\Delta V \rightarrow$ same



$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{R_2 + R_1}{R_1 R_2}$$

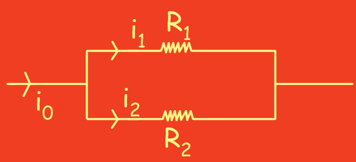
$$R_{eq} = \frac{R_1 R_2}{R_2 + R_2} = \frac{\text{multiply}}{\text{sum}}$$

Q.



Sol. $R_{eq} = \dfrac{10 \times 6}{10 + 6} = \dfrac{60}{16}$

#SKC



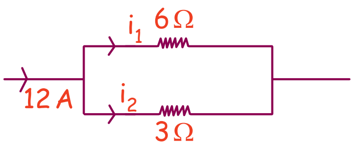
IMP

i_1 = सामने वाला 'R' × total current/total R

$$i_1 = \frac{R_2}{R_1 + R_2} \times i_0$$

$$i_2 = \frac{R_1}{R_1 + R_2} \times i_0$$

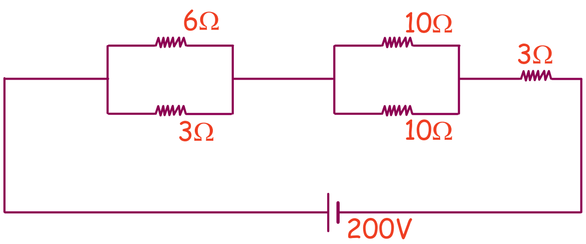
Q. Find i_1 and i_2



$$i_1 = \frac{3}{9} \times 12 = 4A$$

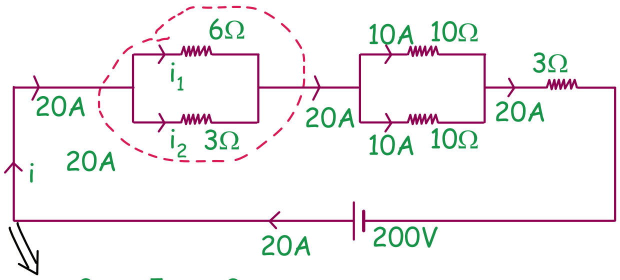
$$i_2 = \frac{6}{9} \times 12 = 8A$$

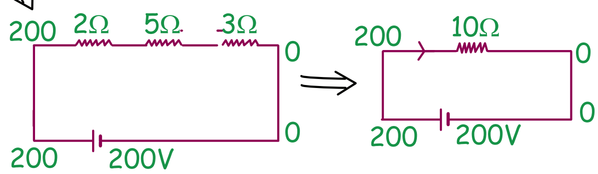
Q. Find current through each resistors.



Sol.

$$R_{eq} = \frac{\text{Multiply}}{\text{sum}}$$





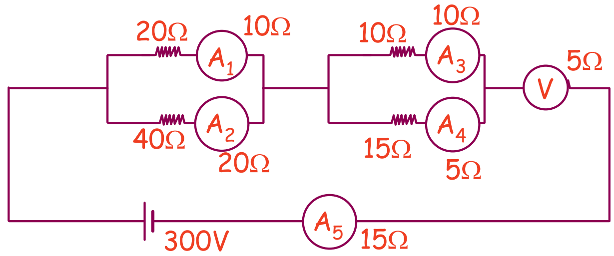
$R_{eq} = 2 + 5 + 3 = 10\Omega$

$$i = \frac{V}{R_{eq}} = \frac{200}{10} = 20A$$

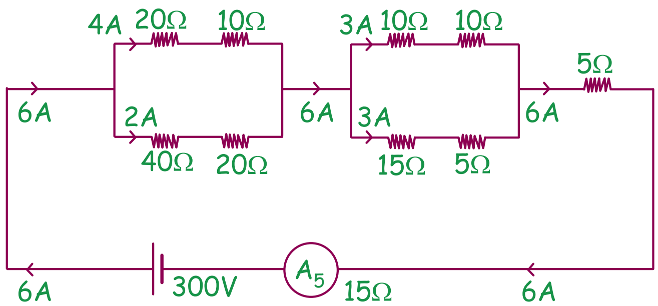
$$i_1 = \frac{3}{3+6} \times 20 = \frac{20}{3}$$

$$i_2 = \frac{6}{3+6} \times 20 = \frac{120}{9}$$

SSSQ. What will be reading of A_1 A_2 A_3 A_4 and V?

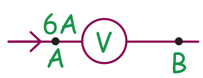


Sol.



Reading of $A_1 \rightarrow 4A$

Reading of $A_2 \rightarrow 2A$



Reading of $A_3 \rightarrow 3A$

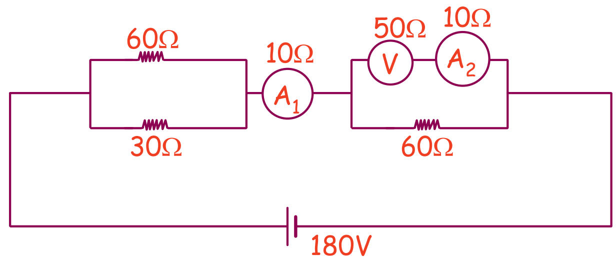
Reading of $A_4 \rightarrow 3A$

Reading of $A_5 \rightarrow 6A$

Reading of voltmeter = 6 × 5 = 30

SSSQ. Saleem Sir Special Question

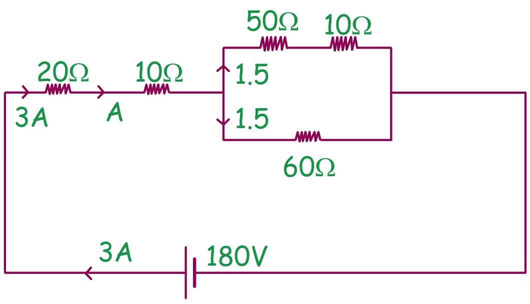
Q.



If reading —A1— —A2— & —V—

are x, y, z, find $\frac{z}{xy}$

Sol.



$R_{eq} = 20 + 10 + 30 = 60\Omega$

—A1— $3A = x$

—A2— $1.5A = y$

—V— $= 75 \text{ volt} = z$

$$\frac{z}{xy} = \frac{75}{3 \times 1.5} = 16.6$$

अब हम R_{eq} निकालना सीखेंगे

- If resistance are in series then

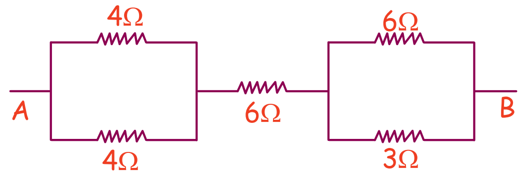
  $R_{eq} = R_1 + R_2 + R_3 + ...$

- If resistance in parallel

  $$R_{eq} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$$

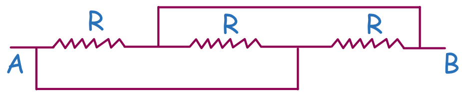
- If R_1 and R_2 are in parallel then $R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$

Q. Find R_{eq}

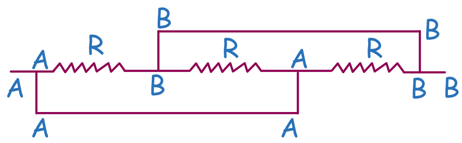


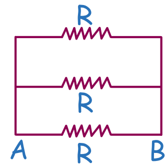
$R_{eq} = 2 + 6 + 2 = 10\Omega$

Q. Find R_{eq} between A and B.



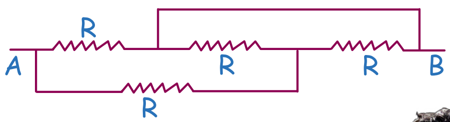
Sol.



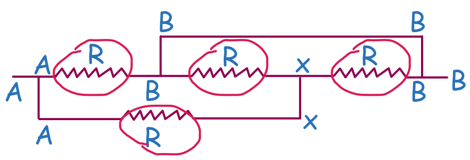


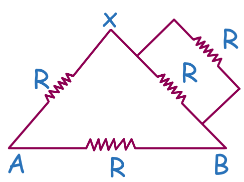
$$\frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} = \frac{3}{R} \qquad R_{eq} = R/3$$

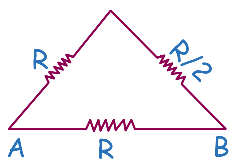
Q. Find R_{eq} between A and B.

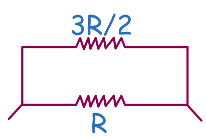


Sol. जहाँ फसो वहाँ x को याद करो और उसके खराब, बेकार, डरावनी सूरत को सूधार लो........ अबे मतलब नया circuit diagram बनाओ।



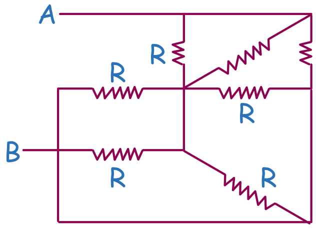






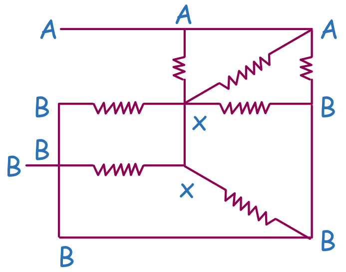
Ans. $R_{eq} = 0.6R$

Q. Find the R_{eq} between A and B.



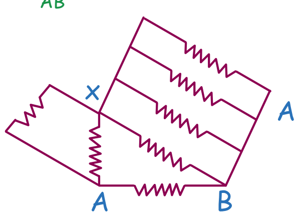
Sol.

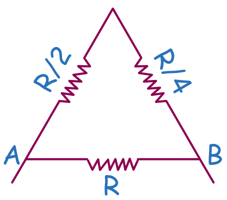
Resistance
$R\Omega$ each



All resistance are equal ($R\Omega$)

$R_{AB} = ?$

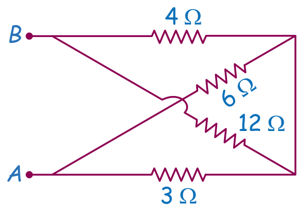




$$R_{eq} = \frac{\frac{3R}{4} \times R}{\frac{3R}{4} + R} = \frac{3}{7}R$$

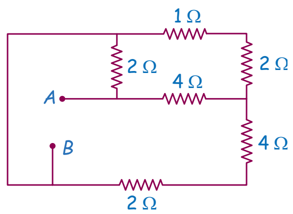
Homework

Q. In the given network, the equivalent resistance between A and B is



Ans. 5

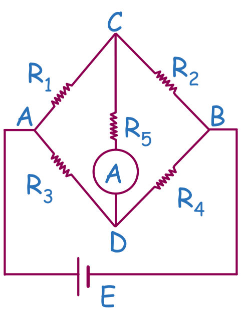
Q. In the circuit shown in figure, equivalent resistance between A and B is



Ans. 1.5

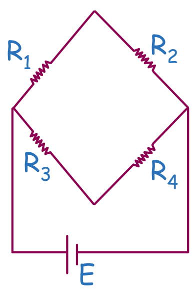
Wheatstone Bridge

☆ In following circuit

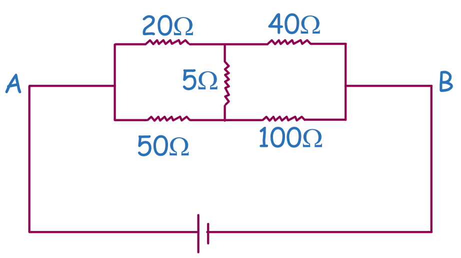


If $\frac{R_1}{R_2} = \frac{R_3}{R_4}$ then be observed that $V_C = V_D$ and current through R_5 is zero तो R_5 को circuit से उड़ा दो such type of circuit called balance wheatstone bridge

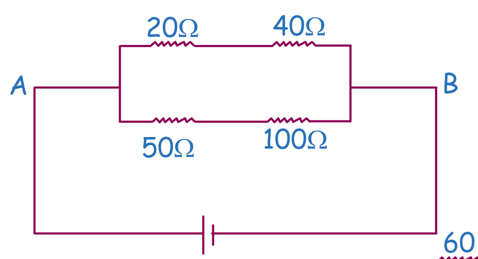
⇒

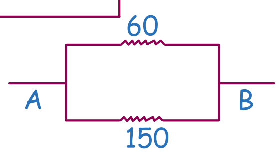


Q. Find R_{eq} between A & B



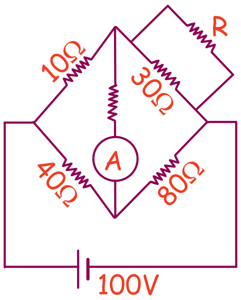
Sol.





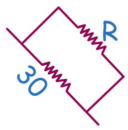
$$R_{AB} = \frac{60 \times 150}{210}$$

Q. Find value of R for which ammeter reading is zero



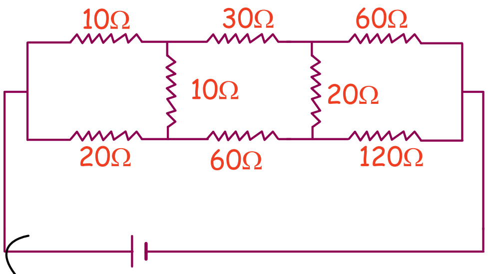
Sol.

R = 60



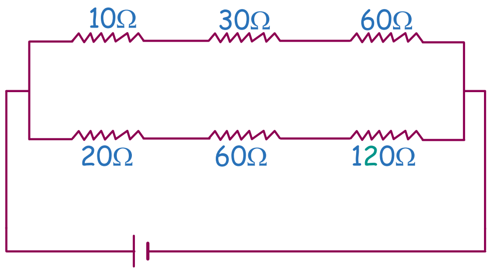
$\Rightarrow$ 20 Ω होना चाहिए

Q. Find equivalent resistance.

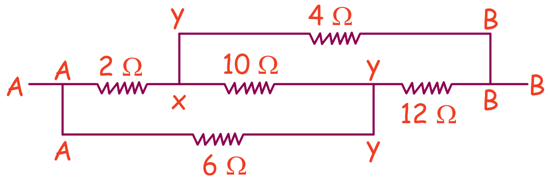


इसमे wheatstone Bridge छुपा है

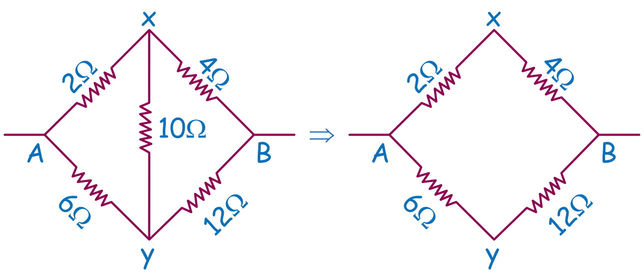
Sol.



Q. find R_{AB} = ?



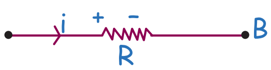
Sol.



$$R_{eq} = \frac{6 \times 18}{6 + 18} = \frac{6 \times 18}{24} = 4.5$$

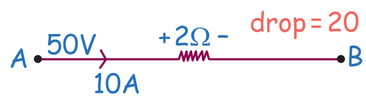
Kirchhoff Voltage Law (KVL)

$V_A - V_B = 10$



$V_A - V_B = iR$

$V_A - iR = V_B$



$V_A - iR = V_B$

$50 - 10 \times 2 = V_B$

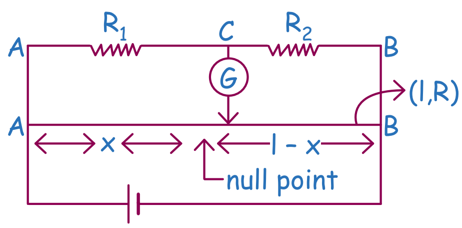
$V_B = 30$

Meter Bridge

- It is used to find unknown resistance.
- Its concept based on balance wheat stone bridge.
- When current through galvanometer is Zero.

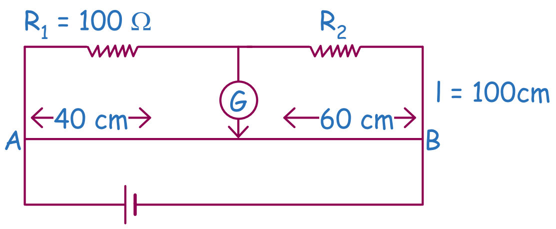
$$\frac{R_1}{R_2} = \frac{R_{AD}}{R_{DB}} = \frac{x}{l - x} \qquad (l = 100 \text{ cm})$$

$$\boxed{\frac{R_1}{R_2} = \frac{x}{l - x}}$$



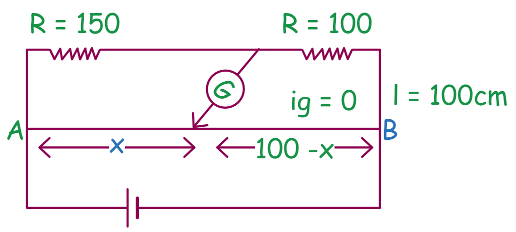
$$\left(\begin{array}{l} R = \dfrac{\rho l}{A} \\ R \propto \text{length} \end{array} \right)$$

Q. In a meter bridge (as shown in fig), if null point is found at a distance of 40 cm from A. Find shift in the null point if R_1&R_2 interchanged



Sol. $\frac{R_1}{R_2} = \frac{40}{60}$

$\frac{100}{R_2} = \frac{40}{60} \Rightarrow \boxed{R_2 = 150}$



$\frac{150}{100} = \frac{x}{100 - x}$

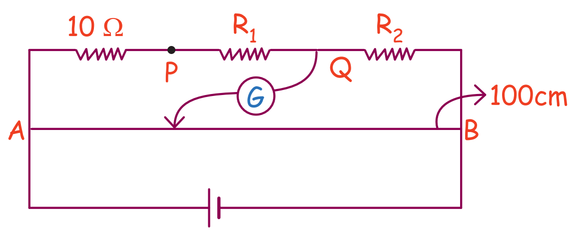
$\frac{3}{2} = \frac{x}{100 - x}$

$300 - 3x = 2x$

$x = 60$

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.



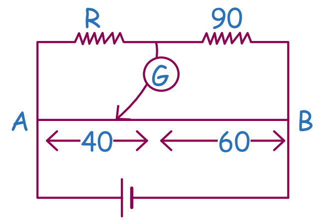
Sol. $\frac{10}{R_1 + R_2} = \frac{40}{60}$ ...(1)

$\frac{10 + R_1}{R_2} = \frac{70}{30}$ ...(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.



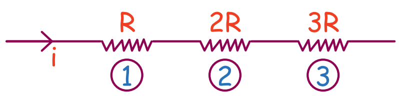
$\frac{R}{90} = \frac{40 + 1}{60 + 3}$

POWER DISSIPATED ACROSS RESISTANCE

- Power dissipated across the resistance = i^2R
- $P = V.i = iR.i = i^2R = \frac{V^2}{R}$
- $H = \int_0^t i^2R\,dt$
- If current is constant heat = i^2Rt

Q. Find the order of power dissipated across the resistance in following question.

(a)

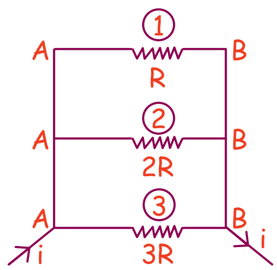


Sol. $P = i^2R$

$R\uparrow = P\uparrow$ Power loss$\uparrow$

$P_3 > P_2 > P_1$

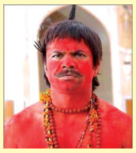
(b)



Sol. $V \to$ same

$P = \frac{V^2}{R}$ $\quad R\uparrow = P\downarrow$

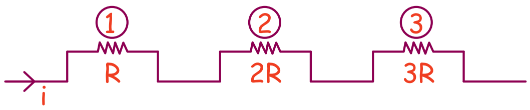
$P_3 < P_2 < P_1$



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.



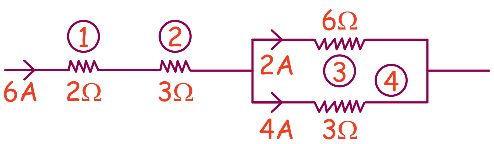
Sol. $i \to$ same $\qquad P = i^2R$

$P \to P_3 > P_2 > P_1$

Brig $\to B_3 > B_2 > B_1$

> Bulb के case मे जिसके across power $\uparrow$ तो Brightness $\uparrow$

Q. Repeat the above problem in following case.



Sol. $P_1 = 6^2 \times 2 = 72$

$P_2 = 6^2 \times 3 = 108$

$P_3 = 2^2 \times 6 = 24$

$P_4 = 4^2 \times 3 = 48$

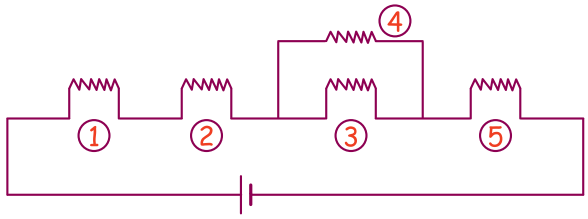
$P_2 > P_1 > P_4 > P_3$

Brightness $B_2 > B_1 > B_4 > B_3$

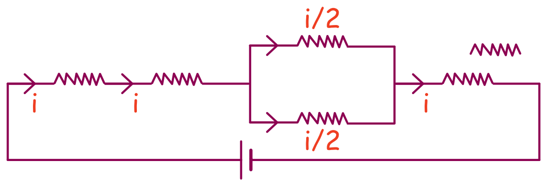
Q. Compare brighten of bulb

All are identical bulb

$R \to$ same

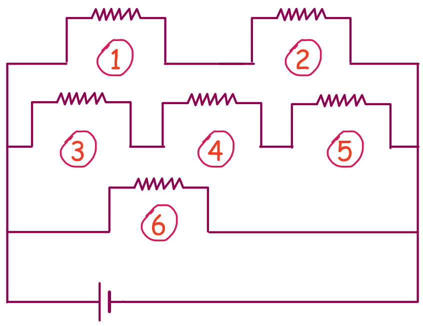


Sol.



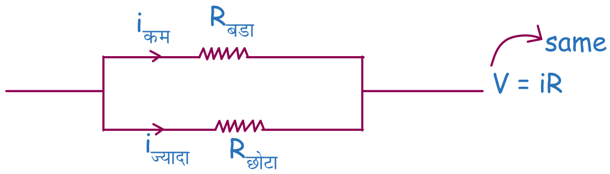
$B_1 = B_2 = B_5 > B_4 = B_3$

Q. All bulbs are indentical having same resistance 10Ω. Find order of brightness



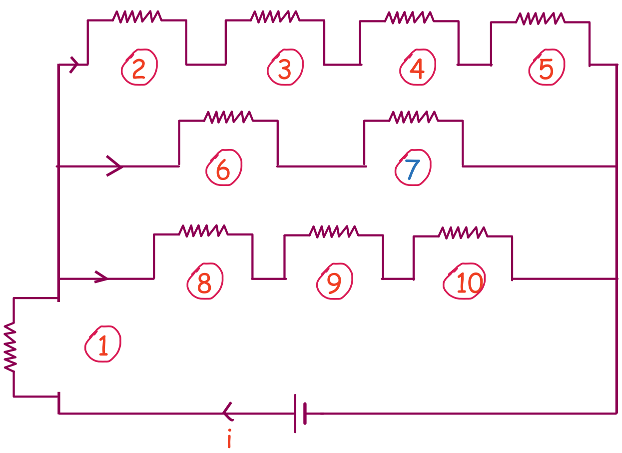
60

Sol. $B_6 > B_1 = B_2 > B_3 = B_4 = B_5$



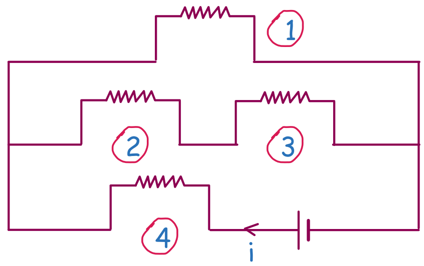
Q. All are identical

(a)



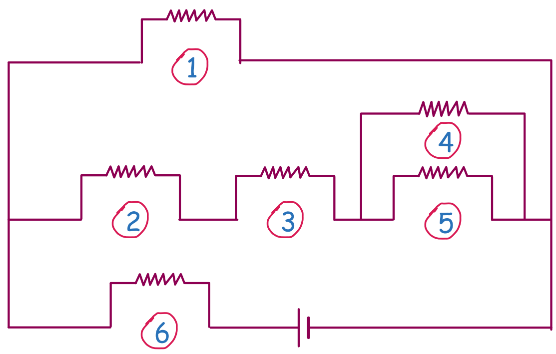
Sol. $B_1 > B_6 = B_7 > B_8 = B_9 = B_{10} > B_2 = B_3 = B_4 = B_5$

(b) All bulbs are identical



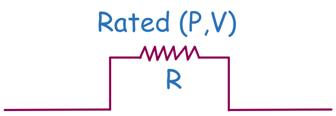
Sol. $B_4 > B_1 > B_2 = B_3$

(c)



Sol. $B_6 > B_1 > B_2 = B_3 > B_4 = B_5$

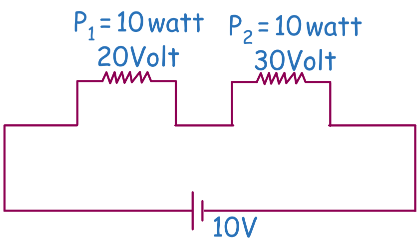
Bulb

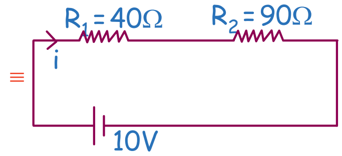


Suppose it's given that rated voltage of bulb is V and rated power is P it means यह bulb का resistance देने का तरीका है

Resistance of bulb = $\frac{V^2}{P}$

Q. Compare brighter of bulbs.





Sol. $R = \frac{V^2}{P} \Rightarrow R_1 = \frac{(20)^2}{10} = 40\Omega$

$i = \frac{10}{130}$

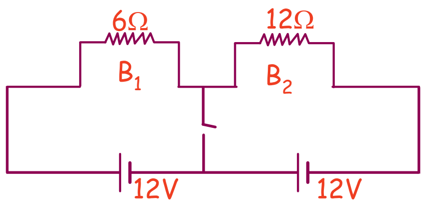
$R_2 = \frac{(30)^2}{10} = 90\Omega$

Power across $B_1 = i^2R_1 = (1/13)^2 \times 40$

$B_2 = i^2R_2 = (1/13)^2 \times 90$

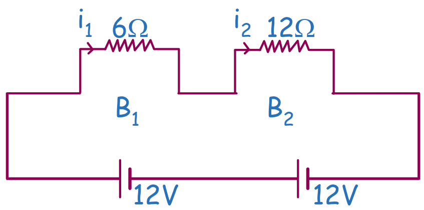
$B_2 > B_1$ (or $i \rightarrow$ same $\Rightarrow$ जिसका R↑ उसकी P↑B↑).

Q. B_1 and B_2 are bulbs. What happens to brightness of bulbs after switch close?



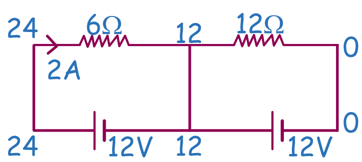
1. Brightness of B_1 inc
2. Brightness of B_1 dec
3. Brightness of B_2 inc
4. Brightness of B_2 dec

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

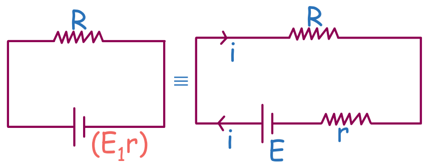
- When connected voltage and rated voltage are same then total power dissipated for n number of bulbs in series,

$$\frac{1}{P_T} = \frac{1}{P_1} + \frac{1}{P_2} + \frac{1}{P_3} + \ldots + \frac{1}{P_n}$$

- When connected voltage and rated voltage are same then total power dissipated for n number of bulbs in parallel,

$$P_T = P_1 + P_2 + P_3 + \ldots + P_n$$

Max Power Theorem



Power dessipited across R = $i^2R = \left(\frac{E}{R+r}\right)^2 R$

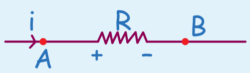
$$P = \frac{E^2R}{(R+r)^2}$$

At what condition $P \to$ 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)

$V_A - V_B = E$

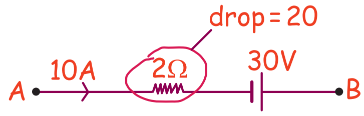
(irrespective of dir^n of current)

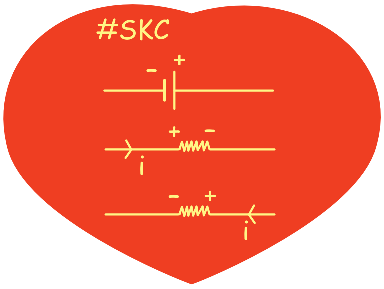
$V_B - V_A = E$

(चाहे current हो या ना हो या कही भी हो)

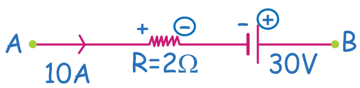
Q. Find $V_A - V_B$

(a)





Sol.

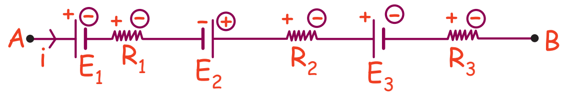


$$\boxed{V_A - iR + E = V_B}$$

$$V_A - 20 + 30 = V_B$$

$$V_A - V_B = -10$$

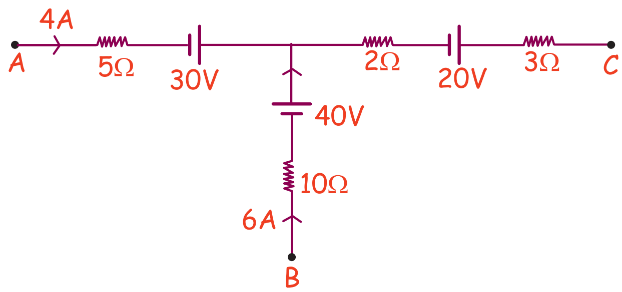
(b)



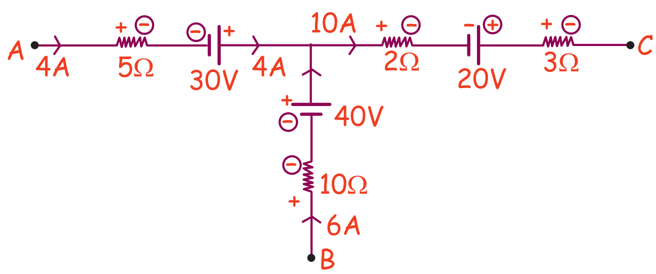
Sol. $V_A - E_1 - iR_1 + E_2 - iR_2 - E_3 - iR_3 = V_B$

$V_A - V_B = \checkmark$

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) $V_A - V_B = ?$

$V_A - 20 + 30 - 40 + 6 \times 10 = V_B$

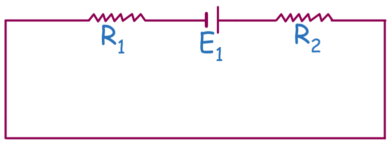
$V_A - V_B = -30$

(3) $V_B - V_C = ?$

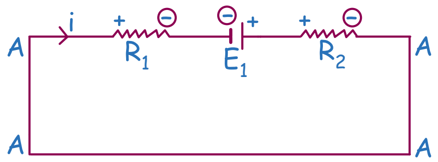
$V_B - 60 + 40 - 20 + 20 - 30 = V_C$

$V_B - V_C = 50$

Q. Find current in the circuit.



Sol.

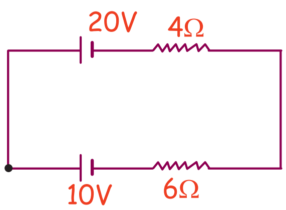


$V_A - iR_1 + E_1 - iR_2 = V_A$

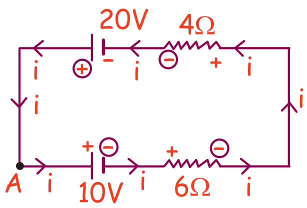
$E_1 = iR_1 + iR_2$

$$\boxed{i = \frac{E_1}{R_1 + R_2}}$$

Q. Find current in the circuit.



Sol.



$V_A - 10 - 6i - i \times 4 + 20 = V_A$

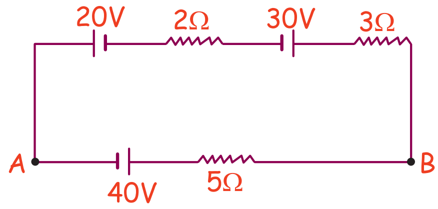
$-10 - 10i + 20 = 0$

$i = 1A$

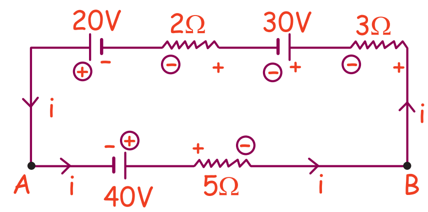
थोड़ी देर के बाद हम देखेंगे 20 V battery is discharging and 10 V batter is charging in this case.

Q. (1) Find current in circuit

(2) $V_A - V_B = ?$



Sol.



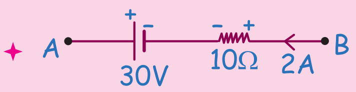
(1) i→ Acw मान लो (let)

$V_A + 40 - 5i - 3i - 30 - 2i + 20 = V_A$

$i = 3A$

(2) $V_A + 40 - 3 \times 5 = V_B$

$\boxed{V_A - V_B = -25}$



1. A से B चलते है

$V_A - 30 + 2 \times 10 = V_B$

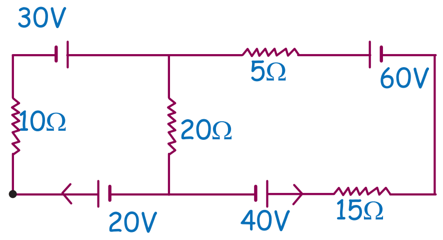
$V_A - V_B = 10V$

2. B से A चलते है

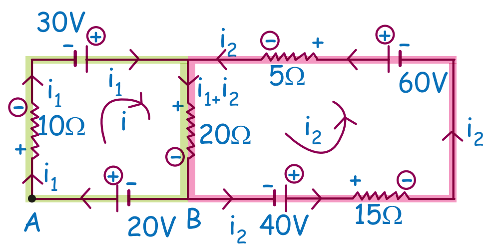
$V_B - 2 \times 10 + 30 = V_A$

$V_A - V_B = 10$

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)

$V_B + 40 - 15i_2 + 60 - 5i_2 - (i_1 + i_2) \times 20 = V_B$

$40 - 15i_2 + 60 - 5i_2 - (i_1 + i_2) \times 20 = 0$ ...(2)

Solve (1) & (2) And get Ans:

Charging & Discharging of Batteries

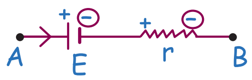
#SKC

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

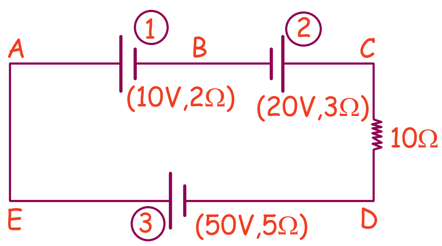
$V_A - E + ir = V_B$

$V_A - V_B = E - ir$

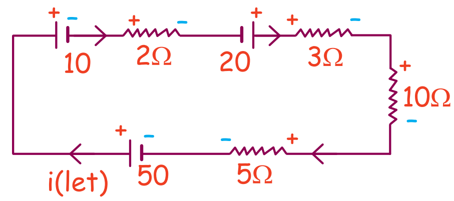
(Pot diff across battery, terminal voltage)

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

$|V_{AB}| = E + ir = 10 + 3 \times 2 = 16V$

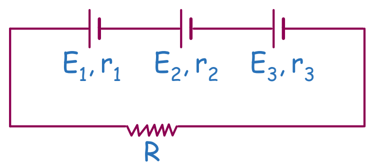
$|V_{BC}| = |E - ir| = |20 - 3 \times 3| = 11V$

$|V_{ED}| = |50 - 3 \times 5| = 35$

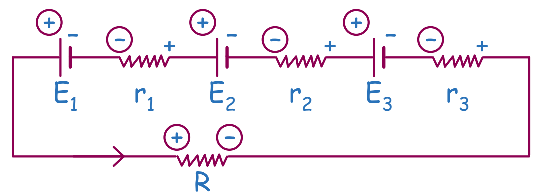
#SKC

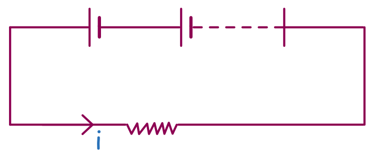
Battery के internal resistance से बिलकुल नही डरना है बस battery के बाजू मे उतना resistance लगा देना है

Q. Find current in circuit



Sol.



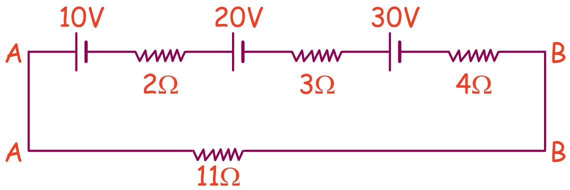


$-iR - iR_3 + E_3 - iR_2 + E_2 - iR_1 + E_1 = 0$

$$i = \frac{E_1 + E_2 + E_3}{r_1 + r_2 + r_3 + R}$$

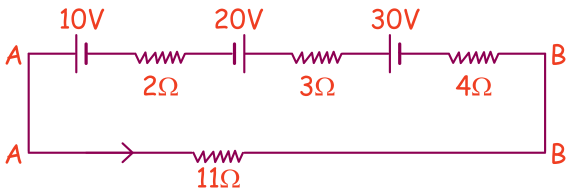
$$i = \frac{E_1 + E_2 + \ldots}{(r_1 + r_2 + \ldots) + R}$$

Q. Find current in circuit



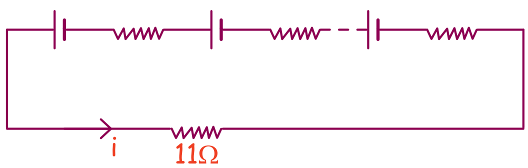
Sol. $i = \dfrac{10+20+30}{2+3+4+11}$ $\quad V_{AB} = \checkmark$

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

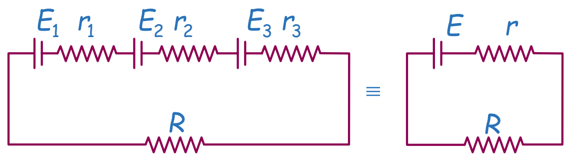
(i) Series Combination

If n sources of emf are connected in series with same polarity, then the equivalent emf is given by

$E = E_1 + E_2 + E_3 + \ldots\ldots\ldots + E_n$

And, total internal resistance is

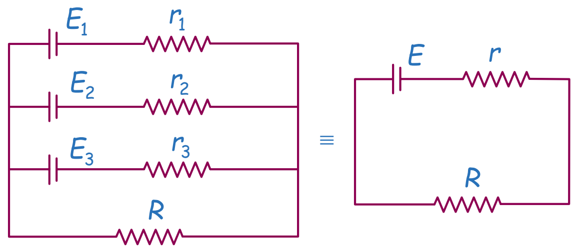
$r = r_1 + r_2 + r_3 + \ldots\ldots\ldots\ldots + r_n$



✦ 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

$$E = \frac{\dfrac{E_1}{r_1} + \dfrac{E_2}{r_2} + \dfrac{E_3}{r_3}}{\dfrac{1}{r_1} + \dfrac{1}{r_2} + \dfrac{1}{r_3}}$$

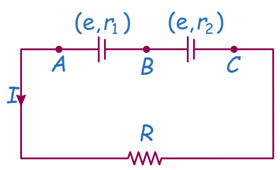
and $\dfrac{1}{r} = \dfrac{1}{r_1} + \dfrac{1}{r_2} + \dfrac{1}{r_3}$

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

$(V_A - V_B) = \varepsilon - Ir_1$

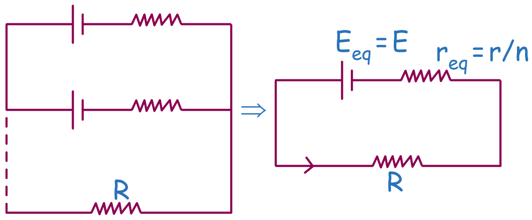
$$V_A - V_B = \varepsilon - \frac{2\varepsilon r_1}{r_1 + r_2 + R} = \varepsilon\frac{(R + r_2 - r_1)}{(R + r_2 + r_1)}$$

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



$$i = \frac{E}{\frac{r}{n} + R}$$

$$E_{eq} = \frac{E/r + E/r + \ldots n \text{ times}}{1/r + 1/r + \ldots n \text{ times}}$$

$\boxed{E_{eq} = E}$

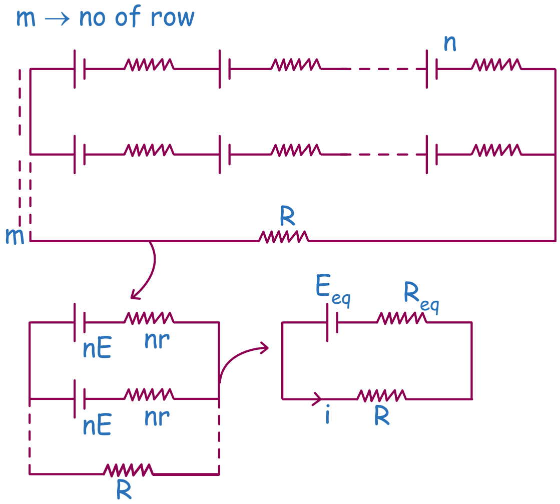
$$\frac{1}{Req} = \frac{1}{r} + \frac{1}{r} + \ldots n \text{ times}$$

$\boxed{req = \frac{r}{n}}$

✦ Mixed Grouping

n identical cell in row in series

m → no of row



net emf = nE

Total internal resistance $= \frac{nr}{m}$

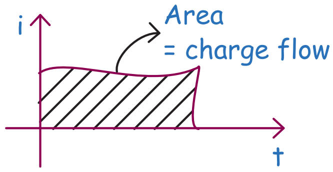
$$i = \frac{nE}{\frac{nr}{m} + R}$$

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

$\Delta q = \int idt$



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.

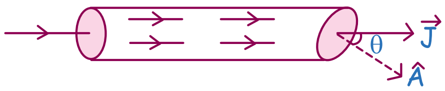
Current Density

✦ 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

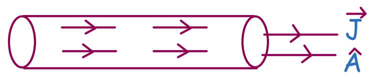


$i = \vec{J}.\vec{A} = JA\cos\theta$

$$\Rightarrow \quad J = \frac{i}{A\cos\theta}$$

For special case

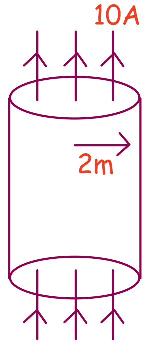
$\theta = 0$



$i = JA \Rightarrow \boxed{J = \frac{i}{A}}$

$i = \int \vec{J}\,.\,d\vec{A}$ अगर J बदला तो we will use this

Q.

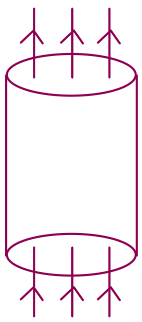


Sol. $\vec{J} = \frac{10}{\pi 2^2}\hat{i}$

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

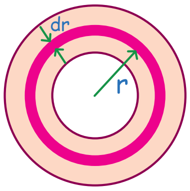
$\boxed{\text{Current density का flux} = \int \vec{J}\cdot d\vec{A} = i}$

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 $\lambda = \frac{\text{total distance travelled}}{\text{number of collisions}}$

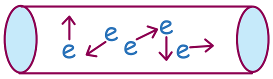
Relaxation Time

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



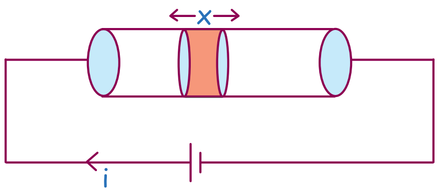
$\vec{u}_1 + \vec{u}_2 + \vec{u}_3 + \ldots \vec{u}_A = 0$

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

$\rightarrow$ Area of cross section

$\rightarrow$ 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.

$$\vec{v}_d = \frac{\vec{v}_1 + \vec{v}_2 + \vec{v}_3 \ldots\ldots\ldots \vec{v}_n}{n}$$

$$= \frac{(\vec{u}_1 + \vec{a}\tau_1) + (\vec{u}_2 + \vec{a}\tau_2) + \ldots..(\vec{u}_n + \vec{a}\tau_n)}{n}$$

$$= \left(\frac{\vec{u}_1 + \vec{u}_2 + \vec{u}_3 + \ldots \vec{u}_n}{n}\right) + \vec{a}\left(\frac{\tau_1 + \tau_2 + \tau_3 + \ldots \tau_n}{n}\right)$$

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 $\vec{E}$.

$$i = V_d enA = \left(\frac{eE}{m}\right)\tau\, enA = \frac{eV}{ml}\tau\, enA$$

$$i = \frac{e^2\tau nvA}{ml} = \frac{v}{\left(\dfrac{ml}{\tau e^2 nA}\right)} = \frac{V}{R} = \frac{\Delta V}{R}$$

$E = \dfrac{V}{l} = \dfrac{\text{Pot. diff}}{\text{length}}$

$\boxed{\Delta V = iR \text{ Ohm's Law}}$

and

$i = V_d enA$

$\dfrac{i}{A} = V_d en = \dfrac{eE}{m}\tau en$

$J = \dfrac{e^2\tau n}{m} E = \sigma E$

$\vec{J} = \sigma\vec{E}$

mobility = μ = $\dfrac{\text{Drift velocity}}{\text{E.F}}$

$\mu = \dfrac{V_d}{E}$

$\Delta V = iR$ (ohm's law)

substance which follow ohm's law called ohmic structure.

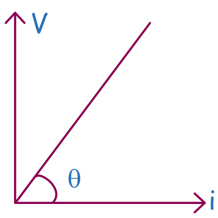
$\dfrac{1}{\rho} = \sigma = \dfrac{\tau e^2 n}{m}$ = conductivity

$R = \dfrac{\rho l}{A} = \dfrac{l}{\sigma A}$

- $V = iR$
- $i = V_d enA$
- $v_d = \dfrac{eE}{m}\tau$
- $\vec{J} = \sigma\vec{E}$
- $R = \rho\dfrac{l}{A} = \dfrac{l}{\sigma A}$ (ρ = resistivity, σ = conductivity)
- $\dfrac{1}{\rho} = \sigma = \dfrac{\tau e^2 n}{m}$ = conductivity
- mobility = μ = $\dfrac{\text{Drift velocity}}{\text{E.F}} = \dfrac{V_d}{E}$

सवाल आएगा तो इसी BOX से आऐगा।

- Ohm's law $i \propto V$



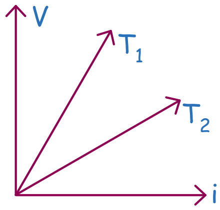
V = iR
y = mn

$i = \frac{V}{R}$ Electric Resistance

$\tan\theta = \frac{V}{i}$ = Resistance

As $T\uparrow \Rightarrow R\uparrow \Rightarrow$ slope$\uparrow$

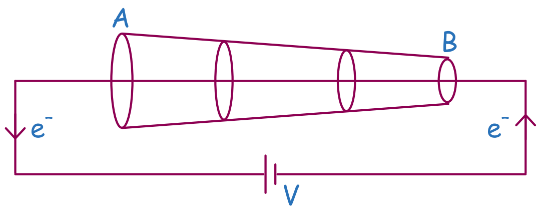
For a given material graph between ΔV & i is plotted at diff temp T_1&T_2



$(\text{Slope})_1 > (\text{Slope})_2$

$(T\uparrow, R\uparrow, \text{slope}\uparrow) \Rightarrow \quad T_1 > T_2$

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. $R = R_0(1 + \alpha\Delta T)$

$50 = R_0[(1 + \alpha(10 - 0)]$

$60 = R_0[(1 + \alpha(30 - 0)]$

$60 + 600\alpha = 50 + 1500\alpha$

$\alpha = \frac{1}{90}$

$50 = R_0(1 + 1/90 \times 10)$

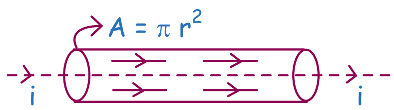
$R_0 = 45$

$R_f = R_0(1 + \alpha\Delta T)$

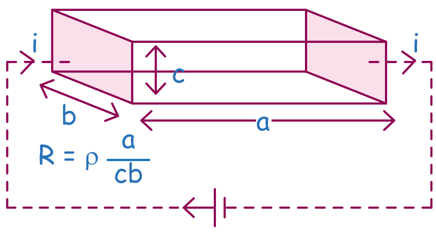
$= 45(1 + 1/90 \times (50 - 0))$

$= 45(1 + 5/9) = \frac{45 \times 14}{9}$

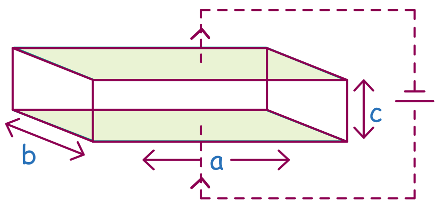
अब in following case में R_{eq} की अच्छे से practice करलो (apply smartly $R = \rho l/A$)

1. 

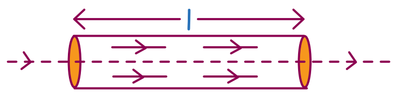
Solid Cylinder $R = \rho\frac{l}{\pi r^2}$

2. 

$R = \rho\frac{a}{cb}$

3. 

$R = \rho\frac{c}{ab}$

4. 

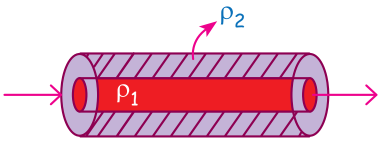
$R = \rho\frac{l}{A} = \rho\frac{l}{\pi r^2}$

5. 

$R = \rho\frac{l}{\pi(R_2^2 - R_1^2)}$

(R_1 is inner radius R_2 is outer radius)

6.

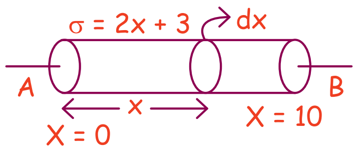


$R_1 = R$ अदर $= \rho_1 \frac{l}{\pi R_1^2}$

$R_2 = R$ 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. $= dR = \rho \frac{dx}{\pi r^2} = \frac{l}{\sigma} \frac{dx}{\pi r^2}$

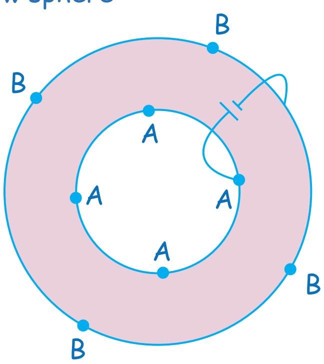
$\int dR = \int \frac{1}{2x+3} \times \frac{dx}{\pi r^2}$

$R_{eq} = \frac{1}{\pi r^2} \int_0^{10} \frac{dx}{2x+3}$

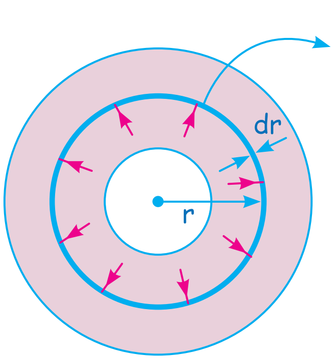
Ans: $R = \frac{1}{\pi r^2 \times 2} \ln\left(\frac{23}{3}\right)$

7. Hollow sphere

$R_2 > R_1$



$R_{eq} = \rho \frac{(R_2 - R_1)}{4\pi(R_1 R_2)}$



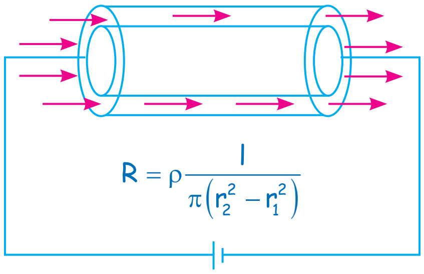
$\int dR = \int_{R_1}^{R_2} \rho \frac{dr}{4\pi r^2}$

$R_{net} = \frac{\rho}{4\pi}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$R_{net} = \frac{\rho(R_2 - R_1)}{4\pi R_1 R_2}$

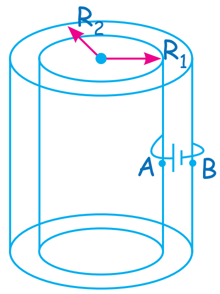
8. Hollow cylinder

(a)



$R = \rho \frac{l}{\pi\left(r_2^2 - r_1^2\right)}$

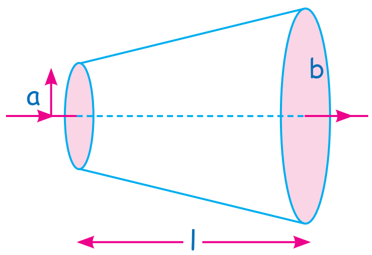
(b) $R_2 > R_1$



$\int dR = \int_{R_1}^{R_2} \rho \frac{dr}{2\pi r l}$

$$\boxed{R_{eq} = \frac{\rho}{2\pi l} \ln\left(\frac{R_2}{R_1}\right)}$$

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)

$R \propto l^2$ $\frac{\Delta l}{l} \times 100 = 5$

$\frac{\Delta R}{R} = \frac{2\Delta l}{l}$

$\frac{\Delta R}{R} \times 100 = 2\left(\frac{\Delta l \times 100}{l}\right)$

$= 2 \times 5 = 10\%$

Q. A cylindrical wire is increased double its original length the % increase in the Resistance of wire

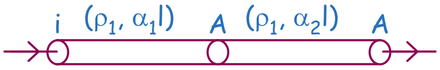
Sol. $R = \frac{\rho l}{A} = \frac{\rho l^2}{Al} = \frac{2l^2}{vol^n}$

$R \propto l^2$ $l \rightarrow$ double

$R \rightarrow 4$ 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 $\rho_1 \alpha_1 + \rho_2 \alpha_2 = 0$

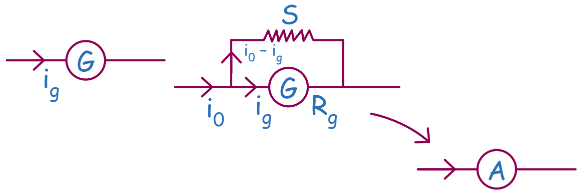
(अब यह मत सोचना ऐसा कैसे हुआ इसका मतलब है कोई एक α negative है)

CONVERSION OF GALVANOMETER INTO AMMETER/VOLTMETER.

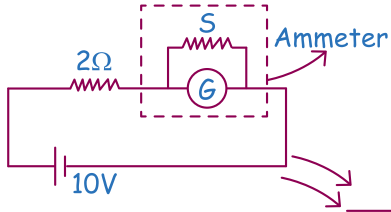
तीनो दिखने में एक जैसे ही होते है बस labelling का अंतर है यकीन नही आता ऊपर के image को ठीक से देखा। बस इतना याद रखो galvanometer के parallel में छोटा सा resistance लगाने पर यह ammeter बन जाता है और galvaometer के बाजू में बहुत बड़ा resistance लगाने पर ये voltmeter बन जाता है।

Ideal ammeter का resistance zero or ideal voltmeter का resistance infinity होता है।

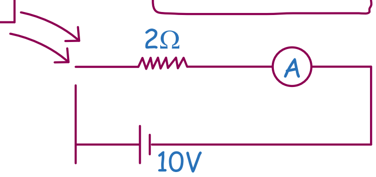
Conversion of Galvanometer into Ammeter



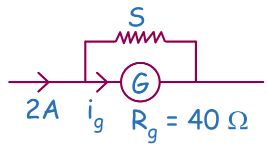
$R\text{ डब्बा} = \frac{S.R_g}{S + R_g}$



$$\boxed{i_g = \frac{S}{S + R_g} \times i_0}$$



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. $i_g = \frac{S}{S + G} \times i$ total

$50 \times 10^{-3} = \frac{S}{S + 40} \times 2$

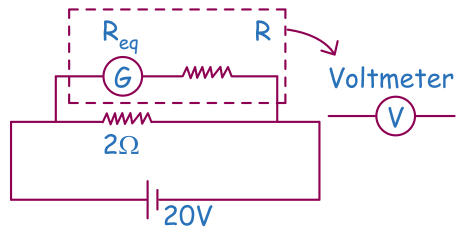
$50(S + 40) = 2000S$

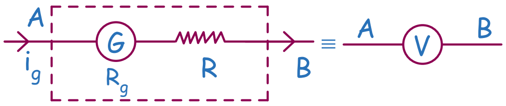
$50S + 2000 = 2000S$

$2000 = 1950S$

$S = \frac{2000}{1950}$

Conversion of Galvanometer into Voltmeter



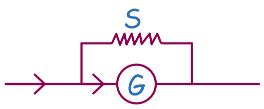


$V_{AB} = i_g(R + R_g)$ (ideally V Resist infinity)

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.



$i_0 = 40A \quad i_g$

$$i = \frac{S}{S+g} \times i_0$$

$$80 \times 10^{-3} = \frac{S}{S+40} \times 40$$

$$80S + 3200 = 40000 \text{ 'S'}$$

$$S = \frac{3200}{39920}$$

2. It become voltmeter of range 40 volt

$$V_{AB} = i_g(R_g + R)$$

$$40 = 80 \times 10^{-3}(40 + R)$$

$$R = 460\Omega$$

Now few important questions practice them sincerly

Q. In following case find r_{eq} & ρ_{eq} if rods A & B are connected in series of length $3l_0$.

Rod A: $\rho_0, l_0, 3\alpha, A$

Rod B ⇒ $2\rho_0, 2l_0, 2\alpha, A$

Sol.

$$R_1 = \rho_0(1 + 3\alpha\Delta T)\frac{l_0}{A}$$

at only temp

$$R_2 = 2\rho_0(1 + 2\alpha\Delta T)\frac{2l_0}{A}$$

$$R_{eq} = R_1 + R_2 = \rho_0\frac{l}{A}(1 + 3\alpha\Delta T) + 4\rho_0\frac{l}{A}(1 + 2\alpha\Delta T)$$

$$\rho_{eq}(1 + \alpha_{eq}\Delta T)\frac{3l_0}{A} = R_{eq} = \rho_0\frac{l_0}{A}(1 + 3\alpha\Delta T) + 4\rho_0\frac{l}{A}(1 + 2\alpha\Delta T)$$

$$3\rho_{eq}(1 + \alpha_{eq}\Delta T) = \rho_0 + 3\alpha\rho_0\Delta T + 4\rho_0 + 8\alpha\rho_0\alpha\Delta T$$

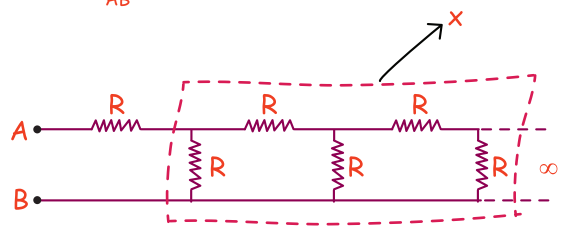
$$3\rho_{eq} + (3\rho_{eq}\alpha_{eq})\Delta T = 5\rho_0 + 11\alpha\rho_0\Delta T$$

$$3\rho_{eq} = 5\rho_0 \quad \boxed{\rho_{eq} = 5/3\rho_0}$$

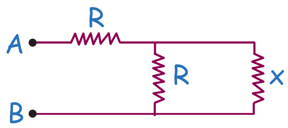
$$3\rho_{eq}\alpha_{eq} = 11\alpha\rho_0 \quad 5\rho_0\alpha_{eq} = 11\alpha\rho_0 \quad \boxed{\alpha_{eq} = \frac{11}{5}\alpha}$$

✦ ∞ ladder question

Q. Find R_{AB} ?



Sol.



Circuit को शुरु मे कितना मिटा दू की उसकी शक्ल सूरत वैसी की वैसी ही रहे

$$R_{AB} = x$$

$$R_{AB} = x = R + \frac{R\,x}{R + x}$$

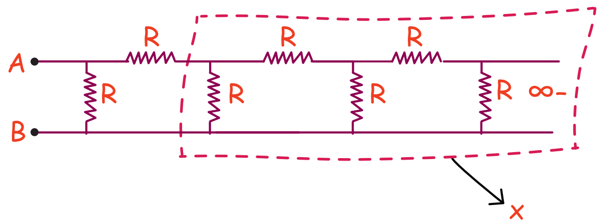
$$x = \frac{R(R + x) + Rx}{R + x}$$

$$xR + x^2 = R^2 + Rx + Rx$$

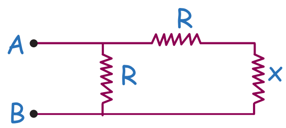
$$x^2 - Rx - R^2 = 0$$

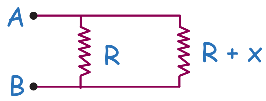
$$x = \text{solve \& get, } x = \frac{R + \sqrt{5}R}{2}$$

Q. R_{AB} = ?



Sol.





$$R_{AB} = \frac{R(R + x)}{R + R + x} = x = \frac{R^2 + Rx}{2R + x} = x$$

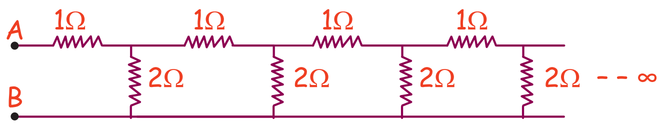
$$R^2 + Rx = 2Rx + x^2$$

$$x^2 - Rx - R^2 = 0$$

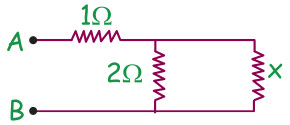
$$x = \frac{-R + \sqrt{R^2 + 4R^2}}{2}$$

$$x = R\left(\frac{\sqrt{5} - 1}{2}\right)$$

Q. R_{AB} = ?



Sol.



$$R_{AB} = x = 1 + \frac{2x}{x+2}$$

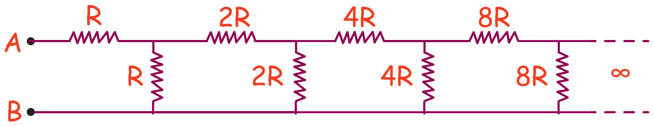
$$x - 1 = \frac{2x}{x+2}$$

$$(x-1)(x+2) = 2x$$

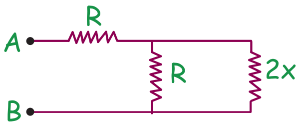
$$\cancel{x^2} + 2x - x - 2 = 2\cancel{x}$$

$$x = \frac{1-\sqrt{1+8}}{2} = 2$$

Q. Find R_{AB} = ?



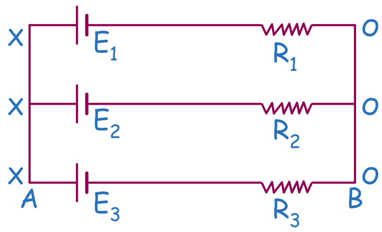
Sol.



$$R_{AB} = x = \frac{R\,2x}{R+2x} + R$$

Solve & get

Grouping of Cell

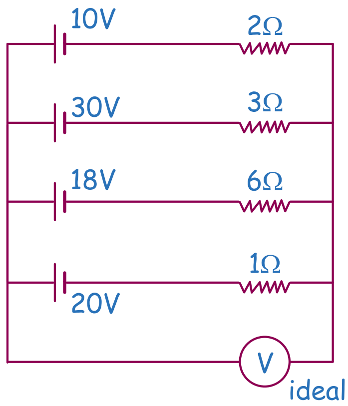


#SKC

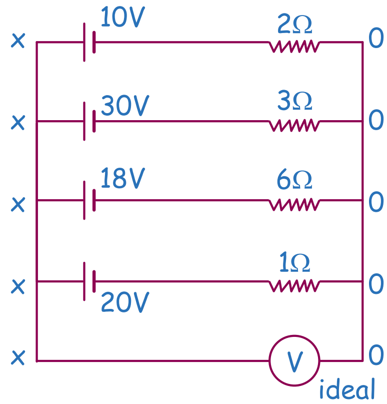
$$x = V_{AB} = \frac{\frac{E_1}{r_1} + \frac{E_2}{r_2} + \frac{E_3}{r_3}}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}}$$

अगर इस तरह के सवाल में direct x पुछे तो बिंदास SKC लगाओ।

Q. Find reading of ideal voltmeter.



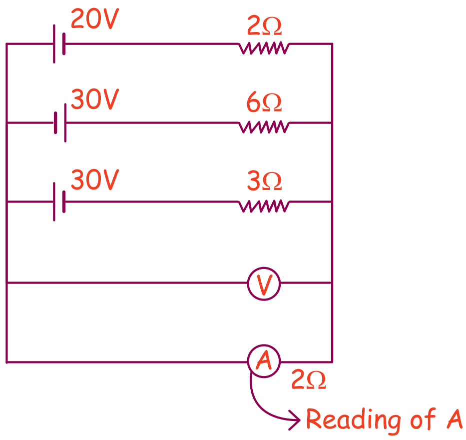
Sol.



$$x = \frac{10/2 + 30/3 + 18/6 + 20/1}{1/2 + 1/3 + 1/6 + 1/1} = \frac{5 + 10 + 3 + 20}{2}$$

$$x = V_{AB} = 19$$

SSSQ. Find volt meter and ammeter reading

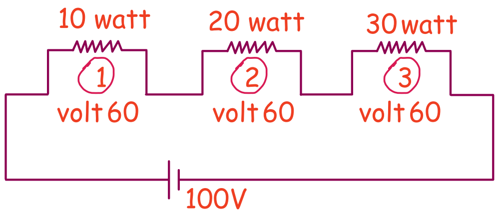


Sol. $x = \frac{20/2 - 30/6 + 30/3 + 0/2}{1/2 + 1/6 + 1/3 + 1/2} = 10$

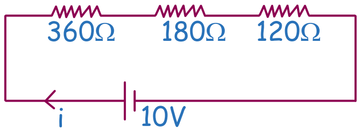
= 10 (V) (Voltmeter Reading)

$$i = \frac{x-0}{2} = \frac{10-0}{2} = 5 = \text{Ammeter reading}$$

Q. Compare brighter of bulbs.



Sol. $R = \frac{V^2}{P} = \frac{60 \times 60}{10} = 360$



$B_1 > B_2 > B_3$

$i = \frac{10}{360 + 180 + 120}$

Q. Find the total average momentum of electrons in a straight wire of length $l = 1000$ 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 $v_d = \frac{I}{neS}$

$P = (nSl)m\frac{I}{(neS)} = \frac{mlI}{e}$

On substituting numerical values, we get

$P = 4\mu$ Ns

Q. The temperature coefficient of resistivity α is given by $\alpha = \left(\frac{1}{\rho}\right)\frac{d\rho}{dT}$, where ρ is the resistivity at temperature T. Assume that α is not constant and follows the relation $\alpha = -\frac{a}{T}$, where T is the absolute temperature and a is a constant. Show that the resistivity ρ is given by $\rho = \frac{b}{T^a}$, where b is another constant.

Sol. $\alpha = \frac{1}{\rho}\frac{d\rho}{dT} \Rightarrow \frac{d\rho}{\rho} = \alpha dT = -a\frac{dT}{T}$

Let $\rho = \rho_0$ at $T = T_0$, then

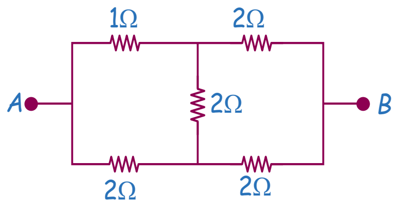
$\int_{\rho_0}^{\rho} \frac{d\rho}{\rho} = -a\int_{T_0}^{T} \frac{dT}{T}$

$\Rightarrow \log_e\left(\frac{\rho}{\rho_0}\right) = -a\log_e\left(\frac{T}{T_0}\right) = \log_e\left(\frac{T_0}{T}\right)^a$

$\Rightarrow \rho = (\rho_0 T_0^a)\frac{1}{T^a} = \frac{b}{T^a}$

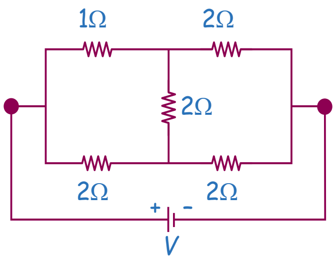
Here, $b = \rho_0 T_0^a$

Q. Find the equivalent resistance across terminals A and B.

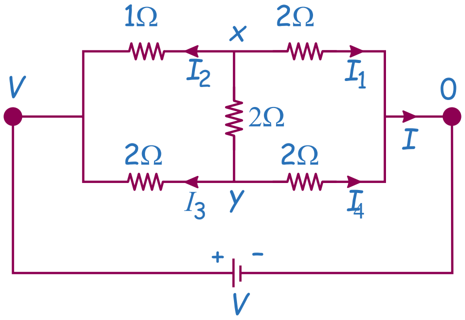


Sol. This is a case of unbalanced Wheatstone bridge.

Step 1: Connect a battery across the terminal.



Step 2: Mark the voltages of nodes.



Step 3: Calculate $R_{eq} = \frac{V}{I}$

Apply KCL at node 'x'

$\Rightarrow \frac{x - V}{1} + \frac{x - 0}{2} + \frac{x - y}{2} = 0$

$\Rightarrow 2x - 2V + x + x - y = 0 \quad \Rightarrow 4x - 2V = y \quad \ldots (i)$

Apply KCL at node 'y'

$\frac{y - x}{2} + \frac{y - V}{2} + \frac{y}{2} = 0 \quad \Rightarrow 3y - V = x \quad \ldots (ii)$

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

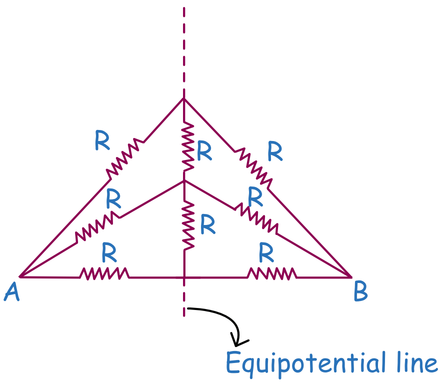
$$R_{eq} = \frac{V}{I} = \frac{V}{I_1 + I_2} = \frac{V}{\frac{7V}{22} + \frac{6V}{22}} = \frac{V}{\frac{13V}{22}} \Rightarrow R_{eq} = \frac{22}{13}\Omega$$

SYMMETRY (Not much important for jee mains)

- Perpendicular Bisector symm
- Folding symm
- input output symm

Perpendicular Bisector symmetry

example



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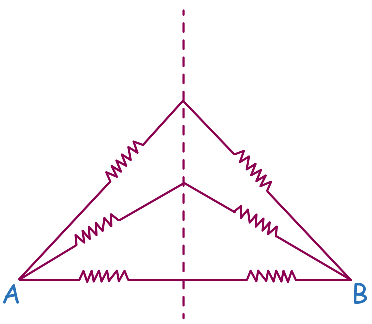
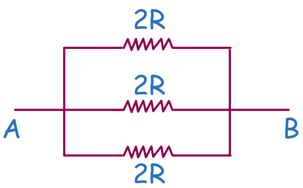


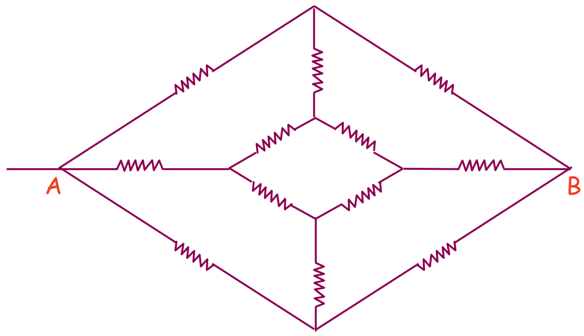


#SKC

A को B से connect करो और AB के $\perp^{ar}$ Bisector लो

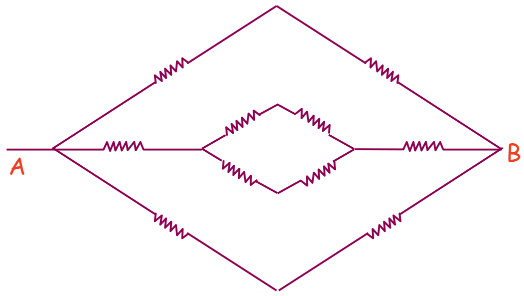
उसके आजू-बाजू अगर circuit mirror image है तो bisector line के resistance उड़ा दो

Q. All resisters have same value 'R'. Find R_{AB}

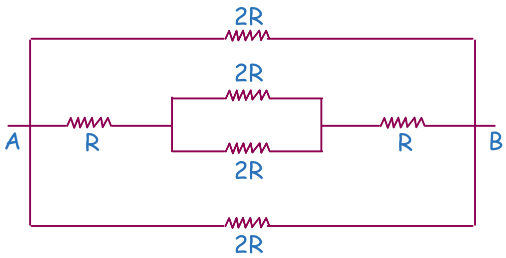


Sol.

≡



All resistance have same 'R'



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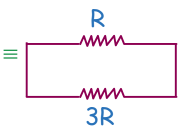


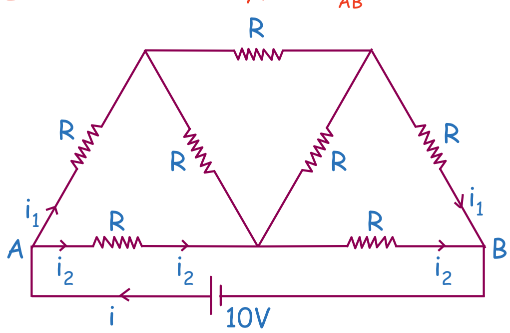
$$\frac{3R}{4} = R_{AB}$$

✦ Input output symmetry

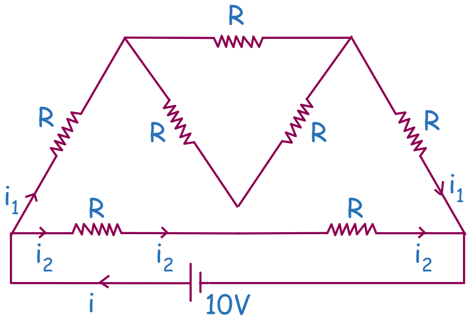
If current has similar path in entering side to exit & vice versa then circuit is said to be input output symmetry.

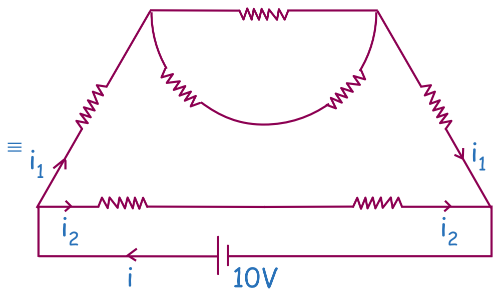
Under such condition for entry side & exit side are same

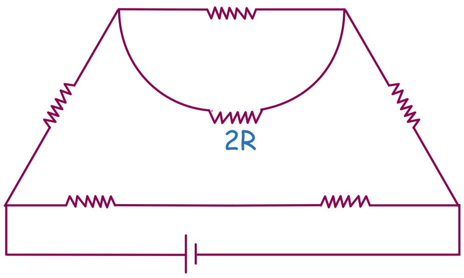
Q. Each resistance = R, Find R_{AB}

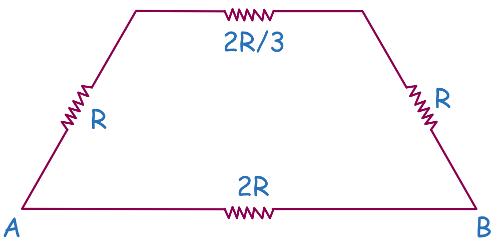


Sol.







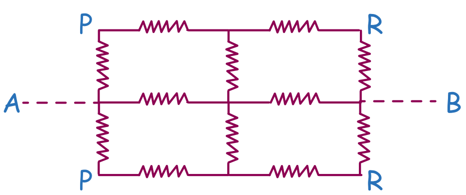


Folding Symmetry

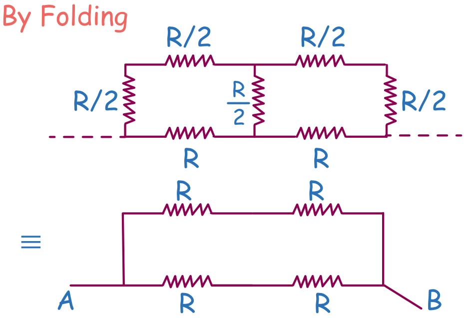
#SKC

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}

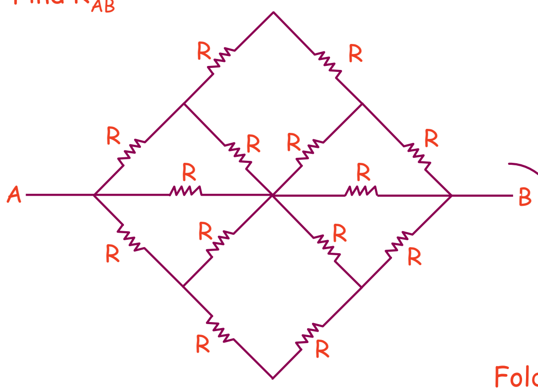


By Folding



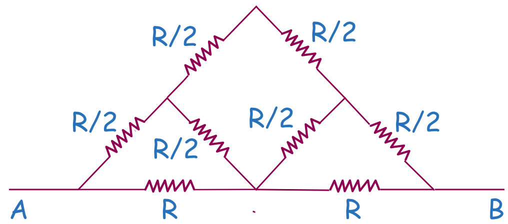
$R_{AB} = R$

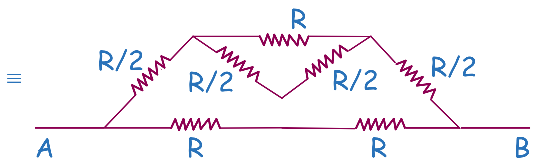
Q. Find R_{AB}



Folding

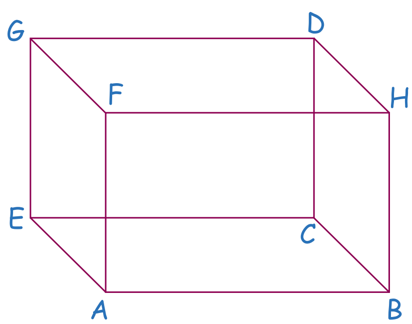
Sol.





Now you can solve.

✦ Cube each of length l, Resistance R(each)



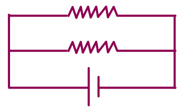
$\frac{7R}{12}$ · $\frac{3R}{4}$ · $\frac{5R}{6}$

R_{AB} R_{AC} R_{AD}

पास-पास थोडा-दूर दूर-दूर

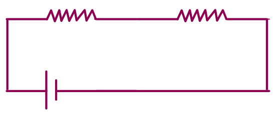
✦ If two appliances with rating (W_1, v)& (W_1, v) are connected to V.

1. In Parallel



Total power dissipated = $\omega_1 + \omega_2$

2. In series



Total power dissipated = ω_{net}

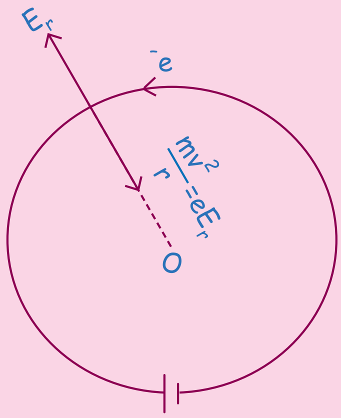
$$\frac{1}{\omega_{net}} = \frac{1}{\omega_1} + \frac{1}{\omega_2}$$

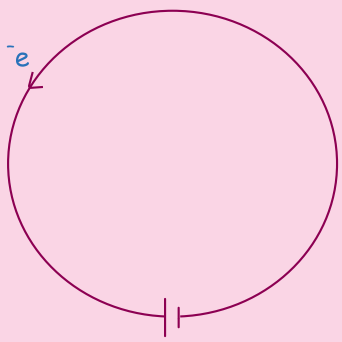
Q. A wire is in a circular shape connected to a battery as shown in figure. Find value of radial electric field.

$eE_r = \frac{mv_d^2}{r}$

↓ Very law value

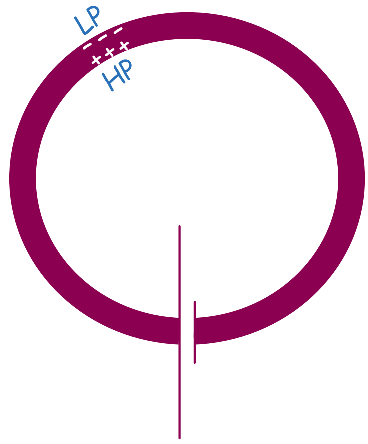
(अक्सर neglect कर देते है)



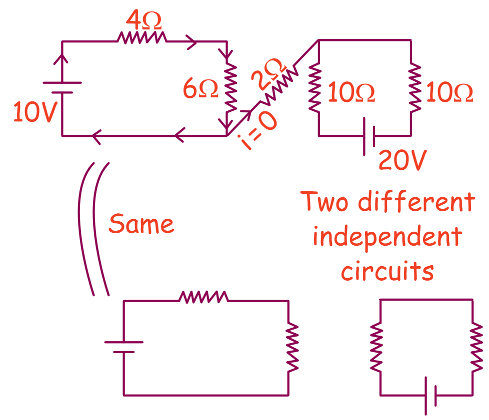


#SKC

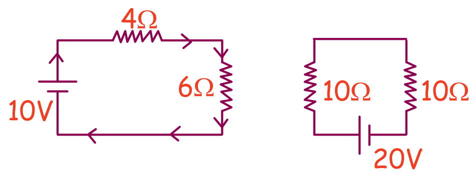
यह ध्यान से देखना Current किसकी वजह से आया? e^- की वजह या +ve charge के motion की वजह से



Q.



Now solve and get

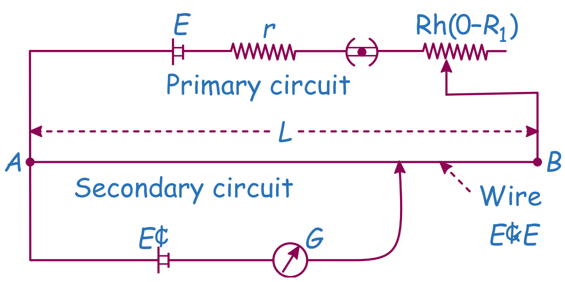


POTENTIOMETER (Not in Jee Mains 2025)

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.

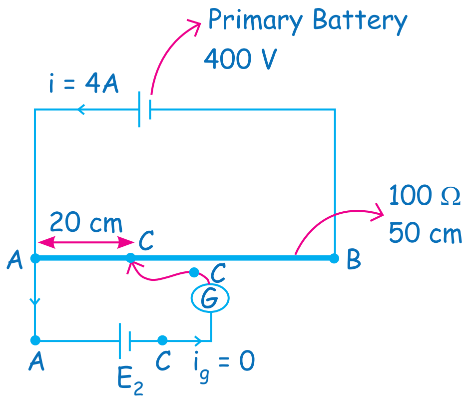
Circuit of Potentiometer



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

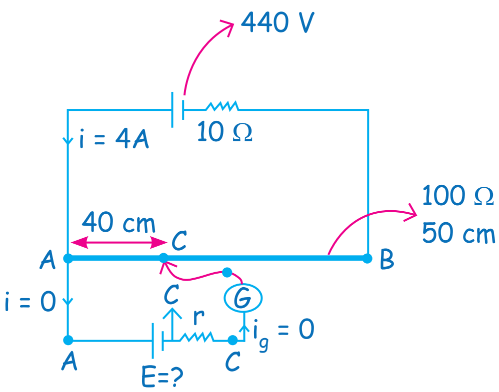
50 cm $\longrightarrow$ 400 V

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.

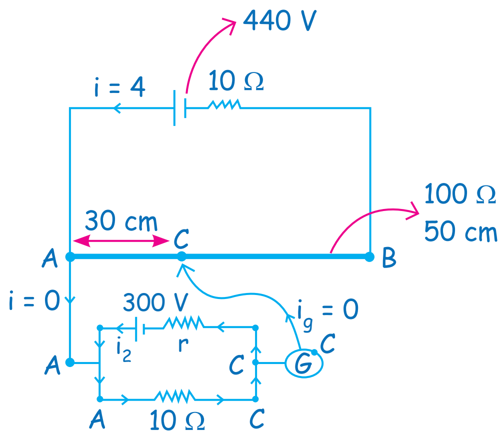


$V_{AB} = 400$ V

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.



$$i_2 = \frac{300}{10+r}$$

$V_{AB} = 400$

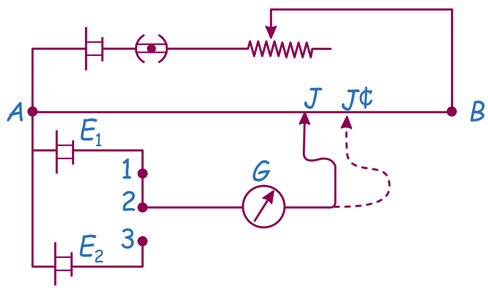
$V_{AC} = \dfrac{400}{50} \times 30 = 240$

$V_{AC} = \dfrac{300}{10+r} \times 10$

$240 = \dfrac{3000}{10+r}$

$r = 2.5\ \Omega$

☆ Comparison of emf of two cells



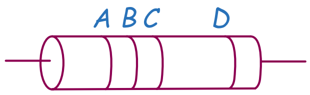
Plug only in (1– 2): Balance length $AJ = \ell_1$

Plug only in (2 – 3): Balance length $AJ' = \ell_2$

$E_1 = x\ell_1$ and $E_2 = x\ell_2$

$\Rightarrow \dfrac{E_1}{E_2} = \dfrac{\ell_1}{\ell_2}$

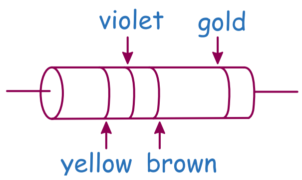
COLOUR CODE FOR CARBON RESISTORS (Removed from Mains 2025 and in Advance also)



	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

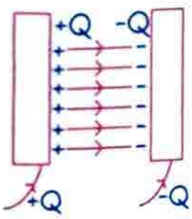
$47 \times 10^1\ \Omega \pm 5\% = (470\ \pm 5\%)\ \Omega$

3 Capacitors

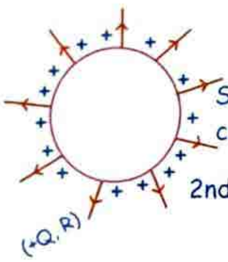
बहुत मजेदार chapter है इसे पढ़ने से पहले electrostatics में conductor (plates) or basic CE revise करके आओ।

CAPACITOR

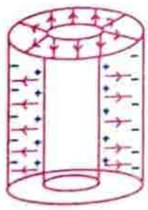
- It is a device to store the electrostatic energy in form of electric field b/w two boundaries.
- It consist of two conducting boundary, having equal & opposite charge. Generally they are kept very close to each other wrt size of the boundary.



Parlallel Plate Capacitor



Spherical capacitor



Cylinderical capacitor

CAPACITANCE OF CAPACITOR

It is observed that potential difference between boundary Where electric field is stored is directly proportional to modulus of bound charge.

$$\Delta V \propto Q$$

ΔV → Pot. energy b/w boundary where E.f stored.

Q → Charge on +ve boundary

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

$$\boxed{\begin{array}{c} Q = C\Delta V \\ Q = CV \end{array}}$$

V → Pot. diff.

C → Capacitance

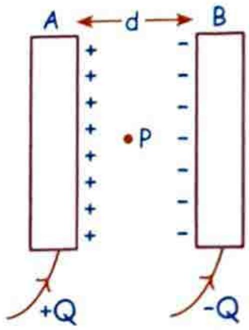
→ Unit = farad

→ Independent on ΔV & charge

(Const. depend on shape, size, medium, geometry)

CALCULATION OF CAPACITANCE

⇒ Parallel Plate Capacitor



$V_A - V_B = \Delta V = ?$

$$E_P = \frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$$

$$\Delta V = E \cdot d = \frac{\sigma \cdot d}{\varepsilon_0} = \frac{Qd}{A\varepsilon_0}$$

A → Area

$$\Delta V = \frac{Q}{A\varepsilon_0 / d} = \frac{Q}{C}$$

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

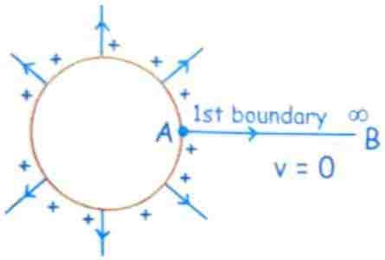
A → Area of plate

d → Gap b/w plate

#SKC

Agar mujhe 'C' nikalna hai to, ΔV nikalo, aur $\frac{Q}{C}$ ke barabar kar do.
[$\Delta V \rightarrow$ dono boundary ke beech]

Q. Find capacitance of a metal ball of radius R.



(Q, R) spherical capacitor

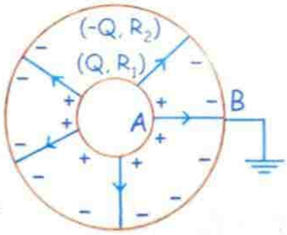
Sol. $\Delta V = V_A - V_B = V_A - V_\infty$

$$\Delta V = \frac{KQ}{R} - 0 = \frac{Q}{C}$$

$$C = \frac{R}{K} = 4\pi\varepsilon_0 R$$

Q. Find value of Capacitance of two concentric shells of radii R_1 & R_2. Find equivalent capacitance.

Sol. $V_A - V_B = \Delta V$



$$V_A = \frac{KQ}{R_1} + K\left(\frac{-Q}{R_2}\right)$$

$$V_B = 0$$

$$V_A - V_B = KQ\left[\frac{1}{R_1} - \frac{1}{R_2}\right] = \frac{Q}{C}$$

$$K\left[\frac{1}{R_1} - \frac{1}{R_2}\right] = \frac{1}{C}$$

$$K\frac{(R_2 - R_1)}{R_1 R_2} = \frac{1}{C} \Rightarrow C = \frac{R_1 R_2 4\pi\varepsilon_0}{R_2 - R_1}$$

If outer shell has infinite radius.

If $R_2 = \infty$

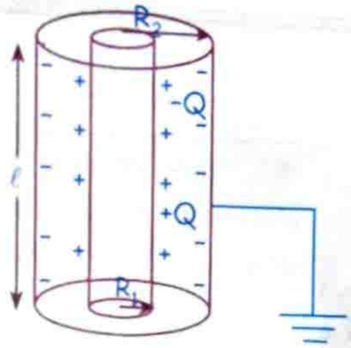
$$\frac{1}{C} = K\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{K}{R_1}$$

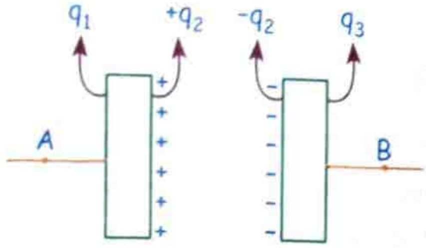
$$C = \frac{R_1}{K} = 4\pi\varepsilon_0 R_1$$

अबे यह तो ऊपर वाला ही सवाल हो गया

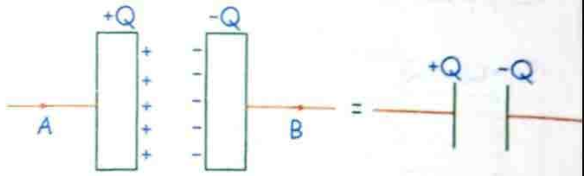
CYLINDRICAL CAPACITOR

$$C = \frac{2\pi\varepsilon_0 l}{\ln(R_2 / R_1)}$$



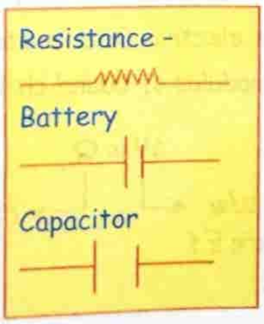


$$\Delta V = V_A - V_B = \frac{q_2}{C}$$



#SKC

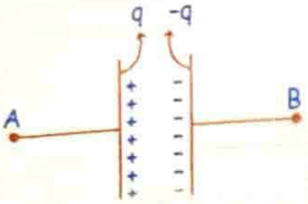
कुछ बच्चे सोचते है capacitor पर total charge तो 0 है उनका सोचना गलत नही है but from our defination charge on capacitor का मतलब है प्लेट के अंदर वाला +ve charge और जिधर बड़ा potential होगा capacitor पर उधर +ve charge दिखायेगे।



काम का डब्बा

पूरा capacitor इन पाँच formula पर टिक्का है इन्हें अच्छे से याद कर लो।

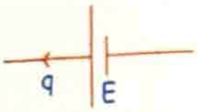
1.



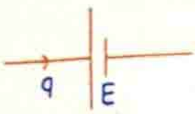
$V_{AB} = V = \frac{q}{C}$ $\quad \boxed{q = CV}$ यहाँ q अंदर वाला charge का magnitude है।

2. $U = \frac{1}{2}\frac{q^2}{C} = \frac{1}{2}CV^2$ अगर capacitor पर charge q है तो उसके पेट में $\frac{1}{2}\frac{q^2}{C}$ energy होगी।

3.



$(\text{Work Done})_{\text{by battery}} = +Eq$

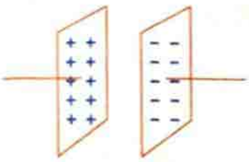


$(\text{WD})_{\text{by battery}} = -Eq$

4. E.F b/w cap. plate = V/d

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

(parallel plate capacitor)



Energy Stored in a Capacitor

During the charging of a capacitor, work has to be done to add charge to the capacitor against its potential. This work is stored in the capacitor as electric energy.

During the charging of capacitor its potential at any instant is given by $V = \frac{q}{C}$. Small amount of work done in adding a charge dq is given by $dW = \frac{q}{C}dq$.

The work done in giving a charge Q to the condenser is $W = \int_0^Q \frac{q}{C}dq$

$$\therefore \quad W = \left[\frac{q^2}{2C}\right]_0^Q \quad \therefore \quad W = \frac{Q^2}{2C}$$

$$\therefore \quad U = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$

Energy Density in Parallel Plate Capacitor

The volume of a parallel plate capacitor is Ad.

$\therefore$ Energy density $u = \frac{U}{Ad} = \frac{\frac{1}{2}CV^2}{Ad}$ where

$C = \varepsilon_0 \frac{A}{d}, V = Ed$

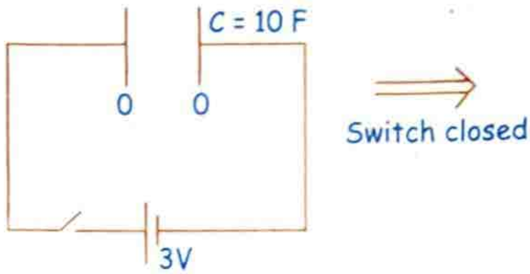
$$\therefore \quad u = \frac{1}{2}\left(\frac{\varepsilon_0 A}{d}\right)\left(\frac{E^2 d^2}{Ad}\right) = \frac{1}{2}\varepsilon_0 E^2$$

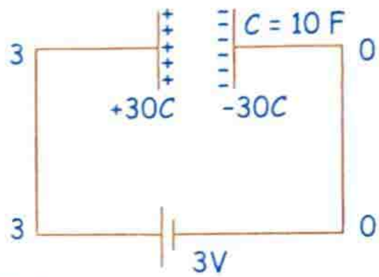
Force Between the Plates of Parallel Plate Capacitor

As the field due to charge of the first plate on the other plate is $E = \frac{\sigma}{2\varepsilon_0}$, the force exerted by one plate on the other

$$F = qE = (\sigma A)\left[\frac{\sigma}{2\varepsilon_0}\right] = \left(\frac{\sigma^2}{2\varepsilon_0}\right)A$$

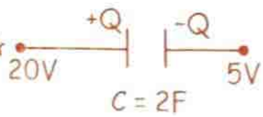
#



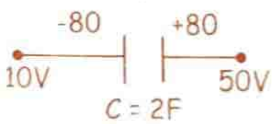


$Q = CV = 10 \times 3 = 30\ C$

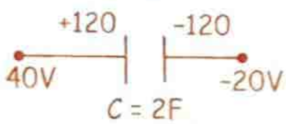
Q. Find charge on capacitor in following questions.

☆ 

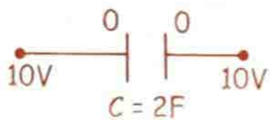
$Q = CV = 2 \times 15 = 30$

☆ 

$Q = CV = 2 \times 40 = 80$

☆ 

$Q = CV = 2 \times 60 = 120$

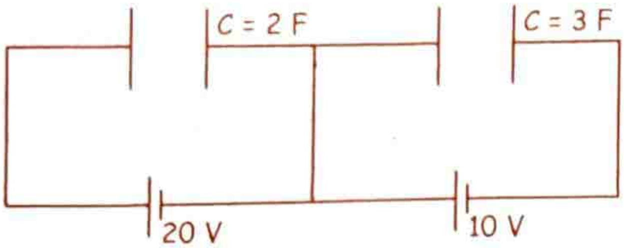
☆ 

$Q = CV = 2 \times 0 = 0$

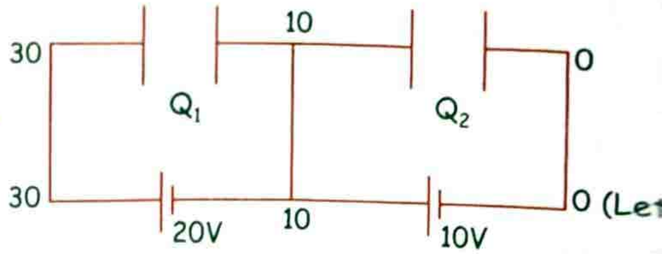
माना की no. of pages of book को कम से कम रखने का pressure है to minimise the MRP/- लेकिन circuit analysis के सवाल हम यहाँ भी करेंगे और यह बिलकुल CE जैसे है।

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 charge on each capacitor.



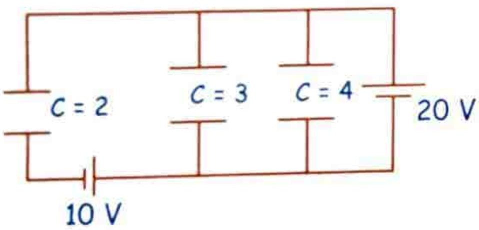
Sol.



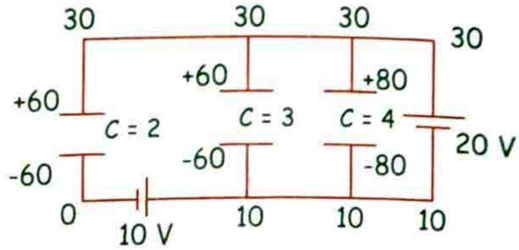
$Q_1 = 2 \times 20 = 40$

$Q_2 = 3 \times 10 = 30$

#



Sol.



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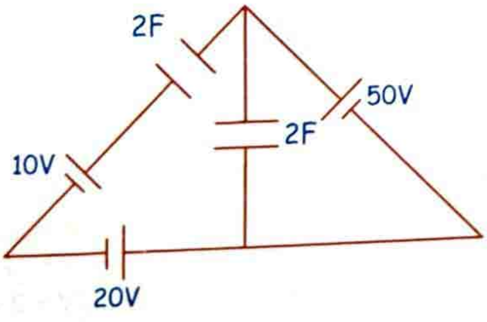
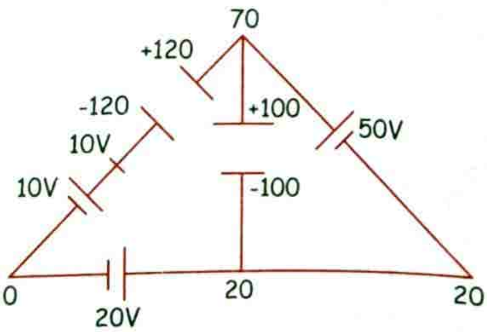
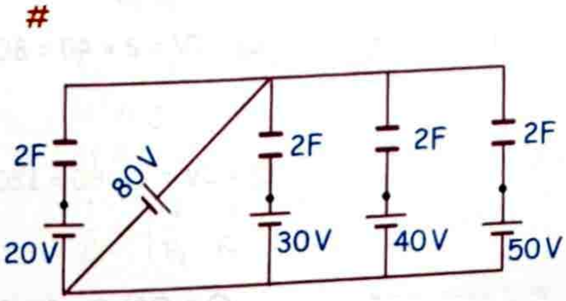


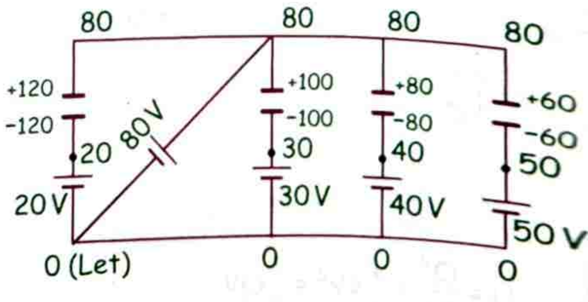
Sol.



#



Sol.



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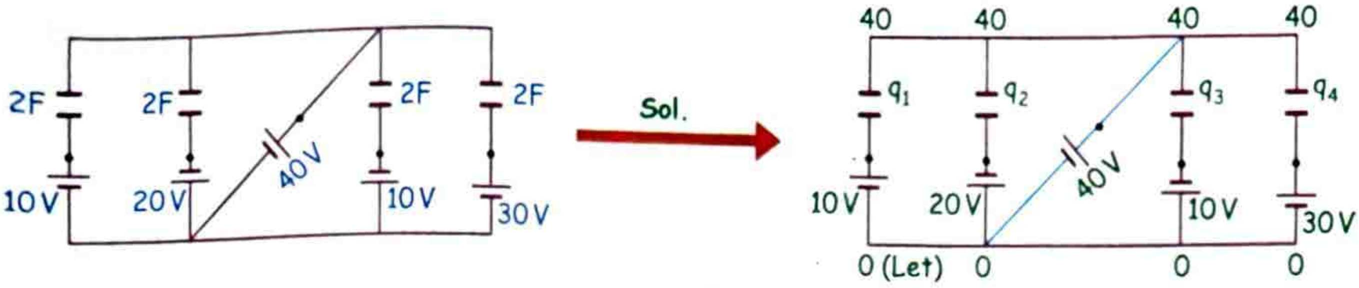
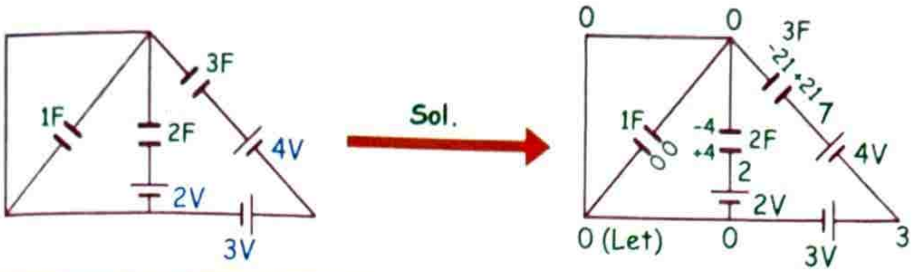


Solve and get $q_1 = 60, q_2 = 120, q_3 = 100, q_4 = 20$

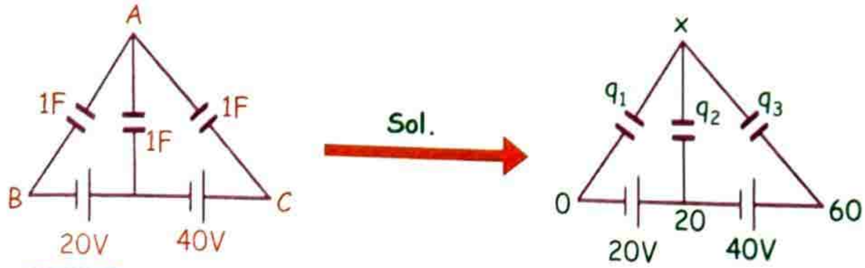
#



इन सवालों मे अकसर मेने देखा है बच्चो से कुछ गलतियाँ हो जाती है plz be careful in following cases:

- ध्यान से देखो की battery का बड़ा डंडा किधर है।
- Battery को capacitor या capacitor को battery मत समझ लेना।
- Zero potential जहाँ मन करे मान सकते हो हर case मे capacitor पर charge same आऐगा लेकिन question मे किसी specific जगह potential दे रखा है या earth कर रखा है। तो वही मान कर question को solve करना है।

Q. Find charge on each capacitor.



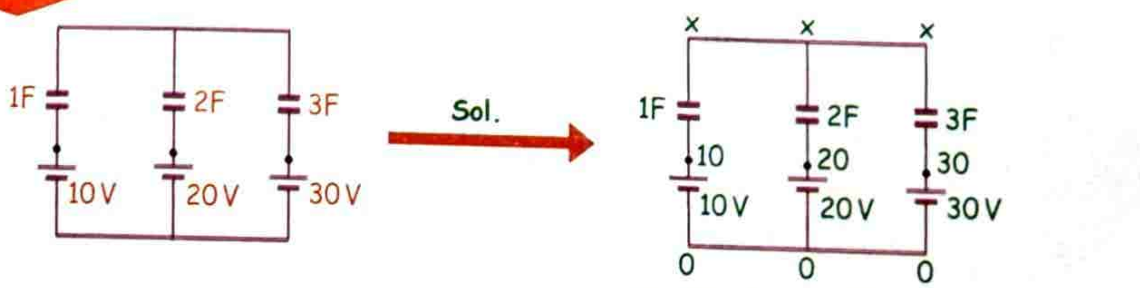
#SKC

अगर B का potential 0 मानू तो C का potential will be 60 volt लेकिन हम A का potential नहीं बता सकते, हम फँस गए...... जहाँ फँस जाओ वहाँ EX को याद करो...... और उसे high potential मान कर junction law लगादो

$q_1 + q_2 + q_3 = 0$

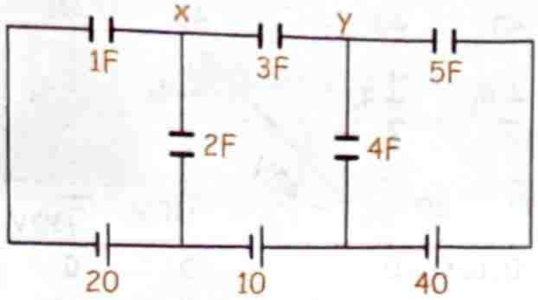
$(x - 0) \times 1 + (x - 20) \times 1 + (x - 60) \times 1 = 0$

$x = \boxed{\frac{80}{3}}$

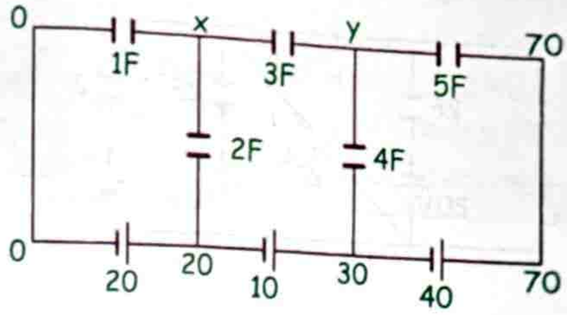


$(x - 10) \times 1 + (x - 20) \times 2 + (x - 30) \times 3 = 0$

Q. Find potential (x and y).



Sol.

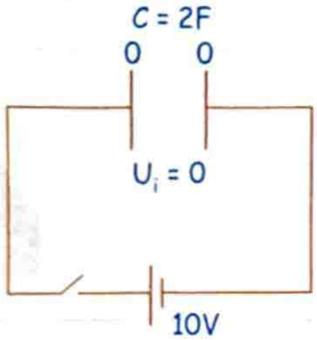


$(x - 0) \times 1 + (x - 20) \times 2 + (x - y) \times 3 = 0$

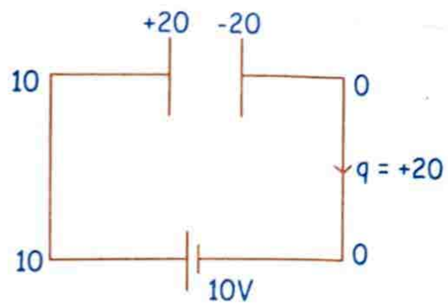
$(y - x) \times 3 + (y - 30) \times 4 + (y - 70) \times 5 = 0$

Now we can solve both equation and get x and y and charge on each capacitor.

#



Switch close



$(WD)_{\text{by battery}} = +qV = 20 \times 10 = +200$

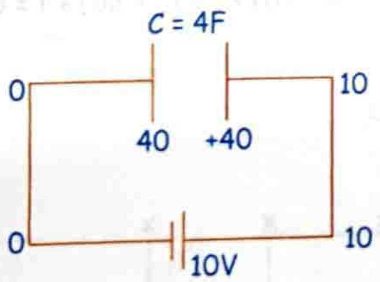
$U_f = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2} \times \frac{(20)^2}{2} = 100$

$U_i = 0$

Heat loss = 100 J

50% goes into heat

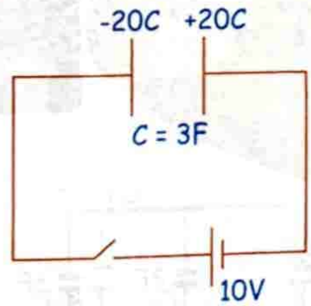
#



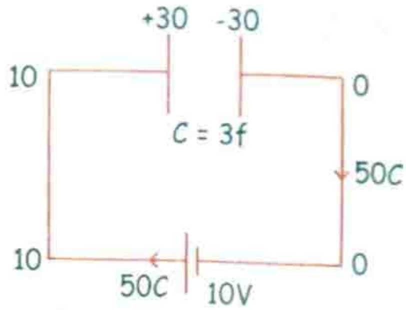
$U = \frac{1}{2}CV^2 = \frac{1}{2} \times 4 \times 10^2 = 200$

or $U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\frac{(40)^2}{4} = 200$

#



Switch closed



$$U_i = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2} \times \frac{(20)^2}{3} = \frac{200}{3} J$$

$$(WD)_{\text{by battery}} = 10 \times 50 = 500\ J$$

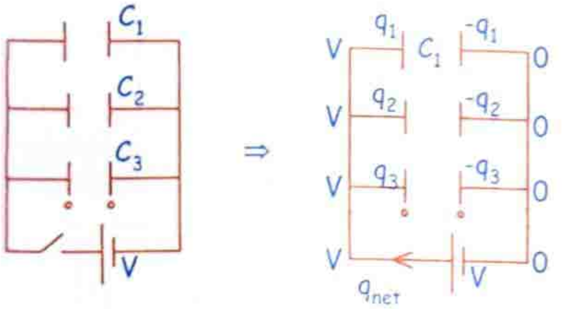
$$U_f = \frac{1}{2}CV^2 = \frac{1}{2} \times 3 \times 10^2 = 150\,J$$

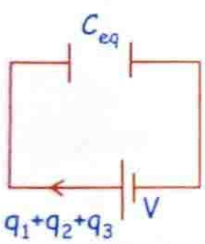
$$\text{Heatloss} = \frac{200}{3} + 500 - 150$$

#SKC

$U_i + (WD)_{\text{by battery}} - U_f$
$= \text{Heat loss}$
$= (WD)_{\text{By Battery}} - \Delta U.$

PARALLEL



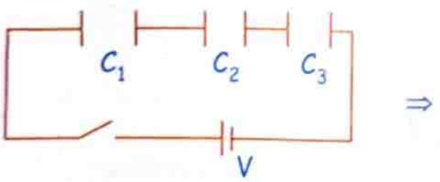


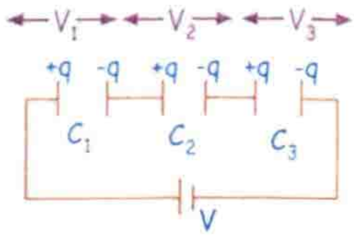
Resistor ke ulte Results hai

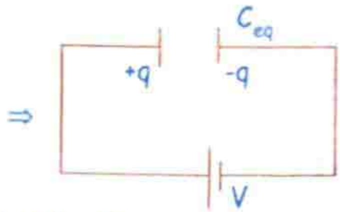
$$q_{net} = q_1 + q_2 + q_3$$

$$C_{eq.} V = C_1V + C_2V + C_3V \Rightarrow C_{eq.} = C_1 + C_2 + C_3$$

SERIES





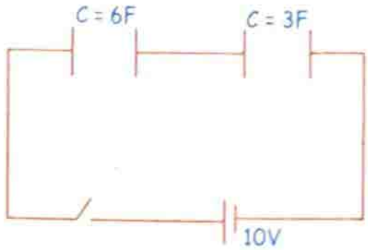


$$V = V_1 + V_2 + V_3$$

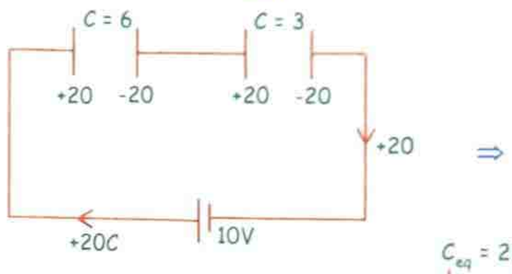
$$\frac{q}{C_{eq}} = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3}$$

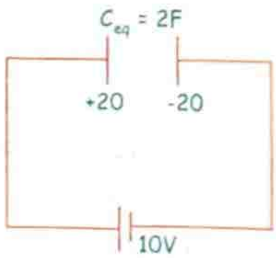
$$\frac{1}{C_{eq.}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

Q. Initially Capacitor was uncharged. Find charge on capacitor after switch closed.



Sol.



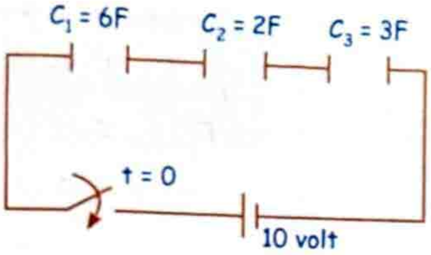


$$C_{eq.} = \frac{C_1C_2}{C_1 + C_2} = \frac{6 \times 3}{6+3} = 2$$

$$q = C_{eq}V = 2 \times 10 = 20$$

→ Series mai cap. mai charge same hota hai.
→ Parallel mai pot. diff. same hota hai.

Q.



Sol. $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

$\frac{1}{C_{eq}} = \frac{1}{6} + \frac{1}{2} + \frac{1}{3} = 1$

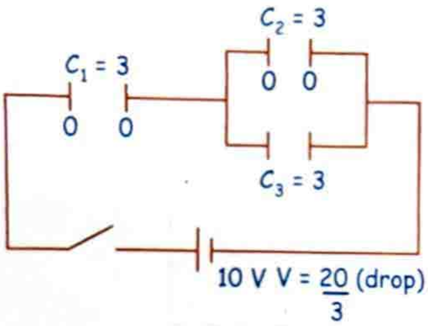
$Q = CV = 1 \times 10 = 10\ C$

Charge on each capacitor will be same = 10 C

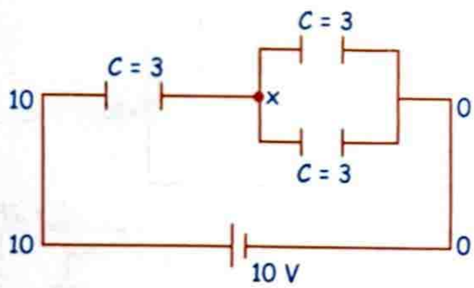
→ (WD) by battery = 10 × 10 = 100

Very simple But Imp.

Q.



M-I:-

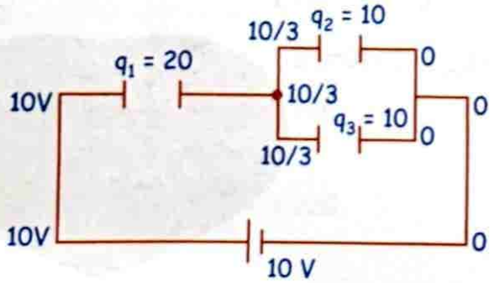


$(x - 10) \times 3 + (x - 0) \times 3 + (x - 0) \times 3 = 0$

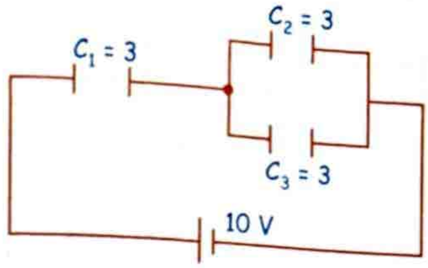
$9x = 30$

$x = 10/3$

Solve and get $Q_2 = 10, Q_3 = 10$



M-II:-



Ceq = 2

$Q_0 = Ceq.\ V = 2 \times 10 = 20$

$C_2, C_3 \rightarrow$ parallel

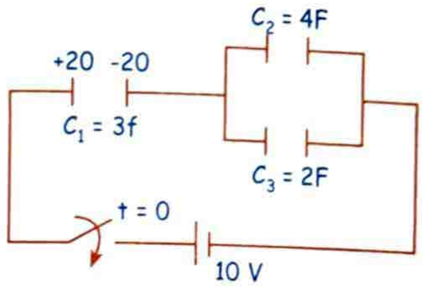
$q = CV \quad (V \rightarrow \text{same})$

$q \propto C$

20 C को C_2, C_3 मे बाटना है।

$C_2 = 3F$ } बराबर बराबर
$C_3 = 3F$ } बांटना है। $Q_2 = Q_3 = 10C$

Q. Find charge on each capacitor.



Ceq = 2 $\quad Q_2$ - charge on C_2

Q = 20 $\quad$ Q3 - charge on C_3

M-I: do your self

M-II:

Q_2, Q_3 ko 4 : 2 mein

Charge 20 → 4 : 2 मे मिलना chaiye

$Q_2 = \frac{40}{3}, Q_3 = \frac{20}{3}$

M - III: Let charge on C_2 is x and C_3 is 20 – x.

$V = \frac{q}{c} = \frac{x}{4} = \frac{20 - x}{2}$

(C_2 or C_3 के across potential same कर दिया)

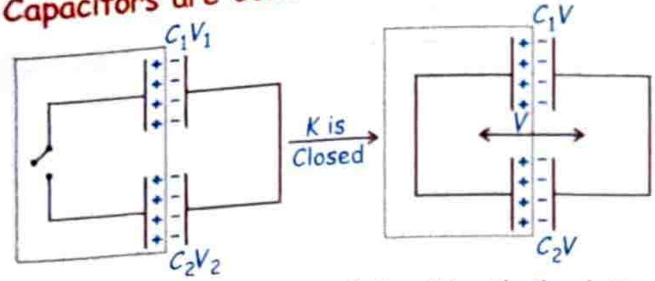
$2x = 80 - 4x$

$x = \frac{40}{3} = Q_2$

$Q_3 = 20 - \frac{40}{3} = \frac{20}{3}$

इस पर based सवाल एक करोड़ बार पूछे गए है। So must must remember the article.

Redistribution of Charge when two Charged Capacitors are Connected to each other



Case-I: Consider the part of circuit inside the dotted loop. This part is isolated from other part. Therefore, total charge of this part remains constant. Hence,
$C_1V_1 + C_2V_2 = C_1V + C_2V$

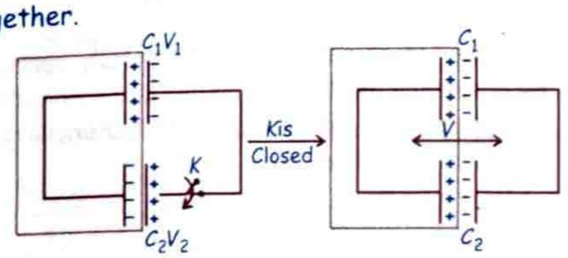
or $\quad V = \dfrac{C_1V_1 + C_2V_2}{C_1 + C_2}$

Loss of energy $\Delta U = U_i - U_f$

$$\Rightarrow \quad \Delta U = \frac{1}{2}C_1V_1^2 + \frac{1}{2}C_2V_2^2 - \frac{1}{2}(C_1 + C_2)V^2$$

$$= \frac{1}{2}\left(\frac{C_1C_2}{C_1 + C_2}\right)(V_1 - V_2)^2$$

Case II: The two capacitors are connected in a manner, so that their unlike terminals are connected together.



Again following the conservation of charge,

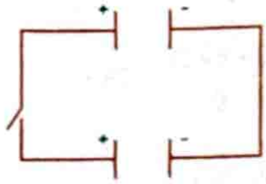
$$C_1V_1 - C_2V_2 = C_1V + C_2V \text{ or, } V = \frac{C_1V_1 - C_2V_2}{C_1 + C_2}$$

$$\text{Heat loss} = \Delta U = \frac{1}{2}\frac{C_1C_2}{C_1 + C_2}(V_1 + V_2)^2$$

Q. A Capacitor of Capacitance 6F is fully charged by a battery of emf 10 volt and another capacitor of capacitance 4 F is fully charge by 5 volt. Both capacitor disconnected from their batteries and connect each other such that

(a) → +Ve terminal of one capacitor is connected to +ve terminal of another capacitor find common potential & heat.

Sol.



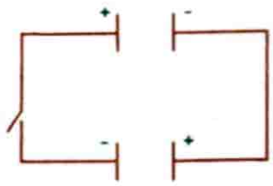
$$V_C = \frac{6 \times 10 + 4 \times 5}{6 + 4} = 8$$

$q_1 = 48, q_2 = 32$

$$\text{Heatloss} = \frac{1}{2} \times \frac{6 \times 4}{10} \times (10 - 5)^2$$

$$= \frac{1}{2} \times \frac{24}{10} \times 25 \Rightarrow 30$$

(b) →+ve terminal of one capacitor is connected to - ve terminal of another capacitor find common potential & Heat loss.



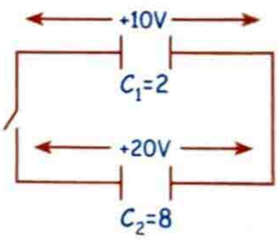
$$V_C = \frac{6 \times 10 - 4 \times 5}{6 + 4} = 4$$

$q_1 = 24, q_2 = 16$

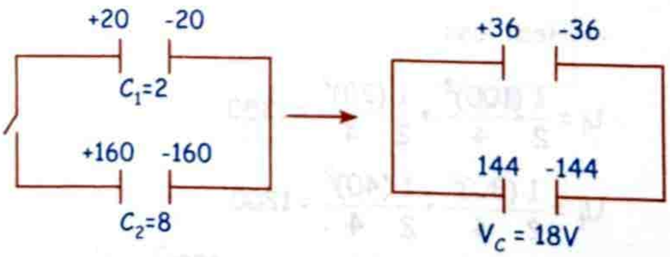
$$\text{Heatloss} = \frac{1}{2} \times \frac{6 \times 4}{10} \times (10 + 5)^2$$

$\Rightarrow 270$

Q.



M-1:-



$$V = \frac{x}{2} = \frac{180 - x}{8} \Rightarrow x = 36$$

M-2:-

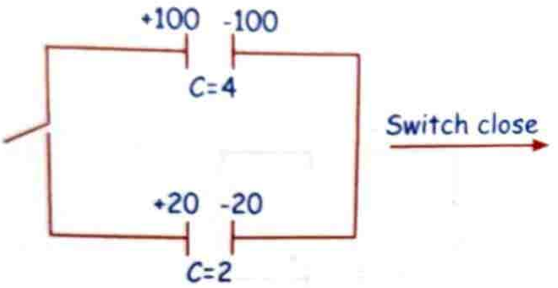
$$V_C = \frac{C_1V_1 + C_2V_2}{C_1 + C_2} = \frac{2\times10 + 8\times20}{2+8} = 18$$

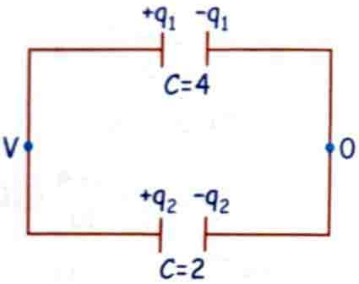
$$\text{Heatloss} = \frac{1}{2}\frac{C_1C_2}{C_1+C_2}(V_1 - V_2)^2$$

$$= \frac{1}{2}\times\frac{2\times8}{10}(10)^2$$

$$\Rightarrow 80$$

Q. Two capacitor of $C = 2$ and $C = 4$ having charge +20 Coulomb and 100 Coulomb respectively are connected to each other as shown in diagram. Find final charge on each capacitor and heat loss.





→ Find charge-

$q_1 + q_2 = 100 + 20$

$4V + 2V = 120$

$V = 20$

$q_1 = 4\times20 = 80$

$q_2 = 2\times20 = 40$

→ Heat loss

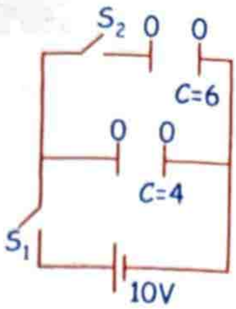
$$U_i = \frac{1}{2}\frac{(100)^2}{4} + \frac{1}{2}\frac{(20)^2}{4} = 1350$$

$$U_f = \frac{1}{2}\frac{(80)^2}{4} + \frac{1}{2}\frac{(40)^2}{4} = 1200$$

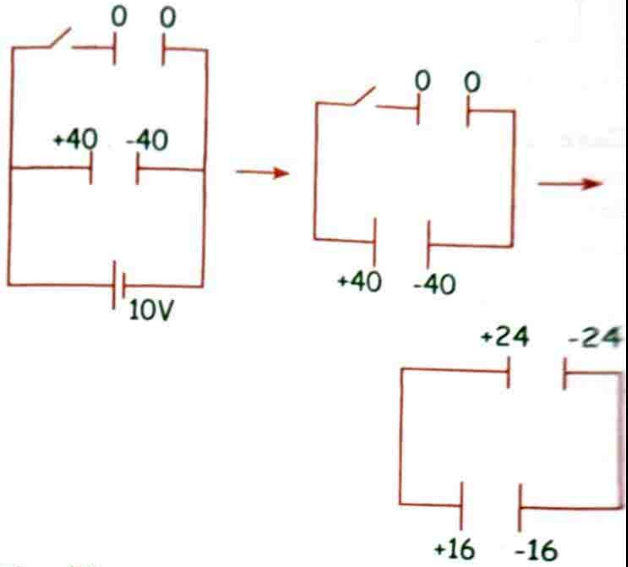
$$\text{Heat loss} = 1200 - 1350 = \frac{-150}{\text{Heat loss}}$$

Heat loss = 150

Q. Initially S_1 is closed & S_2 is open After sometime S_1 is open & S_2 is closed. Find final charge on each cap and heat loss after S_1, open.



Sol.



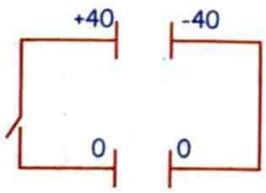
$V_C = 4V$

$$\text{Heat loss} = \frac{1}{2}\times\frac{6\times4}{10}(10-0)^2 \Rightarrow 120$$

Q. A capacitor of capacitance 4F is fully charged by a battery of 10 volt emf. It is disconnected from battery & connected to another uncharged identical capacitor. Find

→ V_C & charge

→ Heat loss



$$V_C = \frac{4\times10 + 0}{4+4} = 5$$

$q_1 = 4\times5 = 20$

$q_2 = 4\times5 = 20$

$$\text{Heatloss} = \frac{1}{2}\times\frac{4\times4}{8}(10)^2$$

$= 100$

Q. A parallel plate capacitor of capacitance C has been charged, so that the potential difference between its plates is V. Now, the plates of this capacitor are connected to another uncharged capacitor of capacitance $2C$. Find the common potential acquired by the system and loss of energy.

Sol. Here, $C_1 = C, C_2 = 2C, V_1 = V$ and $V_2 = 0$

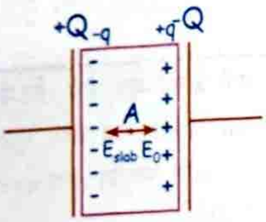
$\Rightarrow$ Common potential $= V = \dfrac{C_1V_1 + C_2V_2}{C_1 + C_2}$

$= \dfrac{CV + 0}{3C} = \dfrac{V}{3}$.

And $\Delta U = \dfrac{1}{2}\dfrac{C \times 2C}{3C} \times (V - 0)^2 = \dfrac{1}{3}CV^2$

MEDIUM/SLAB BETWEEN CAPACITOR

Q. Induced charge on dielectric



$(\vec{E}_{net})_{at\,A} = \vec{E_0} + \vec{E}_{due\ to\ slab}$

Experimentally $\rightarrow (\vec{E}_{net})_{at\,A} = \dfrac{E_0}{K}$

$\dfrac{E_0}{K} = E_0 - E_{slab}$

$E_{slab} = E_0 - \dfrac{E_0}{k} = E_0(1 - 1/k)$

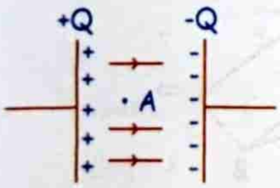
$\dfrac{\sigma_{slab}}{\varepsilon_0} = \dfrac{\sigma}{\varepsilon_0}\left(1 - \dfrac{1}{k}\right)$

$\sigma_{slab} = \sigma(1 - 1/K)$

$\dfrac{\sigma_{slab}}{A} = \dfrac{Q}{A}(1 - 1/K)$

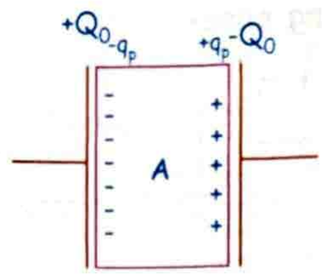
$\boxed{q_{slab} = q_p = Q\left(1 - \dfrac{1}{k}\right)}$

जब slab नही था-



$E_0 = E_A = \dfrac{\sigma}{2A\epsilon_0} + \dfrac{\sigma}{2\epsilon_0} \Rightarrow \dfrac{Q}{A\epsilon_0}$

\#



$q_p = Q_0(1 - 1/K)$

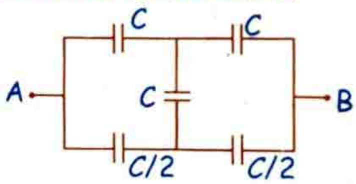
$E_A = \dfrac{E_0}{K} = \dfrac{Q}{A\varepsilon_0 K}$

देख भाई जैसे हम CE में equivalent resistance निकालते थे वैसे ही यहाँ पर equivalent C निकालेंगे। तरीका same है बस यहाँ series parallel में result उलटे है और पहले की तरह यहाँ भी same wheat stone bridge infinite ladder type सवाल मिलेंगे।

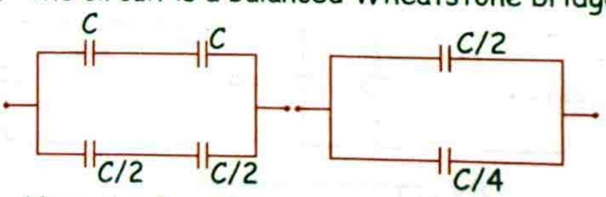
$C_{equiv.}$ वाले सवाल

- If capacitor C_1, C_2, C_3......... are in parallel then
  $C_{equiv.} = C_1 + C_2 + C_3$............
- If capacitor C_1, C_2, C_3......... are in series then
  $\dfrac{1}{C_{eq.}} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}$
- If two capacitor C_1 and C_2 are in series then
  $C_{eq} = \dfrac{C_1C_2}{C_1 + C_2}$

Q. Find the equivalent capacitance of the combination between A and B.



Sol. The circuit is a balanced Wheatstone bridge.



Here $C_1 = C_2 = C$

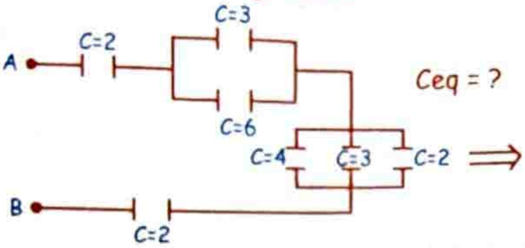
$C_3 = C_4 = \dfrac{C}{2}$

$\therefore \dfrac{C_1}{C_2} = \dfrac{C_3}{C_4}$

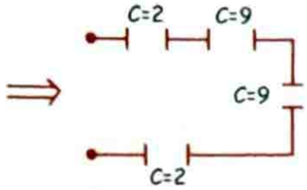
Hence $C_{eq} = \dfrac{C}{2} + \dfrac{C}{4} = \dfrac{3C}{4}$

Find Ceq. in following case-

Q.



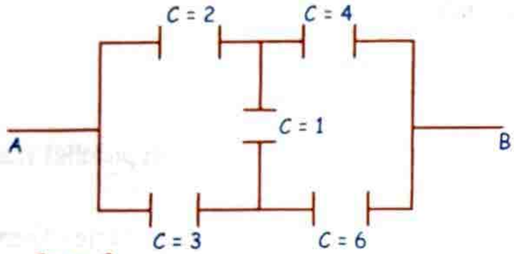
Sol. $\Rightarrow$



$$\frac{1}{Ceq.} = \frac{1}{2} + \frac{1}{9} + \frac{1}{9} + \frac{1}{2} \Rightarrow \frac{11}{9}$$

$$C_{eq} = \frac{9}{11}$$

Q.



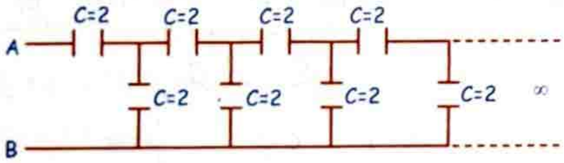
Ceq = ?

Sol. Balanced wheatstone Bridge

$$C_{AB} = \frac{2 \times 4}{2+4} + \frac{3 \times 6}{3+6} = \frac{10}{3}$$

$\Rightarrow$ Infinite ∞-Ladder

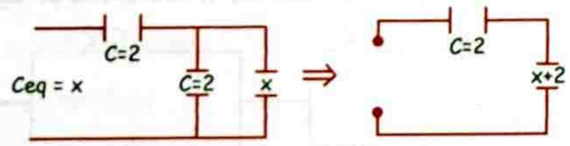
Q.



$\Downarrow$

Ceq = ?

Sol.



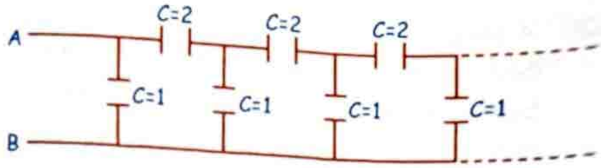
$$Ceq. = \frac{2(x+2)}{2+x+2} = x$$

$$2x + 4 = x^2 + 4x$$

$$x^2 + 2x - 4 = 0$$

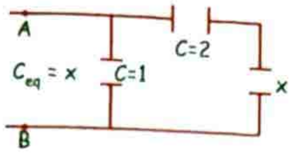
$$x = \frac{-2 \pm \sqrt{4+16}}{2} \Rightarrow -1 + \sqrt{5}$$

Q.



Ceq = ?

Sol.



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

$$x^2 + 2x - x - 2 = 2x$$

$$x^2 - 2 - x = 0$$

$$(x-2)(x+1) = 0$$

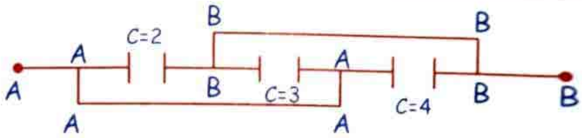
$$\therefore x = 2$$

OR

$$C_{AB} = x = \frac{2x}{x+2} + 1 \Rightarrow x = 2$$

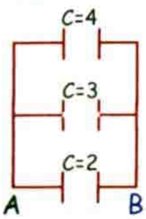
जहाँ फसो वहाँ x को याद करो और उसके खराब, डरावनी, बेकार, गधे जैसी सूरत को सुधार लो........ अबे मतलब नया **circuit** diagram बनाओ।

Q.



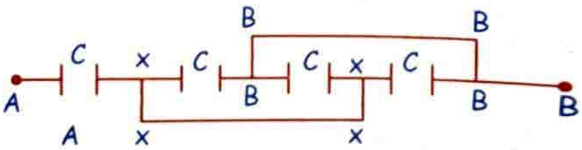
C_{AB} = ?

Sol.



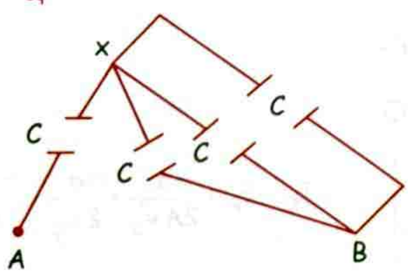
$$Ceq = C_{AB} = 4 + 3 + 2 = 9$$

Q.

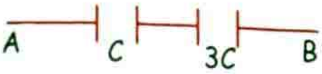


C_{eq} = ?

Sol.

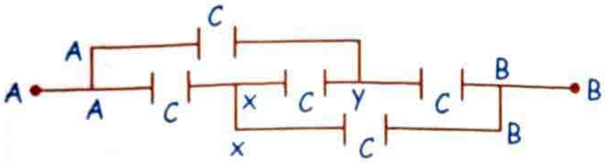


$\Rightarrow$

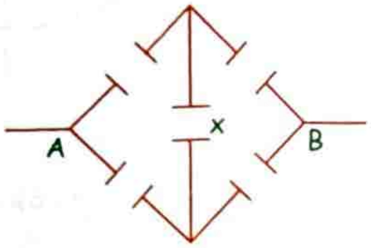


$$C_{AB} = \frac{C \times 3C}{C + 3C} = \frac{3C}{4}$$

Q.



Sol.

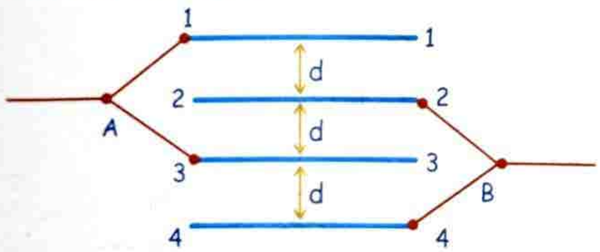


(balance wheatstone bridge)

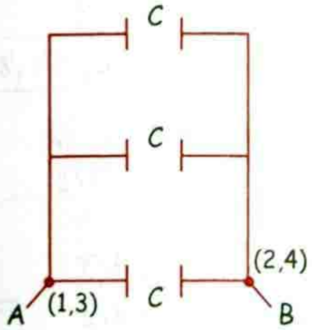
$$C_{AB} = \frac{C}{2} + \frac{C}{2} \Rightarrow C$$

PLATE वाले सवाल

Q. Find Ceq. b/w A & B.



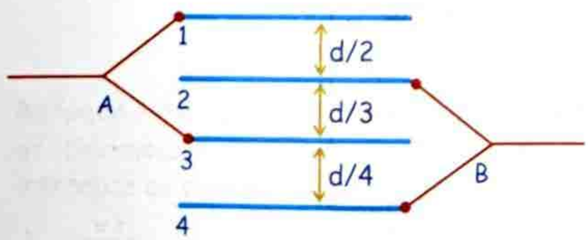
Sol. $\Rightarrow$



$$Ceq = C + C + C = 3C$$

$$= 3\frac{A\epsilon_0}{d}$$

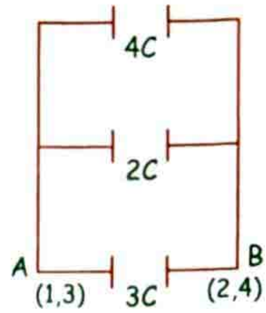
Q.



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

Ceq = ?

Sol. $\Rightarrow$



$$C = \frac{A\epsilon_0}{d}$$

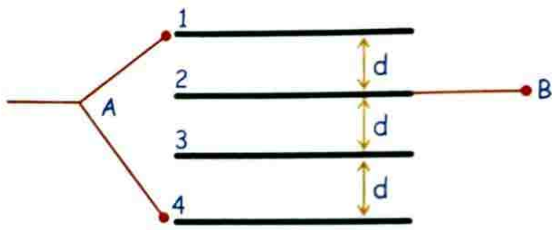
Capacitance between plate 1 & 2 = $\frac{A\epsilon_0}{d/2} = 2C$

Capacitance between plate 2 & 3 = $\frac{A\epsilon_0}{d/3} = 3C$

Capacitance between plate 3 & 4 = $\frac{A\epsilon_0}{d/4} = 4C$

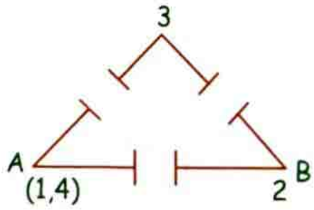
$$Ceq = 4C + 2C + 3C = 9C = \frac{9A\epsilon_0}{d}$$

Q.



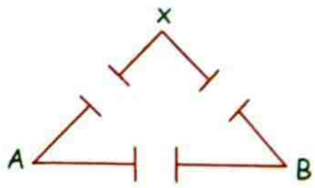
Ceq = ?

Sol. M-1

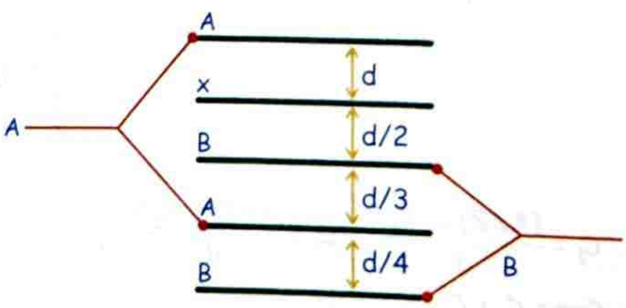


$$C_{eq} = \frac{C}{2} + C = \frac{3C}{2}$$

M-2



#



$\Rightarrow$

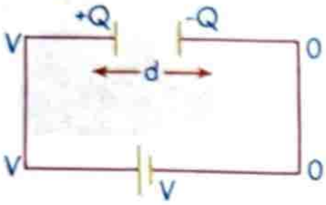
$$C = \frac{A\epsilon_0}{d - t\left(1 - \frac{1}{k}\right)}$$

$$C = \frac{A\epsilon_0}{d - \left(\frac{d}{3} - vt\right)(1 - 1/k)} = \frac{6A\epsilon_0}{5d + 3vt}$$

BATTERY CONNECTED BATTERY DISCONNECTED

When Battery is Connected

If gap between the capacitor plate is reduce to half analyse the situation.



Battery connected
V → same

$d \to d/2$

$C \to 2C$

$V \to$ same

$Q \to 2Q$

$U \to 2U$

Electric field $E_0 \to 2E_0$

Force on plate one → 4 times

Use this

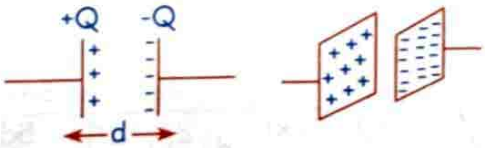
$C = \frac{A\epsilon_0}{d}$, $Q = CV$

$U = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$

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

When Battery is disconnected

If gap between the capacitor plate is reduce to half analyse the situation.



$Q \to$ same

$d \to d/2$

$C \to 2C$

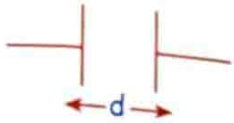
$V \to V/2$

$U \to U/2$

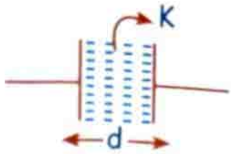
$E \to$ same

force on → same
one plate

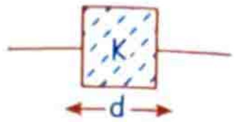
Battery disconnected
Q → same



$C = \frac{A\epsilon_0}{d}$

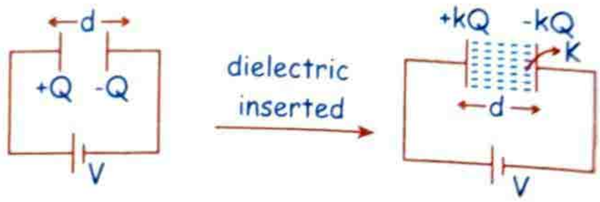


$C_{uk} = \frac{A\epsilon_0 K}{d} = CK$



$C_{uk} = \frac{A\epsilon_0 K}{d} = CK$

When Battery is Connected



$C \to KC$

$V \to$ same

$Q \to KQ$

$U \to KU$

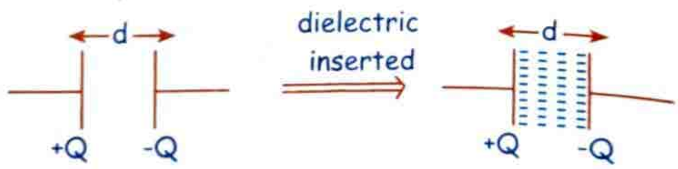
$E \to$ same

Net force → K^2 (times)
on one plate

Charge Flow through battery = KQ - Q

$(WD)_{battery} = V(KQ - Q)$

When Battery is Disconnected



$C \to KC$

$Q \to$ same

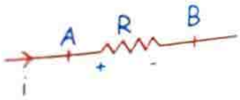
$V \to V/k$ [$Q = CV$]

$U \to U/K$ [$U = 1/2\ Q^2C$]

$E \to E/K$ [$E = Vd$]

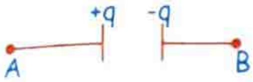
Net force on one plate → same force on one plate by other one

RC CIRCUIT

- 

$V_A - iR = V_B$

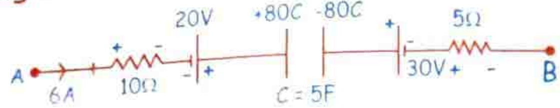
$V_A - V_B = iR$



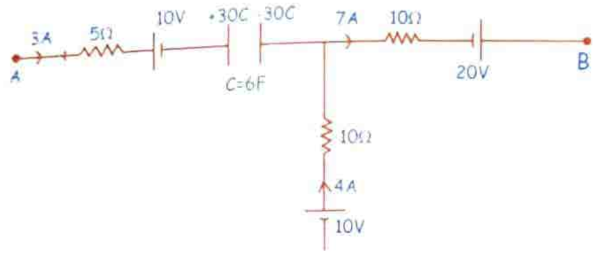
$V_A - q/C = V_B$

$V_A - V_B = q/C$

- **Right the KVL in following circuit.**

\# 

$$V_A - 6\times10 + 20 - \frac{80}{5} - 30 - 6\times5 = V_B$$

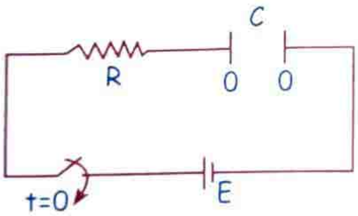
\# 

$$V_A - 15 - 10 - \frac{30}{6} - 70 + 20 = V_B$$

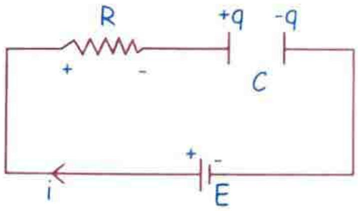
$$V_A - V_B = 80$$

RC CIRCUIT

At t = 0, a uncharge capacitor is closed as shown in figure. Analyse the situation



$\Longrightarrow$

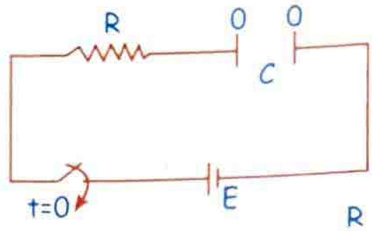


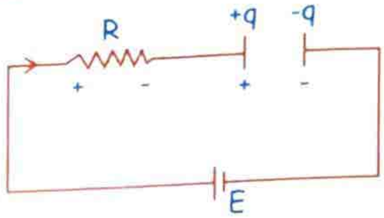
[at any time 't']

$$-iR - \frac{q}{c} + E = 0 \Longrightarrow -\frac{dq}{dt}R - \frac{q}{C} + E = 0$$

$$\frac{dq}{dt}R = E - \frac{q}{C} \Longrightarrow \int_0^q \frac{dq}{EC - q} = \int_0^t \frac{dt}{RC}$$

$$\boxed{q = EC(1 - e^{-t/RC})}$$

\# 



$q = EC(1 - e^{-t/RC})$

$q = Q_0(1 - e^{-t/RC})$

$EC = Q_{max} = Q_0$

→ t = ∞ par cap. par aayega

at t = 0, q = 0 and at t = ∞, $q = Q_0 = Q_{max} = EC$

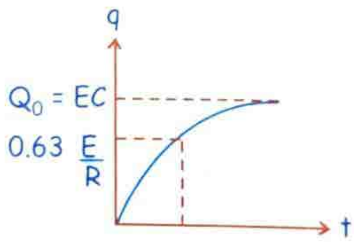
काम का डब्बा

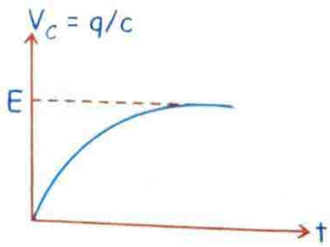
- $q = EC\,(1 - e^{-t/RC})$
- $V_C = \frac{q}{c} = E(1 - e^{-t/RC})$
- $i = \frac{dq}{dt} = \frac{E}{R}e^{-t/RC}$
- $V_R = iR = Ee^{-t/RC}$
- $(P_{loss})_{Resistance} = i^2R = \frac{E^2}{R}e^{-2t/RC}$
- Rate of Energy stored in capacitor $= \frac{dU}{dt}$

  $= \frac{1}{2C}\cdot 2q\cdot\frac{dq}{dt} = \frac{q}{c}i$
- (P_{loss})Resist. $= i^2R$
- $P_{Battery} = Ei$

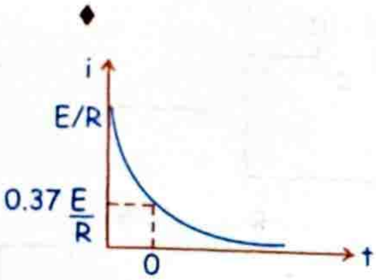
> यह बहुत ही ज्यादा important result है rough copy पर पाँच बार लिख लिख कर सभी को derive करें और graph बनाए और जब हो जाए तो मुझे insta पर tag करें (If you have insta Saleem.nitt) यही same result EMI में आगे use होंगे।

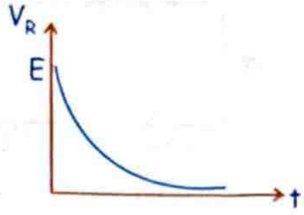
♦



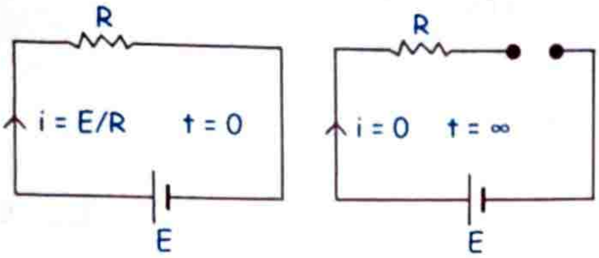


◆



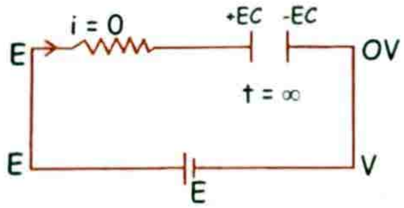


☆ At t = 0, $i = \frac{E}{R}$ and at t = ∞, current become zero.



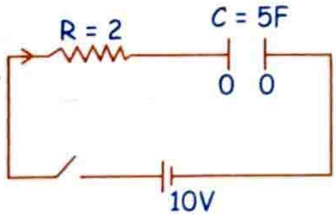
t = 0 par capacitor behaving like connecting taar (closed wire)

t = ∞ → breaking wire.



Q. Initially capacitor is uncharge, at t = 0. Switch is closed find

Sol.



(a) Time constant $\tau = RC = 10$

(b) Charge on capacitor at t = 10 sec.

$q = EC(1 - e^{-t/RC}) = 50(1 - e^{-t/10})$

(c) $Q_{max} = EC = 50$ [t = ∞ par]

(d) find current in wire at t = 10 sec.

$$i = \frac{E}{R}e^{-t/RC} = \frac{10}{2}e^{-10/10} = \frac{5}{e}$$

(e) $i_{max} = \frac{E}{R} = \frac{10}{2} = 5$

(f) pot. diff across capacitor at t = 10 sec.

$$V_C = \frac{q}{C} = \frac{EC(1-e^{-t/RC})}{C} = E(1-e^{-t/RC})$$

$V_C = 10(1 - e^{-10/10})$

(g) pot diff across resistor at t = 10 sec

$V = Ee^{-t/RC} = 10e^{-10/10} = 10/e$

(h) Energy stored in capacitor at t = 10 sec.

$$U = \frac{1}{2}\frac{q^2}{c}$$

(i) Power loss across resistance = $P = i^2R$

(j) Rate of energy stored in capacitor at t = 10 second $= \frac{du}{dt} = \frac{q}{c} \times i$ put the value get the ans.

(k) Find charge flow from $t = 0 \to t = \tau$.

$$\Delta q = \int_0^{\tau} i\,dt = \int_0^{\tau} \frac{E}{R}e^{-t/\tau}dt$$

(l) Find heat loss from $t = 0 \to t = \tau$ sec.

$$H = \int_0^{\tau} i^2R\,dt$$

(m) Find time when current become half of maximum value.

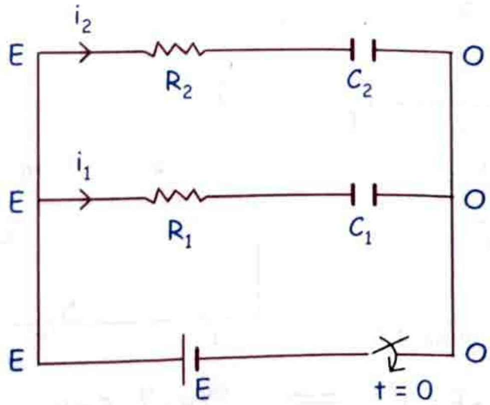
$i = i_0e^{-t/\tau}$

$\frac{i_0}{2} = i_0e^{-t/\tau}$

$\Rightarrow t = \tau \ln 2.$

अबे और कितना part लोगे अब hcv के question try कर सकते हो

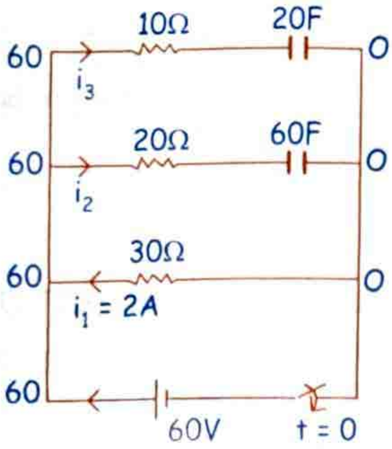
Q. Find i_1 and i_2 in the circuit.



$i_1 = \frac{E}{R_1}e^{-t/\tau_1}$ $[\tau_1 = R_1C$

$i_2 = \frac{E}{R_2}e^{-t/\tau_2}$ $[\tau_2 = R_2C$

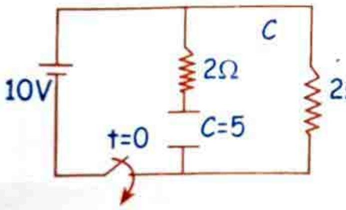
Q. Find current through the battery.



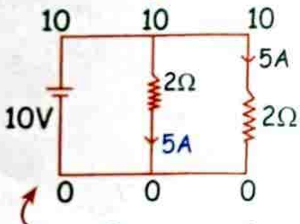
$$i = 2 + \frac{60}{20}e^{-t/1200} + \frac{60}{10}e^{-t/200}$$

हमने देखा t = 0 पर capacitor closing wire और t = ∞ पर टूटा wire की तरह behave करता है Let's do some question on it.

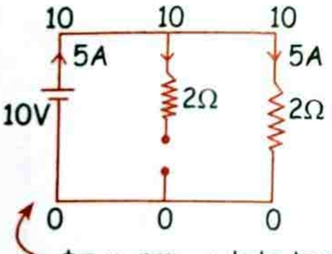
Q. Find current in each resistance at t = 0 & t = ∞.



Sol.

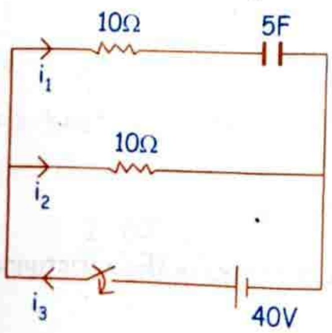


t = 0, cap → wire

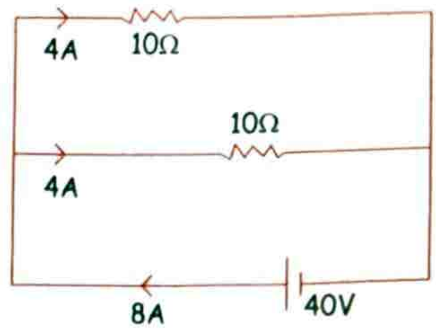


t = ∞, cap. → tuta tar

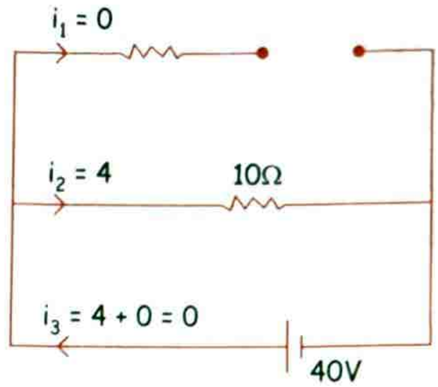
Q. Find i_1, i_2, i_3 just after switch closed ($t = 0^+$) and after very long time (steady state, t = ∞)



Sol. At t = 0



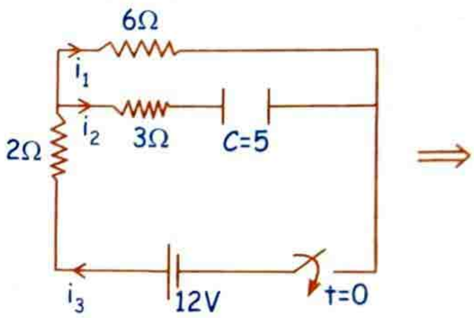
At t = ∞



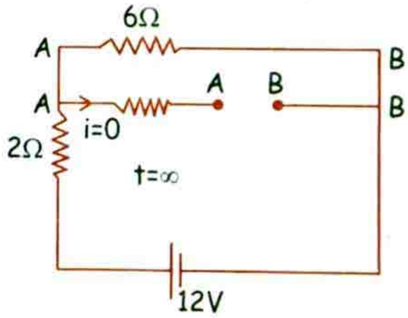
Q. Switch is closed at t = 0, calculate

a. charge on capacitor at ∞

b. value i_1, i_2 & i_3 at t = 0 & t = ∞



Sol.



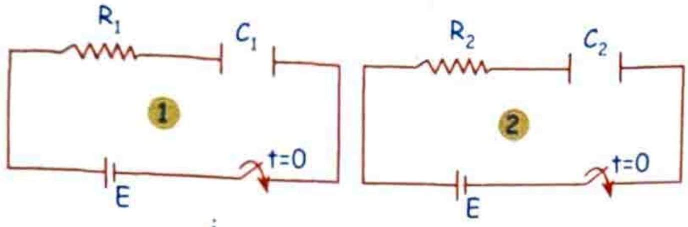
Charge on cap. at t = ∞.

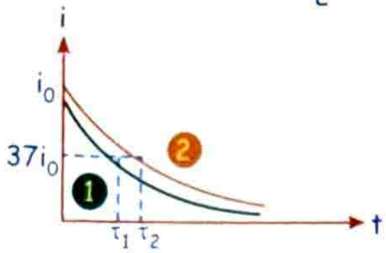
$$V_{AB} = \frac{12}{8} \times 6 = 9$$

$q = 5 \times 9 = 45$

	i_1	i_2	$i_3 = i_{net}$
t = 0	1	2	3
t = ∞	12/8	0	12/8

Q. Suppose we have two RC circuit (R_1, C_1, E) and (R_2, C_2, E) charge on the capacitor vs time graph is given for both the circuit analyse the situation.





Sol. $i_{max} \rightarrow \text{same} = \frac{E}{R}$

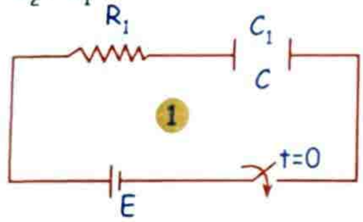
$\frac{E_1}{R_1} = \frac{E_2}{R_2}$ $[E_1 = E_2]$ $\therefore R_1 = R_2$

$\tau_2 > \tau_1$

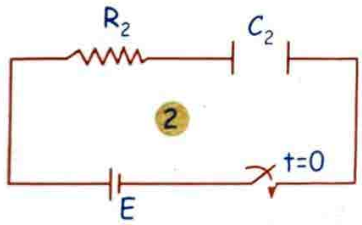
$R_2C_2 > R_1C_1$

$C_2 > C_1$

Q.

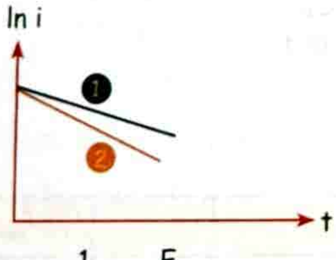


Given E/R same for both plot and $C_1 > C_2$ draw ln i vs t graph



Sol. $i = \frac{E}{R} e^{-t/\tau}$

$\ln i = \ln \frac{E}{R} - \frac{t}{\tau}$



$\ln i = -\frac{1}{\tau} t + \ln \frac{E}{R}$

$y = -mx + C$

$t = 0$, $\ln i \rightarrow$ same

$\frac{E}{R} \rightarrow$ same $(R_1 = R_2)$ $[E_1 = E_2 \text{ (same)}]$

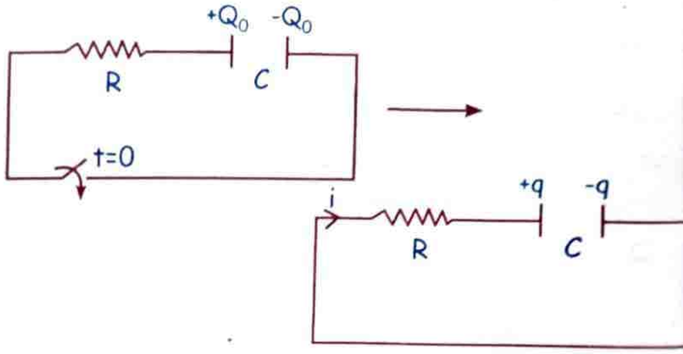
$\tau_2 < \tau_1$ $|\text{slope}|_2 > |\text{slope}|_1$

$C_2 < C_1$

$\left(\frac{1}{\tau_2}\right) > \left(\frac{1}{\tau_1}\right)$

DISCHARGING OF CAPACITOR

Suppose initially capacitor has charge Q_0 and connected to resistance are as shown in figure At t = 0 switch is closed. Find q = f(t) on capacitor



$-iR - \frac{q}{c} = 0$

$iR = -\frac{q}{c}$ $\left[i = \frac{dq}{dt}\right]$

$\frac{dq}{dt} = -\frac{q}{Rc}$

$\int_{Q_0}^{q} \frac{dq}{dt} = \int_0^t -\frac{dt}{Rc}$

$\ln \frac{q}{Q_0} = -\frac{t}{RC}$

$\boxed{q = Q_0 e^{-t/RC}}$

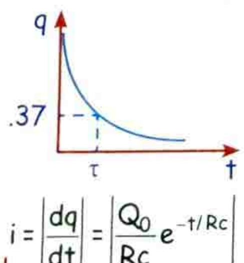
t = τ par charge

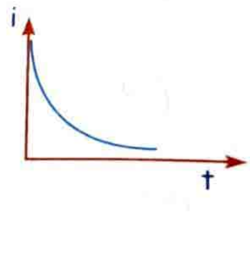
$q = Q_0 e^{-t/\tau}$

$q = Q_0 e^{-1} = Q_0/e$

$q = .37Q_0$

$q = Q_0 e^{-t/RC} = Q_0 e^{-t/\tau}$





$i = \left|\frac{dq}{dt}\right| = \left|\frac{Q_0}{Rc} e^{-t/Rc}\right|$

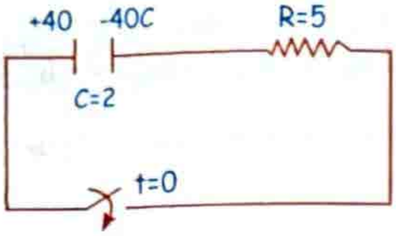
Magnitude

$i = i_0 e^{-t/RC}$

$t\uparrow, \Rightarrow q\downarrow, U\downarrow$

Total heat across in the resistance $= \frac{Q_0^2}{2C}$

Q. Capacitor is initially charged 40 C, and at t = 0, switch closed in following figure.



Sol. $\rightarrow \tau = RC = 5 \times 2 = 10$

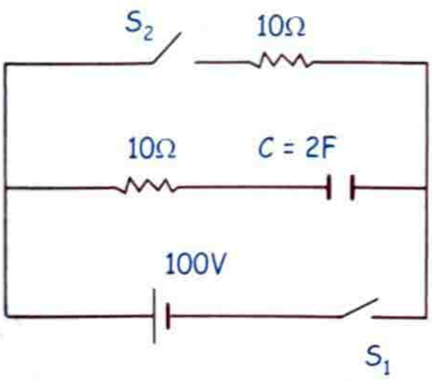
$\rightarrow$ charge as function of time on capacitor

$q = Q_0 e^{-t/RC} \Rightarrow 40\, e^{-t/10}$

$i = \left|\dfrac{dq}{dt}\right| = \dfrac{40}{10} e^{-t/10}$

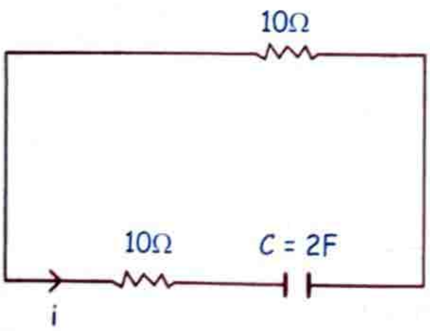
Q. At t = 0 switch S_1 is closed and S_2 is open find current as a function of time and charge on the capacitor as function of time.

(a)



Sol. $i = 10e^{-t/20}$ and $q = 200(1 - e^{-t/20})$

(b) If after very long time S_1 is open and S_2 is closed then charge on the capacitor as a function of time for new observation will be



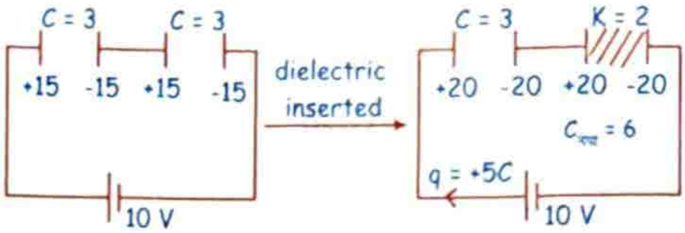
Sol. $q = 200e^{-t/40}$ (Now time constant = 20 × 2 = 40)

(c) Total heat loss across resistance in second observation.

$$= \frac{1}{2}\frac{(200)^2}{2}$$

भाई अब जितने Questions में attach कर रहा हुँ उन्हें अच्छे से लगा लेना till the last

Q.



Ceq = 1.5 V

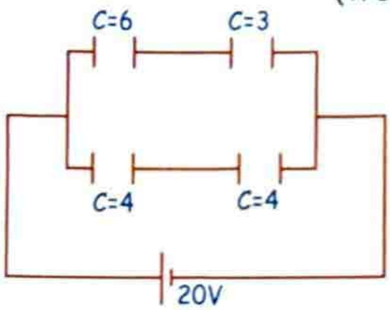
q = Ceq. V = 1.5 × 10 = 15

Ceq. = 2

q = 10 × 2 = 20

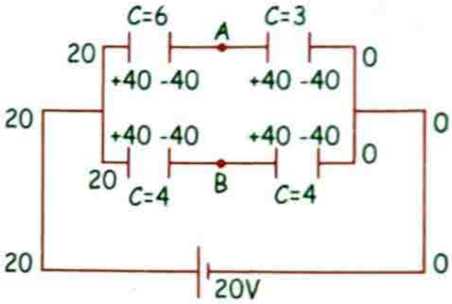
(WD)battery = 10 × 5

Q.



$V_A - V_B = ?$

Sol.



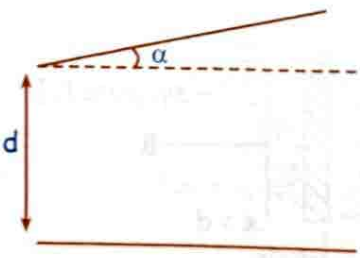
$\rightarrow$ Charge on each capacitor

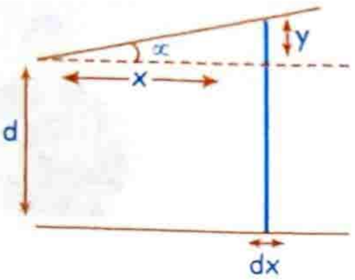
$\rightarrow V_A - V_B$ = हम लगाएगे KVL

$V_A + \dfrac{40}{6} - \dfrac{40}{4} = V_B$

$V_A - V_B = 10 - \dfrac{40}{6} = \dfrac{10}{3}$

Q. Two squence plates (length L) are arranged as shown. Angle α is very small. Calculate equivalent capacitance.





$$\tan\alpha = \frac{y}{x} = \alpha$$

$y = x\alpha$

capacitance of dx strip

$$dC = \frac{Ldx\cdot \epsilon_0}{d+y} = \frac{Ldx\cdot \epsilon_0}{d+x\alpha}$$

$$C_{eq} = \int dc = \int_0^L \frac{L\varepsilon_0 dx}{d+x\alpha} = \frac{L\varepsilon_0}{\alpha}\ln\left(\frac{d+L\alpha}{d}\right)$$

$$C_{eq} = \frac{L\varepsilon_0}{\alpha}\ln\left(1+\frac{L\alpha}{d}\right)$$

Log Expansion-

$$\ln(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} \ldots$$

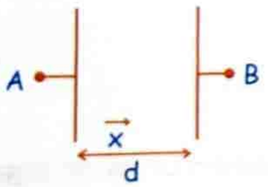
* $C_{eq} = \frac{L\varepsilon_0}{\alpha}\ln\left(1+\frac{L\alpha}{d}\right)$

$$C_{eq} = \frac{L\varepsilon_0}{\alpha}\left[\frac{L\alpha}{d} - \left(\frac{L\alpha}{d}\right)^2\frac{1}{2} + \ldots\right]$$

$$C_{eq} = \frac{L\varepsilon_0}{\alpha}\frac{L\alpha}{d}\left[1-\frac{L\alpha}{2d}+\ldots\right] \quad (\alpha \text{ is very small})$$

$$C_{eq} = \frac{\varepsilon_0 l^2}{d}\left[1-\frac{L\alpha}{2d}\right]$$

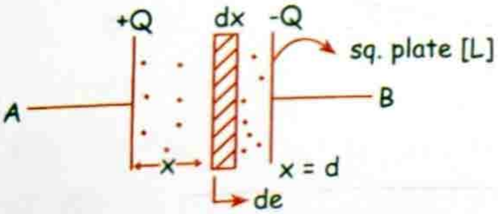
Q. Dielectric constant is given



$K = A + Bx$

find C_{AB}.

Sol.

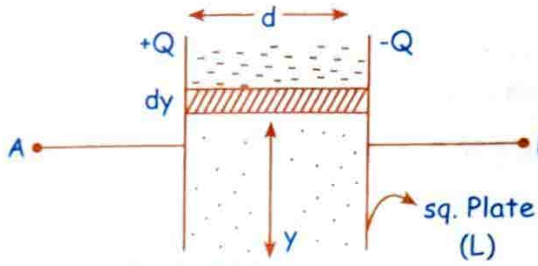


$$dC = \frac{A\varepsilon_0(A+Bx)}{dx}$$

$$\frac{1}{C_{eq}} = \int\frac{1}{dC} = \int_0^d \frac{dx}{A\varepsilon_0(A+Bx)} = \frac{1}{A\varepsilon_0 B}\ln\left(\frac{A+Bd}{A}\right)$$

Q. Dielectric constant is given is given as K = A + By. Plates are square of side L.

Sol.

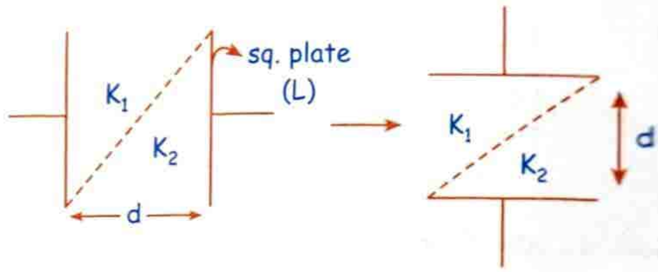


Find C_{AB} [k = A + By]

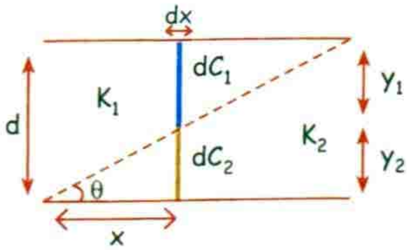
$$dc = Ldy.\frac{\varepsilon_0}{d}(A+By)$$

$$C_{eq.} = \int_0^L dc = \int_0^L L\varepsilon_0(A+By)dy$$

Q. find Ceq.



Sol.



$$\tan\theta = \frac{d}{L}$$

$$y_2 = x\tan\theta = \frac{xd}{L}$$

$y_1 = d - x\tan\theta$

$$y_1 = d - x\frac{d}{L}$$

$$dC_1 = \frac{(Ldx)\epsilon_0 K_1}{y_1}$$

$$dC_2 = \frac{Ldx\epsilon_0 K_2}{y_2}$$

$$\frac{1}{dC} = \frac{1}{dC_1} + \frac{1}{dC_2} = \frac{y_1}{Ldx \in_0 K_1} + \frac{y_2}{Ldx \in_0 K_2}$$

$$\frac{1}{dC} = \frac{1}{L.dx. \in_0}\left[\frac{y_1}{K_1} + \frac{y_2}{K_2}\right]$$

$$dc = \frac{L \in_0 dx}{\frac{y_1}{K_1} + \frac{y_2}{K_2}} = \frac{L \in_0 dx}{\frac{d - \frac{xd}{L}}{K_1} + \frac{xd}{L.K_2}}$$

$$dc = \frac{L \in_0 dx}{\frac{d}{K_1} + x\left[\frac{d}{LK_2} \frac{d}{LK_1}\right]}$$

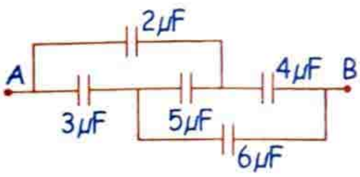
$$\int dc = \int_0^L \frac{L \in_0 dx}{\frac{d}{K_1} + x\left[\frac{d}{LK_2} - \frac{d}{LK_1}\right]}$$

$$\Rightarrow \int \frac{A dx}{B + cx} = \frac{A}{C}\ln(B + Cx)$$

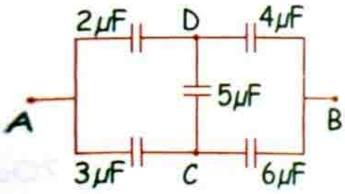
$$Ceq. = \frac{L \in_0}{\left(\frac{d}{LK_1} - \frac{d}{LK_2}\right)} \ln\left\{\frac{\frac{d}{K_1} + L\left[\frac{d}{LK_2} - \frac{d}{LK_1}\right]}{\frac{d}{K_1}}\right\}$$

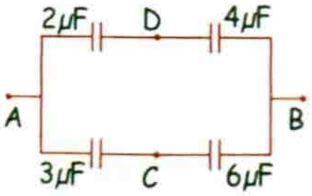
$$\Rightarrow \frac{L^2 \in_0 K_1 K_2}{d.(K_2 - K_1)} \ln\left(\frac{K_1}{K_2}\right)$$

Q. Find the equivalent capacitance of the combination between A and B in the figure.



Sol. The simplified form of the given combination has been shown in the figure.





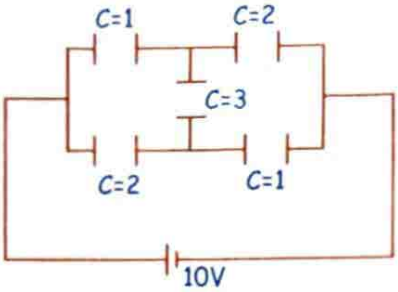
Here $\frac{C_1}{C_2} = \frac{2\mu F}{4\mu F} = \frac{1}{2} \Rightarrow \frac{C_3}{C_4} = \frac{3\mu F}{6\mu F} = \frac{1}{2}$

Thus, $\frac{C_1}{C_2} = \frac{C_3}{C_4}$

Hence $C_{eq} = \frac{C_1 C_2}{C_1 + C_2} + \frac{C_3 C_4}{C_3 + C_4}$

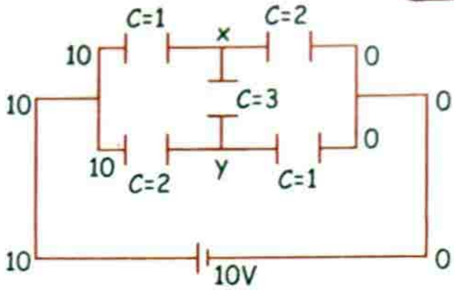
$$= \left(\frac{2 \times 4}{2 + 4} + \frac{3 \times 6}{3 + 6}\right)\mu F = \left(\frac{4}{3} + 2\right)\mu F = \frac{10}{3}\mu F$$

Q. Find C_{eq} of the circuit and charge on each capacitor.



नलायको ये balance wheat stone bridge नही है।

Sol.



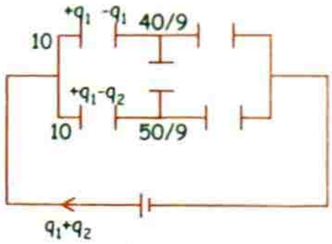
Balance wheatstone X.

$(x - 10) \times 1 + (x - y) \times 3 + (x - 0) \times 2 = 0$ ...(i)

$(y - 10)2 + (y - x)3 + y = 0$ ...(ii)

from (i) & (ii)

$x = \frac{40}{9}, y = \frac{50}{9}$



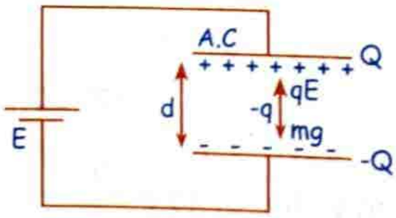
$q_1 = 1 \times \left(10 - \frac{40}{9}\right) \Rightarrow \frac{50}{9}.$

$q_2 = 2 \times \left(10 - \frac{50}{9}\right) \Rightarrow \frac{80}{9}.$

$q_{flow} = q_1 + q_2 = \frac{130}{9}$

$\frac{130}{9} = C_{eq} \times 10 \Rightarrow C_{eq} = \frac{13}{9}$

Q. -q charge b/w the plates is at equilibrium. Find value of q.



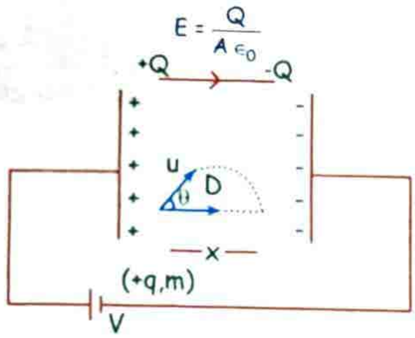
$$qE = mg$$

$$q\frac{\sigma}{\epsilon_0} = mg$$

$$q\frac{Q}{A\epsilon_0} = mg$$

$$q\frac{C \times E}{A\epsilon_0} = mg$$

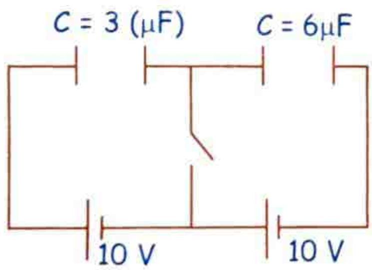
#



$$a_x = \frac{qE}{m}, R = (u\cos\theta)T + \frac{1}{2}\frac{qE}{m}T^2$$

SWITCH WALE SAWAL

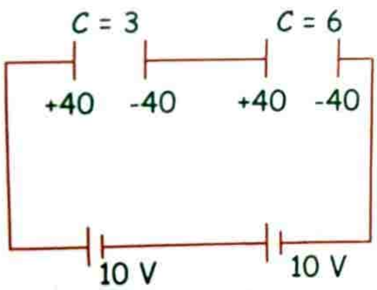
Q. Find charge on capacitor before & after closing the switch.

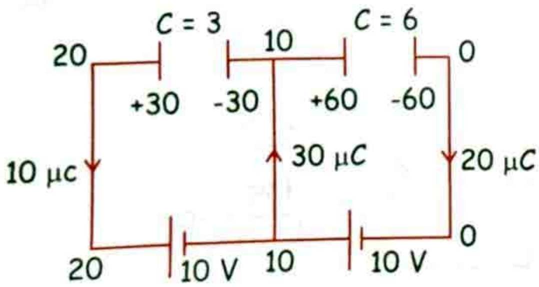


→ (WD) by battery after switch close.

→ Heat loss after switch close.

Sol.





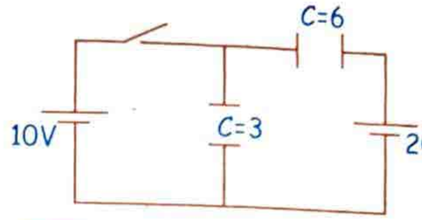
$$(WD)_{left\ battery} = -10 \times 10^{-6} \times 10$$

$$(WD)_{right\ battery} = 10 \times 20 \times 10^{-6}$$

$$\text{Heatloss} = \frac{1}{2}\frac{(40\times10^{-6})^2}{3\times10^{-6}} + \frac{1}{2}\frac{(40\times10^{-6})^2}{6\times10^{-6}} - 10\times10^{-6}\times 10$$

$$+10\times10^{-6}\times20 - \frac{1}{2}\frac{(30\times10^{-6})^2}{3\times10^{-6}} - \frac{1}{2}\frac{(60\times10^{-6})^2}{6\times10^{-6}}$$

Q. Find charge flow through switch when switch closed.

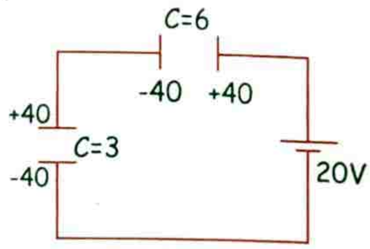


#SKC

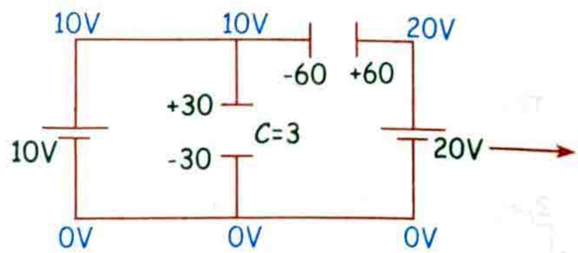
Switch वाले ques Switch बंद करने से पहले और बंद करने के बाद, दोनो की figure Banalo हमेशा।

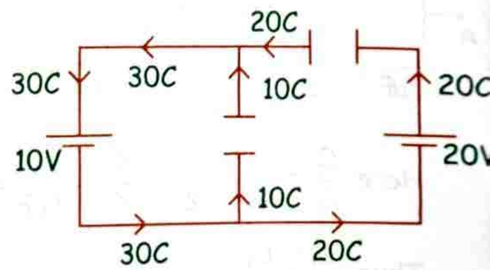
Sol. Before Switch Close-

(initial)



After Switch Close-

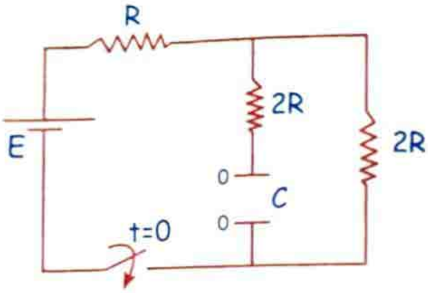


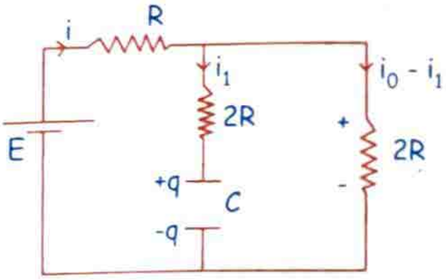


Charge flow through the switch will be 30 C.

FOR ADVANCE IMPORTANT

Q. SSSQ Find charge on each capacitor as function of time. Also find time constant τ.





$$E - iR - 2Ri_1 - \frac{q}{c} = 0 \qquad ...(1)$$

$$-2Ri_1 - \frac{q}{C} + 2R(i - i_1) = 0 \qquad ...(2)$$

Solve -

equ^n - (1) multiply by 2 and add in equ^n (2).

$$2E - 8Ri_1 - \frac{3q}{c} = 0 \qquad i = \frac{dq}{dt}$$

$$2E - 8R\frac{d}{dt} - \frac{3q}{c} = 0$$

$$2Ec - 3q = +8RC\frac{dq}{dt}$$

$$\int_0^q \frac{dq}{2EC} = \int_0^t \frac{dt}{8Rc}$$

$$\frac{1}{-3}\ln(2EC - 3q)\Big|_0^q = \frac{t}{8Rc}$$

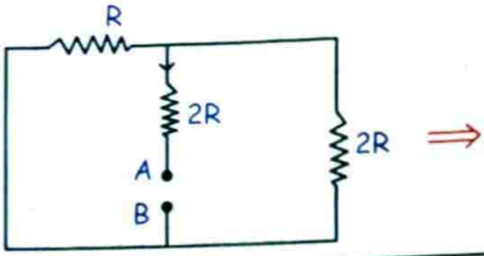
$$\ln\left(\frac{2EC - 3q}{2EC}\right) = \frac{-3t}{8RC}$$

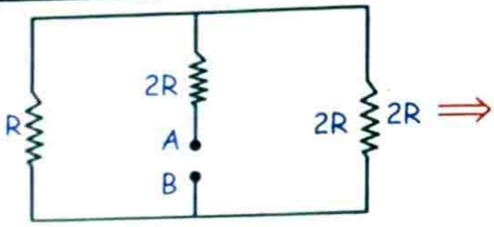
$$1 - \frac{3q}{2EC} = e^{-3t/8RC}$$

$$\frac{3q}{2EC} = (1 - e^{-3t/8RC})$$

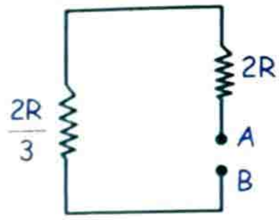
$$q = \frac{2EC}{3}\left(1 - e^{-t/\frac{8RC}{3}}\right)$$

#SKC
Battery Ko wire se replace cap ke across Req. nikalo.
τ = Req. C





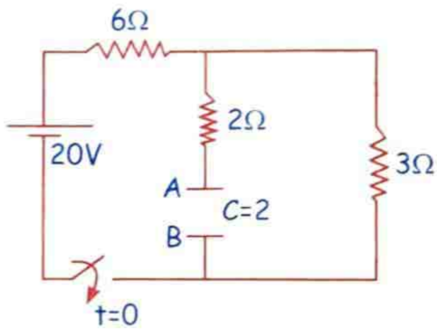
#SKC
Energy Density
= Energy per unit vol^n
$= \frac{1}{2}\varepsilon_0 E^2$



$$R_{AB} = 2R + \frac{2R}{3} = \frac{8R}{3}$$

$$\tau = \frac{8R}{3} \cdot C$$

Q. Calculate charge on capacitor an a function of time. Switch closed at t = 0.



Sol. $\rightarrow \tau = R_{AB} \cdot C = 4 \times 2 = 8$

$\rightarrow Q_{max}$. at $t = \infty$

$$q_{max} = \frac{120}{9}$$

$\rightarrow q = f(t)$

$i_1 = f(t)$

$$q = Q_{max}(1 - e^{-t/\tau_{eq.}})$$

$$= \frac{120}{9}(1 - e^{-t/8})$$

Q. A charge q is distributed uniformly over the volume of a ball of radius R. Find energy stored in the ball energy in the surrounding space.

Sol. To calculate the energy stored in an electric field.

we can use energy per unit volume = $1/2\ \varepsilon_0 E^2$

$$\Rightarrow dU = \frac{1}{2}\varepsilon_0 E^2 dV$$

Let us recall the expression for the field of a uniformly distributed charge of a non-conducting sphere.

$$E = \begin{cases} \dfrac{Qr}{4\pi\varepsilon_0 R^3} & \text{for } r \le R \\ \dfrac{Q}{4\pi\varepsilon_0 r^2} & \text{for } r > R \end{cases}$$

(a) **Energy inside the ball**

$$U_1 = \int \frac{1}{2}\varepsilon_0 E^2\, dV$$

Consider an element of radius r and thickness dr

$$\Rightarrow U_1 = \int_0^R \frac{1}{2}\varepsilon_0 \left(\frac{Qr}{4\pi\varepsilon_0 R^3}\right)^2 4\pi r^2 dr$$

$$U_1 = \frac{Q^2}{8\pi\varepsilon_0 R^6}\int_0^R r^4\, dr$$

$$U_1 = \frac{Q^2}{40\pi\varepsilon_0 R}$$

(b) **Energy outside the ball**

$$U_2 = \int \frac{1}{2}\varepsilon_0 E^2 dV$$

$$U_2 = \int_R^\infty \frac{1}{2}\varepsilon_0 \left(\frac{Q}{4\pi\varepsilon_0 r^2}\right)^2 4\pi r^2 dr$$

$$U_2 = \frac{Q^2}{8\pi\varepsilon_0}\int_R^\infty \frac{dr}{r^2}$$

$$U_2 = \frac{Q^2}{8\pi\varepsilon_0 R}$$

Total energy = $U_1 + U_2$

$$\Rightarrow U_1 + U_2 = \frac{Q^2}{40\pi\varepsilon_0 R} + \frac{Q^2}{8\pi\varepsilon_0 R}$$

$$\Rightarrow U_1 + U_2 = \frac{3Q^2}{20\pi\varepsilon_0 R}$$

Alternatively: Total energy = work done to assemble the parts of the ball starting from infinity.

The potential at the surface of the ball at the instant when it has a radius x is

$$V = \frac{\text{Charge on ball}}{4\pi\varepsilon_0 x} = \frac{Qx^2}{4\pi\varepsilon_0 R^3}$$

The work done to add a charged layer of thickness dx from infinity is

$$dW = V\, dq = \frac{Q x^2}{4\pi\varepsilon_0 R^3}(\rho\, dV)$$

$$dW = \frac{Qx^2}{4\pi\varepsilon_0 R^3}\left(\frac{Q}{\frac{4}{3}\pi R^3}\right) 4\pi x^2 dx$$

Total work done $= W = \int dW$

$$W = \int_0^R \frac{3Q^2}{4\pi\varepsilon_0 R^6} x^4\, dx = \frac{3Q^2}{20\pi\varepsilon_0 R}$$

Hence total energy of the system $= \dfrac{3Q^2}{20\pi\varepsilon_0 R}$

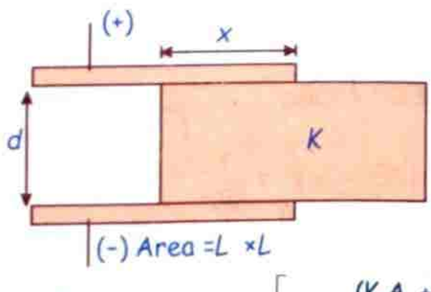
Force on a Dielectric Slab Placed Between the Plates of a Parallel Plate Capacitor

Case I: Isolated capacitor

Consider a charged isolated capacitor. The capacitance is $C = \dfrac{\varepsilon_0 A}{d}$

Here $A = L \times L$ (L is side of its plate).

When a dielectric slab is kept in it as shown, the capacitance becomes



$$\Rightarrow C = \frac{\varepsilon_0}{d}\{KLx + L(L-x)\}\left[\because C = \frac{(K_1A_1 + K_2A_2)\varepsilon_0}{d}\right]$$

$$\text{or,}\quad C = \frac{\varepsilon_0 L}{d}\{L + (K-1)x\}$$

If slab moves inside (without change in kinetic energy), x increases, which increases the capacitance, causing a decrease in electrostatic energy $\left(\text{as } U = \dfrac{Q^2}{2C}\right)$.

Thus, the slab experiences a force $F = \frac{-dU}{dx}$, which pulls the slab inside.

As, $U = \frac{Q^2}{2C} \Rightarrow \frac{dU}{dx} = \frac{-Q^2}{2C^2} \times \frac{dC}{dx}$

As, $C = \frac{\varepsilon_0 L}{d}\left[L + (K-1)x\right] \Rightarrow \frac{dC}{dx} = \frac{\varepsilon_0 L}{d}(K-1)$

$$\Rightarrow \frac{dU}{dx} = \frac{-Q^2}{2C^2} \times \frac{\varepsilon_0 L}{d}(K-1) = \frac{-Q^2 d(K-1)}{2\varepsilon_0 L[L + (K-1)x]^2}$$

As, $F = \frac{-dU}{dx}$,

$$\therefore F = \frac{Q^2 d(K-1)}{2\varepsilon_0 L[L + (K-1)x]^2}$$

Case II: A constant potential difference is maintained across the capacitor

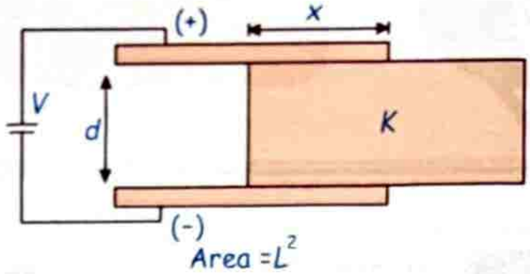
In this case, a constant potential difference is being maintained. When the slab moves inside by a small distance dx, capacitance increases and thus battery supplies extra charge to the capacitor thereby increasing its potential energy.

During the displacement, an external force (external agent) of equal magnitude F should be applied in opposite direction, so that the dielectric moves with no acceleration.

Note: Slab moves inside the capacitor without change in kinetic energy.

Again, $C = \frac{\varepsilon_0 L}{d}\left[L + (K-1)x\right]$ and $\frac{dC}{dx} = \frac{\varepsilon_0 L}{d}(K-1)$

Now, $Q = CV \Rightarrow dQ = dC.V$



Work done by battery = $dW = dQ \times V = dCV2$

Area = L^2

Work done by external force $dW_2 = -Fdx$

$\therefore$ Change in potential energy dU = Work done by battery + Work done by external force = $dCV^2 - Fdx$

[Battery and external force (external agent) both are "external" to the system of capacitor]

or $\frac{dU}{dx} = \frac{dC}{dx}V^2 - F$ or $F = \frac{dC}{dx}V^2 - \frac{dU}{dx}$

As $U = \frac{1}{2}CV^2 \Rightarrow \frac{dU}{dx} = \frac{1}{2}\frac{dC}{dx}.V^2$

$$\Rightarrow C = \frac{\varepsilon_0 L}{d}\left\{L + (K-1)x\right\} \Rightarrow \frac{dC}{dx} = \frac{\varepsilon_0 L}{d}(K-1)$$

$$\Rightarrow F = \frac{dC}{dx}V^2 - \frac{1}{2}\frac{dC}{dx}V^2 = \frac{1}{2}\frac{dC}{dx}V^2$$

$$\therefore F = \frac{1}{2}\frac{\varepsilon_0 L(K-1)}{d}V^2$$

The force is independent of x.

In case (1), the force depends on x as $F \propto \frac{1}{\left[L + (K-1)x\right]^2}$ whereas in case (2) force is independent of x.

4 Magnetism

Student: Naya chapter start hone wala hai......

Saleem Bhaiya

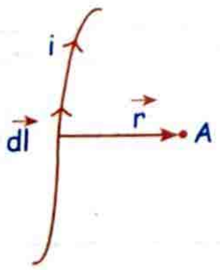
देख भाई exam के point off view से बहुत important chapter है जिसको 5 टुकड़ो में हम cover करेंगे

1. किसी point पर magetic field की value और direction निकालना इसमें कुछ formule आपको याद करने पड़ेंगे नही करोगे तो पिटाई होगी।
2. किसी charge (q, m) को magnetic field में फेक कर मारू तो उसके साथ क्या होगा।
3. किसी current carrying wire को magnetic field में रखा तो उसपे क्या होगा।
4. किसी loop को magnetic field में रखा तो उसपे क्या होगा।
5. Bar magnet और magnetic material

CALCULATION OF MAGNETIC FIELD

Biot Savart Law

Magnetic field at a point 'A' due to small element dl is given by-



$$d\vec{B} = \frac{Ki(d\vec{l} \times \vec{r})}{r^3} \quad \left[K = \frac{\mu_0}{4\pi}\right]$$

$$d\vec{B} = \frac{\mu_0 i(d\vec{l} \times \vec{r})}{4\pi \cdot r^3}$$

$\mu_0 \rightarrow$ permeability of free space

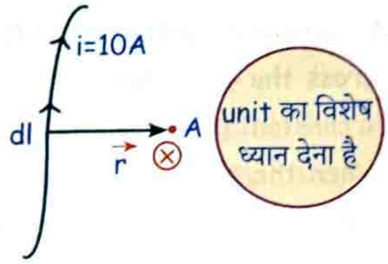
Direction of B at A is given by $(\vec{dl} \times \vec{r})$ (here अंदर ⊗)

$\frac{\mu_0}{4\pi} = 10^{-7}\,Tm/A \Rightarrow \quad \boxed{\mu_0 = 4\pi \times 10^{-7}\,Tm/A.}$

Q. Find the magnetic field due to small element dl $= (3\hat{i} + 4\hat{j})$mm having current 10 A through it at a point whose position vector is $(5\hat{i} - 12\hat{j})$m from this element.

Sol. $d\vec{B} = \frac{\mu_0}{4\pi} \frac{i(d\vec{l} \times \vec{r})}{r^3}$

$$= \frac{10^{-7} \times 10 \times (3\hat{i} + 4\hat{j})(5\hat{i} - 12\hat{j}) \times 10^{-3}}{13^3}$$

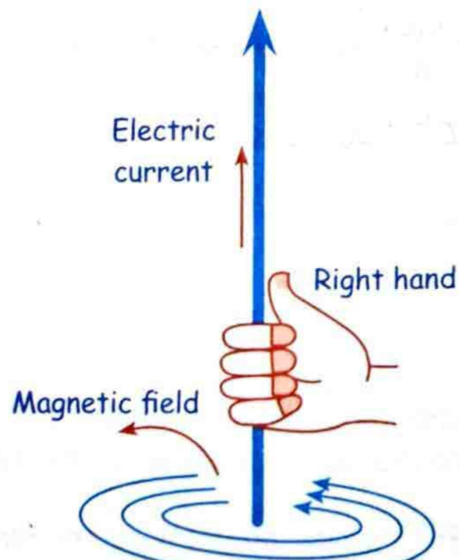


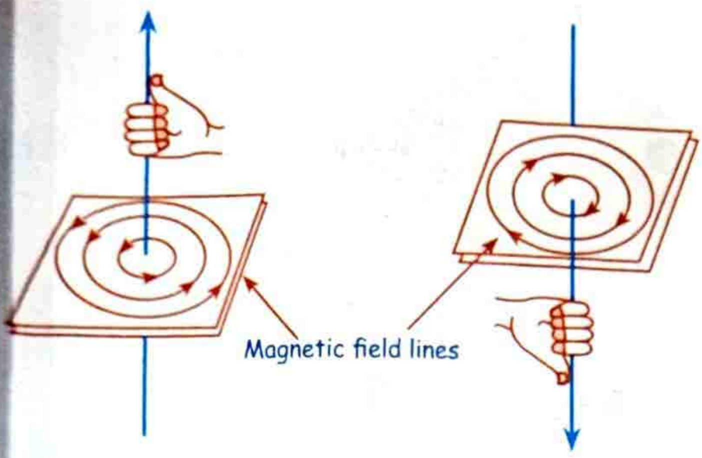
⊗ → perpendicular inwards

⊙ → perpendicular Outward

Direction of Magnetic Field due to Straight Wire

→ Direction is given by "Right Hand Thumb Rule".

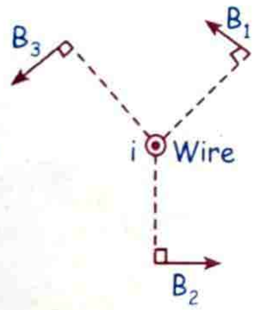




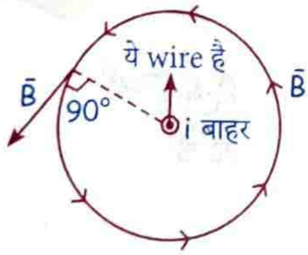
MF की direction निकालना बहुत important है इसलिए हर सवाल में direction निकालने की आदत डालो...

MAGNETIC FIELD DUE TO STRAIGHT CURRENT CARRYING WIRE

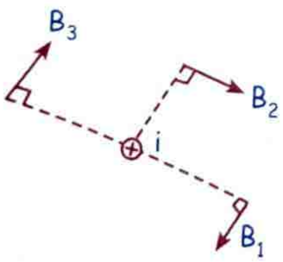
(a)



(b)

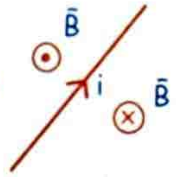


(c)



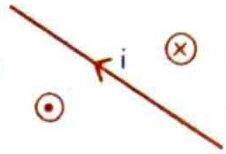
(d)

(e)

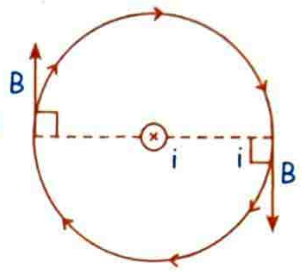


(f)

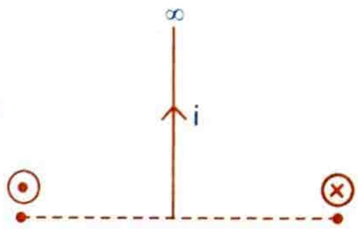
(g)



(h)

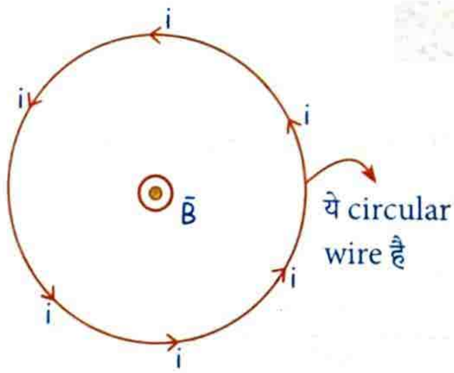


(i)



$\bar{B}$ at centre due to current carying loop.

(a)



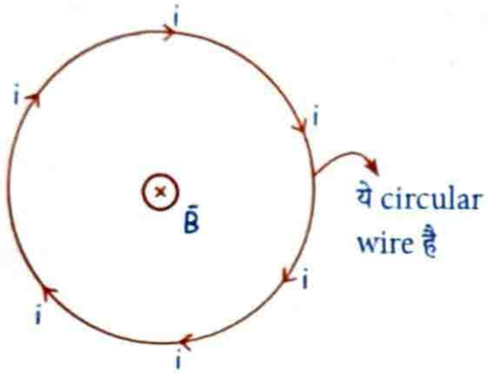
Current → ACW (Anticlockwise)

⇒ centre pr बाहर Magnetic Field hai.

Magnetic field at centre → ⊙

⇒ Perpendicularly outward.

(b)

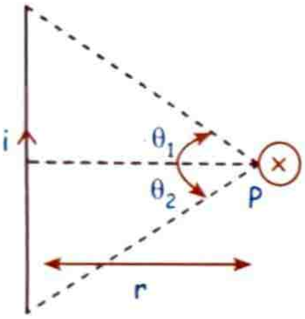


Current carrying wire

Magnetic field at centre

$\rightarrow \otimes \Rightarrow$ perpendicularly inward

Magnetic Field Due To Straight Current Carrying Wire



B at 'P' due to wire [inside] $= \frac{Ki}{r}(\sin\theta_1 + \sin\theta_2)$

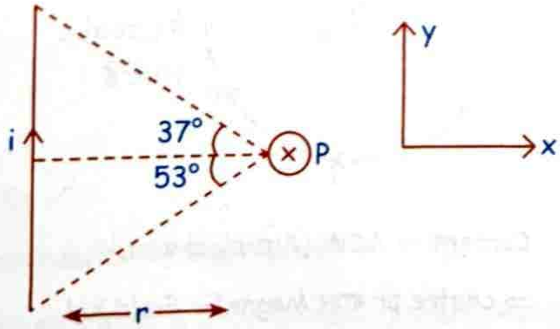
[$\otimes$ inside]

$$\boxed{K = \frac{\mu_0}{4\pi} = 10^{-7}\ \frac{Tm}{A}}$$

निचे B की calculation के 46 questions attached कर रहा हुँ हर question को solve करें नही तो book से बाहर आके मुक्का मारूँगा because exam में यही सवाल आपको मिलेंगे।

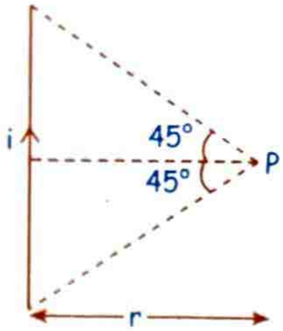
Q. Find the magnetic field at point P.

1



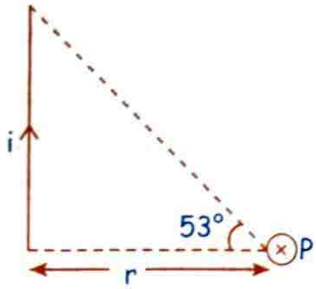
$$B_P = \frac{Ki}{r}(\sin 37^\circ + \sin 53^\circ)\ \otimes\ (-\hat{k})$$

2



$$B_P = \frac{Ki}{r}\left(\frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}}\right) \otimes$$

3

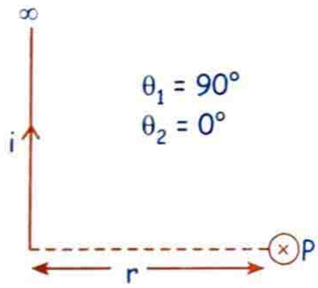


$\theta_1 = 53^\circ$

$\theta_2 = 0^\circ$

$$B_P = \frac{Ki}{r}(\sin 53^\circ + \sin 0^\circ)$$

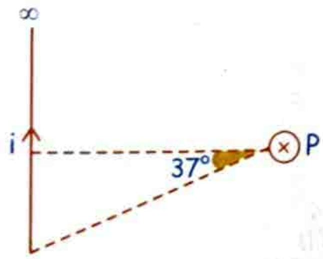
4



$$B_P = \frac{ki}{r}(\sin 90^\circ + \sin 0^\circ)$$

$$= \frac{Ki}{r} \otimes (-\hat{k}) = \frac{\mu_0 i}{4\pi r}$$

5

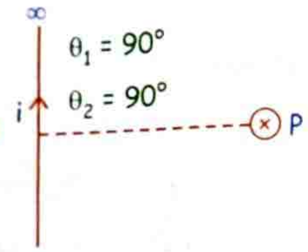


$\theta_1 = 90^\circ$

$\theta_2 = 37^\circ$

$$B_P = \frac{Ki}{r}\left(1 + \frac{3}{5}\right)(-\hat{k})$$

6

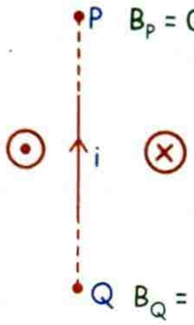


#SKC
इस Formula को कभी नहीं भूलना
$B_P = \frac{2Ki}{r}$ (Due to ∞ wire)

$$B_P = \frac{Ki}{r}(1+1)$$

$$B_P = \frac{2Ki}{r} = 2\cdot\frac{\mu_0}{4\pi}\frac{i}{r} = \frac{\mu_0 i}{2\pi r}(-\hat{k})$$

7

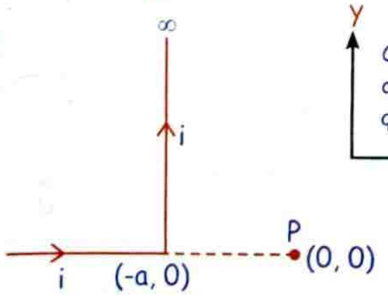


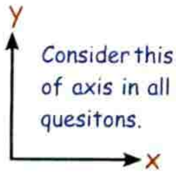
$B_P = 0$, $B_Q = 0$

#SKC
अगर point wire वाली line पर आ गया, तो उस point पर उस wire की वजह से Magnetic field zero होगी।

Q. Find magnetic field at point P due to straight wire arrangement

8

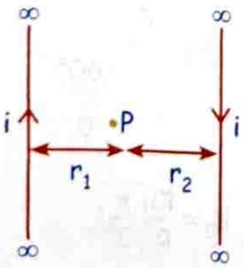




Consider this direction of axis in all following quesitons.

$$\vec{B}_P = 0 + \frac{Ki}{a}(\sin 90^\circ + 0) = \frac{Ki}{a}(-\hat{k})$$

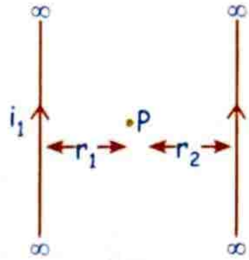
9



$$\vec{B}_A = \frac{2Ki}{r_1}(-\hat{K}) + \frac{2Ki}{r_2}(-\hat{K})$$

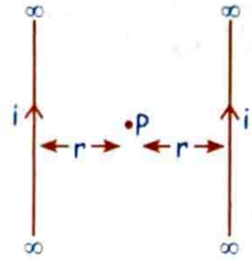
$$= 2Ki\left[\frac{1}{r_1} + \frac{1}{r_2}\right](-\hat{K})$$

10



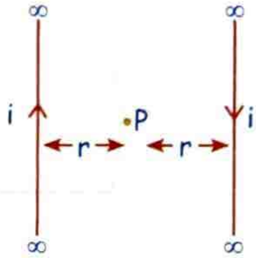
$$\vec{B}_P = \frac{2Ki_1}{r_1}(-\hat{K}) + \frac{2Ki_2}{r_2}(+\hat{K})$$

11



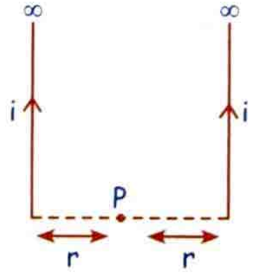
$B_P = 0$

12



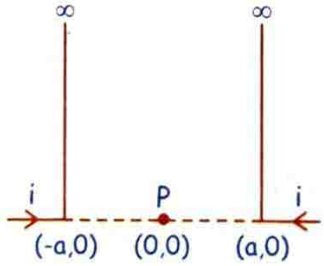
$$B_P = \frac{2Ki}{r} + \frac{2Ki}{r}$$

13



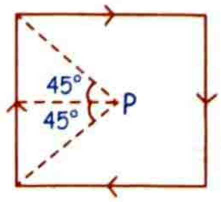
$$B_P = \frac{Ki}{r}\otimes + \frac{Ki}{r}\odot \Rightarrow 0$$

14



$\vec{B}_P = 0$

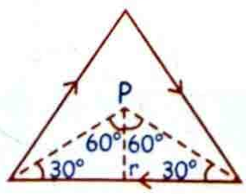
15



$$B_P = \frac{Ki}{L/2}(\sin 45^\circ + \sin 45^\circ)\times 4$$

(Square, L)

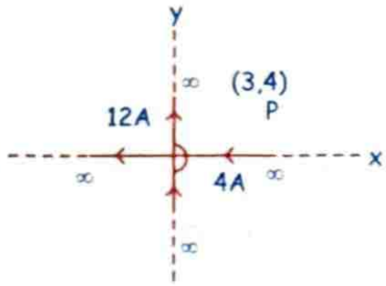
16



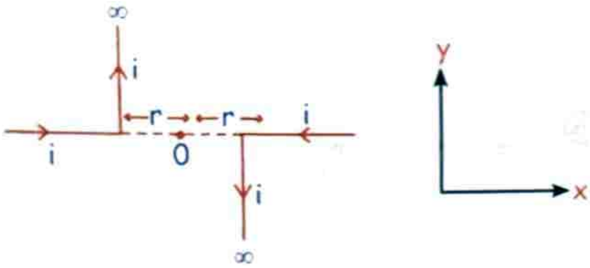
(Equilateral triangle) ('l')

$$\tan 30^\circ = \frac{r}{\ell/2} \Rightarrow r = \frac{\ell}{2\sqrt{3}}$$

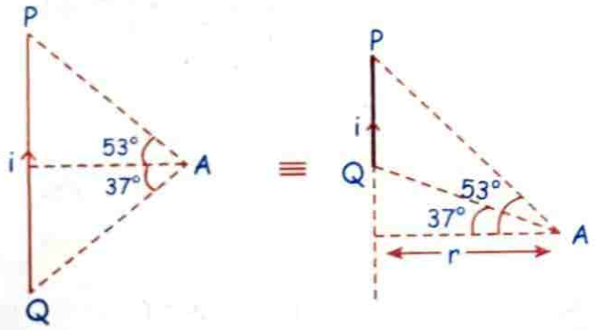
$$B_P = \frac{Ki}{r}(\sin 60^\circ + \sin 60^\circ) \times 3$$

17


$$\overrightarrow{B_P} = \frac{(2K \times 12)}{3} \otimes + \frac{(2K \times 4)}{4} \otimes$$

18


$$(B) \text{ at } P = 0 + \frac{Ki}{r} + 0 + \frac{Ki}{r} = \frac{2Ki}{r} \otimes (-\hat{K})$$

19


$$B_A = \frac{Ki}{r}(\sin 53^\circ + \sin 37^\circ)$$

$\theta_1 = 53^\circ$

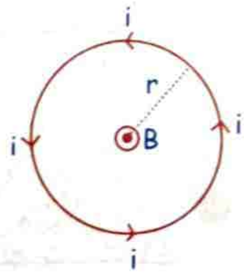
$\theta_2 = -37^\circ$

$$B_A = \frac{Ki}{r}(\sin 53^\circ - \sin 37^\circ)$$

Magnetic field due to Circular loop at the Centre of loop/Ring

$$\boxed{\vec{B}_{centre} = \frac{\mu_0 i}{2r}}$$

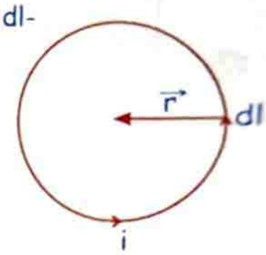
⊙ बाहर



Proof:

$\vec{B}$ at centre due to small element dl-

$$= \frac{Ki(d\vec{l} \times \vec{r})}{r^3}$$



$$= \frac{Ki}{r^3} dl \cdot r \cdot \sin 90^\circ$$

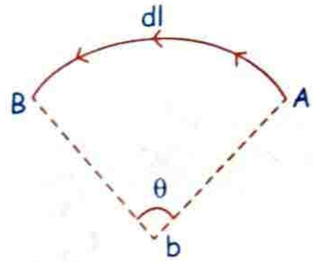
(magnitude)

$$\int dB = \frac{Ki}{r^2}\int dl$$

$$B_{net} = \frac{Ki}{r^2}(2\pi r) = \frac{Ki}{r}(2\pi) = \frac{\mu_0 i}{2r}$$

Magnetic field due to Circular arc at centre

$$\int dB = \int_A^B \frac{Ki(dl \cdot r \cdot \sin 90^\circ)}{r^3}$$

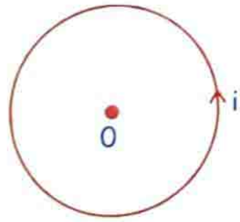


$$\theta = \frac{arc}{Radius}$$

$$B_{net} = \frac{ki}{r_A^2}\int_A^B dl = \frac{Ki}{r^2}(\text{arc length}) = \frac{Ki}{r}\theta$$

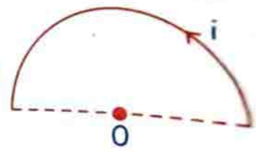
Q. Find magnetic field at point O

20 (a)



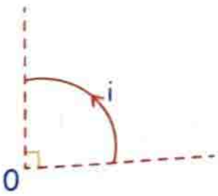
$$B_0 = \frac{\mu_0 i}{2R}$$

(b)



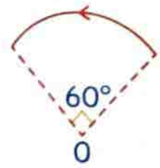
$$B_0 = \frac{Ki}{R}\pi$$

21 (a)



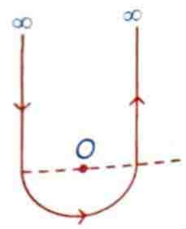
$$B_0 = \frac{Ki}{R}\left(\frac{\pi}{2}\right)$$

(b)



$$B_0 = \frac{Ki}{R}\left(\frac{\pi}{3}\right)$$

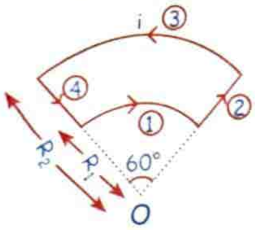
22



$\bar{B}_0 = \bar{B}_{straight} + \bar{B}_{semicircle} + \bar{B}_{straight}$

$\overrightarrow{B_0} = \frac{Ki}{R}(1+0) + \frac{Ki}{R}\pi + \frac{Ki}{R}(1+0) = \frac{Ki}{R}(\pi + 2) \odot$

23



$\bar{B}_0 = \bar{B}_1 + \bar{B}_2 + \bar{B}_3 + \bar{B}_3 + \bar{B}_4$

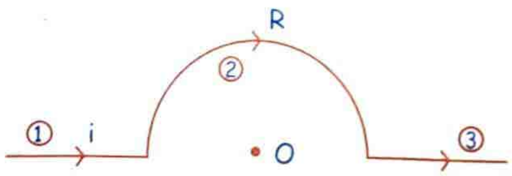
$B_0 = \frac{Ki}{R}\frac{\pi}{3}(\times) + 0 + \frac{Ki}{R}\cdot\frac{\pi}{3}(\cdot) + 0$

$\overline{B_1} = Ki\frac{\pi}{3}\left[\frac{1}{R_1}(-\hat{K}) + \frac{1}{R_2}(+\hat{K})\right]$

#SKC

अगर Qus^n वाला dirx^n मे खेले तो Magnetic field with dirx^n $\pm\hat{k}, \pm\hat{j}$... के Form मे लिखकर Solve Kro, हवा हवा मे मत करना।

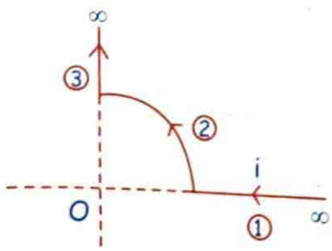
24



$\bar{B}_0 = \bar{B}_2 + \bar{B}_3 + \bar{B}_1$

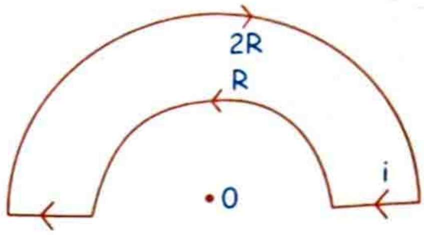
$\overrightarrow{B_0} = \frac{Ki}{R}\cdot\pi + 0$ (inside)

25



$B_0 = 0 + \frac{Ki}{R}\cdot\frac{\pi}{2}\odot + 0$

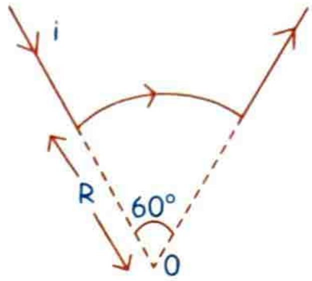
26



$\bar{B} = \bar{B}_R + \bar{B}_{2R}$

$B_0 = \frac{Ki}{R}\pi(\hat{K}) + \frac{Ki\pi}{2R}(-\hat{K}) = \frac{Ki\pi}{R}\left[1 - \frac{1}{2}\right]\hat{K} \Rightarrow \frac{\mu_0 i}{8R}\odot$

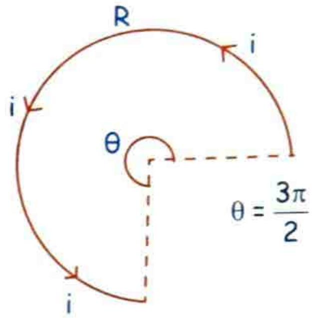
27



$\overline{B_0} = \frac{Ki}{R}\frac{\pi}{3}\ (\times)$

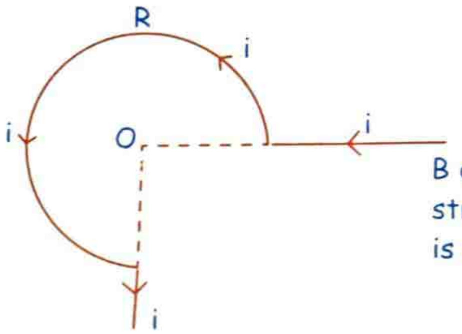
B due to straight wires is zero

28



$\vec{B}_0 = \frac{Ki}{R}\cdot\theta = \frac{\mu_0}{4\pi}\cdot\frac{i}{R}\cdot\frac{3\pi}{2}$

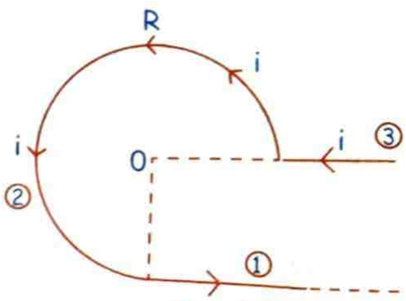
29



B due to straight wires is zero

$\vec{B}_0 = 0 + \frac{Ki}{R}\cdot\frac{3\pi}{2} + 0.\ \odot$

30



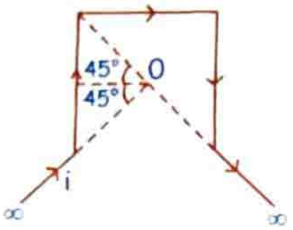
$\theta_1 = 90°$

$\theta_2 = 0$

$$\bar{B} = \bar{B}_3 + \bar{B}_2 + \bar{B}_1$$

$$\bar{B}_0 = 0 + \frac{Ki}{R}\cdot\frac{3\pi}{2} + \frac{Ki}{R}\odot(1+0)$$

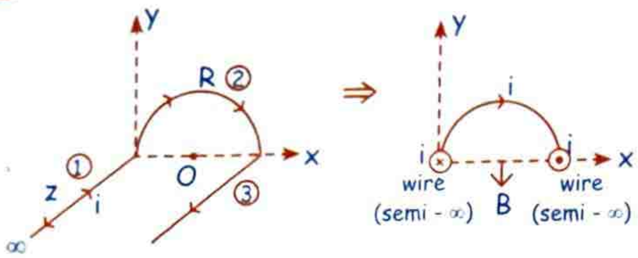
$$= \frac{Ki}{R}\left[\frac{3\pi}{2} + 1\right]\odot$$

31 

(Square, Length 'L')

$$\bar{B}_0 = \frac{Ki}{L/2}(\sin 45^\circ + \sin 45^\circ)3\otimes$$

32

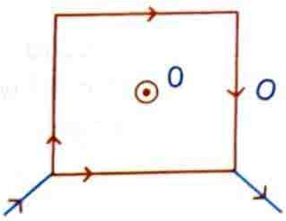


Find Magnetic field at 'O'

$$\bar{B} = \bar{B}_1 + \bar{B}_2 + \bar{B}_3$$

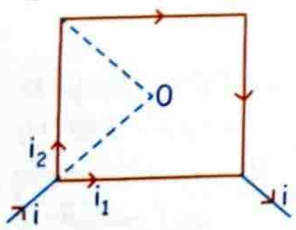
$$\overline{B_A} = \frac{Ki}{R}(0+1)[-\hat{j}] + \frac{Ki}{R}\cdot\pi[-\hat{K}] + \frac{Ki}{R}(1+0)(-\hat{j})$$

$$= \frac{Ki}{R}[-\hat{j} - \pi\hat{K} - \hat{j}] = \frac{Ki}{R}[-2\hat{j} - \pi\hat{K}]$$

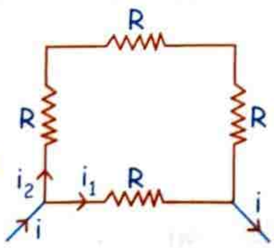


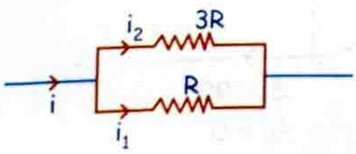
O is centre

33



(Square, length L)





$$i_1 = \frac{3R}{3R+R}\cdot i \Rightarrow i_1 = \frac{3i}{4}, i_2 = \frac{i}{4}$$

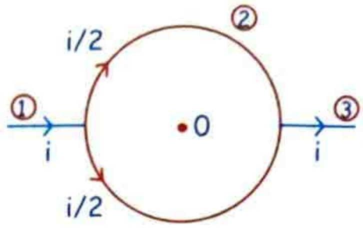
$$\overrightarrow{B_0} = 0 - \frac{Ki_2}{L/2}\left(\frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}}\right)\times 3 \text{ (अंदर)}$$

$$+ \frac{Ki_1}{L/2}\left(\frac{1}{\sqrt{2}} + \frac{1}{\sqrt{2}}\right) \text{ (बाहर)}$$

$$= \frac{K2\sqrt{2}}{L}\left[-3\frac{i}{4} + \frac{3i}{4}\right] = 0$$

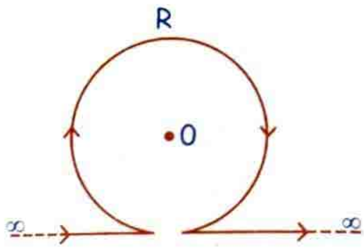
(After puting the value of i_1 and i_2 and solve)

34



$$\bar{B} = \bar{B}_1 + \bar{B}_2 + \bar{B}_3 = 0$$

35

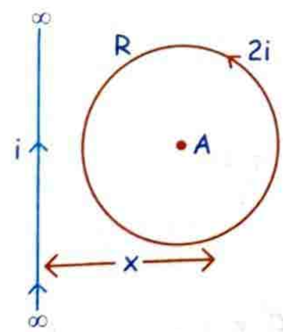


$$\overrightarrow{B_0} = \vec{B}_{\text{due to loop}} + \vec{B}_{\text{due to }\infty\text{ wire}}$$

$$B_0 = \frac{2Ki}{R}\odot + \frac{\mu_0 i}{2R}\otimes$$

$$= \left(\frac{2Ki}{R} - \frac{\mu_0 i}{2R}\right)\hat{K}$$

36 Find x/R if magnetic field at A is zero.

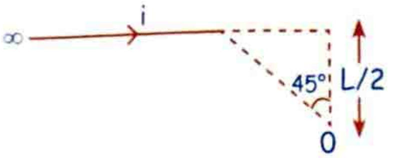


Sol. $\overrightarrow{B_A} = \vec{B}_{\text{due to }\infty\text{ wire}} + \vec{B}_{\text{due to loop}} = 0$

$$\frac{2Ki}{x} = \frac{\mu_0(2i)}{2R}$$

$$x = \frac{R}{2\pi}$$

37

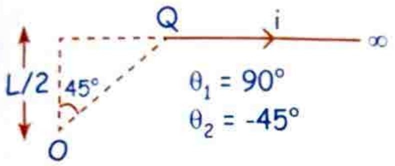


Sol. $\theta_1 = 90°$

$\theta_2 = -45°$

$$\vec{B}_{at\,'O'} = \frac{Ki}{L/2}[\sin 90° + \sin(-45°)] = \frac{2Ki}{L}[1 - 1/\sqrt{2}]$$

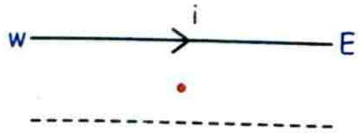
38 Find magnetic field at 0



$$\vec{B}_{at\,'O'} = \frac{2Ki}{L}[1 - 1\sqrt{2}] \odot$$

39 A wire is in air such that current is flowing in wire from west to east. Find direction of magnetic field at a point vertically below the wire.

Sol.

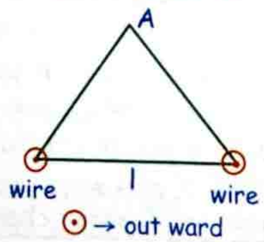


$\Rightarrow$ North

40 A wire is in air such that current is flowing in wire from south to North. Find direction of magnetic field at a point vertically above the wire.

$\Rightarrow$ East

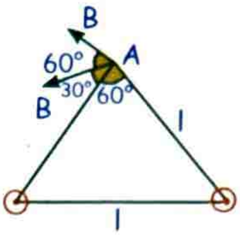
41 Find magnetic field at a point A which is at a distance. 'l' from both wires carrying current i. Field due to each wire at A is



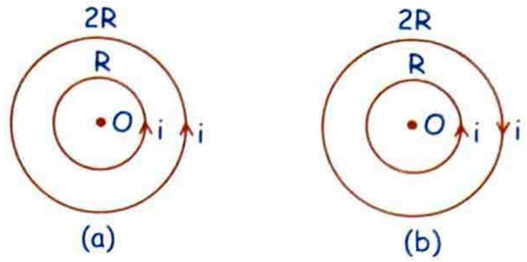
Sol. $B = \frac{2Ki}{\ell}$

net field is

$$(B_{net})_A = B\sqrt{3} = \frac{2Ki\sqrt{3}}{\ell}$$



42 Find magnetic field at centre O.

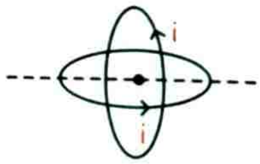


Sol. (a) $B_0 = \frac{\mu_0 i}{2R} + \frac{\mu_0 i}{4R}$ (b) $B_0 = \frac{\mu_0 i}{2R} - \frac{\mu_0 i}{4R}$

43 There are two current carrying ring having same current & same centre such that plane of both the ring are $\perp^{ar}$ [same Radius]. (R, i) find magnetic field at centre

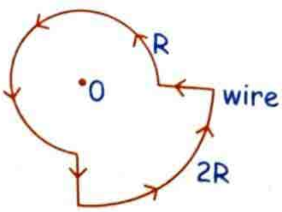
Sol. $B_{centre} = B\sqrt{2}$

$$B_{center} = \frac{\mu_0 i}{2R}\sqrt{2}$$



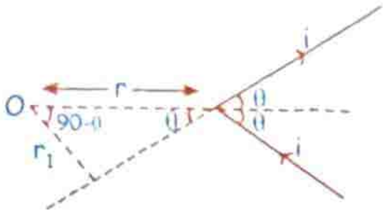
अगर 3 Ring hote to perpendicular to each other $\Rightarrow B_0\sqrt{3}$

44



Sol. $B_0 = \frac{Ki}{R}\left(\frac{3\pi}{2}\right) + \frac{Ki}{2R}\left(\frac{\pi}{2}\right)$

45 Find magnetic field at centre O.



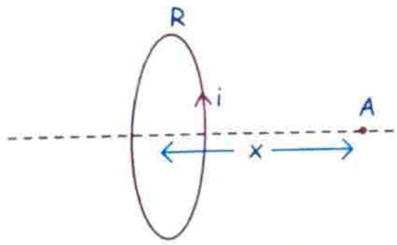
Sol. $r_1 = r\sin\theta$

$\theta_1 = 90$

$\theta_2 = -(90 - \theta)$

$$B_A = \frac{ki}{r\sin\theta}[\sin 90^\circ - \sin(90-\theta)] \times 2$$

Magnetic Field Due to Current Carrying Ring at A Point on Axis



$$\boxed{B_A = \frac{\mu_0 i R^2}{2(R^2 + x^2)^{3/2}}}$$

$x = 0$, $B = \mu_0 i/2R$

$x\uparrow$, $B\downarrow$

$x \to \infty$, $B = 0$

$$\to B_A = \frac{\mu_0 i R^2}{2(R^2+x^2)^{3/2}} \times N$$

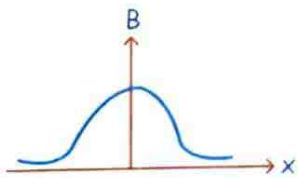
#SKC
If N is the no. of turn = इसका मतलब N ring है।

at $x = 0$

$B = \frac{\mu_0 i}{2R}$, (slope = 0)

B_{max} at $x = 0$

$B = \frac{\mu_0 i}{2R}$



46 Find magnetic field due to current carrying circular loop of radius R at a point on the axis at a distance $R\sqrt{3}$ from the centre.

Sol. $$B = \frac{\mu_0 i R^2}{2[R^2 + (R\sqrt{3})^2]^{3/2}} = \frac{\mu_0 i}{16R}$$

AMPERES LAW

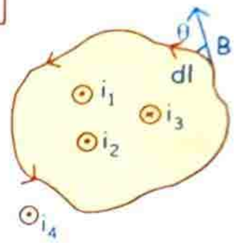
The line integral of magnetic field over a close loop ($\oint \vec{B}\cdot d\vec{l}$) is equal to the μ_0 times of sum of current crossing that loop.

$$\boxed{\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{enclosed}}$$

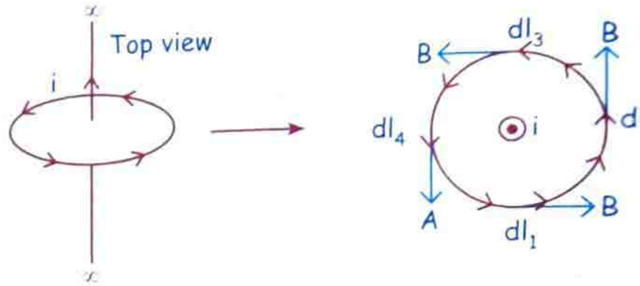
$\oint \vec{B}\cdot d\vec{l} = \mu_0 i_{enclosed}$

$\oint \vec{B}\cdot d\vec{l} = \mu_0(i_1 + i_2 - i_3)$

→ Mag. field due to all the wire



Verification (MF due to Infinite Wire)



$\oint \vec{B}\cdot d\vec{l} = B(dl_1 + dl_2 + \ldots\ldots \infty) = \mu_0\, i_{enclosed}$

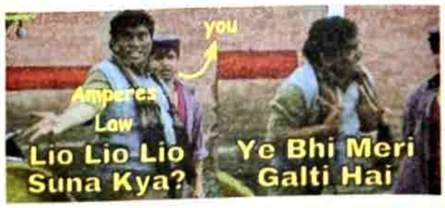
$B\, 2\pi r = \mu_0 i$

$B = \frac{\mu_0 i}{2\pi r} = \frac{2Ki}{r}$

काम की बाते

→ Ampere's Law Ki मदद se hr jagah Magnetic field nhi nikal skte.

→ क्या हो रहा है ये.... वहाँ gauss law हर जगह EF निकालने की guarante नही दे रहा और यहाँ AMPERE भाई हर जगह magnetic field निकालने की guarante नही दे रहा भाई ऐसा क्यों।



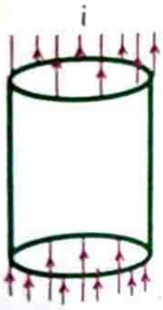
→ jaha Sachin Sir ne मदद nhi ki, aur mathematics fas gyi, waha Kaddu milega, aur sab mein बटेगा, lekin magnetic field nhi pata chlegi.

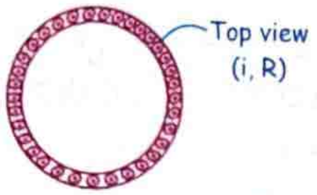
→ Ampere's loop ko चतुराई se मानना hai, esse मानो ki math solve ho ske. [$\theta = 0, 90^\circ, 180^\circ$]

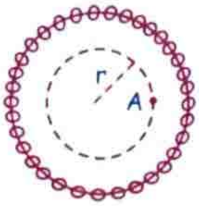
→ This law is valid, only when electric field is const. or current does not change wrt time.

अब हम ampere law की मदद से MF निकालना सिखेंगे rough copy पर इनको जरूर derive करे और इनके formula or graph भी याद करे।

MF DUE TO LONG HOLLOW CYLINDER (∞)





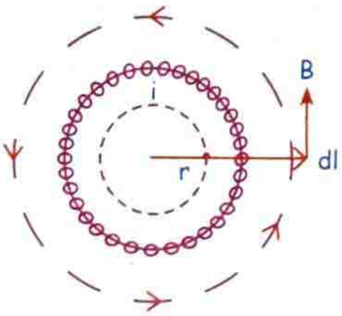


Inside ($r < R$)

$\oint \vec{B} \cdot d\vec{l} = \mu_0 i_{enclose}$

$B \int dl = \mu_0 \times 0$

$\boxed{B = 0}$



Outside ($r > R$)

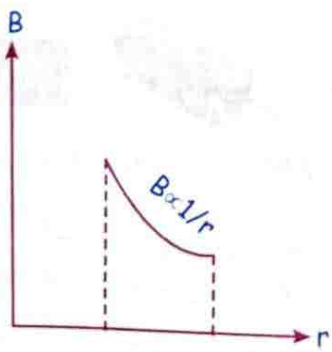
$\oint \vec{B} \cdot d\vec{l} = \mu_0 i_{enclose}$

$B 2\pi r = \mu_0 i$

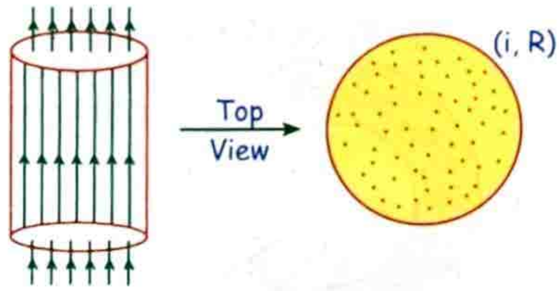
$B.2\pi r = \mu_0 i$

$B = \dfrac{\mu_0 i}{2\pi r} = \dfrac{2Ki}{r}$

Graph

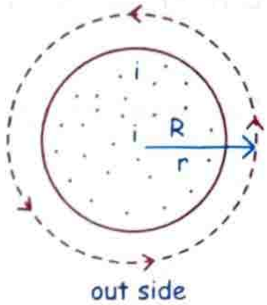


MF DUE TO LONG SOLID CYLINDER (∞)



Current Density $= J = \dfrac{i}{\pi R^2}$

Outside ($r > R$)



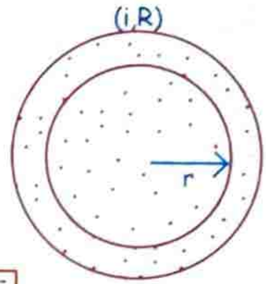
$\oint \vec{B} \cdot d\vec{l} = \mu_0 i_{enclosed}$

$B \int dl = \mu_0 i$

$B\ 2\pi r = \mu_0 i$

$\boxed{B = \dfrac{\mu_0}{2\pi r} = \dfrac{2Ki}{r}}$

Inside ($r < R$)

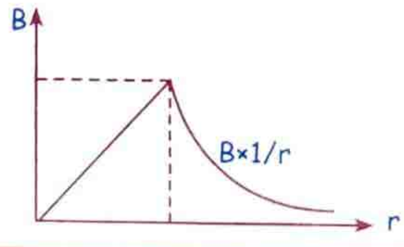


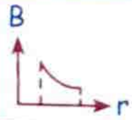
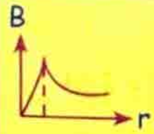
$\int \vec{B} \cdot d\vec{l} = \mu_0 i_{enclosed}$

$B.2\pi r = \mu_0 i_{अदर} \quad \left[i_{enclosed} = \dfrac{i\pi r^2}{\pi R^2} \right]$

$B = \dfrac{\mu_0 i r}{2\pi r^2} = \dfrac{2Kir}{R^2} \qquad \boxed{\vec{B} = \dfrac{\mu_0 \vec{J} \times \vec{r}}{2}}$

Graph



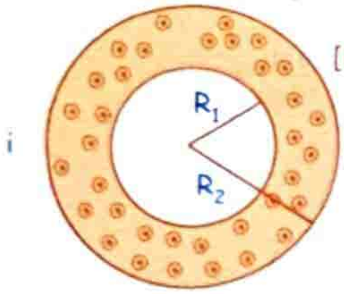
#SKC#			
	Outside	Inside	Graph
Hollow cylinder (Long)	$B = \dfrac{2Ki}{r}$	$B = 0$	
Solid cylinder (Long)	$B = \dfrac{2Ki}{r}$	$B = \dfrac{2Kir}{R^2} = \dfrac{\mu_0 \vec{J} \times \vec{r}}{2}$	

HOLLOW THICK LONG CYLINDER/PIPE

R_1 & R_2 . ($R_2 > R_1$)

[Top View]

[Dot shows current]



Current Density $\Rightarrow J = \dfrac{i}{\pi(R_2^2 - R_1^2)}$

For Points Outside Pipe

$B_{outside}$ for ($r > R_2$), $\quad B = \dfrac{2Ki}{r}$

For Points Inside Radius R_1

B_{inside} for ($r < R_1$), $\quad B = 0$

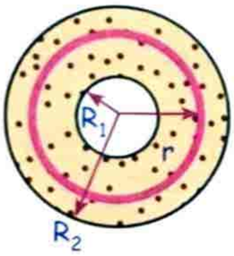
For Points between Radius R_1 & R_2

B at a pt. ($R_1 < r < R_2$)

$\Rightarrow B \cdot 2\pi r = \mu_0 i_{अंदर}$

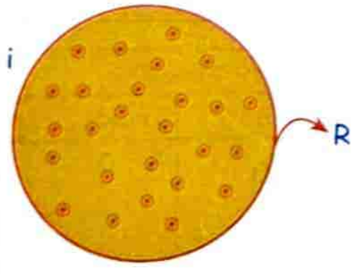
$B 2\pi r = \mu_0 J \times (\pi r^2 - \pi R_1^2)$

$B 2\pi r = \mu_0 \dfrac{i}{\pi(R_2^2 - R_1^2)} \times \pi(r^2 - R_1^2)$



(Solve and get B)

Q. Suppose we have a Long Solid Cylinder of current density $J = J_0 r$, of radius R, where r is radial distance from centre.



first find total current passing

$di = JdA$

$\int di = \int_0^R J_0 r 2\pi r \cdot dr \Rightarrow i = \dfrac{J_0 2\pi R^3}{3}$

For $r > R$ outside magnetic field

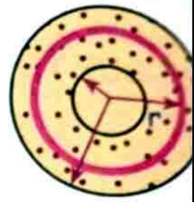
$B \cdot 2\pi r = \mu_0 i_{inside} = \mu_0 i$

$B = \dfrac{\mu_0 i}{2\pi r} = \dfrac{2Ki}{r}$

For Inside ($r < R$) $r = R/2$ पर

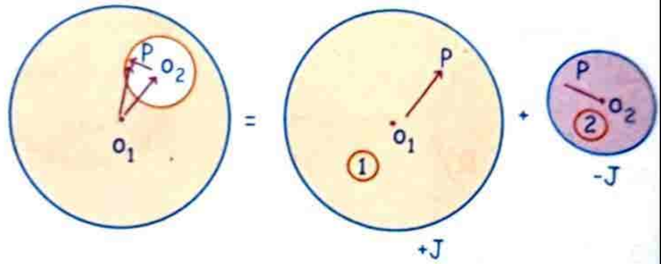
$B \cdot 2\pi r = \mu_0 i$ inside

$B \cdot 2\pi r = \mu_0 \left[\int_0^{R/2} J_0 r 2\pi r dr\right]$



MAGNETIC FIELD INSIDE LONG CYLINDER IN CAVITY

Long cylinder has centre O_1 & Cavity has centr O_2 consider a point p in cavity



$(\vec{B}_{net})_{at}$ 'P' $= \left[\vec{B}_{due\ to}(1) + \vec{B}_{due\ to}(2)\right]$ wire & wire 2 hav current densities +J & -J respectively

$= \dfrac{\mu_0 \times \vec{J} \times \overrightarrow{O_1P} - \mu_0 \vec{J}\overrightarrow{O_2P}}{2}$

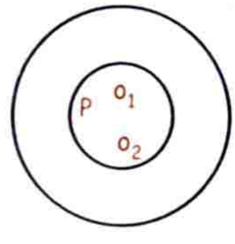
$$\boxed{B = \dfrac{\mu_0(\vec{J} \times \overrightarrow{O_1O_2})}{2}}$$

When O_1 and O_2 coincide

P = cavity मै आ गया

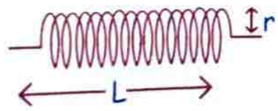
$\vec{B_p} = \dfrac{\mu_0 \times \vec{J} \times \overrightarrow{O_1O_2}}{2}$ 0

$\boxed{\overrightarrow{B_p} = 0}$



SOLENOID

→ Current carrying coil in a helical form (spring shap



→ for ideal solenoid - L >>> r

Assumption-

- B inside the ideal solenoid is axial and uniform.
- B outside the ideal solenoid is so weak, so that we neglect that value

→ It consists of a conducting wire which is tightly wound over a cylinderical frame in the form of helix.

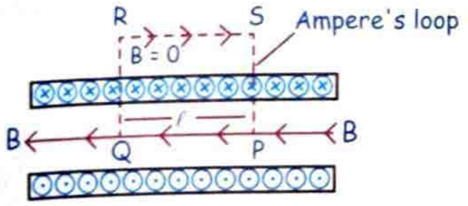
→ $\boxed{B = \mu_0 ni}$

n = number of turn per unit length

Proof:

$$\oint_{(PQRS)} \vec{B}\cdot\vec{dl} = \mu_0 i_{enclose}$$

$$\int_P^Q \vec{B}\cdot\vec{dl} + \int_Q^R \vec{B}\cdot\vec{dl} + \int_R^S \vec{B}\cdot dl + \int_S^P \vec{B}\cdot\vec{dl} = \mu_0 i$$



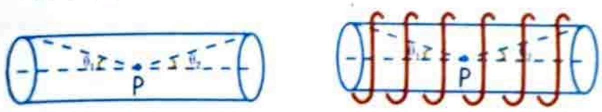
$$\Rightarrow Bl + 0 + 0 + 0 = \mu_0 i_{\text{वृ}}$$

$\boxed{B = \mu_0 ni}$

Q. A long solenoid cylinder carrying a current produces a magnetic field B along its axis. If the current is doubled and the no. of turns per cm is halved, the new value of magnetic field will be equal to:

Sol. $B = \mu_0 ni$, $B' = \mu_0 \frac{n}{2} \times 2i = \mu_0 ni$

$B' \Rightarrow B$

* 

$$B_P = \frac{\mu_0 ni}{2}[\cos\theta_1 + \cos\theta_2]$$

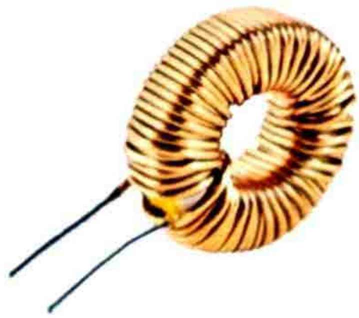
→ If solenoid is ∞ and point is well inside

$\theta_1 = 0,\ \theta_2 = 0 \Rightarrow \boxed{B_P = \mu_0 ni}$

→ If solenoid is ∞ length and point is near at one end.

$\theta_1 = 90°,\ \theta_2 = 0° \Rightarrow \boxed{B_p = \frac{\mu_0 ni}{2}}$

TOROID



If solenoid bend into circular shape and ends are joined.

$\boxed{B_{\text{inside toroid}} = \mu_0 \frac{N}{2\pi r} i = \mu_0 ni}$ $[n = N/2\pi r]$

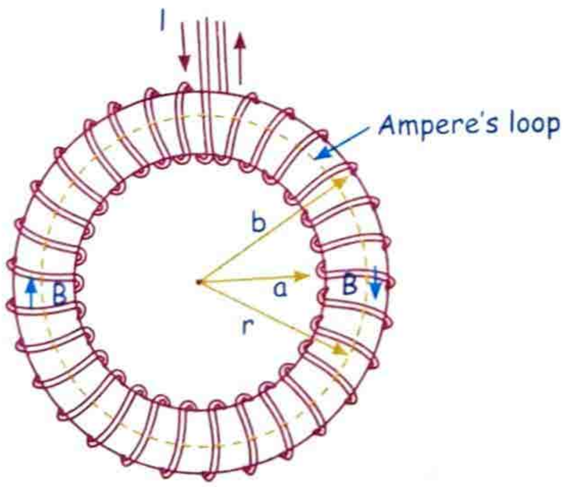
N → Total no. turns.

Proof:

$$\oint \vec{B}\cdot\vec{dl} = \mu_0 i_{enclose}$$

$$B \cdot 2\pi r = \mu_0 Ni$$

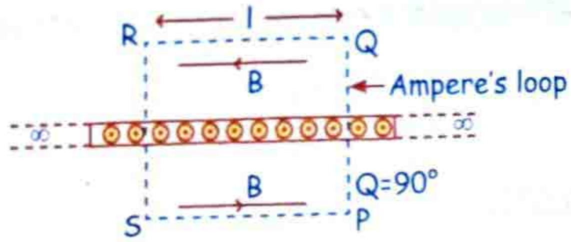
$$B = \mu_0 \frac{N}{2\pi r} i \qquad \Rightarrow N \to \text{No. of Turns}$$



MAGNETIC FIELD DUE TO CURRENT CARRYING ∞-SHEET.

Current flowing through sheet out of plane. We can find magnetic field near it using Ampere's Law

K → current per unit length.



$$\oint_{(PQRS)} \vec{B}\cdot d\vec{l} = \mu_0 i_{inside}$$

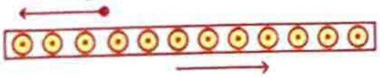
$$\int_P^Q \vec{B}\cdot d\vec{l} + \int_Q^R \vec{B}\cdot d\vec{l} + \int_R^S \vec{B}\cdot d\vec{l} + \int_S^P \vec{B}\cdot d\vec{l} = \mu_0 i_{inside}$$

$0 + Bl + 0 + Bl \Rightarrow \mu_0 Kl.$

$B = \dfrac{\mu_0 K}{2}$

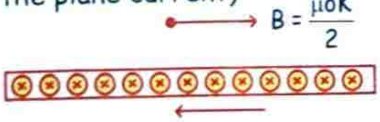
Magnetic field due to signle sheets
(K is current per unit length)

(a) $B = \dfrac{\mu o K}{2}$ (Out of plane current)



$B = \dfrac{\mu_0 K}{2}$

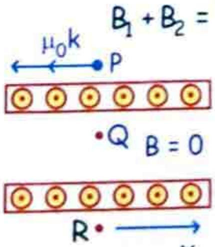
(b) (Into the plane current) $B = \dfrac{\mu o K}{2}$



$B = \dfrac{\mu_0 K}{2}$

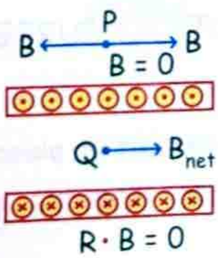
Magnetic field due to two plane sheets
(K is current per unit length)

(a) $B_1 + B_2 = \dfrac{\mu_0 K}{2} + \dfrac{\mu_0 K}{2}$



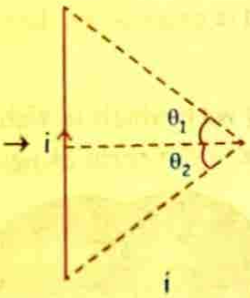
$B_{net} = \dfrac{\mu_0 K}{2} + \dfrac{\mu_0 K}{2}$

(b)

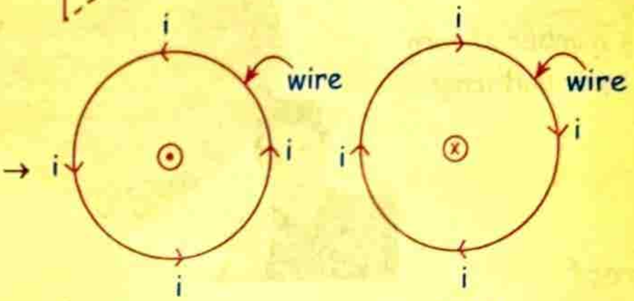


कामकी बाते

→ Exam se pahle ye box jarur dekh kar jaye

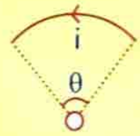


$B = \dfrac{Ki}{r}(\sin\theta_1 + \sin\theta_2)$



(ACW)	(CW)
$B_{centre} = \dfrac{\mu_0 i}{2R}$	$B_{centre} = \dfrac{\mu_0 i}{2R}$
बाहर ⊙	अंदर ⊗

→



$B_{centre} = \dfrac{Ki}{r}(\theta)$

$\theta \rightarrow$ radian

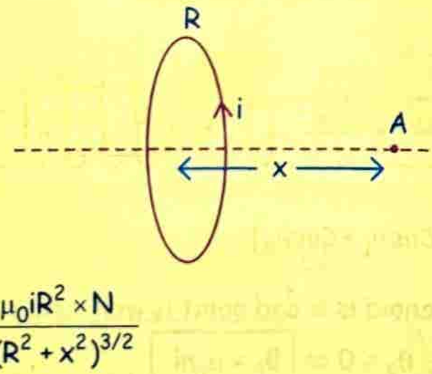
→ MF inside ideal solenoid $B = \mu_0 ni$
Here n is number of turn per unit length

→ MF inside toroid

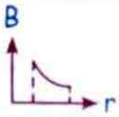
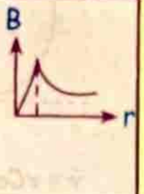
$\boxed{B_{inside\ toroid} = \mu_0 \dfrac{N}{2\pi r} i = \mu_0 ni}$ $[n = N/2\pi r]$
N → Total no. turns

→ MF due to infinite sheet $B = \dfrac{\mu_0 K}{2}$

→ MF due to correct carrying circular loop at a point on the axis.



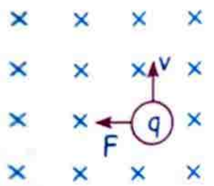
$$B = \frac{\mu_0 i R^2 \times N}{2(R^2 + x^2)^{3/2}}$$

	Outside	Inside	Graph
Hollow cylinder (Long)	$B = \frac{2Ki}{r}$	$B = 0$	
Solid cylinder (Long)	$B = \frac{2Ki}{r}$	$B = \frac{2Kir}{R^2}$ $= \frac{\mu_0 \vec{J} \times \vec{r}}{2}$	

→ Magnetic field inside Long cylinder in Cavity

$$\boxed{B = \frac{\mu_0(\vec{J} \times \overline{O_1O_2})}{2}}$$

Magnetic Force on Moving Charge in Uniform Magnetic field



→ $\vec{F} = q(\vec{v} \times \vec{B})$ ↳ with sign

→ $\vec{F} \perp \vec{v}$ and $\vec{F} \perp \vec{B}$

→ Dirx^n of force is given by F.L.H rule.

→ speed - constant (uniform circular motion)

→ If $\vec{v} \uparrow\uparrow \vec{B}$ or $\vec{v} \uparrow\downarrow \vec{B} \Rightarrow \vec{F} = 0$

$(\theta = 0°)$ $(\theta = 180°)$

अगर मे किसी charge particle Ko uniform magnetic field pe फेंक Ke maro, to usper magnetic force 'F = $\vec{F} = q(\vec{v} \times \vec{B})$' लगेगा और वो uniform circular motion करेगा। (For $\theta \neq 0°, \theta \neq 180°$)

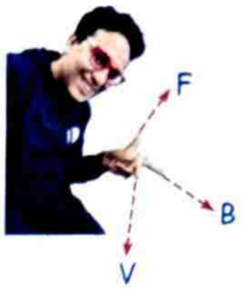
- $\vec{F} = q(\vec{v} \times \vec{B})$ ↳ with sign
- dirx^n of force nikalne ke तरीके -

1. $\hat{i}, \hat{j}, \hat{k}$.
2. Cross product
3. Fleming's Left Hand Rule. [F.L.H] and many more.

#SKC
अगर charge -ve hua to, force की dirx^n reverse krdo.

→ [f.L.H] → पिसतोल Method

Index finger → $\vec{B}$
Middle finger → $\vec{V}$
Thumb finger → $\vec{F}$
} q = +ve



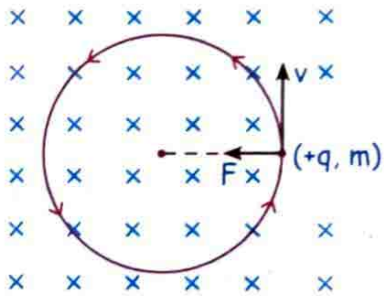
$$F = qvB = \frac{mv^2}{R} \Rightarrow R = \frac{mv}{qB}$$

* Time period $T = \frac{2\pi m}{qB}$

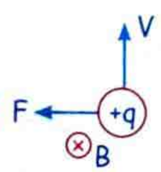
$$\left[T = \frac{2\pi R}{v} = \frac{2\pi mv}{vqB} = \frac{2\pi m}{qB}\right]$$

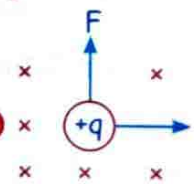
Here time period is independent on speed

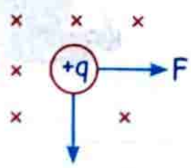
$$\omega = \frac{2\pi}{T} = \frac{qB}{m}$$

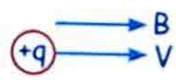


Q. Show the direction of magnetic force ($\vec{F}$) on charge particle moving in magnetic field $\vec{B}$.

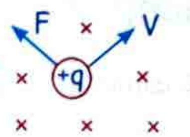
1. 

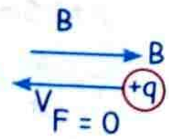
2. 

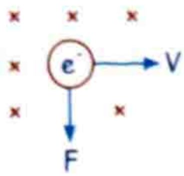
3. 

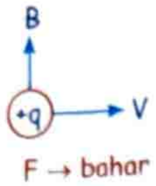
4. 

$\theta = 0°, F = 0$

5. 

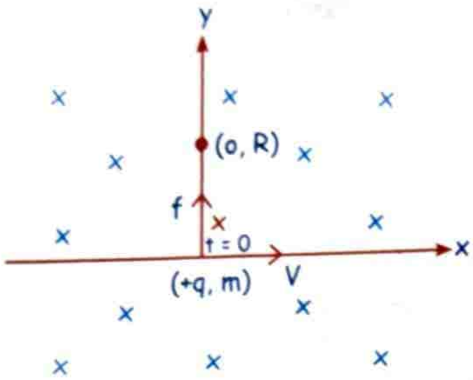
6. 

7 

8 

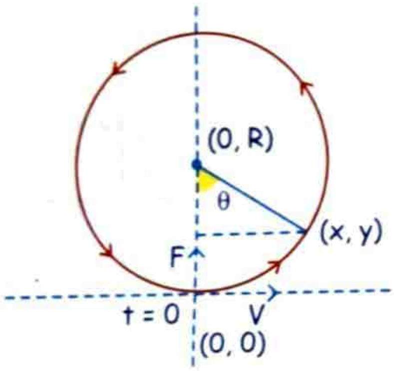
Q. A particle of charge and mass (q, m) is projected along +ve x-axis from origin with velocity $\vec{v}$ at t = 0. Calculate (a) center of the circle., (b) position $\vec{r}$, velocity ($\vec{v}$) and acceleration $\vec{a}$ at time t.

Sol.



(a) Center of Circle = (0, R) = $\left(0, \frac{mv}{qB}\right)$

(b)



$\vec{r} = x\hat{i} + y\hat{j}$

$x = R\sin\theta,\ y = R - R\cos\theta$

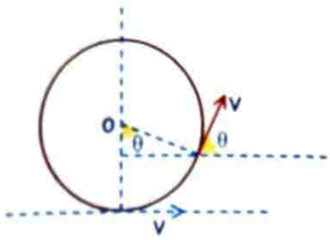
$\vec{r} = (R\sin\theta)\hat{i} + (R - R\cos\theta)\hat{j}$

Abe $\vec{r}$ ko time ke respect me differentiate karke velocity or velocity ko time ke respect me differentiate karke answer to nikal loge na... Acha chalo me likh deta hu niche

$\vec{r} = R\sin\omega t\hat{i} + (R - R\cos\omega t)\hat{j}$

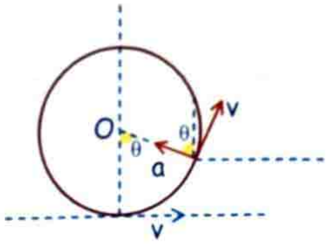
$\vec{v} = \frac{d\vec{r}}{dt} = \omega R\cos\omega t\hat{i} + (R\omega\sin\omega t)\hat{j}$

$\theta = \omega t,\ \theta = \frac{qB}{m}t$



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

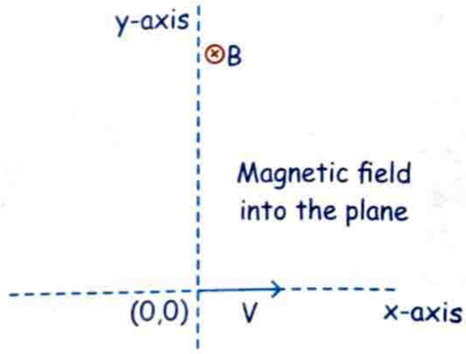
$\vec{v} = v\cos\omega t\hat{i} + v\sin\omega t\hat{j}$



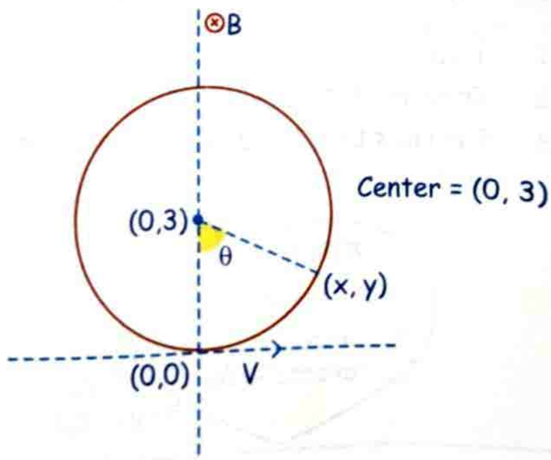
$\vec{a} = -a\sin\theta\hat{i} + a\cos\theta\hat{j}$

Q. A particle is projected with velocity 8 m/s as shown in a magnitic field $\vec{v}$. Calculate (a) radius, (b) time period, (c) postion vector at time t.

Given: q = +2C, m = 3Kg, B = 4T, V = 8 m/s



Sol. Path of particle will be a circle



(a) $R = \frac{mv}{qB} = \frac{24}{8} = 3$

(b) $T = \frac{2\pi R}{v} = 2 \times \pi \times \frac{3}{8} = \frac{3\pi}{4}$

$\omega = \frac{2\pi}{T} = \frac{8}{3}$

$f = \frac{4}{3\pi} \Rightarrow \frac{1}{T}$

$x = R \sin\theta$

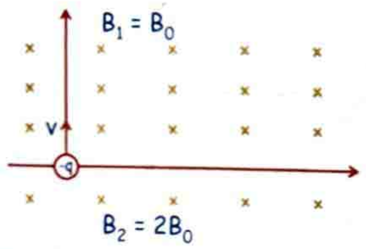
$y = R - R\cos\theta$

$\theta = \omega t$

(c) $\vec{r} = \left(3\sin\frac{8}{3}t\right)\hat{i} + \left(3 - 3\cos\frac{8}{3}t\right)\hat{j}$

max. y - co-ordinate = 2R

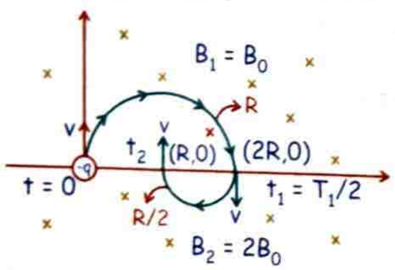
Q. Magnetic field above x-axis is B_0 while below x-axis is to $2B_0$ a charge particle $-q$ is projected as shown in figure.



(a) When & where particle will cross x-axis.

(b) Average speed from t = 0 to when particle cross x-axis 2nd time.

Sol. Radius of circle in two parts will be different



(a) Time period in two parts will be T_1 and T_2 respectively. Particle will cross x-axis at t_1 and t_2.

$T_1 = \frac{2\pi m}{qB}, T_2 = \frac{2\pi m}{q2B}$

$t_2 = \frac{T_1}{2} + \frac{T_2}{2}$

$R_1 = \frac{mv}{qB} = R$

$R_2 = \frac{mV}{q2B} = \frac{R}{2}$.

(b) $t = 0 \rightarrow t = t_2$

Dist. $= \pi R_1 + \pi R_2$

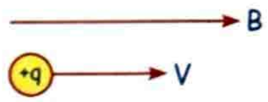
$$\langle speed \rangle = \frac{\pi R_1 + \pi R_2}{\frac{T_1}{2} + \frac{T_2}{2}} = v$$

$$\langle velocity \rangle = \frac{R\hat{i}}{\frac{T_1}{2} + \frac{T_2}{2}}$$

$$\frac{mv/qB}{\frac{\pi m}{qB} + \frac{\pi m}{q2B}} = \frac{2v}{3\pi}$$

PATH OF PARTICLE IN UNIFORM MAGNETIC FIELD

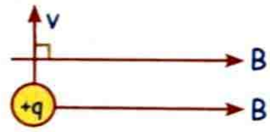
1 When $\theta = 0°$



$\Rightarrow \theta = 0°, f = 0, \vec{v} \rightarrow$ const. straight line path.

Velocity will be constant and particle moves on straight line.

2 When $\theta = 90°$



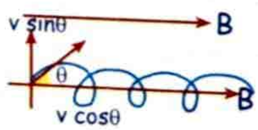
$\Rightarrow F = qvB\sin 90° = qvB, r = \frac{mv}{qB}$

Center → अंदर, f → अंदर,

Circular Motion

Speed will be constant and particle moves on circular part.

3 When θ is different from 0, 90°, 180°



[helical path → spring जैसा, solenoid जैसा]

Particle moves on helical path.

Pitch = $v\cos\theta \times T$

$r = \frac{mv}{qB}$

LORENTZ FORCE (Ab Ham MF Ke Sath EF Bhi Lagayege)

$$\vec{F}_{net} = \vec{F}_m + \vec{F}_e$$

$$\underbrace{\vec{F}_{net}}_{\text{Lorentz force}} = \underbrace{q(\vec{V}\times\vec{B})}_{\text{Magnetic force}} + \underbrace{q\vec{E}}_{\text{Electric force}}$$

Lorentz force ⇓ [Frame Independent] | Magnetic force ⇓ [Frame depend] | Electric force ⇓ [Frame depend]

Q. A particle's charge (q), velocity ($\vec{v}$) are given in a region. Electric field ($\vec{E}$) and magnetic field ($\vec{B}$) are given as

$\vec{E} = 10\hat{i}$, $\vec{B} = 20\hat{j}$, $v = 3\hat{i} + 4\hat{j}$, $q = +2C$

What is net force on charge?

Sol. $\vec{f}_{net} = ?$

$\vec{f}_{net} = q(\vec{V}\times\vec{B}) + q\vec{E}$

$\vec{F}_{net} = 2[(3\hat{i}+4\hat{j})\times 20\hat{j}] + 2\times 10\hat{i}$

$= 2[60\hat{k}] + 20\hat{i}$

MOTION OF CHARGED PARTICLE IN BOTH ELECTRIC AND MAGNETIC FIELD

1 Particle has initial velocity v

$\vec{f}_{net} = q(\vec{V}\times\vec{B}) + q\vec{E}$

→ Speed up, $a = qE/m$

→ St. line path

→ E.f ne WD kiya

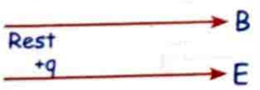
in time

$t = 0 \rightarrow t = t_0$

$(WD)_{E.F} + \cancel{(W.D)}^{0}_{mag.force} = \Delta K.E$

$s = vt_0 + \frac{1}{2}at_0^2$

2 Particle at rest initially



→ Straight line

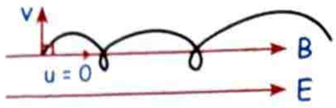
→ Speed up, $a = qE/m$

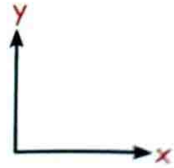
→ $(WD)_{E.F} = \Delta K.E$

$t = 0 \longrightarrow t = t_0$

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

3 Particle has initial velocity perpendicular to both electric field and magnetic field





$R = \frac{mv}{qB}, T = \frac{2\pi m}{qB}, a_x = \frac{qE}{m}$

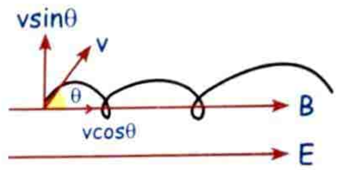
$(pitch)_1 = (t = 0 \rightarrow t = T)$ (जितना चला)

$= 0 + \frac{1}{2}\cdot\frac{qE}{m}T^2$

$(pitch)_2 = (x_{t=0\rightarrow t=2T}) - (x_{t=0\rightarrow t=T})$

$= \frac{1}{2}a(2T)^2 - \frac{1}{2}aT^2$

4 Particle has initial velocity at and angle θ to B and E



$\rightarrow r = \frac{mv\sin\theta}{qB}$

$\rightarrow T = \frac{2\pi m}{qB}$

→ inc. pitch.

$(pitch)_1 = (t = 0 \rightarrow t = T)_{(x \text{ mai चला})}$

$= v\cos\theta T + \frac{1}{2}\left(\frac{qE}{m}\right)T^2$

$(pitch)_2 = (t = T \rightarrow t = 2T)_{x \text{ mai चला}}$

$= x_{(t=0\rightarrow t=2T)} - x_{(t=0\rightarrow t=T)}$

$= \left[v\cos\theta\cdot 2T + \frac{1}{2}a(2T)^2\right] - \left[v\cos\theta + \frac{1}{2}aT^2\right]$

$= v\cos\theta\cdot T + \frac{1}{2}a[(2T)^2 - T^2]$

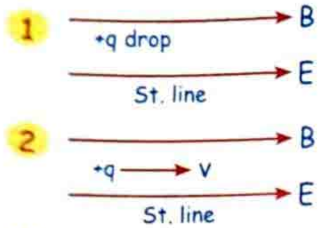
$(pitch)_5 = x_{t=0\rightarrow t=5T} - x_{t=0\rightarrow t=4T}$

$= [v\cos\theta\cdot 5T + \frac{1}{2}a(5T)^2] - [v\cos\theta\cdot 4T + \frac{1}{2}a(4T)^2]$

$= (v\cos\theta)T + \frac{1}{2}a[(5T)^2 - (4T)^2]$

$(pitch)_{13} = (v\cos\theta)T + \frac{1}{2}a[(13T)^2 - (12T)^2]$

If $\vec{E}$, $\vec{B}$ both are present, cases where charge particle will move in st. line path.



This is very important article jo advance me kafi bar pucha gaya he

3 Motion under perpendicular electric and magnetic field

$$\cancel{\vec{f}_{net}}^{\,0} = q(\vec{V} \times \vec{B}) + q\vec{E}$$

$$\boxed{\vec{E} = -(\vec{V} \times \vec{B})}$$

$\vec{E} \perp \vec{V}, \vec{E} \perp \vec{B}$

Q. A charge particle (m,q) is projected with velocity v along the +y Axis inside the magnetic filed Bo $\hat{i}$. In which direction E.F must apply so that particle move undeviated / st. line path / unaccelerated.

Find magnitude of E.F.

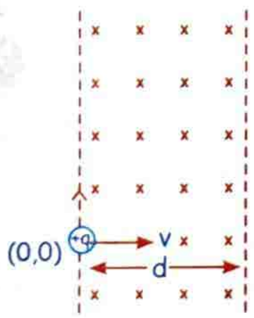
Sol. $f = q(\vec{V} \times \vec{B}) + q\vec{E} = 0$

$\vec{E} = -\vec{V} \times \vec{B} = -(\hat{j} \times \hat{i}) = +\hat{k}$

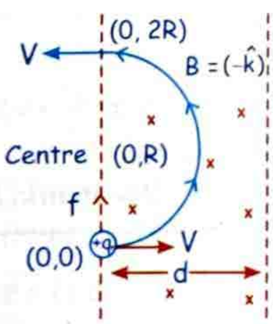
$E = VB \sin 90°$

$E = VB$

Q. Given $mv/qB < d$, find the time inside magnetic field and distance.



Sol. Particle will move in circular path



$\rightarrow R = mv/qB$

$\rightarrow R < d \Rightarrow \dfrac{mv}{qB} < d$

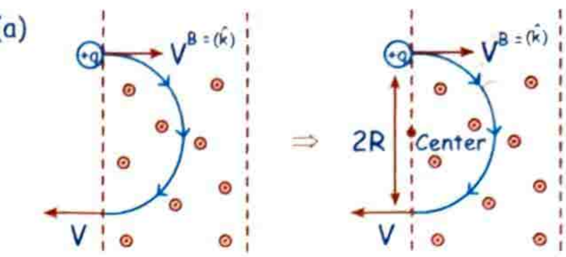
$\rightarrow \Delta\vec{p} = 2mv(-\hat{i})$

$\rightarrow$ time spend inside magnetic field $= T/2 = \dfrac{\pi m}{qB}$

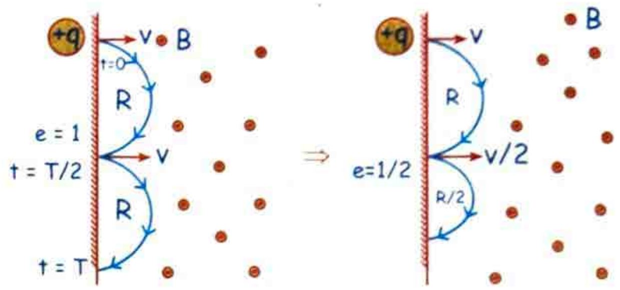
$\rightarrow$ Dist travel in magnetic field $= \pi R$

Motion of charge particle in uniform magnetic field

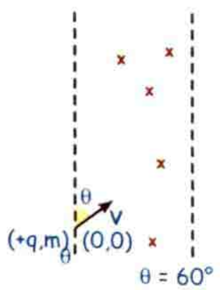
(a)



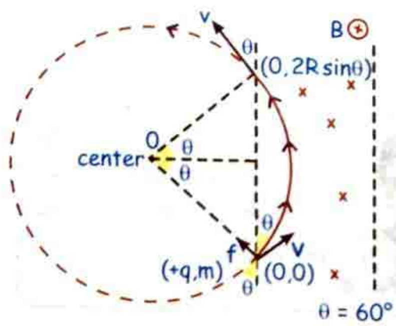
(b) SSSQ With reflecting surface



Q. A charge particle enters at an angle $\theta = 60°$ inside perpendicular magnetic field B as shown, moves along circle. Find (a) time spent inside, (b) average velocity.

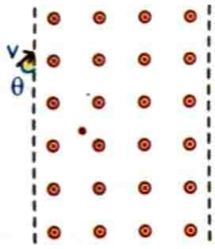


Sol.



- $R = mv/qB$
- angle rotated inside $B = 2\theta, = 120° \Rightarrow 2\pi/3$
- Time spend in magnetic field, $\theta = \omega t \Rightarrow t = \frac{(2\pi/3)}{\omega}$
  $t = T/3$
- Dist. travel inside B. Angle $= 2\pi/3 = \text{Arc}/R$.
  Arc. $= 2\pi R/3 = 2\pi mv/3qB$
- Dist. = speed × time $= V \times T/3 = \frac{V \cdot 2\pi m}{3qB}$
- $\Delta\vec{p} = 2mv\sin\theta(-\hat{i})$
- $<\vec{a}> = \frac{2v\sin\theta}{T/3}$
- $\langle speed \rangle = v, <\vec{v}> = \frac{2R\sin\theta\hat{j}}{T/3}$

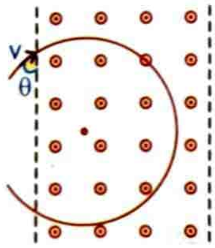
Q. A charge particle +q enters a perpendicular magnetic field as shown. Calculate (a) time spent inside magnetic field, (b) distance in B, (c) change in momentum.



Sol. Particle will move in circular path inside magnetic field

- $R = mv/qB$
- angle rotated inside $B = 360°-60° = 300 = 5\pi/3$
- Time spend in B

  $\theta = \omega t \Rightarrow 5\pi/3 = \frac{qBt}{m}$



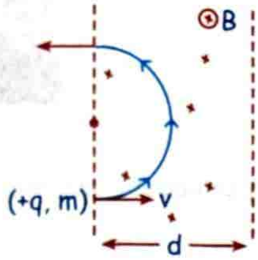
- Dist travel in B.

  $= vt =$ or $\theta \times R$.
- $\Delta\vec{P} = 2mv\sin 30°(-\hat{i}))$

Next queation is Very very very important ye JEE Advance me 5 bar pucha he

बेशर्म QUES^N:

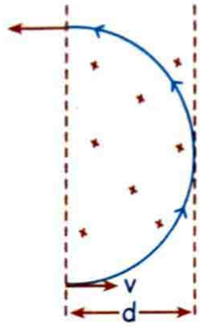
1 180° deviation of charge particle.



d > R

$(\Delta P) = 2mv = max$

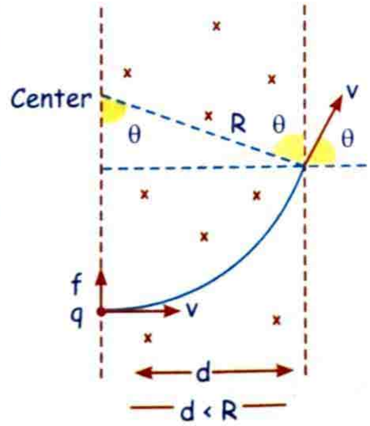
2



$\Rightarrow d = R$

$(\Delta P) = 2mv = max$

3 Deviation of charge particle by θ.



रूक भाई जा कहाँ रहा है पहले इसकी अच्छे से practice कर और Ja के Question लगा।

$\vec{V_f} = v\cos\theta\hat{i} + v\sin\theta\hat{j}$

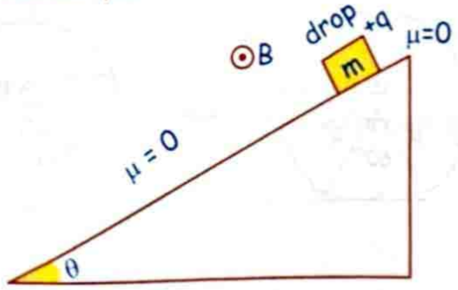
$\vec{V_i} = V\hat{i}$

$d = R\sin\theta$

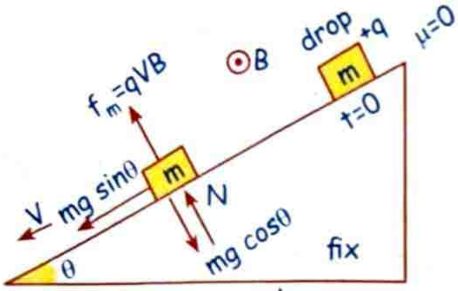
$\sin\theta = \frac{d}{R}$

$\vec{v}_i = v\hat{i}$
$\vec{v}_f = v\cos\theta\hat{i} + v\sin\theta\hat{j}$
$\Delta\vec{v} = \vec{v}_f - \vec{v}_i$
$\theta =$ Deviation in MF

Q. Find when particle will loose the contact



Sol. जैसे - 2 नीचे ⇒ $V\uparrow$, $f_m\uparrow$



$v = u + at$
$= 0 + g\sin\theta t$

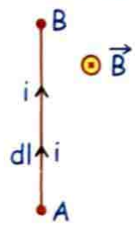
Magnetic force $(f_m) = mg\cos\theta$ (contact loose)
$N = 0$

$qVB = mg\cos\theta$

$q \times g\sin\theta t \,.\, B = mg\cos\theta$

$$t = \frac{mCot\theta}{qB}$$

MAGNETIC FORCE ON CURRENT CARRYING WIRE INSIDE MAGNETIC FIELD



Force on small element dl

$\vec{df} = i(\vec{dl} \times \vec{B})$

AB → st. wire, $\vec{\ell}$, (AB = ℓ)

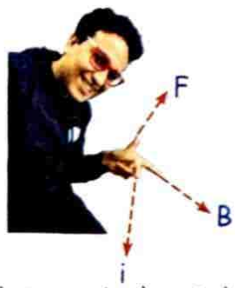
$\vec{f}_{net} = i(\vec{\ell} \times \vec{B})$

Dirx^n → $\hat{i}, \hat{j}$ wala

→ Cross product

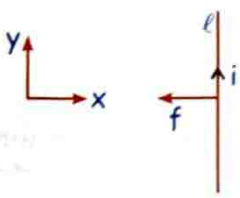
→ पिस्तौल

- → Index finger - B
- → Middle finger - i
- → Thumb - F



अबे यह तो moving charge पर लगने वाले force के जैसा ही है बस V की जगह i आगया वैसे इसको कुछ बच्चे right hand palm rule से भी कर लेते है।

Q. Find force on this wire -

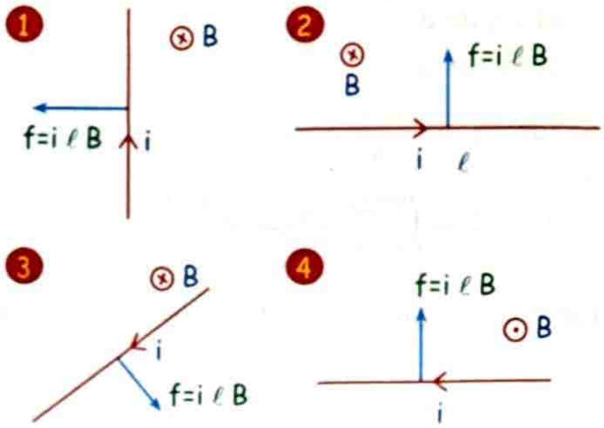


Sol. $\vec{f} = i(\vec{\ell} \times \vec{B})$

$f = i\ell\sin 90°$

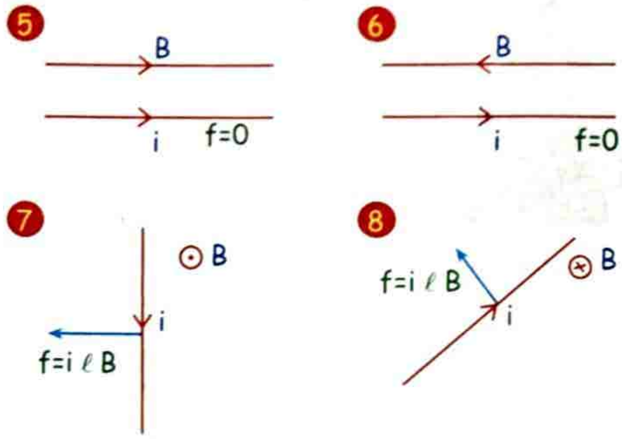
$\vec{f} = i\ell B(-\hat{i})$

Q. Find force on wire in the figures as shown.

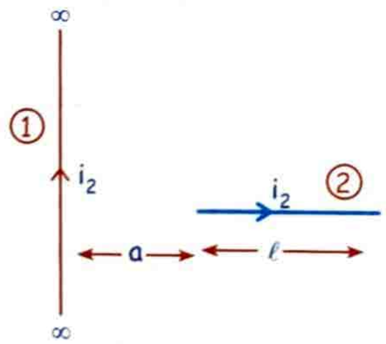


#SKC

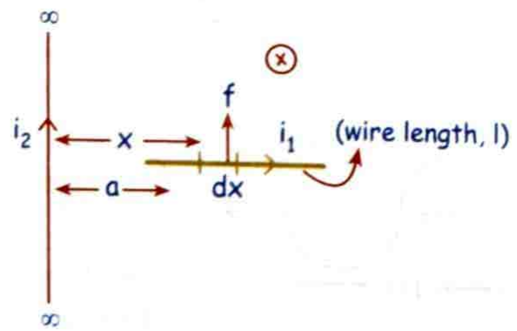
जैसे पहले +ve moving charge particle पर force लगता था वैसे ही current की तरफ भागता हुआ +ve charge मान लो।



Q. Find force applied by ∞ wire '1' on wire '2'



Sol.



Force on dx

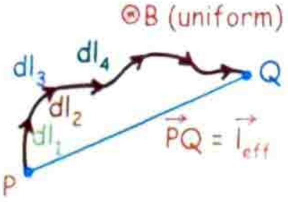
$df = i_1\, dx\, B$

Total force

$$\int df = \int i_1 \cdot dx \cdot \frac{2Ki_2}{x}$$

$$f_{net} = 2Ki_1i_2 \int_a^{a+l} \frac{dx}{x} = 2Ki_1i_2 \ln\left(\frac{a+l}{a}\right)$$

Magnetic force on उटपटांग wire in uniform M. Field.



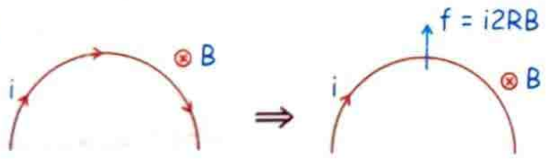
$$\vec{f}_{net} = i(\vec{dl_1} \times \vec{B}) + i(\vec{dl_2} \times \vec{B}) + \cdots \infty$$

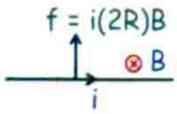
$$= i[\vec{dl_1} + \vec{dl_2} + \vec{dl_3} + \cdots \infty) \times B$$

$$\vec{F}_{net} = i(\vec{l}_{eff.} \times \vec{B})$$

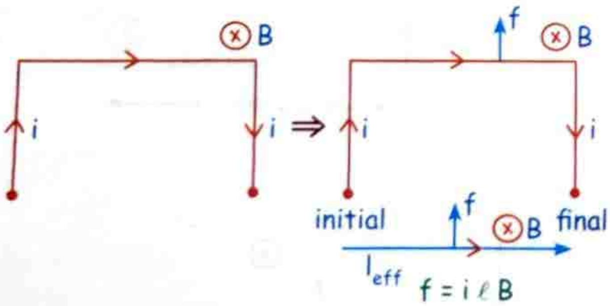
Q. Find magnetic force on the given wires in the given magnetic field.

1

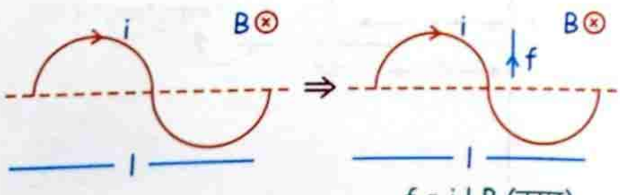




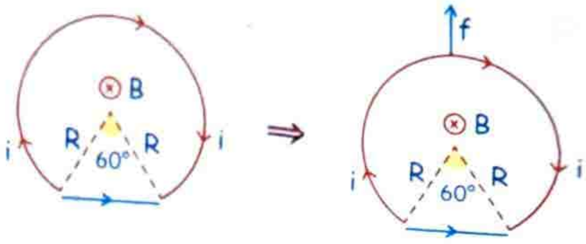
2



3

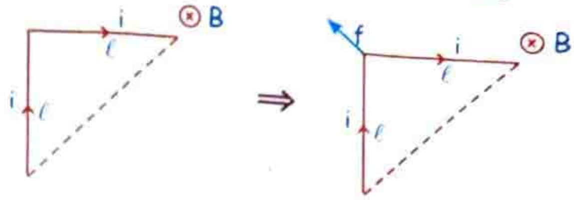


4



f = i R B

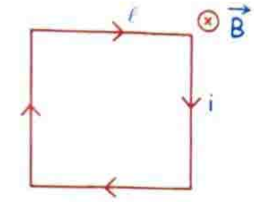
5



$f = i\ell\sqrt{2}B$

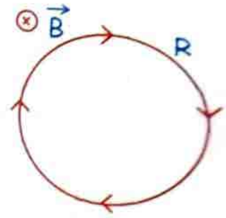
6 Both square, circular and heart wire are inside uniform magnetic field

(a)



$\vec{l}_{eff} = 0 \therefore \vec{f}_{net} = 0$

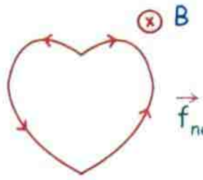
(b)



$\vec{\ell}_{eff} = 0$

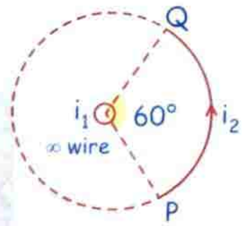
$\therefore \vec{f}_{net} = 0$

(c)



$\vec{f}_{net} = 0$

Q. Force by ∞ wire on wire PQ

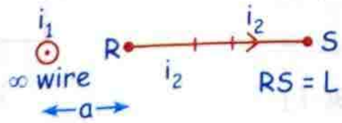


Sol. [हर जगह angle between ($\vec{B}_1$ and $\vec{dl}$) θ = 0°]

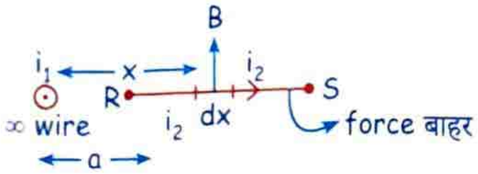
$\vec{f} = (\vec{dl} \times \vec{B})i = id\ell\; B\sin\theta$

$f = 0 \Rightarrow \theta = 0°$

Q. Find the magnetic force on RS carrying current (i_2) due to current (i_1) carrying infinite wire



Sol. Consider a small length dx at a distance x from i_1.

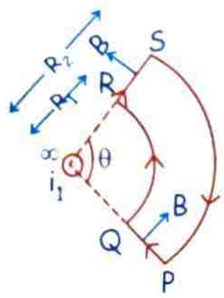


Magnetic force on RS will be

$$f_{net} = \int df = \int_a^{a+L} i_2 . dx . B = \int_a^{a+L} i_2 . dx . \frac{2Ki_1}{x}$$

$$\Rightarrow 2Ki_1 . i_2 \ln\left(\frac{a+\ell}{a}\right)$$

Q Find force applied by ∞-wire on wire PQRS.



Sol. Force on QR = 0

Force on SP = 0

Force on RS = from above question

$$= 2Ki_1i_2 \ln\left(\frac{R_2}{R_1}\right) \quad (\text{बाहर} \odot)$$

$$\text{Force on PQ} = 2Ki_1i_2 \ln\left(\frac{R_2}{R_1}\right) \quad (\text{अंदर} \otimes)$$

$\therefore f_{net} = 0$

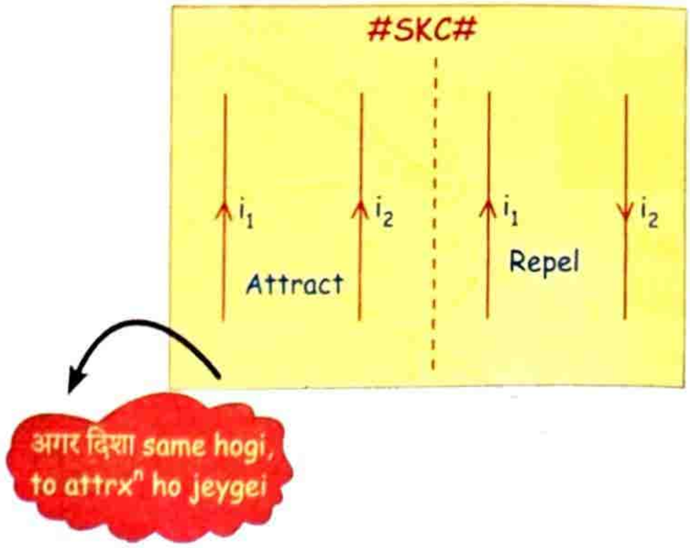
सच बता तुने उट-पटांग wire वाला concept लगाया ना।

Force b/w two long parallel wire

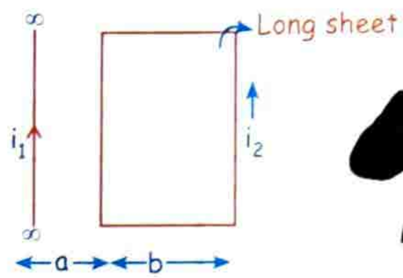
Force on wire (2) due to wire (1) $= i_2 \cdot \ell \cdot \frac{2Ki_1}{r}$

Force per unit length

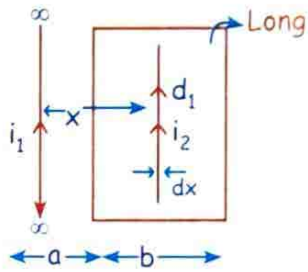
$= \frac{f}{\ell} = \frac{2Ki_1i_2}{r}$ } एक Meter ke wire pr force hai!



Q. (Irodov) find the force per unit length of interaction between infinite wire carring current i_1 and long sheet carring current i_2 as shown



Sol.



$b \rightarrow i_2$

$1 \rightarrow i_2/b$

$dx \rightarrow \frac{i_2}{b} dx = di$

Force per unit length on strip of width dx carring current $\frac{i_2}{b} dx = di$

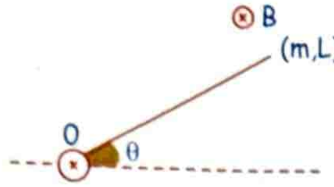
$$\underset{\text{(per unit length)}}{df} = \frac{2Ki_1 di}{x}$$

Net force per unit length will be

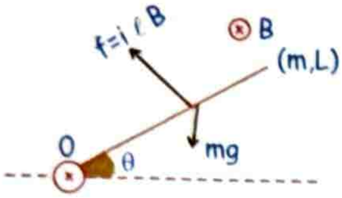
$$\underset{\text{(Per unit length)}}{f_{net}} = \int_a^{a+b} \frac{2Ki_1i_2 dx}{x \cdot b}$$

$$\Rightarrow \frac{2Ki_1i_2}{b} \ln\left(\frac{a+b}{a}\right)$$

Q. A wire carring current i is resting at angle θ with horizontal as shown in figure. Magnetic field B is into the plane. Calcualte hinged force on wire hinged at one and O on ground.



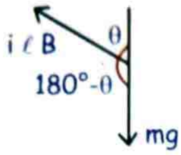
Sol.



$\tau_0 = 0$

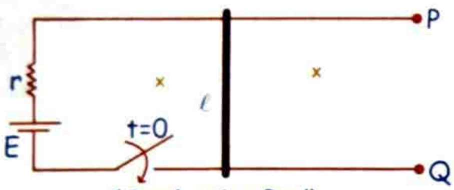
$mg\frac{L}{2}\cos\theta = ilB\cdot\frac{L}{2}$

hinged force $= \vec{F}_h = \vec{F}_g + \vec{f}_m$



रेल वाला **Ques"**

Q. Rails lie on horizontal plane and magnetic field is in vertically downward as shown in the figure. A rod of length L can slide on the rail. Circuit is switch on at t = 0. Find (a) and (b)



(Conducting Rod)

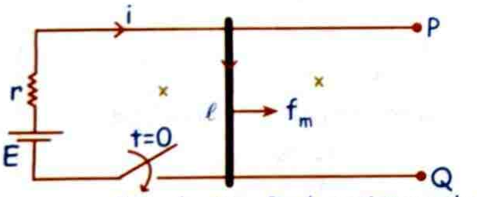
(a) if पटरी are rough, μ.

find μ_{min} so that rod remain at rest.

(b) If $\mu = \frac{\mu_{min}}{2}$, find acc. of wire.

(c) if पटरी are smooth speed of rod release at PQ.

Sol. (a) Magnetic force



(Conducting Rod, resistanceless)

Force on the rod

$F = ilB = \frac{E}{r}l\cdot B$

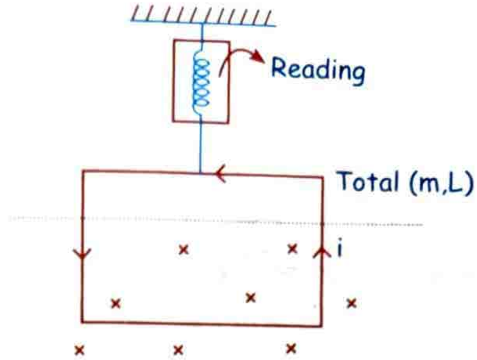
Magnetic force on the rod = Force of friction

$F_m = i\,\ell\,b = \mu mg \qquad \mu_{min} = \frac{ilB}{mg}$

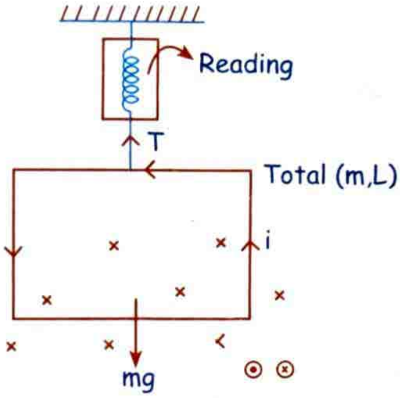
(b) $a = \frac{i\ell B - f}{m} = \frac{i\ell B - \mu N}{m} = \frac{i\ell B - \frac{i\ell B}{2mg}\cdot mg}{m} = \frac{i\ell B}{2m}$

(c) $V^2 = 0 + 2\cdot\frac{ilB}{m}\cdot x_0$

Q. Find the reading of spring balance as shown in the figure if mass of square is m and side L.



Sol.

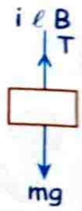


$T + i\,\ell\,B = mg$

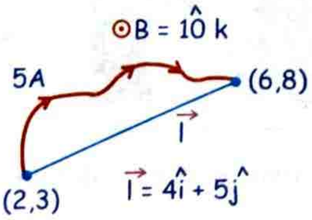
$T = mg - i\,\ell\,B$

if current dirx^n reverse-

$T_f = mg + i\,\ell\,B$



Q. Find Magnetic force on wire

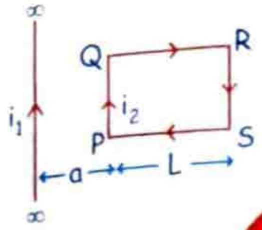


Sol. $\vec{f} = i(\vec{l}\times\vec{B})$

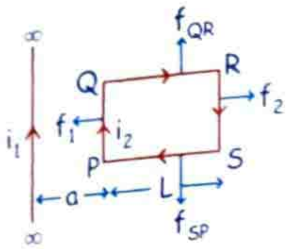
$\vec{f} = 5(4\hat{i} + 5\hat{j})\times 10\hat{k}$

$\vec{F} = 50(-4\hat{j} + 5\hat{i})$

Q. Find force applied by ∞ wire on rectangular loop $(L \times b)$. PQRS.



Sol.



#SKC
यहाँ उटपटांग वाला Method nhi lga skte. Kyonki- M.F → Non-uniform है।

Force on PQ due to ∞ wire

$$= \frac{2Ki_1i_2b}{a} = f_1(\text{left})$$

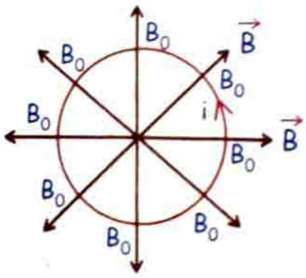
force on RS due to ∞ wire.

$$= \left(\frac{2Ki_1i_2}{a+L}\right)b(\text{Right})$$

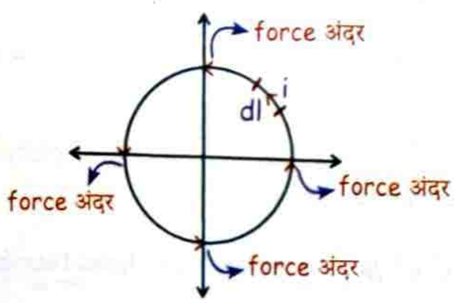
$$\vec{f}_{net} = \vec{f}_{PQ} + \vec{f}_{RS} + \cancel{\vec{F}_{QR}} + \cancel{\vec{F}_{SP}}$$

$$\vec{F}_{net} = \frac{2Ki_1i_2}{a}b - \frac{2Ki_1i_2}{(a+b)}b\,[\text{Attraction}]$$

Q. A current carrying circular loop is placed on x - y plane in a two dimensional magnetic field. Strength of M.F on pheripheri of loop is B_0. Find magnetic force on wire.



Sol. Force on small element $d\ell$



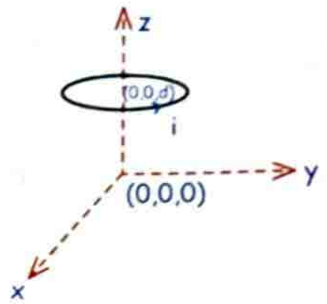
$dF = i.\,d\ell\,.\,B$ [अंदर ⊙]

Total force $f_{net} = \int dF = \int i.dl.B$

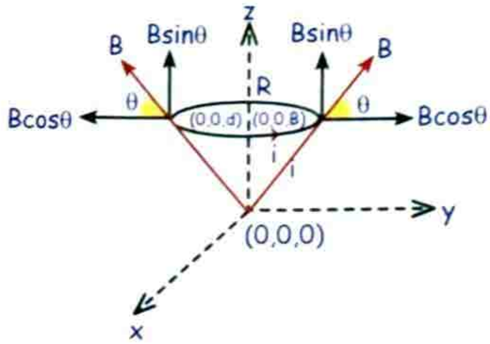
$f_{net} = i.B\int d\ell$

$f_{net} = i\,.\,B\,.\,2\pi R$ (इस result को याद कर ले।)

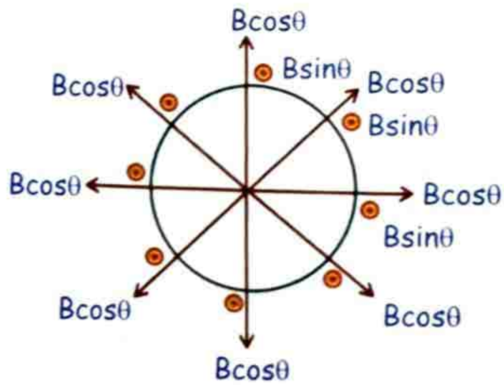
Q. $\vec{B} = B_0\,\vec{e}_r$ where e_r is unit vector along radial dirx^n from origin. A circular loop is of radius R is carrying current i is placed parallel to x-y plane and center at (0, 0, d). find magnitude of magnetic force on loop.



Sol.



Top View-

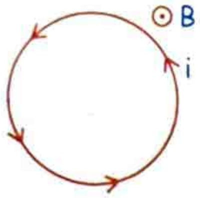


Force due to BSinθ = 0 (उटपटांग wire concept)

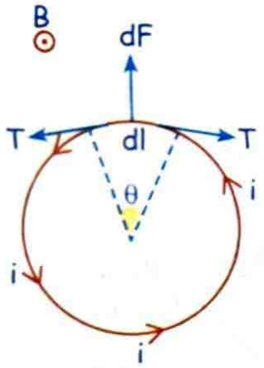
Force due to Bcosθ = $i.2\pi R\,B\cos\theta$ (from last Q.)

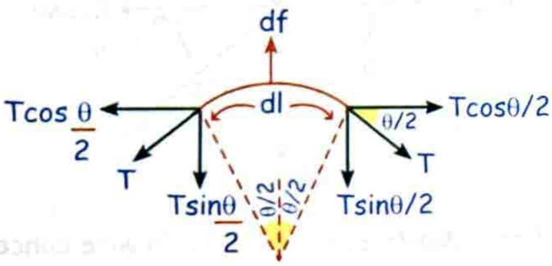
$$\vec{f}_{net} = i\cdot 2\pi RB\cos\theta = \frac{i\cdot 2\pi RB\cdot R}{\sqrt{R^2+d^2}}$$

Q. Find net force on circular loop and tension develop in wire -



Sol.





$$dF = 2T\sin\frac{\theta}{2} \qquad \left[\sin\frac{\theta}{2} \approx \frac{\theta}{2}\right]$$

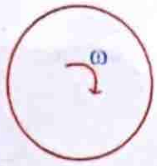
$$dF = 2T\frac{\theta}{2}$$

$$i \cdot d\ell \cdot B = T\theta = T \cdot \frac{dl}{R}$$

$$\Rightarrow T = i.R.B$$

#SKC

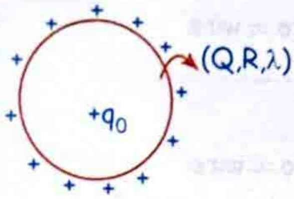
+



Ring rotating on horizontal floor $\mu = 0$.

$T = \lambda R^2\omega^2$ → Mass per unit length

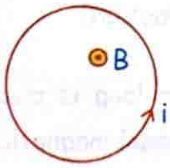
+



After placing q_0 at center in tension-

$$\Delta T = \frac{Kq_0\lambda}{R}$$

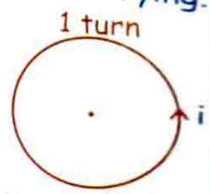
+



Tension developed in wire = iRB

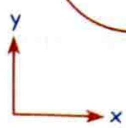
MAGNETIC DIPOLE MOMENT/MAGNETIC MOMENT

+ Magnetic dipole moment of a current carrying loop is given by- $\boxed{\vec{M} = i\vec{A}}$



for n loop- $\boxed{\vec{M} = in\vec{A}}$

$n \to$ no. of turns.



$\vec{M} = i\pi R^2(\hat{K})$

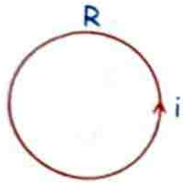
$M = i\pi R^2$ [magnitude]

Current C.w $\Rightarrow \hat{K}$
Current a.C.w $\Rightarrow -\hat{K}$ } x - y plane

+ Dirx^n of $\vec{M}$ is given by right hand thumb rule

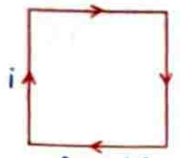
Q. Find Magnetic Moment -

1



$\vec{M} = i\pi R^2(\hat{K})$

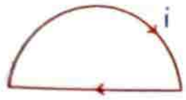
2



[sq., L]

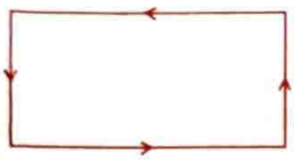
$\vec{M} = i\ell^2(-\hat{K})$

3



$\vec{M} = \frac{i\pi R^2}{2}(-\hat{K})$

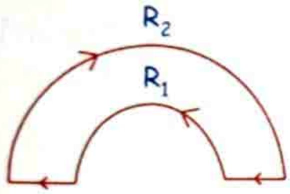
4



(Rect., L)

$\vec{M} = i\ell b(\hat{K})$

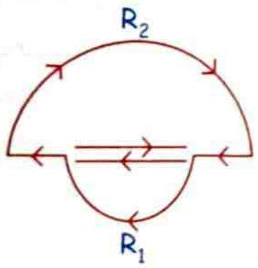
5



$\vec{M} = i\vec{A}$

$= i\left(\frac{\pi R_1^2}{2} - \frac{\pi R_2^2}{2}\right)\hat{k}$

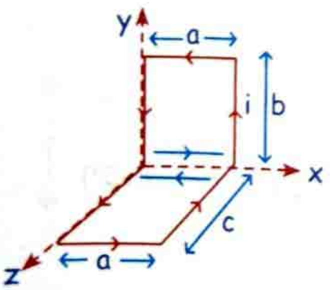
Q.



Sol. $\vec{M} = \frac{i\pi R_2^2}{2}(-\hat{K}) + \frac{i\pi R_1^2}{2}(+\hat{K})$

$\vec{M} = i\left(\frac{\pi R_2^2}{2} + \frac{\pi R_1^2}{2}\right)(-\hat{K})$

Q



Sol. $\vec{M}_{net} = iab(\hat{K}) + iac(\hat{j})$

$M_{net} = ia\sqrt{b^2 + c^2}$

$\left|\vec{M}_{net}\right| = \sqrt{(iab)^2 + (iac)^2}$

CURRENT CARRYING LOOP IN UNIFORM MAGNETIC FIELD

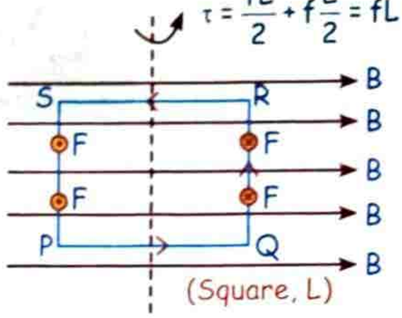
Force on PQ = 0

Force on RS = 0

Force on QR = iLB (अंदर)

Force on SP = iLB (बाहर)

$\tau = \frac{fL}{2} + f\frac{L}{2} = fL = iL^2B$

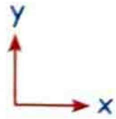


(Square, L)

$F_{net} = 0$

$(\vec{\tau})_{abt\,SP} = FL = iLBL$

$= iL^2B(+\hat{j}) = mB(\hat{j})$



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

$\boxed{\vec{\tau} = \vec{m} \times \vec{B}}$

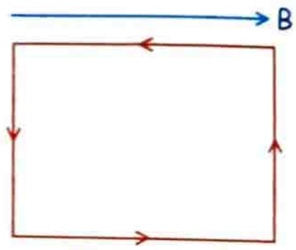
$\vec{M} = iL^2\hat{k}$

$\vec{B} = B\hat{i}$

$\vec{\tau} = \vec{M} \times \vec{B} = (iL^2\hat{K}) \times (B\hat{i})$

$= iL^2B(\hat{j})$

$\boxed{\vec{\tau} = iL^2B(\hat{j})}$



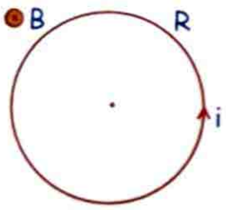
[Square, L]

अब इस चीज को भेजे में डाल लो की Current carrying loop को uniform magnetic field में रखेंगे तो उस पर torque लगेगा $\tau = \vec{M} \times \vec{B}$ और $U = -\vec{M}.\vec{B}$

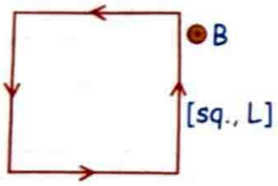
Electric Dipole Moment	Magnetic Dipole Moment
$\vec{\tau} = \vec{P} \times \vec{E}$ $T = 2\pi\sqrt{\frac{I}{PE}}$ $U = -\vec{P}\cdot\vec{E} = -PE\cos\theta$ $\to \theta = 0, f = 0, \tau = 0$ $U_{min} \to$ stable eqb^m. $\to \theta = 180°, f = 0, \tau = 0$ $U_{max} \to$ Unstable eqb^m.	$\vec{\tau} = \vec{M} \times \vec{B}$ $T = 2\pi\sqrt{\frac{I}{MB}}$ $U = -\vec{M}\cdot\vec{B} = -MB\cos\theta$ $\to \theta = 0, f = 0, \tau = 0$ $U_{min} \to$ stable eqb^m. $\to \theta = 180°, f = 0, \tau = 0$ $U_{max} \to$ Unstable eqb^m.

जैसे electrostatics में dipole in uniform E.F में question बनते थे वैसे ही यहाँ magnetic dipole in uniform M.F में question बन जाते है तो plz उन्हे revise करलो।

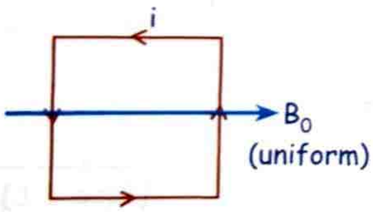
Q. Current carrying loops are placed in uniform magnetic field. Calculate torue on the loop.

(a)


$f = 0, \vec{\tau} = \vec{m} \times \vec{B}$
$\theta = 0°, \ \tau = 0$
[stable]

(b)


$F = 0$
$\theta = 0, \tau = 0$
[stable]

(c)


$f = 0$

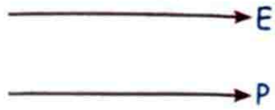
$\tau \neq 0 \qquad \vec{M} = L^2\,\hat{k}$

$\theta = 90°, \quad \vec{B} = B_0\hat{i}$

$\vec{\tau} = \vec{m} \times \vec{B} \neq 0$

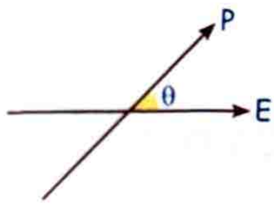
Q. A dipole is released from a small angle θ from the uniform electric field E. Calculate time period of oscillation.

Sol. Tourqe on diople is given by $\vec{\tau} = \vec{P} \times \vec{E}$



$\theta = 0$
$\tau = 0$
$\vec{F} = -k\vec{x}$
$T = 2\pi\sqrt{\frac{I}{K}}$

$\Rightarrow$



$\tau = PE\sin\theta$

for small disp. $[\sin\theta \approx \theta]$

$\vec{\tau} = -PE\,\vec{\theta}$

$\vec{\tau} = -(K)\vec{\theta}$ [Angular. SHM]

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

#SKC#

+ $\vec{P} \upuparrows \vec{E}$ [Stable]

$\longrightarrow P$
$\longrightarrow E$

$\theta = 0° \Rightarrow \vec{M} \upuparrows \vec{B}$ [Stable]

$\theta = 0°$, parallel

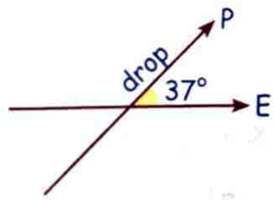
+ $\vec{P} \upharpoonleft\downharpoonright \vec{E}$ [unstable]

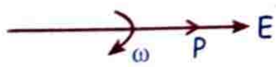
$\theta = 180° \quad \Rightarrow \vec{M} \upharpoonleft\downharpoonright \vec{B}$ [unstable]

$\theta = 180°$, anti parallel

$\longrightarrow E$
$P \longleftarrow$

Q. A dipole of dipole movment P is released at angle $\theta = 37°$ from electric field a calculate anglular velocity of dipole when it aligns with electric fields.



Sol.


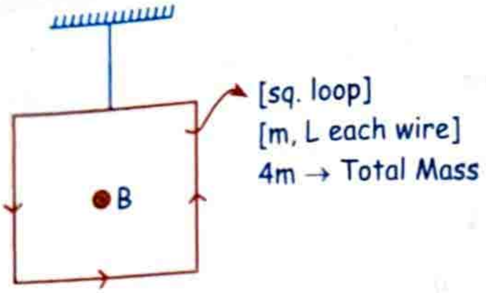
$PE = U = -\vec{P}\cdot\vec{E} = -PE\cos\theta°$

$K_i + U_i = K_f + U_f$

$0 + (-PE\cos 37°) = \frac{1}{2}I\omega^2 + (-PE\cos 0°)$

$\omega = ✓$

Q. If loop is rotated by small angle 'θ' & release. Find time period of oscillation.



Sol. Initially net force 0

$f_{net} = 0$ and $(\tau_{net})_{\text{by mag. field}} = 0$

$\tau_{net} = 0$

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

I → moI

mB → magnetic moment

Net torque at angle θ

$\vec{\tau}_{net} = \vec{M} \times \vec{B}, \tau = MB\sin\theta \approx MB\theta$

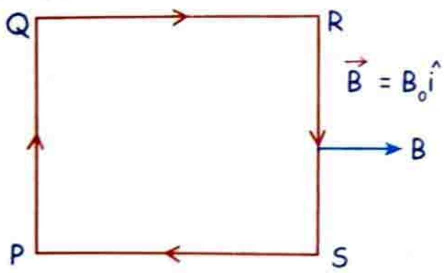
$$\vec{\tau} = MB\vec{\theta} \Rightarrow T = 2\pi\sqrt{\frac{I}{MB}}$$

M = magnetic moment = $i\ell^2$

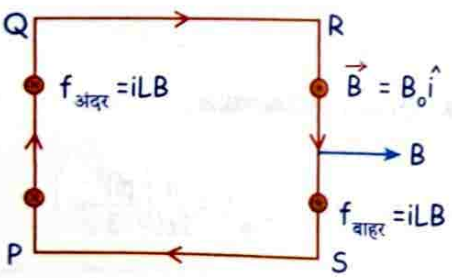
$$I = \frac{mL^2}{12} + m\left(\frac{L}{2}\right)^2 + \frac{ml^2}{12} + m\left(\frac{L}{2}\right)^2 = \frac{2}{3}mL^2$$

$$T = 2\pi\sqrt{\frac{\frac{2}{3}mL^2}{iL^2 \cdot B}}$$

Q. If a square loop having current i in it of mass m, L is placed on horizontal x-y plane on ground. Find B_{min} so that wire PQ ke abt. Uth jaye



Sol.



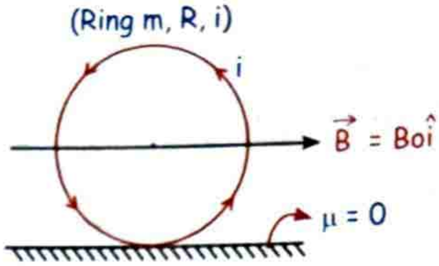
mg (अंदर), N - बाहर

$\tau_{iLB} \geq \tau_{mg}$ (उठ जाये)

$$iLBL \geq mg\frac{L}{2}$$

$B \geq mg/2Li$

Q. Find angular acceleration 'α' of ring at given instant as shown in figure.



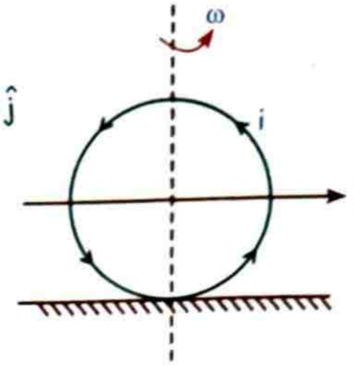
Sol. $\vec{\tau} = \vec{M} \times \vec{B}$

→ Dirx^n = $\hat{k} \times \hat{i} = \hat{j}$

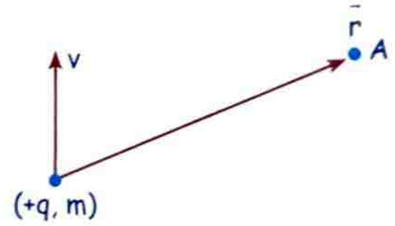
$\tau = i\pi R^2 B_0$

$\tau = i\pi R^2 B_0 = I\alpha$

$$i\pi R^2 B_0 = \frac{mR^2}{2}\alpha$$



MAGNETIC FIELD DUE TO MOVING CHARGE PARTICLE AT A POINT P



$$\vec{B_A} = \frac{Kq(\vec{v} \times \vec{r})}{r^3}$$

Q. A charge particle (+q, m) is moving in a circular path with const w find magnetic field at center due to it.

Sol. $$B_{center} = \frac{Kq.vR}{R^3} = \frac{Kq(R\omega)R}{R^3}$$

$$= \frac{\mu_0}{4\pi}\frac{qw}{R}, \left(\omega = \frac{2\pi}{T}\right)$$

$$= \frac{\mu_0\left(\frac{q}{T}\right)}{2R} = \frac{\mu_0 i}{2R}$$

Q. A charge particle (+q, m) is moving in a circular path of Radius R with speed v. (or ω) in anti c.w.

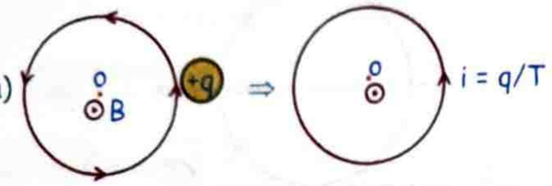
(a) Find magnetic field at center

(b) Find magnetic moment

(c) Find angular momentum

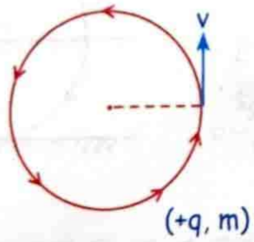
(d) Ratio of magnitude of magnetic moment to the angular moment

Sol. (a)



$$B = \frac{\mu_0 i}{2R} = \frac{\mu_0 (q/T)}{2R}$$

(b) Magnetic Moment $M = iA = \frac{q}{T}\pi R^2 (\hat{K})$



(c) Angular Momentum = $mvr_{\perp} = mvr = mvr\ (\hat{K})$

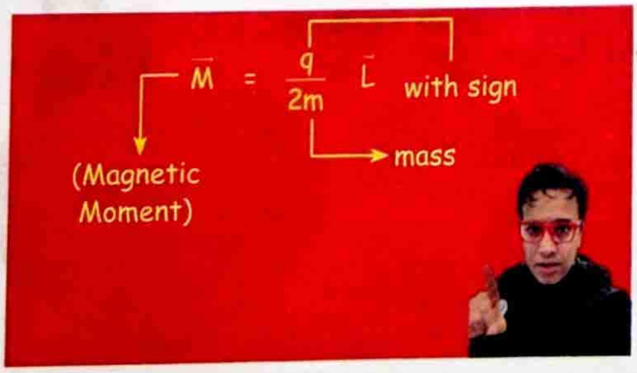
(ACw)

(d) Ratio of magnitude of magnetic moment to the angular moment =

$$\frac{|\vec{M}|}{|\vec{L}|} = \frac{q}{T}\frac{\pi R^2}{mvR} \Rightarrow q/2m$$

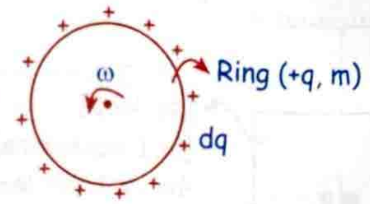
Magnetic Moment ← $\boxed{|\vec{M}| = \frac{q}{2m}|\vec{L}|}$ (Magnitude)

→ mass



Q. Find magnetic moment in the following rotating objects in magnetic fields.

1 Ring



M-I

$$\vec{M} = \frac{q}{2m}\vec{L} \quad [L = I\omega = mR^2\omega]$$

$$\vec{M} = \frac{q}{2m}(mR^2\omega)(\hat{K})$$

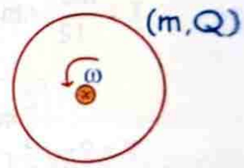
$$\vec{M} = \frac{qR^2\omega}{2}\hat{K}$$

M-II

$$\int dm = \int di \,.\, \pi R^2 = \frac{\pi R^2}{T}\int dq$$

$$M_{net} = \frac{\pi R^2 q}{2\pi/\omega} = \frac{qR^2\omega}{2}$$

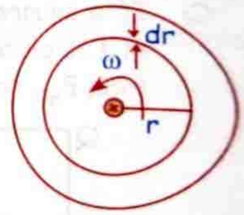
2 A charged disc (+Q, m, R) is rotating abt an axis with ω. Find M.M of disc.



M-I

$$\vec{M} = \frac{q}{2m}\vec{L}$$

$$M = \frac{Q}{2m}\cdot\frac{mR^2\omega}{2} = \frac{QR^2\omega}{4}$$



M-II

$$M_{net} = \int dm = \int_0^R \frac{dq}{T}\pi r^2$$

$$= \int_0^R \frac{\sigma 2\pi r dr \cdot \pi r^2}{T}$$

$$= \frac{\sigma \cdot 2\pi \cdot \pi}{T}\cdot\frac{R^4}{4} = \frac{Q\omega R^2}{4}$$

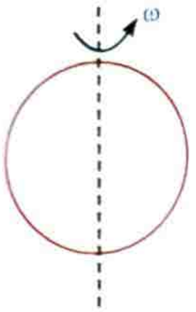
3 Rod rotating about hinge at end

Magnetic Moment $= \frac{q}{2m}L = \frac{q}{2\cancel{m}}\left(\frac{\cancel{m}l^2}{3}\omega\right)$

4 Rod rotating about centre

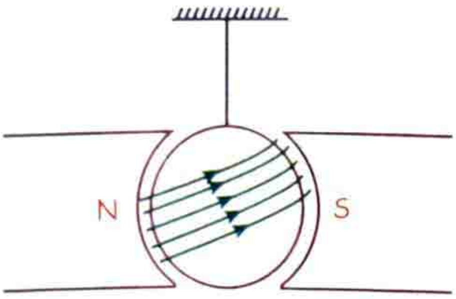
$$\text{Magnetic Moment} = \frac{q}{2m}L = \frac{q}{2\cancel{m}}\left(\frac{\cancel{m}l^2}{12}\omega\right)$$

5



$$M = \frac{q}{2m}\left(\frac{2}{5}mR^2\omega\right)$$

MOVING COIL GALVANOMETER



Tortional Pendulum

$\vec{\tau} = \vec{M} \times \vec{B}$

बना रहे

(Construction)

$\tau = MB \sin 90°$

$\tau = iABN = C\theta$

[torsional const.]

- torque of magnetic force is counter balance by torque by torsional wire.

$\rightarrow$ current sensitivity $= \frac{\theta}{i} = \frac{NBA}{c}$

$= \frac{BNA}{C} \longrightarrow$ deflection per unit current

काम की बाते

$\rightarrow \tau = NIBA = C\theta$

$\rightarrow$ Current sensitivity $= \frac{\theta}{i} = BNA/C$

$\rightarrow$ Voltage sensitivity $= \frac{\theta}{V} = \frac{BNA}{CR}$

$\rightarrow$ Voltage sensitivity $= \frac{\theta}{V} = \frac{\theta}{iR} = \frac{BNA}{CR} \rightarrow$ deflection per unit volt.

If no. of turn become double.

$N \rightarrow 2N$

Current sensitivity $\rightarrow$ double

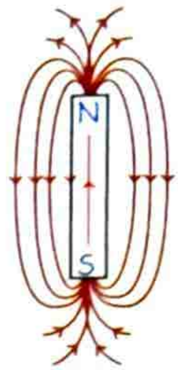
Voltage sensitivity $\rightarrow$ same.

BAR MAGNET

m $\rightarrow$ pole strength

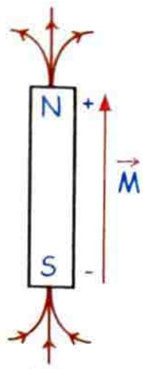
Magnetic dipole moment

$\vec{M} = m\ell$ (south to North)



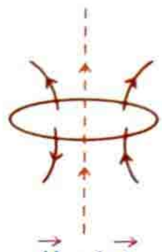
North pole $\rightarrow$ like +ve charge

South pole $\rightarrow$ like -ve charge



$\vec{M} = ml$

(South-North)

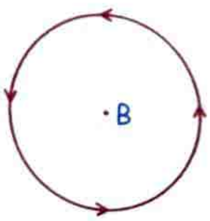


$\vec{M} = i\vec{A}$

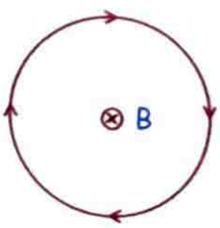
Samne Pole dikhega ACw

Current Carrying Loop

Current carrying loop acts as bar magnet when seen from front anticlockwise loop north pole is visible and in clockwise loop south pole is visible.

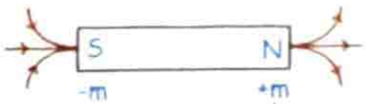


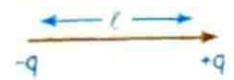
A.C.W $\Rightarrow$ North Pole



C.W $\Rightarrow$ South Pole

**





$\vec{P} = q\vec{l}$
↓
Electric dipole moment

Magnetic dipole moment

$\vec{M} = m\vec{\ell}$ (South → North)
↓
Pole strength

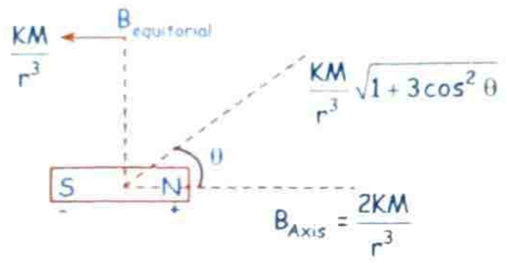
Electric Dipole Moment	Magnetic Dipole Moment (Magnet)
$\vec{\tau} = \vec{P} \times \vec{E}$ $T = 2\pi\sqrt{\frac{I}{PE}}$ $U = -\vec{P}\cdot\vec{E} = -PE\cos\theta$ $\rightarrow \theta = 0, f = 0, \tau = 0$ $U_{min} \rightarrow$ stable eqb^m. $\rightarrow \theta = 180°, f = 0, \tau = 0$ $U_{max} \rightarrow$ Unstable eqb^m.	$\vec{\tau} = \vec{M} \times \vec{B}$ $T = 2\pi\sqrt{\frac{I}{MB}}$ $U = -\vec{M}\cdot\vec{B} = -MB\cos\theta$ $\rightarrow \theta = 0, f = 0, \tau = 0$ $U_{min} \rightarrow$ stable eqb^m. $\rightarrow \theta = 180°, f = 0, \tau = 0$ $U_{max} \rightarrow$ Unstable eqb^m.

जैसे electrostatics में dipole in uniform E.F में question बनते थे वैसे ही यहाँ magnet in uniform M.F में question बन जाते हैं तो plz उन्हें revise करलो।

+ $(WD)_{external}$ to rotate magnetic dipole from θ_1 to $\theta_2 = -MB(\cos\theta_2 - \cos\theta_1)$

+ $(WD)_{external}$ to rotate electric dipole from θ_1 to $\theta_2 = -PE(\cos\theta_2 - \cos\theta_1)$

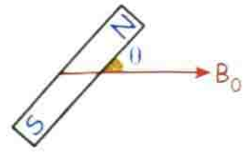
Magnetic Field Due To Short Bar Magnet



$\vec{B}_{axis} = \frac{2K\vec{M}}{r^3}$ $\left[K = \frac{\mu_0}{4\pi}\right]$

$\vec{B}_{eq} = -\frac{K\vec{M}}{r^3}$

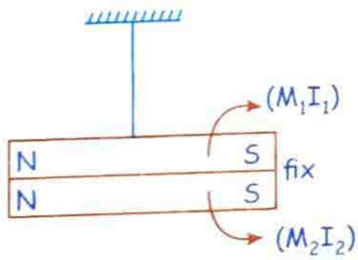
» When bar magnet is released in uniform MF to small angle θ to magnetic it starts oscillating.



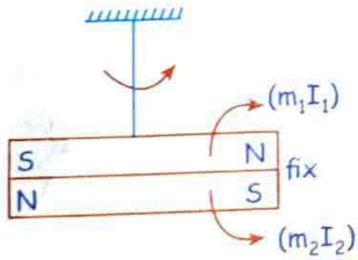
Release = oscillate

$\vec{M} = m\vec{\ell}$ $\qquad$ $\vec{\tau} = \vec{M} \times \vec{B}$
↓
Pole strength

Q. Find the time period of oscillation for small deflection inside uniform MF.



1



2

Sol. (a) $T = 2\pi\sqrt{\frac{I_1 + I_2}{(M_1 + M_2)B}}$

$M_{net} = M_1 + M_2$

(b) $T = 2\pi\sqrt{\dfrac{I_1 + I_2}{(m_1 - m_2)B}}$

$M_{net} = |M_1 - M_2|$

Q. Find the magnetic field due to a dipole of magnetic moment 1.2 A-m^2 at a point 1 m away from it in a direction making an angle of 60° with the dipole-axis.

Sol. The magnitude of the field is

$$B = \frac{\mu_0}{4\pi}\frac{M}{r^3}\sqrt{1 + 3\cos^2\theta}$$

$$= \left(10^{-7}\frac{\text{T-m}}{\text{A}}\right)\frac{1.2\text{A-m}^2}{1\text{m}^3}\sqrt{1 + 3\cos^2 60°}$$

$= 1.6 \times 10^{-7}$ T.

The direction of the field makes an angle α with the radial line where

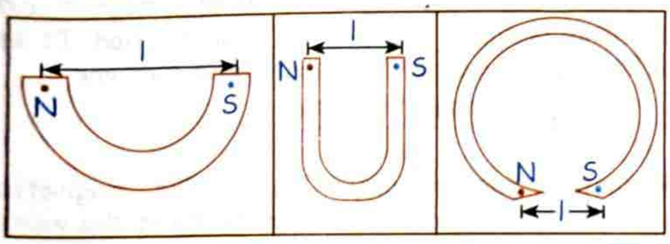
$$\tan\alpha = \frac{\tan\theta}{2} = \frac{\sqrt{3}}{2}$$

Magnetic Dipole Moment of Different Shaped Magnets & Their Composition

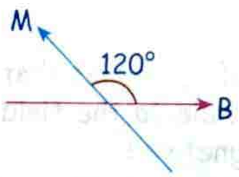
- The magnetic dipole moment of a magnet is equal to product of pole strength and distance between poles.

  $M = m\ell$

  here, ℓ = length between the poles of the magnet



Q. A magnet of magnetic dipole moment M is released in a uniform magnetic field of induction B from the position shown in the figure.



Find:

(i) Its kinetic energy at $\theta = 90°$.

(ii) its maximum kinetic energy during the motion. Will it perform SHM, oscillation or periodic motion? What is its amplitude?

Sol.

(i) Apply energy conservation at $\theta = 120°$ and $\theta = 90°$

$-MB\cos 120° + 0 = -MB\cos 90° + (\text{K.E.})$

$$\Rightarrow KE = \frac{MB}{2}$$

(ii) K.E. will be maximum where P.E. is minimum. P.E. is minimum at $\theta = 0°$. Now apply energy conservation between $\theta = 120°$ and $\theta = 0°$.

$-MB\cos 120° + 0 = -MB\cos 0° + (KE)_{max}$

$$\Rightarrow (KE)_{max} = \frac{3}{2}MB$$

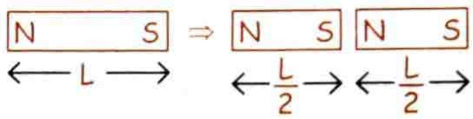
The K.E. is max at $\theta = 0°$ can also be proved by torquemethod. From $\theta = 120°$ to $\theta = 0°$ the torque alwaysactsonthedipoleinthesamedirection(here it is clockwise) so its K.E. keeps on increasing till $\theta = 0°$. Beyond that torque reverses its direction and then K.E. starts decreasing.

$\therefore \theta = 0°$ is the orientation of M to have the maximum K.E.

Since 'θ' is not small

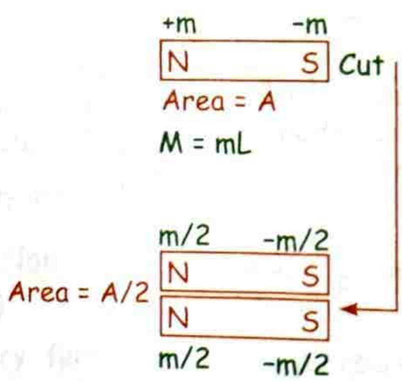
$\therefore$ the motion is not S.H.M. but it is oscillatory and periodic. Amplitude is 120°.

☆ Suppose a bar magnet (m, L) is cut perpendicularly into two half of length L/2. Magnetic dipole moment of the one bar magnet after cut will be

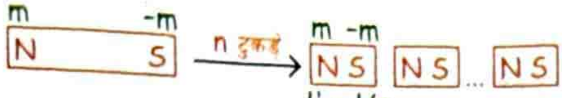


$M_i = mL$ $\qquad$ $M_{\text{new of each}} = m.\dfrac{L}{2} = \dfrac{M_i}{2}$

☆ Suppose a bar magnet (m, L) is cut along its lengthsuch that it's area become half.



$M_{\text{new of each}} = m\,L/2$

Q. 

Sol.

$$T_0 = 2\pi\sqrt{\frac{I}{MB}}$$

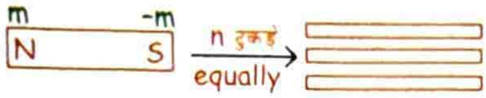
$$M = ml$$

$$I = \frac{ml^2}{12}$$

$$I' = \frac{\left(\frac{M}{n}\right)\left(\frac{L}{n}\right)^2}{12} = \frac{I}{n^3}$$

$$M' = m\frac{l}{n} = \frac{M}{n}$$

$$T_{-} = \sqrt{\frac{I/n^3}{\frac{M}{n}B}} = \frac{1}{n}T_0$$

Q. 

Sol.

$$T_0 = 2\pi\sqrt{\frac{I}{MB}}$$

$$M = ml$$

$$I = \frac{ml^2}{12}$$

Pole strength → Cross-section Area
M → Magnetic moment, depend on Vol

$$T'_{,} = \sqrt{\frac{I/n}{\frac{M}{n}B}}$$

$$m' = \frac{m}{n} = \text{pole strength}$$

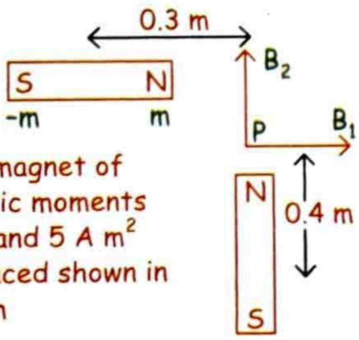
$$T' = T_0 = \text{same}$$

$$M' = \frac{m}{n} \times l = \frac{M}{n}$$

Gauss Law in Magnetism

- Not magnetic flux through any closed surface is always zero.
  $\oint \vec{B} \cdot \vec{ds} = 0$
- It implies monopole does not exist.

Q.



Short magnet of magnetic moments 2 Am^2 and 5 A m^2 are placed shown in diagram

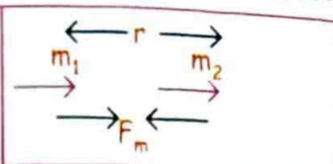
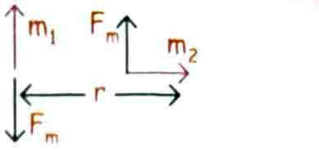
Sol.

$$B_1 = \frac{2Km_1}{r_1^3},\ B_2 = \frac{2Km_2}{r_2^3}$$

$$\overline{B_{net}} \text{ at } P = B_1\hat{i} + B_2\hat{j}$$

$$\text{Magnitude} = \sqrt{B_1^2 + B_2^2}$$

Dipole-Dipole Interaction (short dipole)

1.		$F_m = \frac{6Km_1m_2}{r^4}$ (along r)
2.		$F_m = \frac{3Km_1m_2}{r^4}$ (along r)
3.		$F_m = \frac{3Km_1m_2}{r^4}$ (perpendicular to r)

MAGNETIC MATERIAL

(Majority part removed from JEE Mains 2025 so least priority Topic not in advance)

Magnetic Field Strength or Magnetizing Field

The magnetic field strength or magnetizing field is given by $\vec{H} = \frac{\vec{B}}{\mu}$ A/m and is independent of the medium.

For a coil having n number of turns per unit length and i_0 as the (true) current in the winding, then $H = ni_0$. This value of H is independent of the core material.

Magnetisation and Magnetic Intensity

The measure of the magnetization of a magnetized specimen is called intensity of magnetization. It is defined as the magnetic moment per unit volume.

Thus, $I = \frac{\text{magnetic momen}}{\text{volume}}$

Magnetic Susceptibility (χ_m): The magnetic susceptibility (χ_m) of a specimen measures the ease with which the specimen can be magnetized and can be defined as the ratio of the intensity of magnetization induced in it and the magnetizing field

$$\chi_m = \frac{I}{H}$$

- Large value of χ_m implies that the material is more susceptible to the field and hence can be easily magnetised.

Magnetic permeability (μ): When a magnetic material is placed in a magnetic field, it acquires magnetism due to induction. The lines of force of the magnetizing field concentrate inside the material and it results in the magnetizing of the material. The measure of the degree to which the lines of force can penetrate or permeate the medium is called absolute permeability of the medium and denoted by μ. The permeability is defined as the ratio of the magnetic induction B in the medium to the magnetizing field H.

$$\mu = \frac{B}{H}, \text{i.e., } B = \mu H$$

Relative permeability μ_r: It is the ratio of magnitude of total field inside the material to that of magnetising field or it is the ratio of permeability of a medium to that of free space.

$$\mu_r = \frac{B}{B_0} = \frac{\mu H}{\mu_0 H} = \frac{\mu}{\mu_0}$$

Relation Between Permeability and Susceptibility

When a magnetic material is placed in a magnetising field for its magnetisation, the field inside the magnetic material is the resultant of the magnetising field $\overrightarrow{B_0}$ and the induced field $\vec{B_i}$, i.e., $\vec{B} = \overrightarrow{B_0} + \vec{B_i}$

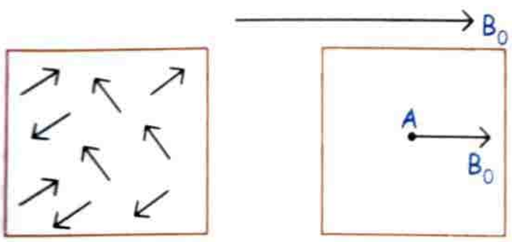
But by definition of intensity of magnetising field and intensity of magnetisation

$$\overrightarrow{B_0} = \mu_0 \vec{H} \text{ and } \vec{B_i} = \mu_0 \vec{I}$$

$$\vec{B} = \mu_0\left(\vec{H} + \vec{I}\right) \Rightarrow \frac{B}{H} = \mu_0\left(1 + \frac{I}{H}\right)$$

$$\mu = \mu_0\left(1 + \chi_m\right)$$

$$\mu_r = \left(1 + \chi_m\right) \text{ (since } \mu_r = \frac{\mu}{\mu_0}\text{)}$$

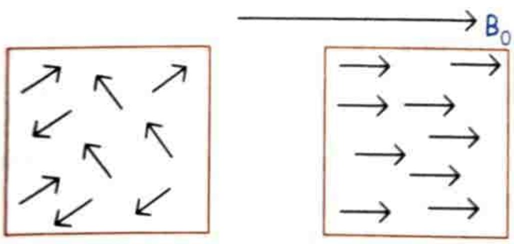
◆ 

$\vec{M}_{net} = 0$

Net magnetic moment

$(\vec{B}_{net})_{inside} = \vec{B}_0 + \vec{B}_{induce}$

$\vec{B}_{net} = \vec{B}_0 + \vec{B}_m$ (due to material)

◆ 

$\vec{M}_{net} = 0$

Net magnetic moment

$\vec{M}_{net} \neq 0$

$\vec{I} = \frac{\overrightarrow{m_{net}}}{Vol^n}$

- $\vec{I} = \frac{\vec{M}}{vol^n}$
- $\vec{H} = \frac{\vec{B}}{\mu}$
- $\chi = \frac{I}{H}$
- $\vec{I} = \chi\vec{H}$
- MP = 1 + ms

Paramagnetic Substances

The substances which when placed in a magnetic field acquires a weak magnetization in the same direction as the applied field are called paramagnetic substances.

(i) These substances in non-uniform magnetic field, experience an attractive force towards the stronger part of the field.

(ii) Their relative permeability μ_r for a paramagnetic substance is slightly greater than one.

(iii) Their magnetic susceptibility is small positive value.

(iv) For a given temperature χ does not change with variation in H.

Diamagnetic Substances

The substances, which when placed in a magnetic field acquire weak magnetization in a direction opposite to that of the applied field are called diamagnetic substances.

(i) These substances are repelled by strong magnetic field.

(ii) The relative permeability μ_r for diamagnetic substance is less than one but positive.

(iii) Susceptibility for diamagnetic has a small negative value, $-1 < \chi_m < 0$. This value does not vary with field or temperature.

Ferromagnetic Substance

Such substances acquire high degree of magnetization in the same sense as the applied magnetic field.

(i) They have relative permeability of the order of hundreds and thousands.

(ii) Susceptibility is also very large and positive.

(iii) For small values of H susceptibility remains constant and for moderate value of H increases rapidly with H and for large value attains a constant value.

(iv) They are attracted even by weak magnet.

Explanation of Ferromagnetism (Domain Theory)

(i) Every ferromagnetic material is made of a number of very small regions which are known as domains.

(iii) **Exchange interaction:** It is the interaction through which the magnetic moments of individual atoms are coupled to neighbouring moments very strongly.

(iv) **Domain:** A small volume of the order 10^{-6} to 10^{-2} cm^3 containing 10^7 to 10^{21} atoms whose magnetic moments are aligned in the same direction.

(v) Due to exchange interaction domains are formed in ferromagnetic substance. Each domain possesses a resultant magnetic moment.

(vi) In the absence of external magnetic field the magnetic moments of domains are randomly oriented giving zero resultant magnetic moment.

(vii) When the ferromagnetic substance is placed in an external magnetic field the domains having the magnetic moment in the direction of external magnetic field increase their volume at the cost of those which are in opposite direction till saturation state of magnetization.

Curie's Law

It states that intensity of magnetization(I) is directly proportional to the magnetic induction (B) and inversely proportional to the absolute temperature (T)

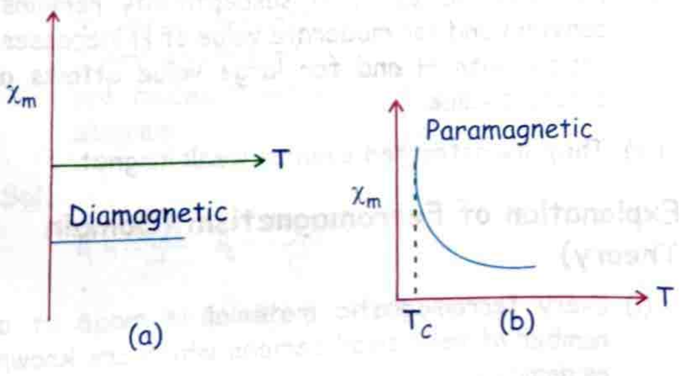
$$I = \frac{CB}{T}$$, where C is Curie constant

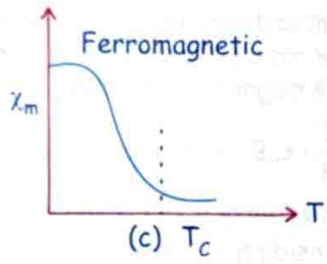
+ Curie temperature is the temperature at which ferromagnetic substance converts into paramagnetic substance.

Curie-Weiss Law

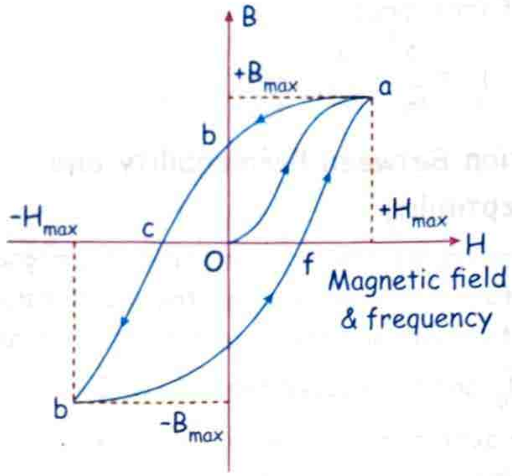
At temperature above Curie temperature the magnetic susceptibility of ferromagnetic materials is inversely proportional to $(T - T_C)$ $\chi_m \propto \frac{1}{T - T_C}$, where T_C is called Curie temperature.

Susceptibility-Absolute Temperature Curve





Hysteresis Loop



To get this graph, measure B and H and plot these values. Increase H from zero to H_{max} and draw the curve oa (the maximum value is known as saturation value), this is the normal magnetization curve. Now decrease H from H_{max} to zero. B will not fall as rapidly as it increased and will fall back to b rather than zero giving curve ab. Therefore, even when the magnetizing force is made zero or removed, the material is still magnetic and the flux density ob is called residual magnetism or retentivity. Now, reverse the magnetizing field H. The value of B becomes zero at point c at which the substance is no longer a magnet. Now, H is increased to $-H_{max}$ and curve cd is obtained. Change $-H_{max}$ to zero and then to H_{max} again, curve dfa is obtained. This lagging of the B with respect to the magnetizing force H is called hysteresis and the close loop graph is known as hysteresis loop. The value of H required to destroy the residual magnetism is called the coercivity which is represented by oc.

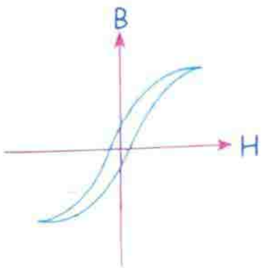
Energy Loss due to Hysteresis

To produce a magnetic field, a certain amount of energy has to be supplied. This energy is stored in free space where field is established and is returned to circuit when field collapses.

However in case of ferromagnetic substances not all the energy supplied can be returned; part of it is lost in form of heat etc. If the magnetization is carried through a complete cycle, the energy lost is proportional to the area of the hysteresis loop.

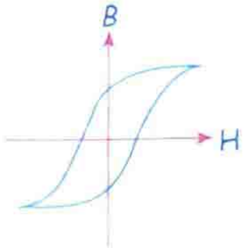
When a magnetic material is taken round cycle, there is an energy loss per unit volume of the material given by the area enclosed by B-H curve.

Properties of Soft Iron and Steel



Soft Magnetic Materials

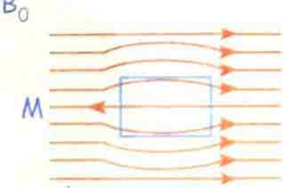
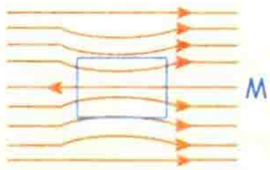
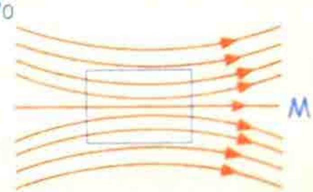
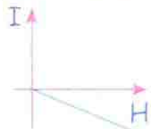
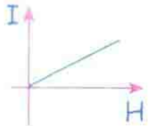
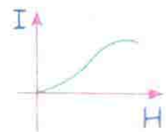
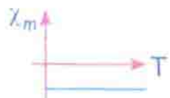
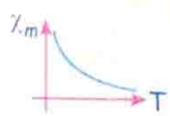
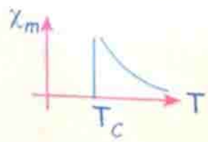
For soft iron, the susceptibility, permeability are greater while retentivity, coercivity and hysteresis loss per cycle are smaller than those of steel.



Hard Magnetic Materials

Permanent magnets are made of steel and cobalt while electromagnets are made of soft iron.

Properties of Diamagnetic, Paramagnetic and Ferromagnetic Materials

Properties	Diamagnetic	Paramagnetic	Ferromagnetic
Cause of magnetism	Orbital motion of electrons	Orbital motion as well as spin motion of electrons	Formation of domains
Substance placed in uniform magnetic field.	Poor magnetisation in opposite direction. Here $B_m < B_0$ 	Poor magnetisation in same direction. Here $B_m > B_0$ 	Strong magnetisation in same direction. Here $B_m >>> B_0$ 
I - H curve	I → Small, negative, varies linearly with field 	I → Small, positive, varies linearly with field 	I → very large, positive & varies non-linearly with field 
χ_m - T curve	χ_m - small, negative & temperature independent $\chi_m \propto T^0$ 	χ_m - small, positive & varies inversely with temperature $\chi_m \propto \frac{1}{T}$ (Curie law) 	χ_m - very large, positive & temperature. dependent $\chi_m \propto \frac{1}{T - T_C}$ (Curie Weiss law) (for $T > T_C$) (T_C = Curie temperature) 
μ_r	$(\mu < \mu_0)$ $0 < \mu_r < 1$	$\mu > 1$ (small value)	$\mu_r >>> 1$ $(\mu >>> \mu_0)$

Super conductor

When certain material is cooled below a certain temperature (called as critical temperature), it shows exactly zero electrical resistance and expulsion of magnetic flux. These materials are known as superconductors.

Superconductors are diamagnetic materials. The currents are induced in atomic orbitals by an applied magnetic field due to diamagnetism. Super conductors will take the diamagnetic effect to the extreme since in a superconductor the field is zero and the field is completely screened from the interior of the material. This is called Meissner effect. The magnetic susuptibility χ of superconductor is -1 and relative permeability $\mu_r = (1 + \chi) = 0$.

Q. The magnetic intensity at the centre of a long current carrying solenoid is found to be 1.6×10^3 Am^{-1}. If the number of turns is 8 per cm, then the current flowing through the solenoid is: **[08 April 2023 - Shift 1]**

Sol. (2A) $n = \frac{N}{l} = \frac{8}{1cm} = 800$

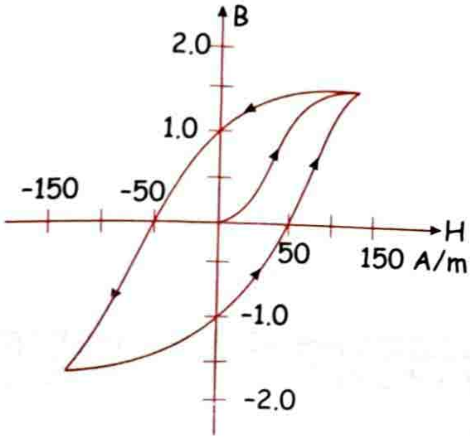
$$\frac{B_0}{\mu_0} = 1.6 \times 10^3 = ni = 800 \times i$$

Q. A solenoid of 1200 turns is wound uniformly in a single layer on a glass tube 2m long and 0.2 m in diameter. The magnetic intensity at the center of the solenoid when a current of 2 A flows through it is:

Sol. $B = \mu_0 ni$

$$\frac{B_0}{\mu_0} = ni = \frac{1200}{2} \times 2$$

Q. The figure gives experimentally measured B vs. H variation in a ferromagnetic material. The retentivity, co-ercivity and saturation, respectively, of the material are:



Sol. 1.0 T, 50 A/m and 1.5 T

Let's go to next chapter

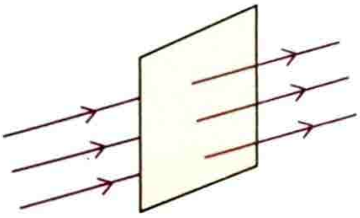
5 Electromagnetic Induction

देख भाई faraday ने observe किया कि जब भी किसी loop से magnetic flux वक्त के हिसाब से बदलेगा तो loop में EMF induce होगा लेकिन इस बात की feel तो तुम्हे तब आएगी ना जब magnetic flux निकालना आता हो जो कि बिलकुल electric flux जैसा है तो चलो फिर पहले magnetic flux ही पढ़ लेते है।

1. MAGNETIC FLUX

- Magnetic Flux (ϕ) through a plane of area A placed in a uniform Magnetic field B can be written as -

$$\phi = \vec{B} \cdot \vec{A} = BA\cos\theta$$

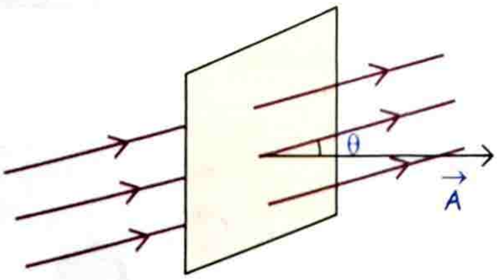


[B uniform let]

- Magnetic Flux through small area dA is given by -

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

$$\phi_{net} = \int d\phi = \int \vec{B} \cdot d\vec{A}$$



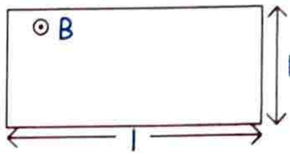
If $\vec{B}$ uniform -

$$\phi_{net} = \vec{B} \cdot \int d\vec{A} = \vec{B} \cdot \vec{A}$$

- Magnetic Flux -
  - Scaler
  - $[ML^2T^{-2}A^{-1}]$
  - Proportional to no. of MFL crossing a surface perpendicular to it.
  - Joule/Ampere = wb (weber) or T-m^2.

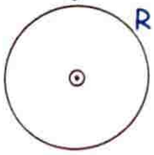
Q. Find magnetic flux in following area $\vec{B} = B_0K$ (uniform).

(a)



$\Rightarrow \phi = Blb$

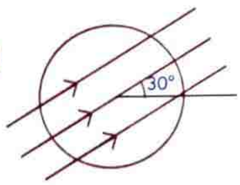
(b) $\vec{B} = B_0\hat{k}$



$\Rightarrow \phi = B_0\pi R^2$

#SKC
लाईन का area में घुसकर दूसरी तरफ बाहर निकलना जरूरी है तभी flux आयेगा।

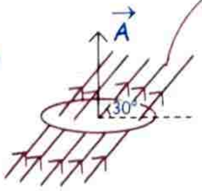
(c)



$\Rightarrow \phi = 0$

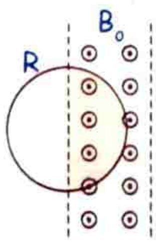
#SKC
यहाँ angle normal के साथ लेना है ना की plane के साथ

(d)



$\Rightarrow \phi = BA\cos\theta = BA\cos 60°$

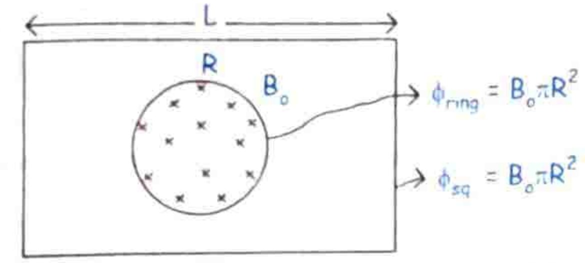
(e)



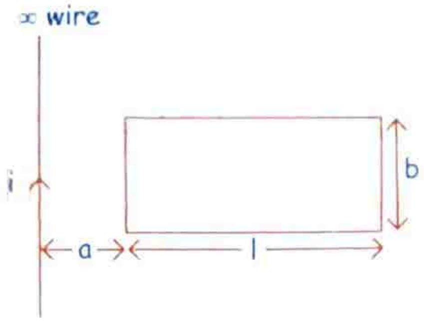
If ur ans is $\phi = B_0\pi R^2$ then bcz it's ✗

$\phi = B_0\pi R^2$ ✗

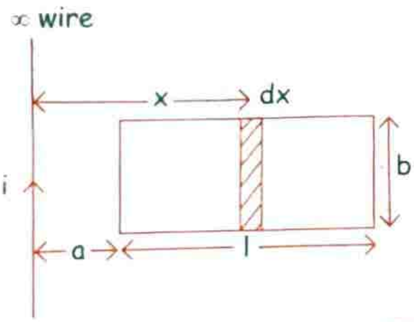
$\phi = \dfrac{B_0\pi R^2}{2}$ ✓

☆ 

Q. Find flux through the rectangle in following figure.



Sol.



$d\phi = B \cdot dA$

$$\phi_{net} = \int_{a}^{a+l} \frac{2Ki}{x} \cdot b \cdot dx$$

$$\phi_{net} = 2Kib \ln\left(\frac{a+l}{a}\right)$$

> अगर infinite wire में current को time के according बदला तो flux भी बदलेगा इस बात को याद रखना।

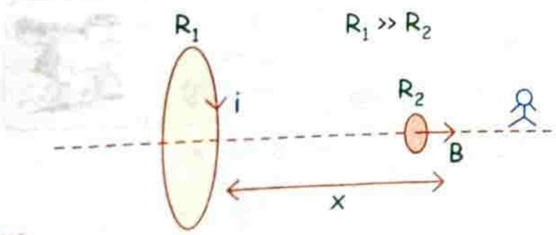
+ If $i = 2t + 3$, then $\phi = f(t)$ through area

$$\phi = 2Kib \ln\left(\frac{a+l}{a}\right)$$

$$\phi = 2K(2t+3)b \ln\left(\frac{a+l}{a}\right)$$

Q. If current in the bigger loop is i then find flux through the smaller loop in following figure.

Sol.



$$\phi_{\text{छोटा loop}} = B \cdot \text{Area}$$

$$= \frac{\mu_o i R_1^2}{2(R_1^2 + x^2)^{3/2}} \pi R_2^2 = \phi$$

FARADAY LAW OF INDUCTION

+ Whenever magnetic flux changes through an area wrt time, an emf is induced. Magnitude of the induced emf in area is equal to the rate of change of magnetic flux through that area.

$$\text{emf} = \left|\frac{d\phi}{dt}\right| \Rightarrow \text{magnitude}$$

$$i_{induced} = \frac{|d\phi|/|dt|}{R \longrightarrow \text{Resistance}}$$

LENZ LAW

+ Direction of induced current in a loop such that is oppose the cause.
+ Polarity of induce emf is such that it tends to produce a current oppose the change in magnetic flux that produced it.

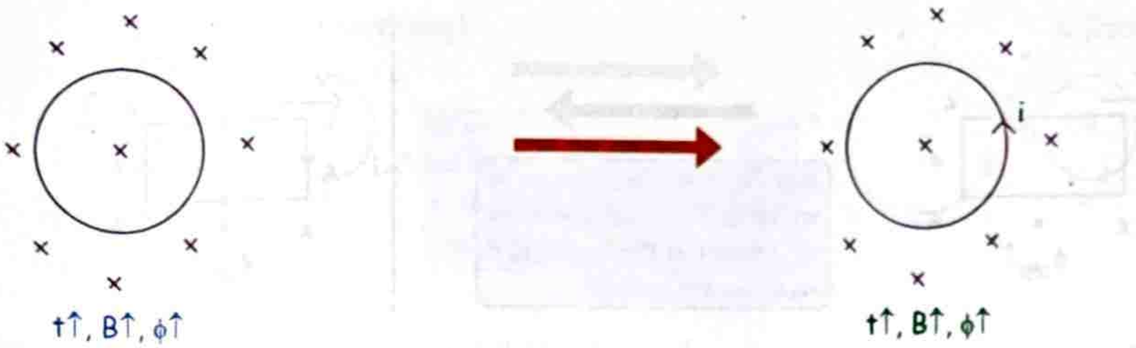
$$\text{emf} = -\left(\frac{d\phi}{dt}\right)$$

#SKC
Current esse flow Krao
Ki- ϕ Badhe to Badhne mat do
≡ (matlab ghatao)
Aur ghate to ghatne mat do
≡ (matlab badhao)

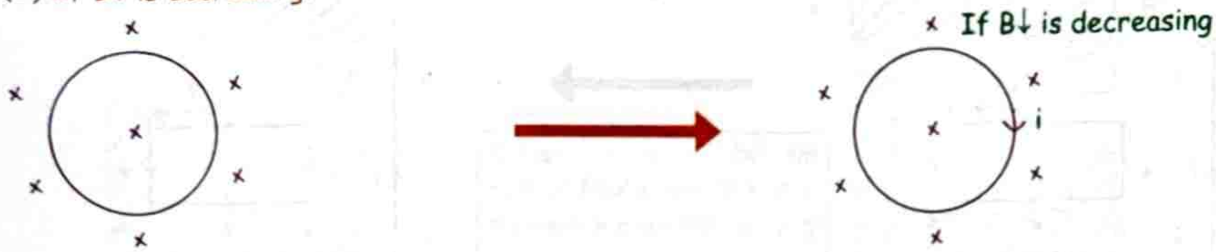
Q. In following question find the direction of induce current.

हर एक question को अच्छे से try करना वरना पिटाई होगी।

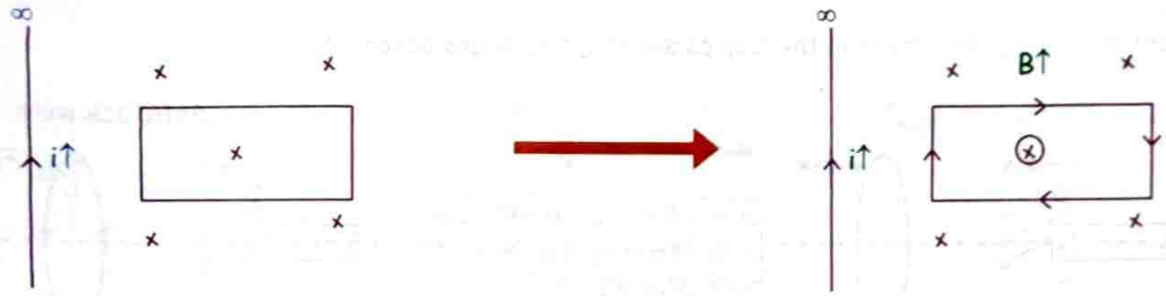
(a) If magnetic field is increasing ($B\uparrow$ or $B = 2t + 3$) find direction of current in the conducting ring.



(b) If $B\downarrow$ is decreasing.



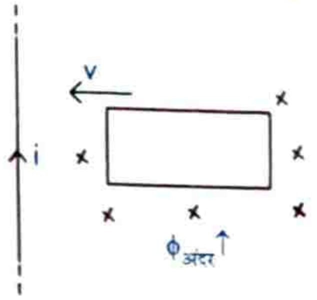
(c) If current in the ∞ wire increasing then direction of induce current in rectangle.



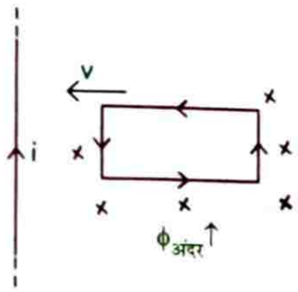
(d) If current in the ∞ wire increasing then direction of induce current in the ring.

(e) If current in the ∞ wire decreasing then direction of induce current in the ring.

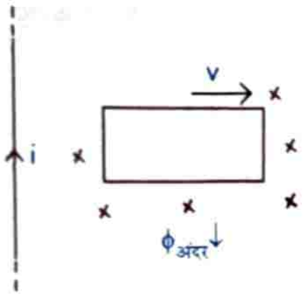
(f) If rectangle is moving towards current carrying ∞ wire. Direction of induce current rectangle will be



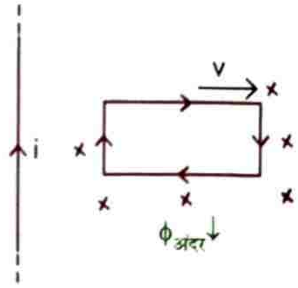
Method-2 यहाँ loop ∞ wire के पास आ रहा है तो ∞ wire बोलेगी कि भाई तू पास मत आ (दिशा opposite तो repulsion वाला concept)



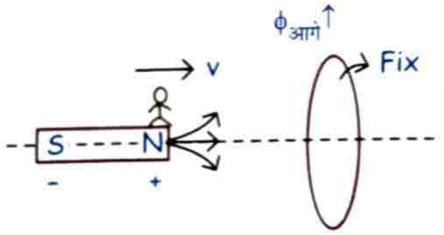
(g) If rectangle is moving away current carrying ∞ wire. Direction of induce current rectangle will be



Method-2 यहाँ loop ∞ wire से दूर जा रहा है तो ∞ wire बोलेगी कि बाबू तू दूर मत जा (दिशा same तो मोहब्बत होगी वाला concept)

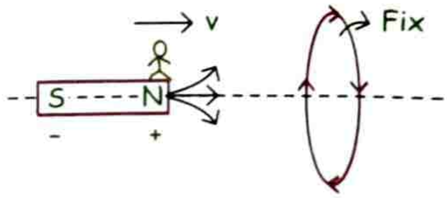


(h) Direction of induce current in the loop as seen by saleemians observer.

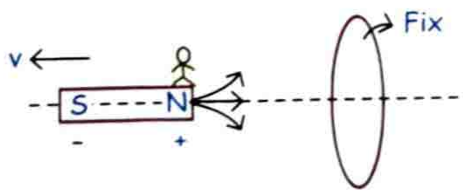


Method-2 Observer की तरफ loop में northpole type develope हो जाएगा जो magnet को बोलेगा भाई तू पास मत आ।

Anticlock wise

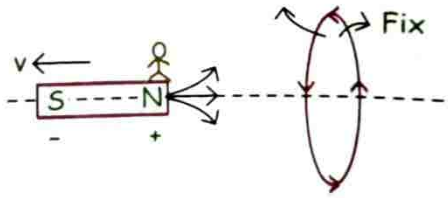


(i) Direction of induce current in the loop as seen by saleemians observer.

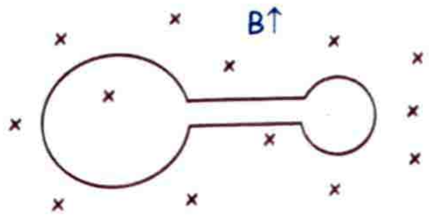


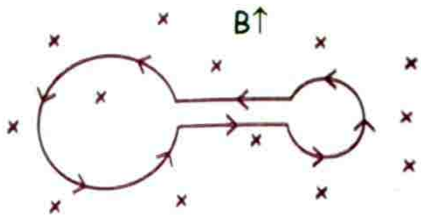
Method-2 magnet loop से दूर जा रहा है तो loop बोलेगा भाई तू दूर मत जा so observer की तरफ south pole type बन जाएगा

South pole बना दो Clock wise

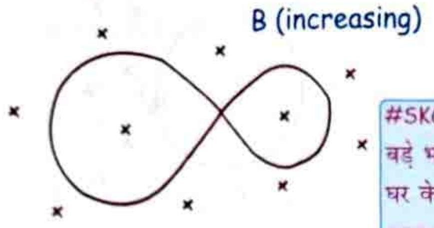


(j) If magnetic field is increasing in following figure then direction of induce current in the loop.

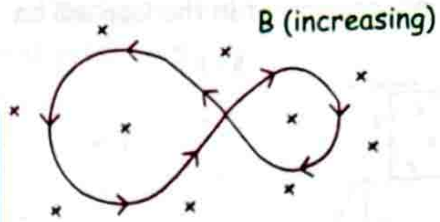




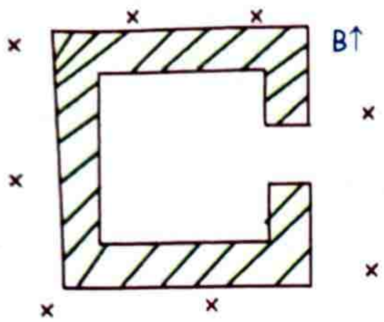
(k) If magnetic field is increasing in following figure then direction of induce current in the loop.

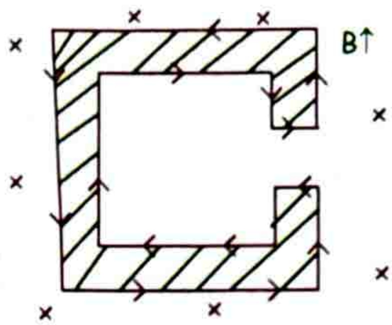


#SKC
बड़े भाई का कहना मानना है अबे समझे ना घर के unpaid servent यहाँ जिसका area बड़ा है उसका कहना मानना है।

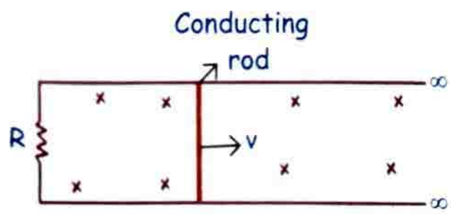


(l) If magnetic field is increasing in following figure then direction of induce current in the loop.

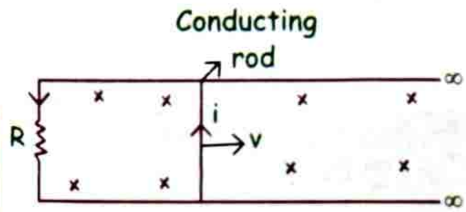




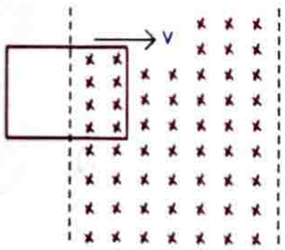
(m) If rod is moving inside magnetic field in following figure. Direction of current in resistance will be

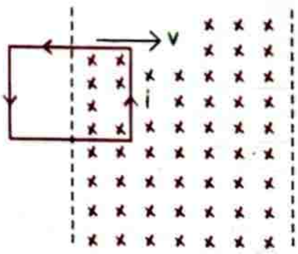


जैसे rod दूर जाएगी area enclose बढता चला जाएगा जिससे अंदर की तरफ ϕ_{in} बढता चला जाएगा तो current ऐसे flow करेगा ताकि ϕ_{in} ना बढ़े

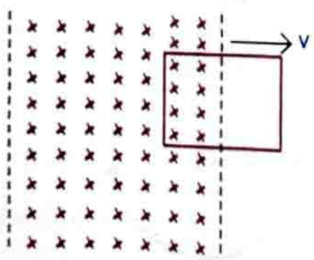


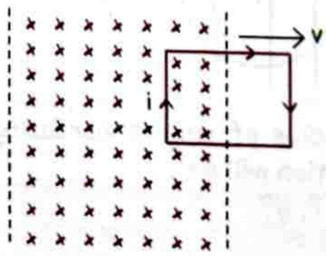
(n) Loop is moving inside magneticfield region. Direction of induce current in the loop.



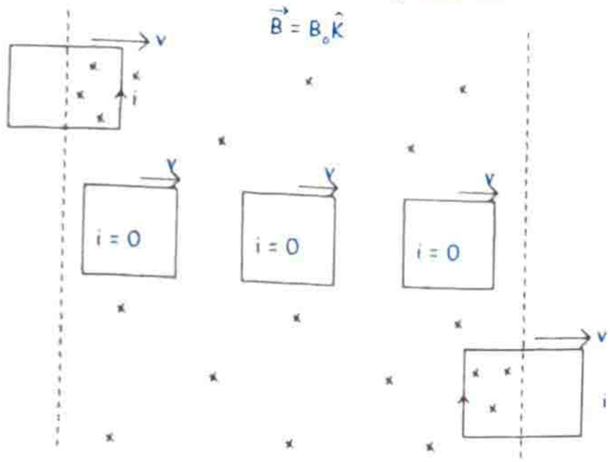


(o) Loop is moving away magneticfield region. Direction of induce current in the loop.

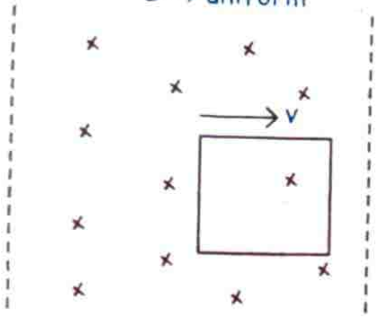




☆ If loop is moving with constant velocity direction of induce current in the loop will be

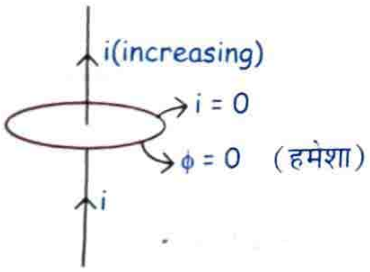


☆ B → uniform

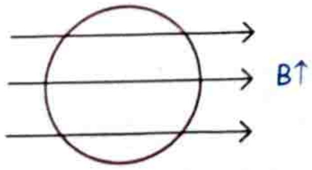


$\phi \rightarrow$ constant
emf = 0
i = 0

☆

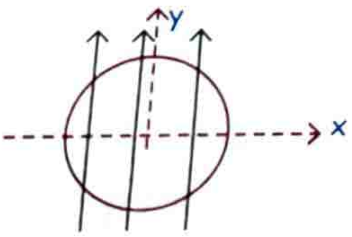


☆



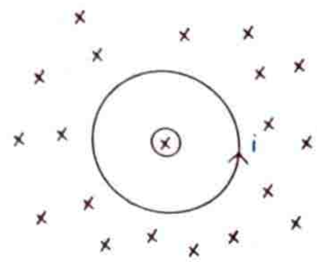
$\phi = 0$
$i = 0$

☆

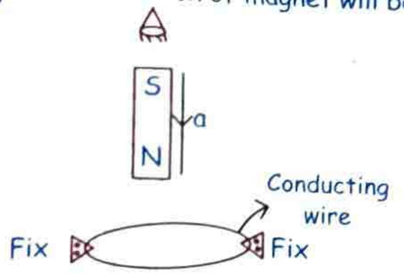


$\vec{B} = 3t^2\hat{j}$
$\phi = 0$
emf = 0
$i = 0$

☆ *If radius of ring is increasing, induce current direction will be*
R↑, A↑, ϕ↑

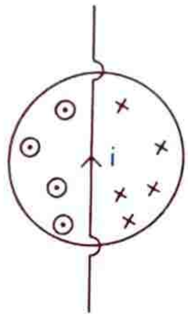


☆ A magnet is falling vertically downward as shown in figure acceleration of magnet will be



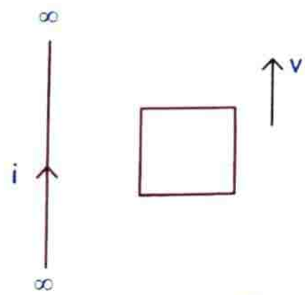
Acceleration of bar magnet will be: $a < g$

☆



$\phi_{ring} = 0$
$i\uparrow \Rightarrow \phi = 0$
emf = 0

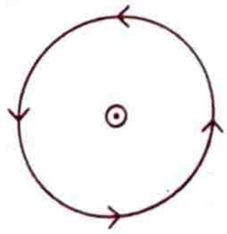
☆



ϕ = Constant.
emf = 0 (Faraday)
i = 0

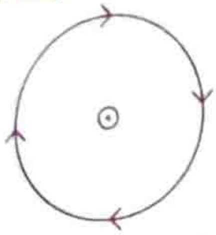
Important Note:-

+ ACW ⇒ saamne north pole hai
  [+m → pole strength]



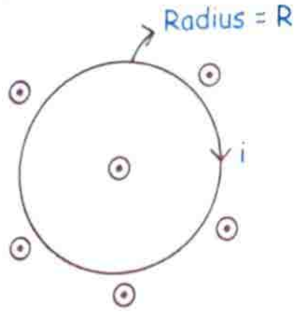
- CW ⇒ saamne south pole hai

[-m → pole strength]



Q. Find emf induce in the loop.

$B = 2t + 3$



Sol. $\text{emf} = \frac{d\phi}{dt}$ (magnitude)

$$\phi = \vec{B}\cdot\vec{A} = (2t+3)\pi R^2$$

$$\text{emf} = \frac{d}{dt}[(2t+3)\pi R^2]$$

$$= \pi R^2(2) \Rightarrow 2\pi R^2$$

$$i = \frac{\text{Emf}}{\text{Resist.}} = \frac{2\pi R^2}{\text{Resistance}} \text{ (C.W)}$$

#SKC

कभी भी kisi loop में emf निकालना हो ⇒ time 't' पर flux निकालो और उसको differentiate कर दो emf = $d\phi/dt$ (magnitude)

Q. If radius of loop is increasing at the rate of 2m/sec. Find emf induced in the loop when radius is 4m.

Sol. $\phi = BA$

$$\text{emf} = \frac{d}{dt}(dA) = \frac{BdA}{dt} = B\frac{d}{dt}(\pi r^2)$$

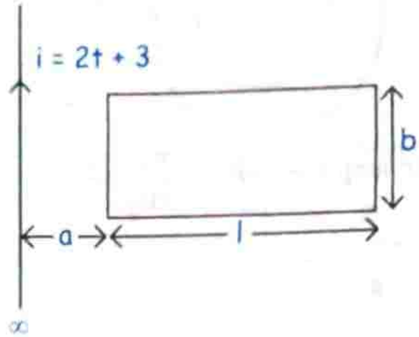
$$\text{emf} = B\pi 2r\frac{dr}{dt}$$

$$= 10\pi \times 2 \times 4 \times 2$$

$$= 160\pi$$

Q. Find

- emf induced in the loop.
- current in the loop.



Sol. अगर ∞ wire में current i है तो loop से पास flux will be

$\phi_{net} = 2Kib \ln\left(\frac{a+l}{a}\right)$ already solve

Flux at any time -

$$\phi = 2K(2t+3)b\ln\left(\frac{a+l}{a}\right)$$

$$\text{emf} = \frac{d\phi}{dt} = 2Kb\ln\left(\frac{a+l}{a}\right)\frac{d}{dt}(2t+3)$$

$$= 2Kb\ln\left(\frac{a+l}{a}\right)\times 2$$

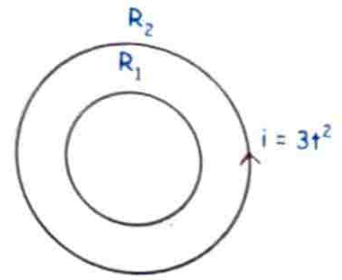
$$i = \frac{\text{Emf}}{\text{Resist.}}$$

#SKC

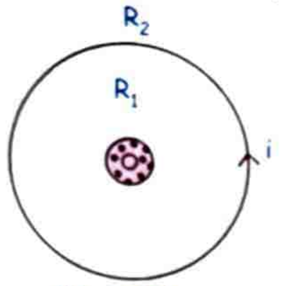
यहाँ हमने देखा एक wire में कुछ-कुछ-कुछ-कुछ करने पर loop में कुछ-कुछ-कुछ-कुछ हुआ (current) कुछ-कुछ-कुछ-कुछ होने की प्रक्रिया को mutual inductance कहते है।

Q. If $R_2 \ggg R_1$ then find

- ϕ inner loop
- emf induced in the inner wire (at t = 2 sec)
- If resistance of inner loop is R_0 find direction of magnitude of current in inner wire (at t = 2 sec)



Sol. ϕ inner loop $= B \cdot \pi R_1^2 = \dfrac{\mu_o i}{2R_2}\pi R_1^2$



$[R_2 \ggg R_1]$

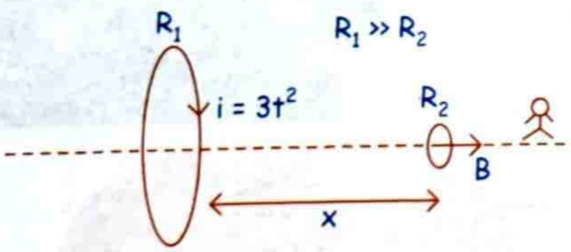
At time 't' -

$$\phi_{inner} = \frac{\mu_o 3t^2}{2R_2}\pi R_1^2$$

$$emf = \frac{d\phi}{dt} = \frac{\mu_o}{2R_2}\pi R_1^2(6t)$$

$$i = \frac{Emf}{Resist.}$$

Q. If current in the bigger loop is increasing as $i = 3t^2$ find current induce in smaller loop in following figure.



Sol. $\phi_{\text{छोटा loop}} = B \cdot Area$

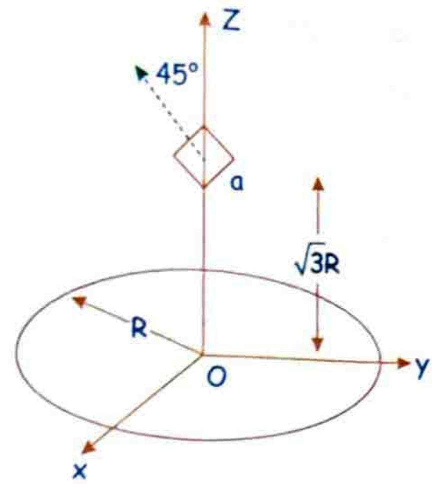
$$= \frac{\mu_o i R_1^2}{2(R_1^2 + x^2)^{3/2}}\pi R_2^2 = \phi$$

$$(emf)_{\text{छोटा loop}} = \frac{d\phi}{dt}$$

$$i_{\text{छोटा loop}} = \frac{Emf}{Resist.}$$

Homework.

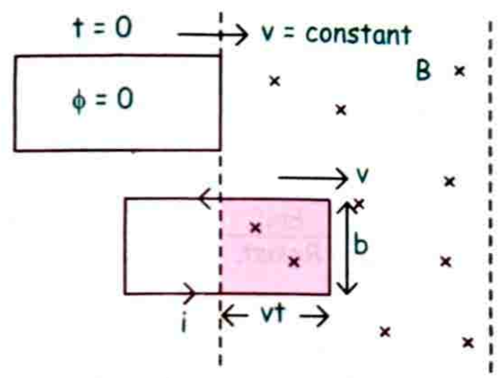
A circular wire loop of radius R is placed in the x-y plane centered at the origin O. A square loop of side a ($a \ll R$) having two turns is placed with its center at $z = \sqrt{3}R$ along the axis of the circular wire loop, as shown in figure. The plane of the square loop makes an angle of 45° with respect to the z-axis. Find the magnetic flux through the square loop



Sol. $\dfrac{\mu_0 I a^2}{2^{\left(\frac{9}{2}\right)}R}$

Q. Rectangle (l, b) is moving with constant velocity (given) inside the magnetic field.

Find emf induced and current loop at given inst.

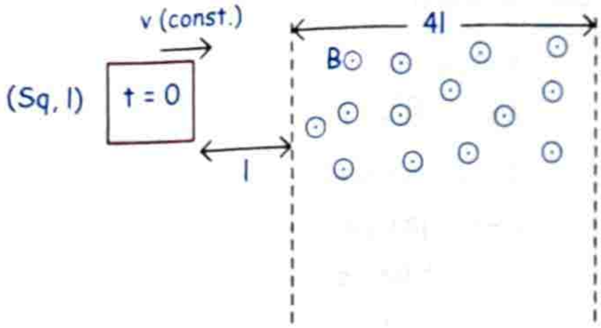


Sol. $\phi = B(vtb)$

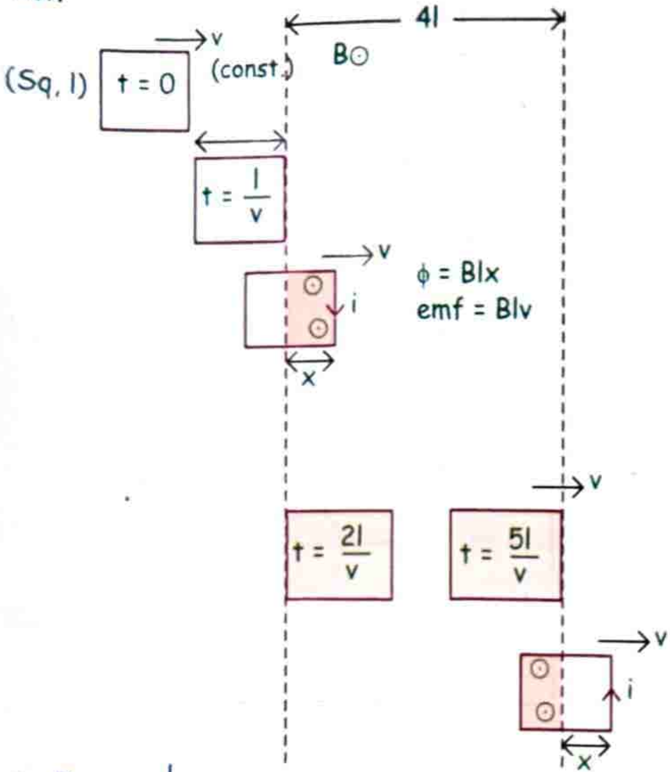
$$emf = \frac{d\phi}{dt} = Bvb(1)$$

$$i = \frac{Emf}{Resist.}$$

Q. Square (l) is moving with constant velocity (given) inside the uniform magneticfield and at t = 0 location of loop is given. Find analyse the question for flux emf and current.



Sol.



- For $t < \frac{l}{v}$

  $\phi = 0$, emf $= 0 = I = 0$

- $\frac{l}{v} < t < \frac{2l}{v}$

  $\phi = Blx,\ i = \frac{Blv}{R}$

  emf $= Blv$

- $\frac{2l}{v} < t < \frac{5l}{v}$

  $\phi \to \text{const} = Bl^2$

  emf $= 0,\ i = 0$

- $\frac{5l}{v} < t < \frac{6l}{v}$

  $\phi = Bl(l - x)$

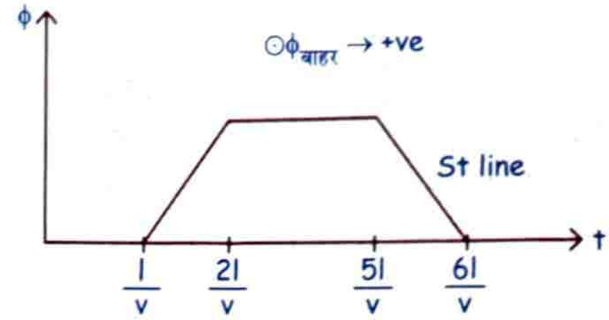
  emf $= \left|\frac{d\phi}{dt}\right| = Blv$(magnitude)

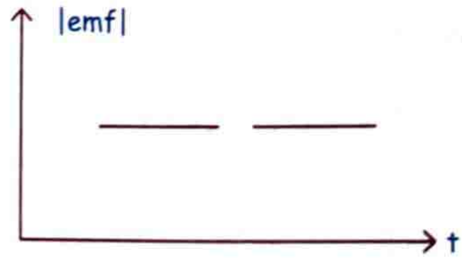
- $t > \frac{6l}{v}$

  $\phi = 0$, emf $= 0$

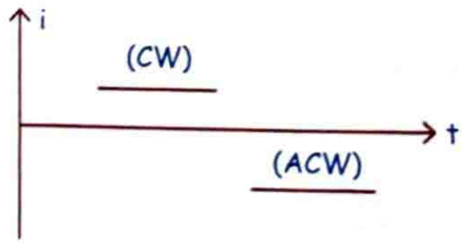
- Result

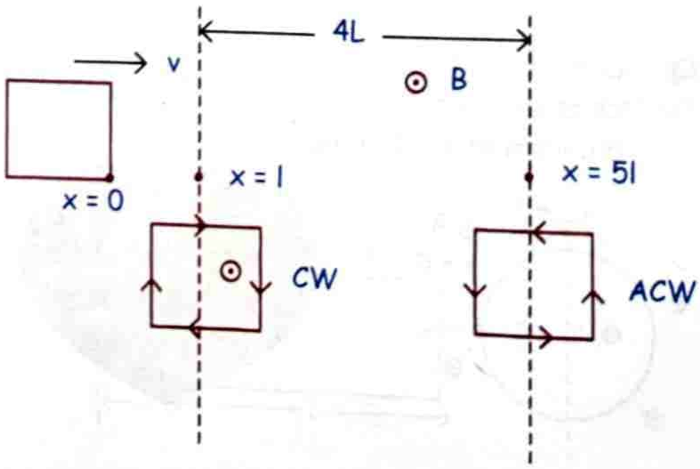
	ϕ	emf	i
$0 < t < \frac{l}{v}$	0	0	0
$\frac{l}{v} < t < \frac{2l}{v}$	Blx	Blv	$\frac{Blv}{R}$(C.w)
$\frac{2l}{v} < t < \frac{5l}{v}$	Const. BL^2	0	0
$\frac{5l}{v} < t < \frac{6l}{v}$	$Bl(l-x)$ as in dig.	Blv	$\frac{Blv}{R}$(ACw)

- 

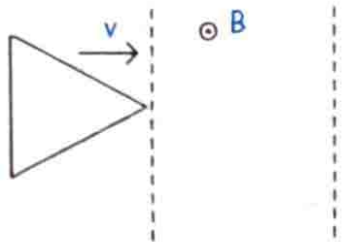


emf $= \left|\frac{d\phi}{dt}\right| = |\text{Slope}|$

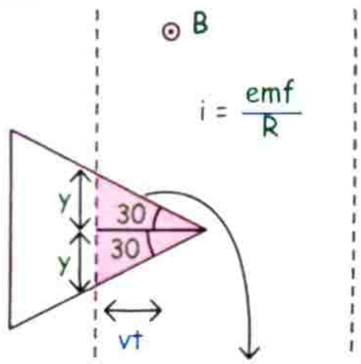




Q. If a equilateral triangle of length l is moving with constant velocity in entire motion in following figure. Find emf induce when it is entering inside magneticfield.



Sol.

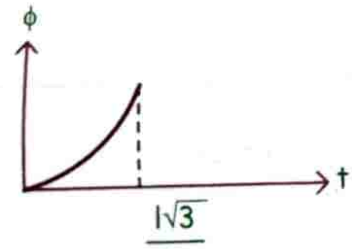


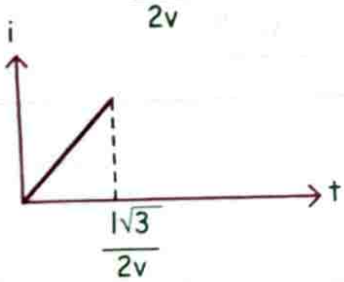
$\tan 30° = y/vt$

$y = \frac{vt}{\sqrt{3}}$

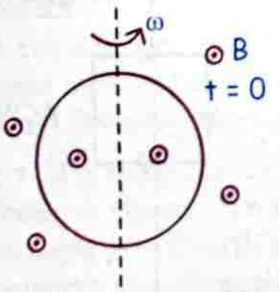
$$\phi = BA = B \cdot \frac{1}{2} \cdot 2y \cdot vt = \frac{Bv^2t^2}{\sqrt{3}}$$

$$emf = \left|\frac{d\phi}{dt}\right| = \frac{2}{\sqrt{3}} Bv^2 t$$





Q. Loop is rotating about its diameter with constant angular velocity as shown in diagram at t = 0. Find emf = f(t).



Sol. At any time 't', $\theta = \omega t$

$$\phi = \vec{B} \cdot \vec{A} = BA \cos \omega t$$

$$emf = -\frac{d\phi}{dt} = BA\omega \sin \omega t$$

If loop has N no. of turn -

$$emf = NBA\omega \sin \omega t$$

$$i = \frac{NBA\omega \sin \omega t}{Resist.} \quad \text{[AC Alternating current]}$$

$$(emf)_{max} = NBA\omega$$

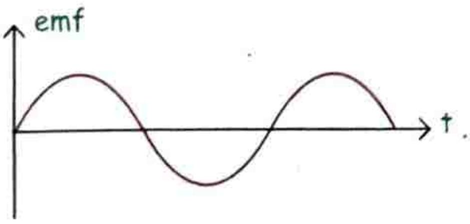
$$i_{max} = \frac{NBA\omega}{Resist.}$$

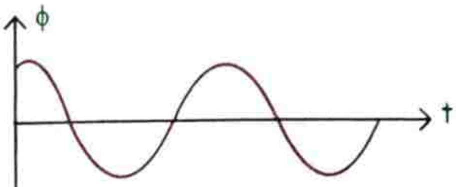
$\Rightarrow$ जब emf max तब flux = 0

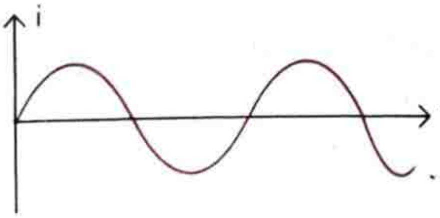
$$\phi = NBA \cos \omega t$$

$$emf = NBA\omega \sin \omega t$$

$$i = \frac{NBA\omega \sin \omega t}{R_o}$$







ये कभी मत भूलना

$$emf = NBA\omega \sin \omega t$$

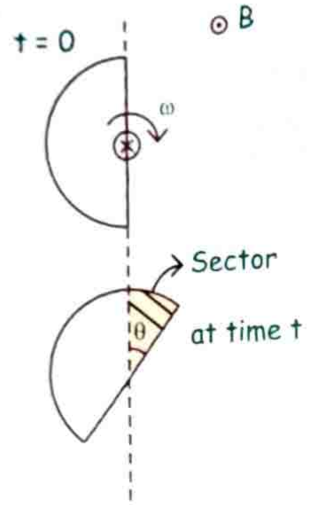
$$(Emf)_{max} = NBA\omega = \text{नवाब}$$

$$i = \frac{NBA\omega}{R} \sin \omega t$$

$$(i)_{max} = \frac{NBA\omega}{R} = \frac{\text{नवाब}}{R}$$

Q. Here we have semi-circular conducting loop of radius r which is made to rotate about O with constant angular velocity ω as shown in figure. If at t = 0 figure is given find emf and current as function of time.

Sol.



when loop rotates through an angle θ ($\theta < \pi$), area inside the field region is

$$A = \frac{\theta}{\pi}\frac{\pi r^2}{2} = \frac{\theta r^2}{2} = \frac{\omega t r^2}{2}$$

$$\text{flux} = BA = B\frac{\omega t r^2}{2}$$

$$\text{Magnitude of induced emf} = \frac{d\Phi}{dt} = \frac{B\omega r^2}{2}$$

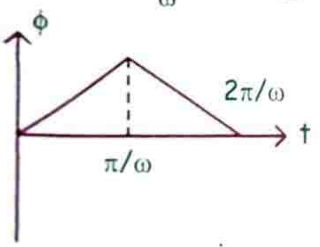
$$\text{Induced current} = \frac{\text{emf}}{\text{resistance of loop}}$$

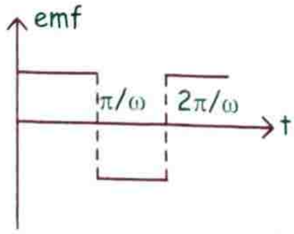
(b) In above question find time when ϕ will be max. 1st time.

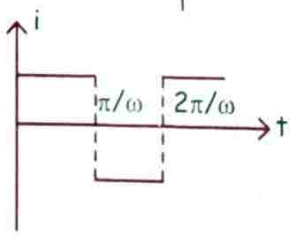
Sol. $\theta = \omega t$

$\pi = \omega t$

$\Rightarrow t = \frac{\pi}{\omega} \Rightarrow \phi_{max}$







AVERAGE EMF

+ $\text{emf} = \frac{d\phi}{dt}$ (magnitude)

  $\text{Average emf} = \frac{\Delta\phi}{\Delta t}$

+ $\phi = 2t^2 + 3$

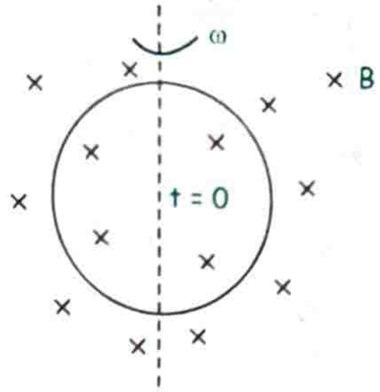
  $t = 2 \to t = 3$

$$\text{Average emf} = \frac{\Delta\phi}{\Delta t} = \frac{\phi_f - \phi_i}{t_2 - t_1}$$

$$= \frac{21 - 11}{3 - 2} = 10$$

Q. A loop is rotating about is diameter as shown in figure find average emf from (a) $t = 0$ to $t = T/4$ (b) $t = 0$ to $t = T/2$.

Sol.



$$\phi = B \cdot A = BA\cos\omega t$$

$t = 0 \to t = T/4$

$$\langle \text{emf} \rangle = \frac{\Delta\phi}{\Delta t} = \left|\frac{\phi_f - \phi_i}{\Delta t}\right|$$

$$= \left|\frac{0 - BA}{t/4}\right| = \frac{4BA}{T}$$

$t = 0 \to t = T/2$

$$\langle \text{emf} \rangle = \frac{2BA}{T/2}$$

$t = 0 \to t = T$

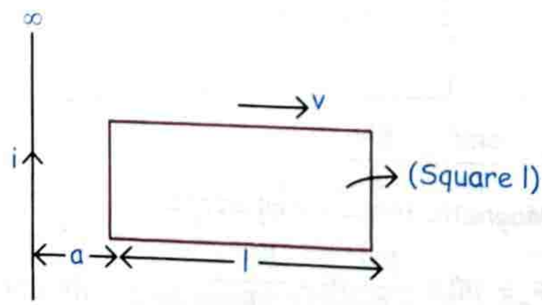
$$\langle \text{emf} \rangle = \frac{0}{T} = 0$$

#SKC

अगर Δt time में $\Delta\phi$ flux charge hua तो कितना charge flow krega?

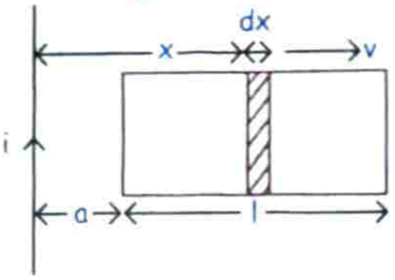
$$\text{emf} = \frac{d\phi}{dt} \Rightarrow \frac{\Delta\phi}{R} = \Delta q$$

Q. If loop is moving away from infinite wire as shown in figure with velocity v. Find emf at this instant.



Sol. $\phi_{net} = \int d\phi = \int_a^{a+l} BLdx$

$= \int_a^{a+l} \frac{2Ki}{x} \cdot L \cdot dx$



$\phi_{net} = 2KLi[\ln(a+l) - \ln a]$

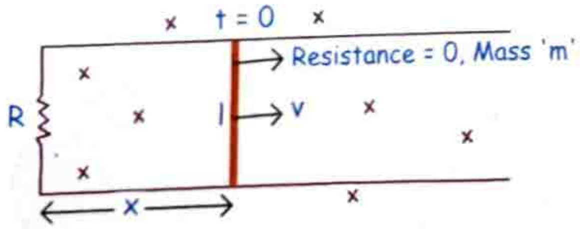
$emf = -\frac{d\phi}{dt}$

$= -2KLi\left[\frac{v}{a+L} - \frac{v}{a}\right]$

$emf = \frac{2KL^2iv}{(L+a)a}$ Use $\left(\frac{da}{dt} = V\right)$

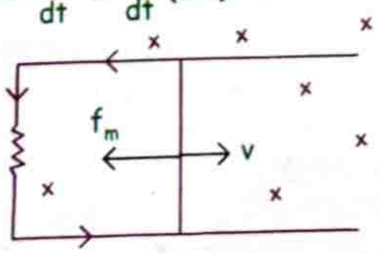
Rail वाला सवाल very important

Q. (a) A conducting rod of length l, mass m is given velocity v at t = 0 as shown in figure. Find ϕ, emf, i at t = 0.



Sol. $\phi = Blx$

$|emf| = \frac{d\phi}{dt} = \frac{d}{dt}(Blx) = Blv$



$i = \frac{emf}{R} = \frac{Blv}{R}$

(b) Magnetic force acting on rod.

Sol. $F_m = ilB = \frac{Blv}{R} lB = \frac{B^2l^2v}{R}$

(c) Find v of rod at time 't' sec.

Sol. $v = f(t)$. Let at $t = 0$, $v = v_0$.

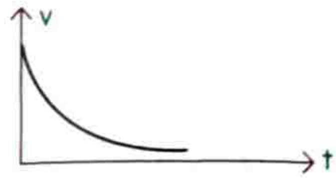
$F_m = ilB = \left[\frac{Blv}{R}\right]lB$

$m\vec{a} = -\frac{B^2l^2}{R}\vec{v}$

$a = -\frac{B^2l^2}{Rm}v$

$\frac{dv}{dt} = \frac{-B^2l^2}{Rm}v$

$\int_{v_0}^{v} \frac{dv}{v} = \int_0^t -\frac{B^2l^2}{Rm}dt$

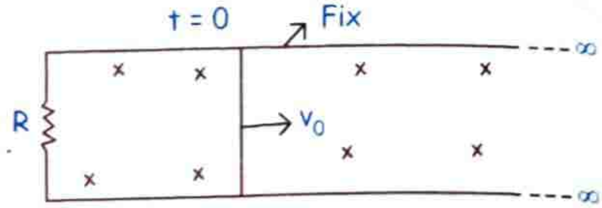


Solve and get $v = v_0 e^{-\frac{B^2l^2}{Rm}t}$

$a = \frac{dv}{dt}$

$t = \infty \Rightarrow v \to 0$

(d) Find the external force required so that rod moves with constant velocity (Magnitude and direction).



Sol. $F_{ext} = ilB = \frac{BlV_o}{R} \cdot lB = \frac{B^2l^2V_o}{R}$

(e) Power supply by external agent in (d) part.

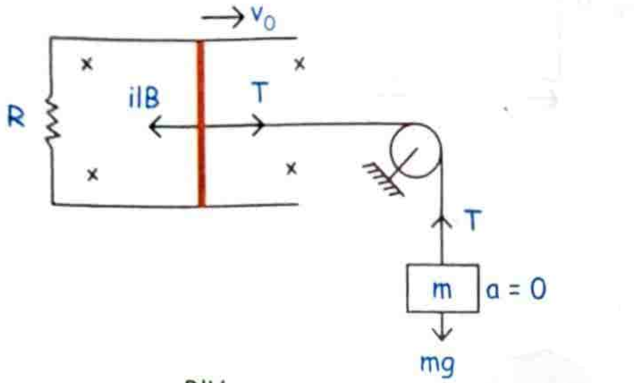
Sol. $P = Fv = \frac{B^2l^2V_o}{R} \cdot V_o$

$= \frac{B^2l^2V_o^2}{R}$

Q. Power loss across the resistance.

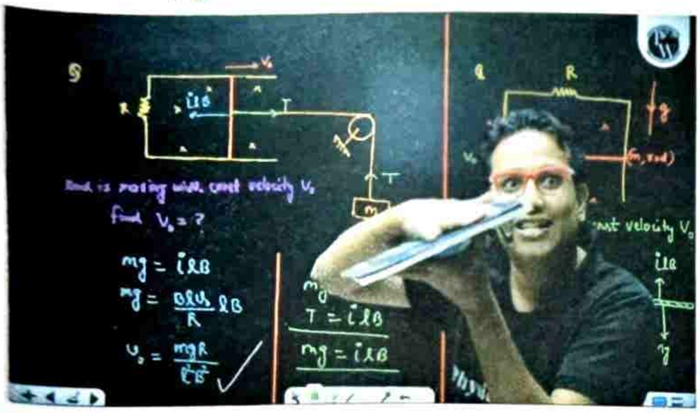
Sol. $i^2R = \left[\frac{Blv_o}{R}\right]^2 R = \frac{B^2l^2V_o^2}{R}$.

Q. If rod and block are moving with constant velocity in following figure. Find velocity

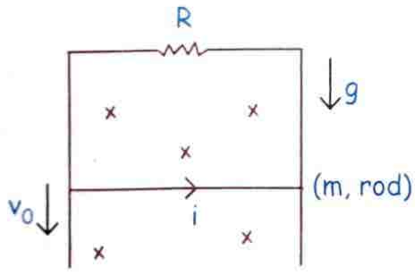


Sol. $mg = ilB = \frac{BIV_o}{R} \cdot IB$

$$v_0 = \frac{mgR}{I^2B^2}$$



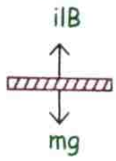
Q.



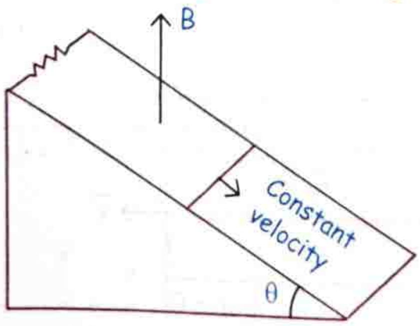
Rod is falling with constant velocity V_0.

Sol. $mg = ilB$

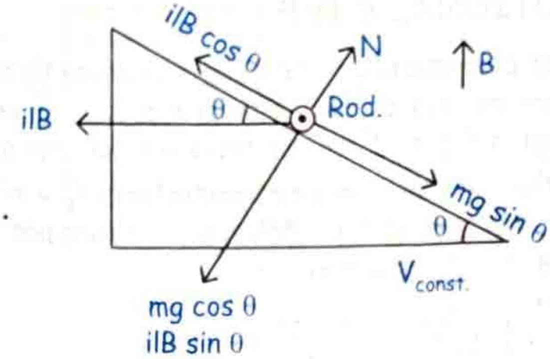
$$= \frac{BIV_o}{R} \cdot IB$$

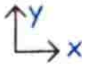


Q. Rod is moving constant velocity down the inclined plane as shown in figure. Find the v_o



Sol.





$$\vec{F}_m = i(\vec{l} \times \vec{B}) = \hat{k} \times \hat{j}$$

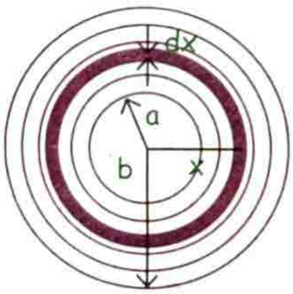
direction of $F_m = -\hat{i}$

$$mg \sin\theta = ilB\cos\theta.$$

Q. If $B\uparrow$ as $\frac{dB}{dt} = \alpha$, find emf induced. Emf induced in the spiral of inner radius R_1 and outer radius R_2 and total number of tight turn is N as shown in figure.

Sol. x पर जाकर dx thickness का एक ring पकड़ा जिसमे let no. of turn is dN. Now flux through the area is $= \phi = B\pi x^2 \cdot$

dN where $dN = \frac{N}{b-a} \times dx$



$$\phi = \int_a^b \frac{N}{b-a} \cdot dx \cdot B\pi x^2$$

$$\phi_{net} = \frac{N}{b-a} B\pi \left[\frac{b^3 - a^3}{3}\right]$$

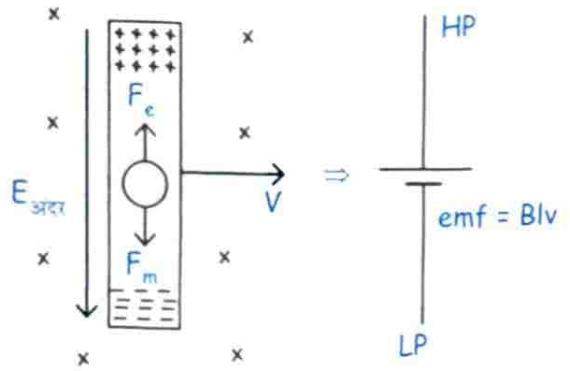
Magnitude of emf $= \frac{d\phi}{dt}$

$$= \frac{N}{b-a}\left[\frac{b^3 - a^3}{3}\right]\pi\left[\frac{dB}{dt}\right]$$

Put the value get the answer.

1. MOTIONAL E.M.F

Consider a conducting bar of length l moving through a uniform magnetic field which points into the page, as shown in figure. Free electrons with charge $q < 0$ inside the bar experience a magnetic force $\vec{F}_B = q\vec{v} \times \vec{B}$ which tends to push them downwards, leaving positive charges on the upper end.



When equillibrium is achieved

$$F_{net} = 0$$

$$q\vec{E} + q\vec{v} \times \vec{B} = 0$$

$$\vec{E} = -(\vec{v} \times \vec{B})$$

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

$$dV = -(-\vec{v} \times \vec{B} \cdot d\vec{l})$$

$$\int dV = \int \vec{v} \times \vec{B} \cdot dl$$

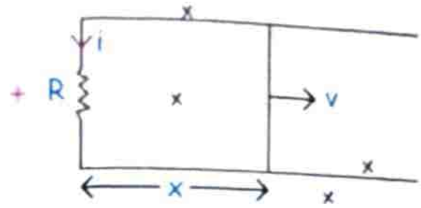
$$emf = (\vec{v} \times \vec{B}) \cdot \vec{l}$$

#SKC

भागती hui conducting rod inside Magnetic field will behave like सच्ची मुच्ची की battery $(\vec{v} \times \vec{B}) \cdot \vec{l}$. Battery का बड़ा डंडा उधर, जिधर +ve charge पर Magnetic Force लगता hai.

#SKC

यहाँ Rod के across emf ϕ की वजह से नहीं आया, charge के separation की वजह से आया है।



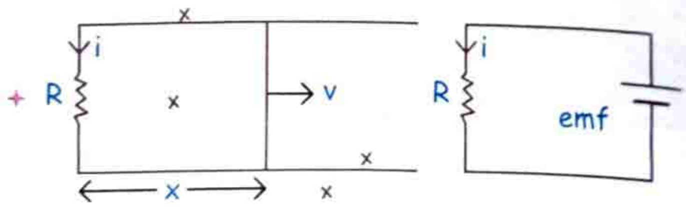
$$\phi = Blx$$

$$emf = Blv$$

$$i = \frac{Blv}{R}$$

#SKC

यही सवाल पहले हमने flux को differentiate करके किया था अब पता चला कएदे में battery जैसी चीज rod में developed हो गई जिसके वजह से current आया।

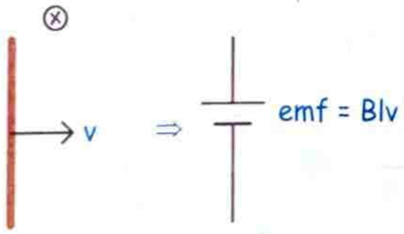


$$emf = Blv$$

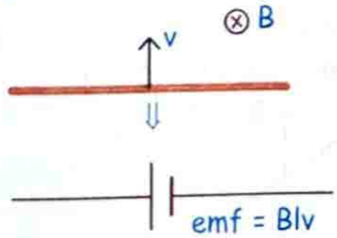
$$i = \frac{Blv}{R}$$

Q. Find emf across the rod in following case,

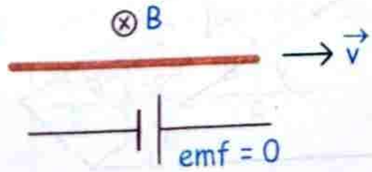
(a)



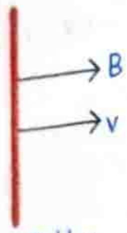
(b)



(c)



(d)



emf = 0

$B \parallel v$

$$\text{emf} = (\vec{v} \times \vec{B}) \cdot \vec{l}$$

$$\vec{l} = \hat{j}, \quad v \to \hat{i}, \quad B \to \hat{i}$$

$$\text{emf} = [\hat{i} \times (-\hat{i})] \cdot \hat{j} = 0$$

#SKC

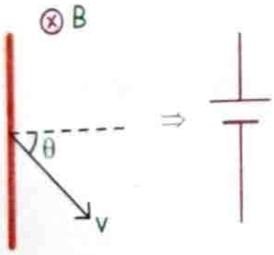
$\text{emf} = (\vec{v} \times \vec{B}) \cdot \vec{l}$

अगर कोई भी दो parallel या A.P हुऐ तो emf = 0

$$\vec{v} \parallel \vec{B} \to \text{emf} = 0$$

$$\vec{l} \parallel \vec{v} \to \text{emf} = 0$$

$$\vec{l} \parallel \vec{B} \to \text{emf} = 0$$



emf = $Blv \cos\theta$

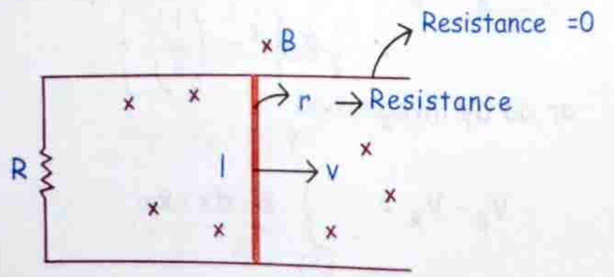
Q. Find emf across the moving rod.

$$\vec{v} = v_1\hat{i} + v_2\hat{j}$$

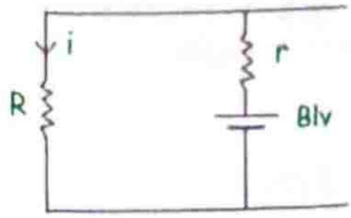
$$\vec{B} = B_1\hat{i} - B_2\hat{k}$$

$$\text{emf} = B_2 l v_2$$

Q. If rod has resistance r then current through resistance will be

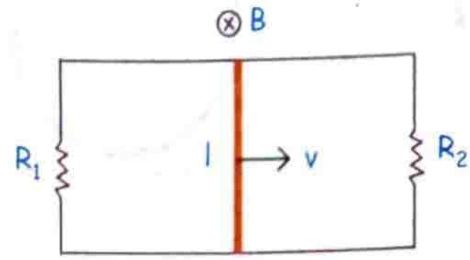


Sol.

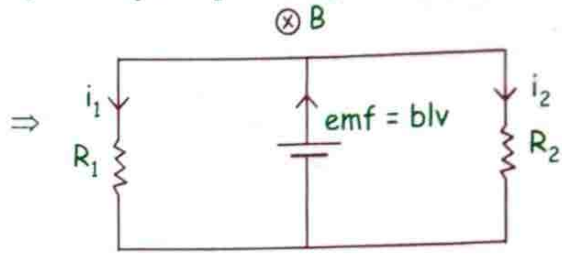


$$i = \frac{Blv}{R+r}$$

Q. Find the current through R_1 and R_2 resistance if resistance of rod is zero.

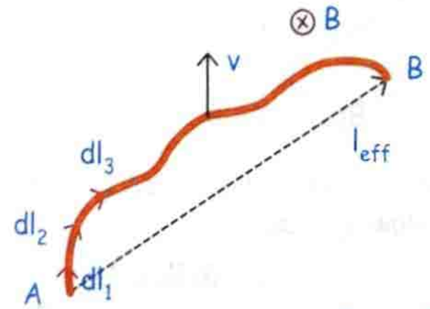


Sol. $i_1 = blv/R_1$ and $i_2 = blv/R_2$



IF ROD IS उटपटाँग (RANDOM WIRE)

✦



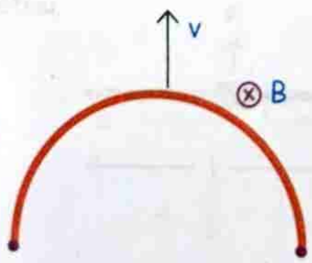
$$(\text{Emf})_{net} = (\vec{v} \times \vec{B}) \cdot \vec{dl_1} + (\vec{v} \times \vec{B}) \cdot \vec{dl_2} + (\vec{v} \times \vec{B}) \cdot \vec{dl_3} + \ldots + \infty.$$

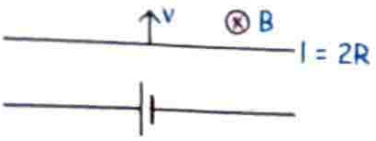
$$= (\vec{v} \times \vec{B}) \cdot (\vec{dl_1} + \vec{dl_2} + \ldots \infty)$$

$$= (\vec{v} \times \vec{B}) \cdot \vec{l}_{eff}$$

Q. Find emf develope across the wire

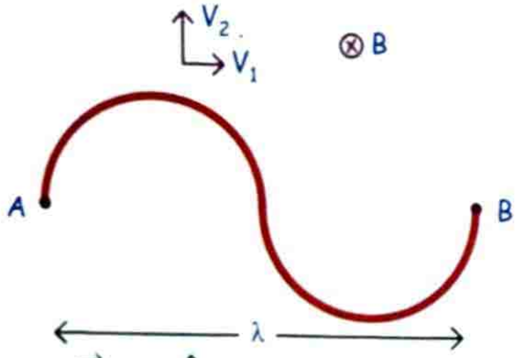
(a)





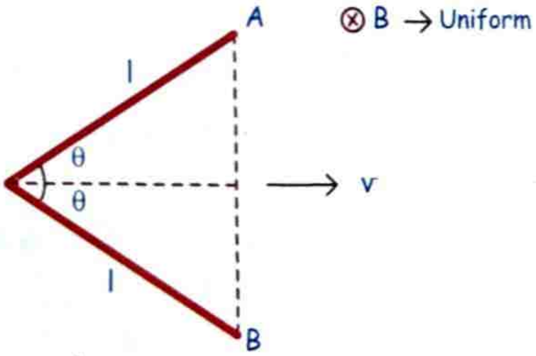
$$emf = B2Rv$$

(b)



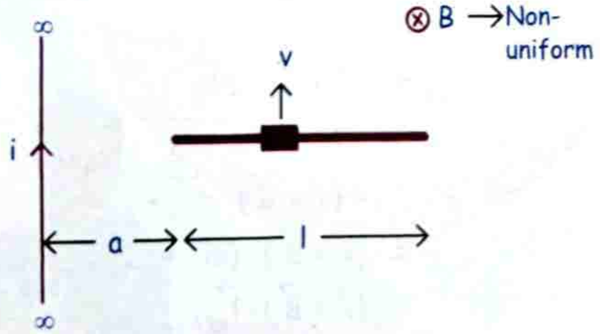
$$\vec{v} = v_1\hat{i} + v_2\hat{j}$$
$$V_A - V_B = B\lambda v_2$$
$$V_B - V_A = -B\lambda v_2$$
$$emf = B\lambda v_2$$

(c)

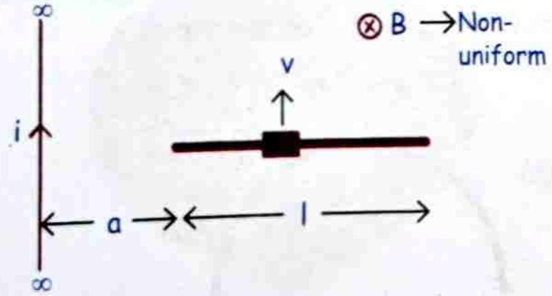


$$V_A - V_B = B(2l\sin\theta)v$$

Q. Find the emf developed across the rod of length l in following case.



Sol.



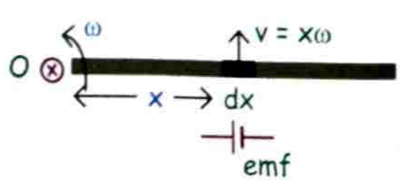
$$d(emf) = B \cdot dx \cdot v = \frac{2Ki}{x} dx \cdot v$$

$$(Emf)_{net} = \int_a^{a+l} \frac{2Kivdx}{x}$$

$$= 2Kiv \ln\left(\frac{a+l}{a}\right)$$

Q. A conducting rod is fixed at O rotating inside uniform magnatic field with constant angular velocity. Find emf developed across the rod.

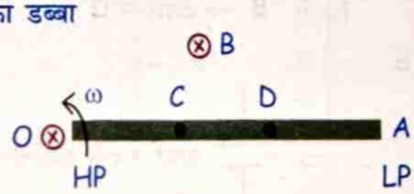
Sol. ⊗ B → Uniform



$$V_O - V_A = \frac{1}{2}B\omega l^2$$
$$d_{emf} = B \cdot dx \cdot x\omega$$
$$(Emf)_{net} = \int_a^l B \cdot dx \cdot x\omega = \frac{B\omega}{2} l^2$$

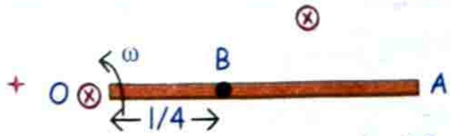
काम का डब्बा

⊗ B



$$V_O - V_A = \frac{1}{2}B\omega l^2$$
$$V_O - V_C = \frac{1}{2}B\omega(OC)^2$$
$$V_O - V_D = \frac{1}{2}B\omega(OD)^2$$

⊗

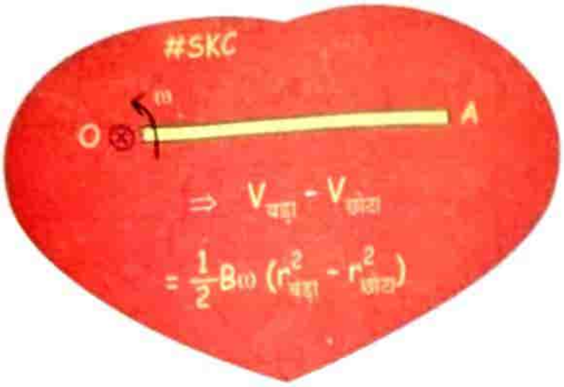


$$V_O - V_B = \frac{1}{2}B\omega\left[\frac{l}{4}\right]^2 \quad ...(1)$$
$$V_O - V_A = \frac{1}{2}B\omega l^2 \quad ...(2)$$
$V_B - V_A =$ Subtract above equation
$$= \frac{1}{2}B\omega\left[l^2 - \left(\frac{l}{4}\right)^2\right]$$

or do by integration

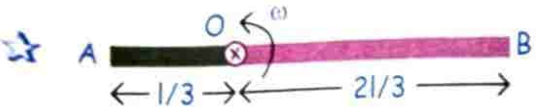
$$V_B - V_A = \int_{l/4}^{l} B \cdot dx \cdot x\omega$$

$$= \frac{B\omega}{2}\left[l^2 - \left(\frac{l}{4}\right)^2\right]$$



⊗ B → Uniform

☆



Find $V_A - V_B = ?$

$$V_O - V_A = \frac{1}{2}B\omega\left(\frac{l}{3}\right)^2$$

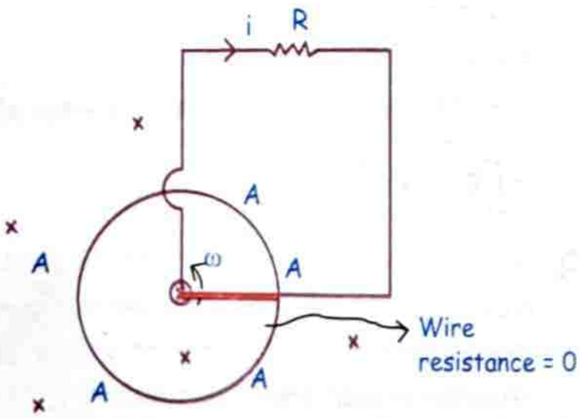
$$V_O - V_B = \frac{1}{2}B\omega\left(\frac{2l}{3}\right)^2$$

Solve and get

$$V_A - V_B = \frac{1}{2}B\omega\left[\left(\frac{2l}{3}\right)^2 - \left(\frac{l}{3}\right)^2\right]$$

Q. A conducting rod of length l fixed at O is rotating about O on a horizontal surface such that it's another end always lie on the conducting ring of zero resistance as shown in figure. Find current through the R.

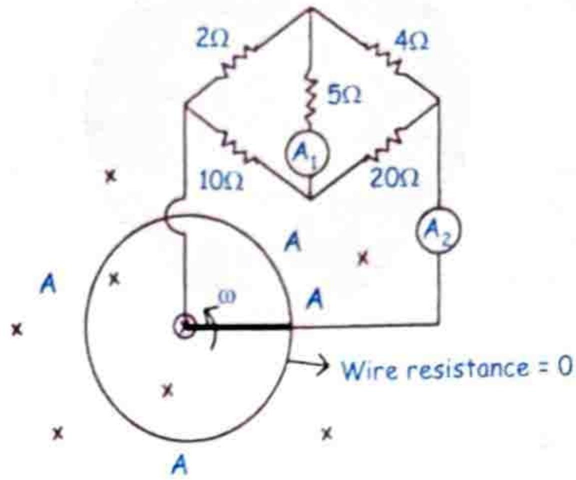
Sol.

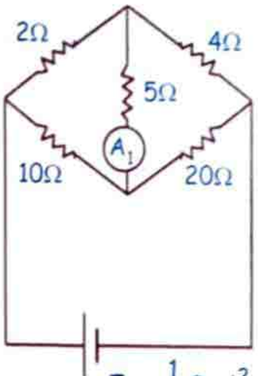


$$V_O - V_A = \frac{1}{2}B\omega l^2$$

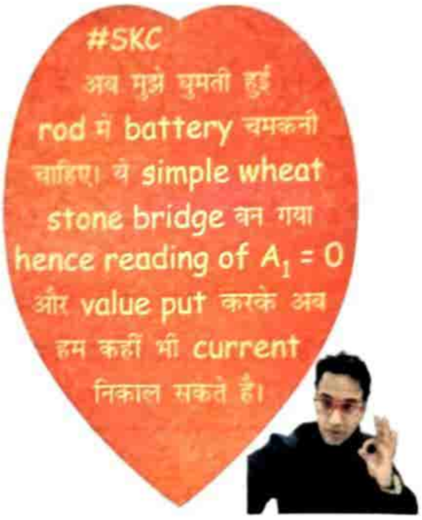
$$i = \frac{1}{2}\frac{B\omega l^2}{R}$$

Q. Find reading of ammeter A_1 and A_2.





$$E = \frac{1}{2}B\omega l^2$$



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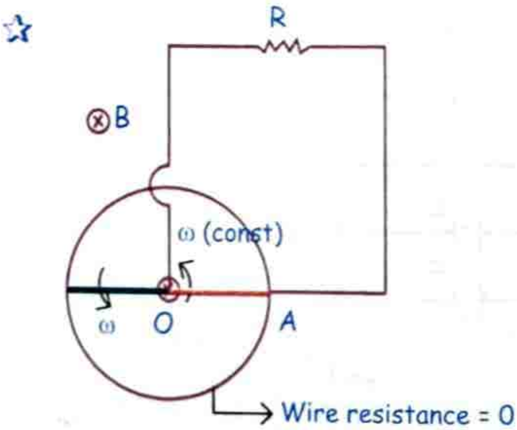
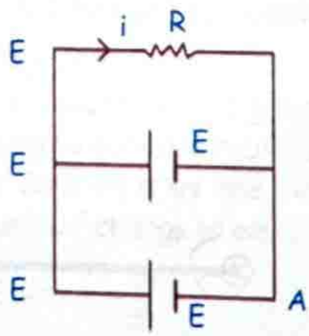


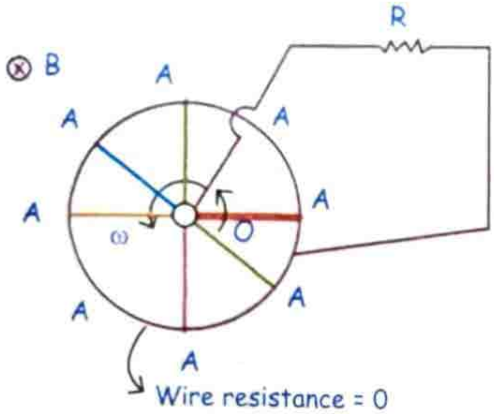
Resistance of both rod = 0



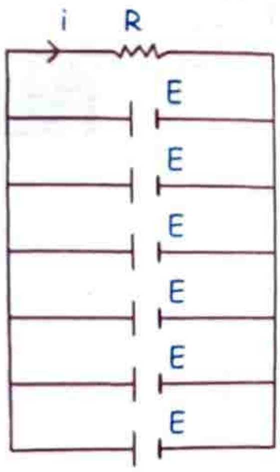
$$i = \frac{E}{R} = \frac{1}{2}\frac{Bwl^2}{R}$$

#SKC
अगर यहाँ पर Rod resistance वाली होती, तो मैं Internal Resistance वाली Battery लगाती

☆



Resistance of all rod are zero.

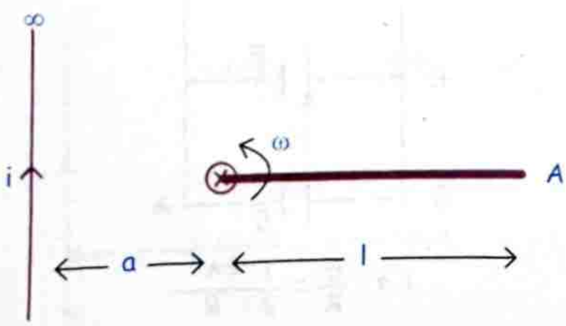


Here current in the R is independent on the no. of rod.

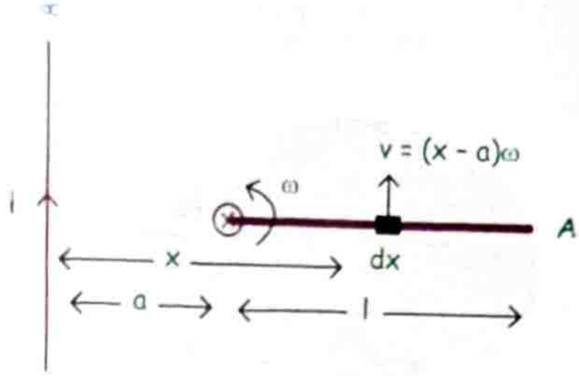
$$i = \frac{emf}{R} = \frac{\frac{1}{2}Bwl^2}{R}$$

Radius
Resistance

Q. Find the emf develope across the rod in following figure.



Sol.

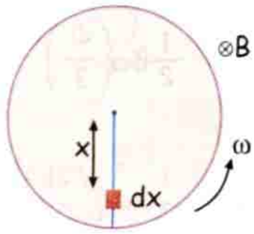


$$dEmf = B \cdot dx \cdot V$$

$$dEmf = \int_a^{a+l} \frac{2Ki}{x} \cdot dx \cdot (x-a)\omega$$

Now you can solve.

ROTATION OF DISK INSIDE UNIFORM MAGNETICFIELD



Consider a disc of radius r rotating in a magnetic field B, which is along axis of rotation.

Consider an element dx at a distance x form the centre. This element is moving with speed $v = \omega x$.

∴ Induced emf across dx

$= B(dx)v = Bdx\omega x = B\omega xdx$

∴ Emf between the centre and the edge of disc

$$= \int_0^r B\omega x dx = \frac{B\omega r^2}{2}$$

Q. *A wire bent as a parabola $y = kx^2$ is located in a uniform magnetic field as shown in figure. At the moment $t = 0$ a connector starts sliding translation wise from the parabola apex with a constant acceleration a along y-axis. Find the emf across the rod develope as a function of y.*

Sol. $t = 0 \Rightarrow u = 0$

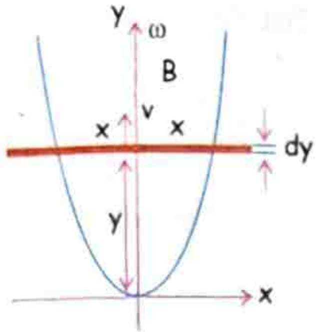
$$y = 0 + \frac{1}{2}at^2$$

$$t = \sqrt{\frac{2y}{a}} \quad \text{...(i)}$$

$$V = at = a\sqrt{\frac{2y}{a}}$$

$$V = \sqrt{2ay} \quad \text{...(ii)}$$

$$e = Blv = B.2x.\sqrt{2ay} \quad \text{...(iii)}$$



We know $y = kx^2$

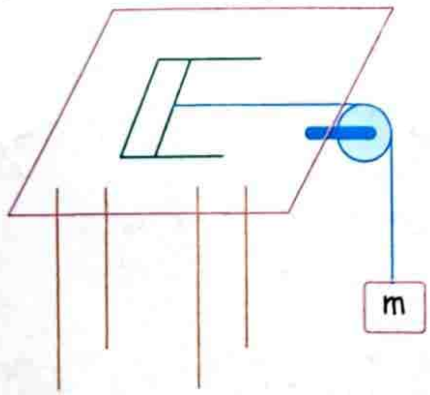
$$x = \sqrt{\frac{y}{k}}$$

$$\text{emf} = B.2\sqrt{\frac{y}{k}}.\sqrt{2ay}$$

$$\text{emf} = By\sqrt{\frac{8a}{k}}$$

Homework

Q. A pair of parallel horizontal conducting rails of negligible resistance shorted at one end is fixed on a table. The distance between the rails is L. A conducting massless rod of resistance R can slide on the rails frictionlessly. The rod is tied to a massless string which passes over a pulley fixed to the edge of the table. A mass m, tied to the other end of the string hangs vertically. A constant magnetic field B exists perpendicular to the table. If the system is released from rest, calculate terminal speed of rod.



Ans. $\frac{mgR}{B^2L^2}$

Q. A bicycle is resting on its stand in the east-west direction and the rear wheel is rotated at an angular speed of 50 revolutions per minute. If the length of each spoke is 30.0 cm and the horizontal component of the earth's magnetic field is 4×10^{-5} T, find the emf induced (in μV) between the axis and the outer end of a spoke. Neglect centripetal force acting on the free electrons of the spoke.

Ans. [9.4]

Q. A person peddles a stationary bicycle whose pedals are attached to a coil having 100 turns each of area 0.1 m^2. The coil, lying in the x-y plane, is rotated about y-axis, at the rate of 50 rpm in a region where a uniform magnetic field, $\vec{B} = (0.01)\hat{k}$ tesla is present. Find the (*i*) maximum emf, (*ii*) average emf generated in the coil over one complete revolution.

Sol. (i) Maximum emf generated is given as

$$\varepsilon_0 = NBA\omega = NBA \times 2\pi f$$

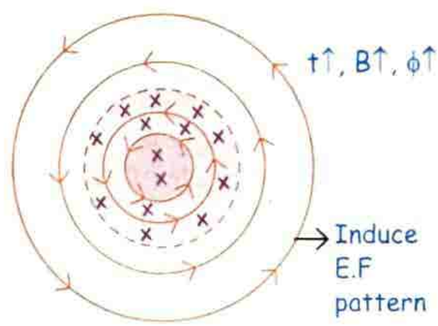
$$= 100 \times 0.01 \times 0.1 \times 2 \times \pi \times \frac{5}{6} = \frac{\pi}{6}\ V = 0.52\ V$$

(ii) Average emf generated in the coil over one complete cycle is zero as the generated emf varies sinusoidally with time.

INDUCED ELECTRIC FIELD

+ Time varying magnetic field produce induce E.F, which is non conservative in nature.

$$B = B_0t^2$$



+ This induced E.F form close loop upto ∞.
+ (WD) by this field in close path is non-zero.
+ Non-conservative in nature.
+ For cylindrical symmetry, the electric field has the same magnitude at every point on the circle and it is tangential at each point.
+ $\vec{F} = q\vec{E}$ (Applicable)
+ Direction of induced E.F is given by Lenz law.
+ When a charge q goes one round in the loop, the total work done on it by the induced electric field per unit of charge is equal to the emf.

Hence $\oint \vec{E}.\vec{dl} = \varepsilon = -\frac{d\phi}{dt}$

This equation is valid only if the path around which we integrate is stationary.

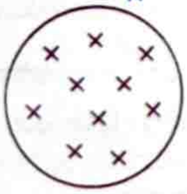
SKC

Electrost. wali E.F	EMI wala E.F [जो $B = f(t)$ की वजह से आई]
☆ EF due to charge at rest	☆ Induced E.F due to time varying magnetic field.
☆ Close loop nhi banati thi	☆ Close loop banati hai.
☆ Conservative nature	☆ Non-conservative nature
☆ Close path mein agar kisi charge q ko move kre $\Rightarrow$ (WD) = 0	☆ Close path mein agar kisi charge q ko move kre (WD) $\neq$ 0.
☆ $\vec{F} = q\vec{E}$ (Applicable)	☆ $\vec{F} = q\vec{E}$ (Applicable).

$$\boxed{\oint \vec{E}\cdot\vec{dl} = \vec{A}\cdot\frac{\vec{dB}}{dt}}$$

I.E.F ← $\vec{E}$ $\vec{A}$ → Flux वाला

Q. Find the value of induced E.F at a point -
— inside the boundary ($r < R$)
— outside the boundary ($r > R$)



Sol. If magnetic field is increasing as shown -

Outside ($r > R$) Flux (वाला)

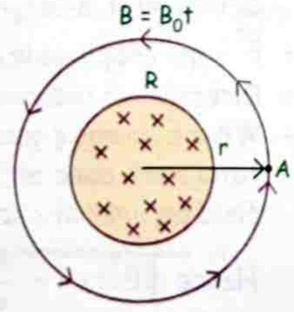
$$\oint \vec{E}\cdot\vec{dl} = A\cdot\frac{dB}{dt}$$

$$E\cdot\int dl = A\cdot\frac{dB}{dt}$$

$$E\cdot 2\pi r = A\cdot\frac{dB}{dt}$$

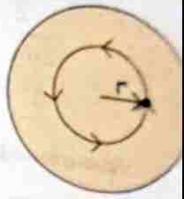
$$E = \frac{A\left(\frac{dB}{dt}\right)}{2\pi r}$$

$$= \frac{\pi R^2\cdot B_0}{2\pi r}\ (\because B = B_0 t \Rightarrow \frac{dB}{dt} = B_0)$$



Inside ($r < R$)

$$\oint \vec{E}\cdot\vec{dl} = \vec{A}\cdot\frac{\vec{dB}}{dt}$$

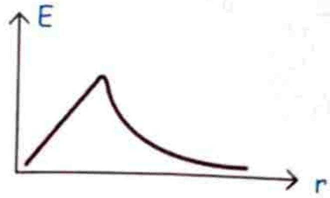


$$E\cdot\int dl = A\cdot\frac{dB}{dt}$$

$$E\cdot 2\pi r = A\cdot\frac{dB}{dt}$$

$$E = \frac{A}{2\pi r}\left(\frac{dB}{dt}\right) = \frac{\pi r^2}{2\pi r}B_0 = \frac{r}{2}B_0$$

GRAPH



Q. Repeat last question if $B = 3t^2 + 4$

(a) Find induce E.F at $r = 3R$.

Sol. $E = \dfrac{A_{flux}}{2\pi r}\dfrac{dB}{dt}$

$$E = \frac{\pi R^2}{2\pi 3R}\cdot 6t = Rt$$

(b) Find value of induce E.F at $r = R/2$.

Sol. $E = \dfrac{\pi(R/2)^2}{2\pi R/2}\cdot 6t = \dfrac{3}{2}Rt.$

Result

$$E = \frac{A}{2\pi r}\frac{dB}{dt}$$ → ϕ (वाला)

Inside $A = \pi r^2$

Outside $A = \pi R^2$ [Flux वाला Area]

Inside $r < R$

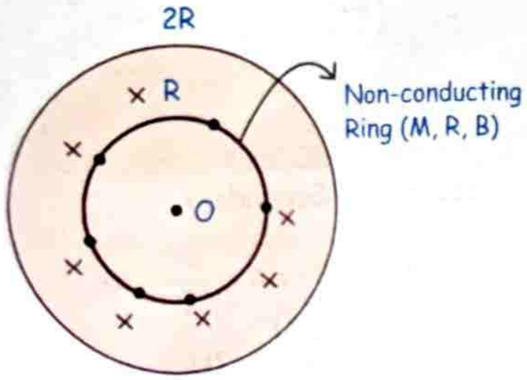
$$E = \frac{r}{2}\frac{dB}{dt}$$

Outside $r > R$

$$E = \frac{\pi R^2}{2\pi r}\cdot\frac{dB}{dt}$$

Q. Suppose we have uniform cylinderical magnetic field $B = 3t^2 + 4$ inside region of radius 2R. Now a non-conducting ring of charge Q and radius R is placed as shown in figure.

[jo 0 से 2R tk hai]



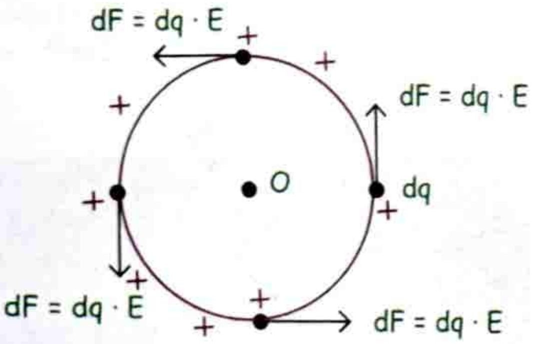
(a) Find induce E.F at r = R [inside wala case]

Sol. $E \cdot 2\pi r = \pi r^2 \cdot \frac{dB}{dt}$

$E = \frac{r}{2}\frac{dB}{dt} = \frac{R}{2}6t = 3Rt$

(b) Find the torque applied by induced electric field on non-conducting ring

Sol.



$\int (d\tau)_{abt'o'} = \int dq \cdot E \cdot R$

$(\tau_{net})_{E.F} = ER\int dq = QER.$

$\tau = QER = I\alpha = MR^2\alpha$

$\alpha = \frac{QE}{MR}$

(Now put the value of E and get α also)

(c) Find the ω(angular velocity) of the ring after 10 sec.

Sol. $\omega = \omega_i + \alpha t = 0 + \frac{QE}{MR} \times 10$

अगर α time का function होता तो हम integrate करके ω निकाल लेते।

(d) If coefficient of static friction μ_s. Find when ring start rotating.

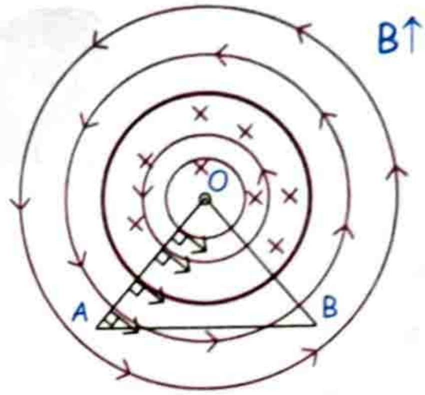
Sol. $\tau_{\text{due to induce E.F}} \geq \tau_{\text{due to friction}}$

$QER \geq \mu_s mgR$

$Q3RtR \geq \mu_s mgR$

$t \geq \frac{\mu_s mg}{3QR}$

+ $(WD)_{by}$ induce E.F on a charge particle if charge move along OA line (radial) = 0 (θ = 90° everywhere).



$(Emf)_{OA} = 0$

$(Emf)_{OB} = (Emf)_{BO} = 0$

$(Emf)_{A\to B} = A\frac{dB}{dt} = (Emf)_{OAB}$

(Area of ΔOAB)

Emf along radial line = 0 (for circular induced EF).

$(Emf)_{OAB} = \frac{d\phi}{dt} = A\frac{dB}{dt}$ (Area of ΔAOB)

#SKC

अगर मैं किसी point charge q को OA line पर चलाऊ तो यहाँ induced E.F का WD → 0 होगा, क्योंकि field displacement के perpendicular हैं। मतलब यहाँ centre se join krne वाली कोई भी line हो → No emf. जैसे की OB line.

MUTUAL INDUCTANCE

+ Whenever there is flux in primary coil it produce flux in secondary coil called mutual flux.
+ Whenever there is change in current in primary coil it change the flux in secondary coil resulting into induce Emf in secondary coil this property is called mutual inductance.

$$\phi_s \propto i_p$$

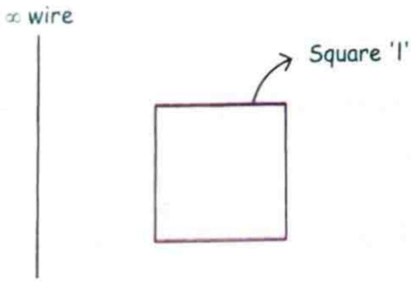
$$\Rightarrow \qquad \phi_s = \underset{\downarrow}{M} i_p$$

(Coefficient of Mutual inductance it depend on shape, size, medium, orientation)

+ $M_{12} = M_{21}$

#SKC
यहाँ हमने देखा एक wire में
कुछ-कुछ-कुछ-कुछ करने पर loop में
कुछ-कुछ-कुछ-कुछ हुआ (current)
कुछ-कुछ-कुछ-कुछ होने की प्रक्रिया
को mutual inductance
कहते है।

Q. Find coefficient of Mutual Inductance in following case.

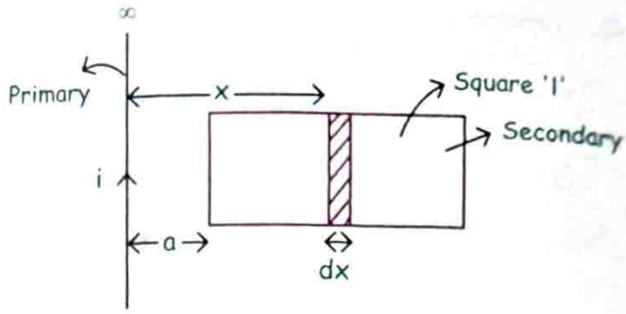


Sol.

#SKC
Mutual Inductance -
दिमाग लगाके primary and secondary मान लो
Primary में i flow करके secondary में flux निकालों

$\phi = Mi$

(M is coefficient of Mutual Inductance)



∞ wire = Primary

square = Secondary

$$d\phi = B \cdot dA = \frac{2Ki}{x} L dx$$

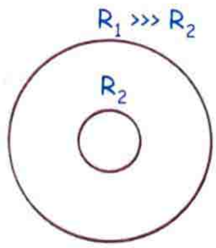
$$\phi = \int_a^{a+l} \frac{2Ki}{x} \cdot L dx$$

$$\phi = 2KiL \ln\left(\frac{a+l}{a}\right)$$

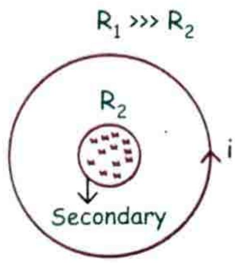
Secondary $\quad \phi_s = \left[2KiL \ln\left(\frac{a+l}{a}\right)\right] i = Mi$

$$M = 2KL \ln\left(\frac{a+l}{a}\right)$$

Q. Suppose we have to cocentric ring of radius R_1 and R_2 as shown in figure. Find coefficient of Mutual Inductance.



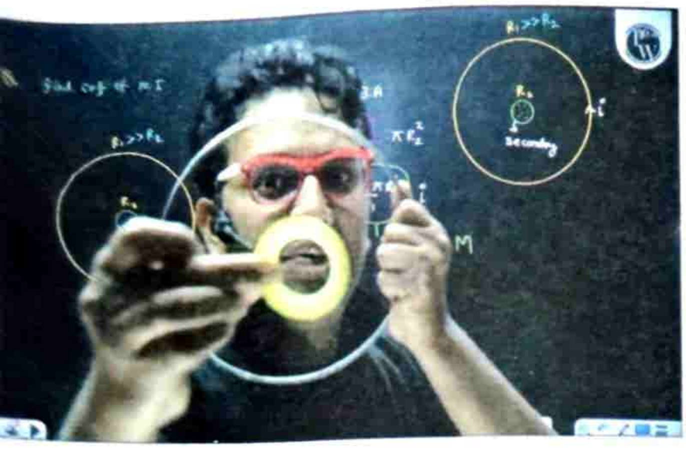
Sol.



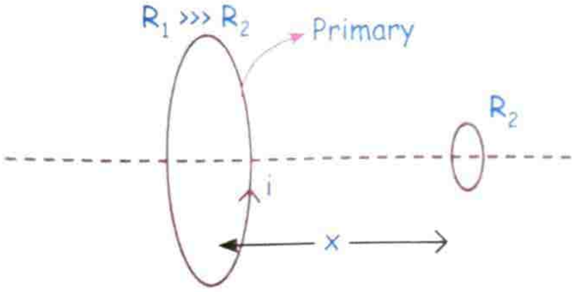
$$\phi_{अंदर} = B \cdot A$$

$$\phi_{अंदर} = \frac{\mu_0 i}{2R_1} \cdot \pi R_2^2$$

$$\phi_s = \underbrace{\frac{\mu_0}{2R_1} \cdot \pi R_2^2}_{M} i = M \times i$$



Q. Find mutual inductance for following case.



$$\phi_s = B \cdot A$$

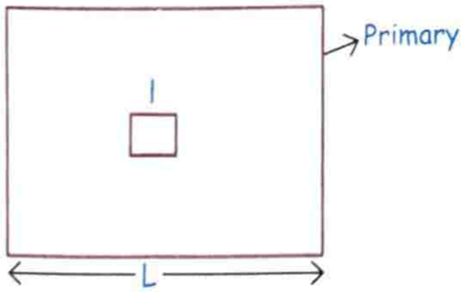
$$\phi_s = \left[\frac{\mu_0 i R_1^2}{2(R_1^2 + x^2)^{3/2}} \cdot \pi R_2^2\right]$$

$$\phi_s = \underbrace{\left[\frac{\mu_0 R_1^2}{2(R_1^2 + x^2)^{3/2}} \cdot \pi R_2^2\right]}_{M} i$$

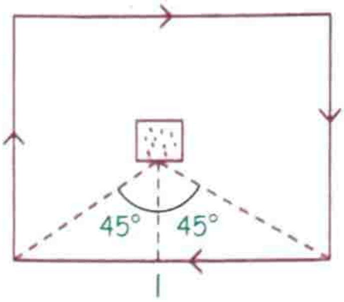
#SKC

कायदे में यह flux निकालने वाले ही सवाल है जिसमें primary में current flow करके secondary में flux निकालना है। चाहो तो primary में 1 A का current flow करा कर secondary में flux निकाल लो वही mutual inductance बन जायेगा।

Q. Find mutual inductance.



Sol. $L >>> l$

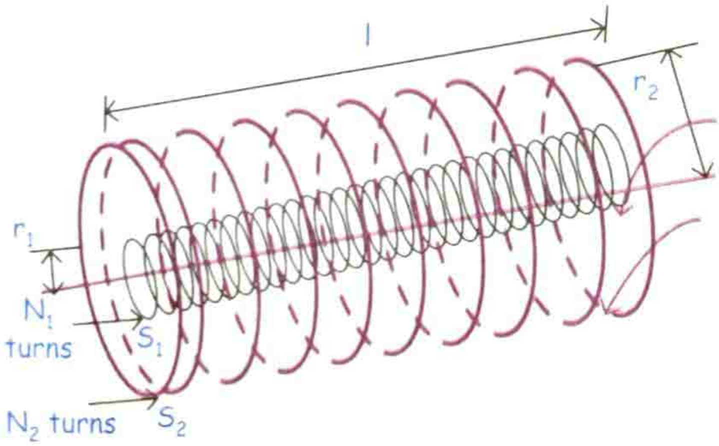


$$\phi_{\text{अंदर}} = B_{center} \cdot Area$$

$$= \frac{Ki}{L/2}(\sin 45° + \sin 45°) \times 4l^2$$

$$= \left[\frac{8\sqrt{2}\,K}{L} l^2\right] i = M \times i$$

Mutual Inductance between two Co-axial Solenoid



+ बाहर वाले को Primary

$$\phi_{inner} = N_1 BA = N_1\left(\mu_0 \frac{N_2}{l} i\right) \cdot \pi r_1^2$$

(यहाँ r अंदर वाला है)

$$M = \frac{\mu_0 N_1 N_2}{l} \cdot A = \mu_0 \frac{N_1}{l} \cdot \frac{N_2}{l} Al$$

$$= \mu_0 n_1 n_2 l A_{\text{अंदर}} \qquad [A = \pi r_1^2]$$

Self Flux

+ Whenever there is current in the coil, it produce flux in the coil is called self flux.

$$\phi_s \propto i \Rightarrow \phi_{self} = Li$$

(L is coefficient of self inductance)

+ If current changes wrt time, then self flux will also change resulting into an emf is induced across the coil.

$$\phi_s = Li$$

$$emf = -\frac{d\phi}{dt} = -\frac{Ldi}{dt}$$

Q. Find coefficient of self inductance for 'l' length of ideal solenoid having current i passing in it.

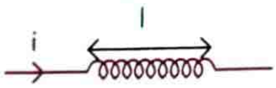
Sol. $\phi_{self} = B \cdot \pi r^2 \cdot N$

($\because$ N is no. of turn)

$= \mu_0 ni \cdot \pi r^2 \cdot N$

($\because$ n is no. of turn per unit lenght {n = N/L})

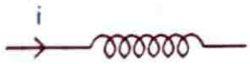
$$\phi_{self} = \mu_0 \frac{N}{l} i \pi r^2 N$$



$$\phi_{self} = \left(\frac{\mu_0 N^2}{l}\pi r^2\right)i = Li$$

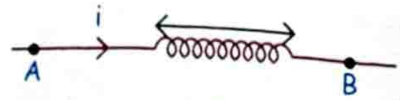
$$L = \left(\frac{\mu_0 N^2}{l}\pi r^2\right)i$$

(Here L is coefficient of self inductance)

+ 

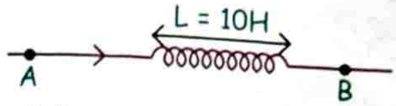
#SKC
अब अगर में solenoid से पास होने वाले current को बढाऊँ तो self flux बढ़ेगा जिससे emf induce होगा जो चाहेगा की current ना बढ़े hence solenoid से पास होने वाला current अगर बदलेगा तो solenoid के across battery जैसी चीज पेदा हो जाएगी जिसके emf की value Ldi/dt होगी।

$$emf = -\frac{d\phi}{dt} = -\frac{Ldi}{dt}$$

+ 

$$V_A - V_B = \frac{Ldi}{dt}$$

Q. Find $V_A - V_B$ if i = 10 and $\frac{di}{dt} = +5$

Sol. 

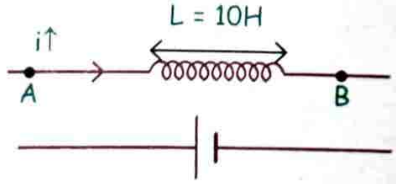
$$V_A - \frac{Ldi}{dt} = V_B$$

$$V_A - 10 \times 5 = V_B$$

$$V_A - V_B = 50$$

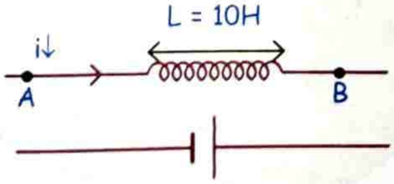
But हम SKC लगायेंगे

#SKC
VVimp
अगर solenoid से पास होने वाला current बदल रहा है तो it will behave like battery and battery का EMF $\left|\frac{Ldi}{dt}\right|$ और battery का बड़ा डन्डा ऐसे लगाओ की current बढ़े तो बढ़ने मत दो और current घटे तो घटने मत दो।



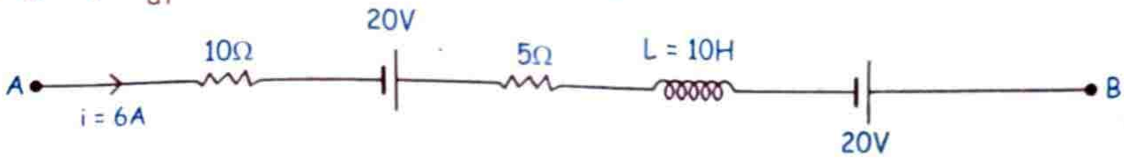
$$EMF = \left|\frac{Ldi}{dt}\right| = 10 \times 5 = 50$$

Q. Find potential different A and B if i = 10 A a[nd] $\frac{di}{dt} = -4$

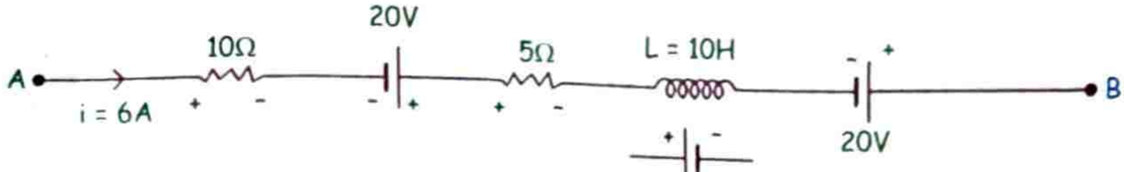


$$V_B - V_A = \left|\frac{Ldi}{dt}\right| = 10 \times 4 = 40$$

Q. Find $V_A - V_B$ if $\frac{di}{dt} = +3$ and current in the circuit is 6A.



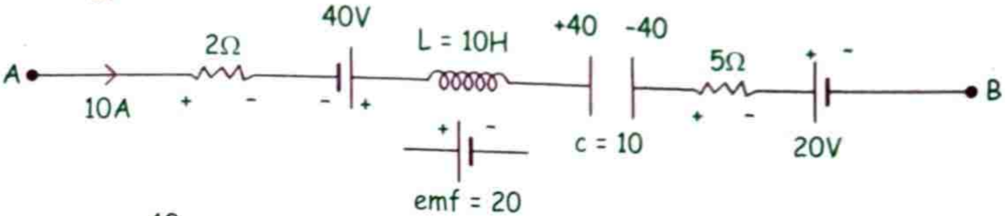
Sol.



$V_A - 60 + 20 - 30 - 30 + 20 = V_B$

$V_A - V_B = 80$

Q. Find $V_A - V_B$ if $\frac{di}{dt} = +2$ and current in the circuit is 10A.



$V_A - 20 + 40 - 20 - \frac{40}{10} - 50 - 20 = V_B$

$V_A - V_B =$ इस वक्त पर आएगा

ENERGY STORED IN AN INDUCTOR

The energy of a capacitor is stored in the electric field between its plates. Similarly, an inductor has the capability of storing energy in its magnetic field. The energy stored in the magnetic field of an inductor when a current I is flowing through it is $\frac{1}{2}LI^2$

MAGNETIC ENERGY PER UNIT VOLUME OR ENERGY DENSITY

The energy of an inductor is actually stored in the magnetic field within the coil. For a long solenoid its magnetic field is uniform and can be assumed completely within the solenoid.

The energy U stored in the solenoid when a current I is flowing in it, is.

$$U = \frac{1}{2}LI^2 = \frac{1}{2}\left(\mu_0 n^2 V\right)I^2$$

($\because L = \mu_0 n^2 V$, V = volume = Al)

The energy per unit volume

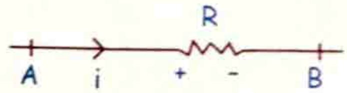
$$u = \frac{U}{V} = \frac{1}{2}\mu_0 n^2 I^2 = \frac{\left(\mu_0 n I\right)^2}{2\mu_0} = \frac{B^2}{2\mu_0} \qquad (B = \mu_0 n I)$$

$$\therefore \quad u = \frac{1}{2}\frac{B^2}{\mu_0}$$

1. Resistor v/s Capacitor v/s Inductor

काम का डब्बा

+ Resistor:

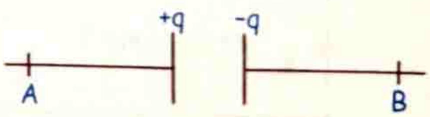


$V_A - iR = V_B$

$V_A - V_B = iR$

$P = i^2R = \frac{V^2}{R}$ (Here P is loss)

+ Capacitor:



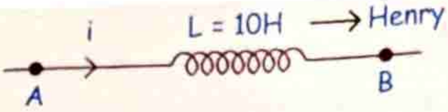
$V_A - q/c = V_B$

$V_A - V_B = q/c = \Delta V$

$U = \frac{1}{2}\frac{q^2}{c} = \frac{1}{2}CV^2$

(Here U is energy stored inside capacitor in the form of E.F)

+ Inductor:



$$V_A - \frac{Ldi}{dt} = V_B$$

$$V_A - V_B = \frac{Ldi}{dt} \qquad \left[L = \frac{\text{Volt time}}{L}\right]$$

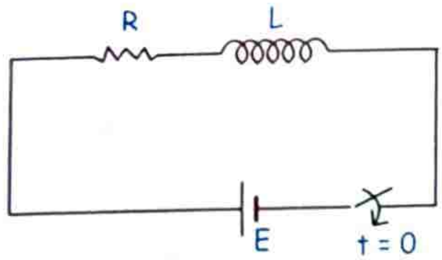
$$U = \frac{1}{2}Li^2 \text{ [In the form of M.F]}$$

(Here U is energy stored)

#SKC

At t = 0, i = 0 so at t = 0 पर inductor टूटे हुए wire की तरह behave कर रहा है, $t = \infty$, $i = \frac{E}{R}$ inductor ⇒ close wire की तरह behave कर रहा है। {RC current के result थे उनके just उलटे}

R-L CIRCUIT



$$E - iR - \frac{Ldi}{dt} = 0$$

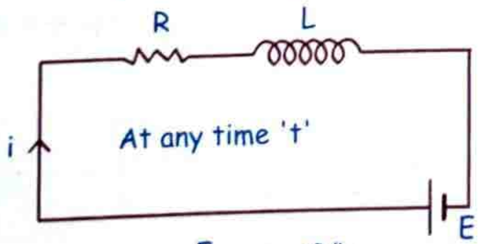
$$E - iR = \frac{Ldi}{dt}$$

$$\int_0^i \frac{di}{E - iR} = \int_0^t \frac{dt}{L}$$

$$-\frac{1}{R}\ln(E - iR)\Big|_0^i = \frac{t}{L}$$

$$\ln(E - iR) - \ln E = \frac{-tR}{L}$$

$$\ln\left(\frac{E - iR}{E}\right) = \frac{-tR}{L}$$



$$i = \frac{E}{R}(1 - e^{-tR/L})$$

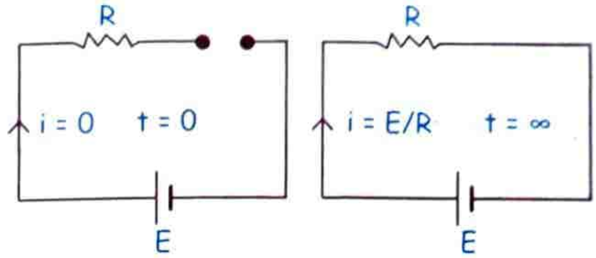
$$i = \frac{E}{R}(1 - e^{-t/L/R})$$

$$i = i_0(1 - e^{-t/\tau})$$

$$\tau = \frac{L}{R} \Rightarrow \text{time constant}$$

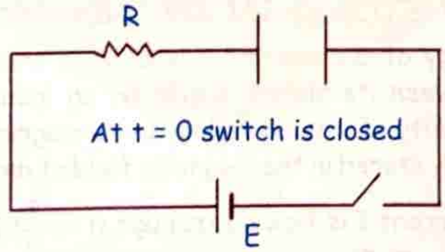
$$t = 0, \quad i = 0$$

$$t = \infty, \quad L = i_0 = \frac{E}{R}$$

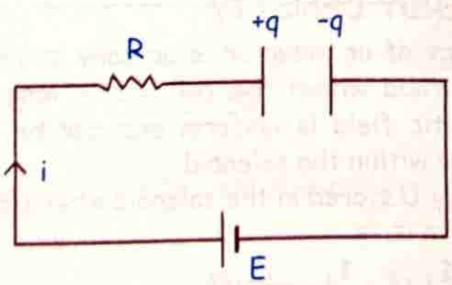


काम का डब्बा

R-C Circuit पुरानी बाते



⇓



$$q = EC(1 - e^{-t/RC})$$

$$q = Q_0(1 - e^{-t/\tau})$$

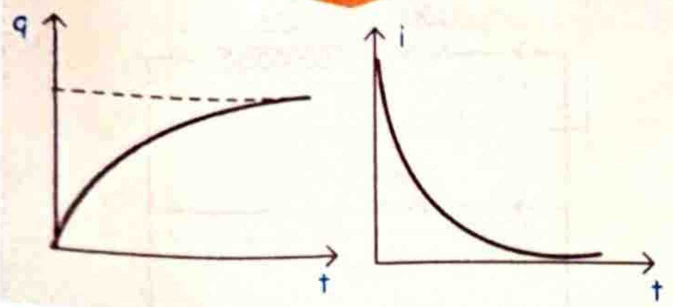
$$i = i_0 e^{-t/\tau}$$

$$i = \frac{E}{R}e^{-t/RC}$$

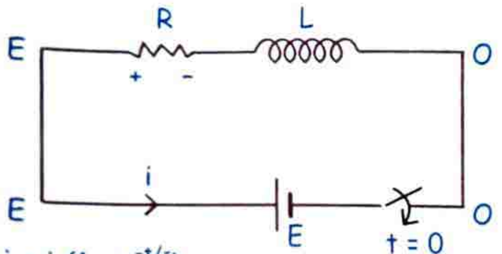
#SKC

t = 0 ⇒ capacitor closed wire की तरह behave

t = ∞ ⇒ very long time के बाद ⇒ capacitor टूटा हुआ wire की तरह behave करेगा।



☆ In LR circuit if at t = 0 switch is closed then saleem bhaiya bole hai ab physics ka maza lo jaise find everything

☆ 

☆ $i = i_o(1 - e^{-t/\tau})$

☆ $i = \frac{E}{R}(1 - e^{-t/\tau})$ $\left[\tau = \frac{L}{R}\right]$

☆ $V_R = iR = E(1 - e^{-t/\tau})$

☆ $P_{Battery} = Ei$

☆ $V_L \text{ (magnitude)} = \frac{Ldi}{dt} = L \cdot \frac{E}{R}\left[0 + \frac{1}{\tau}e^{-t/\tau}\right]$

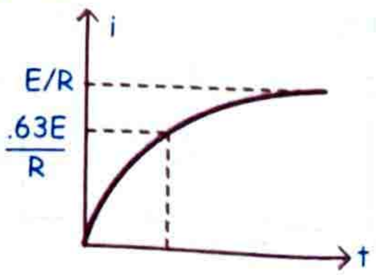
$V_L = L \cdot \frac{E}{R} \cdot \frac{R}{L} e^{-t/\tau}$

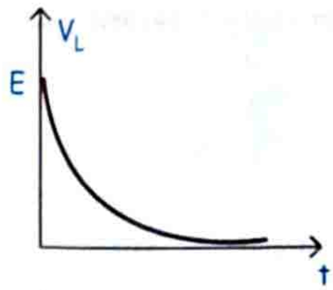
$V_L = Ee^{-t/\tau}$

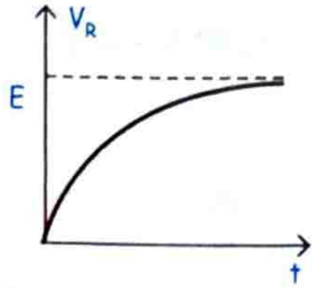
☆ $V_L + V_R = E(1 - e^{-t/\tau}) + Ee^{-t/\tau}$

☆ $V_L + V_R = E$

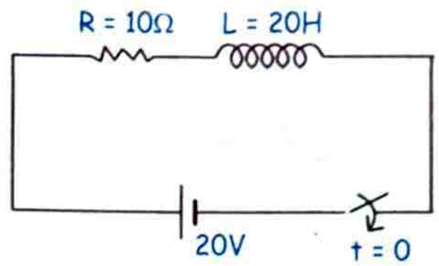
\+ Graph के मजे



\+ 

\+ 

Q. At t = 0 switch is closed find



(a) Time constant $= \tau = \frac{L}{R} = 2$

(b) Current in the circuit as function of time $= \frac{E}{R}(1 - e^{-t/\tau}) = 2(1 - e^{-t/2})$

(c) Maximum current

$$i_{max} = i_0 = \frac{E}{R} = 2 (\text{at } t = \infty)$$

(d) Current at $t = \tau$

$$i = 2(1 - e^{-\tau/\tau})$$

$$i = 2(1 - 1/e) \approx 2 \times 0.63$$

$$i = 1.26$$

(e) Find charge flow from $t = 0 \to t = \tau$.

$$\Delta q = \int_0^\tau i dt = \int_0^\tau \frac{E}{R}(1 - e^{-t/\tau})dt$$

$$\Delta q = \int i dt = \int_0^\tau 2(1 - e^{-t/\tau})dt$$

(f) Find heat loss from $t = 0 \to t = \tau$ sec.

$$H = \int_0^\tau i^2 R dt$$

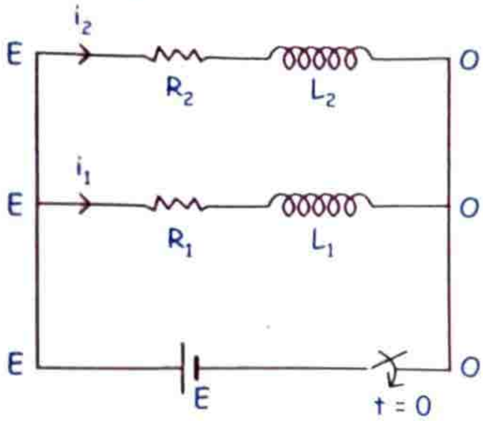
(g) Find time when current become half of maximum value.

$i = i_0(1 - e^{-t/\tau})$

$\frac{i_0}{2} = i_0(1 - e^{-t/\tau})$

$\Rightarrow t = \tau \ln 2.$

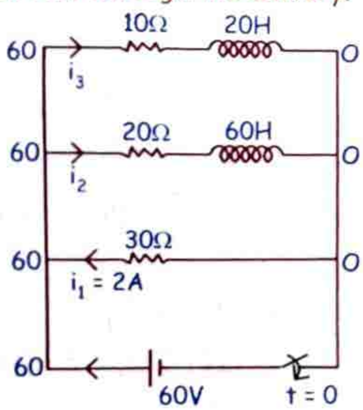
Q. Find i_1 and i_2 in the circuit.



$$i_1 = \frac{E}{R_1}(1 - e^{-t/\tau_1}) \qquad \left[\tau_1 = \frac{L_1}{R_1}\right]$$

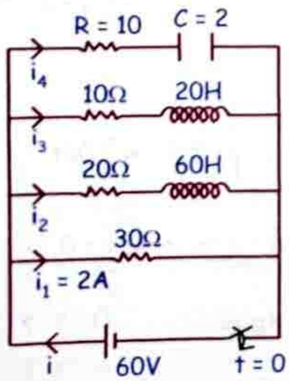
$$i_2 = \frac{E}{R_2}(1 - e^{-t/\tau_2}) \qquad \left[\tau_2 = \frac{L_2}{R_2}\right]$$

Q. Find current through the battery.



$$i = 2 + \frac{60}{20}(1 - e^{-t/3}) + \frac{60}{10}(1 - e^{-t/\tau})$$

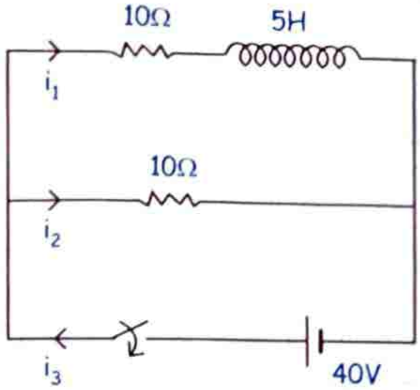
Q. Find current to the battery.



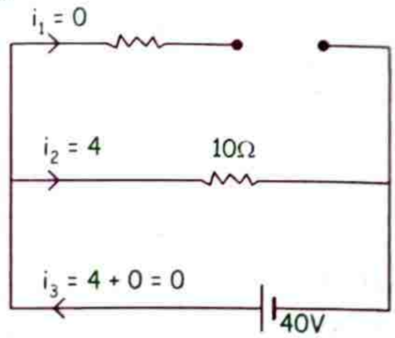
$$i = 2 + \frac{60}{20}(1 - e^{-t/3}) + \frac{60}{10}(1 - e^{-t/2})$$

$$+ \underbrace{\frac{60}{10}(e^{-t/20})}_{\text{RC वाला current}}$$

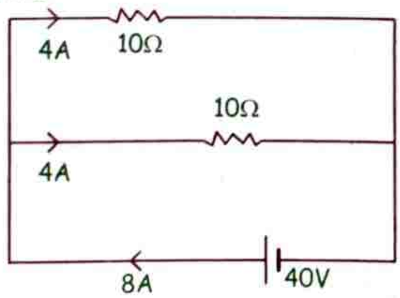
Q. Find i_1, i_2, i_3 just after switch closed ($t = 0^+$) and after very long time (steady state, $t = \infty$)



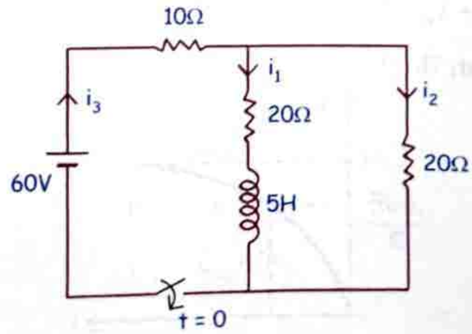
Sol. At $t = 0$



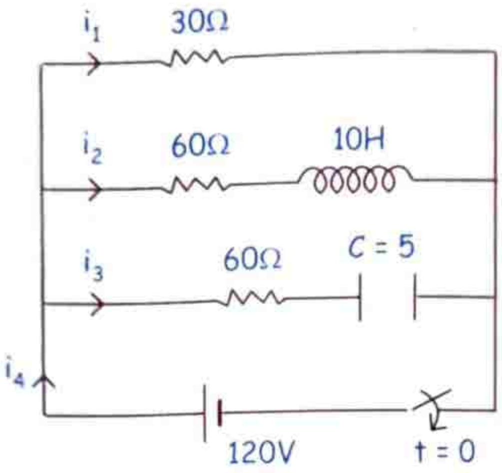
At $t = \infty$



Q. Find i_1, i_2, i_3 just after switch closed ($t = 0^+$) and after very long time (steady state, $t = \infty$)



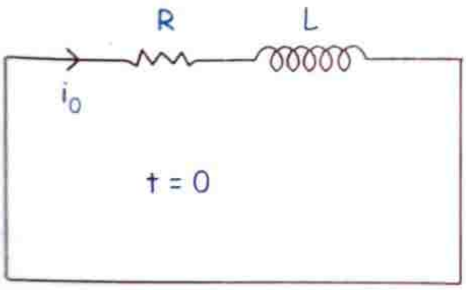
	i_1	i_2	i_3
$t = 0^+$	0	2	2
$t = \infty$ (steady state)	1.5	1.5	3



(Initial charge on cap = 0)

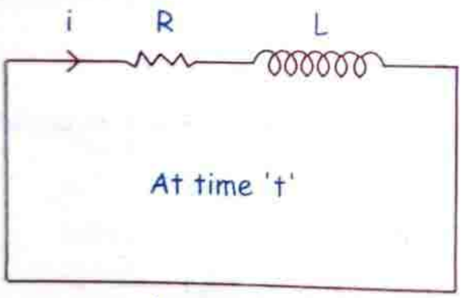
	i_1	i_2	i_3	i_4
$t = 0^+$	4	0	2	6
$t = \infty$	4	2	0	6

DECAY OF CURRENT



$$-iR - \frac{Ldi}{dt} = 0 \Rightarrow -iR = \frac{Ldi}{dt}$$

$$\int_{i_0}^{i} \frac{di}{i} = -\int_0^t \frac{R}{L}dt$$



$$\ln i \Big|_{i_0}^{i} = -\frac{R}{L}t$$

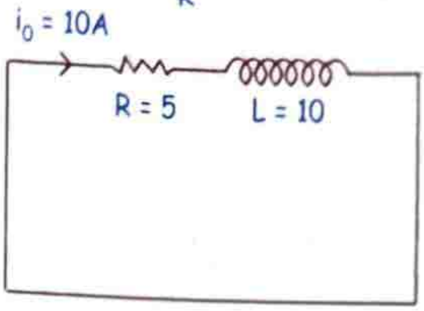
$$\ln i - \ln i_0 = -\frac{R}{L}t$$

$$\Rightarrow \ln\frac{i}{i_0} = -\frac{R}{L}t$$

$$i = i_0 e^{-R/L\,t} = i_0 e^{-t/L/R}$$

$$i = i_0 e^{-t/\tau}$$

$$\tau = \frac{L}{R}$$



$$\tau = \frac{L}{R} = \frac{10}{5} = 2$$

$$i = i_0 e^{-t/\tau}$$

$$i = i_0 e^{-t/2}$$

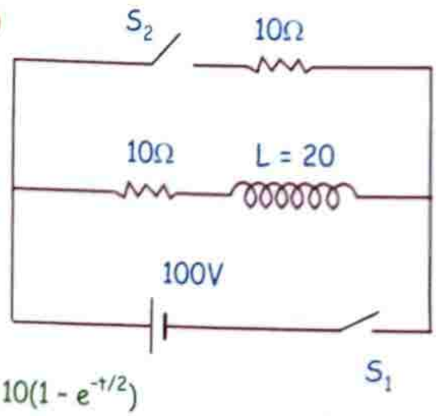
$t = 0$, U_{in} inductor $= \frac{1}{2}Li_0^2 = \frac{1}{2} \times 10 \times (10)^2$

Total loss -

$$H = \int_0^\infty i^2 R dt = \frac{1}{2}Li_0^2$$

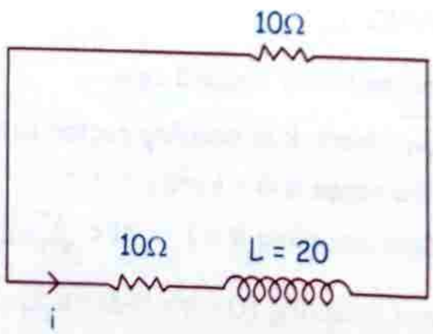
Q. At t = 0 switch S_1 is closed and S_2 is open find current as a function of time.

(a)



Sol. $i = 10(1 - e^{-t/2})$

(b) If after very long time S_1 is open and S_2 is closed then current as a function of time for new observation will be

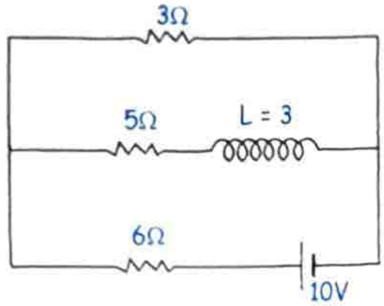


Sol. $i = 10\,e^{-1}$ (Now time constant $= \frac{20}{10+10} = 1$)

(c) Total heat loss across resistance in second observation

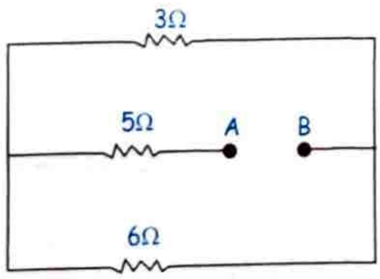
Sol. $= \frac{1}{2} \times 20 \times 10^2$

Q. Find time constant of the circuit.



Sol.

#SKC
Battery को wire बनाके inductor के across R_{eq} निकालो and time constant will be
$\tau = \frac{L}{R_{eq}}$



$R_{AB} = 2 + 5 = 7$

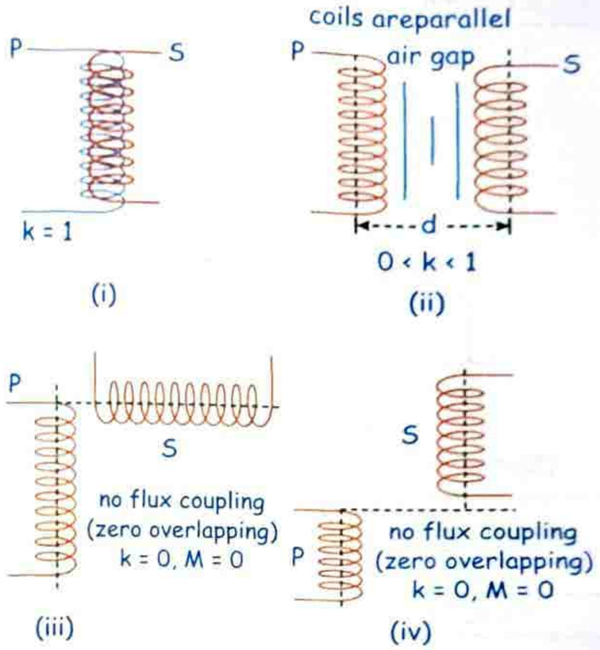
$\tau = \frac{L}{R} = \frac{3}{7}$

MUTUAL INDUCTANCE IN TERMS OF L_1 AND L_2

For two magnetically coupled coils

$M = k\sqrt{L_1 L_2}$ here k is coupling factor between two coils and its range is $0 \le k \le 1$

- For ideal coupling $k = 1 \Rightarrow M = \sqrt{L_1 \times L_2}$
- For real coupling $(0 < k < 1)$ $M = k\sqrt{L_1 \times L_2}$
- Value of coupling factor 'k' depends upon fashion of coupling.



'k' is also defined as

$$k = \frac{\phi_s}{\phi_p} = \frac{\text{magnetic flux linked with secondary (s)}}{\text{magnetic flux linked with primary (p)}}$$

INDUCTANCE IN SERIES AND PARALLEL

Two coils are connected in series: Coils are lying close together.

If $M = 0$, $L_{eq} = L_1 + L_2$

If $M \ne 0$ $L_{eq} = L_1 + L_2 \pm 2M$

(a) When current in both is in the same direction

$L_{eq} = L_1 + L_2 + 2M$

(b) When current flow in two coils are in opposite directions

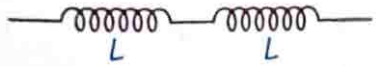
Then $L = L_1 + L_2 - 2M$

Two Coils are Connected in Parallel

If $M = 0$ then $\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2}$ or $L = \frac{L_1 L_2}{L_1 + L_2}$

NOW PRACTICE FOLLOWING QUESTIONS

Q. Two identical coils each of self-inductance L, are connected in series and are placed so close to each other that all the flux from one coil links with the other. The total self-inductance of the system is:

Sol. 

$M = k\sqrt{L_1L_2} = L \ (k = 1)$

$\phi = LI + LI + 2MI \Rightarrow 4LI = L_{eq} I$

$L_{eq} = 4L$

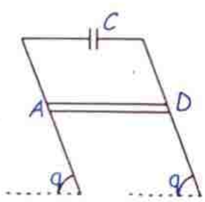
Therefore, option (d) is the correct answer.

Q. A straight horizontal metal rod AD of length l and mass m slides down two smooth conducting fixed parallel bars set inclined at an angle θ to the horizontal. The top ends of the bars are connected to a capacitor of capacitance C. The system is placed in a uniform magnetic field, in the direction perpendicular to the inclined plane formed by bars. If the resistance of the bars and the sliding rod are negligible, show that the acceleration of the sliding rod is given by

$$\frac{mg\sin\theta}{m + B^2l^2C}$$

Sol. The rod slides down due to the component of the weight down the bars. If v is the velocity of the rod at any instant t, then the emf induced across the rod is

$\varepsilon = Blv$



The potential difference across the capacitor will be equal to ε. Therefore the charge on the capacitor

$Q = C\varepsilon = CBlv$

Current $I = \frac{dQ}{dt} = CBl\frac{dv}{dt} = CBla$

where a is the acceleration of the rod.

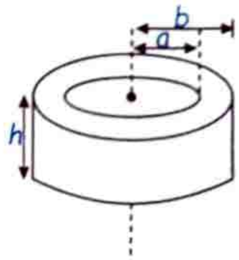
Magnetic force on the rod $= BIl = B(CBla)l = B^2l^2Ca$ acting upwards along the incline.

According to Newton's second law,

$mg\sin\theta - B^2l^2Ca = ma$

$\Rightarrow a = \frac{mg\sin\theta}{m + B^2l^2C}$

Q. A coaxial cable consists of internal solid conductor of radius a and external thin walled conducting tube of radius b. Find the inductance of a unit length of the cable, considering that the current distribution over the cross-section of the internal conductor is uniform. The permeability is equal to unity everywhere.



Sol. The magnetic field inside the coaxial cable is given by

$B_1 = \frac{\mu_0 I \cdot r}{2\pi a^2}$ for $r \le a$

$B_2 = \frac{\mu_0 I}{2\pi r}$ for $a \le r \le b$

$B_3 = 0$ for $r > b$

The magnetic energy stored in the cable per unit length is

$$U = \int_0^a \frac{B_1^2}{2\mu_0}(2\pi r)dr + \int_a^b \frac{B_2^2}{2\mu_0}(2\pi r)dr$$

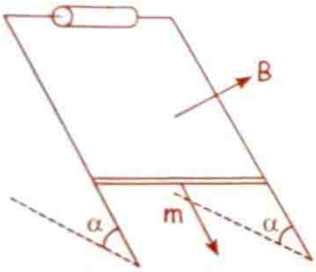
$$\text{or } U = \frac{\mu_0 I^2}{4\pi a^4}\int_0^a r^3 dr + \frac{\mu_0 I^2}{4\pi}\int_a^b \frac{dr}{r}$$

$$\text{or } U = \frac{\mu_0 I^2}{4\pi}\left[\frac{1}{4} + \ln\left|\frac{b}{a}\right|\right]$$

We know $U = \frac{1}{2}LI^2$

$$\therefore L = \frac{2U}{I^2} = \frac{\mu_0}{2\pi}\left[\frac{1}{4} + \ln\left|\frac{b}{a}\right|\right]$$

Q. A copper connector of mass m slides down two smooth copper bars, set at an angle α to the horizontal, due to gravity (Fig.). At the top the bars are interconnected through a resistance R. The separation between the bars is equal to ℓ. The system is located in a uniform magnetic field of induction B, perpendicular to the plane in which the connector slides. The resistances of the bars, the connector and the sliding contacts, as well as the self-inductance of the loop, are assumed to be negligible. Find the steady-state velocity of the connector.



Sol. $v = \dfrac{mgR\sin\alpha}{B^2\ell^2}$

From Lenz's law, the current through the connector is directed from A to B. Here $\xi_{in} = vB\ell$ between A and B.

where v is the velocity of the rod at any moment.

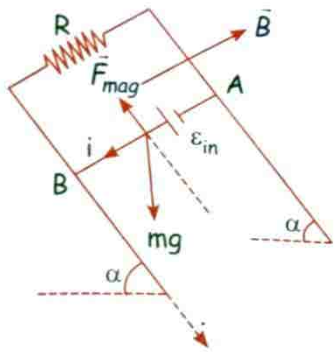
For the rod, from $F_x = mw_x$

or, $mg\sin\alpha - i\ell B = mw$

For steady state, acceleration of the rod must be equal to zero. Hence, $mg\sin a = i\ell B$ ...(1)

But, $i = \dfrac{\xi_{in}}{R} = \dfrac{vB\ell}{R}$

from (1) (2) $v = \dfrac{mg\sin\alpha R}{B^2\ell^2}$



6 Alternating Current

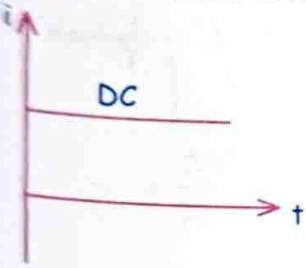
देख भाई इस chapter में physics कम maths ज्यादा है इसलिए maths का दिमाग ON करलो Physics वाला (OP ❤ ❤) दिमाग OFF करलो।

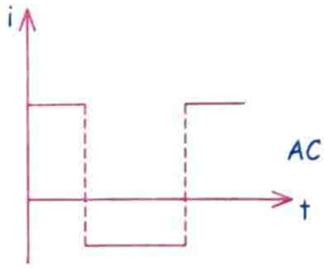
DEFINITION

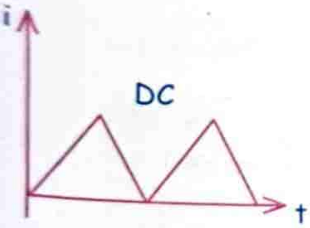
If current changes its direction periodicaly w.r.t time, it is called alternating current

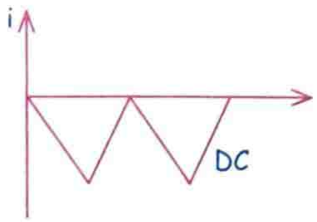
Direct Current (DC)

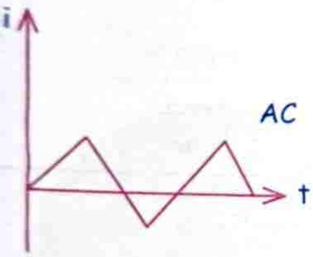
- When their is no change in direction of current
- DC में Current की value कोंस्टेंट होना जरूरी नहीं है।

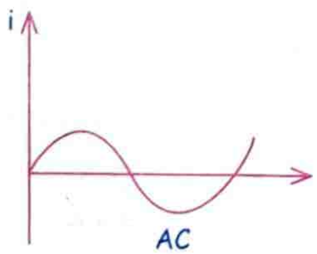










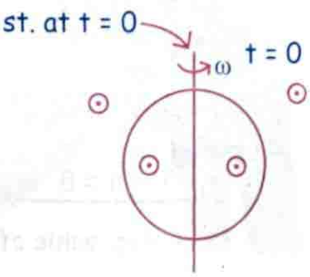


Origin of AC.

Suppose a coil is rotating abt its daimeter with const ω

at any time 't'

$\phi = \vec{B} \cdot \vec{A}$



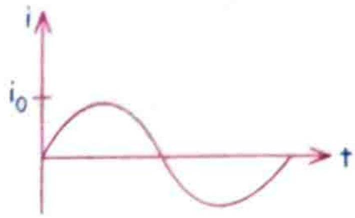
$\phi = B\,A\cos\omega t$

$$emf = -\frac{d\phi}{dt} = BA\omega\sin\omega t$$

$$i = \frac{emf}{R} = \frac{BA\omega\sin\omega t}{R}$$

$$i = \frac{BA\,\omega}{Resis.}\sin\omega t$$

$$\boxed{i = i_0 \sin\omega t}$$



$i = i_0 \sin(\omega t + \phi)$

$i_0 \rightarrow i_{max}$

$\phi \rightarrow$ initial phase

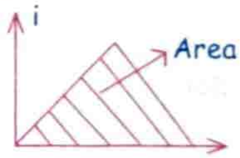
$\omega t + \phi \rightarrow$ phase $\qquad \omega = 2\pi f$

$\omega \rightarrow$ angular freq, rad/sec

$f \rightarrow$ frequency, H_Z

Average Current (<i>)

$$\text{Average Current } \langle i\rangle = \frac{\int i.dt}{\int dt} = \frac{Area}{\Delta t}$$



$$\langle v\rangle = \frac{\int v\,dt}{\int dt} = \frac{dist.}{time}$$

$$\langle a\rangle = \frac{\int a\,dt}{\int dt} = \frac{\Delta\vec{v}}{\Delta t}$$

$$\langle \text{कददू} \rangle = \frac{\int \text{कददू}\ dt}{\int dt}$$

Q. If i = 10t find <i> from t = 0 → t = 5 sec.

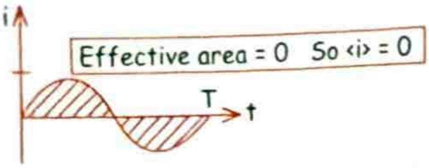
Sol. $$\langle i\rangle = \frac{\int i\,dt}{\int dt} = \frac{\int_0^5 10t.dt}{\int_0^5 dt} = \frac{10 \times \frac{25}{2}}{5} = 25$$

Q. $i = i_0 \sin\omega t \quad \omega = \dfrac{2\pi}{T}$

find $\langle i\rangle$ from $t = 0 \to t = T$ (full cycle)

Sol. $$\Rightarrow \langle i\rangle = \frac{\int_0^T i_0 \sin\omega t \cdot dt}{\int_0^T dt} = \frac{i_0}{\omega t}\left[-\cos\omega t\Big|_{t=0}^{t=T}\right]$$

$$= \frac{-i_0}{\omega T}\left[\cos\frac{2\pi}{T}\times T - \cos 0\right] = 0$$



Q. $i = i_0 \sin\omega t \quad \omega = \dfrac{2\pi}{T}$

find $\langle i\rangle$ from $t = 0 \to t = T/2$ (half cycle)

Sol. $$\Rightarrow \langle i\rangle = \frac{\int_0^{T/2} i_0 \sin\omega t \cdot dt}{\int_0^{T/2} dt} = \frac{2i_0}{\omega t}\left[-\cos\omega t\Big|_{t=0}^{t=T/2}\right]$$

$$= \frac{2i_0}{\frac{2\pi}{T}\times T}\times 2 = \frac{2i_0}{\pi}$$

ओ भाई result याद करने से पहले इन सभी को rough copy पर खुद से integrate कर लेना।

Q. $i = i_0 \sin\omega t \quad \omega = \dfrac{2\pi}{T}$

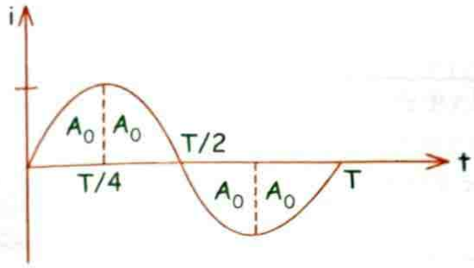
find $\langle i\rangle$ from $t = 0 \to t = T/4$ (quarter cycle)

Sol.

$$\Rightarrow \langle i\rangle = \frac{\int_0^{T/4} i_0 \sin\omega t \cdot dt}{\int_0^{T/4} dt} = \frac{4i_0}{\omega t}\left[-\cos\omega t\Big|_{t=0}^{t=T/4}\right]$$

$$= \frac{-4i_0}{\omega T}\left[\cos\frac{2\pi}{T}\times\frac{T}{4} - \cos 0\right] = \frac{2i_0}{\pi}$$

For $i = i_0 \sin\omega t$	Avg. current
$t = 0 \to t = T$	0
$t = 0 \to t = T/2$	$2i_0/\pi$
$t = 0 \to t = T/4$	$2i_0/\pi$
$t = T/4 \to t = T/2$	$2i_0/\pi$
$t = T/4 \to t = 3T/4$	0

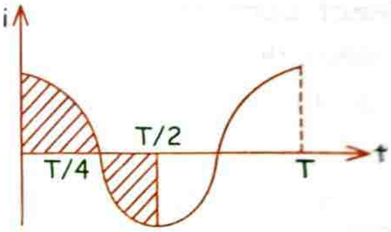


Q. $= i = i_0 \cos\omega t \quad \omega = \dfrac{2\pi}{T}$

(a) $\langle i\rangle$ = ? from $t = 0 \to t = T/4$

Sol.

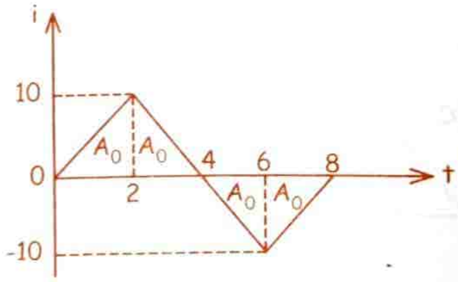
$\langle i\rangle = \dfrac{2i_0}{\pi}$



(b) $\langle i\rangle$ = ? from $t = 0 \to t = T/2$

Sol. $\langle i\rangle = 0$

Q.



Sol.

Avrg. current	$\langle i\rangle = \dfrac{\text{Area}}{\text{time}}$
$t = 0 \to t = 2$	$\dfrac{10}{2} = 5$
$t = 0 \to t = 4$	$\dfrac{10+10}{4} = 5$
$t = 0 \to t = 6$	$\dfrac{10+\cancel{10}-\cancel{10}}{6} = \dfrac{10}{6}$
$t = 0 \to t = 8$	0

$\langle i\rangle \to$ Avg. value of i.

$\langle i^2 \rangle \rightarrow$ Avg. value of $i^2 = \dfrac{\int i^2 dt}{\int dt} = \langle i^2 \rangle$

$$\sqrt{\langle i^2 \rangle} = \sqrt{\frac{\int i^2 dt}{\int dt}} = i_{rms}$$

i^2 के Avrg का under root को i_{rms} कहते है

i_{rms} = root mean square current $= \sqrt{\dfrac{\int i^2 dt}{\int dt}}$

Q. Find i_{rms}:

$I = I_0 \sin \omega t$

i_{rms} from $t = 0 \rightarrow t = T$

काम का डब्बा
for full cycle
$\langle \sin \omega t \rangle = 0$
$\langle \cos \omega t \rangle = 0$
$\langle \sin^2 \omega t \rangle = 1/2$
$\langle \cos^2 \omega t \rangle = 1/2$

Sol.

$$i_{rms} = \sqrt{\frac{\int_0^T I_0^2 \sin^2 \omega t.dt}{\int_0^T dt}} = I_0 \sqrt{\frac{\int_0^T \sin^2 \omega t.dt}{T}} = I_0 \sqrt{\frac{T/2}{T}}$$

$$= \frac{I_0}{\sqrt{2}}$$

or

$$= I_0 \sqrt{\langle \sin^2 \omega t \rangle} = I_0 \sqrt{\frac{1}{2}}$$

वैसे तो
if $i = i_0 \sin(\omega t + \phi)$
$\langle i \rangle = 0$ and $i_{rms} = \dfrac{i_0}{\sqrt{2}}$ (For full cycle)
for any other time interval just integrate

"In AC circuit अगर मैं DC voltmeter, DC ammeter use करूँ तो reading will be 0 (zero). Hence special device called Hot wire ammeter & HOT wire voltmeter based on idea of thermal expansion & heat transfer are used to measure RMS value & RMS current"

Q. Find the average current and i_{rms} from $t = 0 \rightarrow t = 2$ sec. $i = 6t^2$

Sol. $\Rightarrow \langle i \rangle = \dfrac{\int_0^2 6t^2.dt}{\int_0^2 dt} = \dfrac{6 \times \frac{2^3}{3}}{2} = 8$

$$i_{rms} = \sqrt{\frac{\int (6t^2)^2 dt}{\int dt}} = 6\sqrt{\frac{\int_0^2 t^4 dt}{\int_0^2 dt}} = 6\sqrt{\frac{32}{5 \times 2}} = \frac{24}{\sqrt{5}}$$

Q. $i = 3 + 4 \sin \omega t$

for $t = 0 \rightarrow t = T$ $\quad i_{rms} = ?$

Sol. $i_{rms} = \sqrt{\int_0^T (3 + 4\sin\omega t)^2 dt}$

$$= \sqrt{\frac{\int_0^T 9 \cdot dt}{T} + \frac{\int_0^T 16 \cdot \sin^2 \omega t \cdot dt}{T} + \frac{\int_0^T 24 \cdot \sin \omega t \cdot dt}{T}}$$

$$= \sqrt{9 + 16 \times \frac{1}{2} + 24 \times 0} = \sqrt{17}$$

Q. $I = 4 + 6 \sin \omega t$

Sol. $i_{rms} = \sqrt{16 + \dfrac{36}{2} + 0} = \sqrt{34}$

Q. $i = 3 \sin \omega t + 4 \cos \omega t$

Sol. $i_{rms} = \sqrt{9 \times \dfrac{1}{2} + 16 \times \dfrac{1}{2} + 0}$

↓

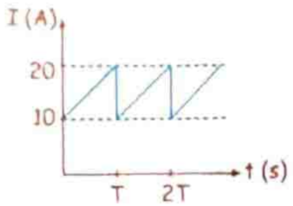
complete cycle $= \dfrac{5}{\sqrt{2}}$ $\qquad i_{rms} = \dfrac{5}{\sqrt{2}}$

Method-2

$i = 3 \sin \omega t + 4 \cos \omega t = 5\sin(\omega t + 53°)$

$i_{rms} = \dfrac{5}{\sqrt{2}}$

Q. Find the rms and average values of the current (in A) shown in graph.



Sol. $i = c + mt$

$i = 10 + (10/T)t$

$i_{avg} = \frac{1}{T}\int_0^T i\,dt = \frac{1}{T}\int_0^T \left(10 + \frac{10}{T}t\right)dt = 15A$

Mean square value $= \frac{1}{T}\int_0^T i^2 dt = \frac{1}{T}\int_0^T \left(10 + \frac{10}{T}t\right)^2 dt$

$= \frac{1}{T}\int_0^T \left(100 + \frac{100}{T^2}t^2 + \frac{200}{T}t\right)dt = \frac{700}{3}$

Hence $i_{rms} = 10\sqrt{7/3} = 15.3A$

Q. Find, f, i_{rms} $i = 10 \sin(100\pi t + \pi/6)$

Sol. * $i_{max} = 10$, $\omega = 100\pi = 2\pi f$

$f = 50$

* $i_{rms} = \frac{i_{max}}{\sqrt{2}} = \frac{10}{\sqrt{2}}$

- $E = E_0 \sin\omega t, E_{rms} = E_0/\sqrt{2}$
- rms value of AC is referred as DC equivalent of AC

SUPER POSITION OF कददू

$y_1 = A_1 \sin\omega t$

$y_2 = A_2 \sin(\omega t + \phi)$

Find $y_{net} = y_1 + y_2 = ?$

$y_{net} = y_1 + y_2 = A_{net}\sin(\omega t + \alpha)$

$y_{net} = A_1 \sin\omega t + A_2 \sin\omega t \cos\phi + A_2 \cos\omega t \cdot \sin\phi$

$y_{net} = (A_1 + A_2\cos\phi)\sin\omega t + A_2 \sin\phi \cos\omega t$

$= a\sin\omega t + b\cos\omega t$

$= \sqrt{a^2+b^2}\left[\frac{a}{\sqrt{a^2+b^2}}\sin\omega t + \frac{b}{\sqrt{a^2+b^2}}\cos\omega t\right]$

$y_{net} = \underbrace{\sqrt{a^2+b^2}}_{= A_{net}}\sin(\omega t + \alpha)$

$A_{net} = \sqrt{a^2+b^2} = \sqrt{(A_1 + A_2\cos\phi)^2 + (A_2\sin\phi)^2}$

$A_{net} = \overset{\text{Solve}}{\sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos\phi}}$

$\tan\alpha = \frac{B\sin\phi}{A + B\cos\phi}$

Q. find $I_1 + I_2 = ?$

$i_1 = 10\sin\omega t$

$i_2 = 10\sin(\omega t + 60°)$

Sol. $A_{net} = \sqrt{10^2 + 10^2 + 2\times10\times10\times\cos60} = 10\sqrt{3}$

$\tan\alpha = \frac{10\sin60}{10 + 10\cos60} = \frac{1}{\sqrt{3}} \Rightarrow \alpha = 30$

$i_{net} = 10\sqrt{3}\sin(\omega t + 30°)$

Q. $i_1 = 3\sin\omega t$

$i_2 = 4\sin(\omega t + 90°)$

Sol. $A_{net} = 5$

$\tan\alpha = \frac{4\sin90}{3 + 4\cos90}$

$\alpha = 53°$

$i_{net} = 5\sin(\omega t + \alpha)$

Q. Find $y_1 + y_2 + y_3 = ?$

If $y_1 = 10\sin\omega t$

$y_2 = 10\sqrt{2}\sin(\omega t + 45°)$

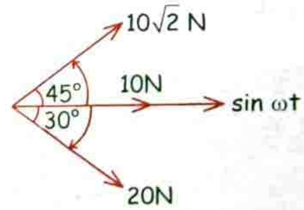
$y_3 = 20\sin(\omega t - 30°)$

Sol. अब इसे सलीम भईया की आयुषी method से solve करेंगे।

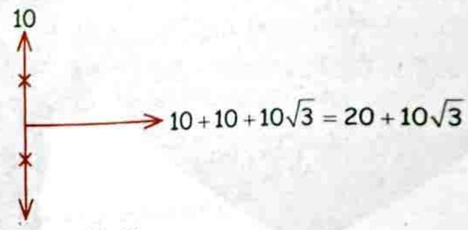
$y_1 = 10\sin\omega t$ Phase

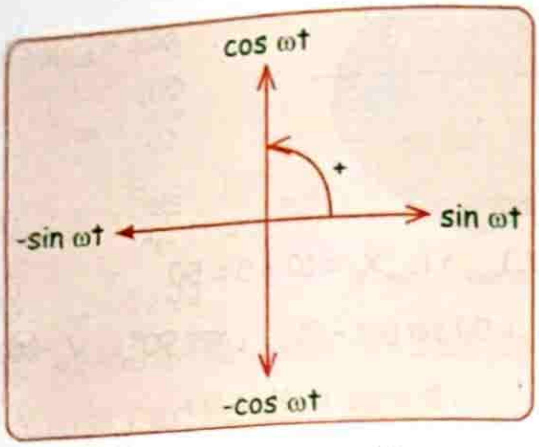
$y_2 = 10\sqrt{2}\sin(\omega t + 45°)$ (+) मतलब ACW

$y_3 = 20\sin(\omega t - 30°)$



$y_{net} = (20 + 10\sqrt{3})\sin\omega t$



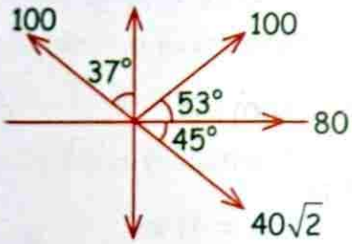


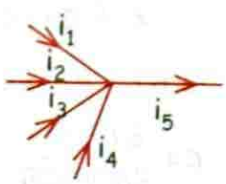
#SKC
आयूषी method
😊 ये vector नही है लेकिन mathematicaly vector के resultant की तरह से component लेकर solve कर सकते है।
सबसे पहले amplitude की value को सही angle के साथ xy-axis पर बनाओ और vector की तरह solve करदो।
Finally ये देखो की resultant कितना और किधर आया है।

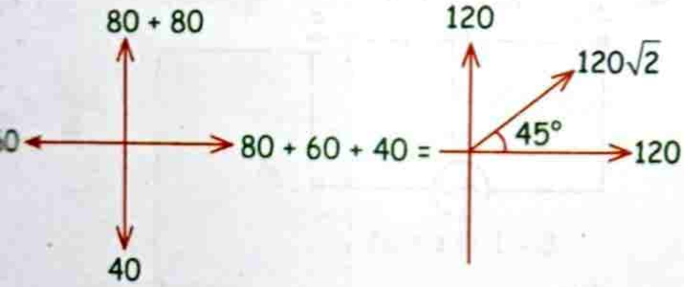
Q. find $i_1 + i_2 + i_3 + i_4$

$$\left.\begin{aligned} i_1 &= 80 \sin \omega t \\ i_2 &= 40\sqrt{2}\sin(\omega t - 45^\circ) \\ i_3 &= 100 \sin(\omega t + 53^\circ) \\ i_4 &= 100 \sin(\omega t + 127^\circ) \end{aligned}\right\} \begin{aligned} i_{net} &= i_1 + i_2 + i_3 + i_4 \\ &= 120\sqrt{2}\sin(\omega t + 45^\circ) \end{aligned}$$

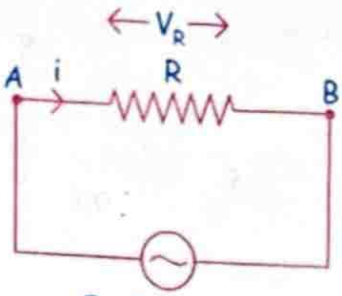
Sol. Solve by आयूषी method







PURE RESISTIVE



$E = E_0 \sin \omega t$

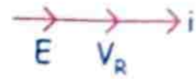
Resistance में current और V_R same phase में होते है

$$i_{max} = \frac{(V_R)_{max}}{R}$$

$$i_{rms} = \frac{(V_R)_{rms}}{R}$$

$$i(t) = \frac{V_R(t)}{R}$$

$$i = \frac{E}{R} = \frac{E_0}{R}\sin\omega t$$



$$\boxed{i = i_0 \sin \omega t}$$

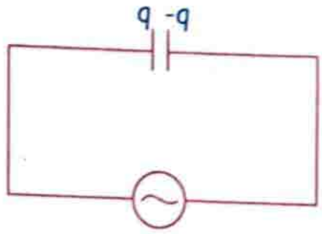
$V_{AB} = E = E_0 \sin \omega t$

$i = i_0 \sin \omega t$

hence

V_{AB} and i are in same phase

PURE CAPACITIVE A/C CKT



$E = E_0 \sin \omega t$

Capacitor मे i 90° आगे होता है V से। यह गलती से भी भूलना नही है।

$q = CE_0 \sin \omega t$

$$i = \frac{dq}{dt} = CE_0\omega\cos\omega t$$

$$i = \frac{E_0}{1/\omega c}\sin(\omega t + 90^\circ) = \frac{E_0}{x_c}\sin(\omega t + 90^\circ)$$

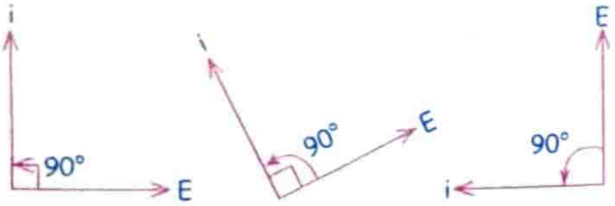
Here the amplitude of the oscillating current is $I_0 = \dfrac{E_0}{(1/\omega c)}$

Comparing it to $I_0 = \dfrac{E_0}{R}$ for a purely resistive circuit, we find that $(1/\omega C)$ plays the role of resistance. It is called **capacitive reactance** and is denoted by X_C

$X_C = 1/\omega C = 1/2\pi f C$

Capacitive reactance = $x_c = \dfrac{1}{\omega c} = \dfrac{1}{2\pi f c}$ if $f = 0, x_c = \infty$

In capacitor current leads by 90° from potential difference.



$E = E_0 \sin \omega t$

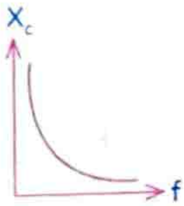
$\Rightarrow i = i_0 \sin(\omega t + 90°)$

$i_{max} = \dfrac{E_{max}}{R}$

$i_0 = \dfrac{E_0}{X_c}, \; i_{rms} = \dfrac{E_{rms}}{X_c}$

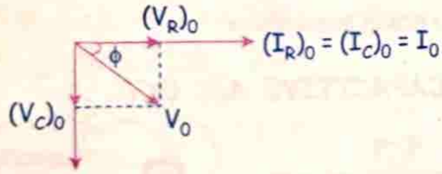
But here

$i(t) \neq \dfrac{E(t)}{X_c}$

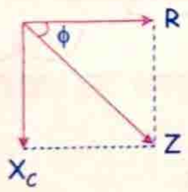


काम का डब्बा

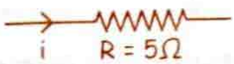
- Applied voltage: $V_0 = \sqrt{(V_R)_0^2 + (V_C)_0^2}$



- Impedance: $Z = \sqrt{R^2 + X_C^2} = \sqrt{R^2 + \left(\dfrac{1}{\omega C}\right)^2}$



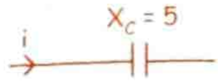
- Current: $I = I_0 \sin(\omega t + \phi)$
- Peak current $I_0 = \dfrac{V_0}{Z} = \dfrac{V_0}{\sqrt{R^2 + X_C^2}}$
- Phase difference: $\phi = \tan^{-1}\dfrac{X_C}{R} = \tan^{-1}\dfrac{1}{\omega CR}$
- Current leads the voltage in this circuit.

Q. 

If $i = 10 \sin \omega t$ find V_R = ? (pot diff across R)

Sol. $(V_R)_{max} = i_{max} \cdot R = 10 \times 5 = 50$

$V_R = 50 \sin \omega t$ ($i, V_R \rightarrow$ will have same phase)

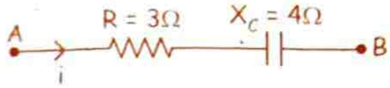
Q. 

If $i = 10 \sin \omega t$

Find V_C

Sol. $(V_C)_{max} = i_{max} X_C = 10 \times 5 = 50$

$V_C = 50 \sin(\omega t - 90)$ i आगे 90° $\Rightarrow V_C$ पीछे 90°

Q. 

If $i = 10 \sin \omega t$ find

(a) V_R (b) V_R

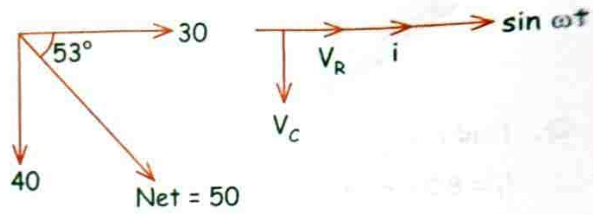
(c) $V_R + V_C$ (d) V_{AB}

Sol. $V_R = 10 \times 3 \sin \omega t = 30 \sin \omega t$

$V_C = 10 \times 4 \sin(\omega t - 90) = 40 \sin(\omega t - 90)$

$V_{net} = V_R + V_C = 50 \sin(\omega t - 53°)$

(Solved by आयुषी method)



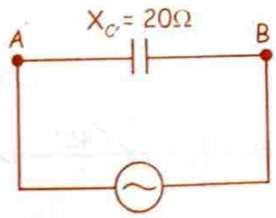
Q. Conduction (RMS) current is 6.6 μA in a circuit with capacitor connected across 220 V source. Angular frequency is 600 rad/s. Value of capacitance is

Sol. $\omega = 600$ rad/s

$I = \dfrac{V}{X_C} = \dfrac{220}{(1/\omega C)}$

$\Rightarrow 6.6 \times 10^{-6} = 220 \times (600) \times C$

$C = \dfrac{6.6 \times 10^{-6}}{220 \times 600} = 50\,pF$

Q. 

$E = 100 \sin \omega t$

Here

Sol. (1) $E_{max} = 100$

(2) $E_{rms} = \frac{100}{\sqrt{2}}$

(3) $i_{max} = \frac{E_{max}}{X_C} = \frac{100}{20} = 5$

(4) $i_{rms} = 5/\sqrt{2}$

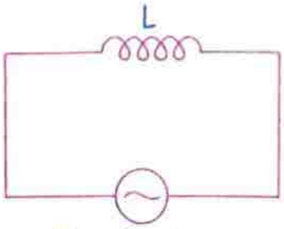
(5) current in the circuit = $i = 5\sin(\omega t + 90^\circ)$

क्योंकि i 90° आगे होता है V_C से

#SKC
यहाँ पर जो V_{AB} है वही V_C है और को E के बराबर है

PURELY INDUCTIVE CIRCUIT:

$$E - \frac{Ldi}{dt} = 0$$



$E \Rightarrow E_0 \sin \omega t$

$$E_0 \sin\omega t = L\frac{di}{dt}$$

$$\frac{E_0}{L}\int \sin\omega t = \int di$$

$$\frac{E_0}{L\omega}(-\cos\omega t) = i$$

$$i = \frac{-E_0}{L\omega}\sin\left(\frac{\pi}{2} - \omega t\right) \Rightarrow i = \frac{E_0}{L\omega}\sin\left(\omega t - \frac{\pi}{2}\right)$$

$$\boxed{i = \frac{E_0}{X_L}\sin\left(\omega t - \frac{\pi}{2}\right)}$$

Inductor में V_L 90° आगे होता है I से। यह भी गलती से भी भूलना नहीं है।

The quantity ωL is analogous to the resistance and is called **inductive reactance**, denoted by X_L.

$X_L = \omega L = 2\pi f L$

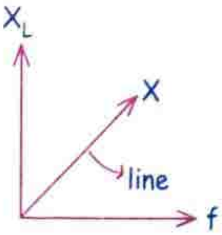
$X_L \Rightarrow 2\pi f L \Rightarrow$ Inductive Reactance.

$i_{max} = \frac{E_0}{X_L}$

as $f\uparrow \Rightarrow X_L \uparrow$ (straight line)

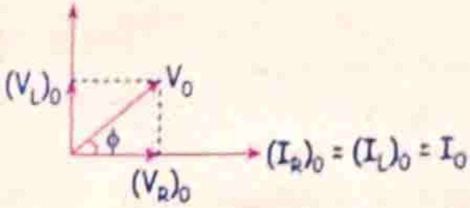
$i_{rms} = \frac{E_{rms}}{X_L}$

But here
$i(t) \neq \frac{E(t)}{X_L}$
क्योंकि phase अलग-अलग है।

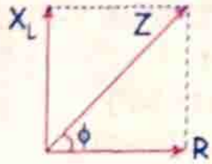


काम का डब्बा

- Applied voltage: $V_0 = \sqrt{(V_R)_0^2 + (V_L)_0^2}$



- Impedance: $Z = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + \omega^2 L^2}$



- Current: $I = I_0 \sin(\omega t - \phi)$
- Peak current $I_0 = \frac{V_0}{Z} = \frac{V_0}{\sqrt{R^2 + X_L^2}}$
- Phase difference: $\phi = \tan^{-1}\frac{X_L}{R} = \tan^{-1}\frac{\omega L}{R}$
- Voltage leads the current in this circuit.

Q. A pure inductor of 50.0 mH is connected to an AC source of 220 V. Find the inductive reactance and rms current in the circuit if the frequency of the source is 50 Hz.

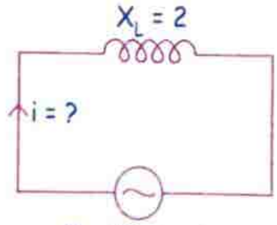
Sol. The inductive reactance,

$X_L = 2\pi f L$

$= 2 \times 3.14 \times 50 \times 50 \times 10^{-3}\,\Omega = 15.7\,\Omega$

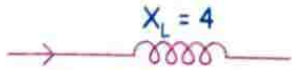
The rms current in the circuit is

$$I_{rms} = \frac{V_{rms}}{X_L} = \frac{220\text{ V}}{15.7\,\Omega} = 14.01\text{ A}$$

- 

E = 10 sin ωt

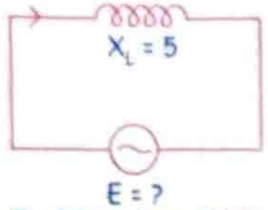
$i_{max} = \frac{10}{2} = 5$, $i = 5\sin(\omega t - 90^\circ)$

- 

$i = 10\sin(\omega t)$

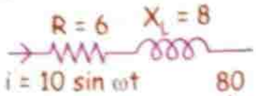
$V_L = 40\sin(\omega t + 90^\circ)$

- $i = 10\sin(\omega t + 30°)$



$E = 50\sin(\omega t + 120°)$

Q. Find V_R, V_L in following circuit.

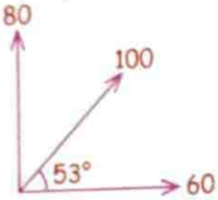


$V_R = 60\sin\omega t$

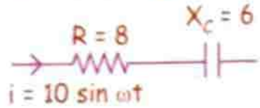
$V_L = 80\sin(\omega t + 90°)$

$V_R + V_L = 100\sin(\omega t + 53°)$

Solved by आयूषी method



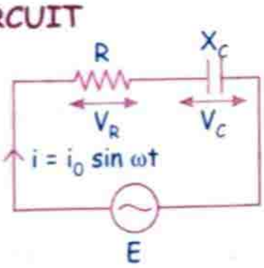
Q. Similarly solve following circuit.



$V_R = 80\sin\omega t$

$V_C = 60\sin(\omega t - 90°)$

RC (AC) CIRCUIT

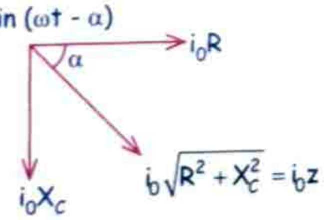


$V_R = i_0 R\sin\omega t$

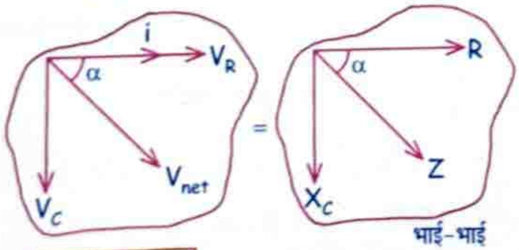
$V_C = i_0 X_C\sin(\omega t - 90°)$

$E = V_R + V_C = i_0 R\sin\omega t + i_0 X_C\sin(\omega t - 90°)$

$E = i_0 Z\sin(\omega t - \alpha)$



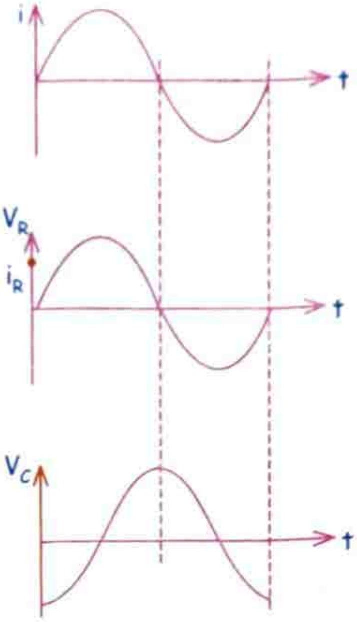
⇒



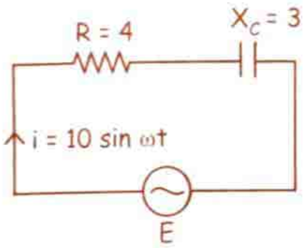
$\boxed{Z = \sqrt{R^2 + X_C^2}}$ = impedance

$$\tan\alpha = \frac{i_0 X_C}{i_0 R} = \frac{X_C}{R}$$

$$\boxed{\cos\alpha = \frac{R}{Z} = \text{power facter}}$$



Q.



Find Z, E_{max}, $E = f(t)$ i_{max}, i_{rms}

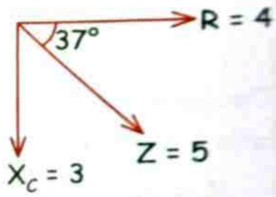
Sol. $i_{max} = 10$

$i_{rms} = 10/\sqrt{2}$

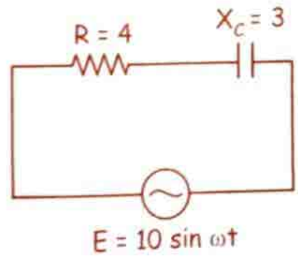
$z = \sqrt{4^2 + 3^2} = 5$

$E_{max} = i_{max}\, z = 10 \times 5 = 50$

$E = 50\sin(\omega t - 37°)$



Q.



(i) Find Z, E_{rms}, i_{rms}, i_{max}, V_R, V_C, i, E_{max}

(ii) Find $i = f(t)$.

Sol. $\Rightarrow Z = 5$

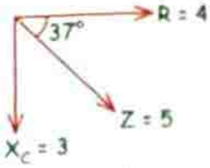
$E_{max} = 10$

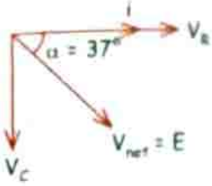
$E_{rms} = \frac{10}{\sqrt{2}}$

$i_{max} = \frac{E_{max}}{Z} = \frac{10}{5} = 2$

$i_{rms} = \frac{2}{\sqrt{2}} = \sqrt{2}$

Power factor = $\cos\alpha = \frac{4}{5}$





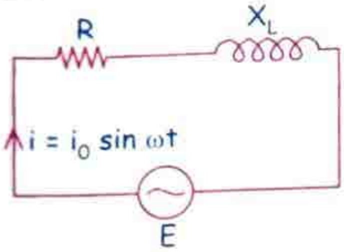
$i = i_0 \sin(\omega t + 37°)$

$i = 2 \sin(\omega t + 37°)$

$V_R = 8 \sin(\omega t + 37°)$

$V_C = 6 \sin(\omega t + 37° - 90°)$

R-L CIRCUIT



$V_R = i_0 R \sin \omega t$

$V_L = i_0 X_L \sin(\omega t + 90°)$

$V_{net} = E = V_R + V_L$

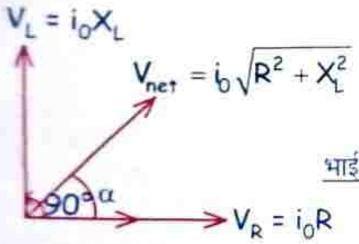
$E = i_0 Z \sin(\omega t + \alpha)$

$Z = \sqrt{R^2 + X_L^2}$

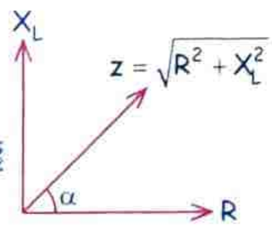
$\tan\alpha = \frac{V_L}{V_R} = \frac{X_L}{R}$

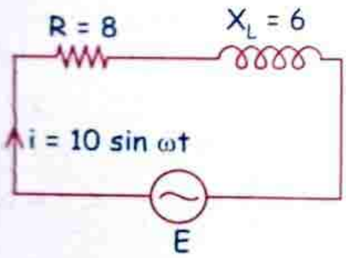
Power factor = $\cos\alpha$

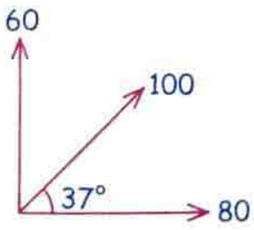
$= \frac{R}{Z}$



भाई-भाई





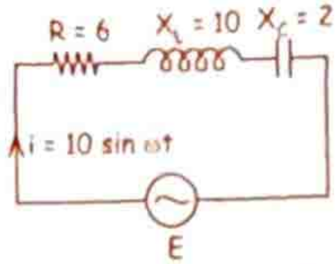


$E_R = 80 \sin \omega t$

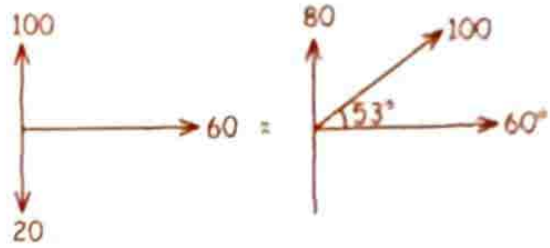
$E_L = 60 \sin(\omega t + 90°)$

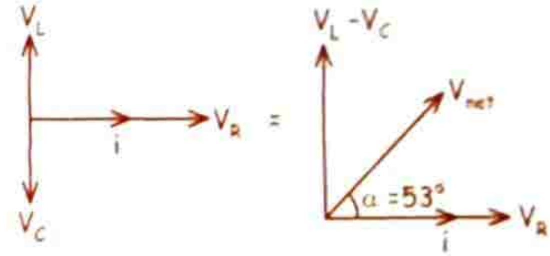
$E = 100 \sin(\omega t + 37°)$

Q.



Find V_R, V_L, V_C, & E





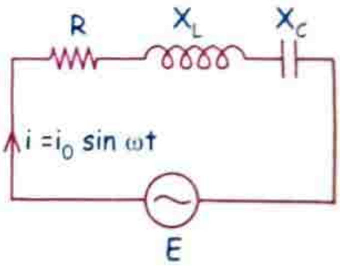
Sol. $V_R = 60 \sin \omega t$

$V_L = 100 \sin(\omega t + 90°)$

$V_C = 20 \sin(\omega t - 90°)$

$V_{net} = 100 \sin(\omega t + 53°) = E$

R-L-C CIRCUIT



$V_R = i_0 R \sin \omega t$

$V_L = i_0 X_L \sin(\omega t + 90°)$

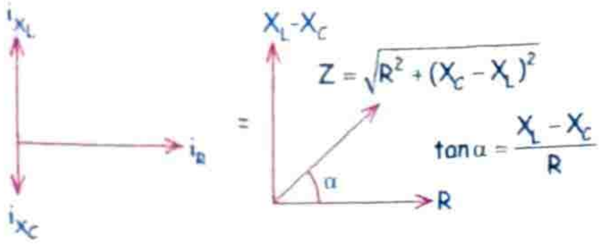
$V_C = i_0 X_C \sin(\omega t - 90°)$

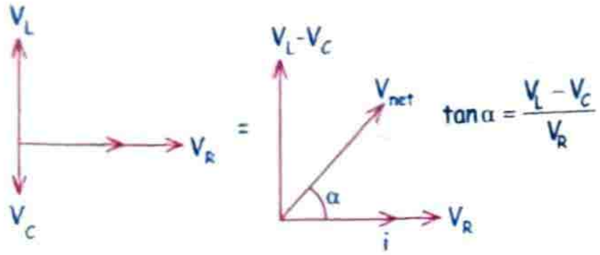
$V_{net} = E = i_0 Z \sin(\omega t + \alpha)$

$Z = \sqrt{R^2 + (X_L - X_C)^2}$

$\tan\alpha = \frac{X_L - X_C}{R}$

$\cos\alpha = \frac{R}{Z} = $ Power factor





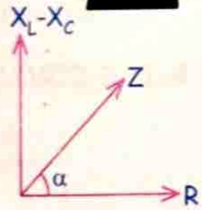
$$\tan\alpha = \frac{X_L - X_C}{V_R} = \frac{V_L - V_C}{V_R}$$

$$\cos\alpha = \frac{R}{Z} \rightarrow \text{(Power factor)}$$

काम का डब्बा

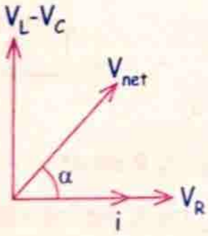
Summary Box भाई यह अच्छे से करलो।

- CIA (Capacitor में current आगे)
- $Z = \sqrt{R^2 + (X_L - X_C)^2}$
- $X_L = L\omega$
- $X_C = \frac{1}{\omega C}$
- $i_{max} = \frac{E_{max}}{Z}$
- $i_{rms} = \frac{E_{rms}}{Z}$



$$\tan\alpha = \frac{X_L - X_C}{R}$$

$$\cos\alpha = \frac{R}{Z}$$



$E = 100 \sin 100\pi t$

$E_{max} = 100$

$E_{rms} = \frac{100}{\sqrt{2}}$

100 V, 50 H_Z

$E_{rms} = 100$

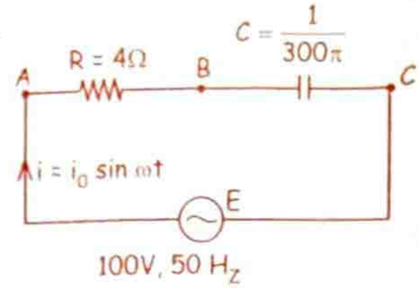
$E_{max} = 100\sqrt{2}$

But here

$i(t) \neq \frac{E(t)}{X_z}$

क्योंकि phase अलग-अगल है।

Q.



Find Z, i_{rms} & E = f(t)

Sol. $\Rightarrow$ $E_{rms} = 100$

$E_{max} = 100\sqrt{2}$

$$X_C = \frac{1}{wc} = \frac{1}{2\pi f c}$$

$$X_C = \frac{1}{2\pi \times 50 \times \frac{1}{300\pi}} = 3$$

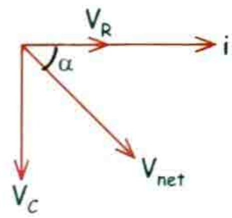
$z = \sqrt{4^2 + 3^2} = 5$ $\quad i_{rms} = \frac{E_{rms}}{z} = \frac{100}{5} = 20$

$$i_{max} = \frac{E_{max}}{z} = \frac{100\sqrt{2}}{5} = 20\sqrt{2}$$

$V_{net} = E$ $\quad$ i से α से पीछे है $E = 200 \sin(\omega t - \alpha)$

$$\tan\alpha = \frac{X_C}{R} = \frac{3}{4}$$

$\alpha = 37°$



Very Important Questions

Q. An LCR series circuit with 100 Ω resistance is connected to an ac source of 200 V and angular frequency 300 rad/s. When only the capacitance is removed, the current lags behind the voltage by 60°. When only the inductance is removed, the current leads the voltage by 60°. Calculate the current in the LCR circuit.

Sol. When capacitance is removed, the circuit becomes *L-R* with, $\tan\phi = \frac{X_L}{R}$ i.e., $X_L = R \tan \phi = 100\sqrt{3}\,\Omega$

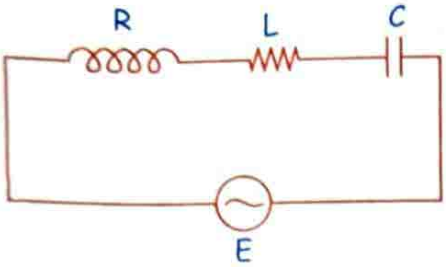
and when inductance is removed the circuit becomes *C-R* with,

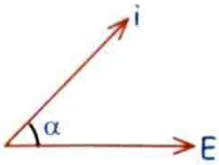
$\tan\phi = \dfrac{X_c}{R}$ i.e., $X_C = R\tan\phi = 100\sqrt{3}\,\Omega$

$Z = \sqrt{R^2 + (X_L - X_c)^2} \Rightarrow Z = R$

So, $I_{rms} = \dfrac{V_{rms}}{Z} = \dfrac{V_{rms}}{R} = \dfrac{200}{100} = 2\text{ A}$

OWER SUPPLY BY SOURCE AND OWER DISSIPATED IN RLC





$E = E_0 \sin\omega t$

$i = i_0 \sin(\omega t + \alpha)$

$P = Ei = E_0 i_0 \sin\omega t.\sin(\omega t + \alpha)$

$P = E_0 i_0 [\sin^2\omega t\cos\alpha + \cos\omega t\sin\alpha\cdot\sin\omega t]$

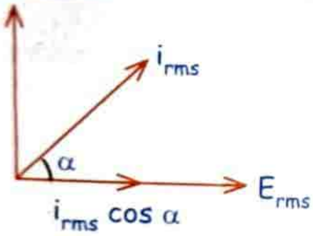
$P = E_0 i_0 [\sin^2\omega t, \cos\alpha + \dfrac{1}{2}\sin 2\omega t\cdot\sin\alpha]$

$<P> = E_0 i_0 [\cos\alpha\cdot<\sin^2\omega t> + \dfrac{1}{2}\cancel{<\sin 2\omega t>}^{\,O}\cdot\sin\alpha]$

$<P> = \dfrac{E_0 i_0\cos\alpha}{2} = \dfrac{E_0}{\sqrt{2}}\cdot\dfrac{i_0}{\sqrt{2}}\cos\alpha$

$\boxed{<P> = E_{rms}\cdot i_{rms}\cdot\cos a}$ power factor $= \cos\alpha$
$= R/Z$

$i_{rms}\sin\alpha \longrightarrow$ watt less current



watt less current $= i_{rms}\sin\alpha$

		α	$\cos\alpha =$ Power factor
1)	Pure Resistive	0°	1
2)	Pure Capacitive	90°	0
3)	Pure Inductive	90°	0
4)	R, L, C	$\tan\alpha = \dfrac{X_L - X_C}{R}$	$\cos\alpha = \dfrac{R}{Z}$

Hence, power supply by source is

$<P> = V_{rms}\cdot i_{rms}\cdot\cos\alpha$

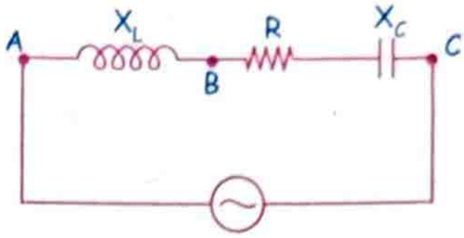
Power Dissipated across resistance

$= i_{rms}^2 R = \left(\dfrac{V_{rms}}{Z}\right)^2 R = V_{rms}\cdot\dfrac{V_{rms}}{Z}\dfrac{R}{Z}$

$= V_{rms}\cdot i_{rms}\cos\alpha$

इन formula पर बहुत सवाल पूछे गए है।

RESONANCE



Since अब तक हम यह जान गए है की

$Z = \sqrt{R^2 + (X_L - X_C)^2}$

$Z = \sqrt{R^2 + \left(L2\pi f - \dfrac{1}{2\pi fc}\right)^2}$

अब अगर f → change z will change

Z will be min when $X_L = X_C$

$$L\omega = \frac{1}{\omega C}$$

$$\omega = \frac{1}{\sqrt{LC}} \quad \omega = 2\pi f$$

$$f = \frac{1}{2\pi\sqrt{LC}} = f_o$$

Resonance frequency

$\omega_0 = 2\pi f_0 = \dfrac{1}{\sqrt{LC}}$ = angular resonance frequency

$f_0 = \dfrac{1}{2\pi\sqrt{LC}}$ Resonance frequency

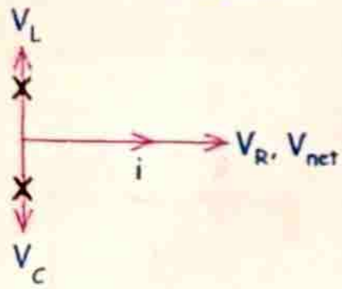
काम का डब्बा

Resonance

At $f = f_0$ we can say that

- $(X_L = X_C)$
- $Z = Z_{min} = R$ (circuit purely resistive की तरह behave करेगा)

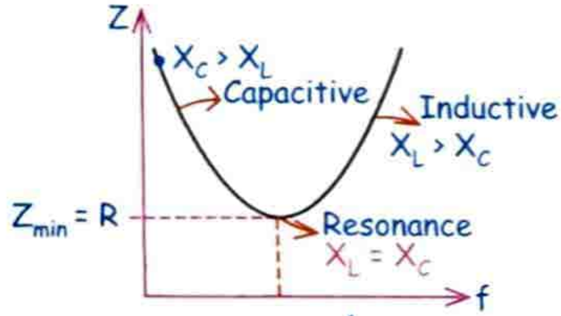
- $\tan\alpha = \frac{X_L - X_C}{R} = 0$
- $\alpha = 0$
- $I_{rms} \sin\alpha = 0$ (watt less current)
- power factor = $\cos\alpha = \cos 0° = 1$
- Since $\alpha = 0$, this implies



$V_L + V_C = 0$

- i, V_R, V_{net}, all are in same phase
- अगर B और C के बीच AC वाला voltmeter लगाया तो reading will be zero.
- $i_0 = \frac{E_0}{Z} = \frac{E_0}{R}$

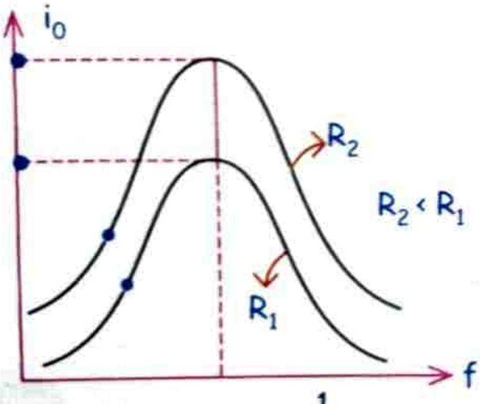
VARIATION OF Z wrt f (frequency)



$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

If $f < f_0 \Rightarrow$ Capacitive CKT,

If $f > f_0 \Rightarrow$ Inductive CKT



$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

- If $R\downarrow \Rightarrow f_0 \rightarrow$ same peak वही रहेगा $R\downarrow$ $Z\downarrow$ $i_0\uparrow$

Quality$\uparrow$ $\Leftarrow$ sharpness$\uparrow$

*$R\downarrow$, sharpness$\uparrow$, $Q\uparrow$ ($X_L = X_C$ use)

Quality factor = $Q = \frac{X_L}{R} = \frac{X_C}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$

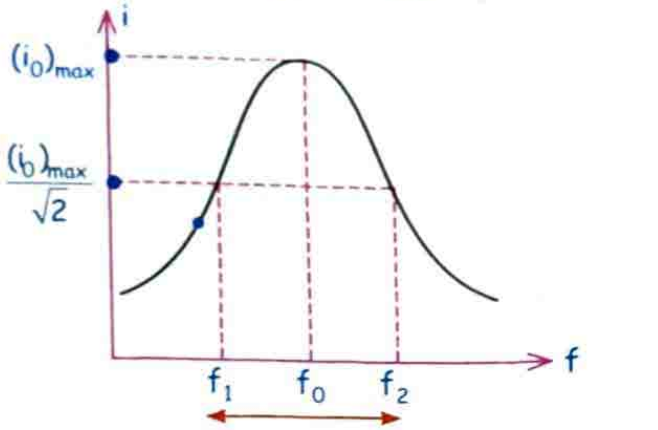
$R\downarrow$ $Q\uparrow$

- Half power freq = f_1 & f_2

$f_2 - f_1$ = frequency Band width = Δf

* Quality factor = $\frac{f_0}{\Delta f} = \frac{f_0}{f_2 - f_1}$

*$R\downarrow$, sharpness$\uparrow$, $\Delta f\downarrow$ $\Rightarrow$ $Q\uparrow$



Δf = Band width for frequency

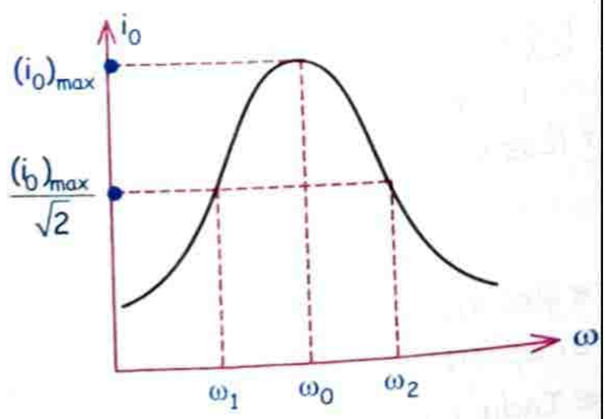
$$Q = \frac{\text{Votatge across L}}{\text{Applied voltage}} = \frac{i_{rms}X_L}{i_{rms}Z}$$

$$Q = \frac{X_L}{R} = \frac{X_C}{R}$$

भाई ये दोनो अलग अलग है confuse मत हो जाना

Power factor = $\cos\alpha = \frac{R}{Z}$

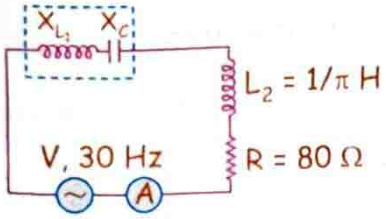
Quality factor = $Q = \frac{X_L}{R} = \frac{X_C}{R}$



$\omega_0 = \frac{1}{\sqrt{LC}}$ = Angular resonance freq.

ω_1 and ω_2 → half power angular frequency

Q. In figure given below if $X_L = X_C$ and reading of ammeter is 1 A, then the value of source voltage, in volt, is



Sol. $X_L = X_C$ and current in both is same.

So, $V_{L_1} = V_C$

So, voltage of other inductor is,

$$V_{L_2} = (I_{L_2})X_{L_2}$$

$$\Rightarrow V_{L_2} = 1 \times 2\pi \times 30 \times \frac{1}{\pi} = 60\,\text{Volt}$$

and

$$V_R = 80 \times 1 = 80 \text{ Volt}$$

$$V = \sqrt{V_{L_2}^2 + V_R^2} = \sqrt{(80)^2 + (60)^2} = 100\,\text{Volt}$$

Q. A FM radio receiver has a series LCR circuit with $L = 1\ \mu H$, and $R = 100\ \Omega$. The antenna receives radio waves and induces a sinusoidally alternating emf of amplitude 10 μV. The induced voltage is fed to the series LCR circuit. The capacitance in the circuit is adjusted to a value of $C = 2$ pF.

(a) Find the frequency of radio wave to which the radio will tune.

(b) Find the rms current in the circuit.

(c) Find quality factor of the resonance.

Sol. (a) Resonance Frequency $f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$

$$= \frac{1}{2\pi}\sqrt{\frac{1}{10^{-6} \times 2 \times 10^{-12}}} = 112.5\text{ MHz}$$

(b) Since circuit is in resonance $Z = R = 100\ \Omega$

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{\frac{10}{\sqrt{2}} \times 10^{-6}}{100} = 70.7\,\text{nA}$$

(c) $Q = \frac{\omega_0 L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{100}\sqrt{\frac{10^{-6}}{2 \times 10^{-12}}} = 7.07$

Q. A series LCR circuit has 120 Ω resistance. When the angular frequency of the source is 4×10^5 rad s^{-1} the voltage across resistance, inductance and capacitance are 60 V, 40 V and 40 V respectively. At what angular frequency of the source the current in the circuit will lag behind the source voltage by $\frac{\pi}{4}$?

Sol. The circuit is in resonance because $V_L = V_C$.

$$\Rightarrow Z = R = 120\ \Omega$$

$$\therefore \text{RMS current } I = \frac{V}{Z} = \frac{V}{R} = \frac{60}{120} = 0.5\,A$$

[Note that source voltage = V_R in resonance]

Now $IX_L = V_L \Rightarrow 0.5(\omega L) = 40$

$$\Rightarrow L = \frac{40}{0.5 \times 4 \times 10^5} = 0.2\text{ mH}$$

And $IX_C = V_C$

$$\Rightarrow 0.5\frac{1}{\omega C} = 40 \Rightarrow C = \frac{0.5}{4 \times 10^5 \times 40} = 31.25\text{ nF}$$

If current lags behind the voltage by $\pi/4$ we must have

$$\tan\left(\frac{\pi}{4}\right) = \frac{X_L - X_C}{R}$$

$$\omega L - \frac{1}{\omega C} = 1 \times 120$$

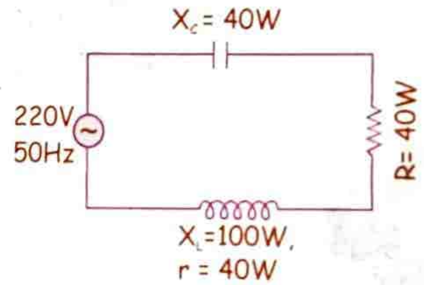
$$0.2 \times 10^{-3}\omega - \frac{1}{\omega \times 31.25 \times 10^{-9}} = 120$$

Solving this quadratic equation gives

$$\omega = 8 \times 10^5 \text{rads}^{-1}$$

भाई कभी कभी खतरनाक calculation भी exam में आ जाती है।

Q. Find the power factor of the circuit shown in figure?



Sol. $R_{net} = 40 + 40 = 80\ \Omega$

$$X_L - X_C = 100 - 40 = 60\Omega$$

$$Z = \sqrt{R_{net}^2 + (X_L - X_C)^2} = \sqrt{80^2 + 60^2} = 100\ \Omega$$

Power factor, $\cos\phi = \frac{R}{Z} = \frac{80}{100} = 0.8$

Q. A current of 4 A flows in a coil when connected to a 12 V dc source. If the same coil is connected to a 12 V, 50 rad/s ac source a current of 2.4 A flows in the circuit. Determine the inductance of the coil. Also find the power developed in the circuit if a 2500 μF capacitor is connected in series with the coil.

Sol. In case of a coil $Z = \sqrt{R^2 + \omega^2 L^2}$

$$\Rightarrow I = \frac{V}{Z} = \frac{V}{\sqrt{R^2 + \omega^2 L^2}}$$

So when dc is applied

$$I = \frac{V}{R} \Rightarrow R = \frac{12}{4} = 3\ \Omega$$

and when ac is applied,

$$I = \frac{V}{Z} \Rightarrow Z = \left(\frac{V}{I}\right) = \left(\frac{12}{2.4}\right) = 5\ \Omega$$

or, $R^2 + X_L^2 = 5^2$ $\quad$ (as $Z = \sqrt{R^2 + X_L^2}$)

so, $X_L^2 = 5^2 - R^2 = 5^2 - 3^2 = 4^2 \Rightarrow X_L = 4\,\Omega$

But, as $X_L = \omega L \Rightarrow L = \frac{X_L}{\omega} = \frac{4}{50} = 0.08\text{H}$

Now when the capacitor is connected to the above circuit in series

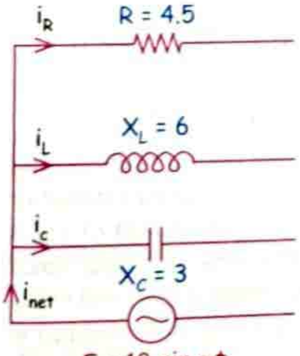
$$X_C = \frac{1}{\omega C} = \frac{1}{50 \times 2500 \times 10^{-6}} = \frac{10^3}{125} = 8\ \Omega$$

$$\text{So, } Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{3^2 + (4-8)^2} = 5\ \Omega$$

$$P = I^2 R = \left(\frac{V}{Z}\right)^2 R = \left(\frac{12}{5}\right)^2 \times 3 = 17.28\text{W}$$

इन सवालो को हलके मे मत लेना AC में physics आसान but calculation अक्सर tough पूछी जाती है। So, solve question till last. क्यों भाई करोगे ना।

PARALLEL CIRCUIT



#SKC
अबे ये तो बहुत लल्लू है L, C, R के across same potential difference ($\Delta V = E$) है तो i_R और E same phase में होंगे i_C E से 90° आगे होगा और i_L E से 90° पीछे होगा।

$i_C = 6 \sin(\omega t + 90°)$

$i_L = 3 \sin(\omega t - 90°)$

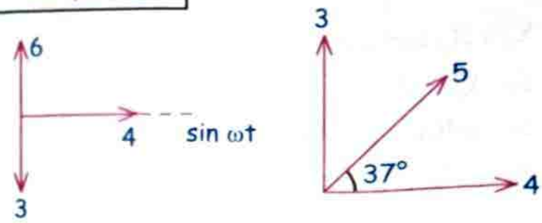
$i_R = 4 \sin \omega t$

Now solved by आयूषी method

(चलो कोई कहीं तो काम आया)

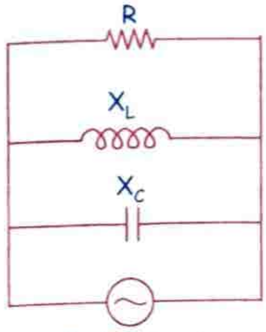
$i_{net} = i_C + i_L + i_R$

$\boxed{i_{net} = 5\sin(\omega t + 37°)}$



$(i_0)_{max} = 5$ $\qquad$ $z = \frac{E_{max}}{i_{max}} = \frac{18}{50}$

$E_{max} = 18$



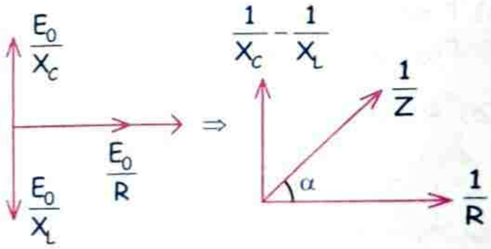
E = E_0 sin wt

$$i_R = \frac{E_0}{R}\sin\omega t$$

$$i_L = \frac{E_0}{X_L}\sin(\omega t - 90°)$$

$$i_C = \frac{E_0}{X_0}\sin(\omega t + 90°)$$

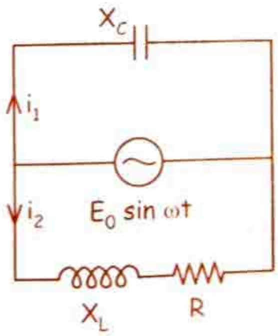
$$i_{net} = \frac{E_0}{Z}\sin(\omega t + \alpha)$$



$$\frac{1}{z} = \sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_C} - \frac{1}{X_L}\right)^2} \qquad \tan\alpha = \frac{\frac{1}{X_C} - \frac{1}{X_L}}{\frac{1}{R}}$$

Here power factor = $\frac{z}{R}$ $\qquad$ admitence = $\frac{1}{z}$

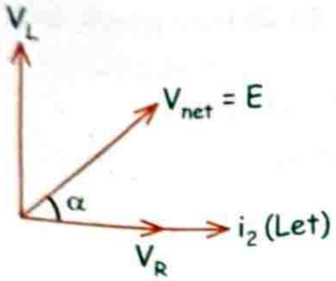
Q.



What is the phase difference b/w i_1 & i_2?

$$i_1 = \frac{E_0}{X_C}\sin(\omega t + 90°)$$

$$i_2 = \frac{E_0}{Z}\sin(\omega t - \alpha)$$



i_2 पीछे है E से α angle

$$\tan\alpha = \frac{V_L}{V_R} = \frac{X_L}{R}$$

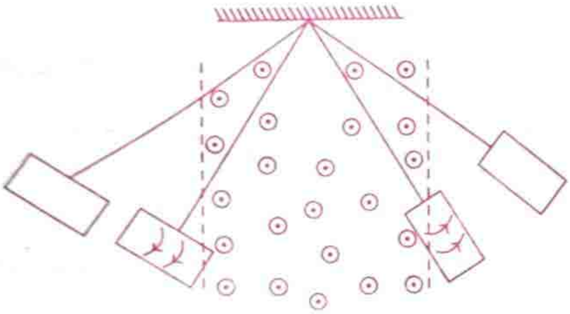
$$\alpha = \tan^{-1}\left(\frac{X_L}{R}\right)$$

$$i_2 = \frac{E_0}{\sqrt{R^2 + X_L^2}}\sin(\omega t - \alpha)$$

Ans = $(\omega t - 90) - (\omega t - \alpha) = \alpha - 90$

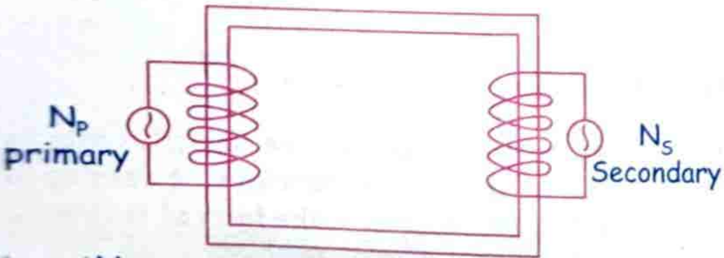
EDDY CURRENT

Magnetic flux associated with the plate keeps on changing as plate moves in and out of the region in mag field. The flux changes induce eddy current in plates which cause heat loss and finally it stopped.



TRANSFORMER

A transformer is a device that transfers electrical energy from one AC circuit to one or more other circuits with either increasing (step-up) or decreasing (step-down) the voltage using the principle of mutual induction. Two coils called the primary and secondary windings, which are not in contact with one another, are wound on a complete soft iron core. When an alternating voltage E_P is applied to the primary coil, the resultant current produces a large alternating magnetic flux which links to the secondary coil and induces an emf E_s in it. It can be shown that for an ideal transformer



$\phi_{in} = \phi N_P$ $\qquad$ $\phi_{out} = \phi N_S$

$$E_P = V_i = \frac{d\phi_{in}}{dt} = N_P\frac{d\phi}{dt}$$

$$V_{out} = E_S = N_S\frac{d\phi}{dt}$$

$$V_{out} = N_S\frac{d\phi}{dt}$$

$$V_{in} = N_P\frac{d\phi}{dt}$$

$$\frac{V_{out}}{V_{in}} = \frac{N_S}{N_P}$$

$$V \propto N$$

$$\frac{V_{out}}{V_{in}} = \frac{N_{out}}{N_{in}}$$

- If $N_S > N_P$

  $V_{out} > V_{in} \Rightarrow$ step up transformer

- If $N_S < N_P$

  $V_{out} < V_{in} \Rightarrow$ step down transformer

For 100% Power transfer (100% efficiency)

$P_{in} = P_{out}$

$V_P \cdot i_P = V_S \cdot i_S$

$$\frac{V_S}{V_P} = \frac{V_{out}}{V_{in}} = \frac{i_P}{i_S} = \frac{i_{in}}{i_{out}}$$

काम का डब्बा

$$V \propto N \propto \frac{1}{i}$$

for 100% power transfer

$$\frac{V_{out}}{V_{in}} = \frac{N_{out}}{N_{in}} = \frac{i_{in}}{i_{out}}$$

Output → secondary

input → primary

Q. A power transformer is used to step-up an alternating emf of 220 volt to 11 kV to transmit 4.4 kW of power. If the primary coil has 1000 turns, what is the current in the secondary?

Sol. $I_s - P_s/V_s$

$$\Rightarrow I_s = \frac{4.4\times10^3}{11\times10^3} = 0.4\text{ A}$$

Energy Losses in Transformer

1. Resistance of the Windings

   The copper wire used for the windings has resistance and so I^2R heat losses occur.

2. Eddy Current

Eddy current is induced in a conductor when it is placed in a changing magnetic field or when a conductor is moved in a magnetic field and/or both. Thus the alternating magnetic flux induces eddy currents in the iron core and causes heating. The effect is reduced by laminating the core.

3. Hysteresis

The magnetization of the core is repeatedly reversed by the alternating magnetic field. The resulting expenditure of energy in the core appears as heat. It is kept to a minimum by using a magnetic material which has a low hysteresis loss.

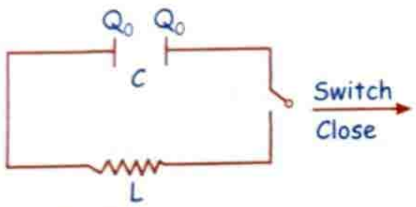
4. Flux Leakage

The flux due to the primary coil may not all be linked to the secondary if the core is badly designed or has air gaps in it.

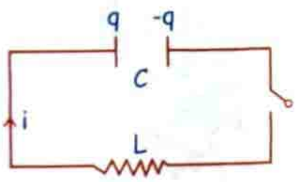
Very large transformers have to be oil cooled to prevent overheating.

LC-OSCILLATION

Suppose at $t = 0$ we have capacitor and inductor as shown in diagram. Charge on capacitor at $t = 0$ is Q_0. Find charge q, i at time t



at $t = 0$



At time 't'

KVL $\frac{-q}{C} - \frac{Ldi}{dt} = 0$

$i = \frac{dq}{dt}$

$\Rightarrow L\frac{di}{dt} = \frac{-q}{c}$

$L\frac{d^2q}{dt^2} = \frac{-q}{c}$

$$\boxed{\frac{d^2q}{dt^2} = \frac{-1}{Lc}q}$$

After solving at ($t = 0$ $q = Q_0$)

$q = Q_0 \sin(\omega t + 90)$

Energy stored in capacitor at time 't'

(in form of EF) $= \frac{1}{2}q^2/c$

Energy stored in Inductor at time 't'

(Inform of mF) $= \frac{1}{2}Li^2$

* Total energy $= \frac{1}{2}\frac{q^2}{c} + \frac{1}{2}Li^2 = \text{const}$

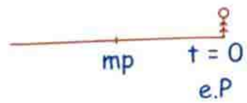
  Total energy $= \frac{1}{2}\frac{Q_0^2}{C} + 0 = \frac{1}{2}\frac{q^2}{c} + \frac{1}{2}Li^2 = 0 + \frac{1}{2}Li_0^2$

* Energy oscillate between cap. to inductor with

  $T = \frac{1}{2\pi\sqrt{LC}}$

  देख भाई

SHM		LC oscillation
$\frac{d^2x}{dt^2} = \frac{-x}{LC}$	$\longrightarrow$	$\frac{d^2x}{dt^2} = \frac{-q}{LC}$
$\Downarrow$		$\Downarrow$
$x = A\sin(wt + \phi)$		$q = Q_0\sin(wt + \phi)$



If At $t = 0$, $x = +A$ $\longrightarrow$ At $t = 0$, $q = Q_0$

$x = A\sin(\omega t + 90)$ $\qquad$ $q = Q_0 \sin(wt + q_0)$

$x \longrightarrow q$

$A \longrightarrow Q_0$

$\frac{dx}{dt} = v \longrightarrow i = \frac{dq}{dt}$

$v_{max} = A\omega \longrightarrow i_{max} = Q_0\omega$

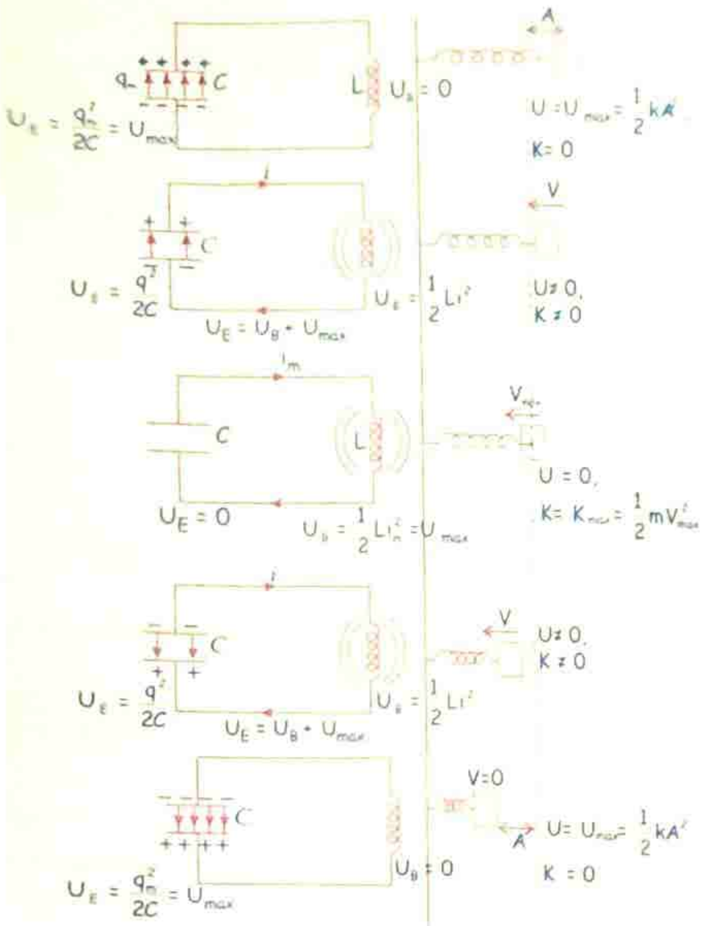
$K\varepsilon = \frac{1}{2}mV^2 \longrightarrow$ Magnetic $= \frac{1}{2}Li^2$ Energy

$PE = \frac{1}{2}Kx^2 \longrightarrow$ E.F energy $= \frac{1}{2}\frac{q^2}{C}$

At $t = 0$, the switch is closed and the capacitor starts to discharge. As the current increases, it sets up a magnetic field in the inductor in the form of magnetic energy: $U_B = \frac{1}{2}Li^2$

As the current reaches its maximum value i_m, (at $t = T/4$) all the energy is stored in the magnetic field: $U_B = \frac{1}{2}Li_m^2$.

Analogies Between Mechanical and Electrical Oscillations



Mechanical system	Electrical system
Mass m	Inductance L
Force constant k	Reciprocal of capacitance $1/C$
Displacement x	Charge q
Velocity $V = dx/dt$	Current $i = dq/dt$
Mechanical energy	Electromagnetic energy
$E = \frac{1}{2}kx^2 + \frac{1}{2}mV^2$	$U = \frac{1}{2}\frac{q^2}{C} + \frac{1}{2}Li^2$

देख भाई LC पढ़ने से पहले SHM revise करके आओ तभी मजा आएगा अगर किसी का SHM का back log है इस सवाल के direct result याद करलो इसी से सवाल बन जाएंगे result मैं लिख रहा हूँ।

$$T = \frac{1}{2\pi\sqrt{LC}}$$

$$q = Q_0 \sin(\omega t + 90)$$

Q. A capacitor of capacitance 25 μF is charged to 300 V. It is then connected across a 10 mH inductor. The resistance of the circuit is negligible.

(a) Find the frequency of oscillation of the circuit.

(b) Find the potential difference across capacitor and magnitude of circuit current 1.2 ms after the inductor and capacitor are connected.

Sol. (a) The frequency of oscillation of the circuit is

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Substituting the given values, we have

$$f = \frac{1}{2\pi\sqrt{(10\times10^{-3})(25\times10^{-6})}} = \frac{10^3}{\pi}\text{Hz}$$

(b) Charge across the capacitor at time t will be

$q = q_0 \cos\omega_0 t \Rightarrow I = -q_0\omega_0 \sin\omega_0 t$

Here $q_0 = CV_0$

$= (25 \times 10^{-6} \times 300)$

$= 7.5 \times 10^{-3}$ C

Now, charge on the capacitor after $t = 1.2 \times 10^{-3}$ s is

$$q = |(7.5\times10^{-3})\cos(2\pi \times \frac{10^3}{\pi} \times 1.2 \times 10^{-3})| C$$

$= 5.53 \times 10^{-3}$ C

∴ Potential difference across capacitor,

$$V = \frac{|q|}{C} = \frac{5.53\times10^{-3}}{25\times10^{-6}} = 221.2 \text{ volt}$$

The magnitude of current in the circuit at $t = 1.2 \times 10^{-3}$ s

$|i| = q_0\omega_0 \sin\omega_0 t$

$$|i| = (7.5\times10^{-3})\left(2\pi\times\frac{10^3}{\pi}\right)\sin\left(2\pi\times\frac{10^3}{\pi}\times1.2\times10^{-3}\right)A$$

$= 10.13$ A

Q. In the above question, find the magnetic energy and electric energy at $t = 0$ and $t = 1.2$ ms.

Sol. At t = 0, current in the circuit is zero.

Hence $U_L = 0$

Charge on the capacitor is maximum

Hence, $U_C = \frac{1}{2}\frac{q_0^2}{C}$

$$U_C = \frac{1}{2}\frac{(7.5\times10^{-3})^2}{25\times10^{-6}} = 1.125 \text{ J}$$

At $t = 1.25$ ms, $q = 5.53 \times 10^{-3}$C

$$U_C = \frac{1}{2}\frac{(5.53\times10^{-3})^2}{25\times10^{-6}} = 0.612 \text{ J}$$

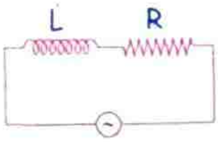
and the magnetic energy, $U_L = (U_C)_{max} - U_C$

$= 1.125 - 0.612$

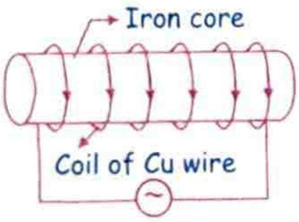
$= 0.513$ J

CHOKE COIL

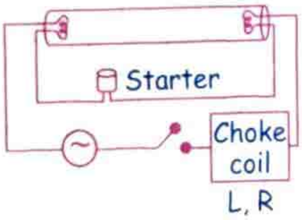
- Choke coil is a device having high inductance and negligible resistance (equivalent to a $R - L$ circuit).



- It is used to control current in ac circuits and is used in fluorescent tubes.
- The power loss in a circuit containing choke coil is least.



Choke coil



Application of choke coil

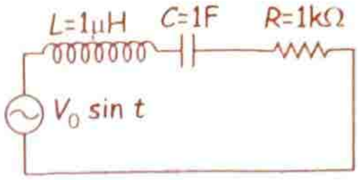
- It consists of a copper coil wound over a soft iron laminated core. This coil is put in series with the circuit in which current is to be reduced.
- The inductive reactance or effective opposition of the choke coil is given by $X_L = \omega L = 2\pi f L$
- For an ideal choke coil $R = 0$, no electric energy is wasted, i.e., average power $P = 0$.
- The choke coil can be used only in ac circuits not in dc circuits, because for dc the frequency, $f = 0$. Hence $X_L = 2\pi f L = 0$
- based on the principle of wattless current.
- The current in the circuit, $I = \frac{E}{Z}$ with $Z = \sqrt{(R+r)^2 + (\omega L)^2}$
- The power loss in the choke

$$P_{avg} = V_{rms} I_{rms} \cos\phi$$

where $\cos\phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + \omega^2 L^2}}$

QUESTIONS PRACTICE

Q. In the circuit shown, $L = 1\mu$H, $C = 1\mu$F and $R = 1\Omega$. They are connected in series with an AC source $V = V_0 \sin \omega t$ as shown. Which of the following options is/are correct? (JEE Adv. 2017)



(a) At $\omega \approx 0$, the current flowing through the circuit becomes nearly zero

(b) The frequency at which the current will be in phase with the voltage is independent of R

(c) The current will be in phase with the voltage if $\omega = 10^4$ rads^{-1}

(d) At $\omega >> 10^6$, rads^{-1}, the current behaves like a capacitor

Sol. (a, b) At $w \approx 0$, $X_C = \frac{1}{\omega C} = \infty$. Therefore, current is nearly zero.

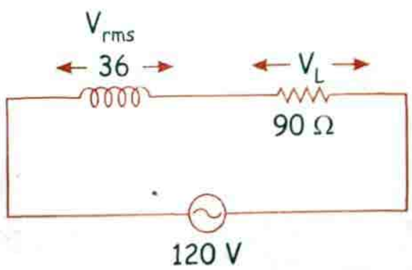
Further at resonance frequency, current and voltage are in phase. This resonance frequency is given by

$$\omega_r = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{10^{-6}\times10^{-6}}} = 10^6 \text{ rad/s}$$

We can see that this frequency is independent of R.

Q. A coil of negligible resistance is connected in series with $90\,\Omega$ resistor across 120 V, 60 Hz supply. A voltmeter reads 36 V across resistance. Inductance of the coil is: [08 April, 2024 (Shift-II)]

Sol.



$$\sqrt{36^2 + V_L^2} = 120$$

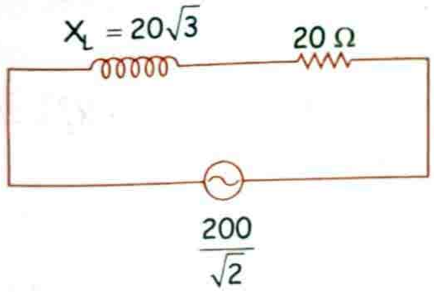
$V_L = iX_L$

$X_L = L \times 2\pi \times 60$

Q. When a dc voltage of 100V is applied to an inductor, a dc current of 5A flows through it. When an ac voltage of 200V peak value is connected to inductor, its inductive reactance is found to be $20\sqrt{3}\Omega$ The power dissipated in the circuit is __________W.

[06 April, 2024 (Shift-I)]

Sol. (250)



$$Z = \sqrt{20^2 + (20\sqrt{3})^2} = 40$$

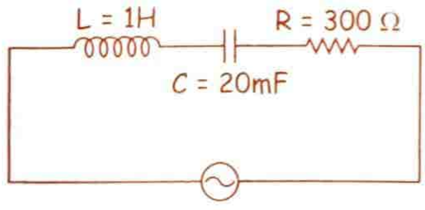
$$\text{Power} = i_{rms}^2 R$$

$$= \left(\frac{E_{rms}}{Z}\right)^2 R = \left(\frac{200}{\sqrt{2}}\right)^2 \times \frac{20}{40 \times 40}$$

$$= \frac{1000}{4} = 250$$

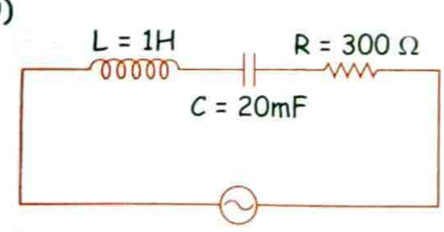
Q. An ac source is connected in given series LCR circuit. The rms potential difference across the capacitor of $20\ \mu F$ is .... V.

[05 April, 2024 (Shift-I)]



$V = 50\sqrt{2}\sin 100t$ volt

Sol. (50)



$V = 50\sqrt{2}\sin 100t$ volt

$$(V_{rm})_{cmp} = \text{irms}\ X_C$$

$$(V_C)_{min} = i_0 X_C$$

$$i_{rms} = \frac{50}{Z}$$

Q. In an a.c. circuit, voltage and current are given by : V = 100 sin (100t) V and I = 100 sin $\left(100 + \frac{\pi}{3}\right)$ mA respectively. The average power dissipated in one cycle is:

[29 Jan. 2024, Shift 2]

Sol. $\frac{100}{\sqrt{2}} \times \frac{100}{\sqrt{2}} \cos 60°$

Q. A series LCR circuit with $L = \frac{100}{\pi}$ mH, $C = \frac{10^{-3}}{\pi}$ F and $R = 10\ \Omega$, is connected across an ac source of 220 V, 50 Hz supply. The power factor of the circuit would be __________.

[27 Jan. 2024, Shift 2]

Sol. $\cos\alpha = Pf = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + (X_L - X_C)^2}}$

$$X_L = L2\pi f$$

Q. Primary side of a transformer is connected to 230V, 50 Hz supply. Turns ratio of primary to secondary winding is 10 : 1. Load resistance connected to secondary side is 46Ω. The power consumed in it is: [27 Jan, 2024 (Shift-II)]

Sol. $\frac{N_1}{N_2} = \frac{10}{1}, \frac{V_1}{V_2} = \frac{N_1}{N_2}$

$$\frac{230}{V_2} = 10, V_2 = 23$$

$$V_2 = i_2 R_o$$

$$23 = i_2 \times 46$$

$$i_2 = \frac{1}{2}$$

$$P = V_2 i_2 = 23 \times i_2$$

$$= 23 \times \frac{1}{2} = 11.5$$

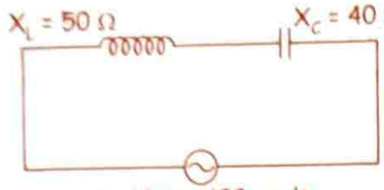
Q. An LCR series circuit with 100Ω resistance is connected to an ac source of 200 V and angular frequency 300 rad/s. When only the capacitance is removed, the current lags behind the voltage by 60°. When only the inductance is removed, the current leads the voltage by 60°. Calculate the current and the power dissipated in the LCR circuit.

Sol. 2A, 400 W

Q. A current of 4 A flows in a coil when connected to a 12 V dc source. If the same coil is connected to a 12V, 50 rad/s ac source a current of 2.4 A flows in the circuit. Determine the inductance of the coil. Also find the power developed in the circuit if a 2500 μF capacitor is connected in series with the coil.

Sol. 0.08 H, 17.28 W

Q. If $X_L = 50\ \Omega$ and $X_C = 40\ \Omega$ Calculate effective value of current in given circuit.

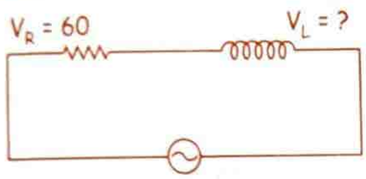


V = 40sin 100π volt

Sol. $Z = X_L - X_C = 10\ \Omega$

$$I_0 = \frac{V_0}{Z} = \frac{40}{10} = 4A \Rightarrow I_{rms} = \frac{4}{\sqrt{2}} = 2\sqrt{2}A$$

Q. In given circuit calculate, voltage across inductor



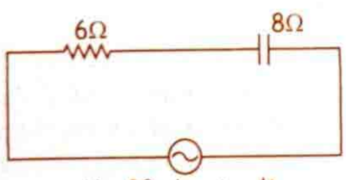
$V = 100\sqrt{2}\ \sin \omega t$ volt

Sol. $\because V^2 = V_R^2 + V_L^2 \qquad \therefore V_L^2 = V^2 - F_R^2$

$$V_L = \sqrt{V^2 - V_R^2} = \sqrt{(100)^2 - (60)^2}$$

$$= \sqrt{6400} = 80\ V$$

Q. In given circuit find out (i) impedance of circuit (ii) current in circuit



V = 20 sin ωt volt

Sol. (i) $Z = \sqrt{R^2 + X_C^2} = \sqrt{(6)^2 + (8)^2} = 10\ \Omega$

(ii) $V = IZ \Rightarrow I = \frac{V_0}{Z} = \frac{20}{10} = 2A$ so $I_{rms} = \frac{2}{\sqrt{2}} = \sqrt{2}A$

Q. When 10V, DC is applied across a coil current through it is 2.5 A, if 10V, 50 Hz A.C. is applied current reduces to 2 A. Calculate reactance of the coil.

Sol. For 10 V D.C. $\because V = IR$

$\therefore$ Resistance of coil $R = \frac{10}{2.5} = 4\Omega$

For 10 V A.C. $V = IZ$

$$\Rightarrow Z = \frac{V}{I} = \frac{20}{10} = 5\Omega$$

$$\because Z = \sqrt{R^2 + X_L^2} = 5 \Rightarrow R^2 + X_L^2 = 25$$

$$\Rightarrow X_L^2 = 5^2 - 4^2 \Rightarrow X_L = 3\Omega$$

Q. When an alternating voltage of 220V is applied across a device X, a current of 0.5 A flows through the circuit and is in phase with the applied voltage. When the same voltage is applied across another device Y, the same current again flows through the circuit but it leads the applied voltage by π/2 radians.

(a) Name the devices X and Y.

(b) Calculate the current flowing in the circuit when same voltage is applied across the series combination of X and Y.

Sol. (a) X is resistor and Y is a capacitor

(b) Since the current in the two devices is the same (0.5A at 220 volt)

When R and C are in series across the same voltage then

$$R = X_C = \frac{220}{0.5} = 440\ \Omega$$

$$\Rightarrow I_{rms} = \frac{V_{rms}}{\sqrt{R^2 + X_C^2}} = \frac{220}{\sqrt{(440)^2 + (440)^2}}$$

$$= \frac{220}{440\sqrt{2}} = 0.35A$$

Q. In LCR circuit with an AC source R = 300Ω, C = 20 μF, L = 1.0 H, E_{rms} = 50V and f = 50/π Hz. Find RMS current in the circuit.

Sol. $$I_{rms} = \frac{E_{rms}}{Z} = \frac{E_{rms}}{\sqrt{R^2 + \left[\omega L - \frac{1}{\omega C}\right]^2}}$$

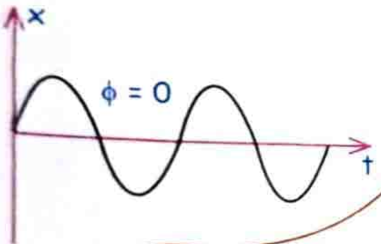
$$= \frac{50}{\sqrt{300^2 + \left[2\pi \times \frac{50}{\pi} \times 1 - \frac{1}{20 \times 10^{-6} \times 2\pi \times \frac{50}{\pi}}\right]^2}}$$

$$\Rightarrow I_{rms} = \frac{50}{\sqrt{(300)^2 + \left[100 - \frac{10^3}{2}\right]^2}}$$

$$= \frac{50}{100\sqrt{9+16}} = \frac{1}{10} = 0.1\ A$$

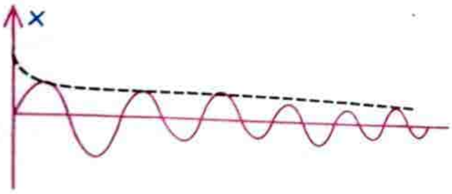
DAMPING
(Removed from JEE MAINS 2025)

Undamping Oscillation	Damping Oscillation
Amplitude $\rightarrow$ const.	$\vec{F} \propto -\vec{x}$
$\vec{F} \propto -\vec{x}$	$\vec{F} \propto -\vec{v}$
$\vec{F} = -k\vec{x}$	$\vec{F} = -k\vec{x} - b\vec{v}$
$\vec{a} = \frac{-K}{m}\vec{x}$	$\frac{d^2x}{dt^2} = \frac{-k}{m}\vec{x} - \frac{b}{m}\frac{d\vec{x}}{dt}$
$x = A_0 \sin(\omega_0 t + \phi)$ $\downarrow$ Amplitude	Solve



- $x = A_0 e^{-rt} \sin(\omega t + \phi)$
- $\boxed{\text{Amplitude} = A_{0e}^{-rt} = A}$

  $r = \frac{b}{2m} = \text{const.}$
- as time $\uparrow$ = Amplitude $\downarrow$



- If $r\uparrow$, Rate of energy loss $\uparrow$

***

$\boxed{\omega = \sqrt{\omega_0^2 - r^2}}$

const.

If $b = 0$
$r = 0$
$\omega = \omega_0$
Amp $= A_0 =$ const.
undamp

Hence we can say that जितना r ज्यादा, faster will be decay of amplitude & will be rate of loss of energy.

- $\omega = \frac{2\pi}{T}$
- $\omega = \sqrt{\omega_0^2 - r^2}$
- $\omega < \omega_0$
- $T > T_0$

ω
$T \longrightarrow$ cost

$\vec{F}_{net} = -k\vec{x} - b\vec{v}$, $\vec{F}_v \propto -\vec{v}$

$\vec{a} = \frac{-k\vec{x}}{m} - \frac{b\vec{v}}{m}$, $\vec{F}_v = -b\vec{v}$

$\frac{d^2\vec{x}}{dt^2} = \frac{-k}{m}\vec{x} - \frac{b}{m}\frac{d\vec{x}}{dt}$

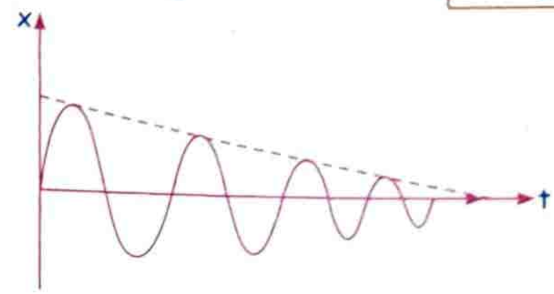
After solving we got

$x = A \sin(\omega t + \phi)$

$x = A_0 e^{-rt} \sin(\omega t + \phi)$

A - Amplitude $= A_0 e^{-rt}$

damping const.
$r = \frac{b}{2m}$



पुराना SHM
$\vec{F} = -k\vec{x}$
$x = A_0 \sin(\omega_0 t + \phi)$

$A = A_0 e^{-rt}$
$r = \frac{b}{2m}$
Const
$w = \sqrt{w_0^2 - r^2}$
$w < w_0$
$T > T_0$
T - const
$T > T_0$

If $b = 0$, Undamped oscillation

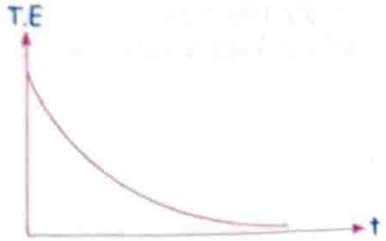
$r = 0$, $A = A_0 =$ const.

Total energy $= \frac{1}{2}KA^2$

T.E. $= \frac{1}{2}K(A_0 e^{-rt})^2$

$$\boxed{\text{T.E.} = \frac{1}{2}KA_0^2 e^{-2rt}}$$

$E = E_0 e^{-2rt}$



Q. Amplitude of a damped oscillator decreases to 9 times to its original magnitude ins 5 sec. In another 10 sec it will decrease to 'a' times to its original magnitude where a equal to?

Sol. $A = A_0 e^{-rt}$ $t = 0$ $t = 5$ $t = 15$

A_0 $.9A_0$ A

$.9A_0 = A_0 e^{-5r}$ $.9 = e^{-5r}$

$A = A_0 e^{-15r}$

$= A_0(e^{-5r})^3 = A_0(.9)^2 = .729\ A_0$

Q. Displacement of damped harmonic oscillator is given by $x = e^{-1t}$ cost $(10\pi t + \phi)$ time taken for its amplitude of vibration to drop to half of its initial value is close to

Sol. $\frac{A_0}{2} = A_0 e^{-rt}$

$2^{-1} = e^{-rt}$

$2 = e^{rt}$

$r = .1$

$\ln 2 = rt \ln e$

$2.3 \times \log 2 = .1 \times t$

$.69 = .1t$

$t = 6.9 = 7$

Q. A damped harmonic oscillator has a frequency of 5 oscillation per second. Amplitude drop to half of its value for every 10 oscillation. The time it will takes to drop to $\frac{1}{1000}$ of the original amplitude is closed to

Sol. $A_0 \longrightarrow A_0/2$

$t = 0$ $t = 2$

$\boxed{\frac{A_0}{2} = A_0 e^{-r\times 2}}$ $\boxed{\frac{A_0}{1000} = A_0 e^{-rt}}$

$\frac{A_0}{2} = A_0 e^{-2r}$

$2 = e^{2r}$

$\ln 2 = 2r \ln e$

$\boxed{r = \frac{1}{2}\ln 2}$

$\frac{\cancel{A_0}}{1000} = \cancel{A_0} e^{-rt}$

$\ln 1000 = rt \ln e$

$3 \ln 10 = rt$

$3 \ln 10 = \frac{\ln 2}{2} t$

$t = \frac{6 \ln 10}{\ln 2} = \frac{6 \times 23 \times \log 10}{2.3 \log 2} = \frac{6 \times 1}{.3} = \frac{60}{3}$

Q. A pendulum with time period of 1 sec is loosing energy due to damping. At certain time its energy is 45J.

If after completing 15 oscillation, its energy become 15J find damping constant

Sol. $E = E_0 e^{-2rt}$

$15 = 45\ e^{-2\times r\times 15}$

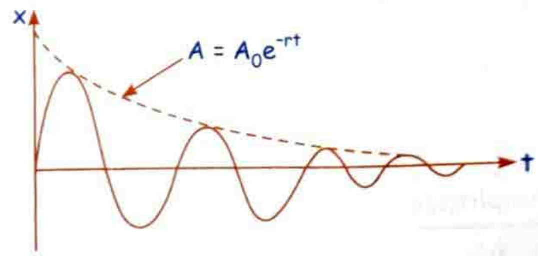
$\ln 3 = 2r \times 15$

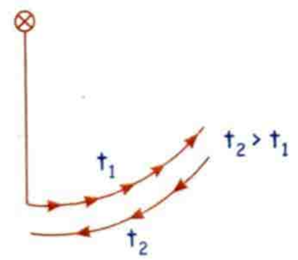
$r = \frac{\ln 3}{30}$

♦ $A_d = A = A_0 e^{-rt}$

$r = \frac{b}{2m}$

$\omega = \sqrt{\omega_0^2 - r^2}$





$t_1 + t_2 = \frac{T}{2}$

♦ $\omega = \sqrt{\omega_0^2 - r^2}$

$\omega = \omega_0 \sqrt{1 - \frac{r^2}{\omega_0^2}}$

$\omega = \omega_0 \sqrt{1 - \lambda^2}$

$r < \omega_0 \Rightarrow$ Under damping
$r = \omega_0 \Rightarrow$ Critical damping
$r > \omega_0 \Rightarrow$ Over damping
$\lambda = \frac{r}{\omega_0}$ = Damping ratio
$\lambda < 1 \Rightarrow$ Under damping
$\lambda = 1 \Rightarrow$ Critical damping
$\lambda > 1 \Rightarrow$ Over damping

- Relaxation time (time const) → it is the time interval in which amplitude decreases by $\frac{1}{e}$ times.

$A = A_0 e^{-rt}$

$\frac{A_0}{e} = A_0 e^{-rt}$ $\quad$ $r = \frac{b}{2m}$

$e^{-1} = e^{-rt}$ $\quad$ $\boxed{\tau = \frac{1}{r} = \frac{2m}{b}}$

- Damping decrement - Factor by which amplitude decreases in one time period = e^{rT}

$A_1 = A_0 e^{-rt}$

$A_2 = A_0 e^{-r(t+T)}$

$\frac{A_1}{A_2} = \frac{e^{-rt}}{e^{-r(t+T)}} = e^{-rt+r(t+T)} = e^{rT}$

$\frac{A_1}{A_2} = e^{rT}$

$\ln \frac{A_1}{A_2} = \ln e^{rT} = rT$

- Logarithm decrement(λ), $\boxed{\lambda = rT}$

$\ln \frac{A_1}{A_2} = \ln e^{rT}$

$\ln \frac{A_1}{A_2} = rT = \frac{b}{2m} T$

$A_1 \rightarrow$ Amplitude at time 't'

$A_2 \rightarrow$ Amplitude at time t + T

$\frac{A_1}{A_2} = e^{rT}$

$\omega = \sqrt{\omega_0^2 - r^2}$

$T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{\omega_0^2 - r^2}}$

- Quality factor 'Q' = $\frac{\pi}{\lambda} = \frac{\pi}{rT}$

r↑, A जल्दी खत्म = Q↓

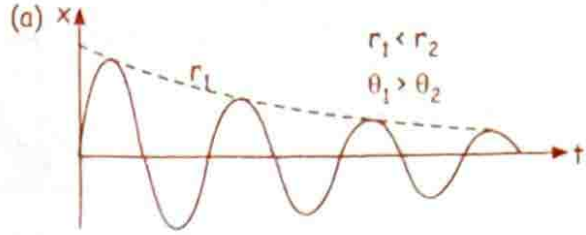
r↓, A हौले-हौले कम होगा, Q ↑

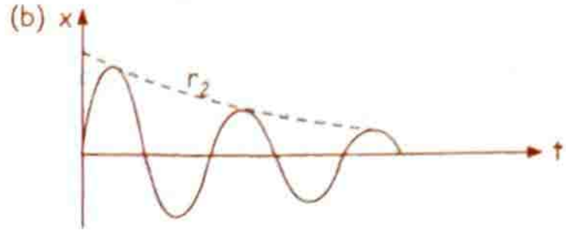
λ↓

$E = E_0 e^{-2rt}$ $\quad$ $A = A_0 e^{-rt}$

r↑, AE जल्दी खत्म होगी

Q. Which graph has heighest 'Q' factor





Sol. $\theta_1 > \theta_2$
$r_1 < r_2$
$b_1 < b_2$

$r = \frac{b}{2m}$

SUMMARY

$\vec{F} = -k\vec{x} - b\vec{v}$

⋮

$x = A_0 e^{-rt} \sin(wt + \phi)$

$r = \frac{b}{2m}$

$\boxed{A = A_0 e^{-rt}}$

$\omega = \sqrt{\omega_0^2 - r^2}$ $\quad$ $r = \frac{b}{2m}$

damped angular freq. $\quad$ National angular freq.

Case 1: $\omega_0 > r$ (under damping oscillation)

T, ω → cons.

$\omega < \omega_0$

$T > T_0$

ω_0 - natural avg. freq

Case 2: $\omega_0 = r$ (Critical damping) T - ∞

(No, oscillation) Ex. → door,

Case 3: $\omega_0 < r$ (Over damping)

No oscillation

ω → imaginary

7 Electromagnetic Waves

देखो भईया seriously बोल रहा हूँ यहाँ से एक सवाल पक्का आना है हमे चाहिए formula को याद रखना और अच्छी calculation.

ELECTROMAGNETIC WAVE

- Emw are produced by accelerated charge particle. (or Oscillating charge particle)
- Emw are non mechanical transverse wave which does not required any medium to propagate.
- In Emw E.F. and M.F. oscillate perpendicular to each other and perpendicular to direction of wave propagation. (Transverse wave)
- $\vec{E} \perp \vec{B}, \vec{E} \perp \vec{V}, \vec{B} \perp \vec{V}$ $\boxed{\vec{B} \perp \vec{E} \perp \vec{V}}$
- Direction of propagation of wave is along $\vec{E} \times \vec{B}$
- In vaccum Emw travel with speed $c = 3 \times 10^8$ m/s = speed of light
- In medium Emw travel with speed $V = \frac{C}{\mu} \rightarrow$ Refractive Index

MAXWELL EQUATION

1. Gauss Law of Electricity $\Rightarrow \oint \vec{E}.d\vec{A} = \frac{q_{in}}{\epsilon_0}$
2. Gauss Law of Magnetism $\Rightarrow \oint \vec{B}.d\vec{A} = 0$
3. Faraday Law $\Rightarrow \oint \vec{E}.d\vec{\ell} = -\frac{d\phi_B}{dt}$
4. Ampere Maxwell law $\oint \vec{B}.d\vec{\ell} = \mu_0(i_{net})_{enclose}$

$$= \mu_0(i_c + i_d)$$

where $i_d \longrightarrow$ Displacement current

$$i_d = \epsilon_0 \frac{d\phi_E}{dt}$$

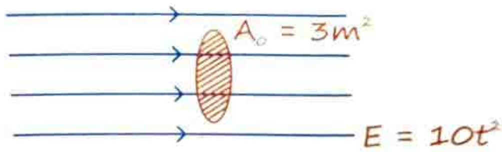
Displacement current (i_d) $\Rightarrow$ Effective current which we can associate with Changing electric field, which will produce Same amount of magnetic field in space is called displacement Current.

$\boxed{I_d = \epsilon_0 \frac{d\phi_E}{dt}}$ $\Rightarrow$ Due to time varying E.F.

#SKC
ϕ_E is the electric flux अगर ये वक्त के हिसाब से बदलेगा तो Displacement current आयेगा

Conduction Current $\Rightarrow$ Current due to flow of charge.

Q. Find ϕ_E through given area, Displacement Current in given diagram.



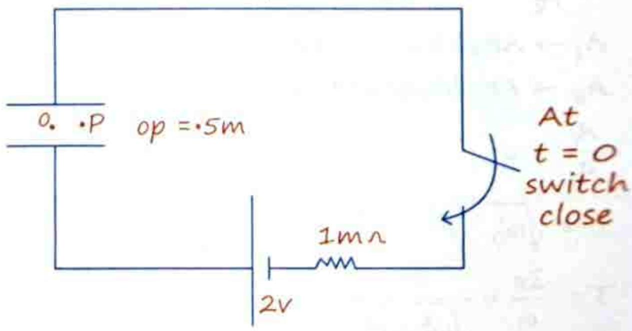
Sol. (1) ϕ_E through given area

$$\phi_E = EA = 10t^2 \times 3 = 30t^2$$

(2) Displacement Current

$$i_d = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 \times 60t$$

Q. In given circuit diagram
Parallel plate capacitor of circular shape r = 1 m and $C = 10^{-9}$ F is given. Find $q = f(t)^{-}$, $i_{\text{तारे वाला}}$, ϕ through circular area of radius $\frac{1}{2}$ m and passing through P



Sol. (1) $q = f(t)^{-} = EC(1 - e^{-t/\tau})$

$$\tau = RC$$

(2) $i_{\text{तारे वाला}} = i_c = i_0 e^{-t/\tau}$, $i_0 = E/R$

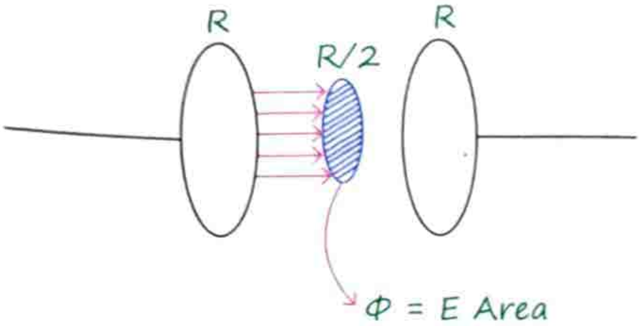
(3) Electric field between plates

$$\Rightarrow E = \frac{q}{A\varepsilon_0} = \frac{q}{\pi r^2 \varepsilon_0}$$

(4) ϕ through circular area of radius $\frac{1}{2}$ m parallel to the plate and passing through P

ϕ_E = E Area of loop

$$= \frac{q}{\pi r^2 \varepsilon_0} . \pi . (1/2)^2 = \frac{q}{4\varepsilon_0}$$



Φ = E Area

$= E\pi(R/2)^2$

(5) Displacement current

$$= \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 \frac{d}{dt}\left(\frac{q}{4\varepsilon_0}\right)$$

$$= \frac{1}{4} i = \frac{i_{\text{तारों वाला}}}{4}$$

(6) Magnetic field at point P

$B 2\pi r = \mu_0(i_c + i_d)$

$B 2\pi \frac{1}{2} = \mu_0(0 + i_d)$

BACK TO EMW THEORY

- Accelerated charge particle produce Emw
- Emw carry energy and momentum
- Light is an example of Emw, (light, x-ray, heat radiation, infrared, micro-wave)
- Speed of Emw in vacuum

$$C = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8 \text{ (Speed of light)}$$

- Speed of Emw in medium

$$v = \frac{1}{\sqrt{\mu_0 \mu_r \varepsilon_0 \varepsilon_r}} = \frac{c}{\sqrt{\mu_r \varepsilon_r}} = \frac{c}{\mu}$$

$\mu \rightarrow$ Refractive Index

$\mu = \sqrt{\mu_r \varepsilon_r}$

$$\mu = \frac{c}{v} = \frac{\text{speed of light in vacuum}}{\text{speed of light in medium}}$$

$\varepsilon_0, \mu_0 \rightarrow$ permitivity and permeability of vacuum

$\varepsilon_r, \mu_r \rightarrow$ Relative permittivity and permeability of medium

In previous Chapter

$$\begin{cases} \varepsilon_r \geq 1, & M.P = \mu_r \geq 0 \\ 0 \leq \mu_r < 1 & \text{Diamagnetic material} \\ 1 < \mu_r & \text{Paramagnetic material} \\ 1 \lll \mu_r & \text{ferromagnetic} \end{cases}$$

- wave equation for light propagating in + x direction in vacuum may be written as

$E = E_0 \sin(\omega t - kx + \phi)$ $\quad V_\omega = \frac{\omega}{k}$

there is also sinusoidal varying magnetic field associate with E.F when light propagate

$B = B_0 \sin(\omega t - kx + \phi)$

E_0 and B_0 are amplitude of E.F. and M.F.

- In Emw $\vec{E}$ and $\vec{B}$ oscillate in Same phase they become zero simultaneously and reach their max value simultaneously.
- $\vec{E} \perp \vec{V}$, $\vec{B} \perp \vec{V}$, $\vec{E} \perp \vec{B}$
- Direction of wave propagation is given by

Direction of $\vec{E} \times \vec{B}$

$\hat{V} = \hat{E} \times \hat{B}$

$E_0 = B_0 C$

$E = BC$

भाई इसे गाली मत समझना लेकिन याद रखने का बहुत बढ़िया तरीका है। EBC EBC EBC (sequence याद रखो)

$\hat{E} = \hat{B} \times \hat{C}$

$\boxed{\hat{B} = \hat{C} \times \hat{E}}$

$\hat{C} = \hat{E} \times \hat{B}$

$\hat{C} = \hat{E} \times \hat{B}$

$\rightarrow$ direction of velocity of light (wave)

Very Very Important

If E = Given or B = given

1. $E_0 = B_0 C \Rightarrow B_0 = \frac{E_0}{C}$
2. phase same
3. direction

Surely will come in exam

यह सवाल ऊपर के तीन step में करने है।

Q. Emw travelling along + x axis Such that EF at a time is 6.3 $\frac{v}{m}\hat{j}$ B at this point.

Sol. $E = BC$

$6.3 = B\,3 \times 10^8$

$\boxed{B = 2.1 \times 10^{-8}}$

$\vec{B} = 2.1 \times 10^{-8}\,\hat{k}$

$\hat{E} = \hat{B} \times \hat{C}$

$\downarrow$

$\hat{j} = \hat{B} \times \hat{i}$

Q. In Emw magnetic field is given by
$B = 2 \times 10^{-7}\,\text{Sin}(1.5 \times 10^{11}\,t + 0.5 \times 10^3 x)\,\hat{j}$
Find everything

Sol. $B_0 = 2 \times 10^{-7}$

$E_0 = B_0 C = 2 \times 10^{-7} \times 3 \times 10^8 = 60$

$E = E_0 \sin(1.5 \times 10^{11} t + .5 \times 10^3 x)$

$v_\omega = \frac{\omega}{k} = \frac{1.5 \times 10^{11}}{.5 \times 10^3} = 3 \times 10^8 (-\hat{i})$

Velocity $\longrightarrow -\hat{i}$

$B \longrightarrow \hat{j}$

$\hat{E} = \hat{B} \times \hat{C} = \hat{j} \times (-\hat{i}) = +\hat{k}$

$\boxed{\hat{E} \longrightarrow +\hat{k}}$

ELECTRIC AND MAGNETIC FIELD DENSITY (DERIVATION)

- $E = E_0\,\text{Sin}(\omega t - kx)$

Electric field density = $\frac{1}{2}\epsilon_0 E^2 = \frac{1}{2}\epsilon_0 E_0^2\,\text{Sin}^2(\omega t - kx)$

$\left\langle \frac{1}{2}\epsilon_0 E^2 \right\rangle = \frac{1}{2}\epsilon_0 E_0^2 \times \frac{1}{2} = \frac{1}{4}\epsilon_0 E_0^2$

Similarly

$B = B_0 \sin(\omega t - kx)$

Magnetic field density = $\frac{1}{2}\frac{B^2}{\mu_0}$

$= \frac{1}{2}\frac{B_o^2}{\mu_o}\sin 2(\omega t - kx)$ $\qquad \boxed{E_0 = B_0 C}$

$= \frac{1}{2}\frac{E_o^2}{\mu_o C^2}\sin^2(\omega t - kx)$ $\qquad C = \frac{1}{\sqrt{\mu_o \epsilon_o}}$

$= \frac{1}{2}E_o^2 \epsilon_o \sin^2(\omega t - kx)$

$= \frac{1}{2}\epsilon_o E^2$

- Total energy of Emw is equally divided in E.F. and M.F.
- Electric field density = $\frac{1}{2}\epsilon_o E^2$
- Magnetic field density = $\frac{B^2}{2\mu_o}$

$\therefore$ E and B are time varying hence energy density also varries with time.

- Avrg electric Energy density = $\left\langle \frac{1}{2}\epsilon_o E^2 \right\rangle$

$= \frac{1}{2}\epsilon_o \langle E^2 \rangle = \frac{1}{4}\epsilon_o E_o^2$

$E_{rms} = \frac{E_0}{\sqrt{2}} \qquad B_{rms} = \frac{B_0}{\sqrt{2}}$

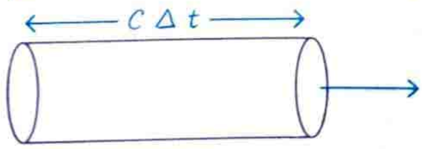
- Avrg magnetic energy density = $\frac{1}{4}\frac{B_o^2}{\mu_o}$
- As electric and magnetic energy are equal. So total energy is double of any energy

$= \frac{1}{4}\frac{B_o^2}{\mu_o} + \frac{1}{4}\epsilon_o E_o^2 = \frac{1}{2}\frac{B_o^2}{\mu_o} = \frac{1}{2}\epsilon_o E_o^2$

$\boxed{\text{Energy density} \equiv \text{Energy per unit volume}}$

Intensity

- Energy crossing per unit area per unit time perpendicular to the direction of propagation



$\text{Intensity} = \frac{\frac{1}{2}\epsilon_o E_o^2 \times \text{Vol}^n}{\text{time.Area}}$

$= \frac{\frac{1}{2}\epsilon_o E_o^2 .A.C\Delta t}{\Delta t\,A}$

$\boxed{\text{Intensity} = \frac{1}{2}\epsilon_o E_o^2 \times C}$

- Power = Energy per unit time

$$P = \frac{1}{2}\epsilon_0 E_0^2 .(AC)$$

Imp Results

- $I = \frac{1}{2}\epsilon_0 E_0^2 C$
- Power = $IA = \frac{1}{2}\epsilon_0 E_0^2 C.A.$

$$U_E = \frac{1}{4}\epsilon_0 E_0^2$$

$$U_B = \frac{1}{4}\epsilon_0 B_0^2 \quad \equiv \text{Bus } C \text{ multiply}$$

$$U_{net} = \frac{1}{2}\epsilon_0 E_0^2 \quad \text{Intensity}$$

Q. If E.F. in an Emw is given by

$$E = 50\sin(\omega t - kx) = 50\sin\omega\left(t - \frac{x}{c}\right)$$

Find

(1) E_0 (2) B_0 (3) $U\omega$

(4) Energy density (5) Intensity

(6) Energy contain in a cylinder of cross section 10 cm^2 and length 50 cm along x-Axis.

Sol. $E = BC$

1) $E_0 = 50$

2) $B_0 = \frac{E_0}{C} = \frac{50}{3\times10^8}$

3) $V = \frac{\omega}{k}$

4) energy density $= \frac{1}{2}\epsilon_0 E_0^2 = \frac{1}{2}\epsilon_0 50^2$

5) intensity of wave $= \frac{1}{2}\epsilon_0 E_0^2 C$

6) Energy $= \frac{1}{2}\epsilon_0 E_0^2 \times (\text{Vol}^n)$

$$= \frac{1}{2}\epsilon_0 E_0^2 \times (Al) = \frac{1}{2}\epsilon_0 50^2 \times (10.10^{-4}\times 0.5 l)$$

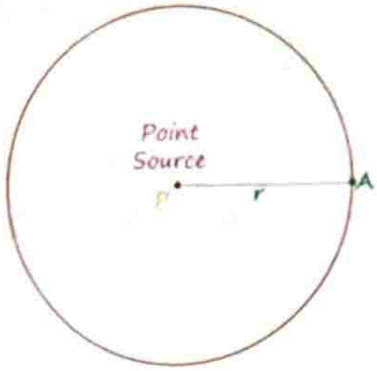
$$B = \frac{50}{3\times10^8}\sin\left[\omega\left(t - \frac{x}{c}\right)\right]$$

Q. Find amplitude of E.F. and M.F. in a parallel beam of light intensity 2 watt/m^2

Sol. $I = \frac{1}{2}\epsilon_0 E_0^2 C$

$$E_0 = \sqrt{\frac{2I_0}{\epsilon_0 \times C}}$$

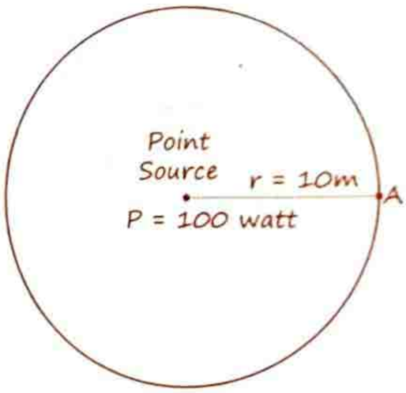
ELECTRIC FIELD AMPLITUDE AT DISTANCE r FROM POINT SOURCE



At point A

Intensity $= \frac{P}{4\pi r^2} = \frac{1}{2}\epsilon_0 E_0^2 C$

Q. Find electric field amplitude at distance 10 m from point source in given diagram at A.



Sol. $I_A = \frac{100}{4\pi(10)^2}$

$$= \frac{1}{2}\epsilon_0 E_0^2 .C$$

$E_0 = \checkmark$

$E_0 = B_0 C$

$B_0 = \frac{E_0}{C}$

Electromagnetic spectrum
(6 ques asked in last 4 year)

- Radio wave > micro wave > Infra Red > Visible > U.V > X-ray > γ rays
- λ decreasing →

Pointing vector

- Rate of flow of energy in an electromagnetic wave is described by vector $\vec{S}$ is called pointing vector. $\vec{S} = \frac{\vec{E} \times \vec{B}}{\mu_0}$
- Magnitude of pointing vector represents the rate at which energy flows through a unit surface area perpendicular to the dirn of wave propagation.
- $S = \frac{EB}{\mu_0} = \frac{E^2}{\mu_0 C} = \frac{B^2 C}{\mu_0}$
- Direction of $\vec{S}$ is along dir^n of wave propagation
- $\vec{S}$ = time dependent its magnitude reacher to max value at same instant E and B become max.

ELECTROMAGNETIC WAVES

X-rays

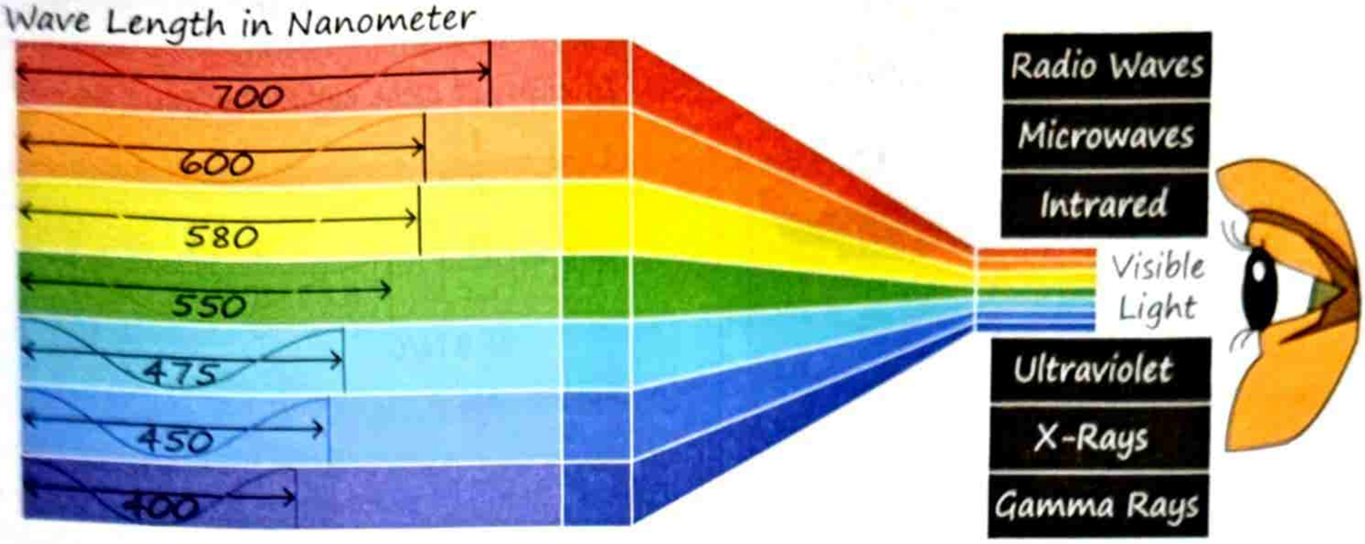
Beyond the UV region of the electromagnetic spectrum lies the X-ray region. We are familiar with X-rays because of its medical applications, it covers wavelengths from about 10^{-8} m (10 nm) down to 10^{-13} m (10^{-4} nm). One common way to generate X-rays is to bombard a metal target by high energy electrons. X-rays are used as a diagnostic tool in medicine and as a treatment for certain forms of cancer. Because X-rays damage or destroy living tissues and organisms, care must be taken to avoid unnecessary or over exposure.

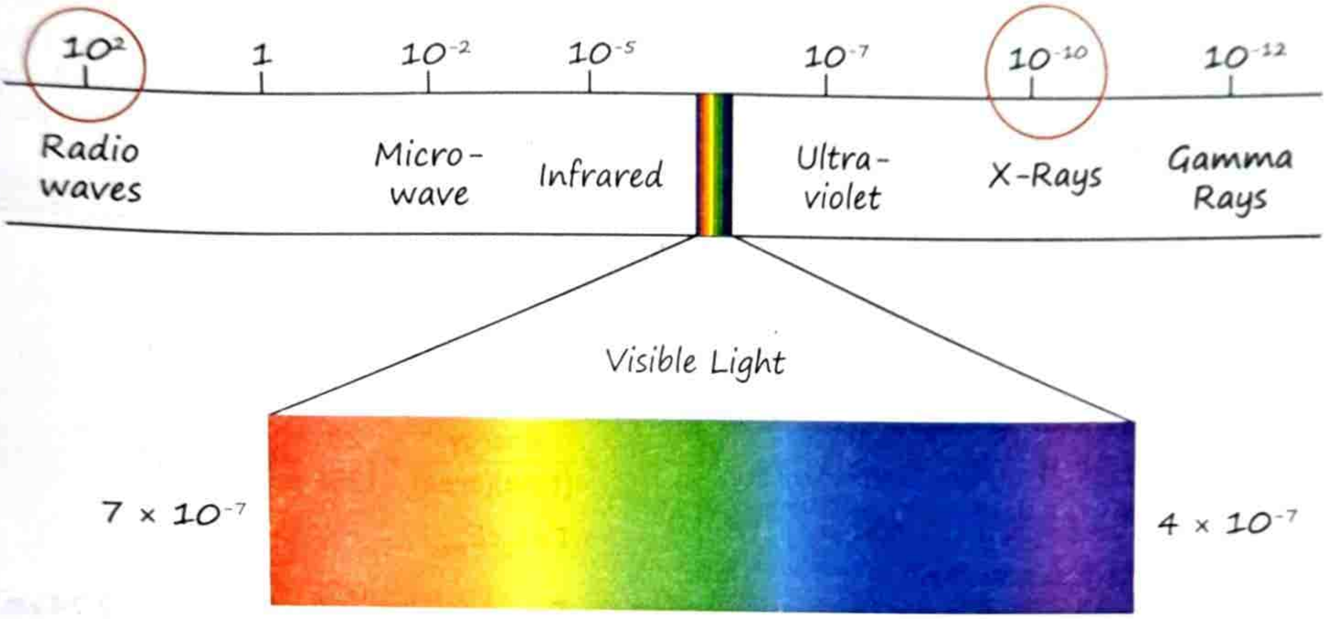
Gamma rays

They lie in the upper frequency range of the electromagnetic spectrum and have wavelengths of from about 10^{-10} m to less than 10^{-14} m. This high frequency radiation is produced in nuclear reactions and also emitted by radioactive nuclei. They are used in medicine to destroy cancer cells.

भाई पाँच सवाल यहाँ से भी JEE Mains पुछे गए है।

Type	Wavelength range	Productions	Desection
Radio	> 0.1 m	Rapid acceleration and decelerations of electrons in aerials	Receiver's aerials
Microwave	0.1 m to 1 mm	Klystron valve or magnetron valve	Point contact diodes
Infra-red	1 mm to 700 nm	Vibration of atoms and molecules	Thermopiles Bolometer, Infrared photographic film
Light visible	700 nm to 400 nm	Electrons in atoms emit light when they move from one energy level to a lower energy level	The eye Photocells. Photographic film
Ultraviolet	400 nm to 1 nm	Inner shell electrons in atoms moving from one energy level to a lower level	Photocells Photographic film
X-rays	1 nm to 10^{-3} nm	X-ray tubes or inner shell electrons	Photographic film Geiger tubes ionisation chamber
Gamma rays	<10^{-3} nm	Radioactive decay of the nucleus	-do-





एक करोड़ बार पुछा गया है।

Q. If the magnetic field in a plane electromagnetic wave is gicven by $\vec{B} = 3 \times 10^{-8} \sin(1.6 \times 10^{3}x + 48 \times 10^{10}t)\hat{j}\,T$, then what will be expression for electric field and energy density and intensity.

Sol. सबसे पहले $E_0 = B_0C$ करके electric field का amplitude निकालो $E_0 = 3 \times 10^{-8} \times 3 \times 10^{8} = 9$

अब phase निकालो और electric field का phase वही होगा जो magnetic field का है।

Hence $E = 9 \sin(1.6 \times 10^{3}x + 48 \times 10^{10}t)$

अब $\hat{E}$ की direction निकालो $\hat{E} = \hat{B} \times \hat{C} = \hat{j} \times -\hat{i} = \hat{k}$

Final answer is

$\vec{E} = 9 \sin(1.6 \times 10^{3}x + 48 \times 10^{10}t)\hat{k}$

energy density $= \frac{1}{2}\epsilon_0 E_0^2$ and put the value

Intensity $= \frac{1}{2}\epsilon_0 E_0^2 \times C$

Similarly $\vec{E}$ देकर $\vec{B}$ पुछ सकता है जैसे

Q. The electric field in the electromagnetic wave is given by

$\vec{E} = 6 \sin(1.6 \times 10^{3}x + 48 \times 10^{10}t)\hat{j}$ find equation of magnetic field and energy density and intensity.

Sol. $E_0 = B_0C$

$$B_0 = \frac{E_0}{C} = \frac{6}{3 \times 10^{8}} = 2 \times 10^{-8}$$

$\hat{B} = \hat{C} \times \hat{E} = -\hat{i} \times \hat{j}$

$\hat{B} = -\hat{k}$

$\vec{B} = 2 \times 10^{-8} \sin(1.6 \times 10^3x + 48 \times 10^{10}t)\text{-}\hat{k}$

Exam से पहले यह पढ़के जरूर जाना।

- $I_d = \epsilon_0 \dfrac{d\phi_E}{dt}$
- Electric field density = $\dfrac{1}{2}\epsilon_0 E^2$
- Magnetic field density = $\dfrac{B^2}{2\mu_0}$
- Avrg electric Energy density = $\dfrac{1}{4}\epsilon_0 E_0^2$
- Avrg magnetic energy density = $\dfrac{1}{4}\dfrac{B_0^2}{\mu_0}$
- $U_{net} = \dfrac{1}{2}\epsilon_0 E_0^2$ (Equally divided into E.F. & M.F.)
- $I = \dfrac{1}{2}\epsilon_0 E_0^2 C$
- Power = $IA = \dfrac{1}{2}\epsilon_0 E_0^2 C.A.$
- From a point source (P) at a distance are
  $I = \dfrac{P}{4\pi r^2} = \dfrac{1}{2}\epsilon_0 E_0^2 C.$

Q. The electric field of a plane electromagnetic wave is given by $\vec{E} = E_0(\hat{x}+\hat{y})\sin(kz-\omega t)$. Its magnetic field will be given by

Sol. $\vec{B}$ will have same phase as $\vec{E}$

$\hat{B} = \hat{c} \times \hat{E} = \hat{z} \times (\hat{x}+\hat{y}) = (\hat{y}-\hat{x})$

Also, $B_0 = \dfrac{E_0}{c}$

$\therefore\ \vec{B} = \dfrac{E_0}{c}(-\hat{x}+\hat{y})\sin(kz-\omega t)$

Q. Find the energy stored in a 120 cm length of a laser beam operating at 6 mW.

Sol. Time taken by laser beam to move through a distance 120 cm is

$t = \dfrac{120}{c} = \dfrac{120}{3\times10^{10}} = 4\times10^{-9}\,s$

The energy contained in the 120 cm length of laser beam is

$U = P \times t = 6\text{ mW} \times (4 \times 10^{-9}\text{ s})$

$= (6 \times 10^{-3}\text{ J s}^{-1}) \times (4 \times 10^{-9}\text{ s}) = 24 \times 10^{-12}\text{ J}$

Q. Find the amplitude of the electric field in a parallel beam of light of intensity 10 watt/m^2.

Sol. Intensity of plane electromagnetic wave is

$I = u_{av}c = \dfrac{1}{2}\varepsilon_0 E_0^2 c$

or $E_0 = \left(\dfrac{2I}{\varepsilon_0 c}\right)^{1/2} = \left(\dfrac{2\times10}{8.85\times10^{-12}\times3\times10^8}\right)^{1/2}$

$= 86.8$ N/C

Only for advance

Q. 25 W power is radiated by a source kept at the centre of a spherical surface and is at a distance of 10 m from the surface. Calculate the force acting on the surface of the sphere by the electromagnetic wave, E_0, B_0 and intensity I of the wave. Consider the source as a point source. Also calculate the energy density on the surface of the sphere

Sol. Energy radiated by the source each second is 25J

Surface area of the sphere

$A = 4\pi R^2 = (4)(3.14)(10^2) = 1256\text{ m}^2$

Intensity I

$= \dfrac{\text{Energy}}{(\text{time})(\text{area})} = \dfrac{25}{1256} = 0.02\,\text{Wm}^{-2}$

$\because I = \varepsilon_0 c E_{rms}^2$

$\therefore\ E_{rms} = \left[\dfrac{0.02}{8.85\times10^{-12}\times3.0\times10^8}\right]^{1/2} = 2.74\,\text{Vm}^{-1}$

Now, $B_{rms} = \dfrac{E_{rms}}{c}$

$B_{rms} = \dfrac{2.74}{3.0\times10^8} = 9.13\times10^{-9}\,\text{T}$

$E_0 = \sqrt{2}\,E_{rms}$

$E_0 = 1.41 \times 2.74 = 3.86\text{ Vm}^{-1}$, $B_0 = \sqrt{2}\,B_{rms}$

$B_0 = 1.41\times9.13\times10^{-9} = 1.29\times10^{-8}\,\text{T}$

The total energy incident on the surface = 25 J

$\therefore$ The momentum (Δp) imparted to the surface per second (= force)

$F = \dfrac{\Delta p}{1\sec} = \dfrac{\Delta U}{c} = \dfrac{25}{3\times10^8} = 8.33\times10^{-8}\,\text{N}$

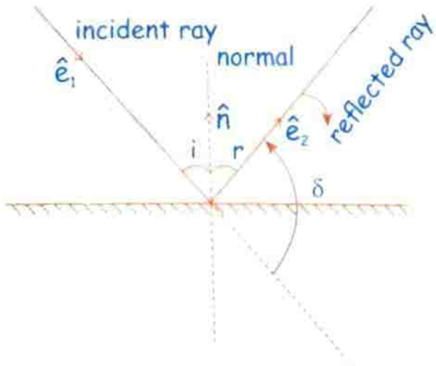
From $I = uc$, where u is energy density

$u = \dfrac{I}{c} = \dfrac{0.02}{3\times10^8} = 6.67\times10^{-11}\,\text{Jm}^{-3}$

8 Ray Optics and Optical Instruments

देख भाई इस chapter में पुराने किसी भी प्रकार के ज्ञान की कोई जरूरत नही है बोले तो ये एक independent chapter है जिसको जब चाहो जहाँ चाहो आप पढ़ सकते हो advance के point of view से reflection or refraction के laws और results कैसे apply करनी है ये important है mains मे तो formula oriented question पूछे गए है

LAWS OF REFLECTION



1. Incident ray, reflected ray & normal ≡ all are in same plane
2. Angle of incidence (∠i) = angle of reflection (∠r)

   $i + r + \delta = 180°$

   $\delta = 180° - i - r$

   $\boxed{\delta = \text{deviation} = 180 - 2i}$ → Single reflection

3. $\boxed{\hat{e}_2 = \hat{e}_1 - 2(\hat{e}_1 \cdot \hat{n})\hat{n}}$

ये formula बहुत simple है इसलिए इसे हल्के मे मत लेना bcz यह आगे बहुत बार use होगा।

OBJECT & IMAGE

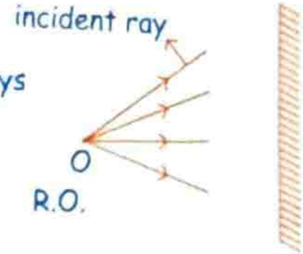
Object → Real obj (R.O.), Virtual obj (V.O.)

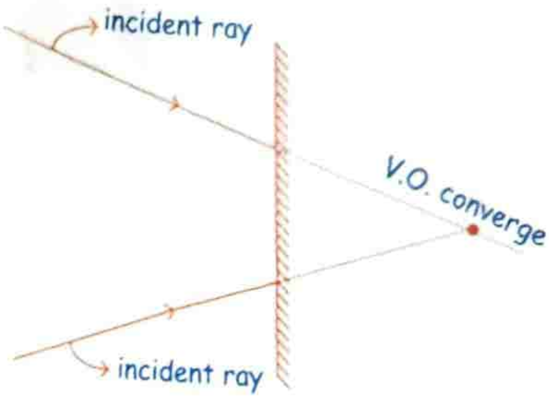
Image → Real image (R. I.), Virtual image (V.I.)

Object → point of intersection of incident ray.

Real Object

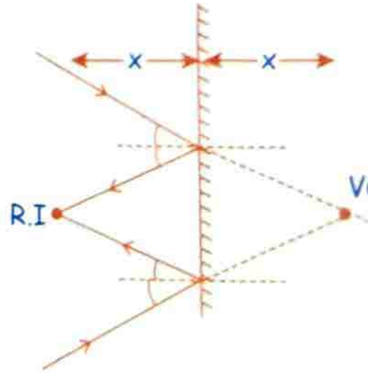
- R.O., diverging incident rays





Image

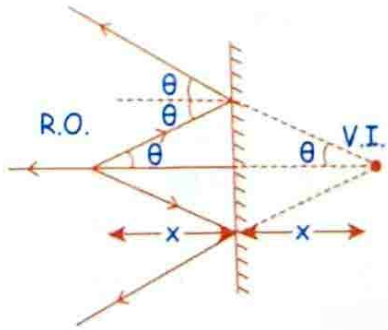
- Point of intersection of reflected ray.
- Point of intersection of refracted ray.



Plane Mirror

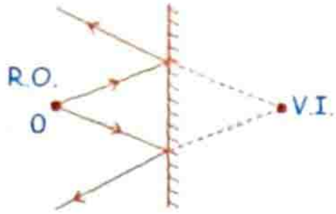
R.O. ⟶ V.I.

V.O. ⟶ R.I.

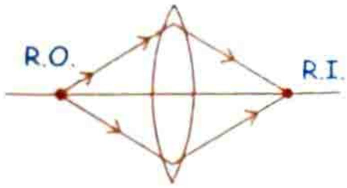


- Few example:

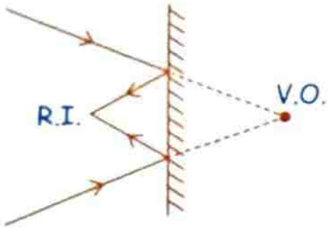
(1)



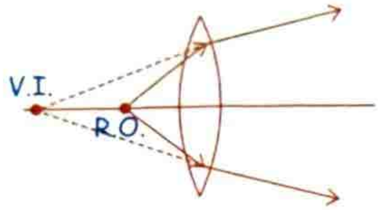
(2)



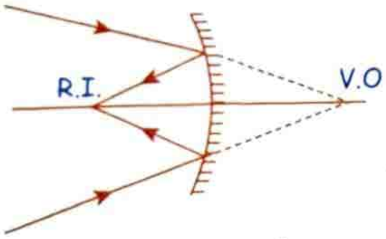
(3)



(4)



(5)



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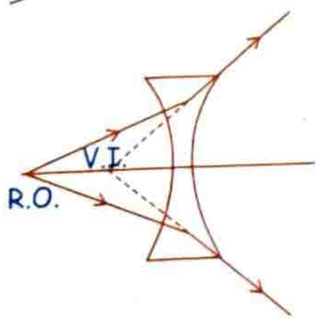

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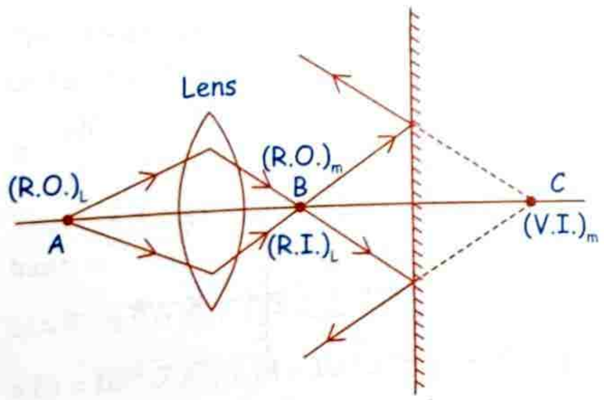
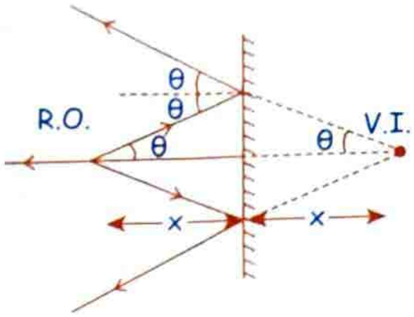


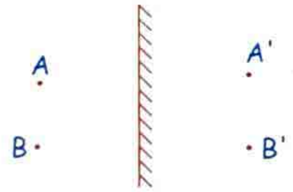
#SKC
Refraction/reflection के बाद अगर rays सच्ची मुच्ची मे मिली तो सच्ची मुच्ची वाली image (RI), जबरदस्ती मिली तो virtual image.

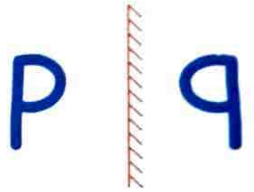
	Lens	Mirror
A	R.O.	×
B	R.I.	R.O.
C	R.O.	V.I.

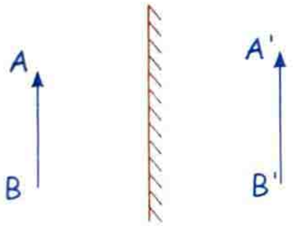
IMAGE FORMATION BY PLANE MIRROR



Plane mirror से perpendicularly जितनी दूरी पर object है image भी उतनी ही दूरी पर बनेगी







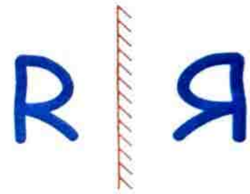
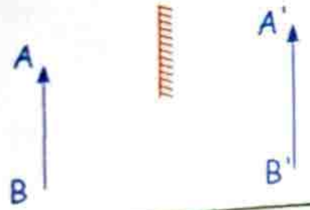


Photo post करने का तरीका थोड़ा casual है

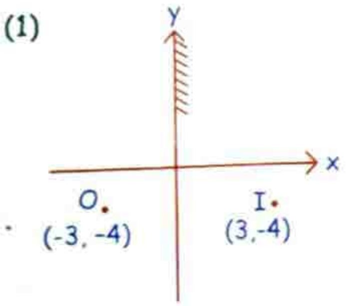
Q.



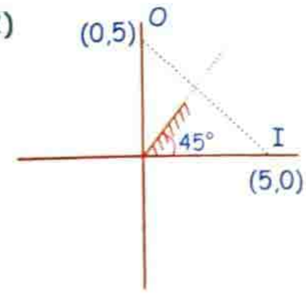
Mirror अगर आधा अधूरा incomplete है तो वो image वही बनाएगा जहाँ complete mirror बनाता so जब भी कभी अधूरेपन का एहसास हो मन ही मन मे पूरा मान लो अबे i mean mirror को complete करलो और object को image बनाने के लिए object से mirror पर perpendicular line draw करो mirror से same distance पर perpendicular line पर image बनेगी।

Q. Draw location of image

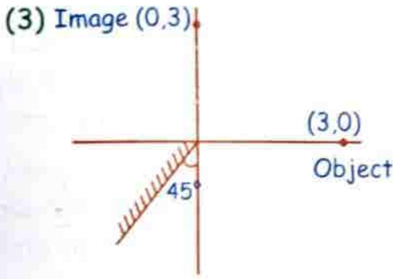
(1)



(2)

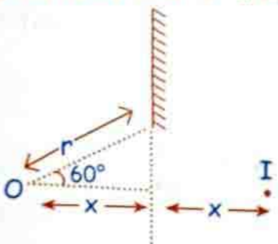


(3)



Q. Find distance b/w 'o' & image.

(1)



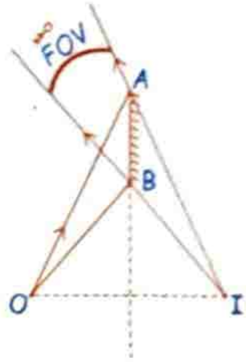
Ans. $= 2x$

$= 2. r \cos 60°$

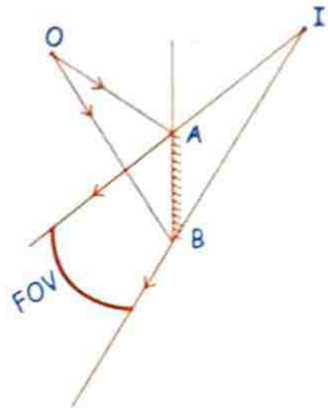
FIELD OF VIEW OF IMAGE

मै किस region मे जाके झाकू मुझे object की image दिखाई देने लगे

(a)



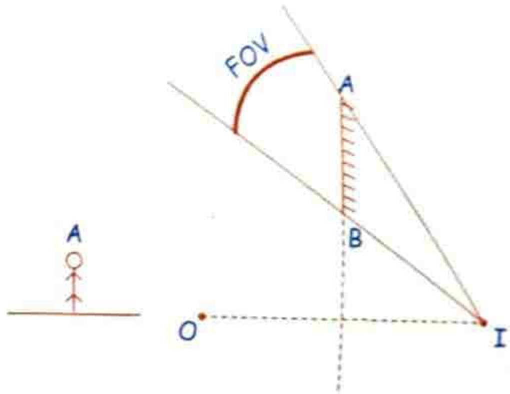
(b)



#SKC

यहाँ FOV of image बनाने के लिए बस image को mirror के दोनों end से join करने वाली lines बनाओ उनके बीच का region ही FOV है।

(c)



(d)

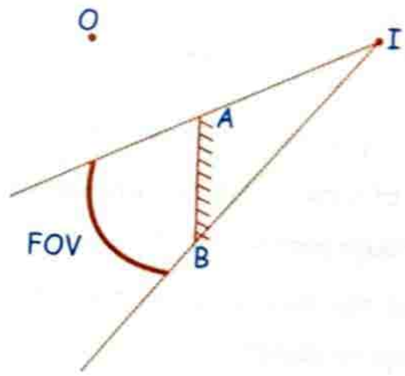


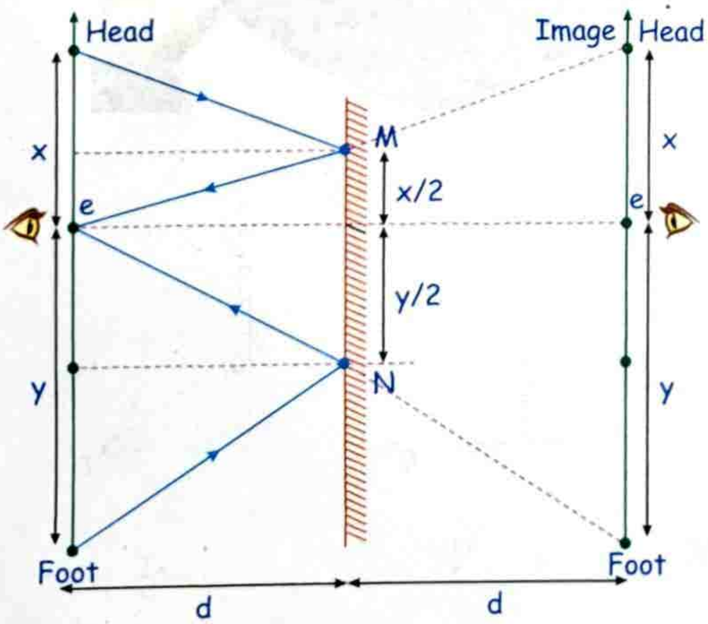
Image formation by plane mirror:

1. Distance of object from plane mirror = distance of image from the plane mirror.
2. The line joining a point object and its image is normal to the reflecting surface.
3. The size of image is same as that of the object.
4. For a real object, image is virtual.
5. For virtual object, image formed is real.

MINIMUM SIZE OF PLANE MIRROR REQUIRED TO VIEW THE FULL IMAGE OF A PERSON

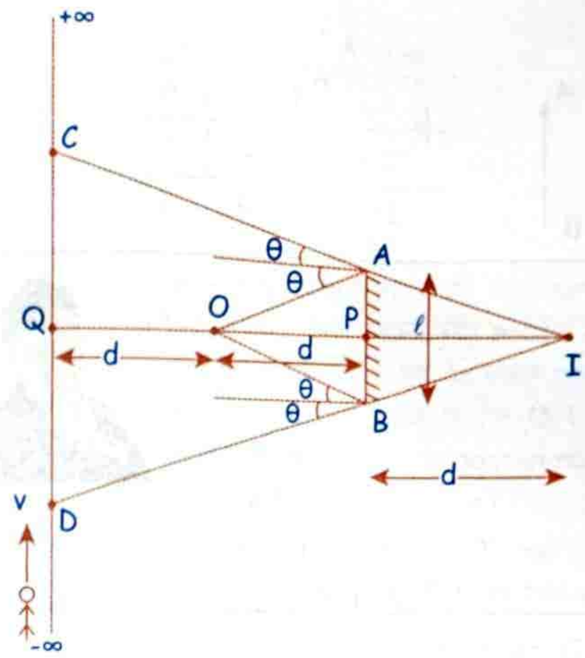
In the figure shown consider a person of height $x + y$. Both top of the head and foot should be visible to the eye.

From the ray diagram we can see that minimum length required is MN which is equal to $\frac{x+y}{2}$ or half the height of person.



Alternatively, whole image of the person must lie in the field of view of the eye. Eye can view the whole image through part MN of the mirror.

Q. Find the time interval in which man can see image of object.



Sol. $\frac{CD}{v}$

$\Delta ABI \sim \Delta CDI$

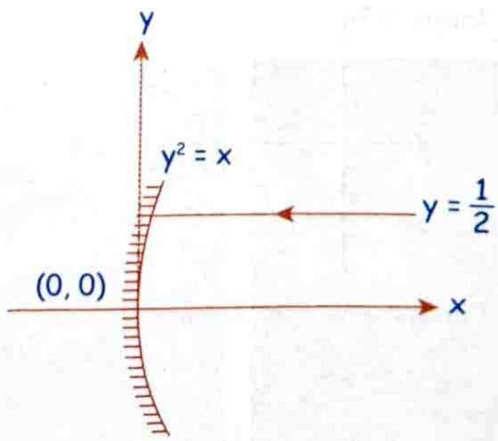
$\frac{AB}{CD} = \frac{PI}{QI}$

$\frac{\ell}{CD} = \frac{d}{3d}$

$CD = 3\ell$

$\boxed{\text{time} = \frac{3\ell}{v}}$

Q. A ray strike the parabolic mirror as shown in diagram. Equation of incident ray is $y = \frac{1}{2}$. Find total deviation (angle)



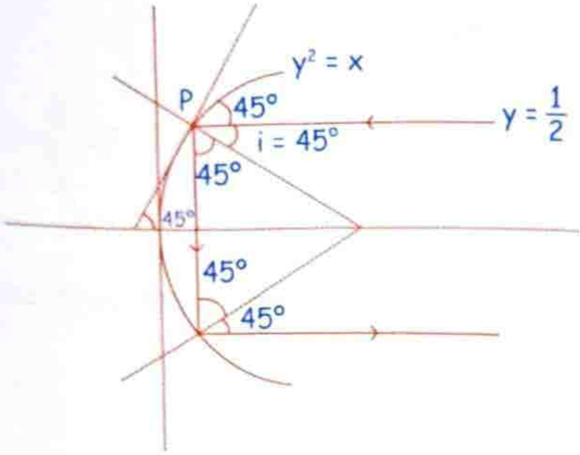
Sol. Slope of tangent at 'P' $= \frac{dy}{dx}$

$y^2 = x$

$2y\frac{dy}{dx} = 1$

$$\frac{dy}{dx} = \frac{1}{2y} \quad y = \frac{1}{2}$$

$$\frac{dy}{dx} = \frac{1}{2 \times \frac{1}{2}} = 1 = \text{Slope}$$

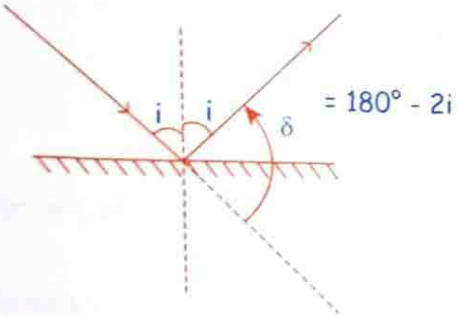


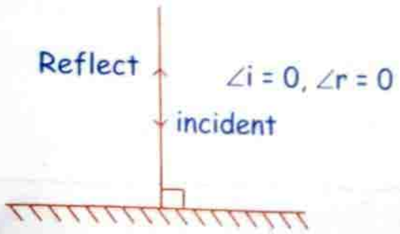
$\angle i = 45° \Rightarrow \angle r = 45°$

$\delta_{net} = \delta_1 + \delta_2$

$\delta_{net} = (180° - 2 \times 45°) + (180° - 2 \times 45°)$

$\delta_{net} = 180°$

- 

- By keeping mirror fix, if incident ray rotate by angle θ in clockwise sense then reflected rays will rotate by angle θ in opposite sense (acw).
- By keeping incident ray fix, if mirror ray rotate by angle θ in clockwise sense then reflected rays will rotate by angle 2θ in same sense (cw).
- 

$\delta = 0$ ✗

$\delta = 180°$ ✓

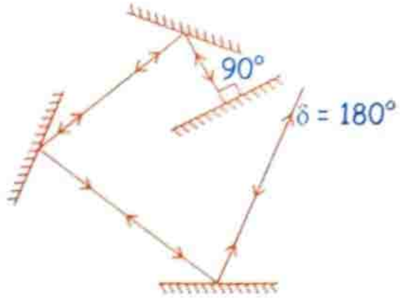
$\delta = 180 - 2i = 180 - 2 \times 0 = 180°$

#SKC

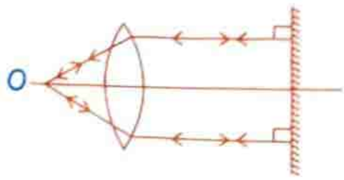
मतलब अगर rays किसी भी प्रकार के mirror पर perpendicularly टकराइं तो अपने path को वापस retrace कर लेगी जहाँ obj पर image बनाना है वहाँ इसे ध्यान मे रखे ये बाद मे काम आयेगा।

In these cases object has to coincide with the image.

(a)

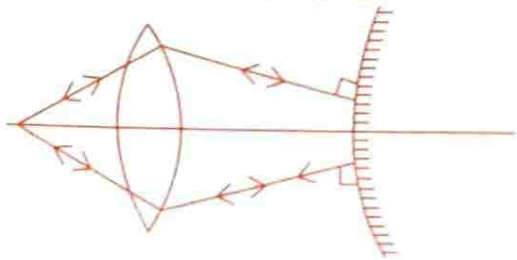


(b)



$\angle i = 0 = \angle r$

(c)

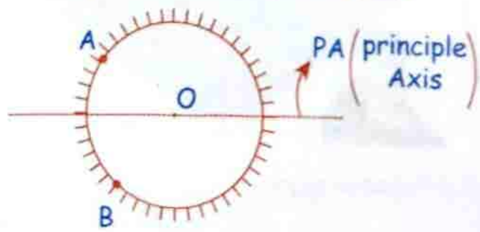


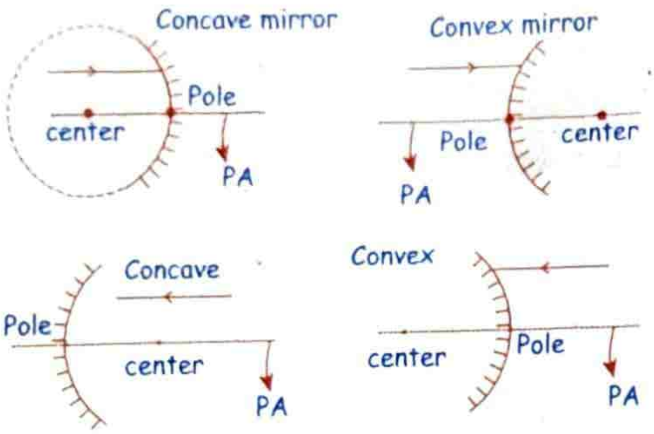
Plane mirror का majority portion JEE Mains 2025 से remove हो चुका है इसलिए ऐसे सारे topic like dispersion, cromatic abbreation, defect of eye etc etc. हम उसे इस chapter के last मे cover करेंगे

SPHERICAL MIRROR

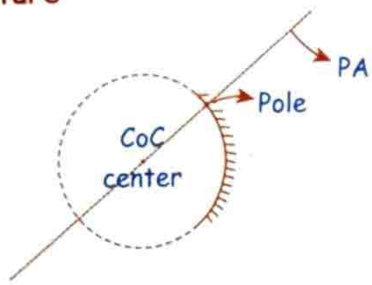
Spherical mirror
- → Concave mirror
- → Convex mirror

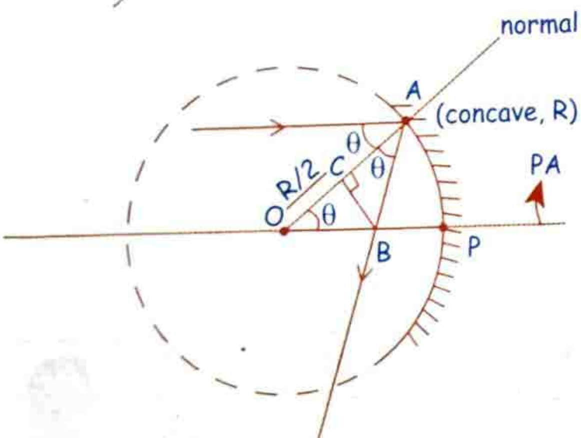
It is a part cut from sphere (AB)





Relation between Focal Length and Radius of Curvature





Paraxial rays $\Rightarrow \theta \rightarrow$ very small
otherwise
Marginal rays

$OB\cos\theta = \frac{R}{2} = OC$

$OB = \frac{R}{2}\sec\theta$

$BP = OP - OB$

$\boxed{BP = R - \frac{R}{2}\sec\theta}$

#SKC
अलग अलग angle वाली rays PA पर अलग अलग जगह टकराएगी लेकिन अगर angle बहुत ही छोटा हो तो सारी rays almost एक ही point से पास करेगी उस point को focus बोलते है।

If θ is very small ≡ Paraxial rays

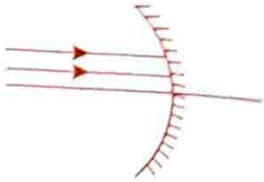
$\cos\theta \rightarrow 1$

$\sec\theta \rightarrow 1$ $\qquad BP = R - \frac{R}{2}\times 1$

$BP = \frac{R}{2}$

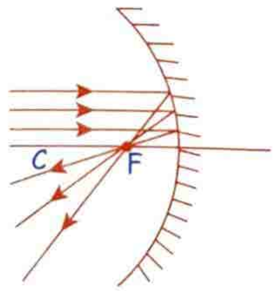
$B \Rightarrow F \equiv$ Focus

Paraxial Rays



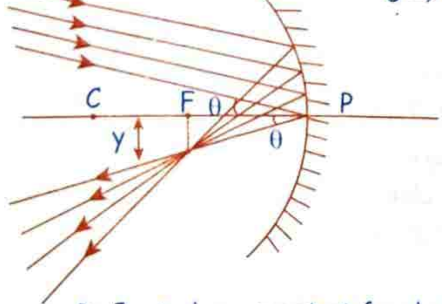
- Very close to P.A
- $\angle i \rightarrow$ very small
  normal
- small aperture
- After reflection they strike PA at point called focus $= \frac{R}{2}$ from pole.

  Focal length $\rightarrow f = \frac{R}{2}$
- If rays are parallel to PA and paraxial then they meet PA at focus.



- If rays are parallel but not parallel to PA and paraxial

$\theta \rightarrow$ Very small

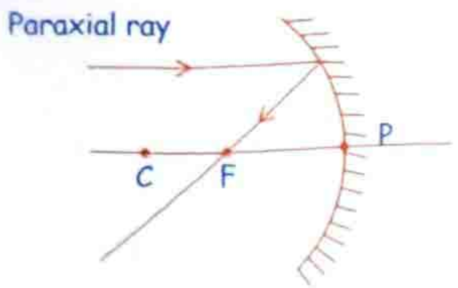


Reflected ray meet at focal plane.

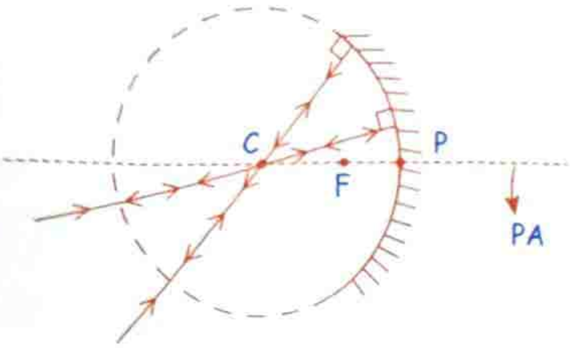
$\tan\theta = \frac{y}{R/2} \Rightarrow y = \theta\cdot\frac{R}{2} \Rightarrow y = \theta f$

Spherical mirror में image बनाने के लिए following points का ध्यान रखे।

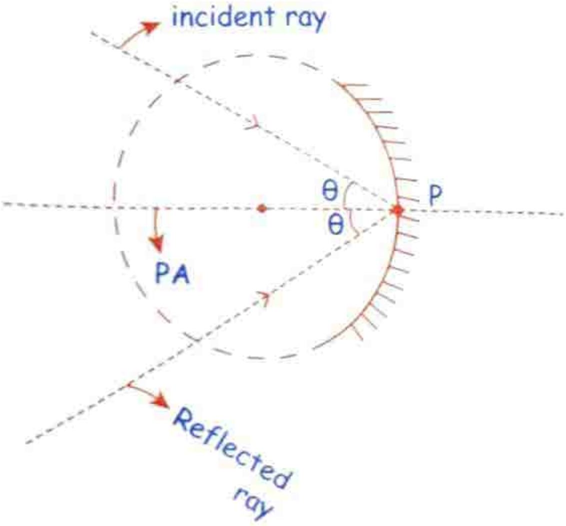
(1)



(2)



(3)



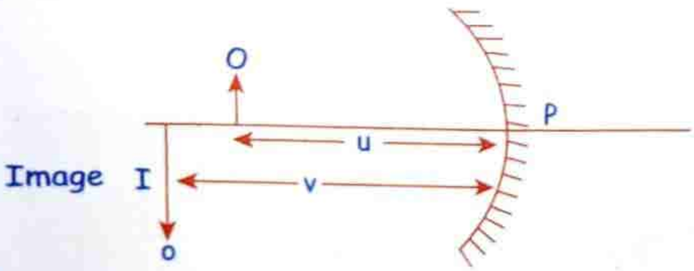
Mirror Formula

- $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$, $m=\frac{h_I}{h_0}=\frac{-v}{u}$

  u → object distances from pole along PA

  v → image distance from pole along PA

  f → focal length
- valid for paraxial rays



$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$$

$$\frac{1}{v}=\frac{1}{f}-\frac{1}{u}$$

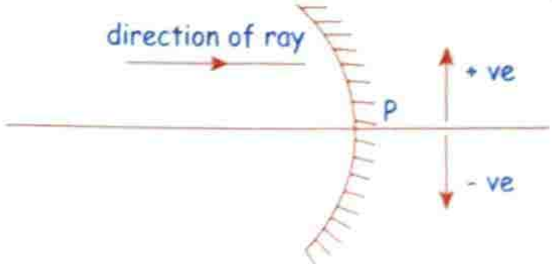
$$\frac{1}{v}=\frac{u-f}{fu}$$

$$\boxed{v=\frac{uf}{u-f}=\frac{fu}{u-f}}$$

- u, v, f with sign put करने है

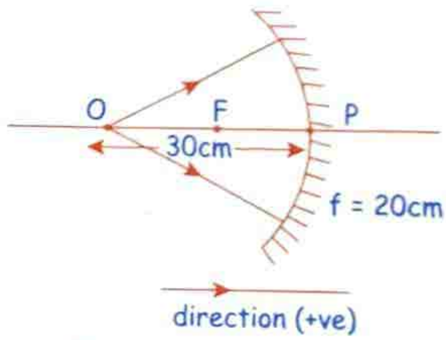
Sign Convention

- Direction of ray is consider +ve.
- All the distance measured from pole.



देख भाई sign convention के लिए पहले ये देखो incident ray left से right जा रही है या right से left. सारे measurement pole (P) से करने है। u के sign के लिए P से object की तरफ चलो अगर incident ray की तरफ जा रहे हो तो u will be + or अगर incident ray के opposite जा रहे हो तो u will be –
Concave mirror की focal length हमेशा negative और convex की हमेशा positive.

Q. Find location of image and magnification



Sol. u = -30

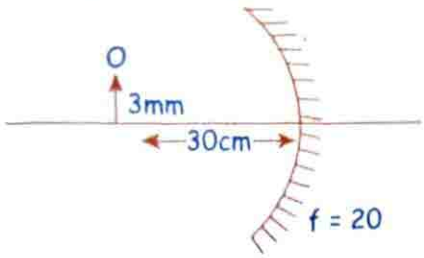
f = -20

v = ?

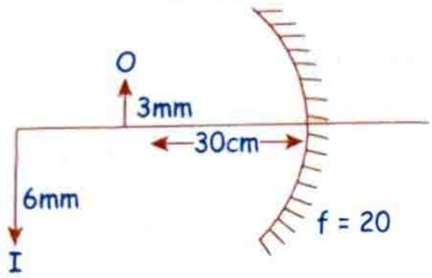
$$v=\frac{uf}{u-f}=\frac{(-30)\times(-20)}{(-30)-(-20)}=\frac{600}{-10}=-60$$

$$m=-\frac{v}{u}=-\frac{-60}{-30}=-2$$

Q. Find height of image



Sol. $v = \dfrac{uf}{u-f} = \dfrac{-30 \times -20}{-30-(-20)} = -60$

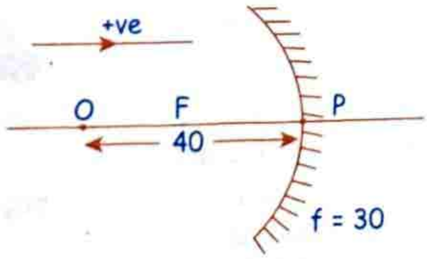


$m = -2 = \dfrac{h_I}{h_0}$

$-2 = \dfrac{h_I}{3mm}$

$\boxed{h_I = -6mm}$

Q. Find the position of image and magnification



Sol. $u = -40$

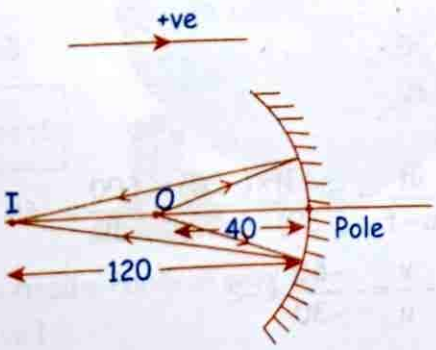
$\underline{f = -30}$

$v = \dfrac{uf}{u-f} = \dfrac{1200}{-40-(-30)} = -120$

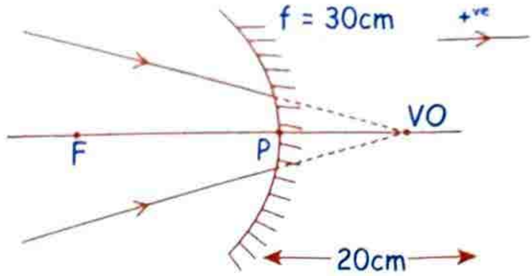
$m = -\dfrac{v}{u} = -\dfrac{-120}{-40} = -3$

$m = \dfrac{h_I}{h_0}$ $\boxed{h_I = h_0 \cdot m}$

0 0



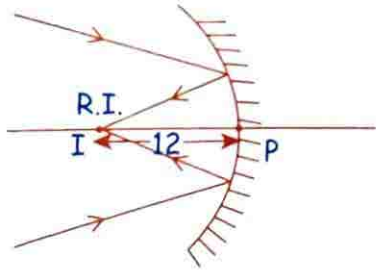
Q. Incidence rays are converging 20 cm behind concave mirror as shown. Find the position of image.



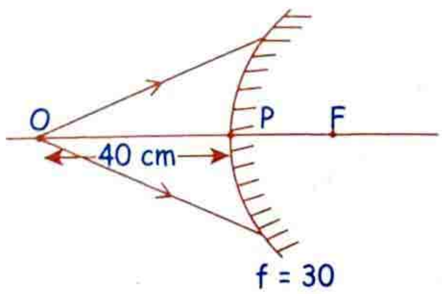
Sol. $u = +20$

$\underline{f = -30}$

$v = \dfrac{uf}{u-f} = \dfrac{20 \times (-30)}{20-(-30)} = \dfrac{-600}{50} = -12$



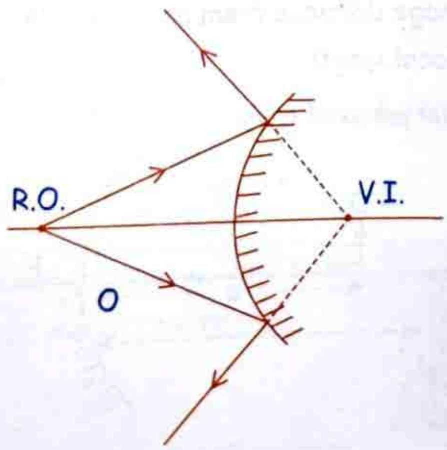
Q. Find the location of image.



Sol. $u = -40$

$\underline{f = +30}$

$v = \dfrac{-1200}{-40-30} = \dfrac{120}{7}$



काम का डब्बा (Spherical mirror)

- R.O. $\Rightarrow u < 0$, $u > 0 \Rightarrow$ V.O.
  R.I. $\Rightarrow v < 0$, $v > 0 \Rightarrow$ V.I.
  (Negative $\rightarrow$ Real)
- Concave mirror $f < 0$, Convex mirror $f > 0$
- $m = \frac{h_I}{h_0} = -\frac{v}{u}$,
- $m > 0$ erect, $m < 0$ inverted
- $|m| > 1$ enlarge
  $|m| < 1$ diminished
  $|m| = 1$ (same size)

तो भाई अब ये table भी देख लो जो हर book में given होती है इसका ज्यादा load मत लेना अगर ये याद ना हो पाए तो चुप चाप mirror formula में value put करके location or nature of image निकाल लेना

IMAGE FORMED BY THE CONCAVE MIRROR

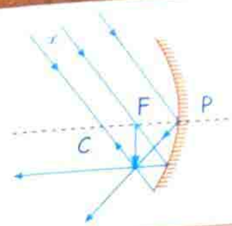
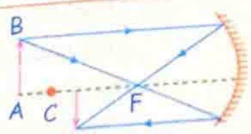
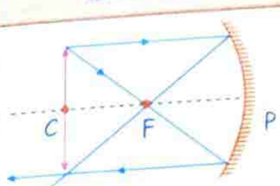
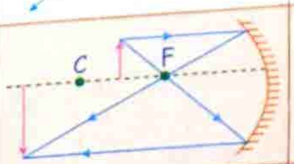
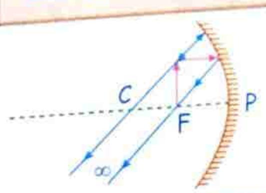
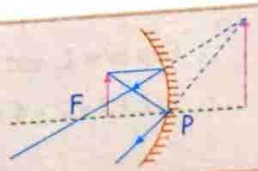
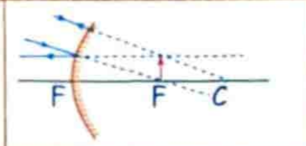
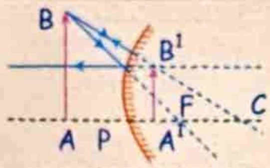
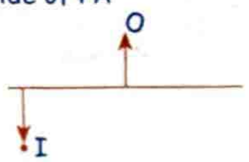
S.No.	Position of Object	Ray Diagram	Position of Image	Nature of Image	Size of Image
1.	At infinity		At focus	Real and inverted	Very small
2.	Between infinity and centre of curvature		Between focus and centre of curvature	Real and inverted	Small
3.	At centre of curvature		At centre of curvature	Real and inverted	Equal to object size
4.	Between focus and centre of curvature		Between centre of curvature and infinity	Real and inverted	Enlarged
5.	At focus		At infinity	Real and inverted	Very large
6.	Between pole and focus		Behind the mirror	Virtual and erect	enlarged

IMAGE FORMED BY THE CONVEX MIRROR					
1.	At infinity		At focus	Virtual and erect	Very small
2.	Between pole and infinity		Between focus and pole	Virtual and erect	Small

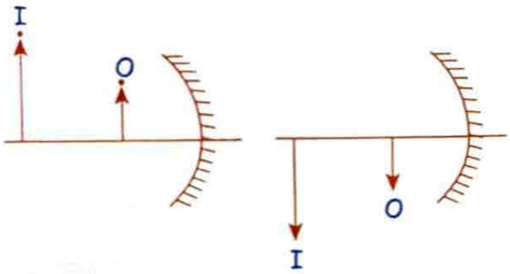
Magnification

$$m = \frac{h_I}{h_0}$$

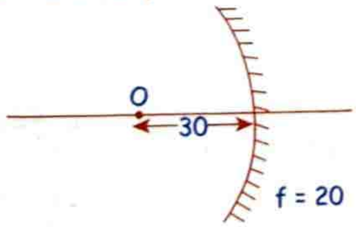
- Inverted image $\Rightarrow m < 0 \Rightarrow$ object and image are on opposite side of PA



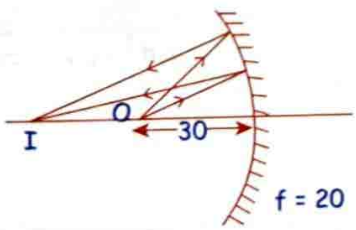
- Erect image $\Rightarrow m > 0 \Rightarrow$ object and image are on same side of PA



Q. Locate the position of image. Based on this answer the other part linked to it.



Sol.

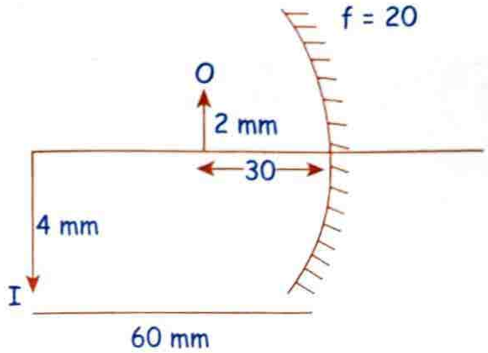


(R.I, inverted enlarge)

$u = -30$
$f = -20$

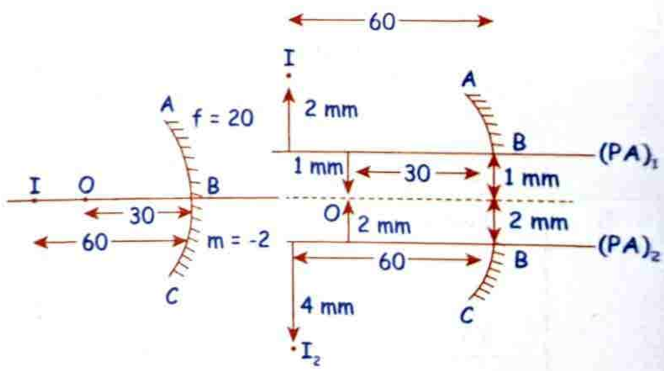
$v = -60$
$m = -2$

(a) Show the image for 2 mm height object.



(b) If mirror in part (a) is cut along principal axis and upper part is shifted up by 1 mm and lower part shifted down by 2 mm.
Then calculate gap between the two images formed of point object by each part of mirror.

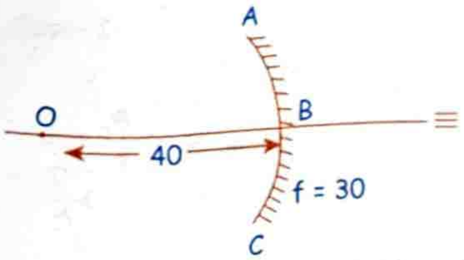
Sol.



Gap b/w I_1 and I_2

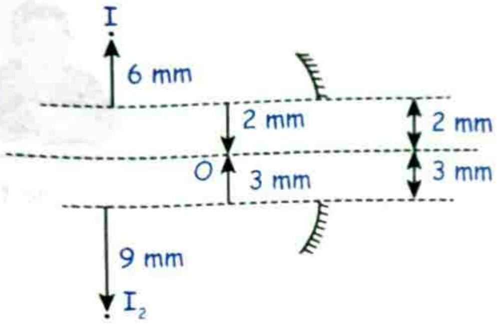
$= 2 + 1 + 2 + 4 = 9$ mm

Q.



Mirror is cut at 'B' upper half is shifted up by 2 mm and lower half is shifted down by 3 mm. Find gap b/w two image.

Sol.



$f = -30$

$u = -40$

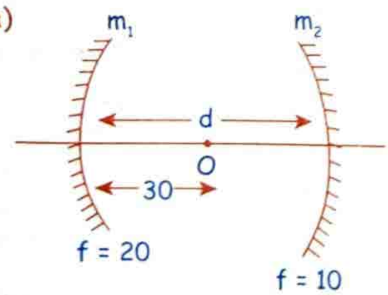
$$v = \frac{1200}{-40+30} = -120$$

$$m = -\frac{-120}{-40} = -3$$

Ans = 6 + 2 + 3 + 9 = 20 mm

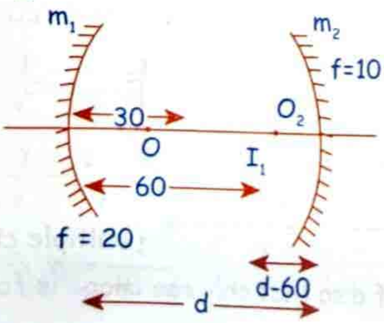
- **Object पर Image वाले Question**

Q. (a)



If image formed on object after two successive reflection find value of d if 1st reflection considered on left mirror.

Sol. m_1 की बनाई image ⇒ object for m_2 ⇒ image ≡ 0 पर



I_1 object from m_2

2nd mirror

$u = -(d-60), f = -10$

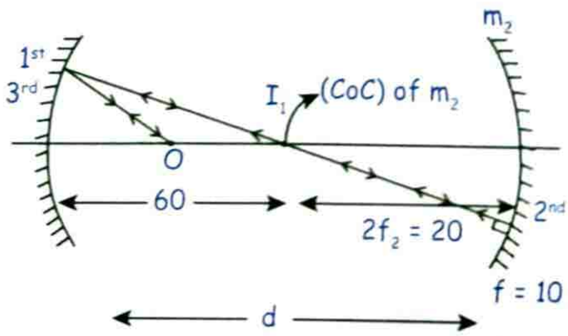
$v = -(d-30)$

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ ⇒ put u, v, f and solve for d.

(b) If image formed on object after three successive reflection find value of d if 1st reflection considered on left mirror.

Sol.

Case-I

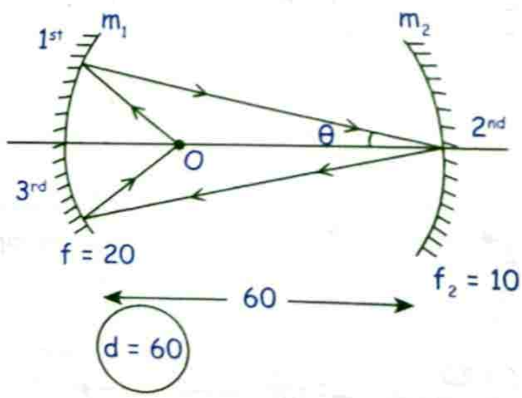


Ans d = 80, 60

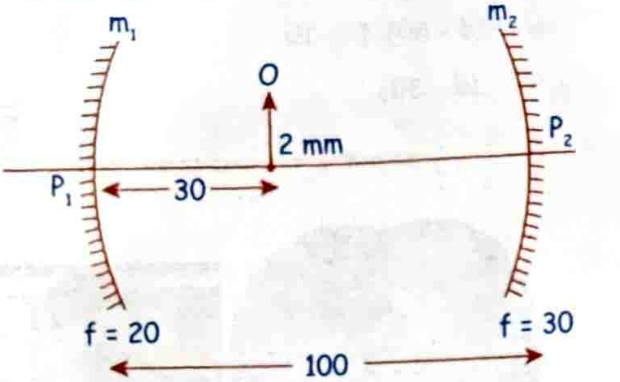
$d = 60 + 20 = 80$

and

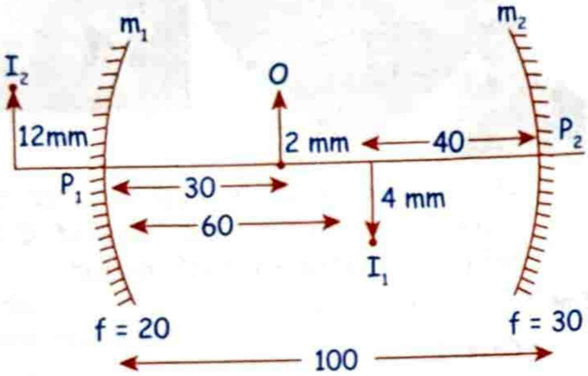
Case-II



Q. Find final location of image if object O of height 2 mm placed as shown in figure. (1[st] reflection at left mirror)



Sol.



If $P_1 \equiv (0, 0) \equiv I_1 \equiv (60, -0.4)$ cm

$$I_2 = (-20, -1.2)\text{ cm}$$

1^{st} reference $\left.\begin{matrix} u = -30 \\ f = -20 \end{matrix}\right\} v = -60, m_1 = -2$

For 2^{nd} reference $\left.\begin{matrix} u = -40 \\ f = -30 \end{matrix}\right\} v_f = -120$

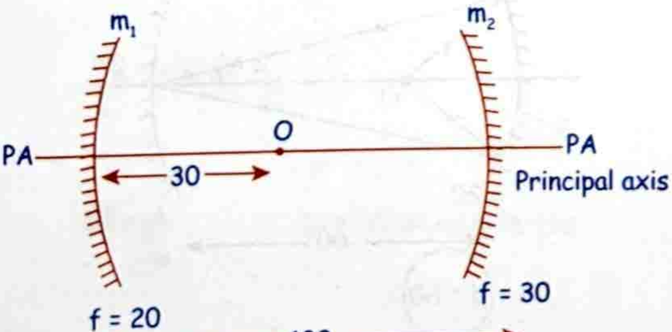
$$m = -\frac{-120}{-40}$$

$m_2 = -3$

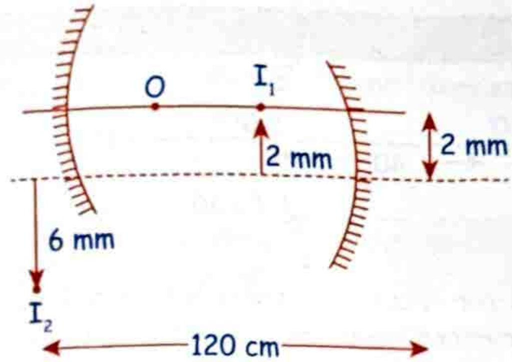
Total magnification $= m_1 \times m_2 = (-2) \times (-3)$

$= +6$

Q. If mirror m_2 is shifted down by 2 mm find net magnification.

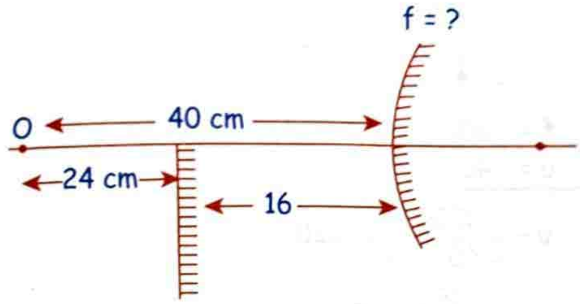


Sol.

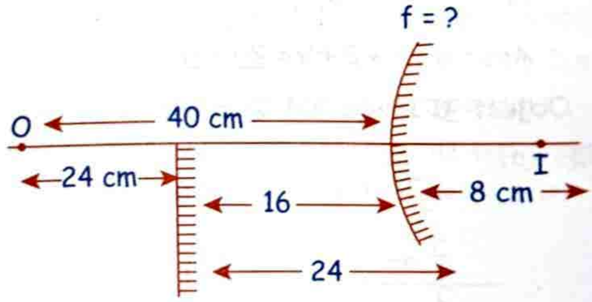


अबे यहाँ $m_{net} = m_1 \times m_2$ मत लगा देना

Q. If image formed by both mirror coincide find f.



Sol.



<u>Convex</u> $\Rightarrow u = -40$

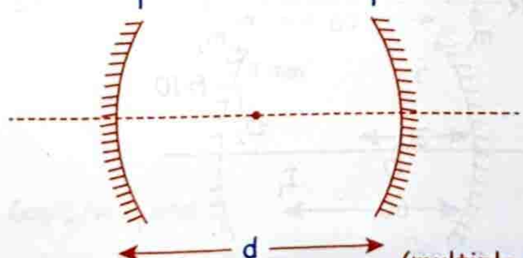
$v = +8$

$f = ?$

$$\frac{1}{-40} + \frac{1}{8} = \frac{1}{f}$$

$f = +10$

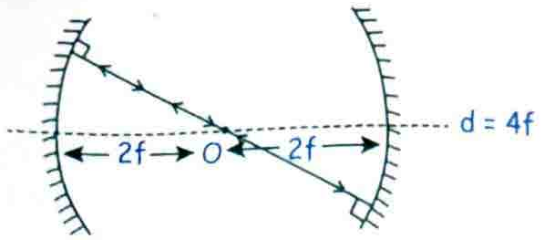
Q.



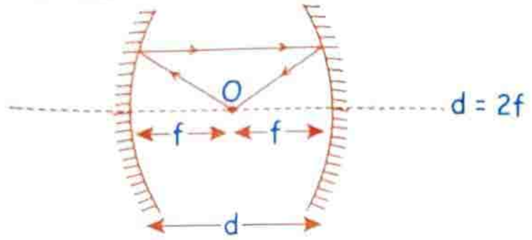
(multiple choice)

Find value of d so that only one image is formed

Sol. **Case-I**



Case-II



Q. Find distance of object from concave mirror of focal length 10 cm if image size is four times of object.

Sol. Real image

$u = -x \quad |m| = 4$

$v = -4x$

$f = -10$

$$\frac{1}{-x} + \frac{1}{-4x} = \frac{1}{-10}$$

$$\frac{5}{4x} = \frac{1}{10}$$

$\boxed{x = 12.5}$

(V.I)

$u = -x$

$v = +4x$

$f = -10$

$$\frac{1}{-x} + \frac{1}{4x} = \frac{1}{-10}$$

$$\frac{-3}{4x} = \frac{-1}{10}$$

$x = 7.5$

Q. When an object is placed at a distance of 25 cm from a mirror, the magnification is m_1. The object is moved 15 cm further away with respect to the earlier position and the magnification becomes m_2. If $\frac{m_1}{m_2} = 4$, then calculate focal length of mirror and type of mirror.

Sol. $$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \quad \text{... (i)}$$

Using equation (i)

$$\frac{1}{v_1} - \frac{1}{25} = \frac{1}{f} \Rightarrow v_1 = \frac{25f}{25+f}$$

$$\frac{1}{v_2} - \frac{1}{40} = \frac{1}{f} \Rightarrow \frac{1}{v_2} = \frac{1}{40} + \frac{1}{f} = \frac{40+f}{40f}$$

$$\Rightarrow v_2 = \frac{40f}{40+f}$$

$$m_2 = \frac{-v_2}{-40} = \frac{f}{40+f}$$

$$m_1 = \frac{-v_1}{-25} = \frac{f}{25+f}$$

$$\frac{m_1}{m_2} = \frac{f+40}{f+25} = 4 \quad \Rightarrow \quad f = -20 \text{ cm}$$

Negative sign shows that mirror is concave.

Q. A concave mirror has a focal length of 36 cm. At what position should an object be placed for its image to be erect and magnified by a factor of three.

Sol. $f = -36$ cm

$$m = \frac{h_i}{h_o} = -\frac{v}{u}$$

$$3 = \frac{h_i}{h_o} = \frac{v}{x}$$

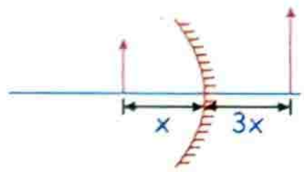
$v = 3x$

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

$$\frac{1}{x}\left[-1 + \frac{1}{3}\right] = \frac{1}{f}$$

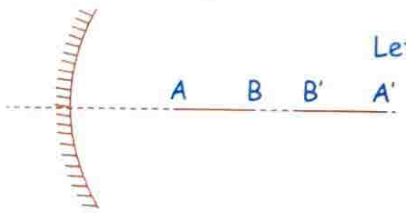
$$\frac{1}{x}\left[\frac{-3+1}{3}\right] = \frac{1}{-36}$$

$$x = \frac{+36 \times 2}{3} = +24 \text{ cm}$$



Longitudinal Magnification

♦ Let



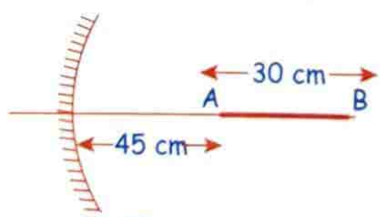
$A \longrightarrow A'$

$B \longrightarrow B'$

$AB \longrightarrow A'B'$

$$\text{Longitudinal mag} = \frac{\text{Length of image}}{\text{Length of object}} = \frac{A'B'}{AB}$$

Q.



f = 30

AB is object (AB = 30 cm)

Find length of image.

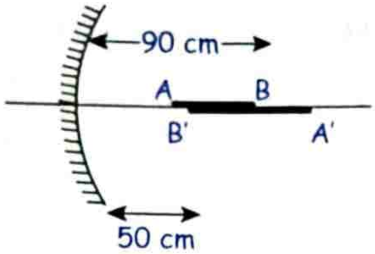
Sol. $A \longrightarrow A'$

$u = -45$

$f = -30$

$$v = \frac{45 \times 30}{-15}$$

$$v_A = -90$$

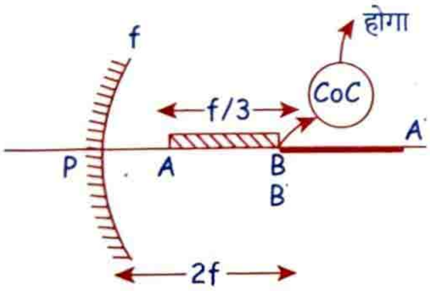


$B \longrightarrow B'$

$$v_B = \frac{(-75)(-30)}{-75-(-30)} = -50$$

$A'B' = 40$

Q. A thin rod of length $\frac{f}{3}$ is placed along the principal axis of a concave mirror of focal length f such that its image which is real and elongated, just touches the rod. What is magnification?



Sol.

Think

$A \longrightarrow A'$

$$A \Rightarrow u = -\left(2f - \frac{f}{3}\right) = -\frac{5f}{3}$$

$f = -f$

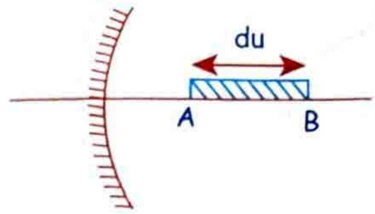
$$V_A = \frac{\frac{5f}{3} \cdot f}{\frac{-5f}{3} + f} = \frac{5f}{-5+3} = \frac{-5}{2}f$$

$$A'B' = 2.5f - 2f = \frac{f}{2}$$

$$AB = \frac{f}{3}$$

$$\boxed{\frac{A'B'}{AB} = \frac{3}{2}}$$

Q. If a very small object is placed on PA. Find length of image.



Sol. $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

$$-\frac{1}{u^2}du - \frac{1}{v^2}dv = 0$$

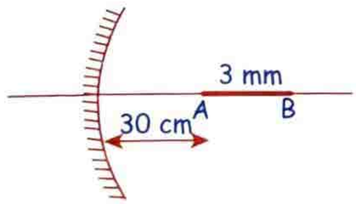
$$-\frac{1}{v^2}du = +\frac{1}{u^2}du$$

$$dv = -\frac{V^2}{u^2}du$$

$$\boxed{dv = -m^2 du}$$

Length of image = m^2 length of object

Q.



f = 20 cm

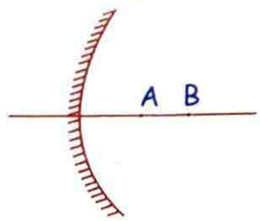
Sol. Length of image = $m^2(AB)$

$$\left.\begin{array}{l} u = -30 \\ f = -20 \\ v = -60 \\ m = -2 \end{array}\right\} \text{Solve} \quad = (-2)^2 \times .3 \text{ mm}$$

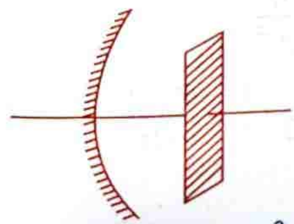
$= 4 \times .3$ mm $= 1.2$ mm

Transverse Magnification

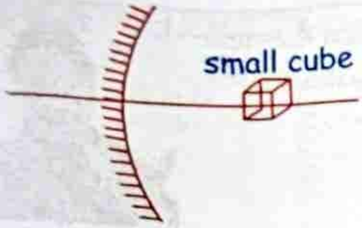
$$\equiv m = \frac{h_I}{h_0} = \frac{-v}{u}$$ (height of image $m \rightarrow$ times)

- 

$A^1B^1 = m^2 AB$

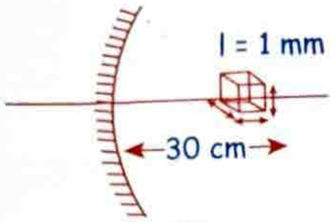
- 

Area of image = m^2 times object area



Volume of image = $(m^2 \times m \times m)$
$= m^4$ times

Q. Find volume of the image of cube.

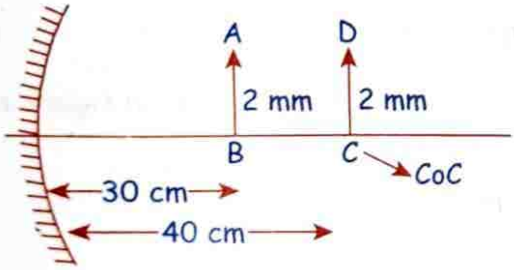


f = 20 cm

Volume of image = m^4(Volume of object)

$= 2^4 \times (1\ \text{mm})^3 = 16\ \text{mm}^3$

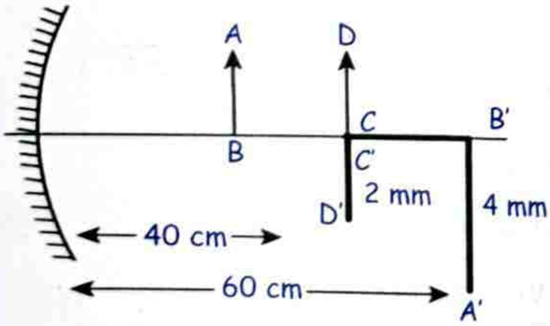
Q. Find the length of image of object ABCD as shown in figure.



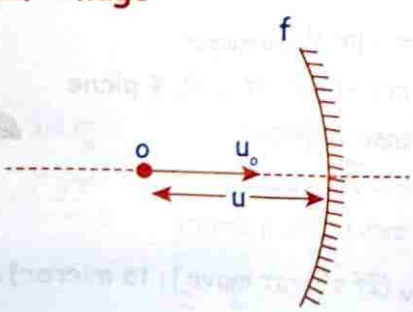
f = 20 cm

Find length of image = .4 + 20 + .2 = 20.6 cm

Sol.



Velocity of image



$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$$

$$-\frac{1}{u^2}\frac{du}{dt}-\frac{1}{v^2}\frac{dv}{dt}=0$$

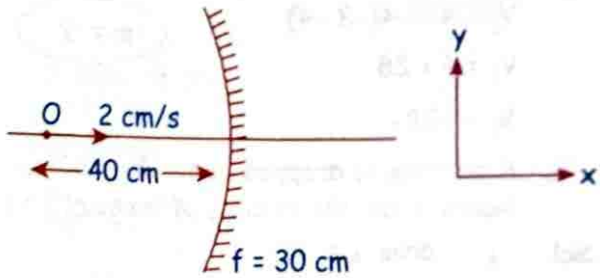
$$-\frac{1}{v^2}\frac{dv}{dt}=+\frac{1}{u^2}\frac{du}{dt}$$

$$\frac{dv}{dt}=\frac{-v^2}{u^2}\frac{du}{dt}$$

$$\boxed{\vec{v}_{Image}=-m^2\vec{v}_{obj}}$$

$$\boxed{\vec{v}_{I/mirror}=-m^2\vec{v}_{obj/mirror}}$$

1 Object moving towards mirror with velocity v_o.



$V_{image} = ?$

$$m=-\frac{v}{u}=-\frac{uf}{(u-f)u}$$

$$\boxed{m=\frac{f}{f-u}}$$

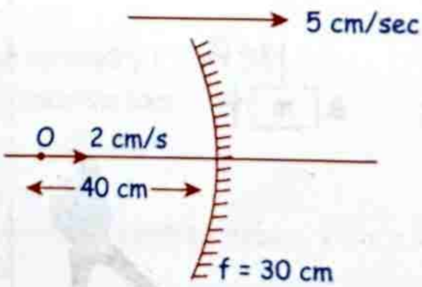
$v = -120$

$$m=-\frac{-120}{40}=-3$$

$V_I = 9 \times 2 = 18$

$$\boxed{\vec{V}_I=-18\hat{i}}$$

2 Object moving towards mirror with velocity v_o and mirror also moving.



$\boxed{m=-3}$ Already solved

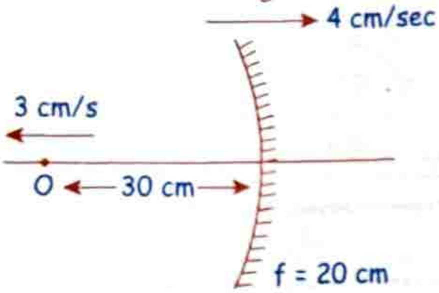
$$\vec{V}_{I/mirror}=-m^2\vec{V}_{obj/morror}$$

$$\vec{v}_I - \vec{v}_m = -m^2\left(\vec{v}_{obj} - \vec{v}_m\right)$$

$$\vec{V}_I - (5\hat{i}) = -9(2\hat{i} - 5\hat{i})$$

$$\vec{v}_I = 32\hat{i}$$

3. Object moving away from mirror with velocity v_o and mirror also moving.



$$\vec{V}_{I/m} = -m^2\vec{V}_{om}$$

$$V_I - 4 = -4(-3 - 4)$$

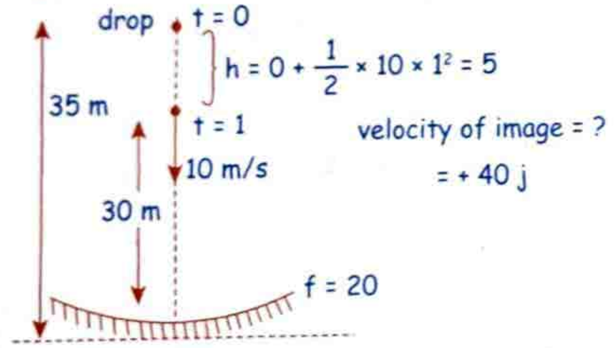
$$V_I = 4 + 28$$

$$\vec{V}_I = +32\hat{i}$$

m = -2

Q. A particle is dropped at t = 0 as shown in the figure. Find the velocity of image at t = 1 sec.

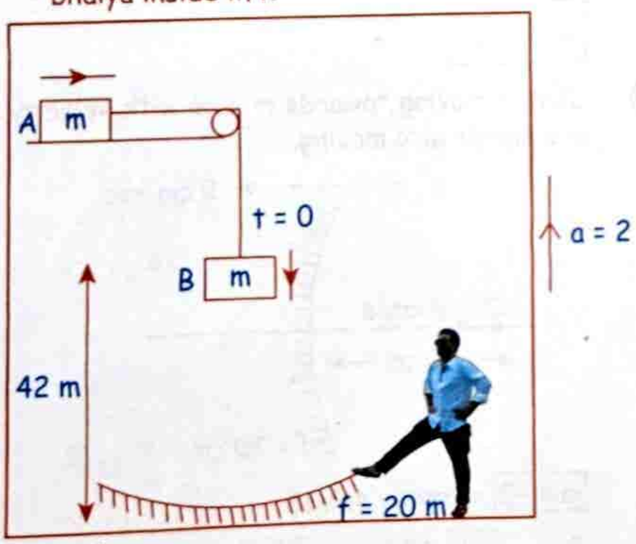
Sol.



velocity of image = ?

= + 40 j

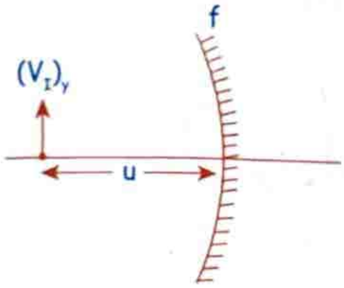
SSSQ. A lift is accelerating upward at $2 m/s^2$. The blocks are released at t = 0. Calculate velocity of image of block B at t = 2s observe by saleem bhaiya inside lift.



Ans. $48\hat{j}$

अबे डर तो नहीं गए सवाल optics मे simple ही है बस NLM और rotation add कर दिया।

Q. A Particle is moving as shown in figure what will be its image velocity.

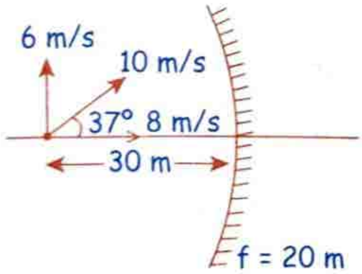


Sol. $m = \frac{h_I}{h_O} \Rightarrow h_I = mh_O$

$$\frac{dh_I}{dt} = m\frac{dh_O}{dt} + h_o\frac{dm}{dt} \quad (\text{Here } h_o = 0)$$

$$\boxed{(\vec{v}_I)_y = m(\vec{v}_O)_y}$$

Q. A Particle is moving as shown in figure what will be its image velocity.



m = -2 धाँसु

$$(\vec{v}_I)_x = -4 \times 8\hat{i}$$

$$(\vec{v}_I)_y = 2 \times 6\hat{j}$$

$$\boxed{\vec{V}_I = -32\hat{i} + 12\hat{j}}$$

since

$$\vec{V}_{I/mirror} = -m^2\vec{V}_{obj/morror}$$

अब अगर मैं m = -1 put कर दूं तो ये plane mirror का case हो जाएगा।

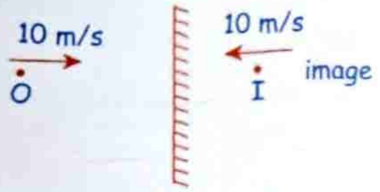
$$\vec{V}_{I/mirror} = -\vec{V}_{obj/morror}$$

(If object move ⊥ to mirror)

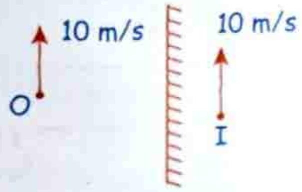
$\vec{V}_{I/M} = \vec{V}_{O/M}$ (If object move || to mirror)

IMAGE VELOCITY

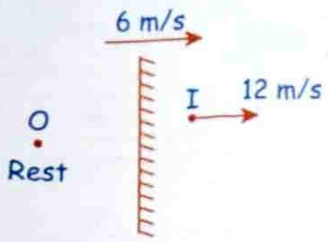
(1)



(2)

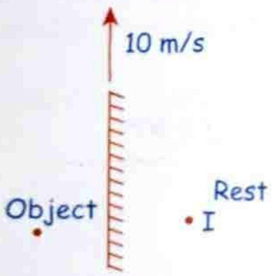


(3)

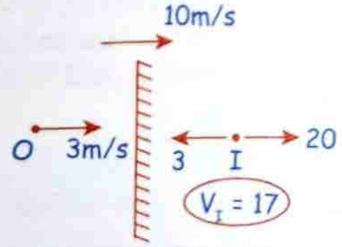


(same dir^n में दुगुनी speed से)

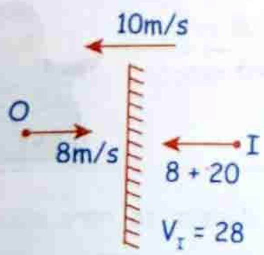
(4)



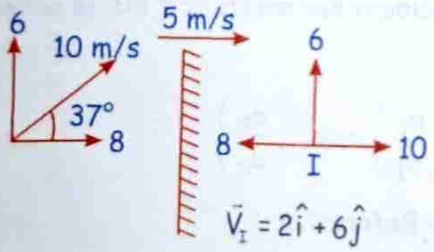
(5)



(6)

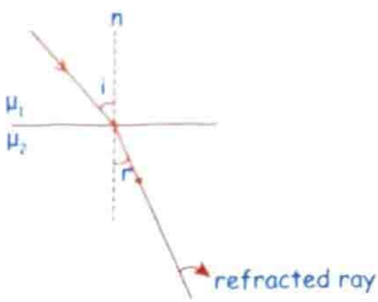


(7)

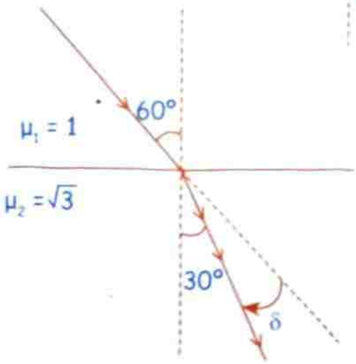


REFRACTION

- Snells law $\boxed{\mu_1 \sin i = \mu_2 \sin r}$
- $\delta = |i - r|$
- speed change
  - f ⟶ Same
  - λ ⟶ change



-



Rare ⟶ Denser
towards normal

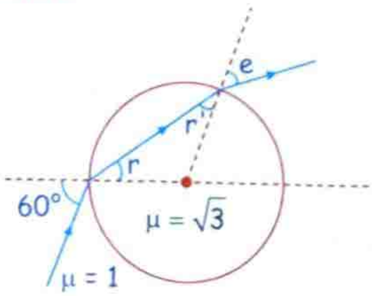
$1 \times \sin 60 = \sqrt{3} \sin r$

$\frac{\sqrt{3}}{2} = \sqrt{3} \sin r$

r = 30 $\quad$ δ = 30

Denser to Rarer ⇒ Away from Normal
Rarer to Denser ⇒ towards Normal

Q. A light ray is incident on a glass sphere ($\mu = \sqrt{3}$) at an angle of incidence 60° as shown. Find the angles r, r', e and the total deviation after two refractions.



Sol. $\sin 60° = \sqrt{3}\ \sin r$

$\Rightarrow r = 30°$

From symmetry $r' = r = 30°$.

At second surface

$1 \sin e = \sqrt{3}\ \sin r'$

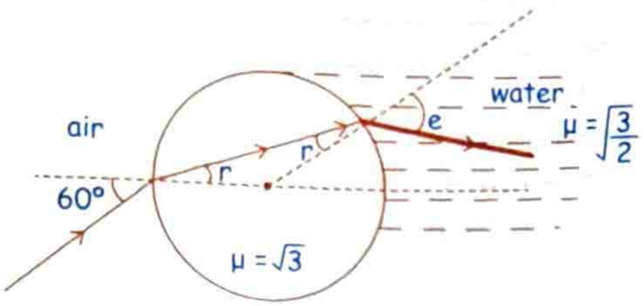
$\Rightarrow e = 60°$

Deviation at first surface = $i - r = 60° - 30° = 30°$

Deviation at second surface = $e - r' = 60° - 30° = 30°$

Total deviation = 60° (clockwise)

Q. Find net deviation



Sol. $1.\sin 60 = \sqrt{3}\sin r$

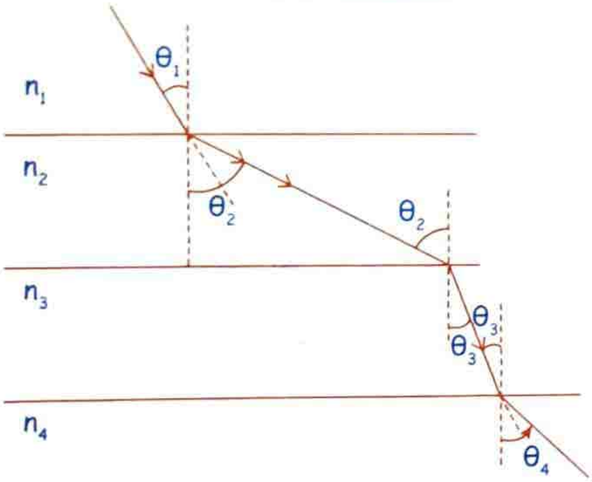
$\boxed{r = 30^\circ}$

$\sqrt{3}\sin r = \sqrt{\frac{3}{2}}\sin e$

$e = 45$

PLANE REFRACTION IN PARALLEL BOUNDARY (SLAB)

It's very important for advance इस article पर advance ने चार बार सवाल पूछा है।



- $n_1 \sin\theta_1 = n_2 \sin\theta_2$

  $n_2 \sin\theta_2 = n_3 \sin\theta_3$

  $n_3 \sin\theta_3 = n_4 \sin\theta_4$

  $n_1 \sin\theta_1 = n_2 \sin\theta_2 = n_3 \sin\theta_3 = n_4 \sin\theta_4$

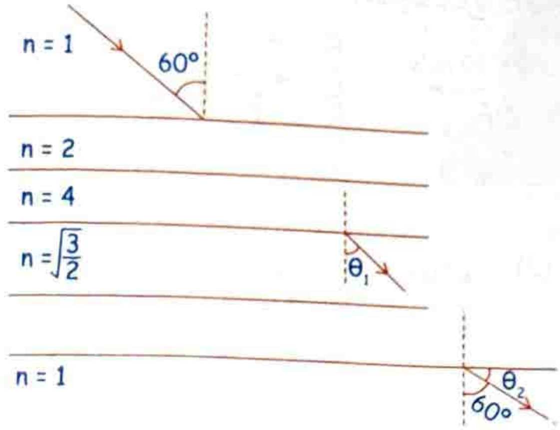
  $n \sin\theta = \text{const}$

  If $n_2 = n_4$

  $\cancel{n_2}\sin\theta_2 = \cancel{n_4}\sin\theta_4$

  $\theta_2 = \theta_4$

Q. find value of θ_1 & θ_2



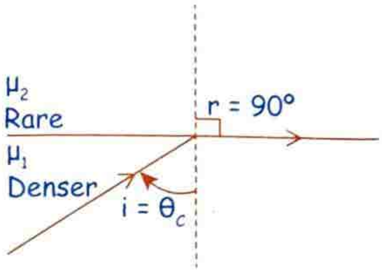
Sol. $1 \sin 60 = \sqrt{\frac{3}{2}}\sin\theta_1$

$\theta_1 = 45$

$\theta_2 = 30$

$\delta_{net} = 0$

TOTAL INTERNAL REFLECTION (TIR)



$\mu_1 \sin i = \mu_2 \sin r$

$\mu_1 \sin\theta_c = \mu_2 \sin 90$

$$\boxed{\sin\theta_c = \frac{\mu_2}{\mu_1} = \frac{\mu_R}{\mu_D}}$$

#SKC

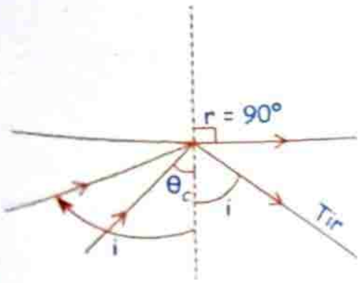
$\text{Sin}\,\theta_c = \frac{\text{छोटा } \mu}{\text{बड़ा } \mu} = \frac{\text{छोटी velocity}}{\text{बड़ी velocity}}$

When light goes from denser to rare medium, the angle of incident for which $\angle r = 90^\circ$ is called critical angle.

$$\theta_c = \sin^{-1}\left(\frac{\mu_2}{\mu_1}\right) = \sin^{-1}\left(\frac{\mu_R}{\mu_0}\right)$$

If $i \le \theta_c \Rightarrow$ Refraction

If $i > \theta_c \Rightarrow$ TIR

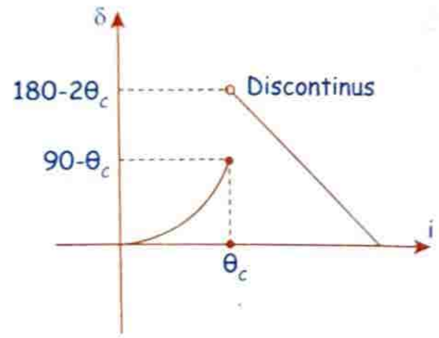


अगर $\angle i$ critical angle से थोड़ा सा भी 0.0000000001 angle ज्यादा हुआ तो TIR होगा

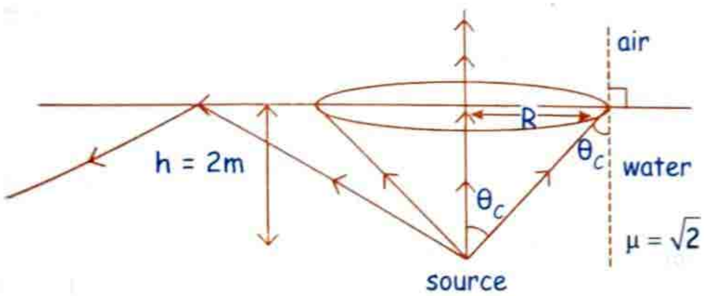
If $i < \theta_c$ = Refraction
$\delta = r - i$
$\mu_1 \sin i = \mu_2 \sin r$
$$\delta = \sin^{-1}\left(\frac{\mu_1}{\mu_2}\sin i\right) - i$$

If $i = \theta_c \Rightarrow \delta = 90 - i = 90 - \theta_c$

If $i > \theta_c \Rightarrow$ TIR
$\delta = 180 - 2i$



Q. A bulb is placed inside water at a depth h from the water surface as shown in figure. Find 'R' radius of Disc so that no ray comes out.



Sol. $\sin\theta_c = \frac{1}{\sqrt{2}}$

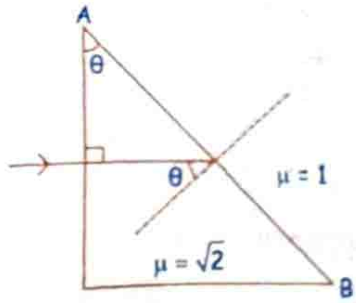
$\boxed{\theta_c = 45^\circ}$

$\tan\theta_c = \frac{R}{h}$

$\tan 45 = \frac{R}{2}$

$\boxed{R = 2m}$

Q. Find value of θ so that ray will not get outside AB



$\theta > \theta_C$

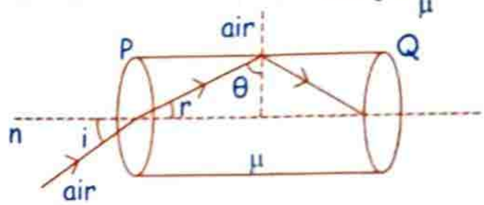
$\sin\theta > \sin\theta_C$

$\sin\theta > \frac{1}{\sqrt{2}}$

$\boxed{\theta > 45}$

Q. Find range of μ so that all the ray will show TiR at PQ

$\sin\theta_c = \frac{1}{\mu}$



Sol. $\theta_{min} > \theta_C$

$(90 - r)_{min} > \theta_C$

$90 - r_{max} > \theta_C$

$90 - \theta_C > \theta_C$

$90 > 2\theta_C$

$\boxed{\theta_C < 45^\circ}$

$\theta_C < 45$

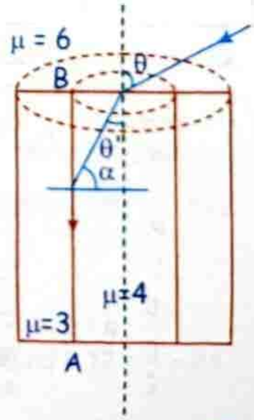
$\sin\theta_C < \sin 45$

$\frac{1}{\mu} < \frac{1}{\sqrt{2}}$

$\boxed{\mu < \sqrt{2}}$

Use this
$\theta \longrightarrow$ min
$r \longrightarrow$ max
$i \longrightarrow$ max $\equiv i_{max} = 90^\circ$
$\mu_1 \sin i\ 90 = \mu_2 \sin r$
$\sin r = \frac{1}{\mu}$ $\sin\theta_c = \frac{1}{\mu}$
$r = \theta_C$
$\hookrightarrow$ max

Q. Find angle θ so that TIR occurs at interface AB in the figure shown below:



Sol. $4\sin\alpha = 3\sin 90^\circ$

$\sin\alpha = \frac{3}{4}$

$\cos\alpha = \sqrt{1 - \frac{9}{16}} = \frac{\sqrt{7}}{4}$

Since $\theta' + \alpha = 90^\circ$,

$\sin\theta' = \cos\alpha = \frac{\sqrt{7}}{4}$

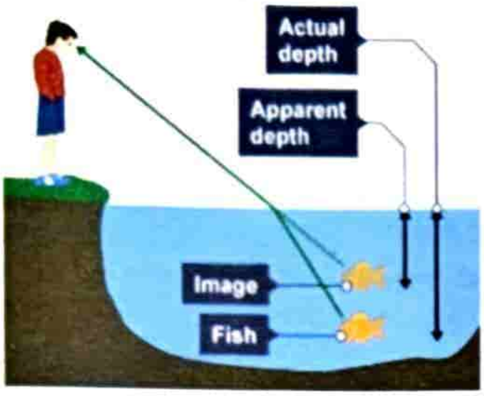
From Snell's law,

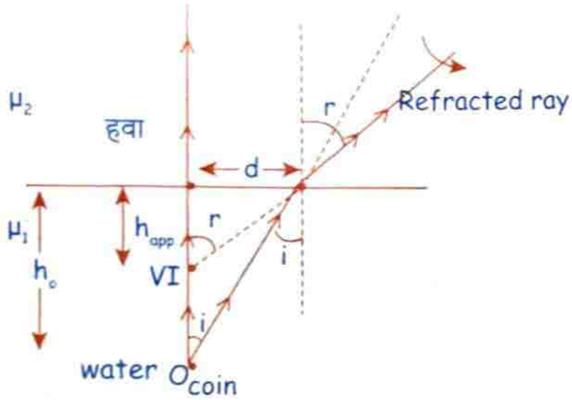
$6\sin\theta = 4\sin\theta'$

$6\sin\theta = \frac{4\sqrt{7}}{4}$

$\sin\theta = \frac{\sqrt{7}}{6} \Rightarrow \theta = \sin^{-1}\left(\frac{\sqrt{7}}{6}\right)$

Idea of Apparent Depth





$\mu_1 \sin i = \mu_2 \sin r$

For paraxial rays

$\sin i = i = \tan i$

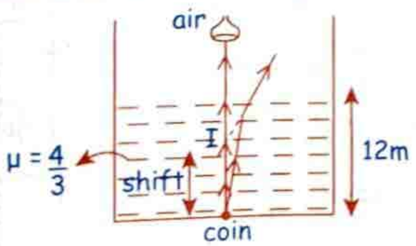
$\sin r = r = \tan r$

$\mu_1 \tan i = \mu_2 \tan r$

$\mu_1 \frac{d}{h_0} = \mu_2 \frac{d}{h_{app}}$

$\boxed{h_{app} = h_0 \frac{\mu_2}{\mu_1}}$ $\boxed{h_{app} = h_0 \frac{\mu_{\text{जाने}}}{\mu_{\text{आने}}}}$

Q. A coin is placed at the bottom of the vessel of depth 12 m at shown in figure. Find the h_{app} observe by man if man is very close to water surface in air and observing coin normally.

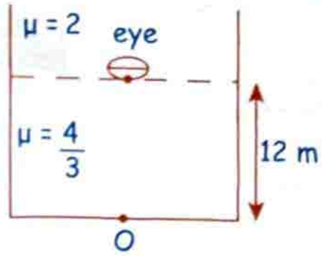


Sol. $h_{app} = 12\frac{1}{4/3}$

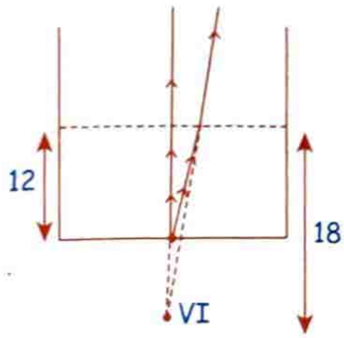
$h_{app} = 9$

shift = 12 – 9 = 3

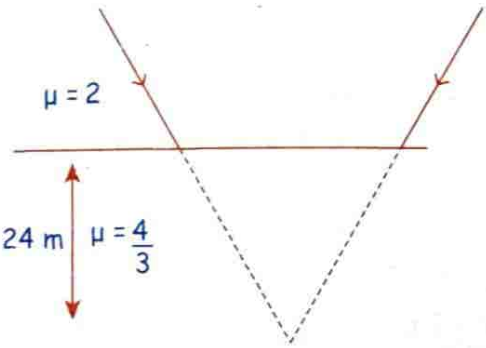
Q. Find apparent depth observed by man



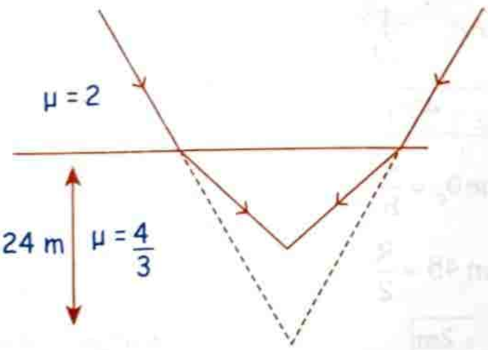
Sol. $h_{app} = 12 \times \frac{2}{4/3} = 18$



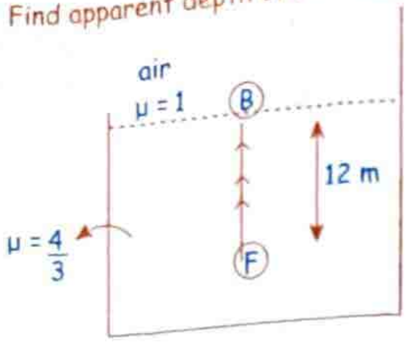
Q. Find where ray will meet after reflection



Sol. $h_{app} = 24 \times \frac{4/3}{2} = 16$



Q. Find apparent depth of fish observed by bird



Sol. $h_{app} = 12 \times \frac{1}{4/3} = 9$ m

If bird is at a height 18 m from the water surface then in this question.

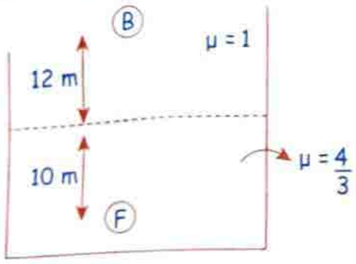
Apparent depth of fish observed by bird

$h_{app} = 12 \times \frac{1}{4/3} + 18 = 27$

#SKC

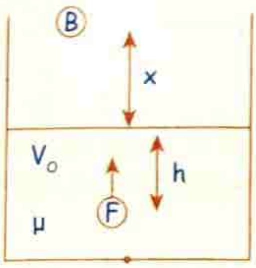
सबसे पहले ये देखो कौन देख रहा है और किस को देख रहा है। जिसको देख रहे है उससे rays आयेंगी और जो देख रहा है उसकी आँखो मे rays जाएगी।

Q. Find the distance of bird observed by fish.



Sol. ray को fish की आखो मे जाना है μ जाने वाली = $\frac{4}{3}$ → μ देखने वाला

$h_{app} = 12 \times \frac{4/3}{1} + 10 = 16 + 10 = 26$



Apparent depth of fish observed by bird

$= \frac{h}{\mu} + x = h_{app}$

Apparent distance of bird observed by fish

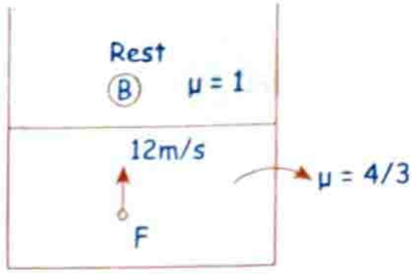
$= h + x\mu = h_{app}$

if x → const   Bird → Rest

$$\frac{dh_{app}}{dt} = \frac{d\left(\frac{h}{\mu}\right)}{dt} + 0$$

$$\boxed{V_{app} = \frac{1}{\mu} V_0}$$

Q. Find speed of fish observe by bird.

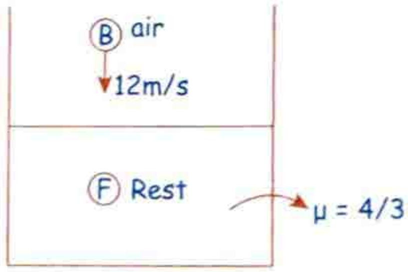


Speed of fish observed by bird $= 12 \times \frac{1}{4/3} = 9$

Bird → देख रही है

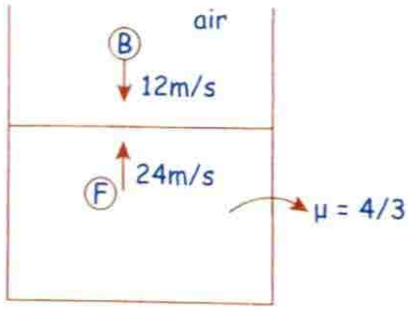
$$\boxed{V_{app} = V_0 \frac{\mu_{जाने}}{\mu_{आने}} = V_0 \frac{\mu_{observed}}{\mu_{object}}}$$

♦



Speed of bird observed by fish $= 12 \times \frac{\frac{4}{3}}{1} = 16$ m/s

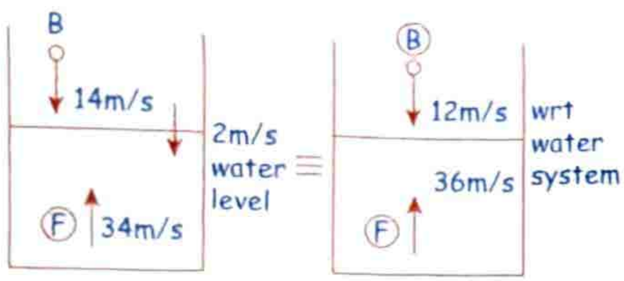
♦



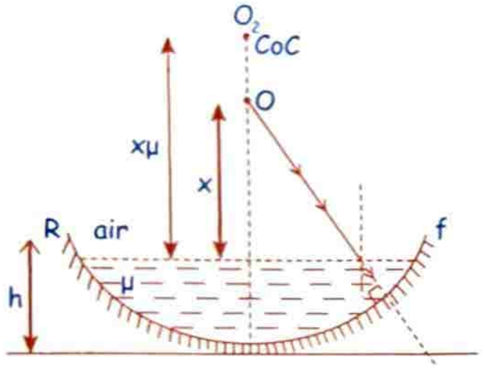
Speed of fish observed by bird $= 24 \times \frac{1}{\frac{4}{3}} + 12$

Speed of fish observed by bird $= 12 \times \frac{\frac{4}{3}}{1} + 24$

♦



Q. Find value of x. So that image formed on object.

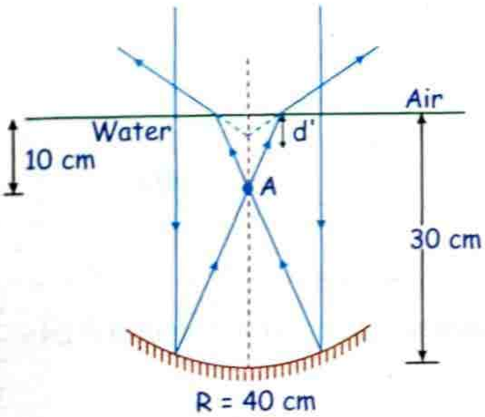


$x\mu + h = 2f$

$$x = \frac{2f - h}{\mu} = \frac{R - h}{\mu}$$

Q. A concave mirror is placed inside water with its shining surface upwards and principal axis vertical as shown in fig. Rays are incident parallel to the principal axis of the concave mirror. Find the position of the final image from the Air-water interface.

Sol.

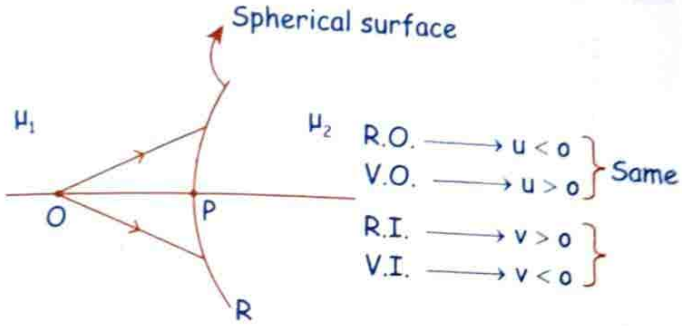


The incident rays will pass undeviated through the water surface and strike the mirror parallel to its principal axis. Therefore for the mirror, object is at infinity and its image A in figure will be formed at focus which is 20 cm from the mirror. Now for the interface between water and air, d = 10 cm.

$$\Rightarrow d' = \frac{d}{\left(\frac{\mu_w}{\mu_a}\right)} = \frac{10}{\left(\frac{4/3}{1}\right)} = 7.5 \text{ cm}$$

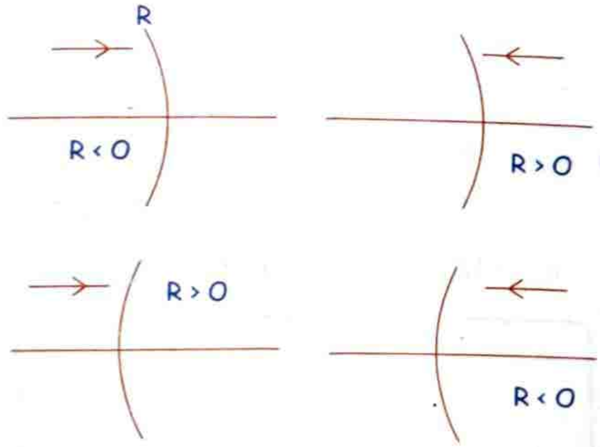
CURVE REFRACTION

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R} \qquad m = \frac{\mu_1 v}{\mu_2 u}$$

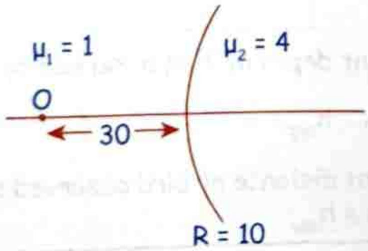


- ♦ सारे measurement 'p' से करने है
- ♦ paraxial rays के लिए valid
- ♦ direction of incident ray taken as positive
- ♦ u, v, R ⟶ with sign
- ♦ μ_2 ≡ जहाँ rays जा रही है उसका Refractive index

R → Sign के लिए **pole** से **center** की तरफ चलो



Q. Find location of image RI on the left side is 1 and on the right side of the curved boundary is 4.

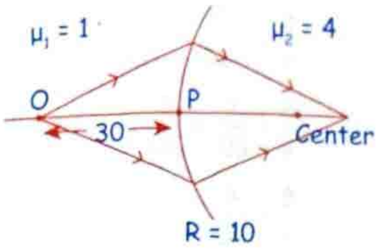


Sol. $u = -30$

$\mu_2 = 4$

$\mu_1 = 1$

$R = +10$



$$\frac{4}{v} - \frac{1}{-30} = \frac{4-1}{+10}$$

$$\frac{4}{v} + \frac{1}{30} = \frac{3}{10}$$

$$\boxed{V = 15}$$

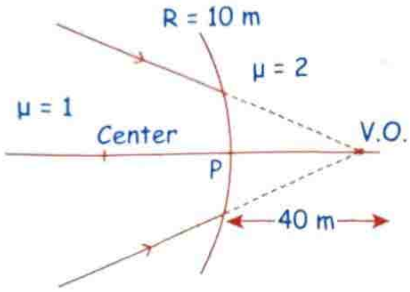
R.I बनेगी

अगर v > 0

|||

R.I बनेगी

Q. Find location of image as shown in the figure

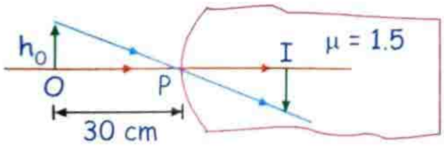


Sol. $u = +40$

$R = -10$

$$\frac{2}{v} - \frac{1}{40} = \frac{2-1}{-10}$$

Q. A small object of height 0.5 cm is placed in front of a convex surface of glass ($\mu = 1.5$) of radius of curvature 10 cm. Find the height of the image formed in glass.



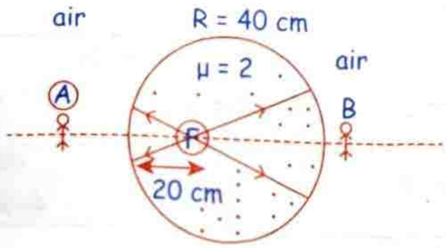
Sol. $$\frac{1.5}{v} - \frac{1}{-30} = \frac{1.5-1}{+10}$$

Solve and get v = 90

$$m = \frac{\mu_1}{\mu_2} \cdot \frac{v}{u} = \frac{h_I}{h_o}$$

$$h_I = \frac{1}{1.5} \times \frac{90}{(-30)} \times \frac{1}{2} = -1 \text{ cm (inverted)}$$

Q. Find the distance of image as observed by A and B



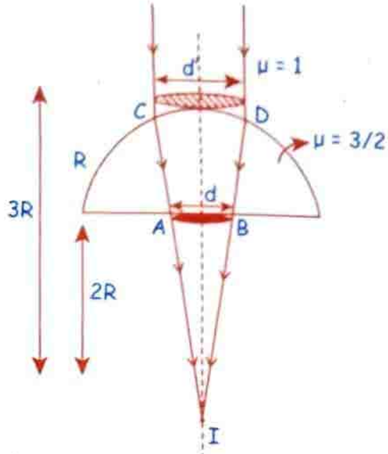
Sol. (for A) $\frac{1}{v} - \frac{2}{-20} = \frac{1-2}{-40}$

$$V = \frac{-40}{3}$$

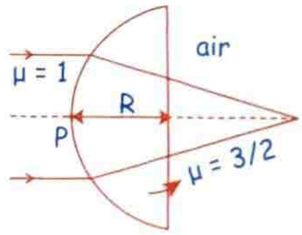
(for B) $\frac{1}{v} - \frac{2}{-60} = \frac{1-2}{-40}$

$$\boxed{V = -120}$$

Q. In the given hemisphere find the value of d' parallel rays are incident on the hemisphere as shown in figure



Sol.



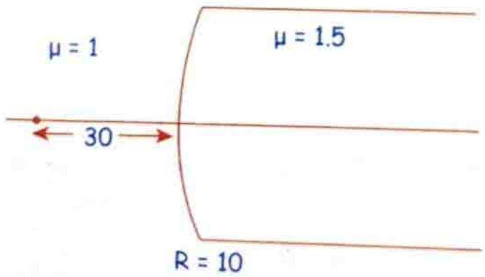
$$\frac{3}{2V} - \frac{1}{\infty} = \frac{3/2-1}{+R}$$

$$\frac{3}{2V} = \frac{1}{2R} \quad \boxed{V = 3R}$$

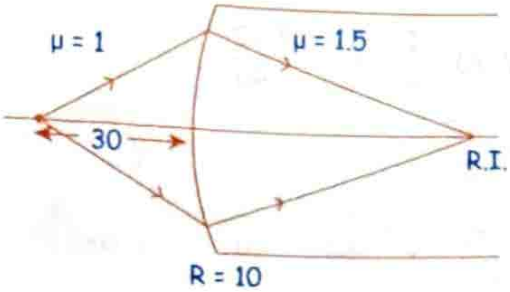
$$\frac{2R}{d'} = \frac{3R}{d}$$

$$\boxed{d' = \frac{2d}{3}}$$

Q. Find the location of image



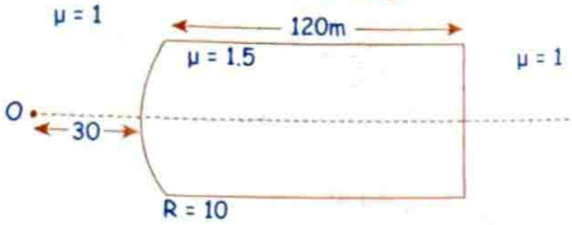
Sol.



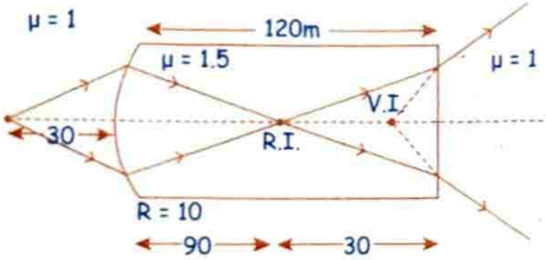
$$\frac{1.5}{v}-\frac{1}{-30}=\frac{1.5-1}{+10}$$

$$\boxed{v = 90}$$

Q. Find the location of the image

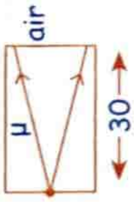


Sol.



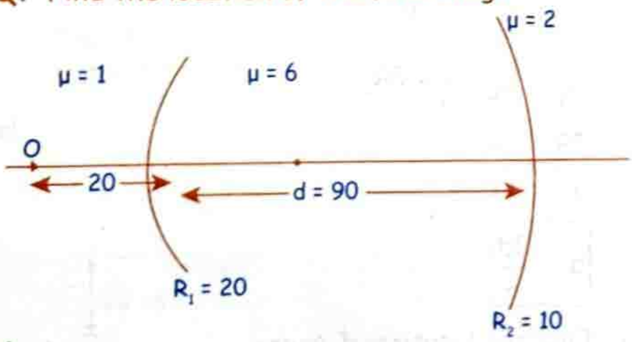
$$\frac{1.5}{v}-\frac{1}{-30}=\frac{1.5-1}{+10}$$

$$h_{app}=30\times\frac{1}{3/2}=20$$

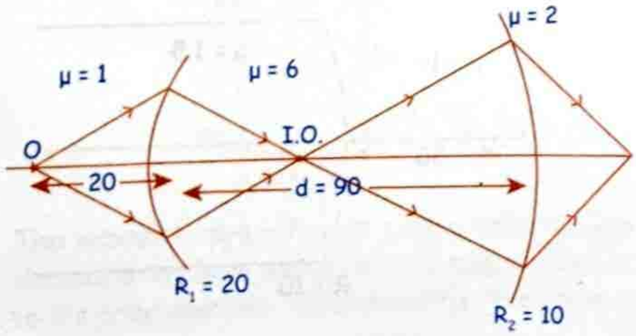


$$\boxed{v = 90}$$

Q. Find the location of the final image.



Sol.



$$\frac{6}{v}-\frac{1}{-20}=\frac{6-1}{+20}$$

$$\frac{6}{v}+\frac{1}{20}=\frac{5}{20}$$

$$\frac{6}{v}=\frac{4}{20}$$

$$\boxed{V = 30}$$

2^{nd} reflection

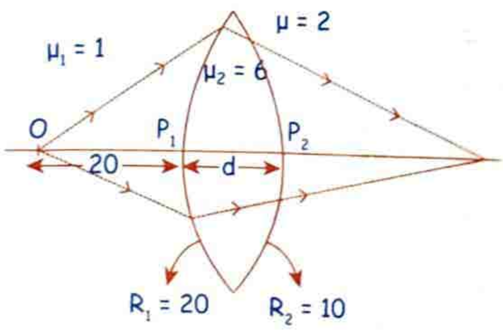
$$\frac{2}{v_f}-\frac{6}{-60}=\frac{2-6}{-10}$$

$$\frac{2}{v_f}+\frac{1}{10}=\frac{4}{10}$$

$$\boxed{v_f=\frac{20}{3}}$$

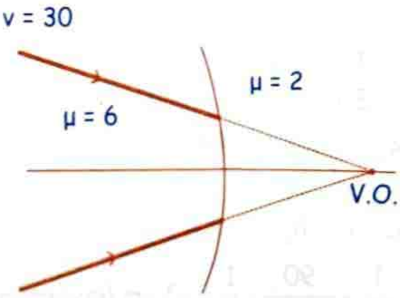
Q. Find the location of the final image.

$d \to 0$ (thin lense)



Sol. 1^{st} **refraction** $\frac{6}{v}-\frac{1}{-20}=\frac{6-1}{+20}\Rightarrow v=30$

2^{nd} **refraction**

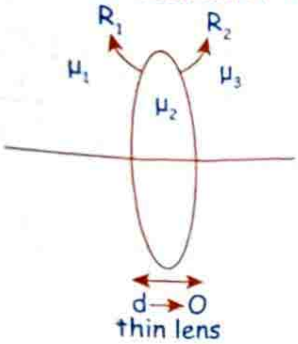


$$\frac{2}{v_f}-\frac{6}{+30}=\frac{2-6}{-10}$$

Now solve and get v_f

देख भाई ये lens का सवाल हो गया जो बिना lens formula के तुमने solve कर दिया। मजे की बात ये है की lens के दोनो तरफ medium अलग अलग है।

Q. Find the location of the final image.



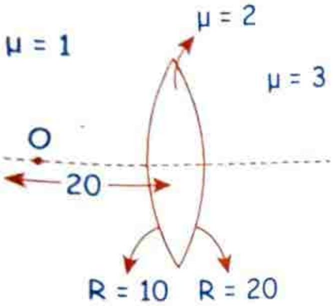
$$1^{st}\text{ refraction}\quad \cancel{\frac{\mu_2}{v}} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R_1} \qquad ...(i)$$

$$2^{nd}\text{ refraction}\quad \frac{\mu_3}{v_f} - \cancel{\frac{\mu_2}{v}} = \frac{\mu_3 - \mu_2}{R_2} \qquad (ii)$$

$$\text{Add (i) \& (ii)}\quad \frac{\mu_3}{v_f} - \frac{\mu_1}{u} = \frac{\mu_3 - \mu_2}{R_2} + \frac{\mu_2 - \mu_1}{R_1}$$

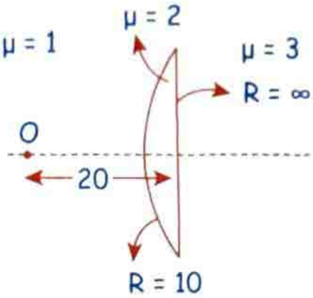
Q. Find the image distance in the following case

(a)



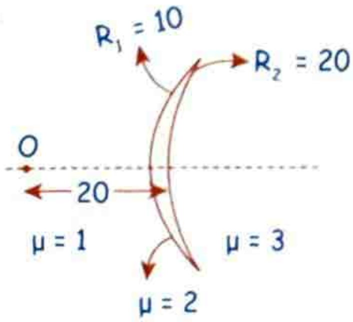
$$\frac{3}{V} - \frac{1}{-20} = \frac{3-2}{-20} + \frac{2-1}{+10} \quad V_f = \infty$$

(b)



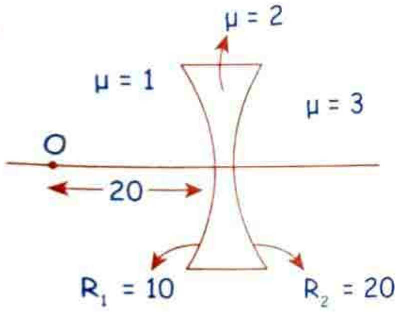
$$\frac{3}{v_f} - \frac{1}{-20} = \frac{3-2}{\infty} + \frac{2-1}{+10}$$

(c)



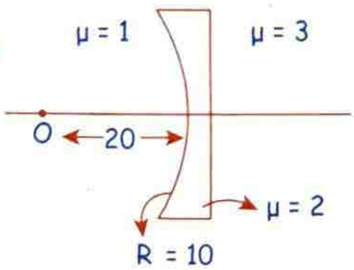
$$\frac{3}{v_f} - \frac{1}{-20} = \frac{3-2}{+20} + \frac{2-1}{+10}$$

(d)



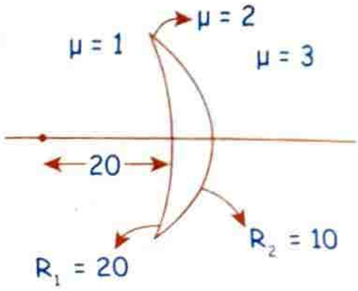
$$\frac{3}{v_f} - \frac{1}{-20} = \frac{3-2}{+20} + \frac{2-1}{-10}$$

(e)



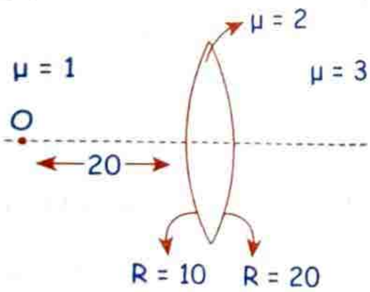
$$\frac{3}{v_f} - \frac{1}{-20} = \frac{3-2}{\infty} + \frac{2-1}{-10}$$

(f)



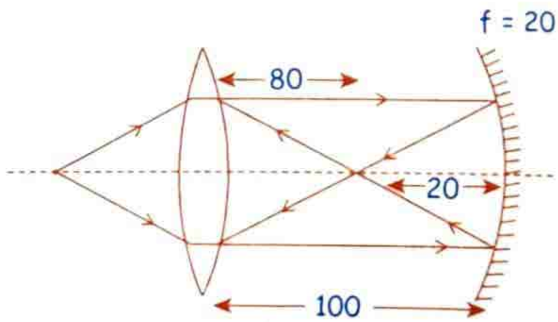
$$\frac{3}{v_f} - \frac{1}{-20} = \frac{3-2}{-10} + \frac{2-1}{-20}$$

Q. (a) Find the location of the final image.



$$\frac{3}{v} - \frac{1}{-20} = \frac{3-2}{-20} + \frac{2-1}{+10} \quad v_f = \infty$$

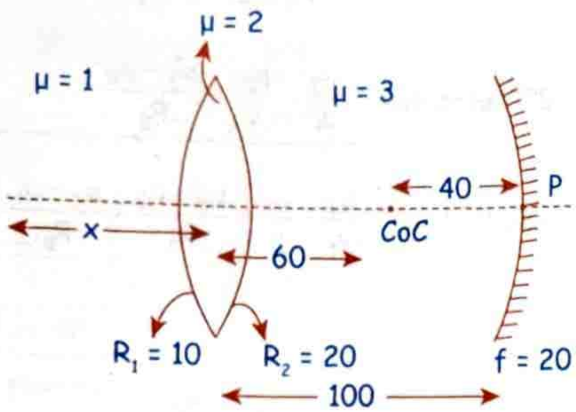
(b) Using the same above data calculate the location of final image if concave mirror is placed as shown.



वापस दोबारा lens से interaction

$$\frac{1}{v_f} - \frac{3}{-80} = \frac{1-2}{-10} + \frac{2-3}{+20}$$

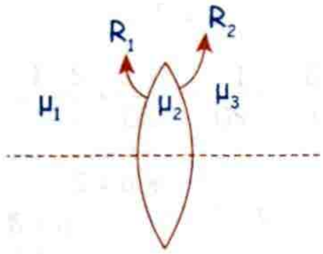
Q. Find the value of x so that final image formed at object.



Sol. $\frac{3}{100}-\frac{1}{-x_1}=\frac{3-2}{-20}+\frac{2-1}{+10}$

$\frac{3}{+60}-\frac{1}{-x_2}=\frac{3-2}{-20}+\frac{2-1}{+10}$

Q. Drive lens makers formula



$$\frac{\mu_3}{v}-\frac{\mu_1}{u}=\frac{\mu_3-\mu_2}{R_2}+\frac{\mu_2-\mu_1}{R_1}$$

If both side medium is same

$\mu_1=\mu_3=\mu_m$

$$\frac{\mu_m}{v}-\frac{\mu_m}{u}=\frac{\mu_m-\mu_2}{R_2}+\frac{\mu_2-\mu_m}{R_1}$$

$$\frac{\mu_m}{v}-\frac{\mu_m}{u}=(\mu_2-\mu_m)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

$$\frac{1}{v}-\frac{1}{u}=\left(\frac{\mu_2}{\mu_m}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

If $\mu_m=1$ $\quad \mu_2=\mu_{lense}=\mu_L$

$$\frac{1}{v}-\frac{1}{u}=(\mu_L-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

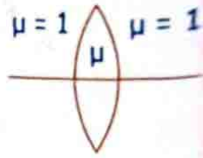
If object is at $\infty \Rightarrow u=-\infty$, $v=f$

$$\frac{1}{f}-\frac{1}{-\infty}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

$$\frac{1}{v}-\frac{1}{u}=(\mu_L-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)=\frac{1}{f}$$

LENS FORMULA

$$\frac{1}{v}-\frac{1}{u}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)=\frac{1}{f}$$



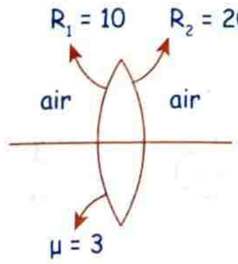
$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$ (Lens Formula) $\qquad \frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

given $\qquad\qquad \equiv$ (Lens in air)

$\frac{1}{f}=\left(\frac{\mu}{\mu_m}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ (If lens is in medium)

$\frac{1}{f}=(\mu-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ (If lens is in air)

Q. For the following lens calculate part (a) and part (b)

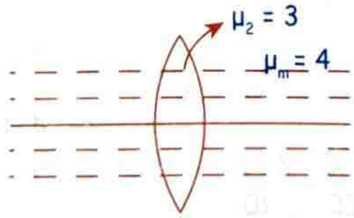


(a) Final focal length

Sol. $\frac{1}{f}=(3-1)\left(\frac{1}{10}-\frac{1}{-20}\right)\Rightarrow f=\frac{10}{3}$

(b) If this lens is dipped in water $\mu=4$, F = ?

Sol.



$$\frac{1}{f}=\left(\frac{\mu}{\mu_m}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

$$\frac{1}{f}=\left(\frac{3}{4}-1\right)\left(\frac{1}{10}-\frac{1}{-20}\right)$$

Solve and get

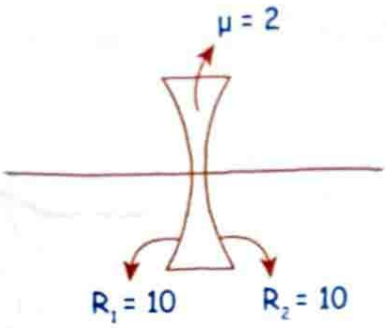
$f=\frac{-80}{3}$, $f<0$ $\;=p=\frac{1}{f}\Rightarrow P<0$ (Diverging)

(c) If this lens is dipped in water $\mu=2$. find focal length

Sol. $\frac{1}{f}=\left(\frac{3}{2}-1\right)\left(\frac{1}{10}-\frac{1}{-20}\right)=\frac{1}{2}\times\frac{3}{20}$

$\boxed{f=+\frac{40}{3}}$ $f>0$

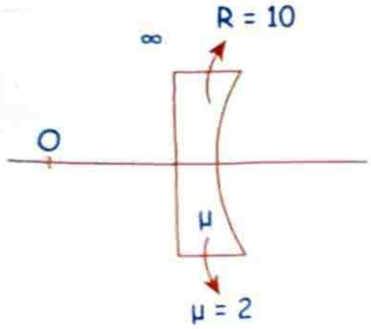
Q. Find focal length



Sol. $\frac{1}{f} = (2-1)\left(\frac{1}{-10} - \frac{1}{+10}\right)$

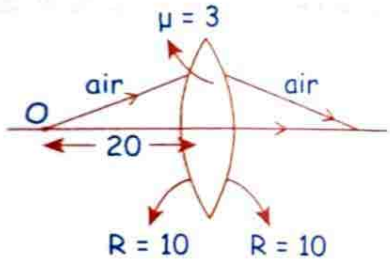
$f = -5$

Q. Find focal length



Sol. $\frac{1}{f} = (2-1)\left(\frac{1}{\infty} - \frac{1}{+10}\right)$

Q. Find F, location and nature of image.



(equiconvex lens)

Sol. $\frac{1}{f} = (3-1)\left(\frac{1}{10} - \frac{1}{-10}\right)$

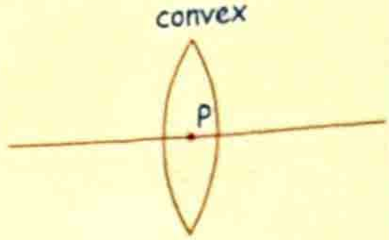
$f = \frac{10}{4} = \frac{5}{2}$

$u = -20, f = \frac{5}{2}$

$\frac{1}{v} - \frac{1}{-20} = \frac{1}{5/2} = \frac{2}{5}$

$\boxed{V = +\frac{20}{7}}$ (R.I.)

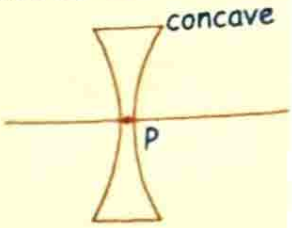
LENS FORMULA



- $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ $\boxed{v = \frac{uf}{u+f}}$
- $m = \frac{h_I}{h_0} = \frac{v}{u} = \frac{f}{u+f}$

Sign Convention (Paraxial Rays)

- सारे measurement 'p' से करने है
- Direction of incident ray taken as +ve
- ↑ +ve, ↓ −ve



$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$\frac{1}{v} = \frac{1}{f} + \frac{1}{u}$

$u < 0 \longrightarrow$ R.O.

$u > 0 \longrightarrow$ V.O.

$v > 0 \longrightarrow$ Real Image

$v < 0 \longrightarrow$ Virtual Image

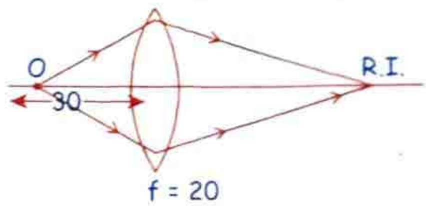
$m > 0 \longrightarrow$ erect

$m < 0 \longrightarrow$ invented

$f > 0$ (convex in air)

$f < 0$ (concave in air)

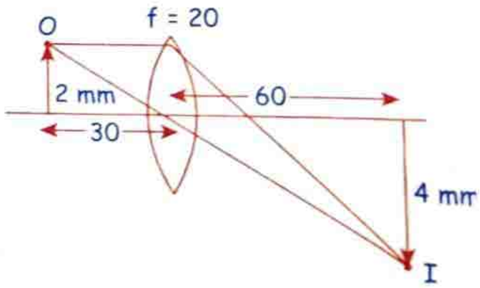
Q. Find location of image and magnification.



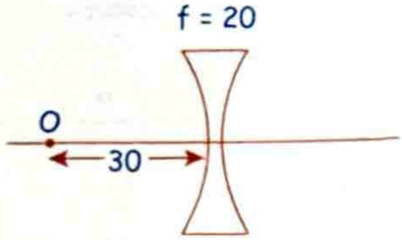
Sol. $v = \frac{uf}{u+f} = \frac{-30 \times (+20)}{(-30)+(+20)} = \frac{-600}{-10} = +60$ (R.I)

$m = \frac{v}{u} = \frac{60}{-30} = -2$ (inverted and enlarge)

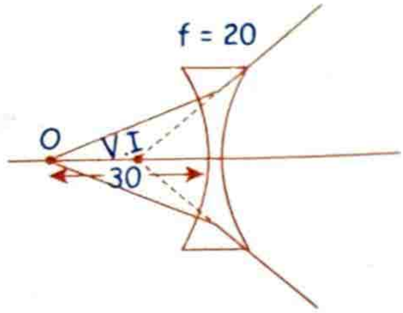
Q. If object is move to 2mm above the PA then distance of image from PA will be



Q. Find the location of image



Sol.



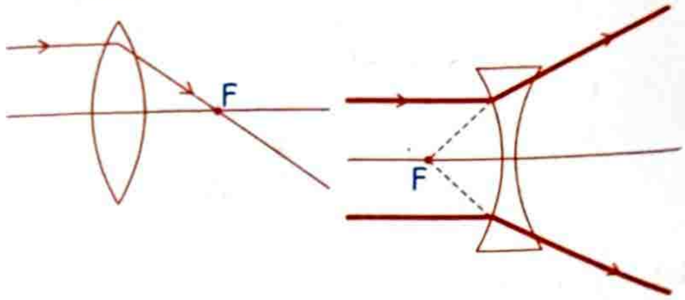
$u = -30$

$f = -20$

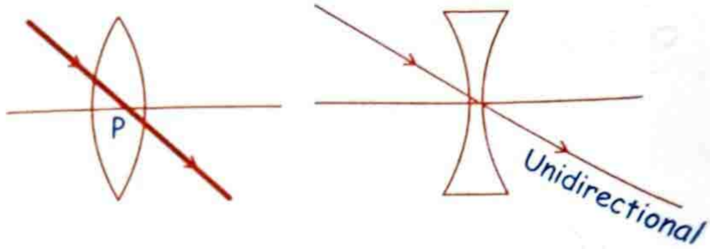
$v = \dfrac{600}{-30-20} = -12$ V.I

Rules for Image Tracing

(1) Rays Parallel to principal axis passes through focus

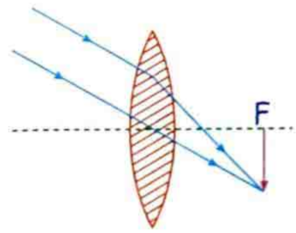
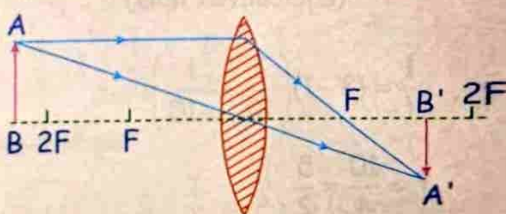
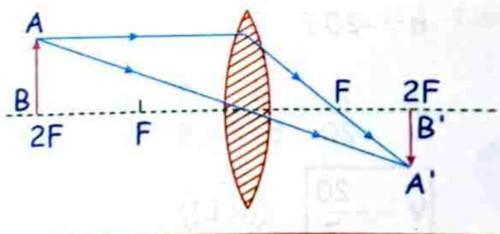


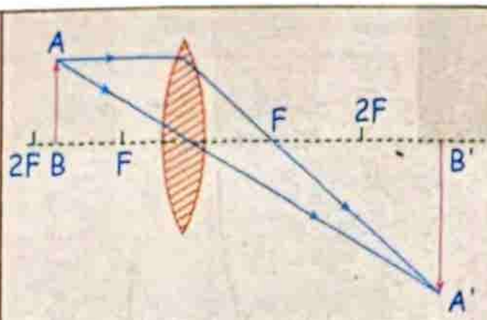
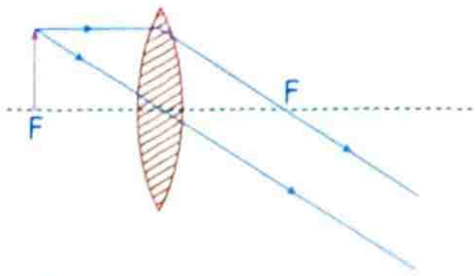
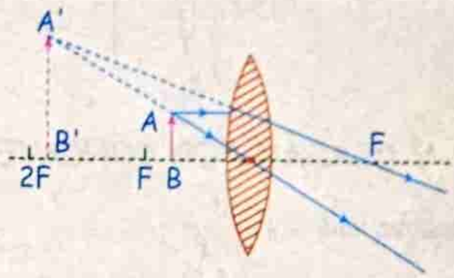
(2) Rays passing thrugh pole passes undeviated



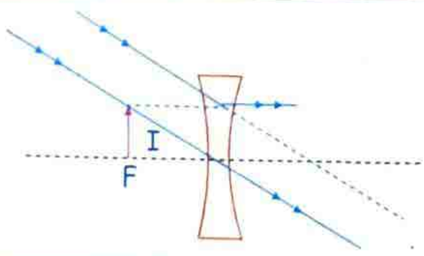
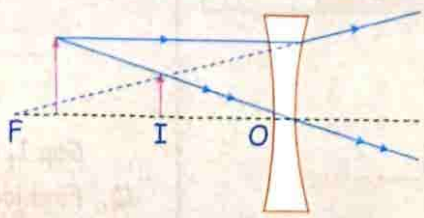
POSITION, SIZE AND NATURE OF IMAGE FROM LENS

For Convergent or Convex Lens

Position of Object	Position of Image	Real/ Virtual	Inverted/ Erect	Magnification and Size of Image	Sign of Magnification	Ray Diagram
at infinity ($u \to \infty$)	at focus ($v = f$)	real	inverted ($m < 0$)	$\|m\| \ll 1$ greatly diminished	negative	
beyond 2f ($\|u\| > 2f$)	between f and 2f ($f < v < 2f$)	real	inverted ($m < 0$)	$\|m\| < 1$ diminished	negative	
at 2f ($\|u\| = 2f$)	at 2f ($v = 2f$)	real	inverted ($m < 0$)	$\|m\| = 1$ same size	negative	

between f and 2f ($f < \|u\| < 2f$)	beyond 2f ($v > 2f$)	real	inverted ($m < 0$)	$\|m\| > 1$ magnified	negative	
at f ($\|u\| = f$)	at infinity ($v = \infty$)	real	inverted ($m < 0$)	$\|m\| \to \infty$ magnified	negative	
between optical centre and focus ($\|u\| < f$)	at a distance greater than the object distance and on the same side of object ($v > u$)	virtual	erect ($m > 0$)	$\|m\| > 1$ magnified	positive	

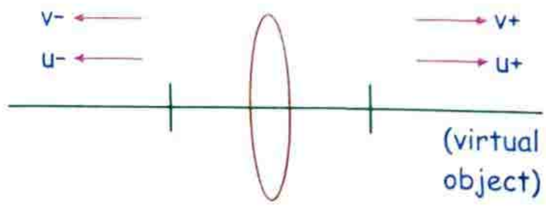
For Divergent or Concave Lens

S.No.	Position of Object	Position of Image	Ray Diagram	Nature of Image	Size
1.	At infinity	At F		Virtual, erect ($m > 0$)	Highly diminished ($\|m\| \ll +1$)
2	In front of lens	Between F and optical centre		Virtual, erect ($m > 0$)	Diminished ($\|m\| < +1$)

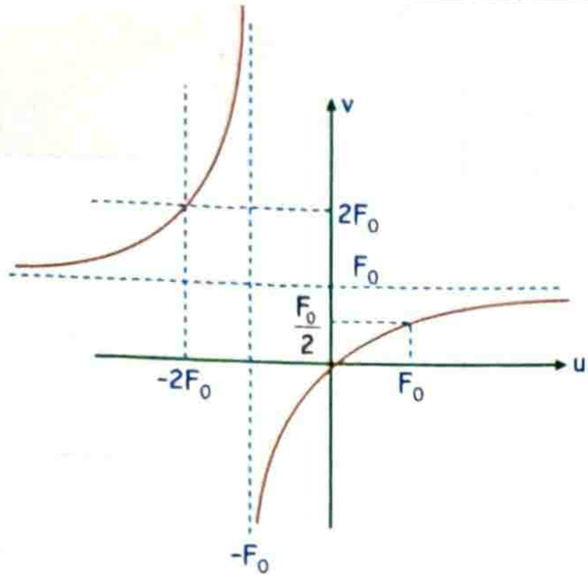
u-v Diagram for Convex Lens

Convex Lens: $v = \dfrac{uf}{u+f}$, f is positive let $f = F_0$

$$v = \frac{uF_0}{u + F_0}$$

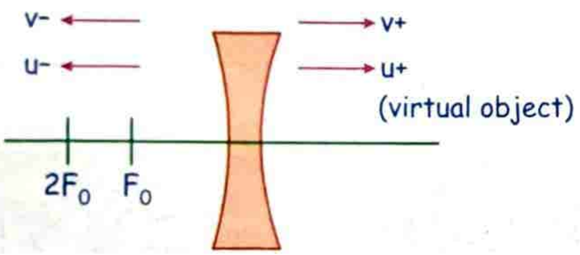


u	$-\infty$	$-2F_0$	$-F_0$	0	F_0	∞
v	F_0	$2F_0$	$\pm\infty$	0	$\frac{F_0}{2}$	F_0



U-V DIAGAM FOR CONCAVE LENS

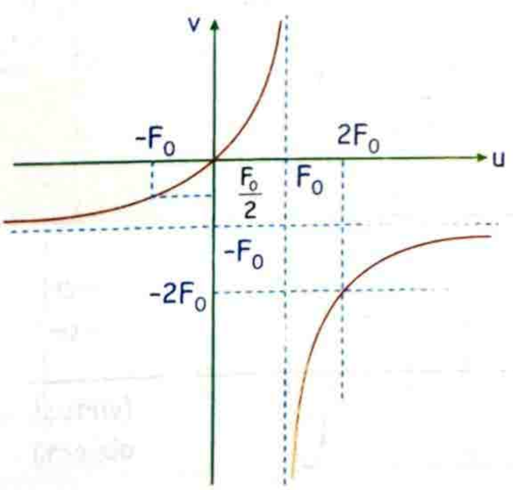
concave lens: $v = \dfrac{uf}{u+f}$



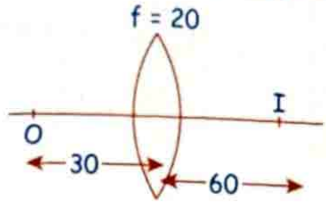
f is negative, let $f = -F_0$

$$v = \frac{-uF_0}{u - F_0}$$

u	$-\infty$	$-F_0$	0	F_0	$2F_0$
v	$-F_0$	$\frac{-F_0}{2}$	0	$\pm\infty$	$-2F_0$



Q. For the following diagram solve all parts



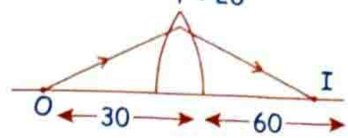
Sol. u = –30

f = +20

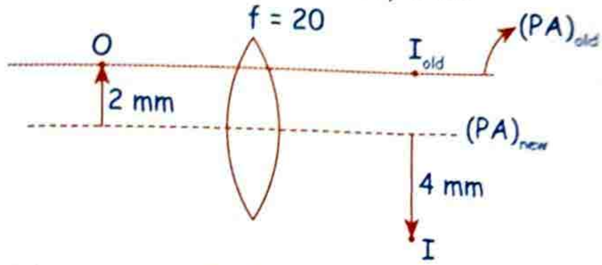
v = +60

m = –2

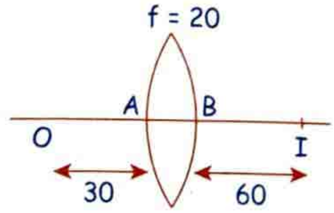
(a)



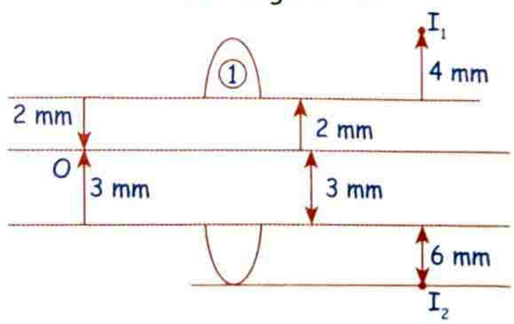
(b) If lens is shifted down by 2 mm



(c)

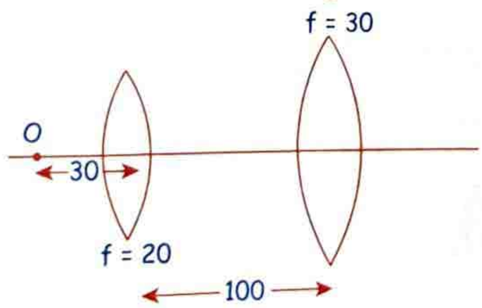


Lens is cut along line AB upper half is shifted up by 2 mm lower half is shifted down by 3 mm Distance b/w two image will be

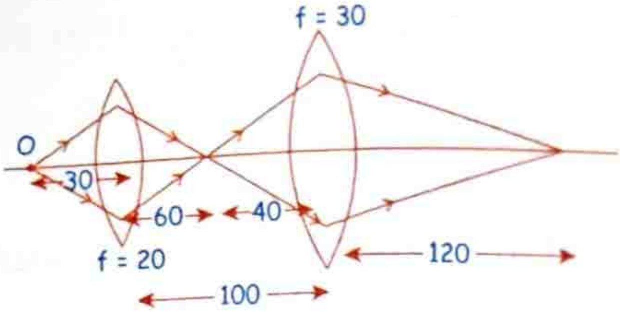


Gap I_1 & $I_2 \Rightarrow 4 + 2 + 3 + 6 = \underline{15}$

Q. Find location of final image.



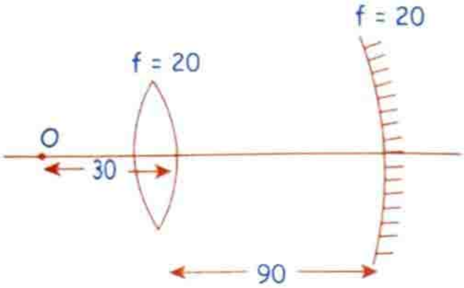
Sol.



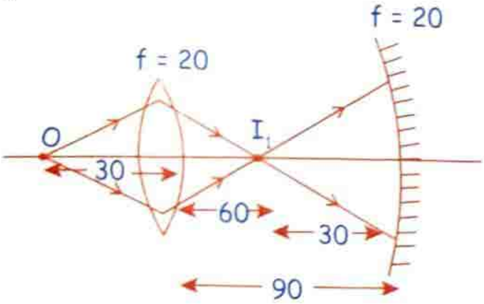
$$2^{nd}\text{ Lens } v = \frac{-40 \times 30}{-40 + 30} = 120$$

$$m_2 = \frac{120}{-40} = -3$$

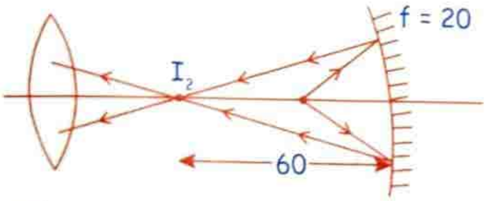
Q. Find the location of image finally formed



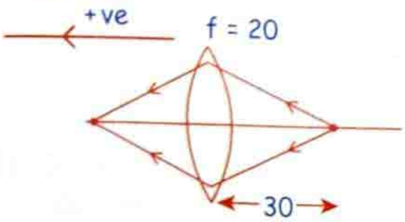
Sol. First lens make real image of object O at a distance 60 cm from it which behave like real object for second mirror.



reflection (u = –30, f = –20 solve and get v = –60)



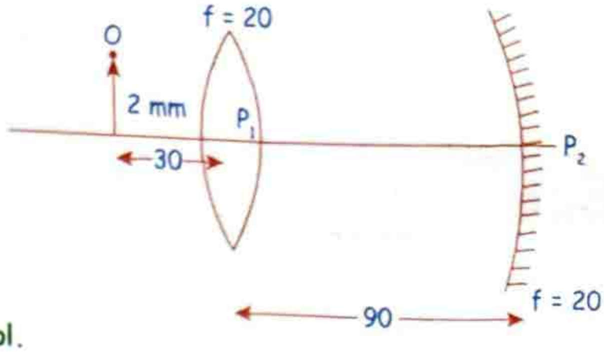
2^{nd} time lens



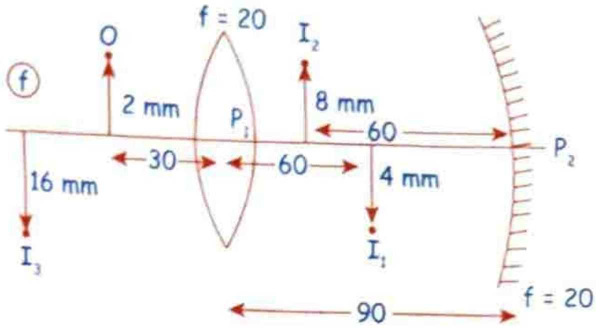
Now for lens u = -30, f = +20

Solve and get v = +60

Q. Find location of final image if object is shifted 2 mm perpendicular to the PA in above question.



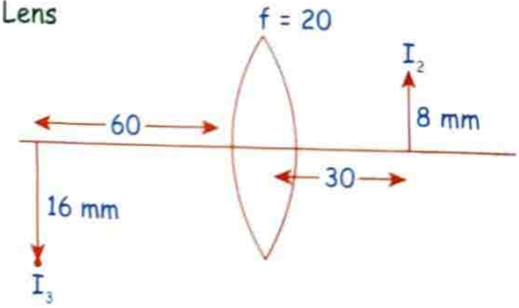
Sol.



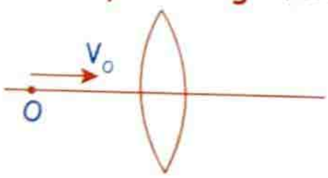
(1) Lens = u = 60, m = –2

(2) mirror $\left.\begin{matrix} u = -30 \\ f = -20 \end{matrix}\right\}$ $\begin{matrix} u = -60 \\ m = -2 \end{matrix}$

(3) Lens



Velocity of image formed by lens



$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$-\frac{1}{v^2}\left(\frac{dv}{dt}\right) + \frac{1}{u^2}\left(\frac{du}{dt}\right) = 0$$

$\frac{dv}{dt} \rightarrow V_{Image}$ $\quad$ $\frac{du}{dt} \rightarrow V_{object}$

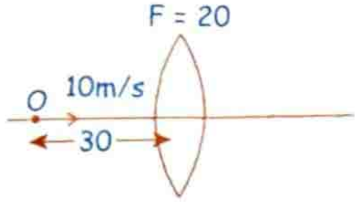
$$\boxed{v_{Image} = \frac{v^2}{u^2} v_{object}}$$

$$\boxed{v_I = m^2 v_O}$$

जैसे mirror के case मे velocity of image के question बने थे same as it is यहाँ बन जाएंगे बस अंतर इतना है कि

Along the PA	Along the PA
$\vec{v}_I = m^2\vec{v}_O$	$\vec{v}_I = -m^2\vec{v}_O$
$\vec{v}_{I/L} = m^2\vec{v}_{O/L}$	$\vec{v}_{I/L} = -m^2\vec{v}_{O/L}$
Lens	Mirror

Q. Find the velocity of image

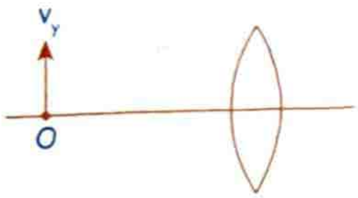


Sol. $v = +60,\ m = -2$

$v_I = m^2 v_O$

$v_I = 4 \times 10\hat{i} = 40\hat{i}$

Q. Find the velocity of image for the object as shown in figure



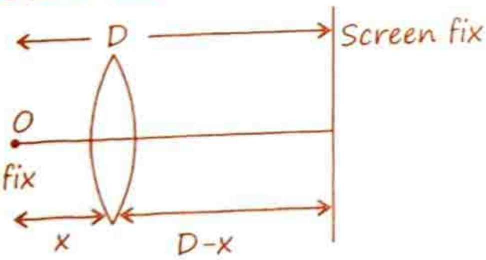
Sol. $m = \frac{h_I}{h_O}$

$h_I = m h_O$

$\frac{dh_I}{dt} = m\frac{dh_O}{dt} + \cancel{h_O}\overset{O}{\frac{dm}{dt}}$

$\boxed{(v_I)_y = m(u)_y}$

Displacement Method



Final image formed at screen.

$u = -x,\ v = D-x$

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$\frac{1}{D-x} - \frac{1}{-x} = \frac{1}{f}$

$\frac{1}{D-x} + \frac{1}{x} = \frac{1}{f} = \frac{x+D-x}{(D-x)x} = \frac{D}{Dx-x^2}$

$Dx - x^2 = Df$

$\boxed{x^2 - Dx + Df = 0}$

$D^2 - 4 \times 1 \times Df > 0$ (2 root, $x_1 : x_2$)

- $\boxed{D > 4f}$ → Two position of lens x_1 and x_2 detect
- $D = 4f$ → one one position
- $D < 4f$ → No position will observe

$$x_1 = \frac{D + \sqrt{D^2 - 4Df}}{2}$$

$$x_2 = \frac{D - \sqrt{D^2 - 4Df}}{2}$$

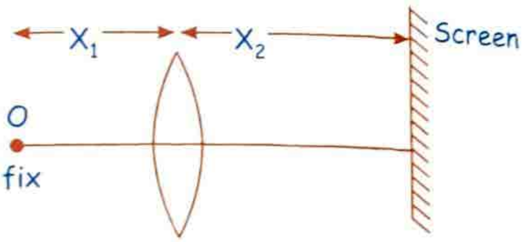
$\boxed{x_1 + x_2 = D}$

$x_1 - x_2 = d$

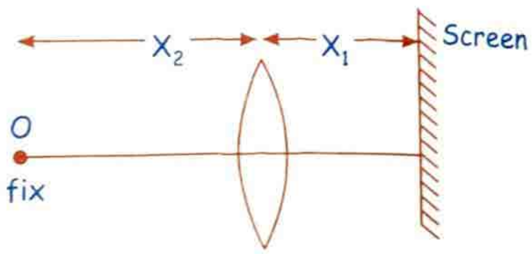
$$\boxed{x_1 = \frac{D+d}{2} \quad x_2 = \frac{D-d}{2}}$$

$x_1 - x_2 = d \equiv$ gap b/w two position of lens जिनसे screen पर image बनी

Suppose we got real image on screen by having two position of lens x_1 and x_2



$m_1 = \frac{x_2}{-x_1}$



$m_2 = \frac{x_1}{-x_2} \qquad m_1 m_2 = 1$

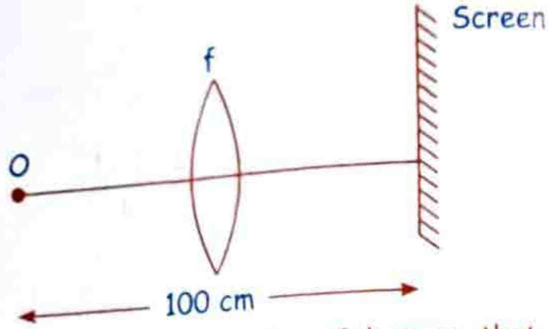
$m_1 = \frac{h_{I_1}}{h_O} = \frac{v}{u} = \frac{x_2}{-x_1}$

$m_2 = \frac{h_{I_2}}{h_O} = \frac{x_1}{-x_2}$

$$m_1 \times m_2 = 1 = \frac{h_{I_1}}{h_0} \times \frac{h_{I_2}}{h_0}$$

$$h_0 = \sqrt{h_{I_1} \times h_{I_2}}$$

Q.



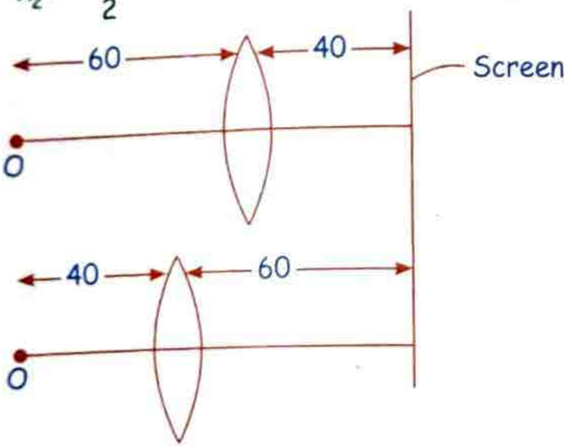
Gap b/w two position of lens so that image formed at screen is 20 cm. Find f

Sol. D = 100

d = 20

$$x_1 = \frac{D+d}{2} = 60$$

$$x_2 = \frac{D-d}{2} = 40$$



$$\frac{1}{40} - \frac{1}{-60} = \frac{1}{f}$$

Solved and get 'f'.

Q. In displacement method distance between object and screen is 100 cm for a given object. Height of image on screen were 4 mm and 9 mm find (1) height of object, (2) focal length

Sol. (1) D = 100cm.

$h_{I_1} = 4, h_{I_2} = 9$

$= \sqrt{h_{I_1} h_{I_2}} = \sqrt{4 \times 9} = 6\text{mm}$

(2) D > 4f

100 > 4f

f < 25

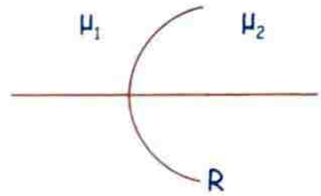
POWER

जिसके पास जितनी ज्यादा positive power है उसके पास rays को converge करने की उतनी ज्यादा क्षमता है similarly जिसके पास जितनी ज्यादा negative power है उसके पास rays को diverge करने की उतनी ज्यादा क्षमता है।

- $P > 0 \longrightarrow$ Converge
- $P < 0 \longrightarrow$ diverge

Unit diopter $\Rightarrow$ f $\longrightarrow$ meter

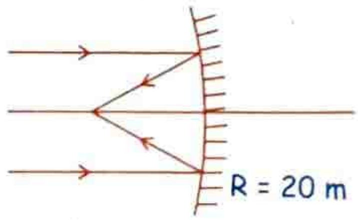
def. का minus है

- $P_{mirror} = -\frac{1}{f}$
- $P_{Lens} = \frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$
- 

$$\boxed{P = \frac{\mu_2 - \mu_1}{R}}$$

Q. Calculate the power in the following cases

(1)

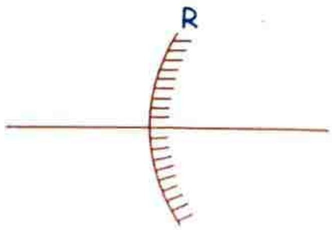


Sol. $f = -\frac{R}{2}$

$$P = -\frac{1}{f} = \frac{-1}{-R/2} = +\frac{2}{R}$$

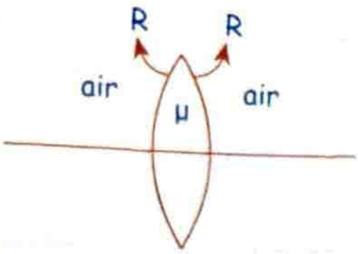
$P > 0$

(2)



$$P = -\frac{1}{f} = \frac{-1}{+R/2}$$

(3)

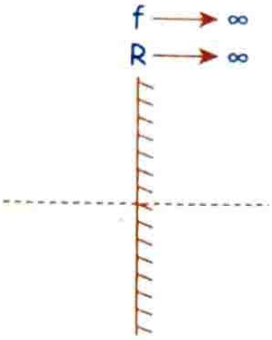


$$P=\frac{1}{f}=(\mu-1)\left(\frac{1}{R}-\frac{1}{-R}\right)$$

$$P=(\mu-1)\frac{2}{R}$$

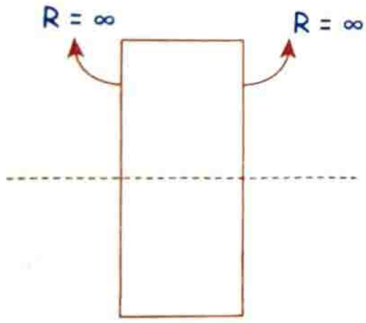
P > 0 = converging
(Convex lens in Air)

(4)



$P=-\frac{1}{f}$ $\boxed{P=0}$

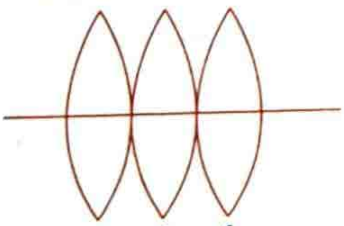
(5)



$$P=\frac{1}{f}=(\mu-1)\left(\frac{1}{\infty}-\frac{1}{\infty}\right)$$

P = 0

Thin Lens in Contact



f_1 f_2 f_3

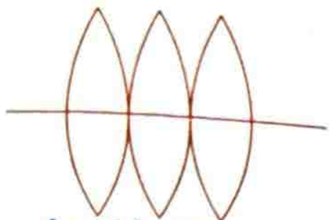
$P=P_1+P_2+P_3$

$$P_{net}=\frac{1}{f_{net}}=\frac{1}{f_1}+\frac{1}{f_2}+\frac{1}{f_3}$$

f_1, f_2, f_3 put with sign

Examples:

(1)

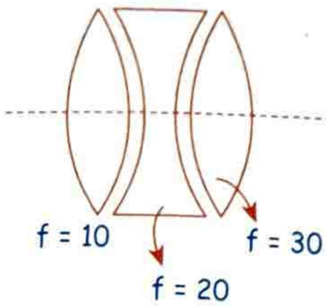


f = 20 f = 60 f = 30

$$P_{net}=\frac{1}{f_{net}}=\frac{1}{20}+\frac{1}{30}+\frac{1}{60}=\frac{3+2+1}{60}$$

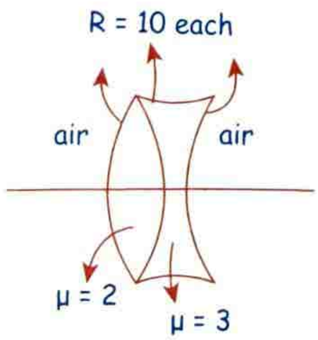
$$\boxed{P=\frac{1}{10}}$$

(2)



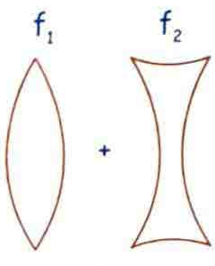
$$\frac{1}{f_{eq}}=\frac{1}{+10}+\frac{1}{-20}+\frac{1}{+30}$$

Q. Find the equivalent power of lens as shown



$P_{net}=$

Sol.



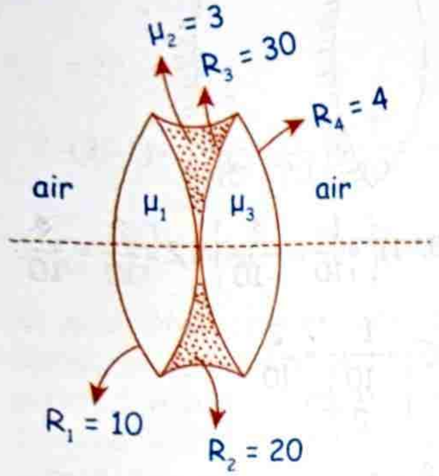
दोनो के बीच very-very small thin layer of air.

$$\frac{1}{f_{eq}}=\frac{1}{f_1}+\frac{1}{f_2}$$

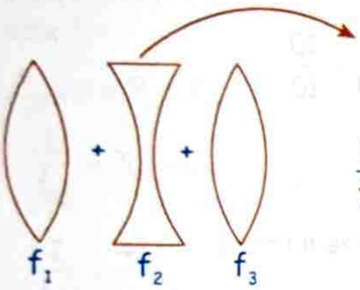
$$=(2-1)\left(\frac{1}{10}-\frac{1}{-10}\right)+(3-1)\left(\frac{1}{-10}-\frac{1}{+10}\right)$$

Q. Find the equivalent power of lens as shown

$\mu_1 = 2$ $\mu_2 = 3$ $\mu_3 = 4$



Sol.



$$\frac{1}{f_2} = (3-1)\left(\frac{1}{-20} - \frac{1}{30}\right)$$

$$= -2 \times \left(\frac{3+2}{60}\right)$$

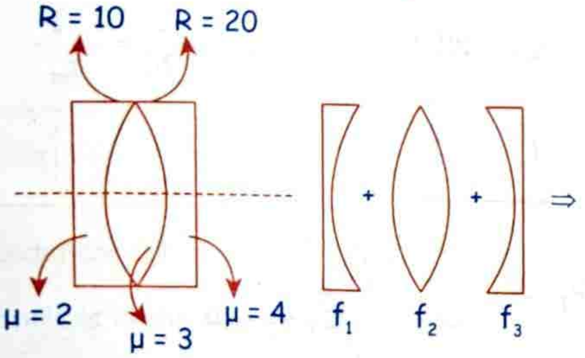
$$\frac{1}{f_{eq}} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3}$$

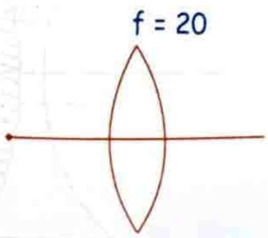
$$= (2-1)\left(\frac{1}{10} - \frac{1}{-20}\right) + (3-1)\left(\frac{1}{-20} - \frac{1}{+30}\right)$$

$$+ (4-1)\left(\frac{1}{+30} - \frac{1}{-40}\right)$$

Q. Find (1) feq (2) Power

(3) If an object is placed at a distance 20 cm from lens find location of image.





(1) $\frac{1}{f_{eq}} = (2-1)\left(\frac{1}{\infty} - \frac{1}{+10}\right) + (3-1)\left(\frac{1}{+10} - \frac{1}{-20}\right)$

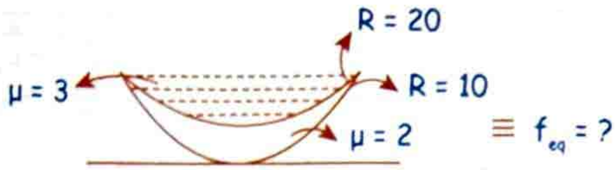
$$+ (4-1)\left(\frac{1}{-20} - \frac{1}{\infty}\right)$$

$f_{eq} = 20$

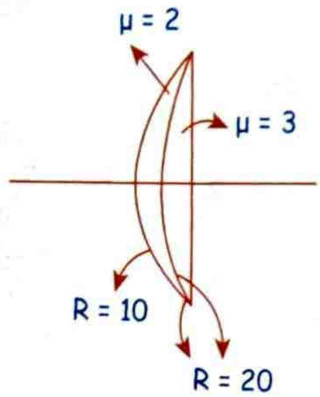
(2) Power $= \frac{1}{20}$ D

(3) $\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \Rightarrow \frac{1}{20} = \frac{1}{v} - \frac{1}{-20}$

Q. Find the equivalent focal length



Sol. Equivalent of above diagram is as follow



Solved by yourself

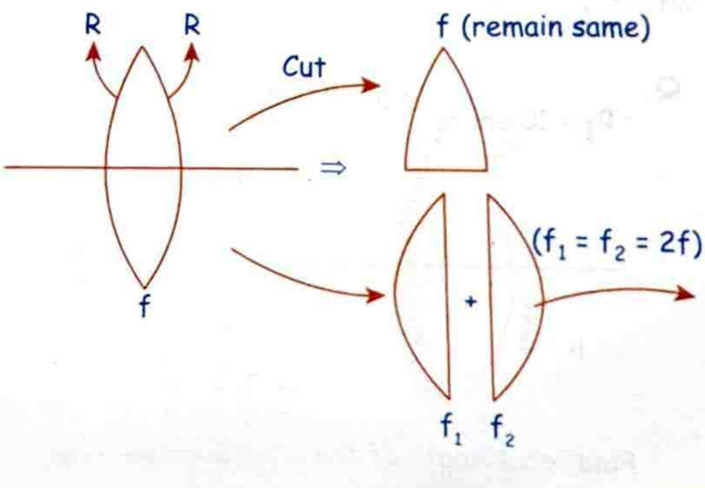
Ans. $f_{eq} = 20/3$

Cutting of Lens

If a equiconvex lens of power P is cut into ways as shown in figure. Find focal length of lens form after cutting.

Before Cutting

$$P = \frac{1}{f} = (\mu - 1)\left(\frac{1}{R} - \frac{1}{-R}\right)$$

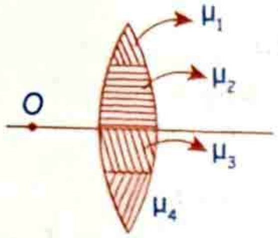


$$\frac{1}{f_1} = (\mu - 1)\left(\frac{1}{R} - \frac{1}{\infty}\right) = \frac{\mu - 1}{R} = \frac{1}{2f}$$

$$\frac{1}{f_2} = (\mu - 1)\left(\frac{1}{\infty} - \frac{1}{-R}\right)$$

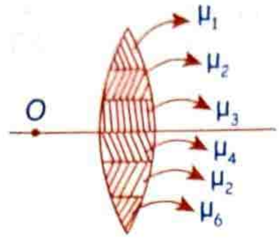
$$\frac{1}{f_2} = \frac{\mu - 1}{R} = \frac{1}{2f}$$

Hence $P_1 = P_2 = P/2$
$f_1 = f_2 = 2f$

♦ 

(4 lens)

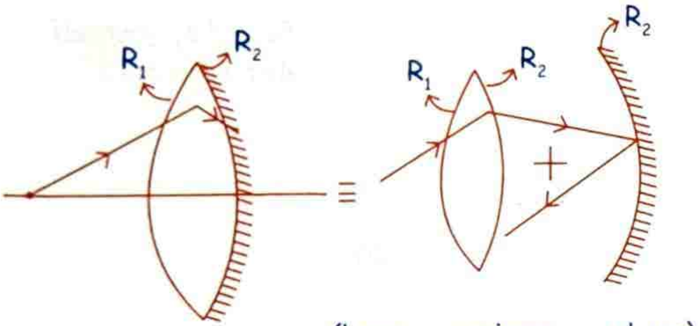
आधे अधूरे f → अलग

♦ 

No. of image = 6 ✗

= 5 ✓

SILVERING OF LENS



(Lens ⟶ mirror ⟶ Lens)

$P_{net} = P_L + P_m + P_L$

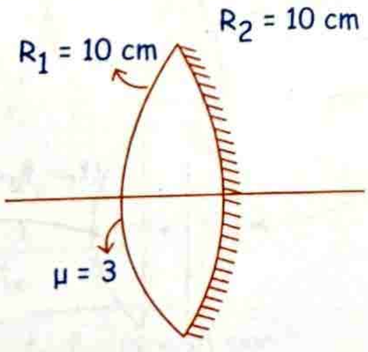
$P_{net} = 2P_L + P_m$

$f_{eq} = ?$

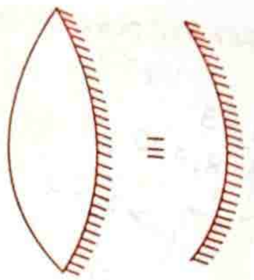
$$P_{net} = -\frac{1}{f_{eq}}$$

$$P_L = \frac{1}{f_L} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$P_m = -\frac{1}{f_m}$$

Q. 

Find focal length of the



Sol. $P_L = \frac{1}{f_L} = (3-1)\left(\frac{1}{+10} - \frac{1}{-10}\right) = 2 \times \frac{2}{10} = \frac{4}{10}$

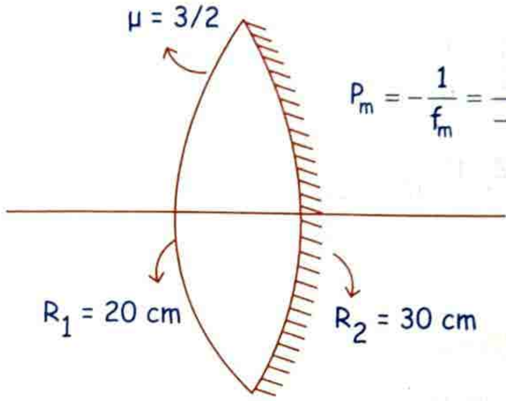
$$P_m = -\frac{1}{f_m} = -\frac{1}{\left(-\frac{10}{2}\right)} = \frac{2}{10}$$

$P_{net} = 2P_L + P_m$

$$P_{net} = 2 \times \frac{4}{10} + \frac{2}{10} = \frac{10}{10}$$

$$P_{net} = \frac{10}{10} = -\frac{1}{f_m}$$

$f_m = -1$ (Concave mirror)

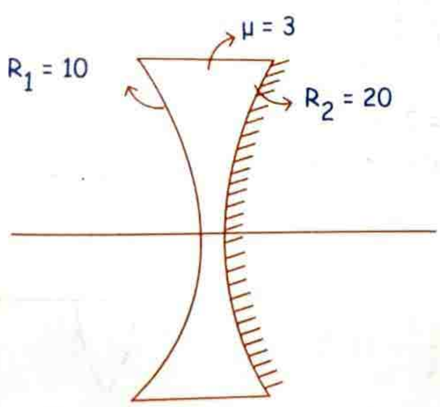
♦ 

$$P_m = -\frac{1}{f_m} = \frac{-1}{-30/2} = \frac{2}{30}$$

$P_{net} = 2P_L + P_m$

$$P_{net} = 2(1.5-1)\left(\frac{1}{20} - \frac{1}{-30}\right) + \frac{2}{30} = -\frac{1}{f_{eq}}$$

$$\boxed{f_{eq} = \frac{-20}{3}}$$

♦ 

$$P_m = -\frac{1}{\frac{20}{+2}} = -\frac{2}{20}$$

$$P_{net} = 2P_L + P_m$$

$$= 2\cdot(3-1)\times\left(\frac{1}{-10} - \frac{1}{20}\right) - \frac{1}{10} = -\frac{1}{f_{eq}}$$

$$\Rightarrow f_{eq} = \frac{10}{7} \text{ (behaving like convex mirror)}$$

Q. An equiconvex lens of refractive index μ and radius of curvature R has its one surface silvered. A point source O is placed before the silvered lens so that its **image is coincident** with it, the **distance of the object from the lens is**:-

Sol. $P_{net} = 2\,P_L + P_m$

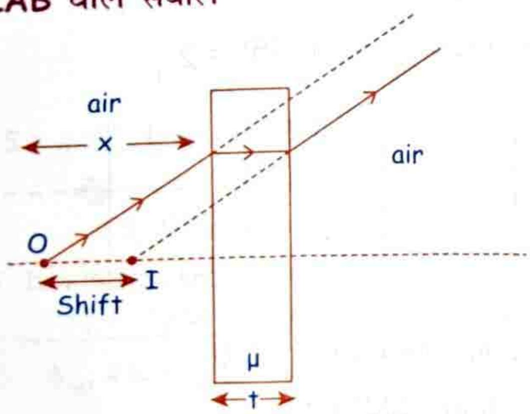
$$-\frac{1}{f_{eq}} = 2(\mu-1)\left(\frac{1}{R} - \frac{1}{-R}\right) + -\frac{1}{-R/2}$$

$$-\frac{1}{f_{eq}} = \frac{4(\mu-1)}{R} + \frac{2}{R} = \frac{4\mu - 4 + 2}{R}$$

$$f_{eq} = \frac{-R}{4\mu-2} \qquad \text{Ans} \qquad 2f_{eq} = \left|\frac{R}{1-2\mu}\right| = \checkmark$$

SLAB वाले सवाल

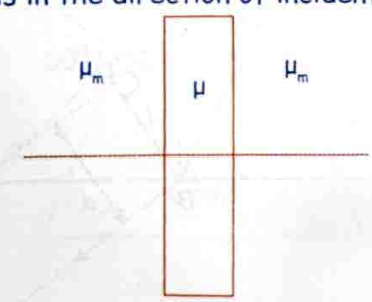
♦



$$\boxed{\text{Shift} = t\left(1 - \frac{1}{\mu}\right)}$$

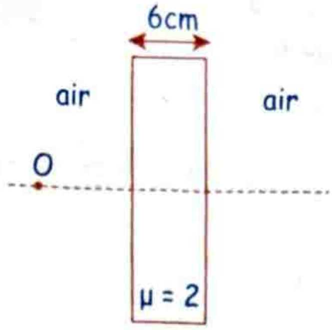
→ Independent of x

→ Shift is in the direction of incident ray.



$$\text{shift} = t\left(1 - \frac{\mu_m}{\mu_{slab}}\right)$$

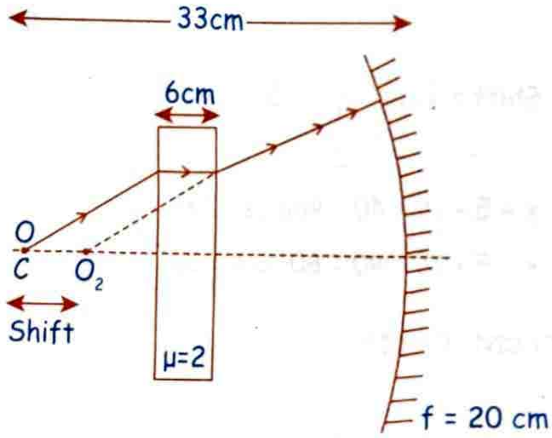
♦



$$\text{Shift} = t\left(1 - \frac{1}{\mu}\right)$$

$$= 6\left(1 - \frac{1}{2}\right) = 3\text{cm}$$

Q. Find location of final image after all possible relection and refraction.



$$\text{shift} = 6\left(1 - \frac{1}{2}\right) = 3\text{cm}$$

For mirror ⇒ object = O_2 (shift होने के बाद)

$u = -(33 - 3) = -30$

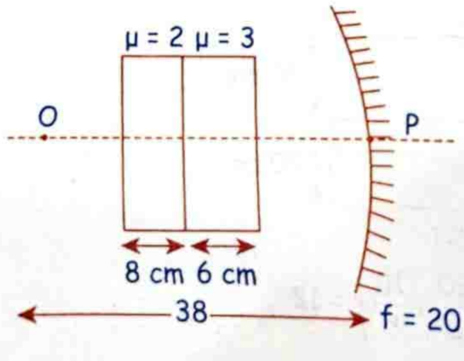
$f = -20$

$v = \frac{uf}{u-f} = -60$ — यहाँ पर mirror Reflected ray भेजना चाहता है

Reflection ≡ slab ≡ shift = 3

Final image will be at = 60 + 3 = <u>63</u>

♦



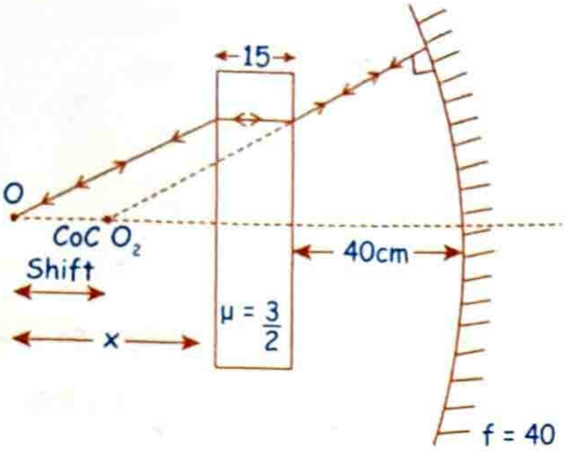
$$(\text{shift})_{net} = (\text{shift})_1 + (\text{shift})_2$$

$$= 8\left(1-\frac{1}{2}\right)+6\left(1-\frac{1}{3}\right) = 8$$

Final image from 'P'

$= 60 + 8 = 68$ ✓

Q. Find value of x. So that final image formed at object.

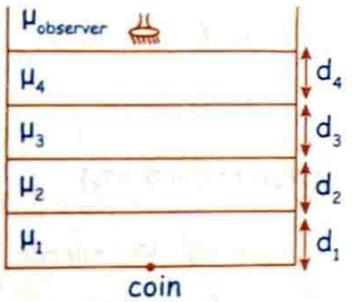


$$\text{Shift} = 15\left(1-\frac{1}{\frac{3}{2}}\right) = 5$$

$x - 5 + 15 + 40 = \text{Radius} = 2f$

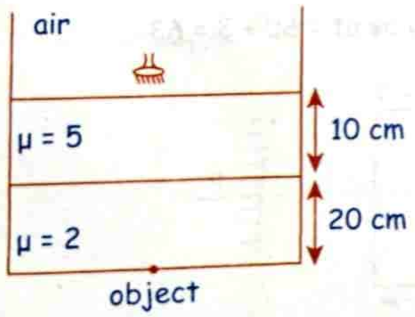
$x - 5 + 15 + 40 = 80 \Rightarrow x = 30$

Apparent Depth:



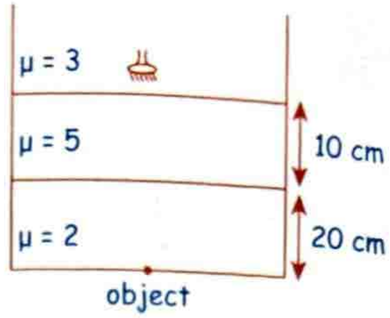
$$d_{app} = \mu_{observer}\left(\frac{d_1}{\mu_1}+\frac{d_2}{\mu_2}+\cdots\right)$$

♦



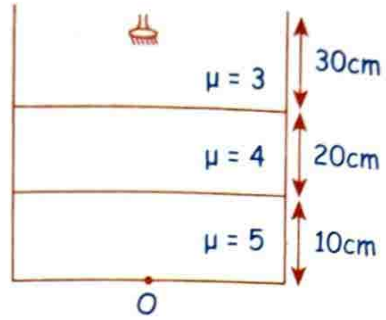
$$h_{app} = 1\left(\frac{20}{2}+\frac{10}{5}\right) = 12$$

♦



$$h_{app} = 3\left(\frac{20}{2}+\frac{10}{5}\right) = 36$$

♦



$$h_{ap} \Rightarrow 3\left(\frac{20}{4}+\frac{10}{5}\right)+30$$

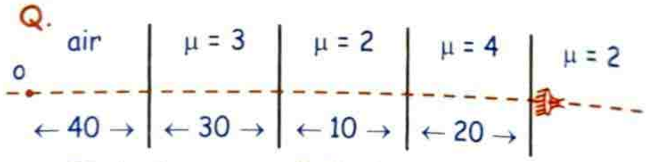
$$= 15 + 6 + 30 = 51$$

or

$$h_{app} = 3\left(\frac{10}{5}+\frac{20}{4}+\frac{30}{3}\right) = 51$$

Shift = (30 + 20 + 10) − (51) = 9

Q.

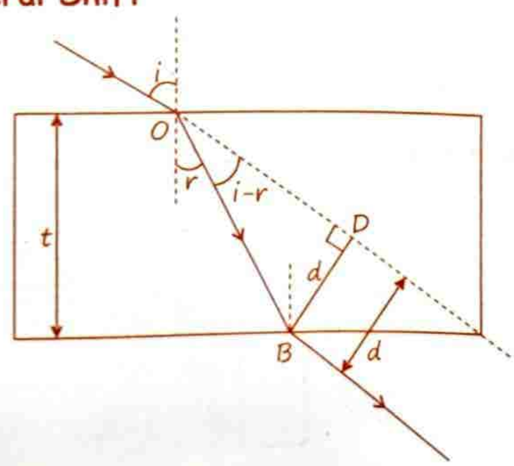


Find distance of final image observed by observer

Sol. $d_{app} = 2(40 + 10 + 5 + 5) = 120$

shift = |100 − 120| = 20

Lateral Shift



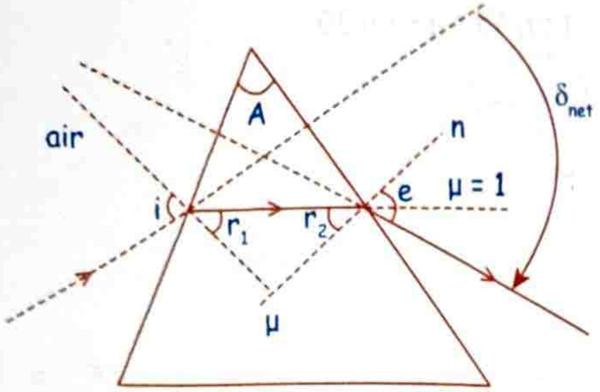
$d = OB \sin(I - r)$

$t = OB \cos r$

Lateral shift

$$d = \frac{t \sin(i - r)}{\cos r}$$

PRISM



$90 - r_1 + 90 - r_2 + A = 180 \qquad A = r_1 + r_2$

$A \rightarrow$ angle of prism, refracting angle

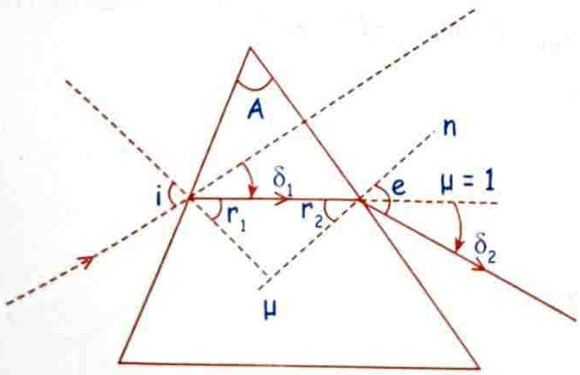
(1) $1 \cdot \sin i = \mu \sin r_1$

$\mu \sin r_2 = 1 \cdot \sin e$

(2) $r_1 + r_2 = A$

(3) $\delta_{net} = i + e - A$

◆



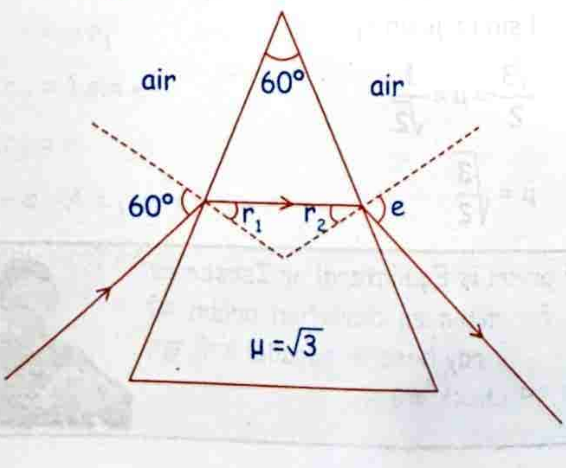
$\delta_1 = i - r_1$ (cw)

$\delta_2 = i - r_2$ (cw)

$\delta_{net} = \delta_1 + \delta_2 = i + e - r_1 - r_2 = i + e - (r_1 + r_2)$

$= i + e - A$

Q. Find δ_{net} = ?



Sol. $1.\sin 60 = \sqrt{3} \sin r_1$

$\frac{\sqrt{3}}{2} = \sqrt{3} \sin r_1$

$r_1 = 30$

$\Rightarrow r_1 + r_2 = A$

$30 + r_2 = 60$

$r_2 = 30$

$\sqrt{3} \sin 30 = 1. \sin e$

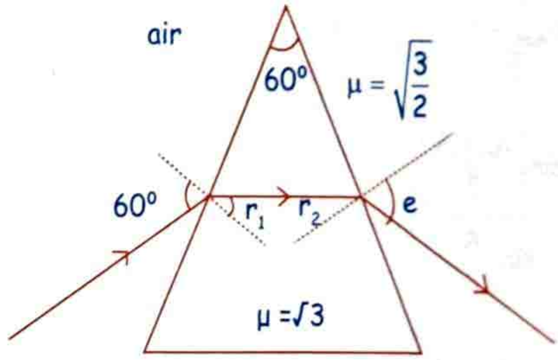
$e = 60°$

$\delta = i + e - A$

$= 60 + 60 - 60$

$\delta = 60°$

Q. Find angle of emergence e.



Sol. $r_1 = 30$ already solved

$r_2 = 30°$

$\sqrt{3} \sin 30 = \frac{\sqrt{3}}{2} \sin e$

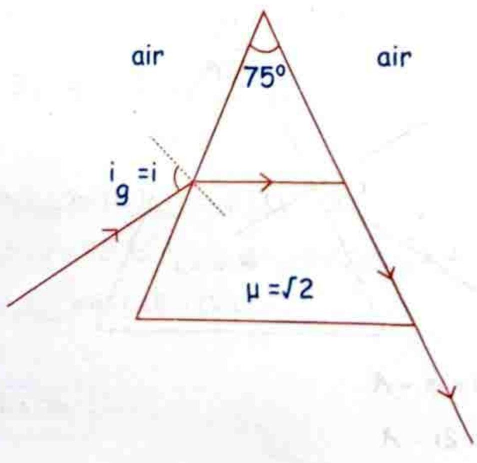
$\boxed{e = 45°}$

$\delta = 30 + 15 = 45°$

$\delta = i + e - A$

$= 60 + 45 - 60 = 45°$

Q. Find the angle of incident for which grazing emerges. i.e $\angle e = 90°$.



Sol. $r_2 = \theta_c = 45°$

$r_1 = 30°$

$1.\sin i_g = \sqrt{2}\sin 30°$

$i_g = 45°$

Mathematically after solving we got

$\delta_{min} \rightarrow$ when $i = e$

$r_1 = r_2 = \frac{A}{2}$

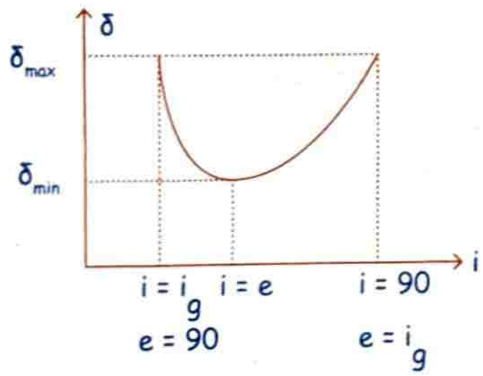
$\delta_{min} = i + e - A = 2i - A$

For min deviation

$1 \cdot \sin i = \mu \sin r_1$

$$\sin\left(\frac{\delta_{min} + A}{2}\right) = \mu \sin\left(\frac{A}{2}\right)$$

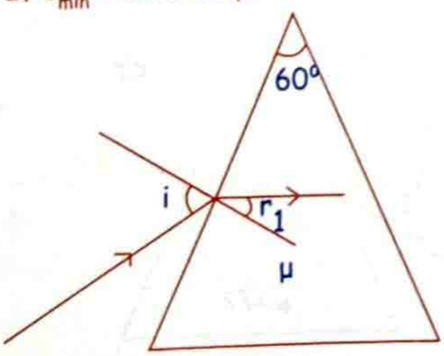
$$\mu = \frac{\sin\left(\frac{\delta_m + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$



$\delta = i + e - A$

$\delta_{max} = i_g + 90 - A$

Q. If $\delta_{min} = 30$. Find μ.



Sol. $\delta = i + e - A$

$\delta_{min} = 2i - A$

$30 = 2i - 60$

$i = 45°$

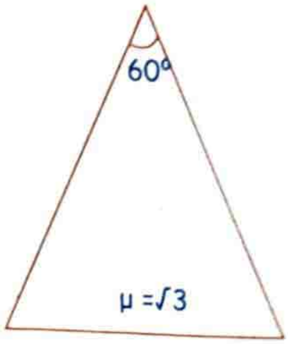
$r_1 = \frac{A}{2}$

$1.\sin i = \mu \sin r_1$

$1.\sin 45 = \mu \times \sin 30$

$\mu = \sqrt{2}$

Q. Find min deviation:



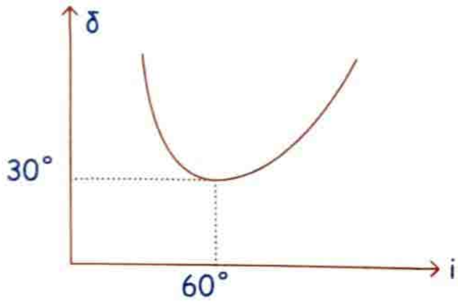
Sol. $\delta_{min} = 2i - A$

$1.\sin i = \sqrt{3}\sin r_1 = \sqrt{3}\sin 30°$

$i = 60°$

$\delta_{min} = 2 \times 60° - 60° = 60°$ ✓

Q. Find μ of prism



Sol. $\delta_{min} = 30$

$i = e = 60$

$\delta_{min} = 2i - A$

$30 = 2 \times 60 - A \quad \Rightarrow \quad A = 90°$

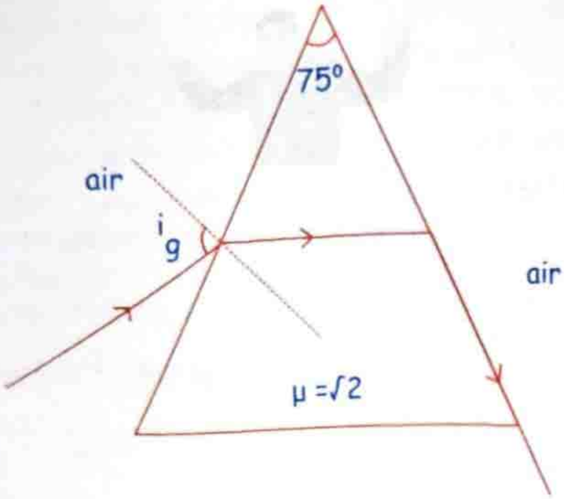
$1.\sin i = \mu \sin r_1$

$$\frac{\sqrt{3}}{2} = \mu \times \frac{1}{\sqrt{2}}$$

$$\mu = \sqrt{\frac{3}{2}}$$

If prism is Equilateral or Isosceles तो for minimum deviation prism की अंदर वाली ray base के parallel होगी खुद एक बार check करो जरा

Q. Find max deviation



Sol. $e = 90, i = i_g$

$\delta_{max} = i + e - A$

$= i_g + 90 - 75$

$\boxed{\delta_{max} = 60}$

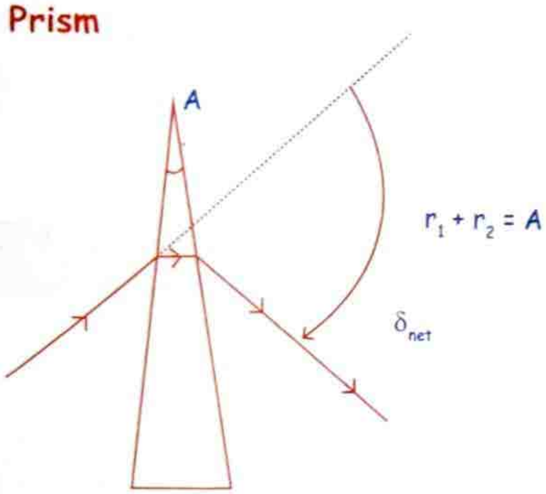
$r_2 = \theta_c = 45°$

$r_1 = 75 - 45 = 30$

$1 \times \sin i_g = \sqrt{2} \sin 30$

$i_g = 45°$

Thin Prism



If Angle of prism → very small

$1 \cdot \sin i = \mu \sin r_1$

$i \approx \mu r_1$

$\mu \sin r_2 = 1 \cdot \sin e$

$\mu r_2 = e$

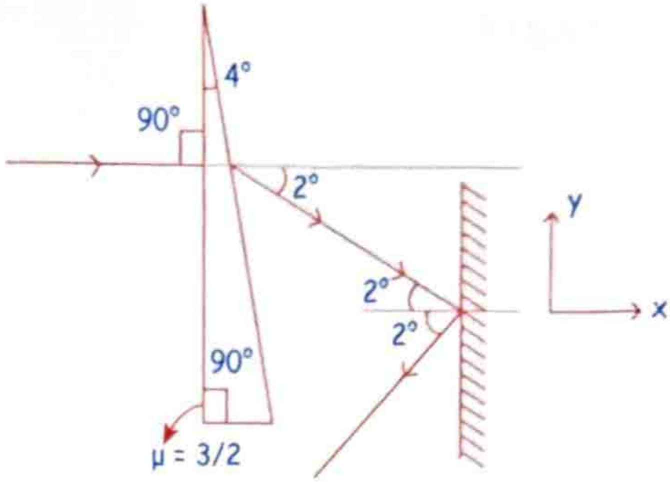
$\delta = i + e - A = \mu r_1 + \mu r_2 - A$

$\delta = \mu(r_1 + r_2) - A$

$\delta = \mu A - A$

$\boxed{\delta = (\mu - 1)A}$

Q. Find net deviation



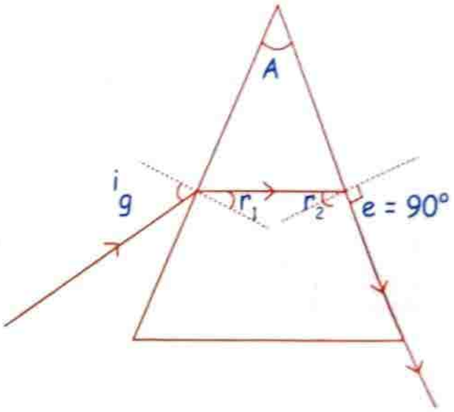
Sol. $\delta_{prism} = (\mu - 1)\ A = \left(\frac{3}{2} - 1\right) \times 4° = 2°$ (CW)

$\delta_{mirror} = 180 - 2i$

$= 180 - 2 \times 2 = 176$ (CW)

$\delta_{net} = 2 + 176 = 178$ (CW)

♦



$i_g = 45$(let)

$i < 45 \equiv$ TIR

$i > 45 \Rightarrow$ All out

If $i < i_g \Rightarrow$ All TIR

If $i > i_g \Rightarrow$ All out All emerges out

♦ **All Rays TIR ($A > 2\theta_c$)**

$(r_2)_{min} > \theta_c$

$(r_2)_{min} \Rightarrow (r_1)_{max} \Rightarrow (i)_{max} = 90$

If $\angle i = 90 \Rightarrow r_{1(max)} = \theta_c \Rightarrow (r_2)_{min} = A - \theta_c$

$(r_2)_{min} > \theta_c$ (All TIR)

$A - \theta_c > \theta_c$

$\boxed{A > 2\theta_c}$

- **All Rays Out (All Out $A < \theta_c$)**

$(r_2)_{max} < \theta_c$

$\downarrow$

$(r_1)_{min} \rightarrow i_{min} = 0$

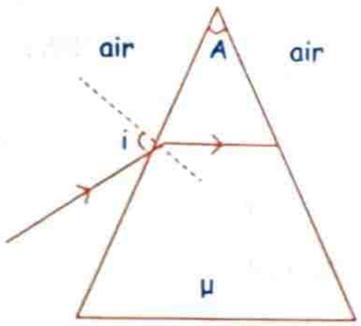
$\downarrow$

$r_1 = 0$ (min)

$r_2 = A$ (max)

$\boxed{A < \theta_c}$

Q. If there is no emergence find μ_{min}



$(r_2)_{min} > \theta_c$

$A - \theta_c > \theta_c$

$A > 2\theta_c$

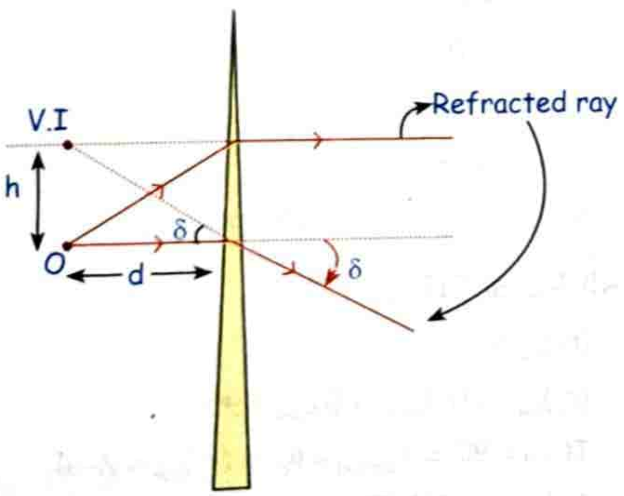
Sol. All TIR

$A > 2\theta_c$

$\frac{A}{2} > \theta_c$

$\sin\left(\frac{A}{2}\right) > \sin\theta_c = \frac{1}{\mu}$

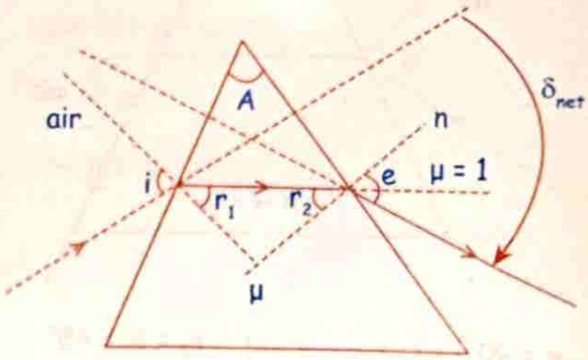
Image formed by thin prism



$\tan\delta = \frac{h}{d}$

$h = d\tan\delta$

काम का डब्बा



(1) $1 \cdot \sin i = \mu \sin r$,

$\mu \sin r_2 = 1 \cdot \sin e$

(2) $r_1 + r_2 = A$

(3) $\delta_{net} = i + e - A$

(4) For minimum deviation

$\delta_{min} \rightarrow$ when $i = e$ and $r_1 = r_2 = \frac{A}{2}$

$$\mu = \frac{\sin\left(\frac{\delta_m + A}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

(5) $\delta_{max} = i_g + 90 - A$

(6) All Rays Out (All Out $A < \theta_c$)

(7) All Rays TIR ($A > 2\theta_c$)

(8) For thin prism $\boxed{\delta = (\mu - 1)A}$

(9) $h = d\tan\delta$ (Image form by thin prism result)

Q. A ray of light is incident at an angle of 60 on the face of prism having refracting angl 30°. The ray emerging out of the prism make an angle 30° with the incident ray. Show tha the emergent ray is perpendicular to the fac through which it emerges.

Sol. $i = 60°$, $A = 30°$, $\delta = 30°$

$\delta = i + i' - 30°$

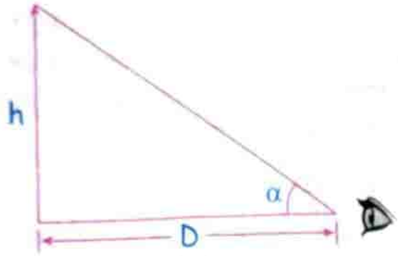
$30° = 60° + i' - 30°$

$\Rightarrow i' = 0°$

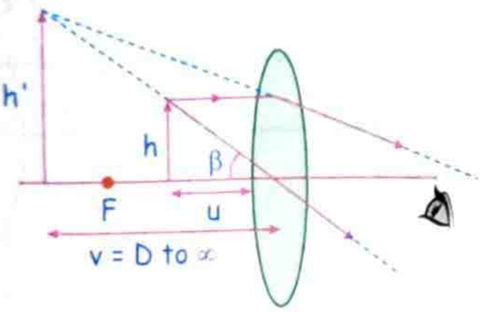
OPTICAL INSTRUMENTS

- The maximum distance, which a person can see things without help of चशमा spectacles is known as FAR POINT. (for normal eye far point is ∞)
- The minimum distance which a person can see without help of चशमा spectacles (without strain) is known as NEAR POINT. For normal eye near point is taken as 25 cm . Near point $\Rightarrow$ Least distance of distinct vision.

Simple Microscope



Unaided eye



Magnifying Power (m.p)

$$\boxed{MP = \frac{\beta}{\alpha} = \frac{h/D}{h/u} = \frac{D}{u}}$$

(1) final image at ∞

$u = f$ (magnitude)

$$mp = \frac{D}{f} \qquad D = 25\ c.m$$

(2) Final image at $v = -D$ (least distance of distinct vision)

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

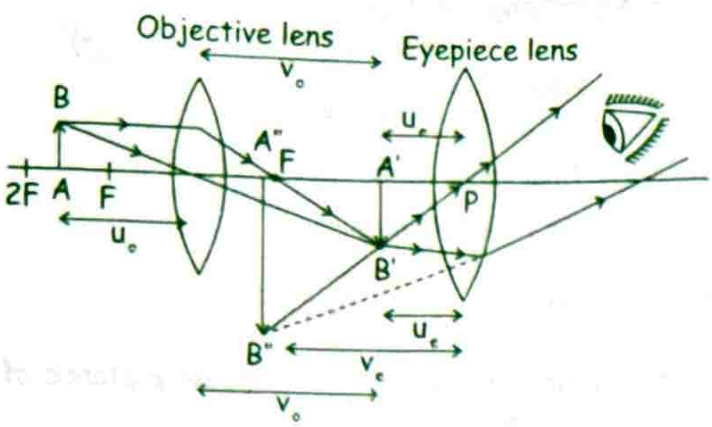
$$\frac{1}{-D} - \frac{1}{-u} = \frac{1}{f}$$

$$-\frac{1}{D} + \frac{1}{u} = \frac{1}{f} \Rightarrow mp = \frac{D}{u} = \frac{D}{f} + \frac{D}{D}$$

$$m.p = 1 + D/f$$

Simple Microscope	Compound Microscope	Astronomical Telescope
$mp = \frac{D}{u}$ (1) final image at ∞, $v = -\infty$ $mp = \frac{D}{f}$ (2) $v = -D$, $mp = 1 + \frac{D}{f}$	$mp = \frac{v_0}{u_0}\frac{D}{u_e}$ (magnitude) (1) final image at ∞, $v = -\infty$ $mp = \frac{v_0}{u_0}\frac{D}{f_e}$ (magnitude) (2) $V = -D$, $mp = \frac{V_0}{u_0}\left(1 + \frac{D}{f_e}\right)$ (magnitude)	$mp = \frac{f_0}{u_e}$ (1) find image at ∞, $v = -\infty$ $mp = \frac{f_0}{f_e}$ (magnitude) $mp = -\frac{f_0}{f_e}$ (2) $v = -D$ $mp = -\frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$

Compound Microscope



$$\boxed{L = |V_o| + |u_e|}$$

→ Lenth of μ-scope.

$$\boxed{m.p = \frac{\beta}{\alpha} = \frac{v_0}{u_0}\frac{D}{u_e} \text{ (after solving)}}$$

(1) final image at '∞'

$U_e = f$(magnitude)

$$mp = \frac{v_0}{u_0}\frac{D}{f}\text{(magnitude.)}$$

(2) final image at least distance of distinct vision

$V = -D$

(3) $V_e = -D$

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{-D} - \frac{1}{-u_e} = \frac{1}{f}$$

$$\frac{D}{U_e} = \frac{D}{f} + \frac{D}{D}$$

$$\boxed{M.P. = \frac{V_o}{U_o}\left(1 + \frac{D}{f}\right)} \text{ magnitude}$$

देख भाई objective lens मे AB की real inverted, magnified image A'B' बनाई अब A'B' की location कुछ ऐसी है की ये eyepiece lens के लिए P or F के बीच मे है जिसके वजह से eyepiece lens ने virtual, erect, enlarge image A"B" बनाई।

Q. A thin convex lens of focal length 5 cm is used as a simple microscope by a person with normal near point (25 cm). What is the magnifying power of the microscope ?

Sol. Simple μ scope

$$mp = 1 + \frac{D}{f_e} = 1 + \frac{25}{5} = 6$$

(for least distance of distinct vision)

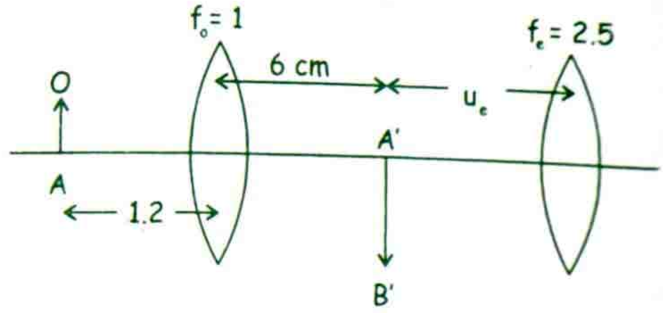
final imge at ∞

$$mp = \frac{D}{f} = \frac{25}{5} = 5$$

Q. A compound microscope has an objective of focal length 1 cm and an eyepiece of focal length 2.5 cm. An object has to be placed at a distance of 1.2 cm away from the objective for normal adjustment. (a) Find the mp. (b) Find the length of the microscope tube.

Sol. Final image at ∞

$u_e = f_e = 2.5$



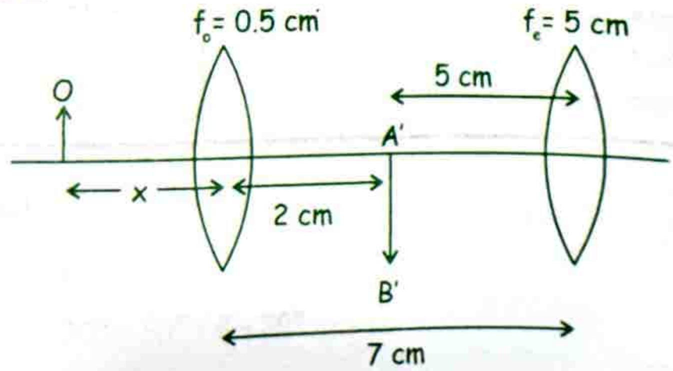
$$v = \frac{uf}{u+f} = \frac{-1.2 \times 1}{-1.2 + 1} = 6$$

$$mp = \frac{v_0}{u_0}\frac{D}{f_e} = \frac{6}{1.2} \times \frac{25}{2.5} = 5 \times 10 = 50$$

$L = 6 + 2.5 = 8.5$

Q. The separation L between the objective (f = 0.5 cm) and the eyepiece (f = 5 cm) of a compound microscope is 7 cm . Where should a small object be placed so that the eye is **least strained to see the image**? Find the angular magnification produced by the microscope.

Sol.



For objective lens

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

$$\frac{1}{2}-\frac{1}{-x}=\frac{1}{0.5}$$

$$\frac{1}{x}=2-\frac{1}{2}=\frac{3}{2}$$

$$u_e=\frac{2}{3}$$

$$mp=\frac{v_0}{u_0}\frac{D}{f_e}=\frac{2}{2/3}\times\frac{25}{5}$$

$$=3\times=5=15$$

$$mp=-15$$

(b) Repeat the above question for final image yet least distance of distinct vision $v_e = -25$ (for L_2)

$f_e = 5$

U_e = ? solve करो

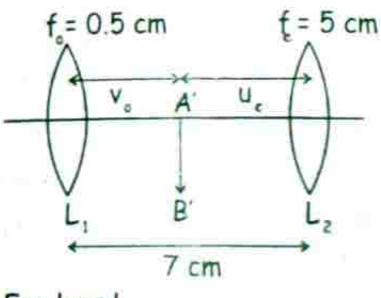
$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

$$\frac{1}{-25}-\frac{1}{-u_e}=\frac{1}{5}$$

$$\boxed{u_e=\frac{25}{6}}$$

$$V_o = L - |U_e|$$

$$V_o = 7-\frac{25}{6}=\frac{17}{6}$$



For lens L_1

$F_0 = .5$

$V_0 = +\frac{17}{6}$ $\equiv U_o =$ ✓

$U_o = ?$

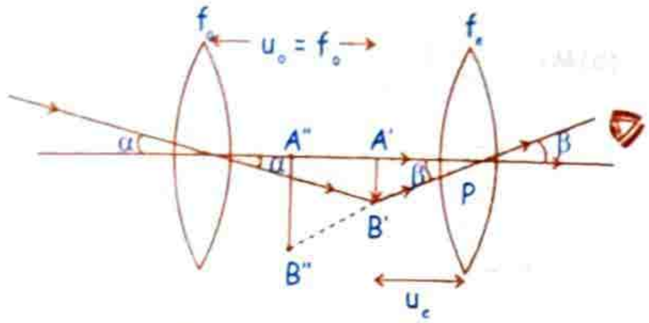
$$\frac{V_0}{U_0}\left(1+\frac{D}{f_e}\right)=\frac{\frac{17}{6}}{u_0}\left(1+\frac{25}{5}\right)$$

♦ A compound microscope consists of an objective lens of focal length 2.0 cm and an eye piece of focal length 6.25 cm, separated by a distance of 15 cm. How far from the objective should an object be placed in order to obtain the final image at (a) the least distance of distinct vision (25 cm) (b) infinity?

Ans. Solve by yourself and get answer

(a) 20 (b) 13.51

Astronomical Telescope



$$M.P.=\frac{\beta}{\alpha}=\frac{A'B'/u_e}{A'B'/f_0}=\frac{f_0}{u_e}$$

Case-(1) final image at ∞, (Normal Adjustment)

$V_e = \infty,\ u_e = -f_0$

$$M.P.=\frac{f_0}{f_e}\text{(magnitude)}\quad \boxed{MP=-\frac{f_0}{f_e}}$$

$$L=f_0+|u_e| \quad \boxed{L=f_0+f_e}$$

Case-(2) final image at $V_e = -D$

$$M.P.=-\frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)$$

$$L=f_0+|u_e|$$

Case '2'

$v_e = -D$

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \quad \text{for eyepiece lens}$$

$$\frac{1}{-D}-\frac{1}{-u_e}=\frac{1}{f_e}$$

$$\frac{1}{u_e}=\frac{1}{f_e}+\frac{1}{D}$$

$$\frac{f_0}{u_e}=\frac{f_0}{f_e}+\frac{f_0}{D}$$

$$M.P.=\frac{f_0}{f_e}\left(1+\frac{f_e}{D}\right)\text{ (magnitude)}$$

Q. Focal length of objective & eyepiece lens of astronomical telescope is 60 cm & 5 cm. Find M.P. and length of telescope if final image is at (1) ∞ (2) Least distance of distinct Vision.

Sol. (a) $f_0 = 60$ $\quad f_e = 5$

Final image at ∞

$$M.P. = -\frac{f_0}{f_e} = -\frac{60}{5} = -12$$

$$L = f_0 + f_e = 60 + 5 = 65$$

(b) $$M.P. = -\frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$$

$$= -\frac{60}{5}\left(1 + \frac{5}{25}\right) = -12 \times \frac{6}{5}$$

$$L = f_0 + |u_e|$$

For 'L'$_2$

$$\left.\begin{matrix} v_e = -25 \\ f_e = 5 \end{matrix}\right\} u_e = \surd$$

$$\text{telescope} \equiv \left.\begin{matrix} M.P. = \dfrac{f_0}{f_e} \\ L = f_0 + f_e \end{matrix}\right\} v = \infty \text{ Normal adjust.}$$

Q. When the length of an astronomical telescope tube increases its magnifying power

Sol. $l \uparrow \Rightarrow u_e \uparrow$

$$M.P. = \frac{f_0}{u_e}$$

Q. An astronomical telescope of angular magnification 10, when final image is at infinite has a length of **44 cm**. The focal length of the objective is.

(A) 4 cm (B) 40 cm

(C) 44 cm (D) 440 cm

Ans. (B)

Q. The magnifying power of telescope is found to be 9 and separation between lenses is 20 cm. What are focal lengths of component lenses

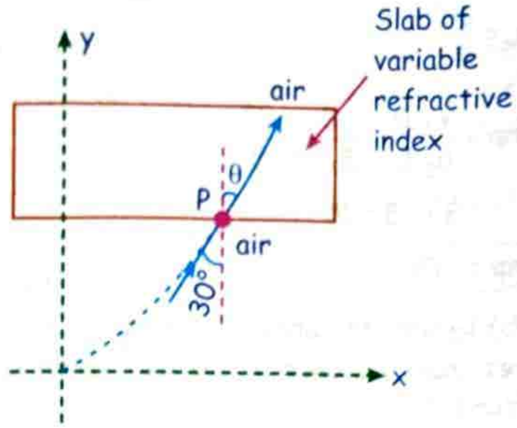
(A) 18 cm, 2 cm (B) 4 cm, 16 cm

(C) 10 cm, 10 cm (D) 12 cm, 8 cm

Ans. (A)

IMPORTANT QUESTION TO SOLVE FOR SPHERICAL MIRROR

Q. A ray of light travelling in air is incident at an[gle] of incidence 30° on one surface of slab in wh[ich] refractive index varies with y. The light trav[els] along the curve $y = 4x^2$ (y and x are in metre) [in] the slab. Find out the refractive index of t[he] slab at $y = 1/2$ m in the slab.



Sol. Let R.I. at $y = 4x^2$ is μ and corresponding angle [of] refraction is θ.

$\mu\sin\theta = 1\sin 30° = 1/2 \Rightarrow \sin\theta = 1/2\mu$ ...

and, $$\tan\left(\frac{\pi}{2} - \theta\right) = \frac{dy}{dx} \Rightarrow \cot\theta = 8x$$

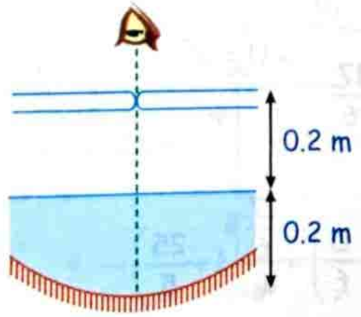
$$\Rightarrow \cot\theta = \frac{8y^{1/2}}{2}$$

$$\cot\theta = 4y^{1/2}$$

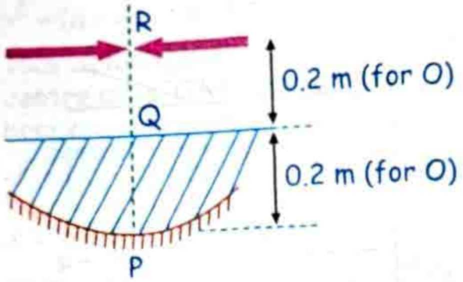
at $y = 1/2$ $$\Rightarrow \cot\theta = \frac{4}{\sqrt{2}} = 2\sqrt{2}$$

$$\Rightarrow \sin\theta = \frac{1}{3} \Rightarrow \frac{1}{2\mu} = \frac{1}{3} \Rightarrow \mu = \frac{3}{2}$$

Q. When a pin is moved along the principal ax[is] of a small concave mirror, the image positi[on] coincides with the object at a point 0.5 m fro[m] the mirror, refer figure. If the mirror is place[d] at a depth of 0.2 m in a transparent liquid, th[e] same phenomenon occurs when the pin is place[d] 0.4 m from the mirror. The refractive index o[f] the liquid is



Sol.



R = 0.5 m

(QP) = 0.3 m (in air)

(QP_0) = 0.2 m (in liquid)

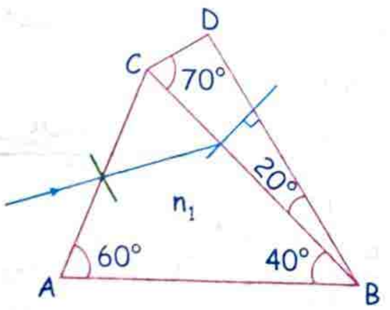
$\Rightarrow (QP) = (QP_0) \times \mu$

$\mu = \dfrac{3}{2}$

Q. A prism of refractive index n_1 and another prism of refractive index n_2 are stuck together without a gap as shown in the figure. The angles of the prisms are as shown. n_1 and n_2 depend on λ, the wavelength of light, according to

$n_1 = 1.20 + \dfrac{10.8 \times 10^4}{\lambda^2}$ and $n_2 = 1.45 + \dfrac{1.80 \times 10^4}{\lambda^2}$

where λ is in nm. The wavelength for which rays incident at any angle on the interface BC pass through without bending at that interface will be:



Sol. $n_1 = 1.20 + \dfrac{10.8 \times 10^4}{\lambda_0^2}$ and $n_2 = 1.45 + \dfrac{1.80 \times 10^4}{\lambda_0^2}$

Here λ is in nm.

(i) The incident ray will not deviate at BC if

$n_1 = n_2$

$\Rightarrow 1.20 + \dfrac{10.8 \times 10^4}{\lambda_0^2} = 1.45 + \dfrac{1.8 \times 10^4}{\lambda_0^2}$

$(\lambda = \lambda_0)$

$\Rightarrow \dfrac{9 \times 10^4}{\lambda_0^2} = 0.25$

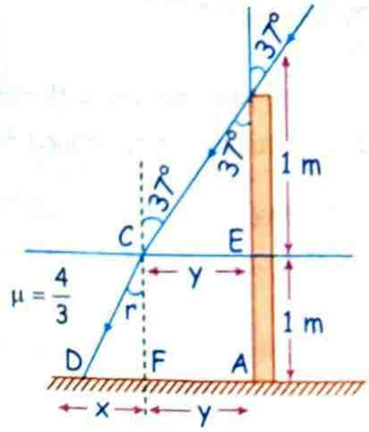
or $\lambda_0 = \dfrac{3 \times 10^2}{0.5}$

or $\lambda_0 = 600$ nm

Q. A pole of length 2.00 m stands half dipped in a swimming pool with water level 1 m higher than the bed (bottom). The refractive index of water is 4/3 and sunlight is coming at an angle of 37° with the vertical. Find the length of the shadow of the pole on the bed.

Use $\sin^{-1}(0.45) = 26.8°$, $\tan(26.8°) = 0.5$

Sol.



Let in the adjoining figure AB be the pole. So, AD represents its shadow on the bed.

[In ΔBCE]

$\tan 37° = \dfrac{CE}{BE} = \dfrac{y}{1} \Rightarrow y = \dfrac{3}{4}$ m.

Also due to refraction of sunrays at the water surface $\sin 37° = \dfrac{4}{3} \sin r$

$\Rightarrow \sin r = \dfrac{9}{20}$

$\therefore \tan r \approx 0.5$

So, In ΔCDF,

we have $\tan r = \dfrac{DF}{CF}$

$\Rightarrow 0.5 = \dfrac{x}{1}$

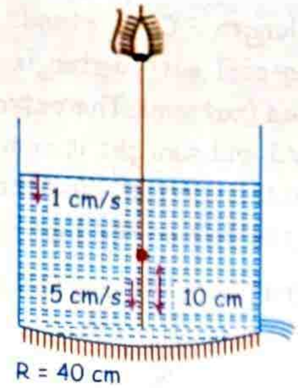
$\therefore x = 0.5$

$\therefore$ Length of the shadow AD = x + y = 1.25 m.

Q. Water level in the tank is decreasing at a constant rate 1 cm/s. A small metal sphere, is moving downwards with a constant velocity 5 cm/s. Base of the tank is a concave mirror of radius 40 cm. Find the velocity of the image seen. [Take $_a\mu_w = 4/3$]

(i) Directly

(ii) After reflection at the mirror.



Sol. (i) Here we calculate the velocity with respect to surface and then convert it to ground frame.

Directly $v_{i\backslash s} = \dfrac{(V_o)_{surface}}{\mu_{rel}}$

$v_i - (+1) = \dfrac{3}{4}(5-1)$

v_i = 4cm/s downwards

(ii) $m = \dfrac{f}{f-u} = \dfrac{-20}{-20-(-10)} = 2$

Object is placed at u = -10 cm its image is virtual and magnified

$v_{i\backslash m} = -m^2 v_{O/M}$

Finally after refraction

$v_{i/s} = \dfrac{\mu_{O/s}}{M}$

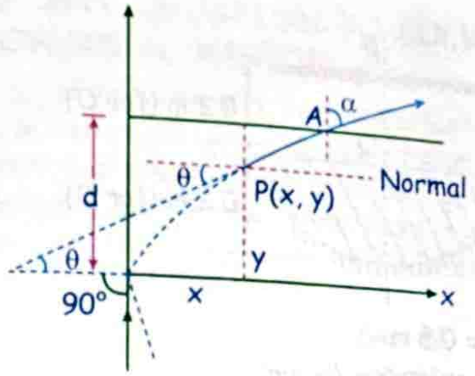
or $v_i - v_s = \dfrac{3}{4}(u_o - u_s)$

$v_i - (1) = \dfrac{3}{4}(-20-1)$

$v_i = \dfrac{-63}{4} + 1$

$\dfrac{59}{4}$ cm/s upwards

Q. Figure shows the cross-section of a thin slice of atmosphere in the vertical plane, the thickness of the layer is d. The refractive index of air varies as $n = \dfrac{n_0}{1-x/a}$ with the ray entering at origin; n_0 and a are constant, (a) Obtain an equation for the trajectory $y(x)$ of the ray in the medium, (b) Find coordinates of the point A where it emerges.



Sol. The refractive index varies along x-axis. The normal at any point P (x, y) is parallel to the x-axis.

Slope of tangent at point $P = \tan\theta = \dfrac{dy}{dx}$

From Snell's law,

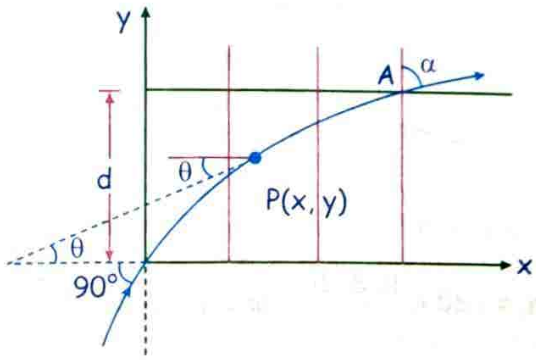
$n_0 \sin 90° = n \sin\theta$

$n_0 = \dfrac{n_0}{1-(x/a)}\sin\theta$

$\sin\theta = \dfrac{a-x}{a}$

$\tan\theta = \dfrac{a-x}{\sqrt{a^2-(a-x)^2}}$

$\dfrac{dy}{dx} = \dfrac{a-x}{\sqrt{a^2-(a-x)^2}}$



$y = \int dy = \int \dfrac{a-x}{\sqrt{a^2-(a-x)^2}}dx$

To integrate the above expression we substitute

$t^2 = a^2 - (a-x)^2$

$2t\,dt = 2(a-x)(dx)$

$t\,dt = (a-x)dx$

$y = \int \dfrac{t\,dt}{t} = t = \sqrt{a^2-(a-x)^2}$

Thus $y^2 = a^2 - (a-x)^2$

$y^2 + (a - x)^2 = a^2$ (equation for trajectory)

This is the equation of a circle of radius a with centre at (a, 0). As y-coordinate of point A is d, hence

$d^2 + (x - a)^2 = a^2$

$x = a \pm \sqrt{a^2 - d^2} = a - \sqrt{a^2 - d^2}$

as x cannot be greater than radius of circle.

so cordinates are $(a - \sqrt{a^2 - d^2}, d)$

DEFECTS OF EYES (Removed from Mains)

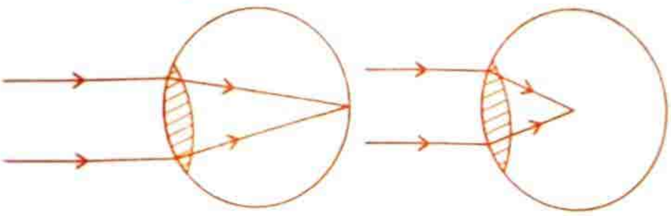
If a person can see an object at a maximum distance 'x'

Power of lens required = $-\frac{1}{x} = \frac{1}{f}$

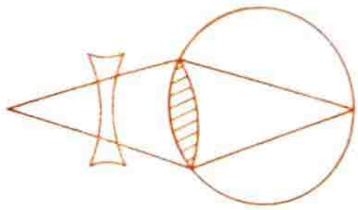
$f \rightarrow$ meter

Power $\rightarrow$ Dioptre

Myopia [Short-sightedness or Near-sightedness]

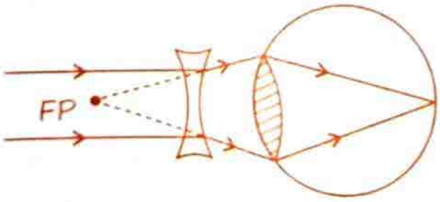


Normal eye Defective eye



Distant object are not clearly visible, but near object are clearly visible because image is formed before the retina.

To remove this effect



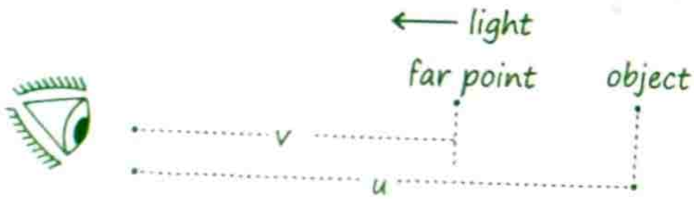
- Concave lens is used, $f < 0$
- $P < 0 \quad P = \frac{1}{f}$
- हमें image F.P पर बनानी है (Concave lens)

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$\frac{1}{-x} - \frac{1}{-\infty} = \frac{1}{f} = P$

$$P = \frac{1}{f} = \frac{1}{-x}$$

Far point - x



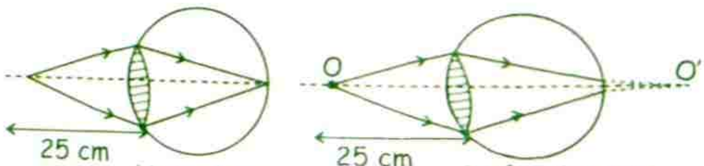
- The maximum distance. which a person can see without help of spectacles is known as far point.
- If the reference of object is not given then it is taken as infinity.
- In this case image of the object is formed at the far point of person.

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} = P$

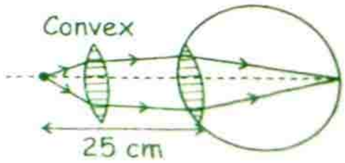
$\Rightarrow \frac{1}{\text{distance of far point (in m)}} - \frac{1}{\text{distance of object (in m)}} = \frac{1}{f} = P$

$\frac{100}{\text{distance of far point (in cm)}} - \frac{100}{\text{distance of object (in cm)}} = P$

Hypermetropia



Normal eye Defective eye



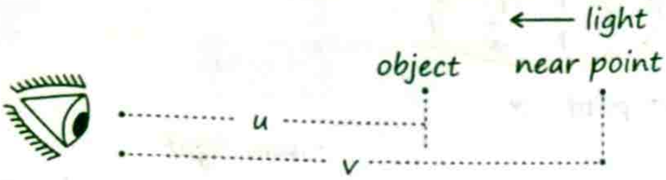
(i) Near object are not clearly visible but far object are clearly visible.

(ii) The image of near object is formed behind the retina.

(iii) To remove this defect convex lens is used.

Near Point

The minimum distance which a person can see without help of spectacles.



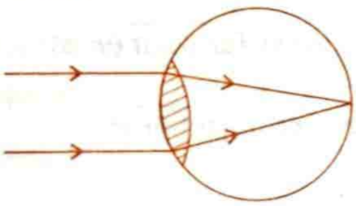
- In this case image of the object is formed at the near point.
- If reference of object is not given it is taken as 25 cm.

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}=P$$

$$\Rightarrow \frac{1}{\text{distance of near point (inm)}}$$

$$-\frac{1}{\text{distance of object (inm)}}=\frac{1}{f}=P$$

distance of near point = –ve, distance of object = –ve, P = + ve



Q. A person cannot see clearly an object kept at a distance beyond of 100 cm. Find nature and power of lens used for seeing clearly the object at ∞.

Sol. $P<0$, myopia, $P=-\frac{1}{x}=-\frac{1}{1m}=-1\,D$.

$$\frac{1}{25}-\frac{1}{60}=\frac{12-5}{300}=$$

Q. A far sighted person (hypermyopia), has near point 60 cm what power of lens should be used for eye glases such that person can read book at a distance 25 cm.

Sol. $u=-25$

$v=-60$

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$$

$$\frac{1}{-60}-\frac{1}{-25}=\frac{1}{f}=\frac{7}{300}$$

$$\text{Power}=\frac{1}{f}=\frac{7}{300}\times 100$$

$$\text{meter}=+\frac{7}{3}D$$

PRESBYOPIA

In this case both near and far object are not clearly visible. To remove this defect two separate spectacles one for myopia and other for hypermetropia are used or bifocal lenses are used.

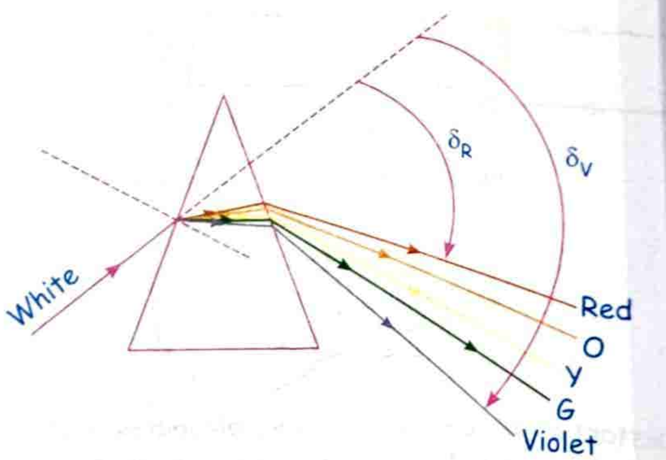
ASTIGMATISM

In this defect eye cannot see object in two orthogonal direction clearly. It can be removed by using cylindrical lens in particular direction.

DISPERSION OF LIGHT
(Removed from Mains)

When a beam of white light (containing several wavelengths) falls on one face of a prism, it splits into its constituent colors. This phenomenon of splitting of light into its constituent colours is called dispersion of light and the band of colours obtained on a screen is called spectrum.

$$\mu(\lambda)=A+\frac{B}{\lambda^2}+\ldots\ldots \text{(Cauchy's relation)}$$



$\delta=(\mu-1)A$

δ_V = Deviation of violet colour = $(\mu_V-1)A$

δ_R = Deviation of red colour = $(\mu_R-1)A$

Angular dispersion (A.D.) = $\delta_V-\delta_R=(\mu_V-\mu_R)A$

mean deviation $\delta_{mean}=\delta_{yellow}=(\mu_y-1)A$

Dispersive power: It is the ratio between angular dispersion to mean deviation produced by the prism.

$$\omega=\frac{\delta_V-\delta_R}{\delta_y}=\frac{\mu_V-\mu_R}{\mu_y-1}=\frac{d\mu}{\mu_y-1}$$ (independent on angle of prism)

Yellow colour is taken as mean colour.

Also $\mu_y=\frac{\mu_V+\mu_R}{2}$

Dispersion without Deviation

Let μ_V, μ and μ_R be the refractive indices of the crown glass for violet, yellow and red colours respectively.

Let μ'_V, μ' and μ'_R, be the corresponding values for the flint glass prism

Let δ and δ' be the deviations suffered by yellow light through crown glass prism and flint glass prism respectively.

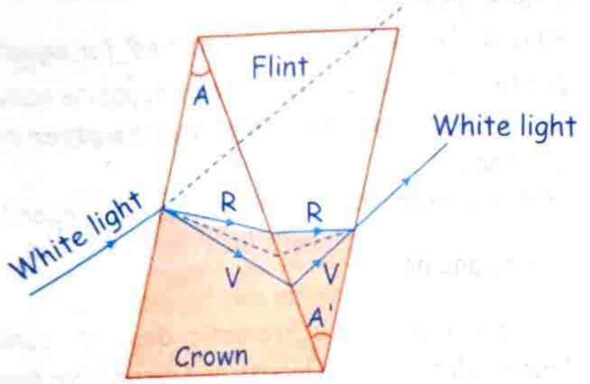
If the combination does not produce any deviation, then

$$\delta + \delta' = 0$$

or $(\mu - 1)A + (\mu' - 1)A' = 0$

or $(\mu' - 1)A' = -(\mu - 1)A$

or $A' = -\left(\dfrac{\mu - 1}{\mu' - 1}\right)A$



Net angular dispersion $(\theta_{net}) = \delta(\omega - \omega')$

- $\theta_{net} = \theta_1 - \theta_2 = (\mu_{V_1} - \mu_{R_1})A_1 - (\mu_{V_2} - \mu_{R_2})A_2$

or $\boxed{\theta_{net} = \theta_1\left(1 - \dfrac{\omega_2}{\omega_1}\right)}$

Deviation without Dispersion

For the combination of prism shown in figure, if there is to be no angular dispersion, then

$$(\delta_V - \delta_R) + (\delta'_V - \delta'_R) = 0$$

or $(\mu_V - \mu_R)A + (\mu'_V - \mu'_R)A' = 0$

or $(\mu'_V - \mu'_R)A' = -(\mu_V - \mu_R)A$

or $A' = -\left(\dfrac{\mu_V - \mu_R}{\mu'_V - \mu'_R}\right)A$

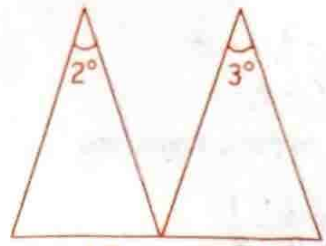
This is the condition for achromatism i.e., the condition for no dispersion.

Q. Prism angle of a prism is 10°. Their refractive index for red and violet color is 1.51 and 1.52 respectively. Then find the dispersive power.

Sol. $\omega = \dfrac{\mu_V - \mu_R}{\mu_y - 1} = \dfrac{1.52 - 1.51}{1.515 -} = \mu_y = \dfrac{\mu_V + \mu_R}{2}$

$\theta = (\mu_V - \mu_R)A$

Q. Find angular dispersion and deviation.



$\mu_V = 1.5$ $\mu'_V = 1.7$

$\mu_R = 1.4$ $\mu'_R = 1.5$

Sol. $\delta_{net} = \delta_1 + \delta_2$

$= (\delta_n)_1 + (\delta_m)_2 = (\mu_{y_1} - 1)A_1 + (\mu_{y_2} - 1)A_1$

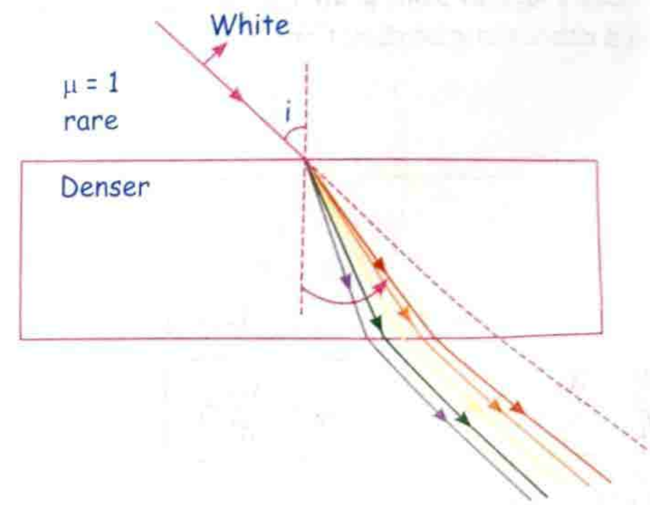
$= (1.45 - 1) \times 2° + (1.6 - 1)3°$

Total angular dispersion $= \theta_1 + \theta_2$

$= (1.5 - 1.4) \times 2 + (1.7 - 1.5) \times 3$

DISPERSION/DEVIATION IN SLAB

Angular dispersion = 0.

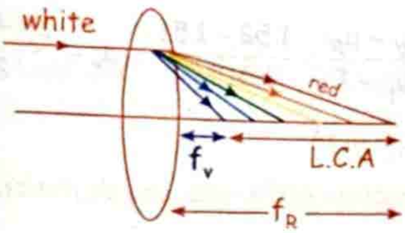


Chromatic Aberration

The image of an object in white light formed by a lens is usually coloured and blurred. This defect of image is called chromatic aberration and arises due to the fact that focal length of a lens is different for different colours. For a single lens.

$$\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

longitudinal chromatic aberration,



$L.C.A = f_R - f_V = -df$

with $df = f_V - f_R$ ... (i)

However, as for a single lens,

$$\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad \text{... (ii)}$$

$$\text{i.e., } -\frac{df}{f^2} = d\mu\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \quad \text{... (iii)}$$

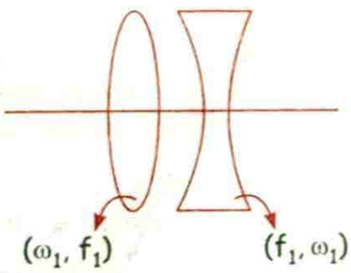
So dividing equation (iii) and (ii)

$$-\frac{df}{f} = \frac{d\mu}{(\mu - 1)} = \omega\left[\text{as } \omega = \frac{d\mu}{(\mu - 1)}\right] \quad \text{... (iv)}$$

And hence, from equation (i) and (iv),

$L.C.A. = -df = \omega f$ ... (v)

To remove this effect we use two or more lens combined together In such a way that this combination produce image at saint point then this combination is called achromatic combination.



$$\boxed{\frac{W_1}{f_1} + \frac{W_2}{F_2} = 0} \qquad \boxed{f_2 = -\frac{W_2}{W_1}F_1}$$

If $F_1 \rightarrow$ Convex

$F_2 \rightarrow$ Concave

Condition of Achromatism (Proof)

In case of two thin lenses in contact.

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} \text{ i.e., } -\frac{dF}{F^2} = -\frac{df_1}{f_1^2} - \frac{df_2}{f_2^2}$$

The combination will be free from chromatic aberration if $dF = 0$

$$\text{i.e., } \frac{df_1}{f_1^2} + \frac{df_2}{f_2^2} = 0$$

equation (v) reduces to

$$\frac{\omega_1 f_1}{f_1^2} + \frac{\omega_2 f_2}{f_2^2} = 0$$

$$\text{i.e., } \frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} = 0 \quad \text{... (vi)}$$

This condition is called condition of achromatism (for two thin lenses in contact) and the lens combination which satisfies this condition is called an achromatic doublet. From this condition, i.e., from equation (vi) it is clear that in case of achromatic doublet:

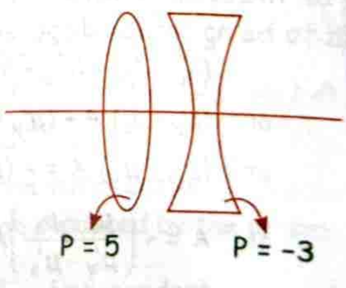
1. The two lenses must be of different materials since, if material is same, then $\omega_1 = \omega_2$. So,
   $\frac{1}{f_1} + \frac{1}{f_2} = 0$ i.e., $\frac{1}{F_{eq}} = 0$ or $F_{eq} = \infty$
   i.e., combination will not behave as a lens, but as a plane glass plate.
2. As ω_1 and ω_2 are positive quantities, for equation (vi) to hold, f_1 and f_2 must be of opposite nature, i.e., if one of the lenses is convex the other must be concave.
3. If the achromatic combination is convergent,
   $f_C < f_D$ and as $-\frac{f_C}{f_D} = \frac{\omega_C}{\omega_D}, \omega_C < \omega_D$
   i.e., a convergent achromatic doublet, convex lens has lesser focal length and dispersive power is lesser than divergent one.

Q. An achromatic convergent doublet of two lenses in contact has a power of + 2D. The convex lens has a power + 5D. What is the ratio of the dispersive powers of the convergent and divergent lenses

Sol. $P_{net} = +2 = P_1 + P_2$

$+2 = +5 + P_2$

$\boxed{P_2 = -3}$



$$\frac{\omega_1}{f_1} + \frac{\omega_2}{f_2} = 0$$

$$\frac{\omega_1}{f_1} = -\frac{\omega_2}{f_2}$$

$$\frac{\omega_1}{\omega_2} = -\frac{f_1}{f_2} = -\frac{P_2}{P_1}$$

$$\frac{\omega_1}{\omega_2} = -\left(\frac{-3}{+5}\right) = \frac{3}{5}$$

Q. Two thin prisms are combined to form an achromatic combination. For I prism $A = 4^\circ$, $\mu_R = 1.35$, $\mu_Y = 1.40$, $\mu_v = 1.42$. For II prism $\mu'_R = 1.7$, $\mu'_Y = 1.8$ and $\mu'_v = 1.9$. Find the prism angle of II prism and the net mean deviation.

Sol. Condition for achromatic combination.

$\theta = \theta'$

$(\mu_V - \mu_R) A = (\mu'_V - \mu'_R) A'$

$$\therefore A' = \frac{(1.42 - 1.35)4^\circ}{1.9 - 1.7} = 1.4^\circ$$

$\delta_{Net} = \delta - \delta' = (\mu_Y - 1) A - (\mu'_Y - 1) A'$

$= (1.40 - 1)\, 4^\circ - (1.8 - 1)\, 1.4^\circ = 0.48^\circ.$

1. Resolving Power (R.P.) of Telescope

$$R.P = \frac{a}{1.22\lambda} = \frac{1}{\Delta\theta} = \frac{D}{d}$$

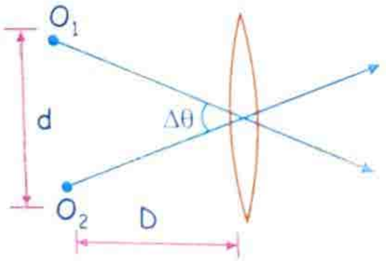
a = diameter of the aperture of objective lens

λ = wavelength of light used

$\Delta\theta$ = Limit of resolution

d = distance of two objects

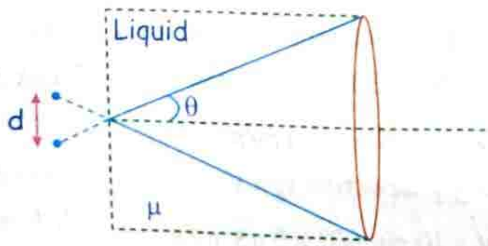
D = distance of objects from objective lens



2. Resolving Power (R.P.) of Microscope

$$R.P. = \frac{2\mu \sin\theta}{1.22\lambda}$$

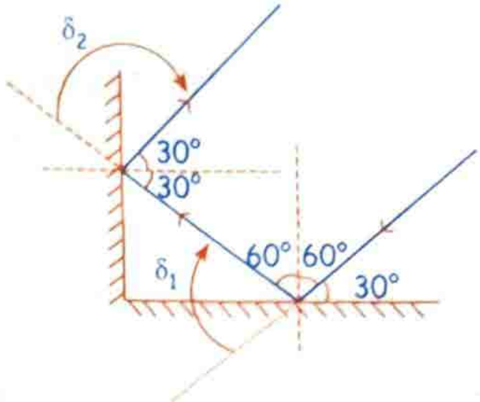
μ = refractive index of medium.



The resolving power of an electron microscope is 4×10^3 times that of an ordinary microscope.

PLANE MIRROR REMAINING (For Advance Only Removed from Mains 2025)

Q. Two plane mirror are perpendicular to each other as shown in figure. Find net deviation for the incident ray.



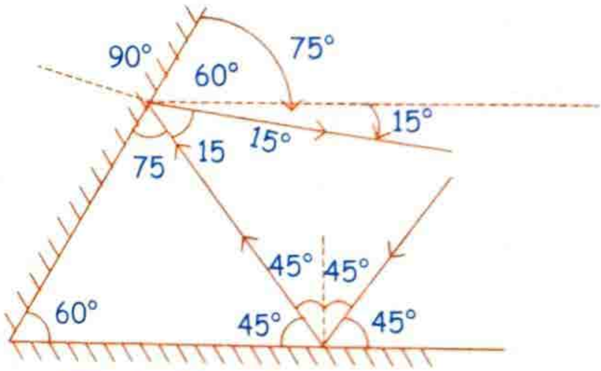
$\delta_1 = 180 - 2i^\circ = 180 - 2 \times 60$

$\delta_1 = 60^\circ$ (cw)

$\delta_1 = 180 - 2 \times 30 = 120$ (cw)

$s_{net} = 60 + 120 = 180$

Q. Find net deviation.



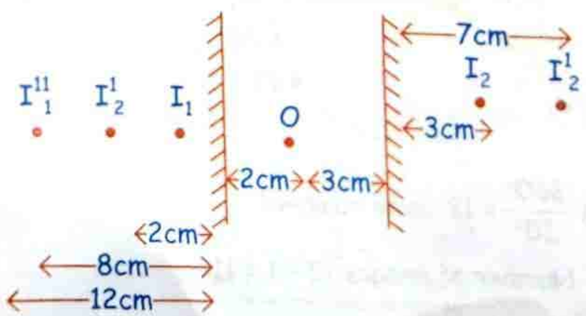
$\delta_1 = 180 - 2 \times 45 = 90^\circ$ (cw)

$\delta_2 = 150$ (cw)

$\delta_1 = 240$ (cw)

Q. Two plane mirror having 5 cm gap between them are parallel to each other. If an object is placed at a distance 2 cm from one mirror as shown in figure. Find location of image form by mirrors.

Location of image when to mirror are parallel



Shortcut method

M_1	M_2
2	3
8	7
12	13

Infinite images will formed

Number of Images Formed by Two Inclined Plane Mirrors

1. If $\frac{360^\circ}{\theta}$ = even number:

   Number of images = $\frac{360^\circ}{\theta} - 1$

2. If $\frac{360^\circ}{\theta}$ = odd number, and the object is placed on the angle bisector.

   Number of images = $\frac{360^\circ}{\theta} - 1$

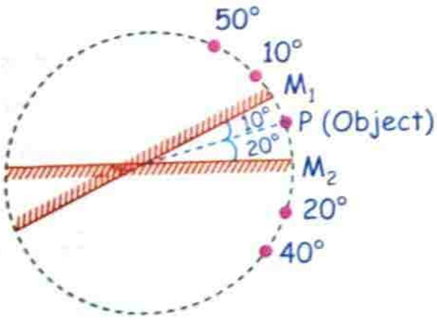
3. If $\frac{360^\circ}{\theta}$ = odd number, and the object is not placed on the angle bisector.

   Number of images = $\frac{360^\circ}{\theta}$.

4. If $\frac{360^\circ}{\theta} \neq$ integer, then count the number of images as explained above.

Q. Two plane mirrors are inclined by an angle 30°. An object is placed making 10° with the mirror M_1. Find the positions of first two images formed by each mirror and the total number of images using (i) direct formula (ii) counting the images.

Sol.



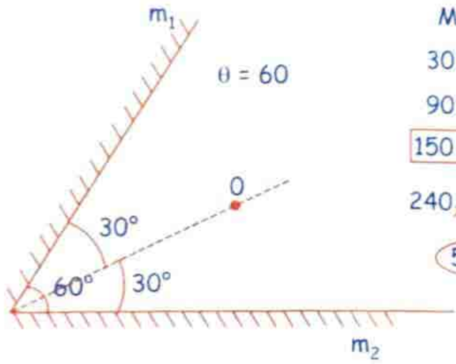
(i) $\frac{360^\circ}{30^\circ} = 12$ (even number)

$\Rightarrow$ Number of images 12 - 1 = 11

(ii) By counting.

Image formed by Mirror M_1 (angles are measured from the mirror M_1)		Image formed by Mirror M_2 (angles are measured from the mirror M_2)
10°	+30°	20°
50°	+30°	40°
70°	+30°	80°
110°	+30°	100°
130°	+30°	140°
170°		160°
Stop because next angle will be more than 180°		Stop because next angle will be more than 180°

To check whether the final images made by the two mirros coincide or not: add the last angles and the angle between the mirrors. If it comes out to be exactly 360°, it implies that the final images formedby the two mirros coincide. Here last angles made by the mirrors + the angle between the mirrors = 160° + 170° + 30° = 360°. Therefore in this case the last images coincide. Therefore the number of images = number of images formed by mirror M_1 + number of images formed by mirror M_2 - 1 (s the last images coincide) = 6 + 6 - 1 = 11



M_1	M_2	
30	30	
90	90	
$\boxed{150}$	$\boxed{150}$	→ coincide
240 ×	240 ×	

5 image

Q. If velocity of object $\vec{u} = (10\cos 60^\circ\,\hat{i} + 10\sin 60^\circ\,\hat{j})$ m/s, velocity of mirror $\vec{v}_m = (-5\cos 30^\circ\,\hat{i} + 5\sin 30^\circ\,\hat{j})$ m/s. Find the velocity of image (mirror is placed along y-z plane).

Sol. Along x direction, applying $v_i - v_m = -(v_o - v_m)$

$v_i - (-5\cos 30^\circ) = -(10\cos 60^\circ - (-5\cos 30^\circ))$

$\therefore v_i = -5(1 + \sqrt{3})$ m/s

Along y direction $v_o = v_i$

$\therefore v_i = 10\sin 60^\circ = 5\sqrt{3}$ m/s

$\therefore$ Velocity of the image

$= [-5(1+\sqrt{3})\,\hat{i} + 5\sqrt{3}\,\hat{j}]$ m/s.

9 Wave Optics

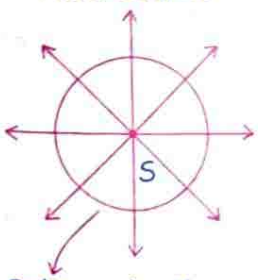
WAVE FRONT (W/F)

- Locus of all the particle vibrating in the same phase.
- For point source $\longrightarrow$ w/f $\Rightarrow$ spherical
  For linear source $\longrightarrow$ w/f $\Rightarrow$ cylindrical
- Rays are always perpendicular to wave front (w/f). Wavefront are always perpendicular to rays.

• Kisi bhi ek w/f के सारे point same phase पर होंगे
• Kisi bhi ek w/f के दो point ke beech phase diff = 0 होगा

- Time taken by wave from one w/f to another w/f for all rays are same.

Point Source

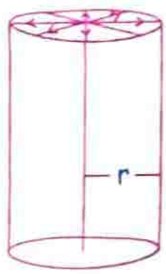


Spherical w/f

$$I = \frac{P}{4\pi r^2}$$

$$I \propto \frac{1}{r^2}$$

Linear Source



$$I = \frac{P}{2\pi rl}$$

$$I \propto \frac{1}{r}$$

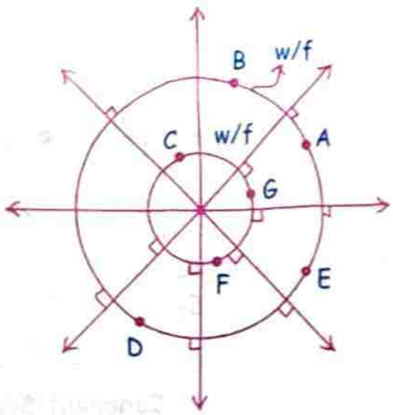
Phase diff. b/w

A & B $\longrightarrow$ 0

A & E $\longrightarrow$ 0

C & G $\longrightarrow$ 0

Phase difference between A & C = phase difference b/w B & G



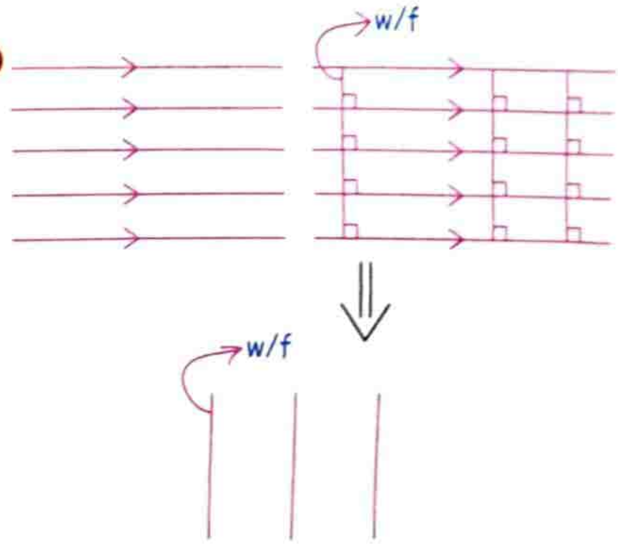
$\phi_A = \phi_B = \phi_D = \phi_E$ (phase)

$\phi_C = \phi_G = \phi_F =$ (phase)

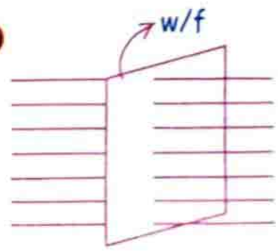
Draw the w/f

ये तो बिलकुल equipotential surface जैसा है ray of light पर perpendicular डालो और मजा लो।

❶



❷



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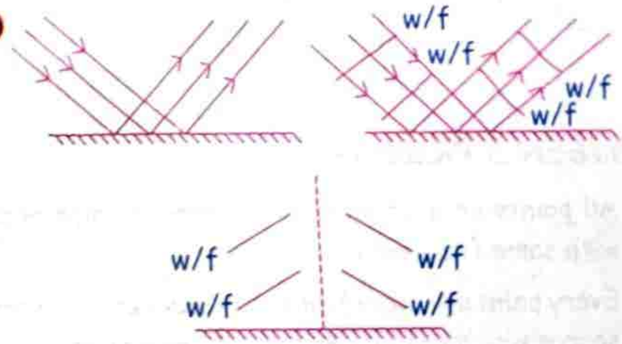
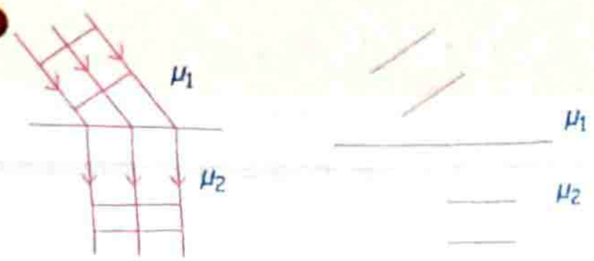
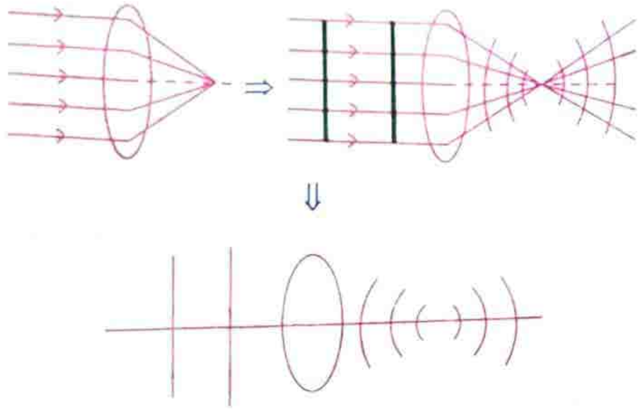
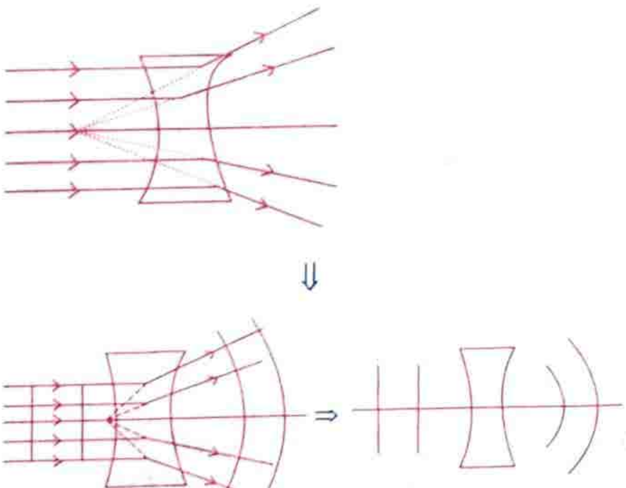




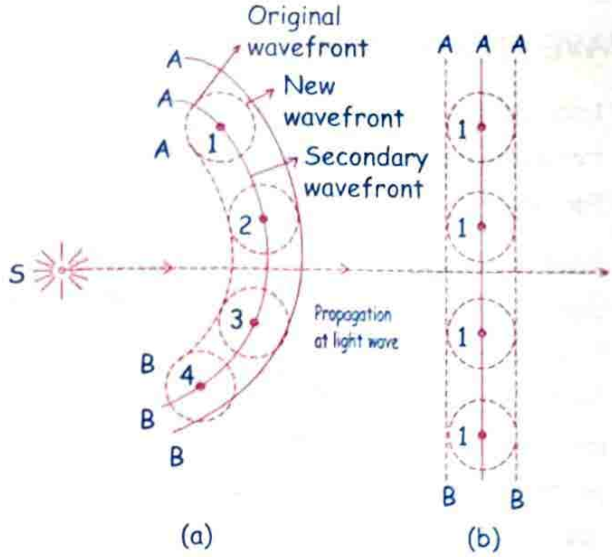




HUYGEN'S PRINCIPLE

- All points on a wavefront vibrates in same phase with same frequency.
- Every point on a wavefront is an independent fresh source which produce secondary wavefront.
- Each point on a wavefront is a source of new disturbance called wavelets

  these wavelets are spherical & wavelets from these points spread out in each directions with speed of wave, if we draw a common tangent to all these sphere we obtain the new position of wavefront at a later time.



The Phenomena Explained by this Theory

(i) Reflection, refraction, interference, diffraction, polarisation and double refraction.

(ii) Rectilinear propagation of light.

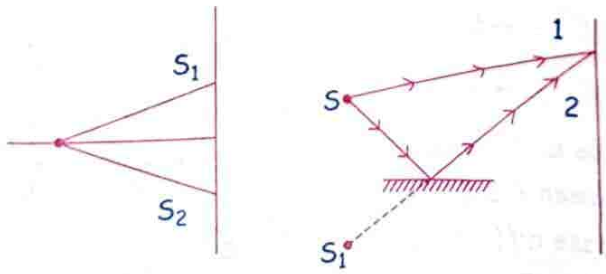
(iii) Velocity of light in rarer medium being greater than that in denser medium.

COHERENT SOURCE

- Two sources are said to be coherent if they produce wave of same frequency with const. phase difference
- Phase difference is const. (independent of time)
- Two independent source cannot be coherent.
- For sustained interference sources must be coherent.
- To create coherent 2 source, it is essential that they should be derived from same common source.

INCOHERENT SOURCE

- Phase diff. = f(t)



Coherent Source

INTERFERENCE OF LIGHT

ये काफी हद तक sound के जैसा ही है एक बार 11th class का sound wave, constructive interference, destructive interference revise कर लेना।

मै तुम्हे ये क्यों बता रहा हुँ कहीं तुम back log वाले तो नही हो।

When two waves from coherent source superimpose they gives definite intensity pattern in definite location at space.

$$y_1 = A_1 \sin(\omega t - kx)$$

$$y_2 = A_2 \sin(\omega t - kx + \phi)$$

$$y_{net} = y_1 + y_2 = A_1 \sin(\omega t - kx) + A_2 \sin(\omega t - kx + \phi)$$

$$= A_{net} \sin(\omega t - kx + \alpha)$$

$$A_{net} = \sqrt{A_1^2 + A_2^2 + 2A_1A_2 \cos\phi}$$

$$\boxed{\text{Intensity} \propto A^2}$$

Let $Kx - \omega t = B$

$$\Rightarrow y_{net} = A_1 \sin B + A_2 \sin(B + \phi)$$

$$= A_1 \sin B + A_2 \sin B \cos\phi + A_2 \cos B \sin\phi$$

$$y_{net} = (A_1 + A_2 \cos\phi)\sin(\omega t - kx) + (A_2 \sin\phi)\cos(\omega t - kx)$$

$$= a \sin(\omega t - kx) + b \cos(\omega t - kx)$$

$$y_{net} = a \sin(\omega t - kx) + b \cos(\omega t - kx)$$

$$= \sqrt{a^2 + b^2}\ \sin(\omega t - kx + \alpha)$$

$$= A_{net} \sin(\omega t - kx + \alpha)$$

$$a = A_1 + A_2 \cos\phi$$

$$b = A_2 \sin\phi$$

$$A_{net} = \sqrt{a^2 + b^2} = \sqrt{(A_1 + A_2 \cos\phi)^2 + (A_2 \sin\phi)^2}$$

$$= \sqrt{A_1^2 + A_2^2 \cos^2\phi + 2A_1A_2 \cos\phi + A_2^2 \sin^2\phi}$$

$$A_{net} = \sqrt{(A_1^2 + A_2^2 + 2A_1A_2 \cos\phi)}$$

phase difference

$$\tan\alpha = \frac{b}{a} = \frac{A_2 \sin\phi}{A_1 + A_2 \cos\phi}$$

देख भाई maths गई भाड़ मे तू बस ये result पर focus कर

Results

$$y_1 = A_1 \sin(\omega t - kx)$$

$$y_2 = A_2 \sin(\omega t - kx + \phi)$$

$$y_{net} = A_{net} \sin(\omega t - kx + \alpha)$$

$$A_{net} = \sqrt{(A_1^2 + A_2^2 + 2A_1A_2 \cos\phi)}$$

$$y_1 = A_1 \sin(\omega t - kx + \theta_1)$$

$$y_2 = A_2 \sin(\omega t - kx + \theta_2)$$

$$y_{net} = A_{net} \sin(\omega t - kx + \alpha)$$

$$A_{net} = \sqrt{(A_1^2 + A_2^2 + 2A_1A_2 \cos\phi}$$

$\Delta\phi = \phi = (\theta_2 - \theta_1)$ phase diff

$$I_{net} = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

phase difference

$$\boxed{\text{Intensity} \propto A^2}$$

$$\boxed{\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda}}$$ path diff

$\Delta\phi \rightarrow$ phase diff.

$$\Delta\phi = \frac{2\pi}{\lambda}\Delta x$$

CONSTRUCTIVE INTERFERENCE

$$A_{net} = \sqrt{A_1^2 + A_2^2 + 2A_1A_2 \cos\phi}$$

$$I_{net} = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

कहीं तो कोई condition होगी जहाँ A_{net}, I_{net} max. मिले

जहाँ $A_{net} \rightarrow$ max. वहाँ $I_{net} \rightarrow$ max.

$\cos\phi = +1$ $\boxed{\phi = 2n\pi}$

$$A_{net} = \sqrt{A_1^2 + A_2^2 + 2A_1A_2 \times 1}$$

$$A_{net} = A_1 + A_2$$

$$I_{net} = (\sqrt{I_1} + \sqrt{I_2})^2$$

If $A_1 = A_2 = A_0$ then $A_{net} = 2A_0$

If $I_1 = I_2 = I_0$ then $I_{net} = 4I_0$

For $\cos(\Delta\phi) = 1$

$\Delta\phi = 2n\pi$, and we know that $\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda}$

So $\frac{2n\pi}{2\pi} = \frac{\Delta x}{\lambda} \rightarrow \boxed{\Delta x = n\lambda}$

DESTRUCTIVE INTERFERENCE

Similarly

$A_{net} \rightarrow$ min.

$I_{net} \rightarrow$ min.

$\cos\phi = -1$ $\boxed{\phi = (odd)\pi}$

$A_{net} = \sqrt{A_1^2 + A_2^2 - 2A_1A_2} = |A_1 - A_2|$

$I_{net} = (\sqrt{I_1} - \sqrt{I_2})^2$

If $A_1 = A_2 = A_0$ then $A_{net} = 0$

If $I_1 = I_2 = I_0$ then $I_{net} = 0$

$\Delta\phi = (odd)\pi = (2\pi + 1)\pi$

$\Delta\phi/2\pi = \Delta x/\lambda$

$\therefore \Delta x = (odd)\lambda/2$

भाई क्या हो गया रोशनी + रोशनी = अंधेरा

रोशनी गई कहाँ

ये तो तभी हो सकता है जब light के पास wave nature हो याद करो शुरू की light के dual nature की लड़ाई.......

Experiment यह देखने के बाद Huygen's theory be like

Exams से पहले यह जरूर देख कर जाना।

Final Results

$A_{net} = \sqrt{(A_1^2 + A_2^2 + 2A_1A_2\cos\phi)}$

$I_{net} = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$

Intensity $\propto A^2$

$\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda}$ (Δx = path diff. and $\Delta\phi \rightarrow$ phase diff.)

$\Delta\phi = \frac{2\pi}{\lambda}\Delta x$ $I = 4I_0\cos^2(\Delta\phi/2)$

****

For Maxima (CI)

$A_{net} = A_1 + A_2$

$I_{net} = (\sqrt{I_1} + \sqrt{I_2})^2$

$\phi = 2n\pi$

$\Delta x = n\lambda$

If $A_1 = A_2 = A_0$ then $A_{net} = 2A_0$

If $I_1 = I_2 = I_0$ then $I_{net} = 4I_0$

****

For Minima (DI)

$A_{net} = A_1 - A_2$

$I_{net} = (\sqrt{I_1} - \sqrt{I_2})^2$

$\phi = (odd)\pi$

$\Delta x = (odd)\lambda/2$

If $A_1 = A_2 = A_0$ then $A_{net} = 0$

If $I_1 = I_2 = I_0$ then $I_{net} = 0$

****

$$\frac{I_{max}}{I_{min}} = \frac{\left(\sqrt{I_1} + \sqrt{I_2}\right)^2}{\left(\sqrt{I_1} - \sqrt{I_2}\right)^2}$$

If S_1 & S_2 are not coherent (market वाले 2 bulb)

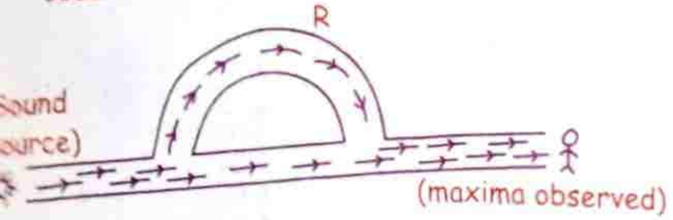
$I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$

$I_{net} = I_1 + I_2$ (because $\cos\phi = 0$)

Q. If $I_1 = 4I_0$ and $I_2 = I_0$ find $\frac{I_{max}}{I_{min}}$

Ans. $\frac{I_{max}}{I_{min}} = \frac{\left(\sqrt{I_1} + \sqrt{I_2}\right)^2}{\left(\sqrt{I_1} - \sqrt{I_2}\right)^2} = 9$ solve and get

Q. Write the equation for maxima detuction for observer.



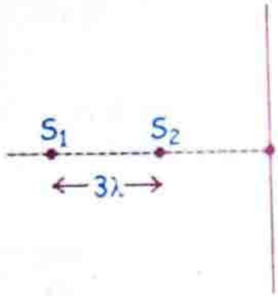
Sol. $\Delta x = n\lambda$

$\pi R - 2R = n\lambda$

$\pi R = n\lambda + 2R;\quad R = \dfrac{n\lambda}{\pi - 2}$

Q. Two cohrents source S_1 and S_2 are on x-axis having separation between them equal to 3λ. Find the intensity at origin P. $(I_1 = I_2 = I_o)$

Sol.



$\Delta x = S_1P - S_2P$

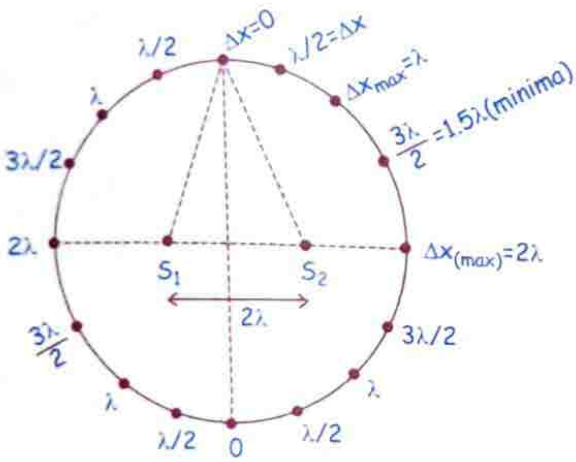
$\Delta x = 3\lambda$ (maxima)

$(I_P) = 4I_0$

$I_1 = I_2 = I_0$

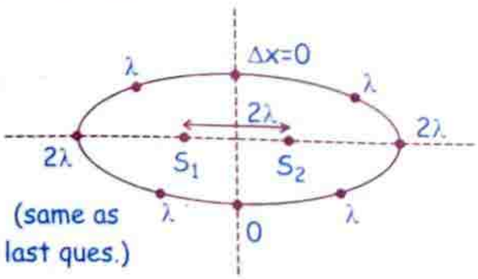
Q. If two cohrents source S_1 and S_2 are on x-axis having separation between them equal to 2λ as shown in figure. Find the number of maxima and minima on the circle.

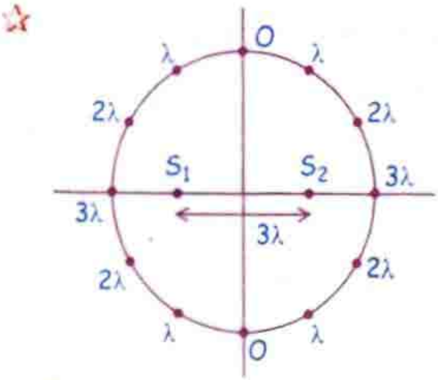
Sol.



No. of maxima = 8

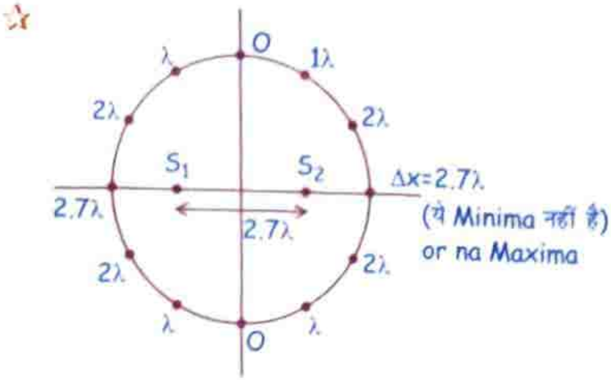
No. of minima = 8





No. of max. on ring = 4 + 8 = 12

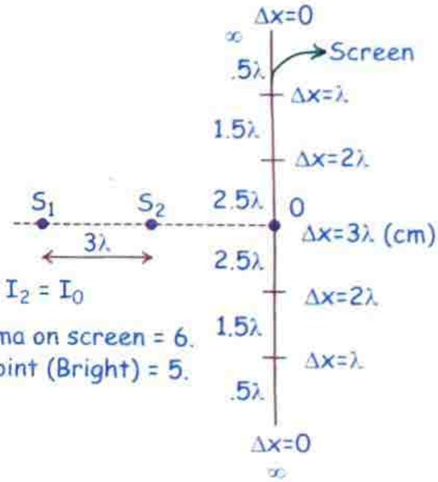
No. of min. = 12



No. of max. = 10

No. of min. = 12

☆ If two cohrents source S_1 and S_2 are on x-axis having separation between them equal to $d = 3\lambda$ as shown in figure. Find the number of maxima and minima on the y-axis.



$I_1 = I_2 = I_0$

No. of minima on screen = 6.

maximum point (Bright) = 5.

Q. Repeat the above problem for different value of d given in table below.

Sol. $I_1 = I_2 = I_0$

	No. of max. on screen	No. of min. on screen
$d = 3\lambda$	5	6
$d = 3.2\lambda$	6	6
$d = 3.5\lambda$	6	7
$d = 3.73\lambda$	6	8

☆ In above question shape of the fringes will be circular, अगर origin से नीचे की screen हटा दो तो shape of the fringes will be semi-circuclar (JEE Adv).

YDSE (YOUNG'S DOUBLE SLIT EXPERIMENT)

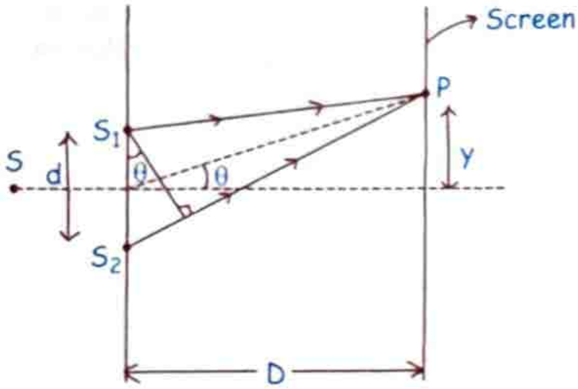
At P

$\Delta x = S_2P - S_1P = d \sin\theta$

$\tan\theta = \dfrac{y}{D}$

If θ is very small $\tan\theta \approx \sin\theta = \theta$

$\Delta x = d\sin\theta = d \cdot y/D$

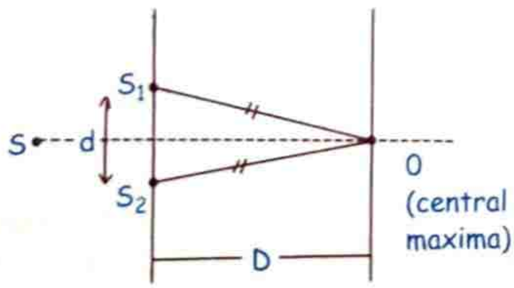


$\Delta x = \dfrac{d}{D}\cdot y,\quad y = \Delta x\,\dfrac{D}{d}$

For maxima, $\Delta x = n\lambda \Rightarrow y = \dfrac{n\lambda D}{d}$

For minima, $\Delta x = (\text{odd})\,\dfrac{\lambda}{2} \Rightarrow y = (\text{odd})\,\dfrac{\lambda}{2}\,\dfrac{D}{d}$

$\Delta x = 0,\ \Delta\phi = 0,\ I_{net} = 4I_0$ (at central maxima)

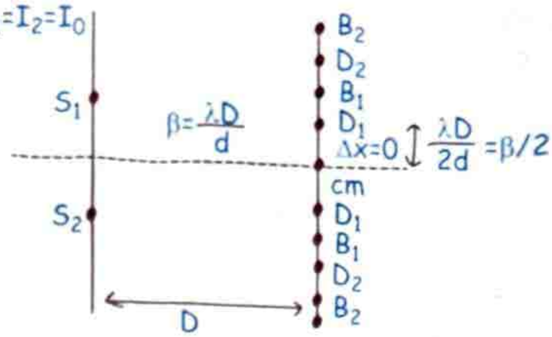


- **For location of maxima**

Maxima $\Rightarrow y = \dfrac{n\lambda D}{d}$

For 1st maxima above cm put n = 1, $y = \dfrac{\lambda D}{d} = B_1$

For 2nd maxima above cm put n = 2, $y = \dfrac{2\lambda D}{d} = B_2$



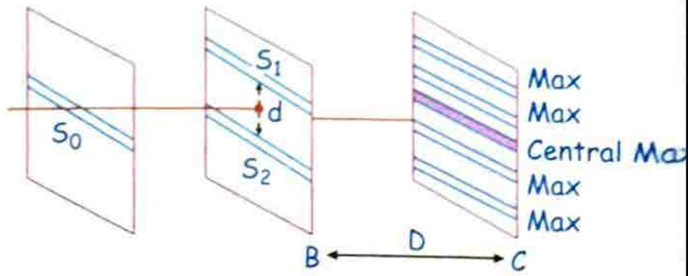
For location of minima/dark

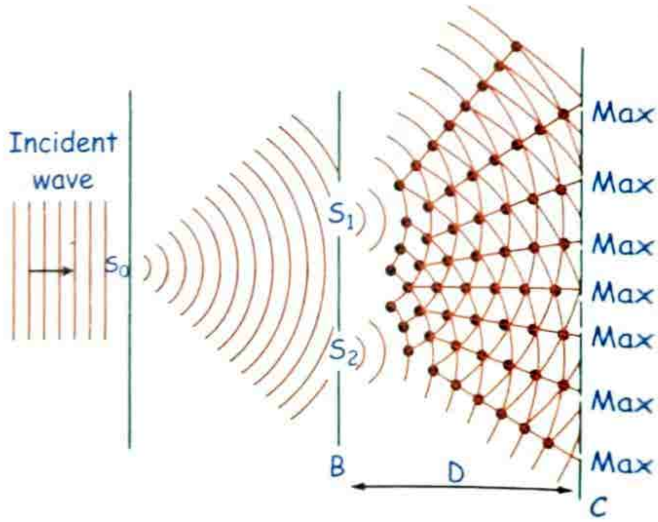
$y = (\text{odd})\,\dfrac{\lambda}{2}\,\dfrac{D}{2} = \dfrac{(2n-1)\lambda d}{2d}$

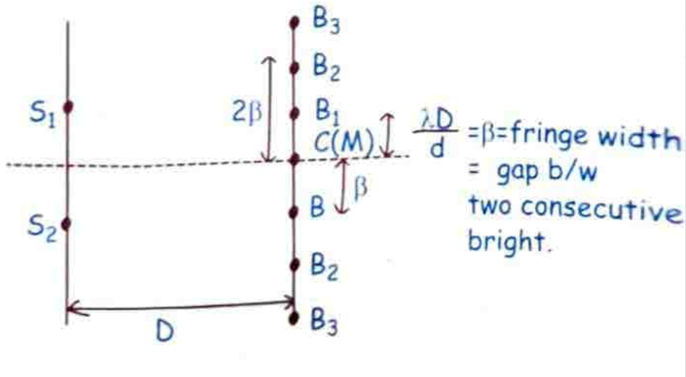
$D_1 \Rightarrow y = \lambda D/2d$

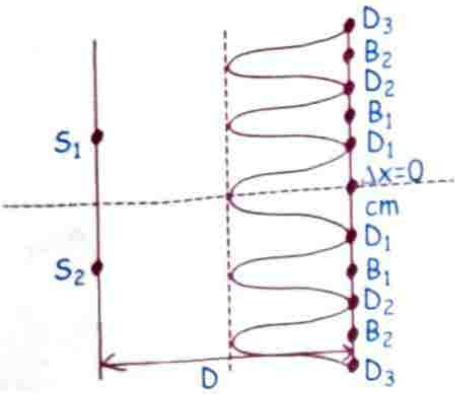
$D_2 \Rightarrow y = 3\lambda D/2d = 1.5\,\dfrac{\lambda D}{d}$

$\dfrac{\lambda D}{d} = \beta =$ fringe width = gap b/w two consecutive bright.





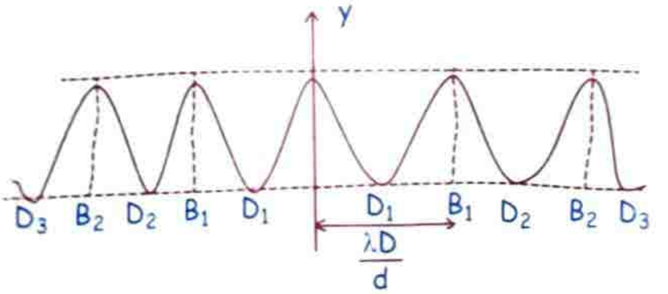




At all the maxima $\Rightarrow I = 4I_0$

At all the minima $\Rightarrow I = 0$

☆ At any point $I = 4I_0 \cos^2 (\Delta\phi/2)$



- If white light is used in YDSE $\longrightarrow$ C.M. is white colourful fringes observed.
- If whole setup is dipped inside water

  $C \longrightarrow C/\mu$

  $f \longrightarrow$ same (C = fλ speed of light)

  $\lambda \longrightarrow \lambda/\mu$

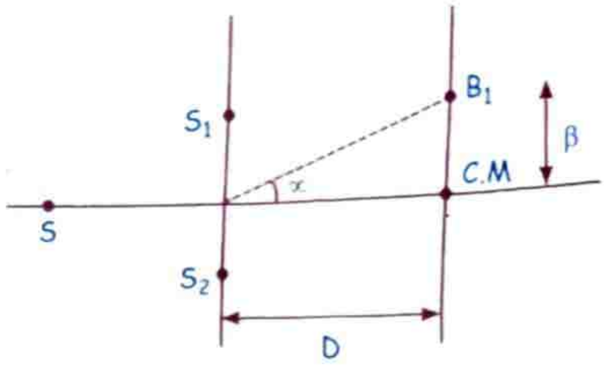
  $\beta \longrightarrow \beta/\mu$

- $\beta = \frac{\lambda D}{d} \Rightarrow \lambda\uparrow \beta\uparrow$
- $\lambda_{red} > \lambda_{green}$

  $\beta_{red} > \lambda_{green}$

- If gap between S_1 and S_2 increase then $d\uparrow$ $\beta\downarrow$ fringe width decreases
- If $D\uparrow$ $\beta\uparrow$ (if screen is moving away)
- $I \propto$ width of slit
- $\tan\alpha = \beta/D = \frac{\lambda D/d}{D} = \frac{\lambda}{d}$

  $\longrightarrow$ Angular width



If screen is moving away from slit

$\beta = \frac{\lambda D}{d} \Rightarrow$ (increase)

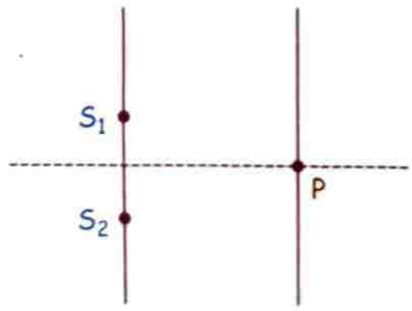
$\alpha = \frac{\lambda}{d} \Rightarrow$ same.

Shape of the fringes will be hyperbolic.

This is very important ये सवाल आपको पूरा YDSE revise करा देगा।

Q. In YDSE, two slits are separated by a distance. .1 mm apart and interference pattern are observed on the screen at a distance 1 m as shown in diagram. Monochromatic light of wavelength $\lambda = 400$nm is used. Find-

$(d = .1\text{mm} = 10^{-4}\text{m})$



- Fringe width

  $B = \frac{\lambda D}{d} = \frac{400 \times 10^{-9} \times 1}{10^{-4}} = 4\text{mm}$

- Location of 5th Bright above C.M.

  $y = 5\beta = 5 \times 4 = 20$ mm

- Location of 7th Bright above C.M.

  $y = 7\beta = 7 \times 4 = 28$ mm

- Location of 5th dark

  $D_5 = 4.5\beta = 4.5 \times 4$ mm $= 18$ mm

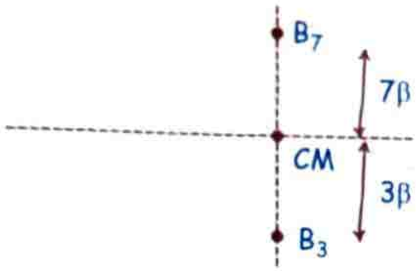
- Location of 10th dark above C.M.

  $y = 9.5\beta = 9.5 \times 4 = 38$ mm

- Gap b/w 7th Bright above C.M. & 3rd Bright above C.M.

  $7\beta - 3\beta = 4\beta = 4 \times 4$ mm $= 16$ mm

- Gap b/w 7th Bright above C.M. & 3rd Bright below C.M.

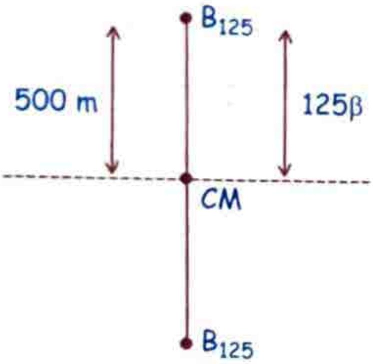


  $7\beta + 3\beta = 10\beta = 10 \times 4$ mm $= 40$ mm

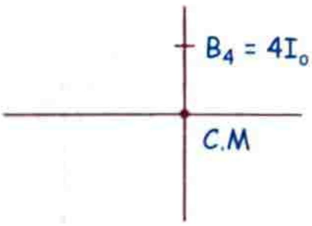
- If length of screen is 1m. Find no. of max. & min. on the screen.

  $125 + 125 + 1 = 251$

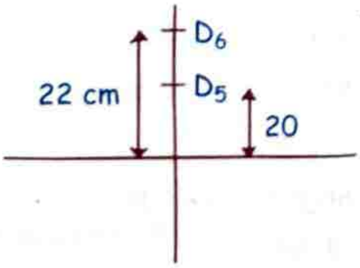
  No. of dark $= 125 + 125 = 250$



- Find intensity at a point 16 cm above C.M.



- Find intensity at a point 22 mm above C.M.



  $\Rightarrow I = 0$ (min.)

- Find location of points where intensity is half of the max. intensity.

  $I = 4 I_0 \cos^2(\phi/2)$

  $\frac{4I_o}{2} = 4 I_0 \cos^2(\phi/2)$

  $\cos(\phi/2) = \pm 1/\sqrt{2}$

  $\phi/2 = 45, 135, 225, \ldots$

  $\phi = 90, 270, 450, \ldots$

  $\phi = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2}, \ldots$

  $\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda}$

  $\Delta x = \frac{3\pi}{2}$

  $\Delta x_1 = \frac{\lambda}{2\pi}\left(\frac{\pi}{2}\right) = \frac{\lambda}{4}$

  $\Delta x_2 = 3\lambda/4 \ldots$

  $\Delta x = d.y/D$

  $y = \Delta x.\frac{D}{d}$

  $y_1 = \frac{\lambda}{4}\frac{D}{d} = \frac{\beta}{4} = 1$mm

  $y_2 = 3$mm

- Find location of points when intensity is 75% of the max. intensity

  $I_{max} = 4I_o$

  75% of $I_{max} = 3I_o$

  $\Delta x = \frac{\Delta\phi}{2\pi}.\lambda$

  $I = 4I_o\cos^2(\phi/2)$

  $3I_o = 4I_o\cos^2(\phi/2)$

  $\frac{3}{4} = \cos^2(\phi/2)$

  $\Delta\phi/2 = 30°, 150°, 210°, \ldots$

  $\Delta\phi = 60°, 300°, 420°, \ldots$

  $\Delta\phi = \frac{\pi}{3}, \frac{5\pi}{3}, \frac{7\pi}{3}, \ldots$

  $\Delta x = \frac{\pi}{3}\cdot\frac{\lambda}{2\pi}, \frac{5\pi.\lambda}{3 \times 2\pi}$

  $\Delta x = \frac{\lambda}{6}, \frac{5\lambda}{6}, \ldots$

  $y = \Delta x.\frac{D}{d}$

  $y = \frac{\lambda}{6} \times \frac{D}{d}, \quad \frac{5\lambda}{6} \times \frac{D}{d}$

  $y \Rightarrow \beta/6, 5\beta/6$

  $y \Rightarrow \frac{2}{3}$mm, $\frac{10}{3}$mm

- Whole system is dipped in water and the length of screen is 1 m
$\mu_{water} = 2$

$\beta_{\text{नया}} = 2$ mm
$\Rightarrow$ No. of max. = 250 + 250 + 1 = 501

Jee बेशर्म Ques

Q. In YDSE setup (d = .1 mm, D = 1m) two light of λ 400 nm & 600 nm are used.

(a) Find location of the point where maxima of both light coincide

Sol. $\lambda_1 = 400$ nm Let किसी जगह पर λ_1 की n_1 Bright
$\lambda_2 = 600$ nm coincide की है

λ_2 की n_2 Bright से

$y = n_1 B_1 = n_2\beta_2$

$n_1\lambda_1 \cdot \frac{\lambda}{d} = n_2\lambda_2\frac{D}{d}$

$n_1\lambda_1 = n_2\lambda_2$

$n_1\, 400 \times 10^{-9} = n_2 \times 600 \times 10^{-9}$

$2n_1 = 3n_2$

integer

n_1	3	6	9
n_2	2	4	6

$2n_1 = 3n_2$

Now put the value of n_1 and get n_2

(b) Find min. distance of a point from C.M. where maxima of both the point coincide.

Sol. $n_1 = 3,\ y = n_1\beta_1 = n_1\frac{\lambda_1 . D}{d}$

$$= \frac{3 \times 400 \times 10^{-9} \times 1}{10^{-4}} = 12 \text{ mm}$$

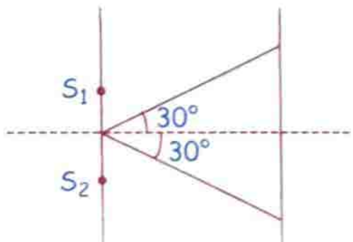
Or $n_2 = 2,\ y = n_2\beta_2 = \frac{2 \times 600 \times 10^{-9} \times 1}{10^{-4}} = 12$ mm

Q. Find the no. of maxima formed b/w angular width

$-30 \le \theta \le +30$

d = .3 mm

λ = 500 nm



Sol. $\Delta x = n\lambda$

$d\sin\theta = n\lambda$

$\sin\theta = n\lambda/d$

$-30 \le \theta \le +30$

$-1/2 \le \sin\theta \le +1/2$

$-1/2 \le n\lambda/d \le +1/2$

$-\frac{d}{2\pi} \le n \le +d/2\pi$

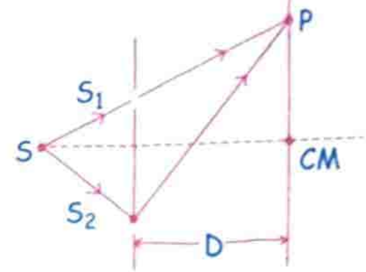
$$\frac{-3 \times 10^{-4}}{2 \times 500 \times 10^{-4}} \le n \le \frac{3 \times 10^{-4}}{2 \times 500 \times 10^{-9}}$$

$-300 \le n \le +300$

Integer

[n = 601]

- $\Delta x = S_2P - S_1P = \frac{dy}{D}$

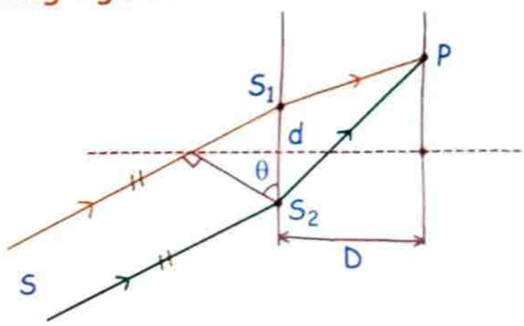


$(\Delta x)_{at\ 'p'} = (SS_2 + S_2P) - (SS_1 + S_1P)$

$= (SS_2 - SS_1) + (S_2P - S_1P)$

$= \frac{d}{D} \cdot y$

If source is moved down to infinity in above case write the path difference for following figure.



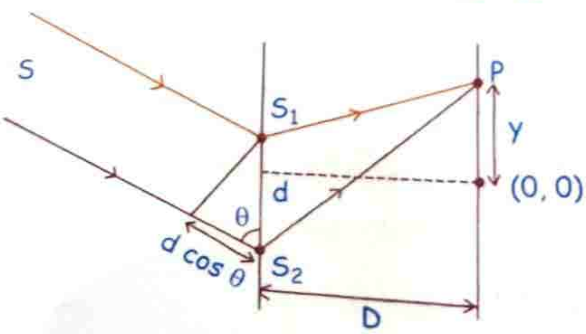
$(\Delta x)_{at\ 'p'} = (SS_2 + S_2P) - (SS_1 + S_1P)$

$= (SS_2 - SS_1) + (S_2P - S_1P)$

$\Delta x = -d\sin\theta + \frac{d}{D}y$

For C.M. $\Rightarrow \Delta x = 0,\ y = (d\sin\theta)\frac{D}{d}$ = shift in C.M.

If source is moved down to infinity write the path difference for following figure.



$\Delta x = (SS_2 + S_2P) - (SS_1 + S_1P)$

$= (SS_2 - SS_1) + (S_2P - S_1P)$

$= d\cos\theta + y\dfrac{d}{D}$

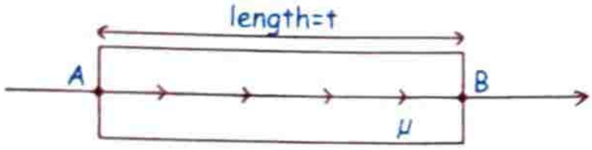
location of C.M., $\Delta x = 0$

$y = -(d\cos\theta).\dfrac{D}{d} = -D\cos\theta$

shift in C.M. (नीचे)

find location of C.M.

IDEA OF OPTICAL PATH



time taken by light to cross the slab ($A \to B$)

$= \dfrac{\text{distance}}{\text{speed}} = \dfrac{t}{c/\mu} = \dfrac{\mu t}{c}$

time taken by light to travel distance $\mu.t$ in vaccum

$= \dfrac{\mu t}{c}$

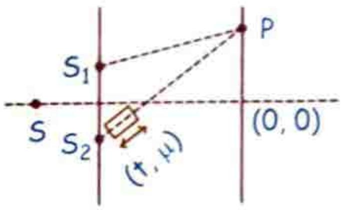
- If light travel a distance 't' in a medium of refractive index 'μ' suffer the same phase as when it travel distance μt in vaccum.

#SKC
Light ka medium (μ) में 't' चलना is equivalent to हवा में 'μt' चलना।

- Path length of 't' distance in medium (μ) is equivalent to path length 'μt' in vaccum.

If slab is placed front of lower slit

- **SSS method:**



At 'P' Δx

$\Delta x = [(S_2P - t)_{\text{हवा}} + t_{slab}] - (S_1P\ _{\text{हवा}})$

$\Delta x = S_2P - t + \mu t - S_1P$

$\Delta x = \dfrac{d.y}{D} + t\,(\mu - 1)$

- Location of C.M.

$\Delta x = 0$ (put)

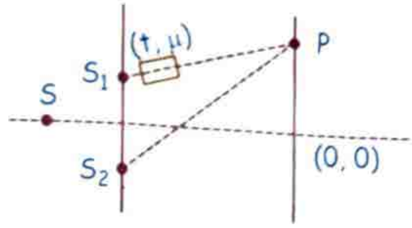
$\boxed{y = -(\mu - 1)t\dfrac{D}{d}}$ → नीचे

- Intensity at origin

$y = 0,\ \Delta x = (\mu - 1)\,t$

$\Delta\phi = ✔,\ I = ✔$

If slab is placed front of upper slit



Δx = at 'P'

$\Delta x = (S_2P)_{\text{हवा}} - [(S_1P - t)_{\text{हवा}} + t_{slab}]$

$\Delta x = S_2P - [(S_1P - t + \mu t]$

$\Delta x = (S_2P - S_1P) + t - \mu t$

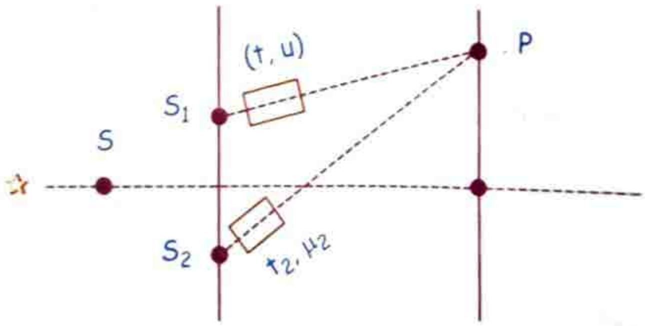
$\Delta x = \dfrac{d.y}{D} - t\,(\mu - 1)$

Location of C.M.

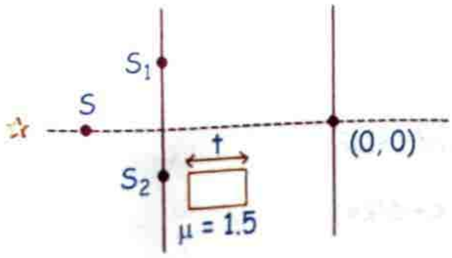
$\Delta x = 0$ (put)

$\boxed{y = +(\mu - 1)\,t\dfrac{D}{d}}$

Shift in C.M.



Sol. $(\Delta x)_{at\ 'P'} = \dfrac{dy}{D} + (\mu_w - 1)t_2 - (\mu_1 - 1)t$



If after placing slab front of S_2 (lower slit) we observe that 5^{th} bright above c.m. before inserting slab take position of y = 0, find thickness of slab.

Sol. shift = 5β

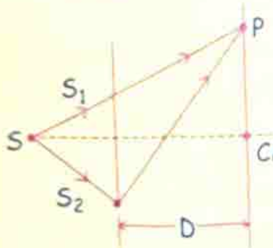
shift in Δx C.M. $\Rightarrow y = \ominus (\mu - 1)t.\ D/d$

$\hookrightarrow$ नीचे

$\Delta x = 0$

$5 \times \frac{\lambda D}{d} = (\mu - 1)t\ \frac{D}{d}$ now you can solve

सीधी बात ये है source S को नीचे shift करोगे तो CM साहब ऊपर जाऐंगे, source S को ऊपर shift करोगे तो CM साहब नीचे जाऐंगे और only ऊपर वाली slit के सामने slab रखा तो CM साहब ऊपर जाऐंगे और only नीचे वाली slit के सामने slab रखा तो CM साहब नीचे जाऐंगे और अगर दोनो के सामने slab रखा तो solve करो।



THIN FILM INTERFERENCE

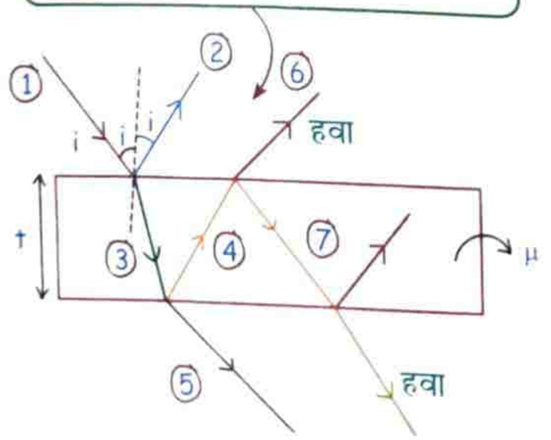
if i → very small i → 0

At reflection side

Δx = path diff. = $2\mu t + \frac{\lambda}{2} = n\lambda$ (maxima)

Hence if $2\mu t$ = odd $\times \frac{\lambda}{2}$ (maxima)

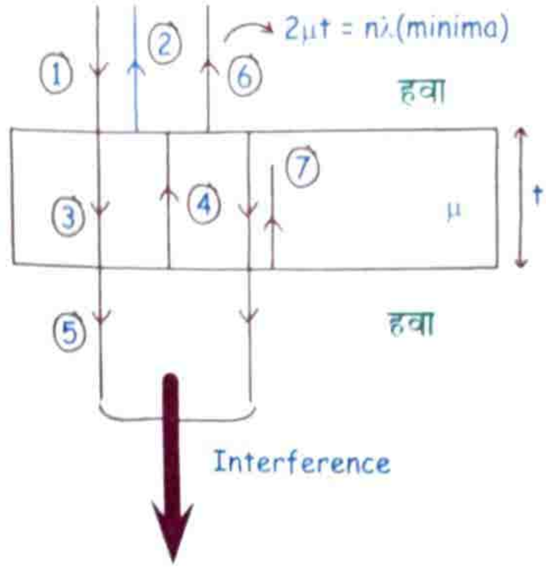
if $2\mu t = n\lambda$ (minima)



Hence at reflection side

Δx = path diff. = $2\mu t + \frac{\lambda}{2} = n\lambda$ (maxima)

$2\mu t = n\lambda - \frac{\lambda}{2} = (2n - 1)\frac{\lambda}{2}$ = odd $\frac{\lambda}{2}$ (maxima)



$2\mu t = (\text{odd})\ \frac{\lambda}{2}$ (maxima)

$2\mu t = n\lambda$ (minima)

#SKC

अगर wave rare → denser

मे जाती है तो– Refraction wali wave में

π का addition phase diff आ जाता है

[transmit वाले में नहीं आता]

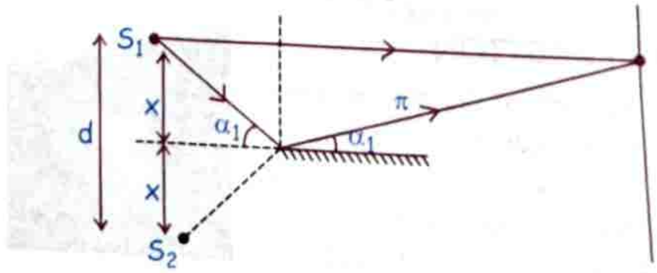
$\Delta x = \lambda/2$

Q. Calculate the minimum thickness of a soap film μ = 1.33 that results in constructive interference in the reflected light if film is illuminated with light whose wavelength in free space is λ = 600 nm.

Sol. $2\mu t = (\text{odd})\ \frac{\lambda}{2}$

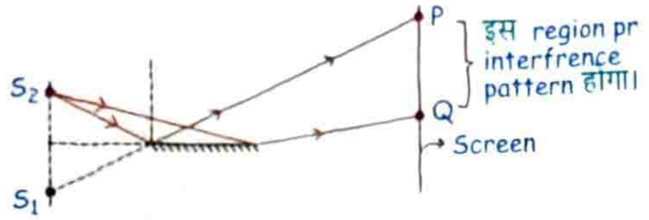
$$\min t = \frac{(\text{odd})\ \lambda}{2 \times 2 \times \mu} = \frac{1 \times 600 \times 10^{-9}}{4 \times 1.33}$$

LOYD'S MIRROR (For Advance Only)

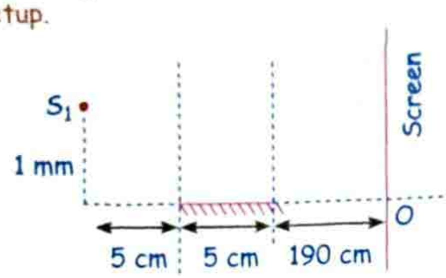


$\Delta x = d\sin\theta = n\lambda$ (minima) (उल्टे)

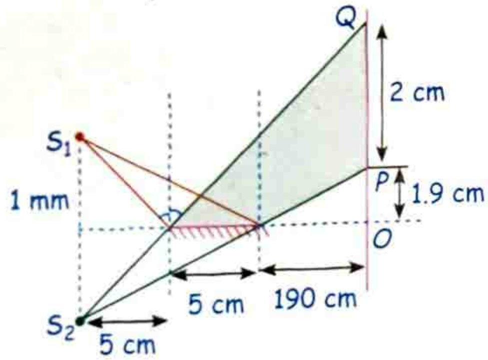
d = 2x.



Q. Find fringe width & total no. of fringes on the screen (given $\lambda = 5000Å$) for the following setup.



Sol. Interference fringes will be between P & Q and interference is due to direct rays of source & reflected rays from mirror.



fringe width

$$\beta = \frac{\lambda D}{d} = 0.5 \text{ mm}$$

By law of reflection

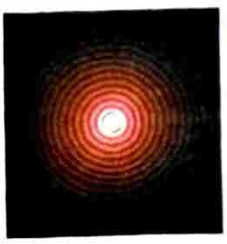
$$\frac{0.1}{5} = \frac{OQ}{195} \Rightarrow OQ = 3.9 \text{ cm}$$

$$\frac{0.1}{10} = \frac{OP}{190} \Rightarrow OP = 1.9 \text{ cm}$$

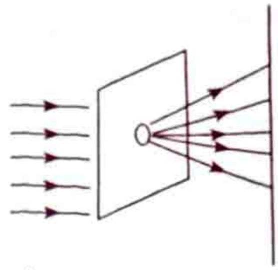
$$\text{No. of fringe} = \frac{2}{0.5 \times 10} = 40$$

DIFFRACTION

- Bending of light rays from sharp edges of an opaque obstacle or aperture and its spreading in this shadow region is defined as diffraction of light or deviation of light from its rectilinear propagation.



Diffraction by circular aperture (airy disk)

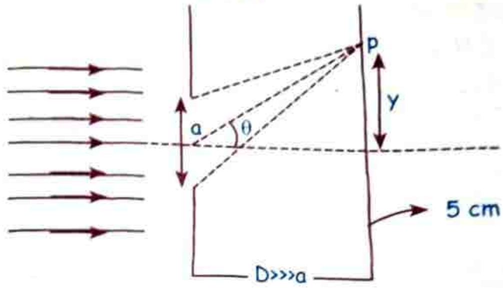


- Size of an obstacle or aperture should be nearly equal to the wavelength of light

$$\lambda = a.$$

- If $\lambda \lll a \Rightarrow$ Then rectilinear motion of light is observed.

- **Fraunhoffer Diffraction**



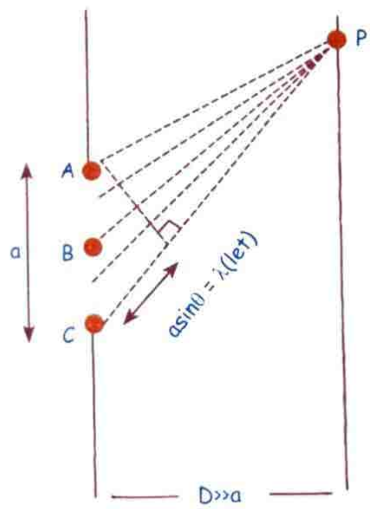
Differaction through single slit-

$a\sin\theta = n\lambda$ (n^{th} minima)

$\tan\theta = y/D$

$$\begin{cases} a\sin\theta = \lambda \ (1^{st} \text{ minima}) \\ a\sin\theta = 2\lambda \ (2^{nd} \text{ minima}) \end{cases}$$

$a\sin\theta = \frac{3\lambda}{2}$ (1^{st} secondary max.)

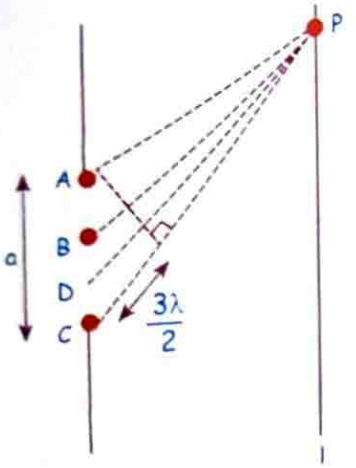
- 

$a\sin\theta = \lambda$ (let) (1st minima)

$a\sin\theta = 2\lambda$ (2nd minima)

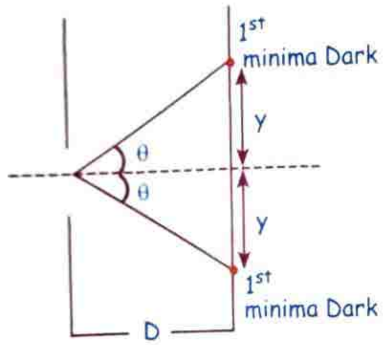
$$\Delta x = \frac{\lambda}{2}, \frac{3\lambda}{4} - \frac{\lambda}{4} = \frac{\lambda}{2}$$

$\Delta\phi = \pi$



$a\sin\theta = \frac{3\lambda}{2}$ (1st secondary maxima)

$a\sin\theta = \frac{5\lambda}{2}$ (2nd secondary maxima)



$a\sin\theta = \lambda$

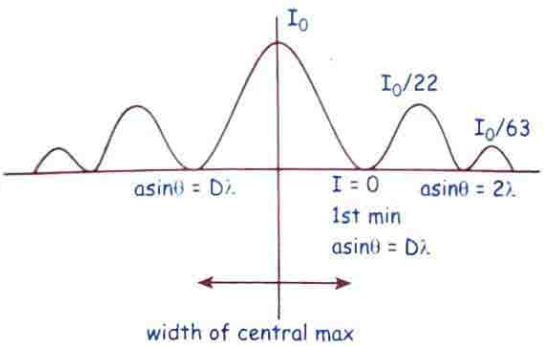
$\tan\theta = y/D$

if θ is very small

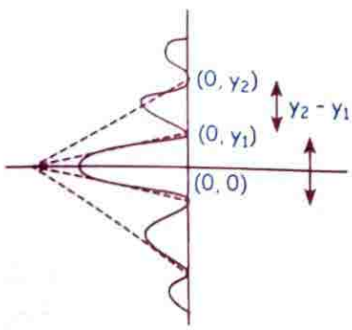
$a.\frac{y}{D} = \lambda$

$y = \frac{\lambda D}{a}$

width of central max. $= 2y = \frac{2\lambda D}{a}$



$$I = I_{max}\left(\frac{\sin\alpha}{\alpha}\right)^2$$



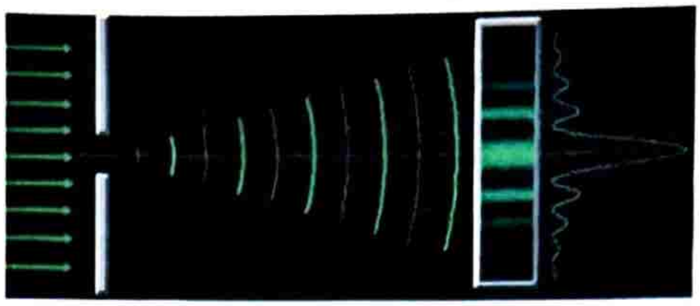
$a\sin\theta = 2\lambda$

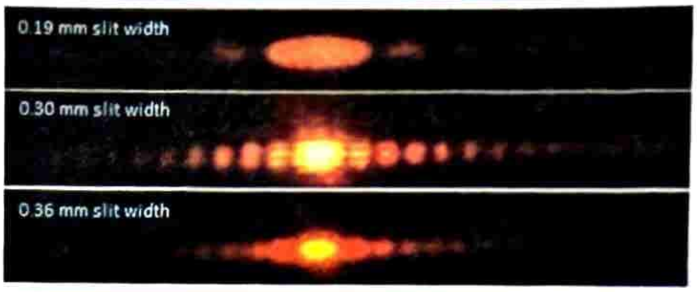
$\sin\theta = \frac{2\lambda}{a} \approx \tan\theta = y_2/D$

$y_2 = \frac{2\lambda D}{a}, y_1 = \frac{\lambda D}{a}$

width of C.M $= 2y_1$

width of 1st Secondary max $= \frac{\lambda D}{a}$





Exams से पहले यह जरूर देख कर जाना।

Final Results

→ $a\sin\theta = n\lambda$ (for nth minima)

→ width of central maxima $= 2\lambda D/a$

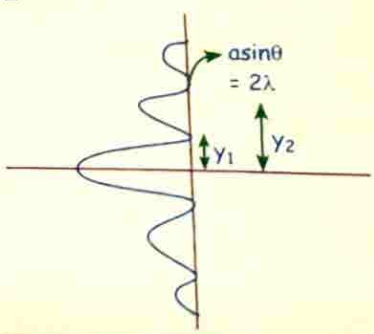
→ Angular spread $= 2\theta = 2\lambda/a$

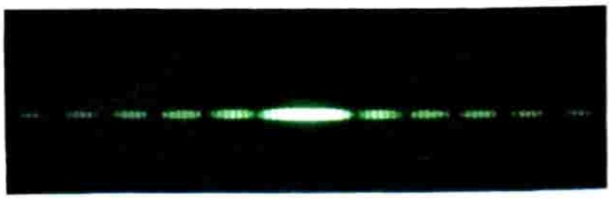
For any style baji use ⇒ $\tan\theta = y/D$
$a\sin\theta = n\lambda$ (n^{th} minima)

If θ is very small width of central max = $2\lambda D/a$
width of 1st secondary max = $\lambda D/a$

→ $a\sin\theta = \frac{3\lambda}{4}$ (1st secondary maxima)

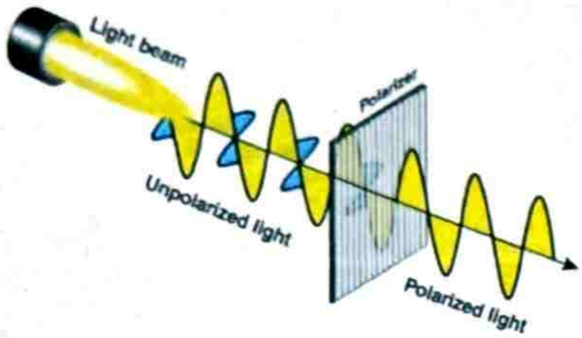
→ $a\sin\theta = \frac{5\lambda}{2}$ (2nd secondary maxima)

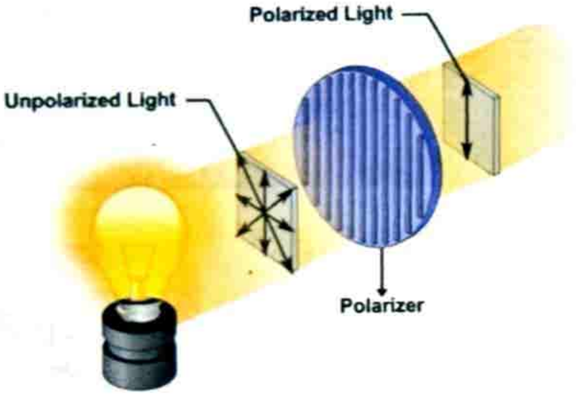




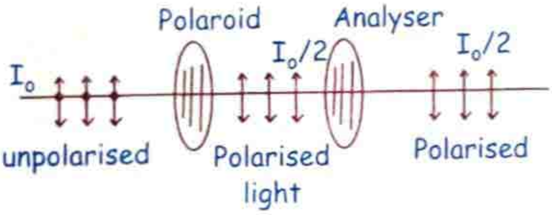
Lab मे experiment करने पर ऐसा दिखता है इसमे interference or diffraction दोनो हुए है

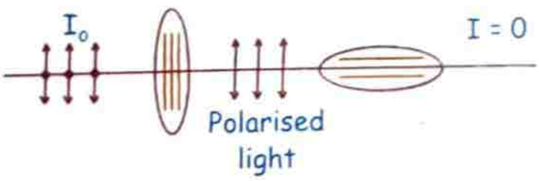
POLARISATION



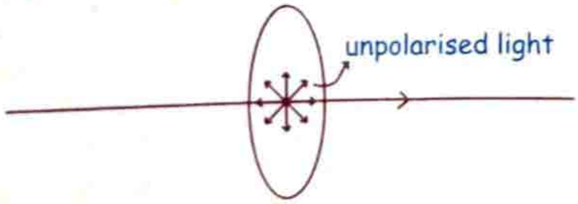


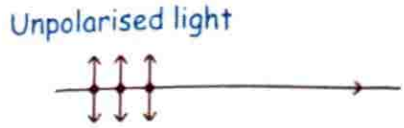
Restriction of vibration of electric field vector in a particular direction $\perp$ ar to the dirx^n of wave motion is called polarisation of light.

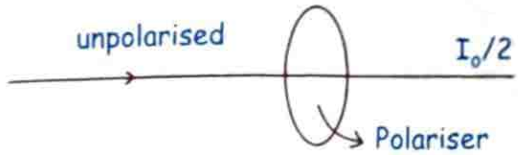




- Unpolarised light

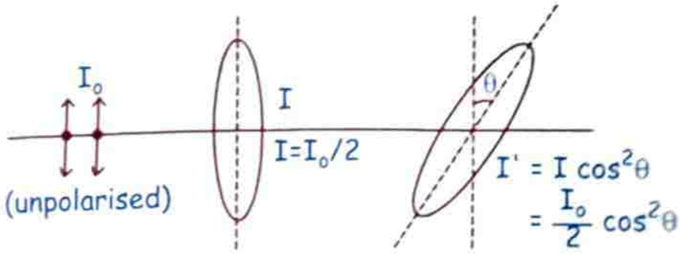


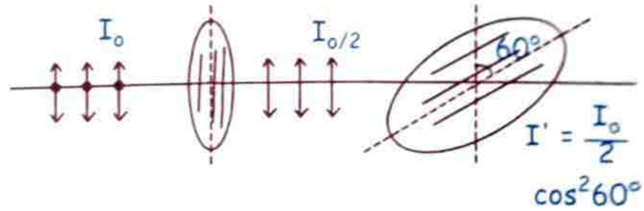


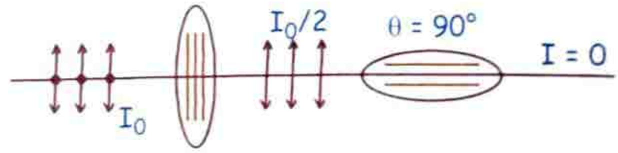


- **Malus law**

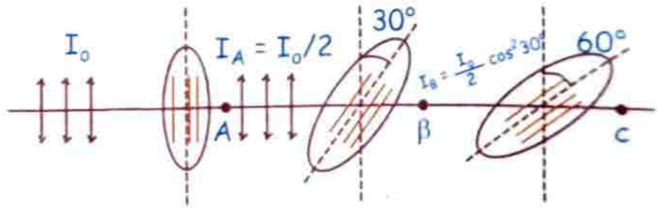
When a completely polarised light is incident on analyser, intensity of emergent light varies as square of cosine of the angle b/w the plane of transmission of the analyser & polariser.



- 

- 

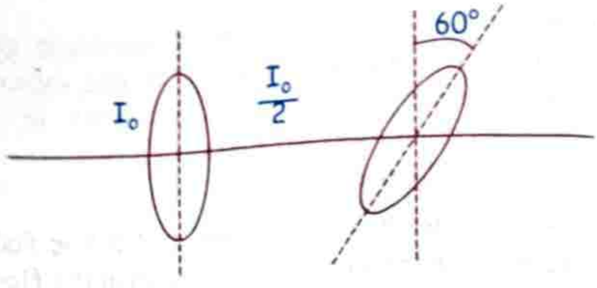
Q. If three polaroid are placed such that angle b/w each axis is 30° to the preceding polaroid. Find intensity coming out from last polaroid.



$$I_C = I_B \cos^2 30°$$

$$= \left(\frac{I_0}{2}\cos^2 30°\right)\cos^2 30°$$

Q. Two polaroids cross each other. Now if our polaroid is rotated by angle 30°. What % of incident unpolarised light is transmitted finally.

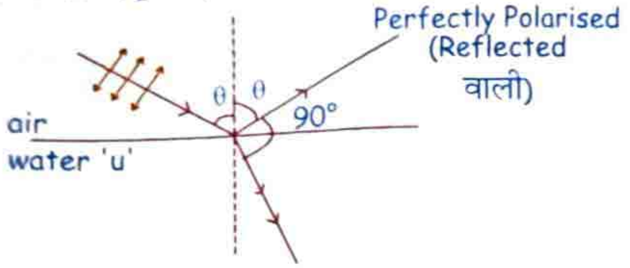


$$I = \frac{I_o}{2}\cos^2 60°$$

POLARISATION BY REFLECTION/ BREWSTER'S LAW

$\mu_1 \sin i = \mu_2 \sin r$

$1 \sin\theta = \mu_2 \sin(90-\theta)$



$\tan\theta = \mu \quad \Rightarrow \quad \theta = \tan^{-1}(\mu)$

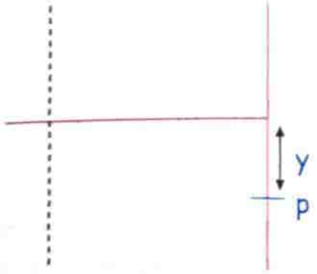
Plane of vibration = Plane within which vibration of polarised light confined.

Plane of polarization = Plane at right ∠ to plane of vibration and passing through dir of propagation of light

NOW SOLVE FOLLOWING QUESTIONS FOR YOUR PRACTICE

Q. In a double slit pattern (λ = 6000 Å), the first order and tenth order maxima fall at 12.50 mm and 14.75 mm from a particular reference point. If λ is changed to 5500 Å, find the position of zero order and tenth order fringes, other arrangements remaining the same.

Sol.



$$\frac{D\lambda}{d} = y + 12.5 \qquad \text{...} (i)$$

$$\frac{10D\lambda}{d} = y + 14.75 \qquad \text{...} (ii)$$

From equation (*i*) and (*ii*)

$9D\lambda/d = 9\beta = 2.25$ mm

$\beta = 0.25$ mm;

$y = -12.25$ mm (Zero order fringe)

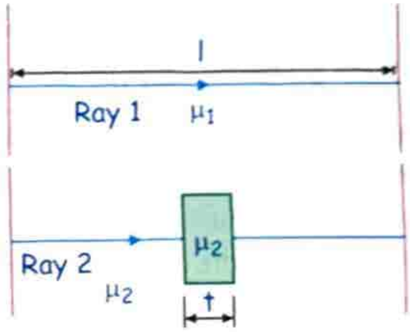
$$\beta = \frac{D\lambda_1}{d};\ \beta' = \frac{D\lambda_2}{d}$$

$$\frac{\beta}{\beta'} = \frac{6000}{5500} \Rightarrow \beta' = \frac{55}{60}\beta = \frac{11}{12}\beta$$

$$\beta' = \frac{11}{12} \times \frac{2.25}{9} = 0.229 = 0.23 \text{ mm}$$

$y = 12.25 \times 0.23 \times 10 = 14.55$ mm.
(10[th] order fringe)

Q. Find the phase difference in medium of refractive index μ_1.



Sol. Equivalent optical length of ray 2 w.r.t.

$$\mu_1 = (l - t) + \frac{\mu_2 t}{\mu_1}$$

$$= l + t\left[\frac{\mu_2}{\mu_1} - 1\right],$$

$$\Delta x = t \times \left[\frac{\mu_2}{\mu_1} - 1\right]$$

$$\phi = \frac{2\pi \times t}{\lambda_1}\left[\frac{\mu_2}{\mu_1} - 1\right]$$

Q. Two coherent light sources *A* and *B* with separation 2λ are placed on the *x*-axis symmetrically about the origin. They emit light of wavelength λ. Obtain the positions of maxima on a circle of large radius lying in *x-y* plane and with centre at the origin.

Sol. At point *P* interference of two waves depends on path difference $AP - BP = \Delta x$ since $r \gg \lambda$

$\therefore \Delta x = AB\cos\theta$

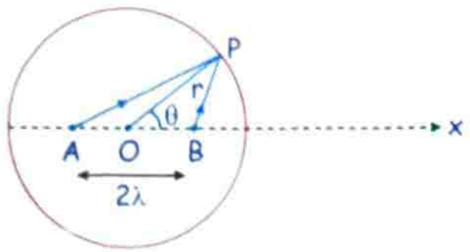
So $\Delta x = 2\lambda\cos\theta$

For maxima $\Delta x = n\lambda$

$\Rightarrow 2\lambda \cos\theta = n\lambda$

$\Rightarrow \cos\theta = \dfrac{n}{2}$

$\therefore -2 \le n \le 2$



So $n = -2, -1, 0, 1, 2$

So For	$n = -2$	$\theta = 180°$
For	$n = -1$	$\theta = 120°, 240°$
For	$n = 0$	$\theta = 90°, 270°$
For	$n = 1$	$\theta = 60°, 300°$
For	$n = 2$	$\theta = 0°$

So there are eight positions on circle where maxima are obtained.

Q. Find the ratio of the intensity at the centre of a bright fringe to the intensity at the point one quarter of the distance between two fringes from the centre in YDSE.

Sol. Total intensity at any point is given by

$I_1 = kR^2 = k(a^2 + b^2 + 2ab\cos\phi)$

when $b = a$,

$I_1 = k(a^2 + a^2 + 2a^2\cos\phi)$

$2a^2k(1+\cos\phi) = 2a^2k\left(1 + 2\cos^2\dfrac{\phi}{2} - 1\right) = 4a^2k\cos^2\dfrac{\phi}{2}$

$I_1 = 4a^2k\cos^2\dfrac{\phi}{2} = 4a^2k$ [At centre $\phi = 0$]

distance between two fringes = β, which is proportional to wavelength (λ)

Now $\dfrac{\lambda}{4}$ corresponds to a phase difference

$= \dfrac{2\pi}{4} = \dfrac{\pi}{2}$

$\therefore I_2 = 2ka^2\left(1 + \cos\dfrac{\pi}{2}\right) = 2ka^2$

$\dfrac{I_1}{I_2} = \dfrac{4ka^2}{2ka^2} = \dfrac{2}{1}$

Q. White light is incident normally on a glass plate of thickness 0.50×10^{-6} m and index of refraction 1.50. Which wavelengths in the visible region (400 nm - 700 nm) are strongly reflected by the plate?

Sol. Let us consider that a beam of light is falling normally on the glass plate as shown in the figure. Some part of the beam is reflected from upper surface (having phase $\phi_1 = \pi$ after reflection) and other part of beam which refracts at the upper surface is reflected from lower surface. This part of beam of light is again refracted at the upper-surface and emerges out with phase $\phi_2 = \dfrac{\Delta x}{\lambda} \times 2\pi = \dfrac{2\mu t}{\lambda} \times 2\pi$. Hence, the total phase difference of wave in reflected system is given by

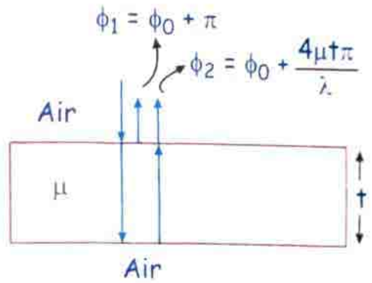
$\Delta\phi = \phi_2 - \phi_1 = \left(\dfrac{2\mu t}{\lambda} \times 2\pi\right) - \pi$

for constructive interference,

$\Delta\phi = 2n\pi$

$\Rightarrow 2\mu t = \left(n + \dfrac{1}{2}\right)\lambda$

Here $2\mu t = 2 \times 1.5 \times 0.5 \times 10^{-6}$ m $= 1.5 \times 10^{-6}$ m



Putting $\lambda = 400$ nm,

$1.5 \times 10^{-6} = \left(n + \dfrac{1}{2}\right) 400 \times 10^{-9}$

$\Rightarrow n = 3.25$

Similarly, by putting $\lambda = 700$ nm

$1.5 \times 10^{-6} = \left(n + \dfrac{1}{2}\right) 700 \times 10^{-9}$

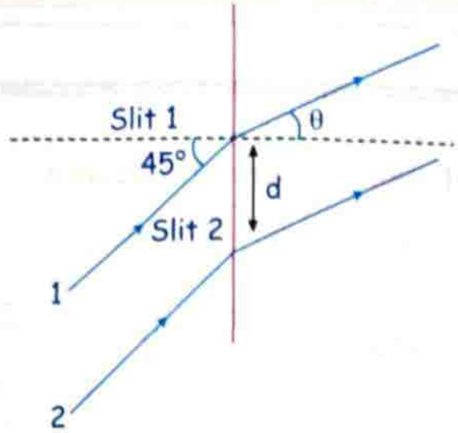
$\Rightarrow n = 1.66$

Thus, within 400 nm to 700 nm for integral values of $n = 2$ and 3 there will be strong reflection.

Now $\lambda = \dfrac{4\mu t}{2n+1} = 600$ nm

and 429 nm are strongly reflected.

Q. Distance between the slits shown in figure is $d = 20\lambda$ where λ is the wavelength of light used.



Find angle θ,

(*i*) where central maxima is obtained

(*ii*) where third order maxima is obtained.

Sol. Ray 1 has a longer path than that of ray 2 by distance $d\sin 45°$ before reaching the slits. Afterwards ray 2 has a path longer than ray 1 by a distance $d \sin \theta$.

$\therefore$ Net path difference $\Delta x = d \sin\theta - d\sin 45°$

(*i*) For central maxima $\Delta x = 0$

$d \sin\theta - d\sin 45° = 0$

$\therefore \theta = 45°$

(*ii*) For third order maxima $\Delta x = 3\lambda$

$d\sin\theta - d\sin 45° = 3\lambda$

$$\sin\theta = \sin 45° + \frac{3\lambda}{d} \qquad (\text{as } d = 20\lambda)$$

$$\sin\theta = \frac{1}{\sqrt{2}} + \frac{3}{20} \Rightarrow \theta = \sin^{-1}\left\{\frac{1}{\sqrt{2}} + \frac{3}{20}\right\}.$$

Q. Angular width of central maximum in Fraunhofer diffraction pattern of a slit is measured. The slit is illuminated by light of wavelength 6000 Å. When slit is illuminated by light of another wavelength, the angular width decreases by 30%. Calculate the wavelength of this light. The same decrease in the angular width of central maximum is obtained when the original apparatus is immersed in a liquid. Find the refractive index of the liquid.

Sol. Angular width of the central maximum can be obtained by finding out the angle subtended at the slit by the two first intensity minima.

1st intensity minima is given by $d\sin\theta = \pm n\lambda [n = 1]$

For small θ, half angular width is $\theta = \left(\frac{\lambda}{d}\right)$

$\therefore$ Angular width is $\theta_0 = \frac{2\lambda}{d}$

Let θ_0' be the changed angular width

$\therefore \theta_0' = \theta_0 - 0.3\theta_0 = 0.7\theta_0$

$\therefore \frac{\theta_0'}{\theta_0} = \frac{\lambda'}{\lambda} [\lambda = 6000 Å]$

$\Rightarrow \lambda' = 0.7\lambda = 0.7 \times 6000 = 4200$ Å

In presence of liquid the wavelength changes to

$\lambda' = \frac{\lambda}{\mu}$

$\therefore \theta_0'' = 2\left(\frac{\lambda}{\mu d}\right) = \frac{\theta_0}{\mu}$ Again, $\theta_0'' = 0.70\theta_0$

$$\mu = \frac{\theta_0}{\theta_0''} = \frac{1}{0.7} = 1.43$$

10 Modern Physics

This is very important chapter हर साल 2 से 3 question पूछे जाते है मजेदार बात यह है इसका काफी part आप chemistry मे पढ़ चुके हो इसलिए अभी हम to the point बात करेंगे।

PHOTON THEORY

- **Light has two characteristics:** Wave as well as particle (Dual nature).
- It shows wave nature by phenomenon like interference and diffraction and it shows particle nature by exerting force, impulse and carrying momentum.
- Photons can be visualized as packet of energy.
- Momentum of one-photon is given by $= \frac{h}{\lambda}$
- Direction of momentum is along the direction of propagation of light.
- Energy of One-photon is given by:

$$\frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8} J}{\lambda \text{ in meter}}$$

Question में ध्यान से देखना है की λ nm मे दिया है या $\AA$ मे

$$\boxed{\text{in eV} = \frac{1240}{\lambda \text{ (in nm)}} = \frac{12400}{\lambda \text{ (in } \AA)}}$$

(approx after full calculation)

Q. Wavelength of light is 310Å. Find the momentum of one photon & energy of one photon in eV.

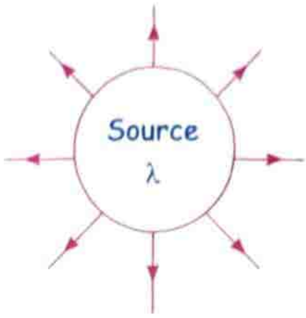
Sol. $P = \frac{h}{\lambda} = \frac{6.6 \times 10^{-34}}{310 \times 10^{-10}}$

$E = \frac{12400}{310} = 40ev$

Q. λ = 620 nm, Energy of photon?

Sol. Energy of one-photon $= \frac{1240}{620} = 2eV$

Power of mono-chromatic source



$P_{source} = \frac{nhc}{\lambda}$

n = no. of photons emitted per second

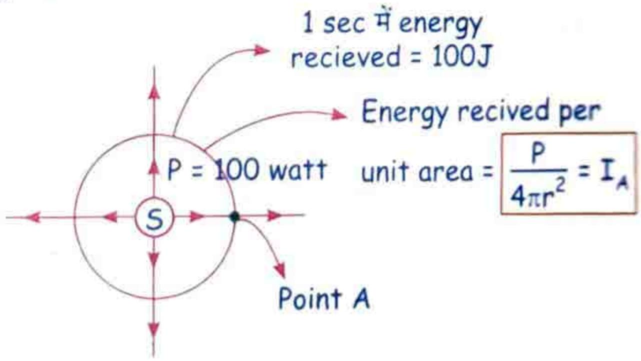
$1eV = 1.6 \times 10^{-19} J$

$1J = \frac{1}{1.6 \times 10^{-19}} eV$

INTENSITY

Intensity (I) = Energy per unit time per unit area
= power per unit area

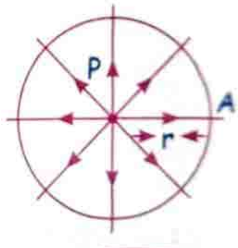
##Suppose we have a point source of power 100 watt and let assume imaginary spherical area at a distance r. Intensity at point A at a distance r from source is I_A then



1. Point source

$I_A = \frac{P}{4\pi r^2}$

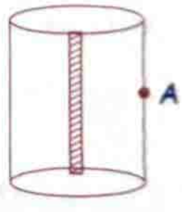
$I \propto \frac{1}{r^2}$



2. Linear source

$I_A = \frac{P}{2\pi rl}$

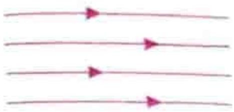
$I \propto \frac{1}{r}$



3. **Parallel Beam**

$I \rightarrow$ const

$I \propto r^0$



Q. Consider a point source of power 100 watt emitting monochromatic light of wavelength 310 Å.

(i) Energy of one-photon

$$= \frac{12400}{310} = 40\text{eV}$$

(ii) No. of photon emitted per sec

$$= \frac{P}{\frac{hc}{\lambda}}$$

$$n = \frac{P}{\frac{hc}{\lambda}} = \frac{100 \times 310 \times 10^{-10}}{6.6 \times 10^{-34} \times 3 \times 10^{8}} = 15.6 \times 10^{18}$$

(iii) Find frequency

$C = f\lambda$ (source)

$= 3 \times 10^8 = f \times 310 \times 10^{-10}$

(iv) Find intensity at a distance r from source.

$$= \frac{P}{4\pi r^2} = \frac{100}{4\pi r^2}\left(\frac{\text{watt}}{m^2}\right)$$

DETECTOR

Energy received per sec by detector of small area A_0 from a point source at a distance r.

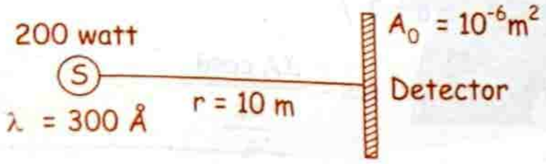
$$= \frac{P}{4\pi r^2} \times A_0 = \text{Intensity.}$$

Energy received in t sec $= \frac{Pt}{4\pi r^2} \times A_0$

No. of photons in t sec received by detector

$$= \left(\frac{\frac{P}{4\pi r^2} . Ao .t}{\frac{hc}{\lambda}}\right)$$

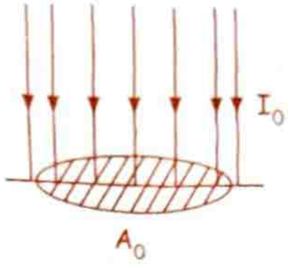
Q.



Sol. No. of photons detected by detector in 15 sec

$$= \frac{\frac{Pt}{4\pi r^2}}{\frac{hc}{\lambda}} A_0.$$

Q.



Sol. Total energy received by Area in 't' time $= I_0 A_0 t$

Total no of photon received by Area in 't' time

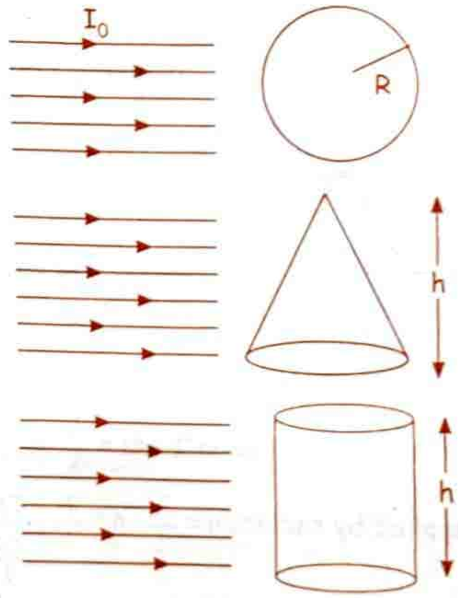
$$= \frac{I_0 A_0 t}{\frac{hc}{\lambda}}$$

Q. In following cases find the no. of photons falls in t. time in the given body.

(a)

(b)

(c)



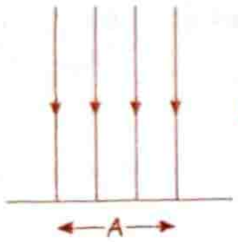
Sol. (a) No. of photons received in t_0 time $= \frac{I.\pi R^2 .t_0}{\frac{hc}{\lambda}}$

(b) No. of photons received in t_0 time

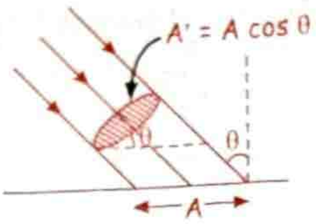
$$\frac{I_0\left(\frac{1}{2} \times 2R \times h\right)t_0}{\frac{hc}{\lambda}}$$

(c) $n = \frac{I_0 (2R.h)\, t_0}{\frac{hc}{\lambda}}$

Q.



Q.



Sol. No. of photons per second

$$n = \frac{I_0 A}{\frac{hc}{\lambda}}$$

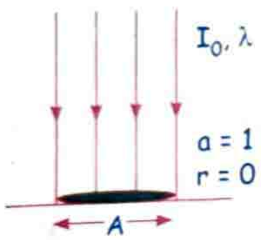
$$n = \frac{I_0 A}{\frac{hc}{\lambda}}$$

$$n = \frac{I_0 A'}{\frac{hc}{\lambda}} = \frac{I.A.\cos\theta}{\frac{hc}{\lambda}}$$

RADIATION PRESSURE

$$a = \text{Absorbing Power} = \frac{\text{Energy absorbed}}{\text{Energy incident}}$$

Case I



(Perfectly absorbing)

$$n = \frac{I_0 A}{\frac{hc}{\lambda}} = \text{No. of photon receive per second.}$$

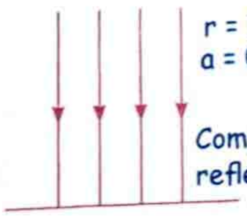
(Δp) of one photon $= \frac{h}{\lambda}$ (magnitude)

Change in momentum in '1' sec $= \frac{h}{\lambda}.n$

'F' applied by radiation $= \frac{h}{\lambda}.n = \frac{h}{\lambda}.\frac{IA}{\frac{hc}{\lambda}}$

$$\boxed{\frac{F}{A} = \text{Pressure} = P = \frac{I}{C}}$$

Case II



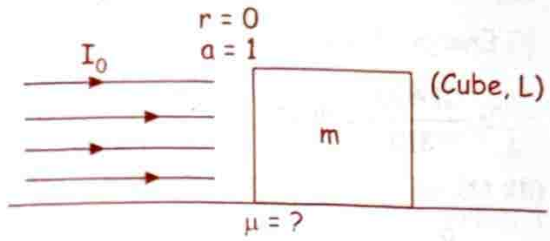
(ΔP) are photon $= \frac{2h}{\lambda}$

Force $= \frac{2h}{\lambda} \times n = \frac{2h}{\lambda}.\frac{IA}{hc/\lambda}$

$F = \frac{2IA}{C}$

$$\boxed{\text{Pressure} = \frac{2I}{C}}$$

Q.



Force on block = pressure × Area $= \frac{I}{C}.L^2$

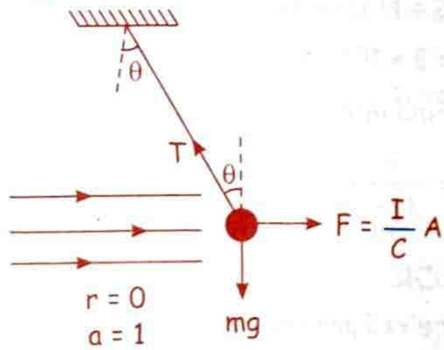
(a) What should be μ_{min} so that block does not slip

$= \mu mg = \frac{IL^2}{C}$

(b) If r = 1 then a = 0

$\frac{2I}{C} \times L^2 = umg$

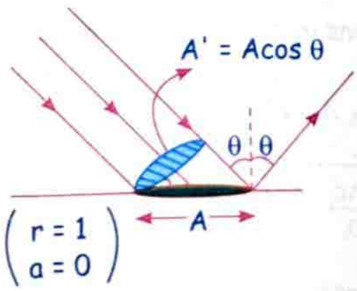
Q. Ball is in equilibrium in diagram below write the equation.



$T\cos\theta = mg$

$T\sin\theta = \frac{I}{C} A = F$

Case-III

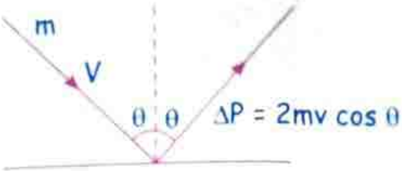


No. of photon per sec $= \frac{IA\cos\theta}{\frac{hc}{\lambda}}$

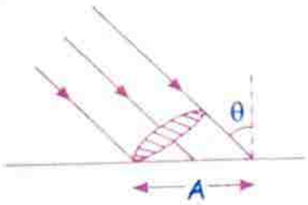
(Δp) of one photon $= \frac{2h}{\lambda}\cos\theta$

$$F = \frac{IA\cos\theta}{\frac{hc}{\lambda}} \times \frac{2h\cos\theta}{\lambda}$$

$$\boxed{P = \frac{F}{A} = \frac{2I\cos^2\theta}{C}}$$



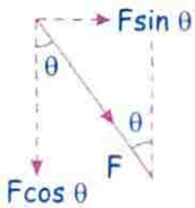
Case-IV



$$\begin{pmatrix} r = 0 \\ a = 1 \end{pmatrix}$$

$$n = \frac{IA\cos\theta}{hc/\lambda} \qquad (\Delta P) \text{ one photon} = \frac{h}{\lambda}$$

$$F \text{ on area } A = \frac{h}{\lambda} \cdot \frac{IA\cos\theta}{\frac{hc}{\lambda}}$$



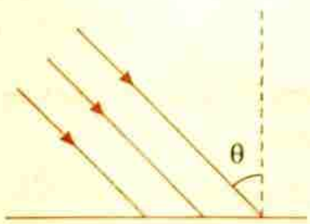
$$\text{pressure} = \frac{F\cos\theta}{A}$$

$$\boxed{P = \frac{I\cos^2\theta}{C}}$$

काम का डब्बा

अब पुराने सारे case भूल जाओ।

1.



$$\boxed{P = \frac{I\cos^2\theta(1+r)}{C}}$$

2. $P = \frac{h}{\lambda}, E = \frac{hc}{\lambda}, = \frac{12400}{\lambda\, Å}$

3. $n = \frac{\text{Power}}{\frac{hc}{\lambda}}$

MATTER WAVE

When particle exhilit wave nature, they have wave character and De-Broglie wavelength associated with is given by $\lambda = \frac{h}{mv} = \frac{h}{P}$

(पहले $p = \frac{h}{\lambda}$ मे p photon का momentum था)

Q. 1 kg, v = 100m/s

Sol. λ debrog $= \frac{h}{mv} = \frac{6.6 \times 10^{-34}}{1 \times 100} = 6.6 \times 10^{-36}$ m this value is very very low almost insignificant.

Q. e^- is moving with velocity 1mm/sec

Sol. $\lambda = \frac{h}{mv} = \frac{6.6 \times 10^{-34}}{9.1 \times 10^{-31} \times 10^{-31}} = 0.73$ m

Hence, we can say that hypothesis is more significant for sub-atomic particle like, e^-, p^+, n.

The wave associated with moving particle is called matter wave or de-broglie wave.

$$KE = \frac{1}{2}mv^2 = \frac{P^2}{2m}$$

$$\lambda = \frac{h}{mv} = \frac{h}{P} = \frac{h}{\sqrt{2m(K.E)}}$$

Q. Consider a α-particle, proton, deutron, all are moving with same speed. Find ratio of λ_{DB}

Sol. $\lambda = \frac{h}{mv} \qquad \lambda \propto \frac{1}{m}$

$\lambda\alpha : \lambda p : \lambda_{deuterium}$

$\frac{1}{4} : \frac{1}{1} : \frac{1}{2}$

1 : 4 : 2

α - particle = ${}_2^4He$

Proton = ${}_1^1H$

Deutron = ${}_1^2H$

THANOS (अबे याद है ना)

- q, Rest, 'Δv' speed up = $(KE)_f = q\,\Delta v$
- Electrostatics (पूरानी बात) अगर मैं एक q charge को rest से ΔV से acceleratre (speed up) करवाऊँ तो final K.E will be $(KE)_f = q\,\Delta V$

एक करोड़ बार पूछा गया सवाल इसे जरूर अच्छे से करके जाना यहाँ से question आने की probability बहुत ज्यादा है।

$$\lambda = \frac{h}{mv} = \frac{h}{P} = \frac{h}{\sqrt{2m\,(K.E)}} = \frac{h}{\sqrt{2m\,q\,\Delta v}}$$

	Mass	Charge
Proton	m	+e
deutron	2m	+e
α	4m	+2e

Q type 1 $\Rightarrow$ Proton, deutron, α are moving with same speed find ratio of De-Broglie wavelength.

Q type 2 $\Rightarrow$ Proton, deutron, α are moving with same kinetic energy find ratio of De-Broglie wavelength

Q type 3 $\Rightarrow$ Proton, deutron, α are accelerated from same potential difference from rest find ratio of De-Broglie wavelength

Q. An e^- is at rest initially, now it is accelerated by p.d ΔV = 10 volt. Find λ_{DB}.

Sol. $(KE)f = q\,\Delta v$

$$\lambda = \frac{h}{\sqrt{2m\,(K.E)}} = \frac{h}{\sqrt{2m\,q\,\Delta v}} = \sqrt{\left(\frac{h^2}{2mq}\right)_{\Delta V}}$$

$$\lambda_e = \sqrt{\frac{150}{\Delta V}}\ \text{Å} \qquad = \sqrt{15}\ \text{Å}$$

Q. If a charged particle (q, m) is accelerated by p.d ΔV from rest, then λ_{DB} associated with will be

Sol. Charge (q, m)

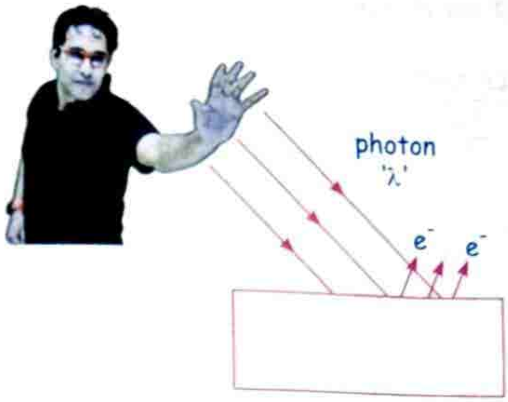
(i) for e^- $\qquad \lambda_{debrog} = \sqrt{\dfrac{150}{\Delta V}}\ \text{Å}$

(ii) for p^+ $\qquad \lambda_{debrog} = \sqrt{\dfrac{0.081}{\Delta V}}\ \text{Å}$

(iii) for deutron $\qquad \lambda = \sqrt{\dfrac{0.04}{\Delta V}}\ \text{Å}$

(iv) for α-particle $\qquad \lambda = \sqrt{\dfrac{0.0102}{\Delta V}}\ \text{Å}$

PHOTO ELECTRIC EFFECT



Photon आये अपने साथ energy लाये, material से टकराये, जिससे e^- बाहर निकल आये, बड़ा मजा आये (लेकिन हो सकता है)

- When a light of sufficient small wavelength is incident on a metal surface, e^-s are ejected from the metals surface. This phenomenon is called photo electric effect.
- **Work Function:** It is the min. amount of energy req. by free e^- for photo electric effect. It is the property of material.
- जो e^- बाहर आ गए are called photoelectorn
- It's value is commonly b/w 0.5ev to 5ev.

Threshold Energy

- It is the min energy that photon must have to cause photoelectric effect.

  $\phi \rightarrow$ work function

  work func = threshold energy

  $$\phi = \frac{hc}{\lambda_0} = h\,\nu_0$$

  threshold warelength (λ_0) ; threshold frequency (ν_0)

- ऐसे photon जिनकी energy E, $\frac{hc}{\lambda}$ work function से कम हैं are called नल्ला photon.

  photon 'λ' ✓, Energy of one photon = $E = \dfrac{hc}{\lambda}$

  $= \dfrac{12400}{\lambda(\text{Å})}$ ev

  $E < \phi$ = No photoelectric effect $\Rightarrow$ नल्ला

  $E > \phi$ = maybe photoelectric effect

  $$\boxed{E = \phi + (KE)_{max}}$$

  E → Energy of one photon ; $\phi \rightarrow$ work fn ; $(KE)_{max}$ → max possible (K.E)

$(KE)_{max} = E - \phi$

$(KE)_{max}$ सबके नसीब मे नही है

- (KE) of any photonelectron $\rightarrow 0 \le (K.E) \le (K.E)_{max}$
- Photo e^- will come out with $(K.E)_{max}$ **(False)**
- Photo e^- will come out with $(K.E) \le (K.E)_{max}$ **(True)**

$E = \phi + (KE)_{max}$

$\frac{hc}{\lambda} = \phi + (KE)_{max}$ $\quad \left(E = \frac{hc}{\lambda} = h\nu\right)$

$\frac{hc}{\lambda} = \frac{hc}{\lambda_0} + (KE)_{max}$ $\quad \left(\phi = \frac{hc}{\lambda_0} = h\nu_0\right)$

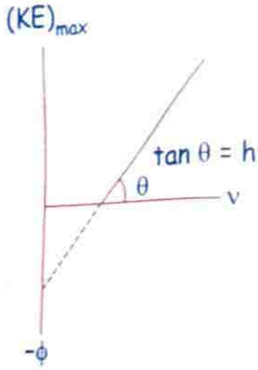
$h\nu = h\nu_0 + (KE)_{max}$

- Draw (KE)max V_S 'ν' graph

$E = \phi + (KE)_{max}$

$h\nu = \phi + (KE)_{max}$

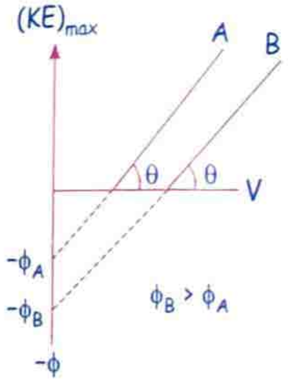
$(KE)_{max} = h\nu - \phi$



$E = \phi + (KE)_{max}$

$h\nu = \phi + (KE)_{max}$

$(KE)_{max} = h\nu - \phi$

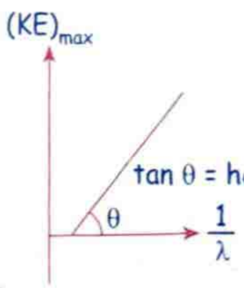


tan θ = h

★ $E = \phi + (KE)_{max}$

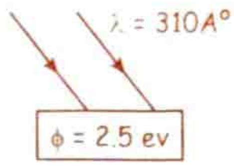
$(KE)_{max} = E - \phi$

$(KE)_{max} = \frac{hc}{\lambda} - \phi$



tan θ = hc = const.

Q.



A monochrometric beam of light of $\lambda = 310$ Å is incident on a material of work function 2.5 eV.

Sol. (i) Find energy of 1 photon

$$E = \frac{1240\cancel{0}}{31\cancel{0}} = 40ev$$

(ii) Find threshold wavelength.

$$\phi = \frac{hc}{\lambda_0}$$

$$2.5 = \frac{12400}{\lambda_0}$$

(iii) Find max K.E. possible

$$\epsilon = \phi + (KE)_{max} = 37.5 \text{ eV}$$

Q. Electric field corresponding to electromagnetic wave falling on metal surface of work function eV is given by $E = E_0 . \sin(2\pi \times 10^{15} t - kx)$. Find $(KE)_{max}$ of photo e^- possible.

$$\omega = 2\pi \times 10^{15}$$

$$2\pi f = 2\pi \times 10^{15} \Rightarrow f = 10^{15}$$

$$E = h\nu = 6.6 \times 10^{-34} \times 10^{15} \text{ 'J'}$$

$$= \frac{6.6 \times 10^{-34} \times 10^{15}}{1.6 \times 10^{-19}} \text{ eV}$$

$$E = 4.12 \text{ eV}$$

$$(KE)_{max} = 3.12 \text{ eV}$$

Q. If frequency of incident photon is doubled then value of $(KE)_{max}$ will be

(a) Doubled

(b) More than double

(c) Halved

(d) Less than double but greater than previous value.

Sol. More than double (RM)

$f \rightarrow 2f$

Let $E = 4ev \rightarrow E = 8ev$

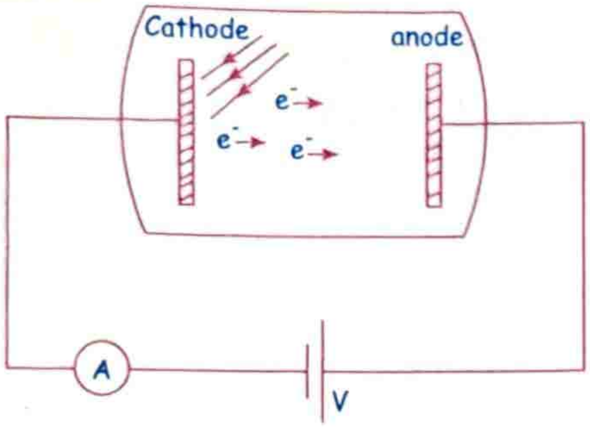
$\phi = 1ev \rightarrow \phi = 1ev$

$(KE)_{max} = 3ev \rightarrow (KE)_{max} = 7$

Photo e^- Efficiency:

$$\boxed{n = \frac{\text{No. of photon emitted/unit time}}{\text{No. of photon incident/unit time}}}$$

Photo Electric Setup:



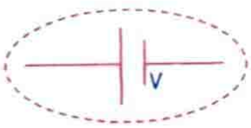
- Cathode और anode के बीच का pd we can change by battery
- Photon आये, photo e^- निकले and they moved towards anode.
- When emf of the battery was zero, we got some current and when p.d between anode & cathode is inc↑, anode becomes more +ve (Electric field पीछे की तरफ inc↑, hence e- will move with faster rate, resulting inc↑ in current)

Saturation Current

- As p.d inc↑ current gradually inc↑ and finally current becomes constant. Constant current की इस value को saturation current बोलते है।

Saturation current $\propto$ No. of photon incident/sec

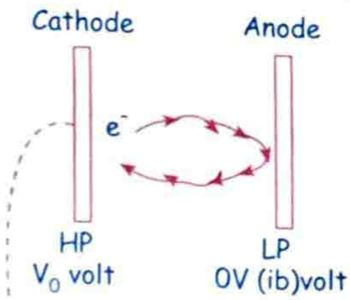
- If we reverse the battery:



so that cathode becomes +ve (high potential)
As we inc↑ EMF of battery here or we inc↑ p.d between cathode and anode, current starts dec and after some time, current becomes zero (stops)

- इस plate के बीच के potential difference को हम **stopping potential** bolte है। and at this p.d even the fastest e^- fails to reach anode.

- मतलब वो नसीब वाला e^- जिसकी $(K.E)_{max}$ है वो भी anode तक नही पहुँच पाया- इसलिए कोई भी नही पहुँचेगा।

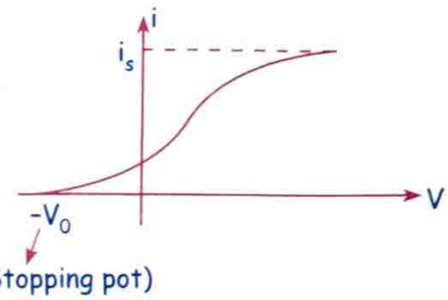


THANOS

- $K_A + U_A = K_B + U_B$
- $(KE)_{max} + -eV_A = 0 + (-eV_B)$
- $(KE)_{max} = e(\Delta V) = e(V_0 - 0)$
- Stopping pot $(\Delta V) = \dfrac{(KE)_{max}}{e}$

$$\boxed{(KE)_{max} = eV_0}$$

→ (Stopping potential)

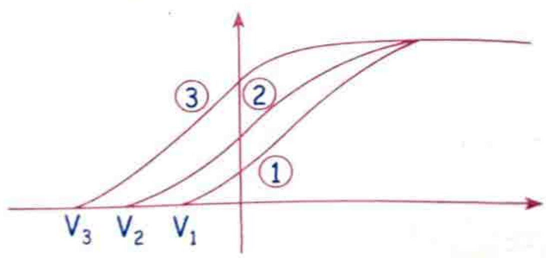


* $E = \phi + (KE)_{max}$

* $(KE)_{max} = eV_0$

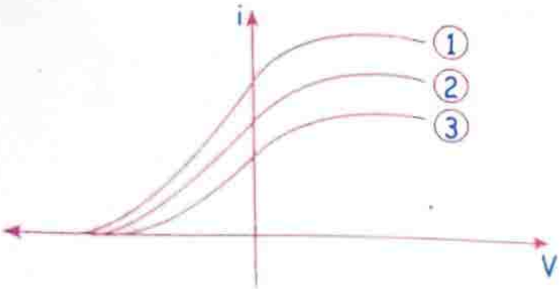
* $E = \phi + eV_0$

 # If no. of photon (n) → same
frequency → increase
$\Rightarrow E\uparrow, (KE)_{max}\uparrow \Rightarrow$ stopping pot↑



$V_3 > V_2 > V_1$
$f_3 > f_2 > f_1$
Intensity $= I_3 > I_2 > I_1$

If Intensity↑ (by keeping freq same)
N → increase



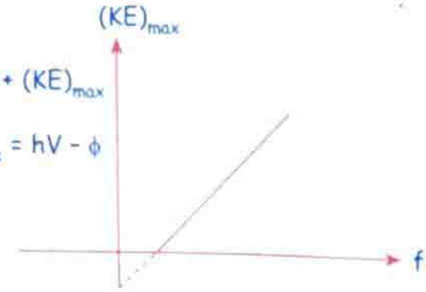
Stopping pot. → same

$I_1 > I_2 > I_3 \Rightarrow$ Intensity

$I_{S_1} > I_{S_2} > I_{S_3} \Rightarrow$ Saturation current

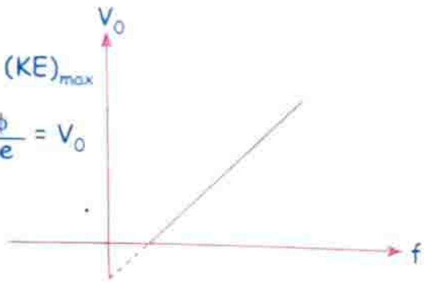
$h\nu = \phi + (KE)_{max}$

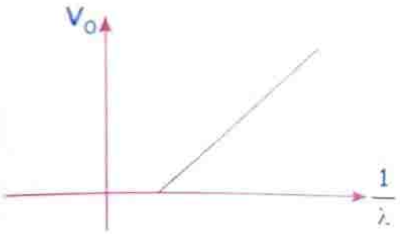
$(KE)_{max} = hV - \phi$

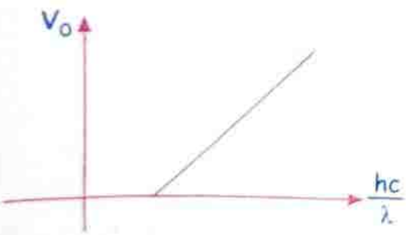


$E = \phi + (KE)_{max}$

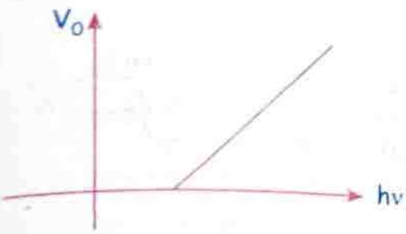
$\frac{hf}{e} - \frac{\phi}{e} = V_0$







Graph की mathematically अच्छे से practice कर लेना



Q. If stopping potential of a material is 3V.

अगर मैं 3V का p.d apply करूँ तो current will definitly stop.

Sol. False

After saturation

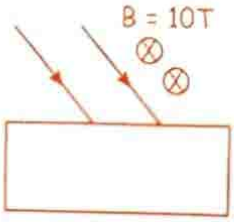
$$\underset{\text{per sec}}{n_{cathode}} = \underset{\text{per sec}}{n_{anode}} = n$$

$$\boxed{i_{saturation} = ne}$$

$$\text{Intensity} = \frac{nh\nu}{\text{Area}}$$

$$i_{saturation} \propto n \propto \text{Intensity}$$

Q. A monochromatic light of wavelength 310 nm is incident on a metal surface of work function 2ev. B = 10 Tesla external magnetic field is applied around the metal surface as shown in diagram. Find the max^m possible radius of photo e^- of the circle photo e^- more.



Sol. **(a)** $E = \frac{124\cancel{0}}{31\cancel{0}} = 40eV$

$\phi = 2eV$

$(KE)_{max} = 2eV$

$$r = \frac{mv}{qB} = \frac{\sqrt{2m\,(K.E)}}{qB}$$

$$= \frac{\sqrt{2 \times 9.1 \times 10^{-31} \times 2 \times 1.6 \times 10^{-19}}}{1.6 \times 10^{-19} \times 10}$$

(b) $(\lambda_{debroglie})_{min} = ?$

$$\lambda = \frac{h}{(mv)_{max}} = \frac{h}{\sqrt{2m\,(K.E)}}$$

Part 2 $\lambda_1 = 310$ mm

$\lambda_2 = 155$ mm

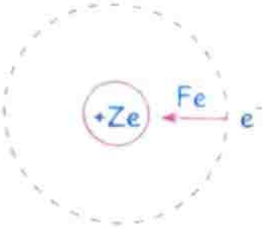
$$r = \frac{mv}{qB} = \frac{(r_1)_{max}}{(r_2)_{max}} = \frac{(V_1)_{max}}{(V_2)_{max}} = \sqrt{\frac{(K.E)_{max\,1}}{(K.E)_{max\,2}}}$$

BOHR'S MODEL

It's V.V Imp for mains as well as advance
यह मत समझना कि तुम्हें chemistry में आता है
question को till the last solve करना।

This model was explained in three steps called three postulates of Bohr's Model.

1. e^- are revolving around the nucleus and required centripital force is given by electrostatic attraction between them.



$$\frac{K\,Zee}{r^2} = \frac{mv^2}{r}$$

radius of orbit

2. Electron can revolve only in those orbit in which angular momentum of the e^- about nucleus is integral multiple of $\frac{h}{2\pi}$. मतलब e^- का angular momentum एक fix orbit में constant है।

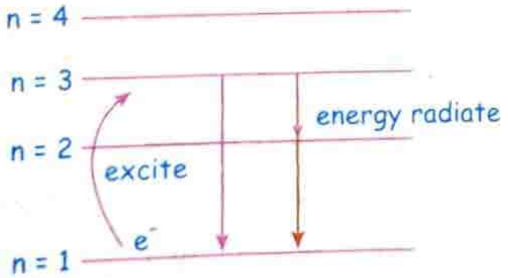
$$mvr = \frac{nh}{2\pi}$$

3. Electon जो nucleus के around अपनी stable orbit में घुम रहा है उसकी total energy constant है। It can absorb or radiate energy अगर मैं बाहर से छेड़ खानी करूँ means if e- absorb energy from outside it will excite to higher excited state.

- e^- will radiate energy if it de-excite from higher energy state to lower energy state.

e^-(absorb energy) $\Rightarrow$ E_1 (lower energy state) $\longrightarrow$ E_2 (higher energy state)

E (higher energy state) $\xrightarrow[e^- \rightarrow \text{radiate energy}]{\text{de excite}}$ E_2 (lower energy state)



- Bohr's Model is applicable for single e^- species only (Hydrogen like species).

1. radius of n^{th} orbit

$$\frac{Kzee}{r^2} = \frac{mv^2}{r} \qquad r = \left(\frac{h^2}{ke^2\,4\pi^2 m}\right)\frac{n^2}{Z}$$

$$mvr = \frac{nh}{2\pi}$$

$$\boxed{\text{Solve and get} \quad r = 0.529\,\frac{n^2}{z}\,Å}$$

2. $v^2 = \frac{n^2h^2}{4\pi^2m^2r^2}$ $\quad \boxed{v = 2.18 \times 10^6\,\frac{z}{n}\ m/s}$

$$\frac{KZe^2}{r^2} = \frac{m}{r}\,\frac{n^2h^2}{4\pi^2m^2r^2}$$

$$\boxed{r \propto \frac{n^2}{z} \qquad v \propto \frac{z}{n}}$$

3. 'T' (time period) $\qquad T = \frac{2\pi r}{V}$

$$T \propto \frac{r}{v} \propto \frac{n^2/z}{z/n} \propto \frac{n^3}{z^2}$$

4. 'f' freq $\qquad f \propto \frac{1}{T} \propto \frac{z^2}{n^3}$

5. $\omega = 2\pi f \quad \Rightarrow \quad \omega \propto f \propto \frac{z^2}{n^3}$

6. $a_{centripetal} \quad \Rightarrow \quad \frac{v^2}{r} \propto \frac{(z/n)^2}{(h^2/z)} \propto \frac{z^3}{n^4}$

7. K.E $\quad \Rightarrow \quad \frac{1}{2}mv^2$

$$K.E \propto \left(\frac{z}{n}\right)^2$$

8. $P.E = \frac{-KZee}{r}$

$$P.E \propto \frac{z}{r} \propto \frac{z}{n^2/z}$$

$$P.E \propto \frac{z^2}{n^2}$$

9. Angular momentum $\quad \propto n$

$$mvr = \frac{nh}{2\pi}$$

10. Orbital current $i = \frac{q}{T} \quad \Rightarrow \quad i \propto \frac{1}{T} \propto \frac{z^2}{n^3}$

11. Magnetic field due to revolving electron at centre:

$$B = \frac{u_0 i}{2r} \quad \Rightarrow \quad B \propto \frac{i}{r} \propto \frac{z^2/n^3}{n^2/z} \propto \frac{z^3}{n^5}$$

12. Magnetic Movement $\qquad M = iA = i.\pi r^2$

$$M \propto \frac{z^2}{n^3}\left(\frac{n^2}{z}\right)^2 \propto n.$$

ENERGY ANALYSIS

- $\frac{KZe^2}{r^2} = \frac{mv^2}{r} \Rightarrow \frac{1}{2}mv^2 = \frac{KZee}{r}$
- T.E = K.E + P.E

$$= \frac{1}{2}\frac{KZe^2}{r} - \frac{KZe^2}{r}$$

$$\boxed{\begin{aligned} T.E &= \frac{-KZe^2}{2r} \\ K.E &= \frac{KZe^2}{2r} \\ P.E &= \frac{-KZe^2}{r} \end{aligned}} \qquad |T.E| = K.E = \frac{|P.E|}{2}$$

Q. If T.E = -3.4 eV

Sol. K.E = 3.4 eV

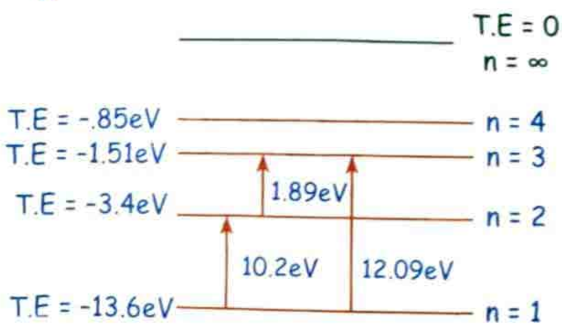
P.E = -6.8 eV

$$T.E = \frac{-KZe^2}{2r} \qquad r = .529\frac{n^2}{z}\text{Å}$$

$$\boxed{T.E = -13.6\frac{z^2}{n^2}\text{ eV}}$$

For z = 1.

$$T.E = \frac{-13.6}{n^2}$$



- e^- नवाब है।
- In ground state, electron can absorb only those photon which has energies equal to difference in energy of the stable energy level.

photon = E = 8eV — e^- will reject photon

photon = E = 10.2eV — e^- may accept

- Energy required to ionize an atom is ionization energy of atom for that particular energy level from which e^- is removed.

$$\boxed{I.E = \frac{13.6\, z^2}{n^2}\text{ eV}}$$

Q. Find energy req. to excite the e^- from n = 2 to n = 4 for Z = 2.

Sol. $\Delta\varepsilon = 13.6 \times (2)^2\left(\frac{1}{2^2} - \frac{1}{4^2}\right)$

इतनी energy देनी पड़ेगी।

$$\Delta E = 13.6\, z^2\left(\frac{1}{n^2_{\text{छोटा}}} - \frac{1}{n^2_{\text{बड़ा}}}\right)$$

Q. Find energy required to excite the e^- from n = 1 to n = 3 for Li^{+2} and λ of photon required.

Sol. $\Delta E = 13.6 \times 3^2\left(\frac{1}{1^2} - \frac{1}{3^2}\right) = \frac{1240}{\lambda_{nm}}$

Q. Find energy required to excite the e^- of z = 2 atom from 1st exited state to 2nd exited state.

Sol. n छोटा = 2, n बड़ा = 3

$$\Delta E = 13.6 \times 2^2\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

Q. If e^- de excite from n = 4 to n = 2, z = 2. How much energy is released and what is the wavelength of the photon emitted.

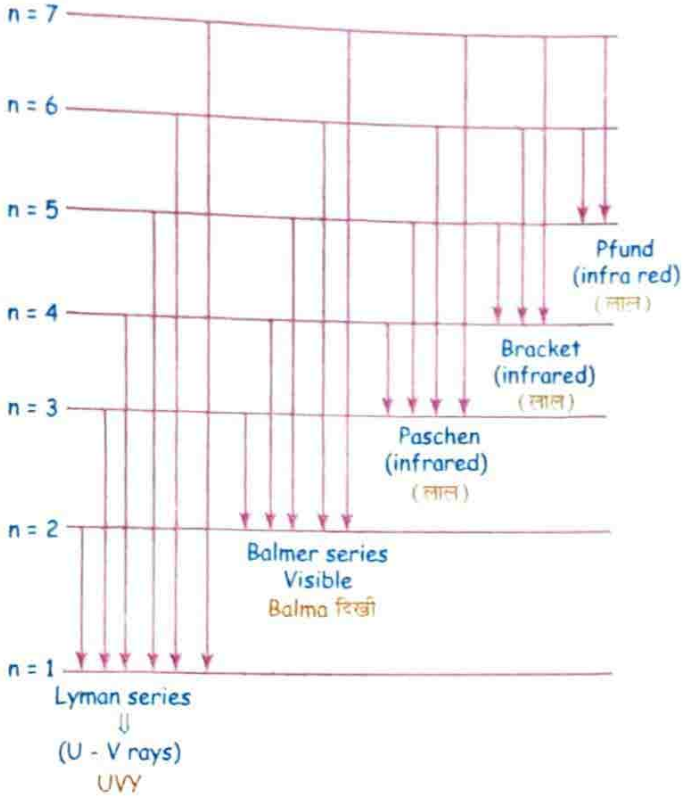
Sol. $\Delta E = 13.6z^2\left(\frac{1}{n^2_{\text{छोटा}}} - \frac{1}{n^2_{\text{बड़ा}}}\right) = \frac{hc}{\lambda} = \frac{1240}{\lambda\text{ nm}}$

$$\Delta E = 13.6 \times 2^2\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{1240}{\lambda\text{ nm}}$$

$$\Delta E = 10.2\text{ eV} = \frac{1240}{\lambda}$$

DE EXCITATION

- जब e^- de-excite करेगा तो दोनो energy level के बीच जो gap होगा उतनी energy का photon वो emit करेगा।



- 3^{rd} line of Lyman series = $n = 4 \rightarrow n = 1$

$$13.6 \times 2^2\left(\frac{1}{1^2} - \frac{1}{4^2}\right) = \frac{1240}{\lambda}$$

Q. Find the wavelength of the photon released for second line of Balmer series of z = 1.

Sol. $n = 4 \rightarrow n = 2$

$$\Delta E = 13.6 \times 1^2\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{1240}{\lambda}$$

Q. For z = 1, find λ_{max} & λ_{min} for lyman series

Sol. $\Delta E = \dfrac{hc}{\lambda}$ $\qquad \lambda \rightarrow \max$

$\Delta E \rightarrow \min \Rightarrow n = 2 \rightarrow 1$

$$\lambda_{max} \Rightarrow 13.6 \times 1^2\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \frac{1240}{\lambda_{max}}$$

$$\lambda_{max} = 121.2 \text{ nm}$$

$\lambda_{min} \Rightarrow$

$(\Delta E)_{max} \Rightarrow (\infty - 1)$

$$= 13.6 \times 1\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) = \frac{1240}{\lambda}$$

$$\lambda_{min} = 91.2 \text{ nm}$$

Q. Find range of λ for Paschen series.

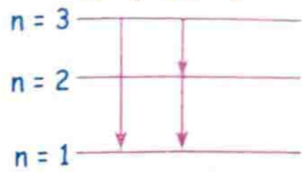
Sol. Paschen = $n_f = 3$

$$\text{For } \lambda_{max} \Rightarrow 13.6 \times \left(\frac{1}{3^2} - \frac{1}{4^2}\right) = \frac{1240}{\lambda_{max}}$$

$$\text{For } \lambda_{min} \Rightarrow 13.6 \times \left(\frac{1}{3^2} - \frac{1}{\infty^2}\right) = \frac{1240}{\lambda_{min}}$$

Suppose from n = 1 electron excited to n = 3 now electron is diexciting to n = 1 then we absorb three types of λ possible.

- $n = 3 \rightarrow n = 1$



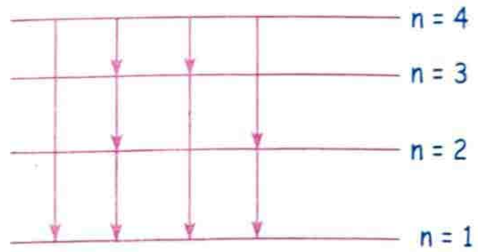
$3 \longrightarrow 1$
$3 \rightarrow 2 \rightarrow 1$

Electron may come directly to n = 1 from n = 3 and हो सकता है रास्ते मे मजे ले लेकर आ रहा हो $(3 \rightarrow 2 \rightarrow 1)$

'2' ways, '3' तरह के 'λ' emit possible $\begin{pmatrix} 3 \longrightarrow 1 \\ 3 \longrightarrow 2 \\ 2 \longrightarrow 1 \end{pmatrix}$

Similarly if electron the excite from n = 4 to n = 1

$n = 4 \rightarrow n = 1$



$$\left.\begin{matrix} 4 \longrightarrow 1 \\ 4 \rightarrow 3 \rightarrow 2 \rightarrow 1 \\ 4 \longrightarrow 3 \longrightarrow 1 \\ 4 \longrightarrow 2 \longrightarrow 1 \end{matrix}\right\} \text{4 ways}$$

8λ ✗

6 तरह के (λ) ✓ $\qquad \boxed{\text{Total } (\lambda) = {}^nC_2}$

$$\Delta E = 13.6\, z^2\left(\frac{1}{n^2\text{ छोटा}} - \frac{1}{n^2\text{ बड़ा}}\right) = \frac{hc}{\lambda} = \frac{1240}{\lambda(\text{nm})}$$

Q. (a) Find energy req to excite e^- from 1st excited state to 2nd excited state for z = 2

Sol. $\Delta E = 13.6\, z^2\left(\dfrac{1}{2^2} - \dfrac{1}{3^2}\right) = \dfrac{68}{9}$ eV

(b) What is the wavelenghth of photon req for this?

$$\Rightarrow \quad \frac{68}{9} = \frac{1240}{\lambda nm}$$

Q. Find wavelength of 3^{rd} line of balmer series for $z = 2$.

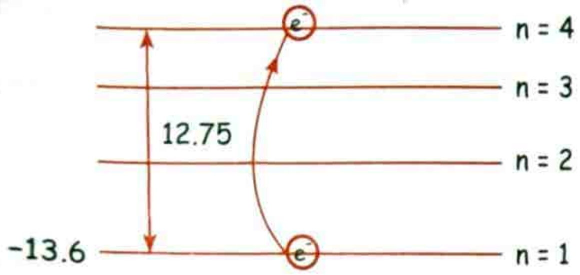
Sol. $\Rightarrow$ n छोटा = 2

n बड़ा = 5

$$13.6 \times 2^2\left(\frac{1}{2^2} - \frac{1}{5^2}\right) = \frac{1240}{\lambda}$$

Q. Hydrogen atom is in its ground state is excited by monochromatic radiation of wavelength 974 Å. How many different wavelength are possible in resulting emmision spectrum. Also find longest wavelength.

Sol. $\Rightarrow E = \frac{12400}{974} = 12.75$



${}^4C_2 = 6$ तरह के 'λ'

$\lambda_{max} \Rightarrow (\Delta E)_{min} \Rightarrow \quad n = 4 \rightarrow n = 3$

$$13.6 \times 1^2\left(\frac{1}{3^2} - \frac{1}{4^2}\right) = \frac{1240}{\lambda_{max}}$$

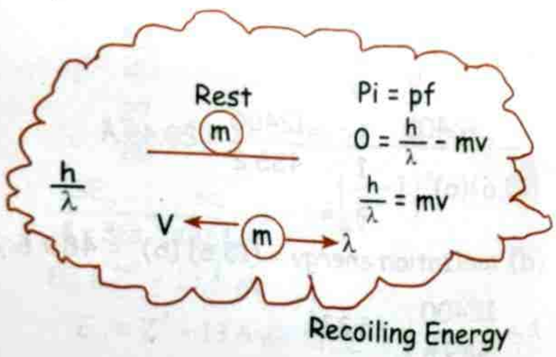
$\lambda_{min} \Rightarrow (\Delta E)_{max} \Rightarrow \quad n = 4 \rightarrow n = 1$

$$\Delta \in = 13.6 \times 1^2\left(\frac{1}{1^2} - \frac{1}{4^2}\right) = \frac{1240}{\lambda_{min}}$$

$$\frac{1240}{974} = 13.6 \times 1^2\left(\frac{1}{1^2} - \frac{1}{n^2 \text{बड़ा}}\right)$$

n बड़ा = nearest integer

$= \sqrt{15.6} = 4.$



भाई तुम्हे कसम है अब जितने Questions में attach कर रहा हूँ उन्हें अच्छे से लगा लेना till the last अगर यह अच्छे से लगा लिए तो advance के आए हुए सारे PYQ बना लोगे Mains को तो ऐसे ही लपेट दोगे।

Q. Electrons in hydrogen-like atoms ($Z = 3$) make transitions from the fifth to the fourth orbit and from the fourth to the third orbit. The resulting radiations are incident normally on a metal plate and eject photoelectrons. The stopping potential for the photoelectrons ejected by the shorter wavelength is 3.95 V. Calculate the work function of the metal, and the stopping potential for the photoelectrons ejected by the longer wavelength (Rydberg constant = $1.094 \times 10^7\ m^{-1}$)

Sol. $E_{4-3} = E_4 - E_3 = \frac{-(13.6)(3)^2}{(4)^2} - \left[\frac{-(13.6)(3)^2}{(3)^2}\right]$

$= 5.95$ eV

Now from the equation,

$K_{max} = E - W$

we have, $W = E - K_{max} = E_{4-3} - K_{max}$

$= (5.95 - 3.95)$ eV

$= 2$ eV

Longer wavelength will correspond to transition from n = 5 to n = 4. From the relation,

$$\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

The longer wavelength,

$$\frac{1}{\lambda} = (1.094 \times 10^7)(3)^3\left(\frac{1}{16} - \frac{1}{25}\right)$$

or $\lambda = 4.514 \times 10^{-7}$ m = 4515 Å

Energy corresponding to this wavelength,

$$E = \frac{12375}{4515} eV = 2.75 eV$$

$\therefore$ Maximum kinetic energy of photo-electrons:

$K_{max} = E - W = (2.75 - 2)$ eV = 0.75 eV

or the stopping potential is 0.75 volt.

Q. A single electron orbits around a stationary nucleus of charge Ze, where Z is a constant and e is the electronic charge. It requires 47.2 eV to excite the electron from the 2nd Bohr orbit to 3rd Bohr orbit. Find

(i) The value of Z,

(ii) Energy required to excite the electron from the third to the fourth orbit

(iii) The wavelength of radiation required to remove the electron from the first orbit to infinity

(iv) The kinetic energy potential energy and angular momentum in the first Bohr orbit

(v) The radius of the first Bohr orbit

Sol. We can find difference of energy of $n = 2$ and $n = 3$ as

$E_3 - E_2 = 47.2$ eV

$$\Rightarrow \qquad (13.6)Z^2\left[\frac{1}{4}-\frac{1}{9}\right]=47.2$$

$$\Rightarrow \qquad Z = 5$$

Energy required to excite from $n = 3$ to $n = 4$,

$$\Delta E = E_4 - E_3 = 13.6(5)^2\left[\frac{1}{9}-\frac{1}{16}\right]=16.5\text{eV}$$

Ionization energy = $13.6\,(Z)^2 = 13.6(5)^5 = 340$ eV corresponding wavelength of photon

$$=\frac{12400}{340}\text{Å}=36.5\text{Å}$$

In first Bohr orbit: ($n = 1$)

$KE_1 = 340$ eV

$PE_1 = -680$ eV

$E_1 = -340$ eV

Radius of n^{th} Bohr orbit,

$$r_n=\frac{(0.53)n^2}{Z}\text{Å}=\frac{0.53}{5}=0.106\text{ Å}$$

Q. A small particle of mass m moves in such a way that the potential energy $U = ar^2$ where a is a constant and r is the distance of the particle from the origin. Assuming Bohr's model of quantization of angular momentum and circular orbits, find the radius of n^{th} allowed orbit.

Sol. The force at a distance r is, $F=-\frac{dU}{dr}=-2ar$

Suppose r be the radius of n^{th} orbit. The necessary centripetal force is provided by the above force. Thus,

$$\frac{mv^2}{r}=2ar \qquad \text{... (i)}$$

Further, the quantization of angular momentum gives,

$$mvr=\frac{nh}{2\pi} \qquad \text{... (ii)}$$

Solving equations (i) and (ii) for r, we get

$$r=\left(\frac{n^2h^2}{8am\pi^2}\right)^{1/4}$$

Q. A gas of hydrogen like atoms can absorb radiations of 68 eV. Consequently, the atoms emit radiations of only three different wavelength. All the wavelengths are equal or smaller than that of the absorbed photon.

(a) Determine the initial state of the gas atoms.

(b) Identify the gas atoms.

(c) Find the minimum wavelength of the emitted radiations.

(d) Find the ionization energy and the respective wavelength for the gas atoms.

Sol. (a) $\frac{n(n-1)}{2}=3$

$\therefore n = 3$

i.e., after excitation atom jumps to second excited state.

Hence $n_f = 3$. So, n_i can be 1 or 2

If $n_i = 1$ then energy emitted is either equal to, greater than or less than the energy absorbed. Hence the emitted wavelength is either equal to, less than or greater than the absorbed wavelength.

Hence $n_i \neq 1$.

If $n_i = 2$, then $E_e \geq E_a$. Hence $\lambda_e \leq \lambda_0$

(b) $E_3 - E_2 = 68$ eV

$$\therefore (13.6)(Z^2)\left(\frac{1}{4}-\frac{1}{9}\right)=68$$

$\therefore Z = 6$

(c) $\lambda_{min}=\frac{12400}{E_3-E_1}$

$$\frac{12400}{(13.6)(6)^2\left(1-\frac{1}{9}\right)}=\frac{12400}{435.2}=28.49\text{Å}$$

(d) Ionization energy = $(13.6)\,(6)^2 = 489.6$ eV

$$\lambda=\frac{12400}{489.6}=25.33\text{Å}$$

Q. The wavelength of the first member of the Balmer series in hydrogen spectrum is 6563 Å. Calculate the wavelength of first member of Lyman series in the same spectrum.

Sol. For the first member of the Balmer series

$$\bar{v} = \frac{1}{\lambda_1} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = \frac{5}{36}R \quad \text{... (i)}$$

For the first member of Lyman series

$$\bar{v} = \frac{1}{\lambda_2} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3R}{4} \quad \text{... (ii)}$$

Dividing equation (i) by equation (ii), we get

$$\frac{\lambda_2}{\lambda_1} = \frac{5}{27} \text{ or } \lambda_2 = \frac{5}{27}\lambda_1$$

$$\lambda_2 = \frac{5 \times 6563}{27} = 1215.37 Å$$

Q. In a hydrogen like ionized atom a single electron is orbiting around a stationary positive charge. If a spectral line of wavelength equal to 4861Å is observed due to transition from $n = 12$ to $n = 6$. What is the wavelength of a spectral line due to transition from $n = 9$ to $n = 6$ and also identify the element.

Sol. Let the ground state energy for the given atom $= E_0$.

For the transition $n_i = 12$ to $n_f = 6$

$$\Delta E_1 = E_0\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = E_0\left[\left(\frac{1}{6}\right)^2 - \left(\frac{1}{12}\right)^2\right]$$

For the transition $n_i = 9$ to $n_f = 6$

$$\Delta E_2 = E_0\left(\frac{1}{36} - \frac{1}{81}\right).$$

$$\Delta E_1 = \frac{hc}{\lambda_1} = E_0\left(\frac{1}{36} - \frac{1}{144}\right) = \frac{3E_0}{4 \times 36} \quad \text{... (i)}$$

$$\Delta E_2 = \frac{hc}{\lambda_2} = E_0\left(\frac{1}{36} - \frac{1}{81}\right) = \frac{5E_0}{9 \times 36} \quad \text{... (ii)}$$

Dividing (i) by (ii),

$$\frac{\lambda_2}{\lambda_1} = \frac{27}{20}$$

$$\lambda_2 = \frac{27}{20} \times 4861Å = 6563Å. \text{ (Nearly)}$$

$$\frac{3E_0}{4 \times 36} = \frac{hc}{4861Å} = 2.55 \text{eV}$$

$E_0 = Z^2 \times 13.6$ eV

$\therefore E_0 = Z^2 \times 13.6$ eV or $Z^2 = 9$ or $Z = 3$

Q. Find the kinetic energy, potential energy and total energy in first and second orbit of hydrogen atom if potential energy in first orbit is taken to be zero.

Sol. $E_1 = -13.60$ eV,

$K_1 = -E_1 = 13.60$ eV

$U_1 = 2E_1 = -27.20$ eV

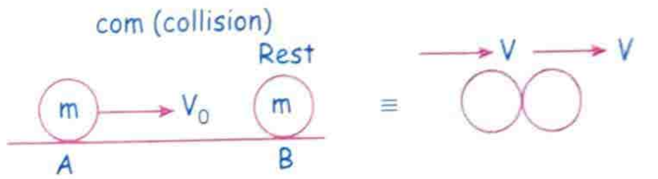
$$E_2 = \frac{E_1}{(2)^2} = -3.40 \text{ eV},$$

$K_2 = 3.40$ eV,

$U_2 = -6.80$ eV

Now $U_1 = 0$, i.e., potential energy has been increased by 27.20 eV while kinetic energy will remain unchanged. So, values of kinetic energy, potential energy and total energy in first orbit are 13.60 eV, 0, 13.60 eV respectively and for second orbit these values are 3.40 eV, 20.40 eV and 23.80 eV.

ATOMIC COLLISION (For Advance)



max loss ⇒ e = 0, perfectly inelastic collision

$$P_i = P_{tf}$$

$$mv_0 + 0 = mv + mv$$

$$\boxed{v = \frac{V_0}{2}}$$

$$(KE)i = \frac{1}{2}mv_0^2 = K$$

$$(KE)f = \frac{1}{2}2m\left(\frac{V_0}{2}\right)^2 = \frac{mV_0^2}{4} = \frac{K}{2}$$

Max. possible loss $= \frac{K}{2}$

$$\boxed{0 \le (KE)_{loss} \le K/2}$$

or method-2

$\Delta KE = \frac{1}{2}\mu V_{rel}^2(1 - e^2)$ (maximum loss will be for e = 0 put the value)

$\Delta KE = \frac{1}{2}\frac{m}{2}V^2(1 - 0^2) = \frac{1}{4}mV^2 = \frac{K}{2}$ (maximum loss)

Max^m possible loss in KE will be $\frac{K}{2}$ [when e = 0] perfectly inelastic collision

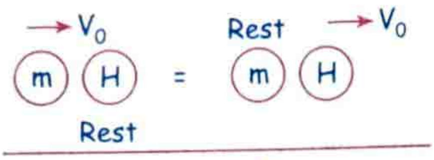
$$0 \le (KE)_{loss} \le \frac{K}{2}$$

- If this loss in K.E is absorbed by hydrogen atom then e^- may excite. We are assuming there is no energy loss in latice deformation.
- If $\frac{K}{2}$ is less than 10.2 $\left(\frac{K}{2} < 10.2\right)$ e^- को sufficient energy नहीं मिल पाई की वो n = 2 तक भी पहुच पाए, so e^- will reject this energy and collision will be elastic और सवाल com का बन गया।

If $\frac{K}{2} < 10.2 \Rightarrow$ elastic

$K < 20.4$

$e = 1$



$$(KE)_i = (KE)_f$$

$$\Delta KE = 0$$

यहां 3 points काम के है

- K.E
- हम e^- को कितना offer कर रहे है।
- e^- कितना खा सकता है।

अगर e^- पूरा का पूरा offer खा सकता है तो e = 0

कुछ भी नहीं खाया तो e = 1

कुछ खाया, कुछ छोड़ दिया तो $0 < e < 1$

Q.

$KE < 20.4$

$e = 1$

Q. Hydrogen atom is at rest and a neutron is coming towards at with kinetic energy K. If both have same mass find the possible value of e in following value of K.

Sol.

(1) K = 20 ev e = 1

(2) K = 15 ev e = 1

(3) K = 10.2 ev e = 1

(4) K = 20.4 ev

$(KE)_{loss} = \frac{K}{2} = 10.2 =$ offer

e = 0 खा गया

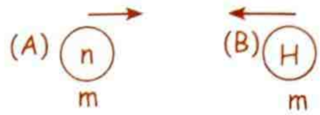
e = 1 reject

(5)	KE = 22 eV	$0 < e < 1$,	e = 1	
(6)	KE = 23 eV	$0 < e < 1$,	e = 1	
(7)	KE = 24.18 eV	e = 0, 12.09 खाया	$0 < e < 1$ 10.2 eV खाया	e = 1 कुछ ना खाया
(8)	KE = 25 eV	$0 < e = 1$,	e = 1	
(9)	KE = 22 eV			

$0 < e < 1 \Rightarrow$ 10.2 eV खाया

Rest of energy $(22 - 10.2) \Rightarrow$ in the form of K.E

Q.



Both have same KE of 6.4 eV. What are the possible $(KE)_A$ after collision.

Sol. (1) T.K.E = 6.4 + 6.4 = 12.8 (Salary)

(2) offer बराबर ?

for max K.E loss consider perfectly inelastic collision.

$e = 0$, $(KE)_{loss} =$ offer

$\hookrightarrow P_i = P_f$

$mV_0 - mV_0 = 2mV_f$

$V_f = 0$

$(KE)_f = 0, (KE)_i = 12.8, (KE)_{loss} = 12.8$

M-2

$$(KE)_{loss} = \frac{1}{2}\mu V_r^2 (1 - e^2)$$

$$= \frac{1}{2} \times \frac{m}{2}(2V_0)^2(1 - 0^2)$$

$$= 2 \times \left(\frac{mV_0}{2}\right)^2 = 6.4 \times 2 = 12.8$$

- Hence, we can offer total energy of 12.8 eV to the hydrogen atom.
- e^- can absorb 10.2eV, 12.09 eV, 12.75 eV.

→ If e^- absorb 10.2 eV then, e^- will excite from

$$n = 1 \longrightarrow n = 2$$

and (KE) system will be equal to 12.8 − 10.2 = 2.6 eV

This KE will be equally divided b/w A & B.

$(KE)_A = 1.3eV \qquad (KE)_B = 1.3eV$

→ If e^- absorb 12.09eV then, e^- will excite from

$$n = 1 \longrightarrow n = 3$$

and (KE) system will be equal to 12.8 - 12.09 = 0.71

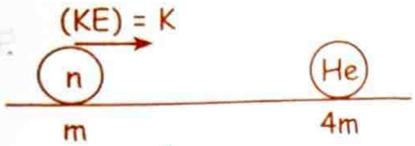
$(KE)_A = .35 \qquad (KE)_B = .35$

If e^- absorb 12.75eV then, e^- will excite from

$$n = 1 \longrightarrow n = 4$$

$(K.E)_f = 12.80 - 12.75 = .05$

$(KE)_A = .025 \qquad (KE)_B = .025$

Q. 

, $\Delta KE = ?$

Sol. $(\Delta E)_{loss} = \frac{1}{2}\mu V^2 rel\,(1 - e^2)$

$$= \frac{1}{2} \times \frac{4m}{5} \times V_0^2\,(1 - 0)$$

$$= \frac{1}{2} mV_0^2 \times \frac{4}{5} = \frac{4k}{5}.$$

Or

$$mV_0 + 0 = 5mvf \Rightarrow v_f = \frac{V_0}{5}$$

$$(KE)_i = \frac{1}{2} mV_0^2 = K$$

$$(KE)_f = \frac{1}{2} 5m\left(\frac{V_0}{5}\right)^2 = \frac{k}{5}$$

$\Delta KE = \frac{4k}{5} \qquad e = 1$

$\frac{4k}{5} < 10.2 \times 4$

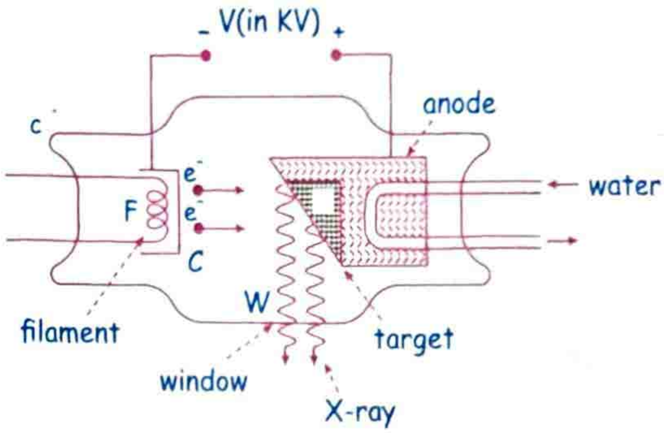
$K < .51 \qquad e = 1$

X-RAY

- X-ray (0.1 - 100Å)
  - → Soft x-ray ⇒ Energy↓, λ ↑ ⇒ (λ = 10Å - 100Å), less penetrating power.
  - → Hard x-ray ⇒ Energy↑, λ ↓ ⇒ λ = (1Å - 10Å), high penetrating power.

COOLIDGE METHOD

Coolidge developed thermionic vacuum X-ray tube in which electrons are produced by thermionic emission method. Due to high potential difference, electrons (emitted due to thermionic method) move towards the target and strike the atom of target due to which X-ray are produced. Experimentally it is observed that only 1% or 2% kinetic energy of electron beam is used to produce X-rays and rest of energy is wasted in form of heat.



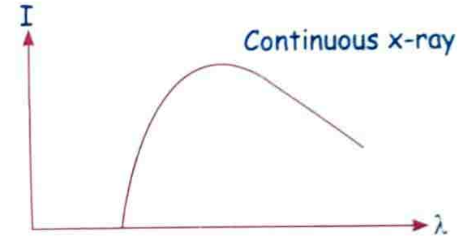
$(KE)_{final}$ of e^- just before striking the target material $= eV_0$

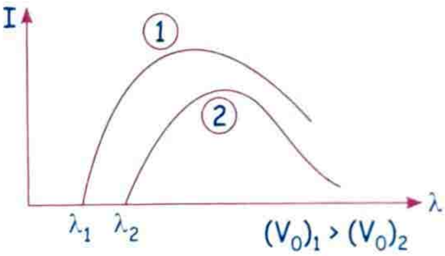
└→ Accelerating voltage

$$(KE)_e = eV_0 = \frac{hv}{\lambda_{min}} = \frac{1240}{\lambda_{min}} eV$$

$$\lambda_{threshold} = \lambda_{cut\ off} = \lambda_{min} = \frac{1240}{V_0}(nm)$$

$$\lambda_{min} = \frac{12400}{V_0}(Å)$$



- If $V_0 \uparrow \Rightarrow \lambda_{min} \downarrow$
- 

- Intensity of x-ray depends on no. of electron striking the target & no. of e^- depends on temp of filament which can be control by filament current.
- If accelerating voltage V_0 increases λ_{min}, $\lambda_{cut\ off}$ decreases. (Graph shift lift)
- X-ray always travel with speed of light, bcz x-ray are E.M.W.
- There is no charge on x-ray as they are not deflected by E'F & M.F.

CHARACTERISTICS OF TARGET

$Z\uparrow$, M.P $\uparrow$, $K\uparrow$

$\quad\quad \hookrightarrow$ Thermal conductivity

Q. A x-ray tube is operated at 30 kV

(1) Max frequency of x-ray emitted

Sol. $eV_0 = h\nu$

$1.6 \times 10^{-19} \times 30000 = 6.6 \times 10^{-34}\ \nu$

$\nu = (\_\_\_\_)$ hz

(2) λ_{min} or λ_{cutt} of x-ray emitted.

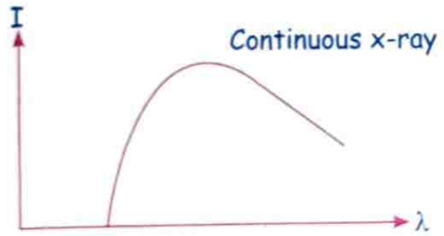
Sol. $\lambda_{min} = \dfrac{1240}{30000} (nm)$

(3) If a particular electron looses 5% of its kinetic energy to emit an x-ray photon at first collision find wavelength corresponding to photon

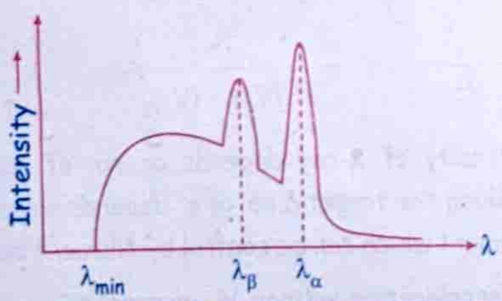
Sol. $(eV_0)\dfrac{5}{100} = \dfrac{hc}{\lambda}$

$\cancel{e} \times 30000\,\cancel{(volt)} \times \dfrac{5}{100} = \dfrac{1240}{\lambda_{(nm)}}\cancel{e}\ \cancel{volt}$

$\lambda = \dfrac{1240 \times 100}{30000 \times 5}$



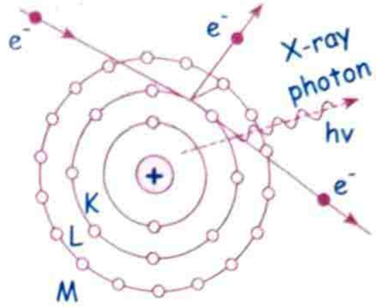
Experiment किए तो इस graph के सींग निकल आए इसे characteristics X-ray कहते है।



CHARACTERISTICS X-RAY

Suppose, the incident electron knocks out an electron from the K shell. This will create a vacancy in the K shell in the sense that now there is only one electron with n = 1, whereas two could be accommodated by Pauli exclusion principle. An electron from a higher energy state may make a transition to this vacant state. When such a transition takes place, the difference of energy ΔE is converted into an X-ray photon of wavelength $\lambda = hc / \Delta E$.

X-rays emitted due to electronic transition from a higher energy state to a vacancy created in the K shell are called K series X-rays.



देख भाई सबका short में निचोड़ यह है की

Filaments से electron निकले जिसको बाहर वाली battery ने मस्त तरीके से accelerate किया फिर वो electron target atom से टकराए और continuous x-ray observe हुई।

अब सुनो सींग निकलने की कहानी........मानलो यह electron K shell के electron से जाके भिड़ गया और उसे knock out कर दिया जिसे vacancy create हो गई अगर वो vacancy L shell के electron ने भरी तो इसे K_α series कहते है अगर M shell के electron ने vacancy भरी होती तो इसे K_β series कहते है जिससे energy निकली क्योंकि vacancy भरने वाला electron तो ऊपर से नीचे आया ना अगर vacancy L shell में create होती तो उसे L series बोलते अगर L shell की vacancy को M shell का electron भरता तो L_α बोलते।

$K_\alpha \Rightarrow n = 2 \longrightarrow n = 1$

$K_\beta \Rightarrow n = 3 \longrightarrow n = 1$

$L_\alpha \Rightarrow n = 3 \longrightarrow n = 2$

$L_\beta \Rightarrow n = 4 \longrightarrow n = 2$

अबे यह तो bohr model जैसा है but यहाँ energy का formula अलग है क्योंकि bohr model मे हम single electron species consider किए थे।

अगर बाहर वाली battery का emf बढ़ाया तो $\lambda_{minimum}$ will decrease, graph will shift left और अगर filament current घटाया तो electron army कम निकलेगी hence intensity will decrease.

ENERGY ASSOCIATED IN CHARACTERISTICS X-RAY

$$\Delta E = 13.6\,(Z - b)^2\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right) = h\nu = \frac{1240}{\lambda_{nanometer}}$$

For K series b = 1 for L series b = 7.4

यह formula अगर तुम भूले तो book से बाहर निकलके पिटाई करने आजाऊँगा

Q. Find energy of K_α series for Al, (Z = 13).

Sol. $\Delta E = 13.6 \times (13-1)^2\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$

Q. For Z = 41 find 'λ' for K_β.

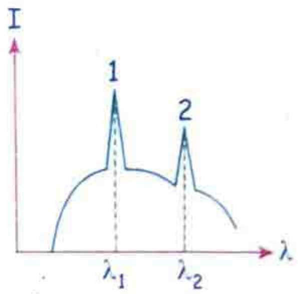
Sol. $\Delta E = 13.6 \times (4.1-1)^2\left(\frac{1}{1^2} - \frac{1}{3^2}\right) = \frac{1240}{(nm)\lambda}$

☆ Since Energy order for $K_\beta\ K_\alpha\ L_\beta\ L_\alpha$

$K_\beta > K_\alpha > L_\beta > L_\alpha$

So, wave length order will be $K_\beta < K_\alpha < L_\beta < L_\alpha$

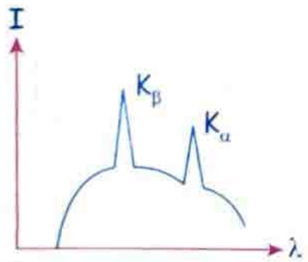
Q. Identify K_α and L_α.

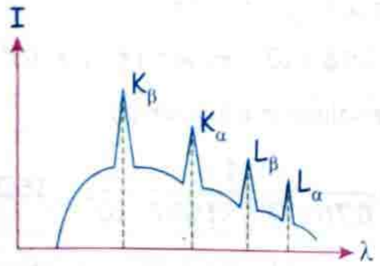


Sol. λ↓ Energy ↑

So, 1 is K_α and 2 is L_α

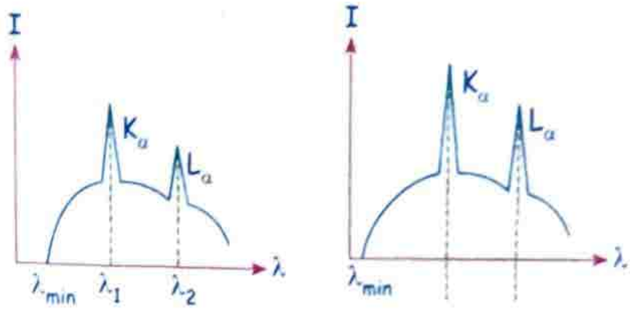
☆





Q. If बाहर वाली battery means accelerating battery emf is increase what will happen

Sol. $\lambda_{minimum}$ will decrease so graph will shift towards left but चांच तो वही की वही रहेगी।



Since

$$\boxed{\frac{13.6}{h}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)}\ (Z - b)^2 = \nu$$

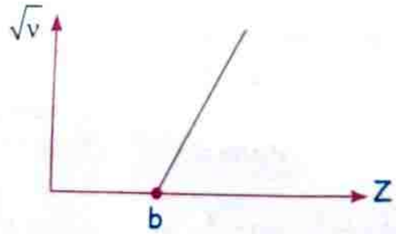
$A(Z - b)^2 = \nu$

$\sqrt{A}\,(Z - b) = \sqrt{\nu}$

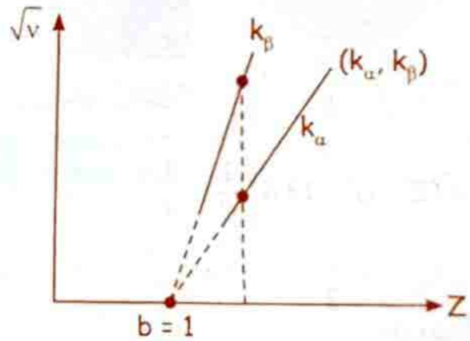
$\boxed{a(Z - b) = \sqrt{\nu}}$

Moseley law

$\sqrt{\nu} = a\,(Z - b)$ → Scattering const.



Q.



Q. The wavelength of characteristic K_α-line emitted by a hydrogen like element is 2.5 Å. Find the wavelength of the K_γ-line emitted by the same element (in Å). [Assume the shielding effect to be same as of K_α]

Sol. (2)

$$\frac{12400}{2.5} = 13.6\,(Z-1)^2\left(\frac{1}{1^2}-\frac{1}{2^2}\right)$$

$$\frac{12400}{\lambda} = 13.6\,(Z-1)^2\left(\frac{1}{1^2}-\frac{1}{4^2}\right)$$

Q. In an X-ray experiment target is made up of copper (Z = 29) having some impurity. The K_α line of copper have wavelength λ_0. It was observed that another K_α line due to impurity have wavelength $\frac{784}{325}\lambda_0$. The atomic number r of the impurity element is

Sol. $\frac{hc}{\lambda_0} = 136\,(29-1)^2\left(\frac{1}{1^2}-\frac{1}{2^2}\right)$

$$\frac{hc}{\frac{784}{625}\lambda_0} = 13.6\,(Z-1)^2\left[\frac{1}{1^2}-\frac{1}{2^2}\right]$$

$$\frac{625}{784} = \frac{(Z-1)^2}{(28)^2}$$

$$\frac{25}{28} = \frac{(Z-1)}{(28)}$$

$Z = 26$

Q. A metal target with atomic number Z = 46 is bombarded with a high energy electron beam. The emission of X-ray from the target is analyzed. The ratio r of the wavelengths of the k_α-line and the cut-off is found to be r = 2. If the same electron beam bombards another metal target with Z = 41, the value of r will be

(Adv. 2024)

Sol. $\frac{\sqrt{r_1}}{\sqrt{r_2}} = \frac{a(Z_1-b)}{a(Z_2-b)} = \frac{\sqrt{\lambda_2}}{\sqrt{\lambda_1}}$

$$\frac{hc}{\lambda_{k_\alpha}} = (Z-1)^2 \times 13.6\left(\frac{1}{1^2}-\frac{1}{1^2}\right)$$

$$r = \frac{\lambda_{k_\alpha}}{\lambda_{\text{cutt off}}} = 2$$

$Z \rightarrow$ change

$\lambda_{\text{cutt}} \rightarrow$ same $= \frac{1240}{V_0}$

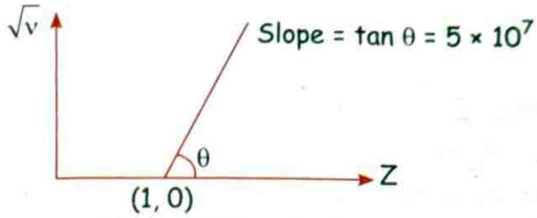
$$\frac{(\lambda_{k\alpha})_1}{(\lambda_{k\alpha})_2} = \frac{2}{r} = \frac{(Z-1)_f^2}{(Z-1)_i^2} = \frac{(41-1)^2}{(46-1)^2}$$

$$\frac{2}{r} = \frac{40\times 40}{45\times 45}$$

$$r = \frac{45\times 45\times 2}{40\times 40} = \frac{81}{32}$$

Q. A graph of $\sqrt{\nu}$ (where ν is the frequency of K_α line of the characteristic X-ray spectrum) is plotted against the atomic number Z of the elements emitting the characteristic X-ray. The intercept of the graph on the Z-axis is 1 and the slope of the graph is 0.5×10^8 S.I. units. The frequency of the K_α line for an element of atomic number 41 is given as $\alpha \times 10^{16}$ Hz. Find the value of α.

Sol. (400)



Z = b = 1, (k series)

$$\sqrt{\nu} = \underbrace{a}_{\text{Slope}}\,(Z-b)$$

$$\sqrt{\nu} = 5\times 10^7\,(41-1)$$

$$\sqrt{\nu} = 200\times 10^7 = 2\times 10^9$$

$$\nu = 4\times 10^8 = 400\times 10^{16}$$

Q. The wavelength of K_α X-rays produced by an X-ray tube is 0.76 Å. Find the atomic number of anticathode materials.

Sol. For K_α X-ray line.

$$\frac{1}{\lambda_\alpha} = R(Z-1)^2\left[\frac{1}{1^2}-\frac{1}{2^2}\right] = R(Z-1)^2\left[1-\frac{1}{4}\right]$$

$$\Rightarrow \frac{1}{\lambda_\alpha} = \frac{3}{4}R(Z-1)^2 \qquad \text{... (i)}$$

With reference to given data,

$\lambda_\alpha = 0.76\text{Å} = 0.76\times 10^{-10}$ m; $R = 1.097\times 10^7$ m

Putting these values in equation (*i*)

$$(Z-1)^2 = \frac{4}{3}\times\frac{1}{0.76\times 10^{-10}\times 1.097\times 10^7} \cong 1600$$

$\Rightarrow Z - 1 = 40 \Rightarrow Z = 41$

NUCLEAR PHYSICS

${}^{A}_{Z}X \Rightarrow$ Total no. of nucleons = A = no. of proton + no. of neutron

A → mass number

Z → Atomic no → Total No of proton

A - Z → Total no of neutron

* ${}^{41}_{20}X \Rightarrow$ No. of proton = 20
  No. of neutron = 21
  No. of neucleons = 41
  No. of Mass no = 41

♦ Shape of the nucleus is approximately spherical & its radius is approx.

$$\boxed{R = R_0 A^{1/3} \quad \text{Where } R_0 = 1.2 \times 10^{-15}\ \text{m}}$$

♦ Volume of nucleus = $\frac{4}{3}\pi R^3 = \frac{4}{3}\pi R_0^3 \cdot A$

♦ Density of nucleus = $\frac{\text{mass}}{\text{volume}} = \frac{mA}{\frac{4}{3}\pi R_0^3 \cdot A} = \frac{m}{\frac{4}{3}\pi R_0^3}$

$$\boxed{m_p = m_n = m(\text{Let})}$$

$$= \frac{16 \times 10^{-27}}{\frac{4}{3} \times \frac{22}{7} \times (1.2 \times 10^{-15})^3} = 2.3 \times 10^{17}\ \text{kg/m}^3$$

Density of nucleus is Independent on A

JEE Mains में हर साल यहाँ से
1 सवाल आजाता है

Isotopes → Same Z, diff. neutron ${}^{12}_{6}C$, ${}^{14}_{6}C$

Isobar → Same mass number ${}^{14}_{6}C$, ${}^{14}_{7}N$

Isotone → Same neutron ${}^{14}_{6}C$, ${}^{16}_{8}O$

NUCLEAR FORCE

♦ Short range force comes into picture when distance between nucleon's become order of fermi

$$\boxed{1\ \text{fermi}\ (f_m) = 10^{-15}\ \text{m}}$$

♦ Stronger than gravitational & coulombic force.

♦ Nuclear force on average are attractive as they compensate for repulsive Coulombic force

♦ When distance between nucleon become less than $7f_m$ nuclear forces are repulsive.

♦ They are not Central force & their value also depends on spin.

♦ They act equally between neutron-neutron, proton-proton, neutron-proton.

♦ Their value decrease rapidly to insignificant value at a distance beyond 2.5 fm. approx.

* Attractive in range of. (0.8-2.5)fm
* Short range force
* Independent on charge
* According to einstein, mass is another form of energy and one can convert mass into another form of energy & vice versa by the relation

$$E = mc^2$$

m → rest mass

E → Rest mass energy

ATOMIC MASS UNIT (AMU)

$m_p \approx m_n = m$

→ 1 amu = $\frac{1}{12}$ (mass of C_{12} at rest in ground state)

$= \frac{1}{12}(6m_p + 6m_n) = m_p = 1.67 \times 10^{-27}$ kg

= 1 amu = 1 u

BINDING ENERGY

Energy required to break the nucleus into nucleons. or energy release during formation of nucleus

(n n p n n p p n p p) + BE → n p n n p p n p p n

Free nucleus

or

p p p p p n n n n n → ${}^{A}_{Z}X$ + energy

(Z-Proton) freely

* $BE = (Zm_p + (A - Z)\,m_n - M)\,C^2 = \Delta m C^2$

$\underbrace{M}_{\text{Mass of nucleus}}$, $\underbrace{\Delta m}_{\text{mass defect}}$

* Δm = mass defect = Difference in mass of independent nucleons & mass of nucleus.

$\Delta m = [Zm_p + (A - Z)m_n - M_x] \equiv$ Mass defect

Energy $= (\Delta m)C^2 = [Zm_p + (A - Z)\,m_n - m_x]\,C^2 =$ B.E

Or

$Zm_p + (A - Z)\,m_n \longrightarrow M_x + \text{energy}$ → ?

देख भाई पहले ही बता रहा हूँ mass defect, binding energy, Q value calculation इस पर हर साल question पूछे जा रहे है और calculation खतरनाक वाली पूछी जाती है।

Calculation तू सम्भाल Physics तेरा भाई सम्भाल लेगा.......अबे डरेगा तो नही।

By Einstien mass energy relationship some amount of mass is converted into energy & released when nucleons bounded with each other to form a stable nucleus. ⇒ This energy which holds the nucleons is called Binding energy.

Q. Find B.E of α particle ^4_2He

Mass of ^1_1H atom = 1.007825 u

Mass of ^1_1H neutron = 1.008665 u

Mass of ^4_2He atom = 4.00260 u

Sol. $^4_2He \longrightarrow$ 2 proton, 2 neutron

$p\,^{p}_{p}\,n \longrightarrow {}^4_2He + \text{energy}$

Free

$\Delta m = (2\,m_p + 2m_n - M_{He})$

$\Delta m = [(2 \times 1.007825 + 2 \times 1.008665) - (4.00260)]u$

Energy release = $\Delta m \times 931.5$ MeV = 0.03038 × 931.5 MeV = B.E

Q. Find B.E of $^{56}_{26}Fe$

Atomic mass of ^{56}Fe = 55.9349 u

& that of ^1_1H is 1.00783u

Mass of neutron is 1.00867 u

Sol. BE = [(26 × 1.00783 + 30 × 1.00867) − (55·9349)] × 931·5 MeV

Q. B.E of $^{35}_{17}Cl$ nucleus is 298 MeV find its atomic mass

Given mass of proton (m_p) = 1.007825 amu

mass of neutron (m_n) = 1.008665 amu

Sol. [17 × 1.007825 + 18 × 1.008665 − M] × 931.5 = 298

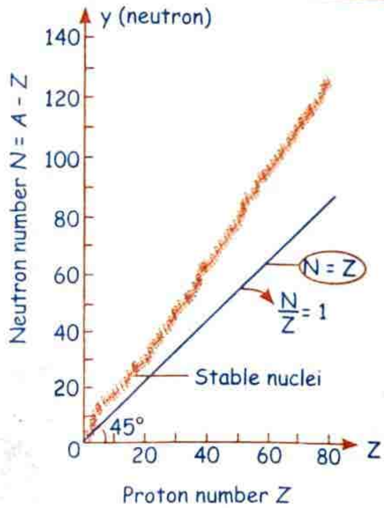
(17·133 025 + 18 · 155970) − ·319 = M

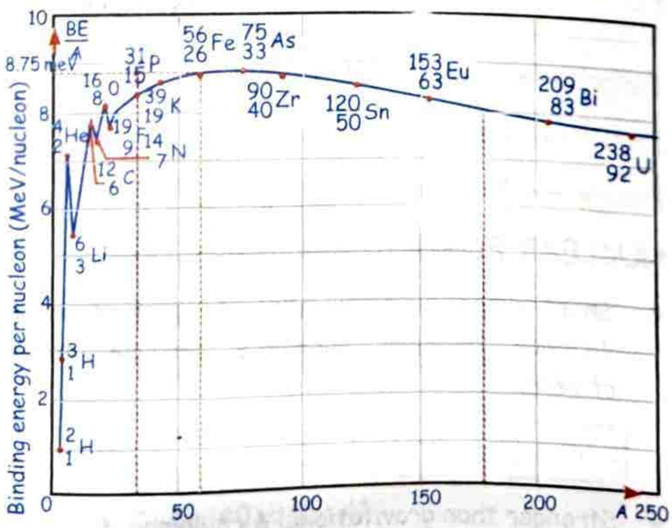
35 · 288995 − 319

35 · 289 − 319 = 34·97

$\cancel{A}$ $\cancel{Z}$

Binding energy = $(ZM_p + (A - Z)M_n - M_x) \times 931.5$





- Criteria for stability of nucleus $\Rightarrow \frac{B.E}{Nucleon} = \frac{BE}{A}$

- $\left(\frac{(B.E)}{A}\right)_{max}$ For F_e = 8.75 MeV

- Heavy nucleus decay into lighter nuclei, energy would be release in this process

  $C \longrightarrow A + B$ Nuclear fission

- Two light nuclei to join to form a heavier nucleus, $\frac{BE}{A}$ of fused heavier nuclei is more than binding energy per nucleon of lighter nuclei, this means that the final system tightly bound than initial

(Nucleus fusion) $x + y \longrightarrow z$

Q. Which is more stable?

	B.E
$^{24}_{12}X$	24 MeV
$^{16}_{8}Y$	18 MeV

Sol. B.E/nucleons $= \frac{BE}{A}$

B.E/A for $x = \frac{24}{24} = 1$ MeV

B.E/A for $y = \frac{18}{16} = 1.12$ MeV

$(\text{stable})_y > (\text{stable})_x$

Q VALUE OF NUCLEAR REACTION

$$A + B \longrightarrow C + D$$

- $Q = (m_R - m_P)C^2 = (m_A + m_B - m_C - m_D)C^2$ = Total energy released in nuclear reaction.
- If $Q > 0 \Rightarrow$ Exothermic
- If $Q < 0 \Rightarrow$ Endothermic

$$Q = (M_R - M_P) \times 931.5 \text{ MeV}$$

Amu

Q. $^{2}_{1}H + ^{14}_{7}N \longrightarrow ^{12}_{6}C + ^{4}_{2}He$

mass (amu)	2.014	14.00	12.00	4.00

Sol. $Q_{value} = (2.014 + 14.00 - 12.00 - 4.00) \times 931.5$ MeV

$= .014 \times 931.5$ MeV (Exothermic)

$= 13.041$ MeV

IN NUCLEAR REACTION

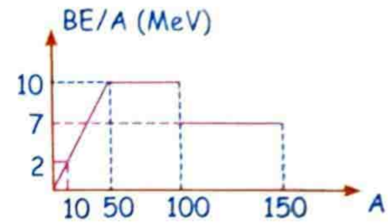
- If $F_{net} = 0 \Rightarrow$ Total momentum of system Conserve
- If $\tau_{ext} = 0 \Rightarrow$ Total angular momentum system Conserve
- Total charge is conserve.
- No of nucleons are conserve
- (mass + Energy) is conserve.

$Q = (M_R - M_p) \times 931.5$ MeV

$Q = (B.E.)_p - (B.E.)_R$

$Q = (K.E.)_f - (K.E)_i$

Q. In following rxn find energy released or absorbed



1. $^{30}X + ^{40}Y \longrightarrow ^{70}Z$

$Q_{value} = (B.E)_p - (B.E)_R$

$= (70 \times 10) - (30 \times 6 + 8 \times 40)$

$= 700 - 180 - 320 = 200$ MeV

(Exothermic)

2. $^{140}P \longrightarrow ^{110}Q + 3\,^{10}R$

$Q = (7 \times 110 + 2 \times 10 \times 3) - (7 \times 140) = -150$

(Endothermic)

Q. The ratio of the density of oxygen nucleus ($^{16}_{8}O$) and helium nucleus ($^{4}_{2}He$) is______.

[25 January 2023 - Shift 1]

(a) 4 : 1 (b) 8 : 1

(c) 1 : 1 (d) 2 : 1

Sol. (c)

Q. A nucleus with mass number 242 and binding energy per nucleon as 7.6 MeV breaks into two fragment each with mass number 121. If each fragment nucleus has binding energy per nucleon as 8.1 MeV, the total gain in binding energy is_____ MeV. [08 April 2023 - Shift 1]

Sol. (121)

$^{242}A \longrightarrow ^{121}B + ^{121}C$

$(BE)_f = (121 \times 8.1) \times 2$

$(BE)_i = 242 \times 7.6$

Q. A common example of alpha decay is

$${}^{238}_{92}U \to {}^{234}_{90}Th + {}_2H^4 + Q$$

Given:

${}^{238}_{92}U = 238.05060u$

${}^{234}_{90}Th = 234.04360u$

${}^{2}_{2}He = 4.00260$ u and $1u = 931.5\frac{MeV}{c^2}$

The energy released (Q) during the alpha decay of ${}^{238}_{92}U$ is____ MeV. [12 April 2023 - Shift 1]

Sol. (4) (238.05060 - 234.04360 - 4.00260) × 931.5

Q. In a nuclear fission process, a high mass nuclide ($A \approx 236$) with binding energy 7.6MeV/Nucleon dissociated into middle mass nuclides (A_B (118)) having binding energy of 8.6 MeV/Nucleon. The energy released in the process would be_____ MeV. [27 Jan. 2024 - Shift 1]

Sol. (236)

$A \longrightarrow 2B$

$\Delta E = (118 \times 8.6 \times 2) - (236 \times 7.6)$

Q. The atomic mass of ${}_6C^{12}$ is 12.000000 u and that of ${}_6C^{13}$ is 13.003354 u. The required energy to remove a neutron from ${}_6C^{13}$, if mass of neutron is 1.008665 u, will be: [27 Jan. 2024 - Shift 2]

Sol. ${}^{13}_{6}C \longrightarrow {}^{12}_{6}C + {}^{1}_{0}n$

$\Delta E = (13.003354 - 12 - 1.008665) \times 931.5$

Q. From the given data, the amount of energy required to break the nucleus of aluminium ${}^{27}_{13}Al$ is____ $\times 10^{-3}$ J.

Mass of neutron = 1.00866 u

Mass of proton = 1.00726 u

Mass of Aluminium nucleus = 27.18846 u

(Assume 1 u corresponds to j of energy)

(Round off to the nearest integer)

(JEE Main-2021)

Sol. (27) $BE = (13\,m_p + 14\,m_n - m_{Al}) \times 931.5$

Q. Two ligher nuclei combine to form a comparative heavier nucleus by the relation given below:

${}^{2}_{1}X + {}^{2}_{1}X = {}^{4}_{2}Y.$

The binding energies per nucleon ${}^{2}_{1}X$ and ${}^{2}_{1}Y$ are 1.1 MeV and 7.6 MeV respectively. The energy released in this process is_____ MeV

(JEE Main-2022)

Sol. (26) (7.6 × 4) - (1.1 × 2 × 2)

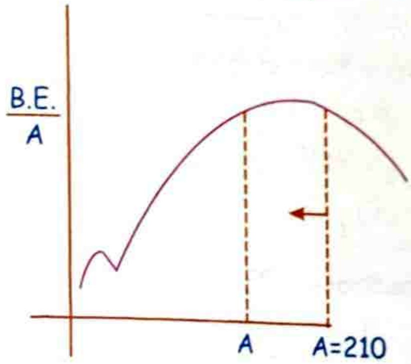
RADIOACTIVITY

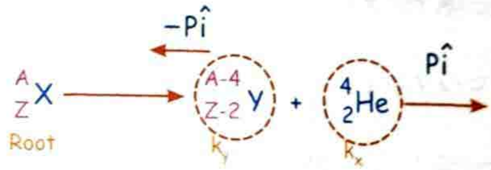
(Removed From Jee Mains)

- The process of spontaneous doiintegration shown by some unstable atomic nucli is known as radioaetivity.

RADIOACTIVE DECAYS

- α-decay: In α decay, the unstable nucleus emits an α particle. By emitting α particle, the nucleus decreases it's mass energy numebr and move towards stability. Nuculeus having A > 210 shows α decay. By reeasing α particle, it can attain higher stability and Q value is positive.





$Q_{value} = K_y + K_\alpha - 0 \qquad K.E. = \frac{p^2}{2m}$

$\frac{(K.E)_y}{(K.E)_\alpha} = \frac{m_\alpha}{m} \qquad \frac{(K.E)_y}{(KE)_\alpha} = \frac{m_\alpha}{m_y} = \frac{4}{A-4}$

$$Q_{value} = K_\alpha\left(1 + \frac{4}{A-4}\right) = K_\alpha \cdot \frac{A}{A-4}$$

$$(K.E)_y = \frac{4}{A-4} \cdot Q_{value}\left(\frac{A-4}{A}\right)$$

$$(K.E)_y = Q_{value} \cdot \frac{4}{A}$$

$$\boxed{K_\alpha = Q_{value}\left(\frac{A-4}{A}\right)}$$

Q. The nucleus of elements X(A=220) undergoes a-decay. If Q value of the reaction is 5.5 meV, then K.E. of a particle will be

Sol. $(K.E.)_a = \frac{A-4}{A}.Q = \frac{220-4}{220} \times 5.5\text{meV}$

β^- DECAY

- These an e^- which an emitted from nucleus when inside the nucleus a neutron to a proton & an e^-

$${}^{1}_{0}n \longrightarrow {}^{1}_{1}P + {}^{0}_{-1}e + \overline{V}$$ Antineutron

$${}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e + \overline{V}$$ β^-

Mass defect eqn

$$\Delta m = (M_x - ZM_e) - (M_y - (Z+1)M_e + M_e^-)$$

$$\Delta m = (Mx - My) \qquad Q = \Delta m\, C^2$$

POSITIVE β DECAY (β^+ DECAY)

- Proton inside nucleus is transformed into neutron.

$p \longrightarrow n + e^+$ (Positron) + v (neutrino)

${}_{Z}X^{A} \longrightarrow {}_{Z-1}Y^{A} + {}_{1}e^{0}$ + Energy released

Mass defect eqn

$$\Delta m = (M_x - ZM_e) - (M_y - (Z-1)M_e + M_e^-)$$

$$\Delta m = (Mx - My - 2M_e) \qquad Q = \Delta m\, C^2$$

K-CAPTUNE (e^- Captune)

Electron capture (K-capture)

Nuclei having an excess number of protons may capture an electron from one of the inner orbits which immediately combines with a proton in the nucleus to form a neutron. This process is called electron capture (EC).

$${}^{1}_{1}P + {}^{0}_{-1}e \longrightarrow n + \upsilon$$

$${}^{A}_{Z}X + {}^{0}_{-1}e \longrightarrow {}^{A}_{Z-1}Y + \upsilon$$

$$\Delta m = (M_x - ZM_e + M_e) - (M_y - (Z-1)M_{e^-})$$

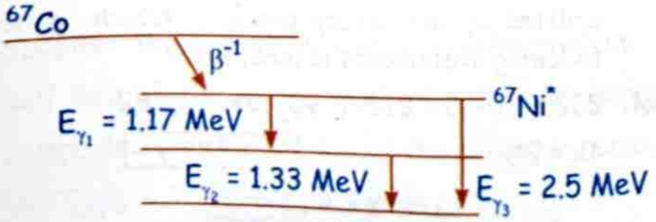
$$= Mx - My$$

$$Q = (M_x - M_y)C^2$$

γ DECAY

- When an a or b decay takes place, the daughter nucleus is usually in higher energy state, such a nucleus comes to ground state by emitting a photon or photons.

Order of energy of γ photon is 100 KeV



LAW OF RADIOACTIVE DECAY

(Statistical)

	A $\longrightarrow$	B
t = 0	No	0
	N	

Rate of diointegration is directly proportional to the number of radioactive atoms present at that time

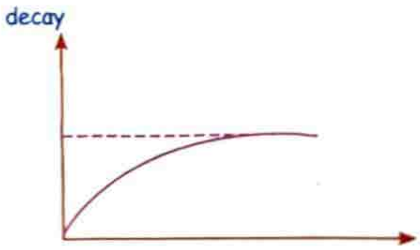
$$-\frac{dN}{dt} \propto N \qquad \int_{N_0}^{N}\frac{dN}{N} = \int_{0}^{t} -Kdt$$

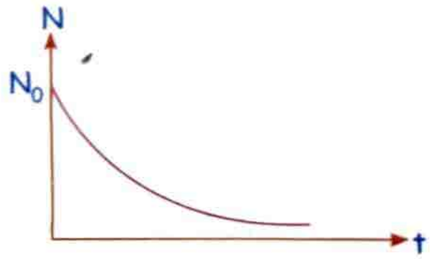
$$\frac{dN}{dt} = -KN \qquad \ln\frac{N}{N_0} = -Kt$$

$$\boxed{N = N_0 e^{-\lambda t}}$$

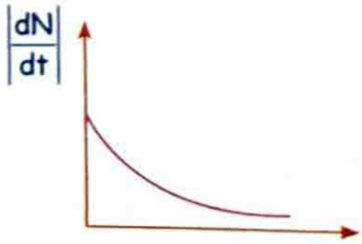
$$\text{decayed} = N_0 - N = N_0 - N_0e^{-Kt}$$

$$= N_0(1 - e^{-Kt})$$





$$\left|\frac{dN}{dt}\right| = N_0\lambda e^{-\lambda t}$$



$$\left|\frac{dN}{dt}\right| = N_0e^{-\lambda t} \Rightarrow \frac{N_0}{2} = N_0e^{-\lambda t} \Rightarrow \ln 2 = \lambda t_{1/2}$$

$$\boxed{t_{1/2} = \frac{\ln 2}{\lambda} = \frac{69}{\lambda}}$$

t = 0

$$N_0 \longrightarrow \frac{N_0}{2} \longrightarrow$$

$$\frac{N_0}{4} \longrightarrow \frac{N_0}{8} \longrightarrow \frac{N_0}{2^n}$$

$t = 0$ $\quad$ $t = t_{1/2}$ $\quad$ $t = 2t_{1/2}$

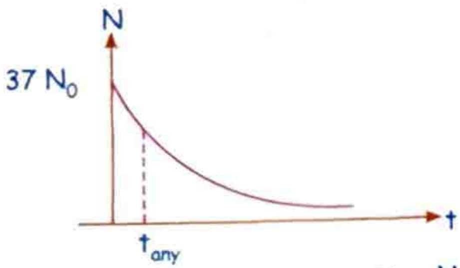
$t = 3t_{1/2}$ $\quad$ $nt_{1/2}$

Average life of sample

$$= \frac{\text{Sum of life of all nuclie}}{\text{total no. of nuclie at } t = 0}$$

$$< T >= \frac{1}{\lambda} = 1.44\, t_{1/2}$$

$$N = N_0 e^{-\lambda t} = N_0 e^{-\lambda t} = \frac{N_0}{e} = 37 N_0$$



$$\text{Probability of servival } P(s) = \frac{N}{N_0} = \frac{N_0 e^{-\lambda t}}{N_0} = e^{-\lambda t}$$

$$\text{Porb. of decay} = P(D) = \frac{N_0 - N}{N_0} = \frac{N_0 - N_0 e^{-\lambda t}}{N_0} = 1 - e^{-\lambda t}$$

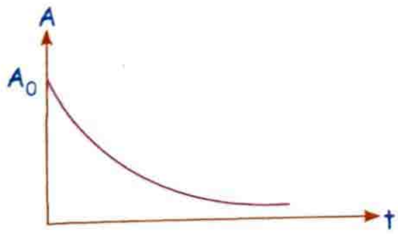
Activity $\rightarrow$ Rate of diointegration

$$A = \left|\frac{dN}{dt}\right|$$

$$N = N_0 e^{-\lambda t}$$

$$\left|\frac{dN}{dt}\right| = N_0 e^{-\lambda t}$$

$$\boxed{A = A_0 e^{-\lambda t}}$$



Q. The half-life of cobalt-60 is 5.25 yrs. After how long does its activity reduce to about one eight of its original value?

Sol. $A = A_0 e^{-\lambda t}$

$$A_0 \longrightarrow \frac{A_0}{8} \qquad \frac{A_0}{8} = A_0 e^{-\lambda t}$$

$$\ln 8 = \lambda t = \frac{\ln 2}{t_{1/2}}.t$$

$$t = \frac{\ln 8}{\ln 2} \times t_{1/2} = 3t_{1/2} = 3 \times 5.25$$

$$A_0 \xrightarrow{t_{1/2}} \frac{A_0}{2} \xrightarrow{t_{1/2}} \frac{A_0}{4} \xrightarrow{t_{1/2}} \frac{A_0}{8}$$

Q. A radioactive decay is given by $A \xrightarrow[t_{1/2} = 8 \text{ year}]{} B$

Only A is present at t = 0. Find the time at which if we are able to pick one atom out of the sample, then probability of getting B is 15 times of getting A.

Sol.

	A $\longrightarrow$	B
t = 0	N_0	O
t	N_0-N	N

P(B) = 15 P(A)

$$\frac{N}{N_0} = 15\left(\frac{N_0 - N}{N_0}\right)$$

$16\ N = 15\ N_0$

$$N(A) = N_0 - N = N_0 - \frac{15}{16} N_0 = \frac{N_0}{16}$$

$4\ t_{1/2} = 32$ year

Q. A nucleus with Z = 92 emits the following in a sequence : $\alpha, \alpha, \beta^-, \beta^-, \alpha, \alpha, \alpha, \alpha, \beta^-, \beta^-, \alpha, \beta^+, \beta^+, \alpha$. The Z of the resulting nucleus is

Sol. $8\alpha,\ 4\beta^-,\ 2\beta^+$

$\downarrow$

$-16 + 4 - 2 = -14$

$$\alpha \Rightarrow {}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$$

$$\beta^- \Rightarrow {}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}Y + {}^{0}_{-1}e + \bar{\upsilon}$$

$$\beta^+ \Rightarrow {}^{A}_{Z}X \longrightarrow {}^{A}_{Z-1}Y + {}^{0}_{+}e + \upsilon$$

Q. Half-lives of two radioactive elements A and B are 20 minutes and 40 minutes, respectively. Initially, the samples have equal number of nuclei. After 80 minutes, the ratio of decayed numbers of A and B nuclei will be:

Sol. $$\frac{N_0 - \frac{N_0}{2^4}}{N_0 - \frac{N_0}{2^2}} = \frac{15 \times 4}{16 \times 3} = \frac{5}{4}$$

Q. In a radioactive decay chain, ${}^{232}_{90}Th$ nucleus decays to ${}^{212}_{82}Th$ nucleus. Let N_α and N_β be the number of α and β^- particles, respectively, emitted in this decay process. Which of the following statements is (are) true?

Sol. $232 - 4x + 0 = 212$ | $90 - 2x + y = 82$

$4x = 20$ $\qquad$ $\boxed{8 = 2x - y}$

$x = 5$ $\qquad$ $y = 2$

SUCCESSIVE DISINTEGRATION AND SECULAR EQUILIBRIUM

Suppose $A \rightarrow B \rightarrow C$ .... (i.e., radioactive nucleus A decays to B and B decays to C)

Let number of radioactive nucleus A (Parent nucleus) at time $t = 0$ be N_0 and that of B be zero.

For A,

$$\frac{dN_A}{dt} = -\lambda_A N_A$$

$$\Rightarrow N_A = N_0 e^{-\lambda_A t}$$

For B,

$$\frac{dN_B}{dt} = \lambda_A N_A - \lambda_B N_B$$

$$\Rightarrow \frac{dN_B}{dt} = \lambda_A N_0 e^{-\lambda_A t} - \lambda_B N_B$$

Multiplying both sides of this equation by $(e^{\lambda_B t} dt)$, we get

$$\Rightarrow e^{\lambda_B t} dN_B + \lambda_B N_B e^{\lambda_B t} dt = \lambda_A N_0 e^{(\lambda_B - \lambda_A)t} dt$$

Since $d(N_B e^{\lambda_B t}) = e^{\lambda_B t} dN_B + N_B \lambda_B e^{\lambda_B t} dt$,

$$\Rightarrow \int d(N_B e^{\lambda_B t}) = \lambda_A N_0 \int e^{(\lambda_B - \lambda_A)t} dt$$

$$\Rightarrow N_B e^{\lambda_B t} = \frac{\lambda_A N_0}{(\lambda_B - \lambda_A)} e^{(\lambda_B - \lambda_A)t} + C,$$

where C is constant of integration.

At $t = 0$, $N_B = 0$

$$\Rightarrow C = \frac{-\lambda_A N_0}{(\lambda_B - \lambda_A)}$$

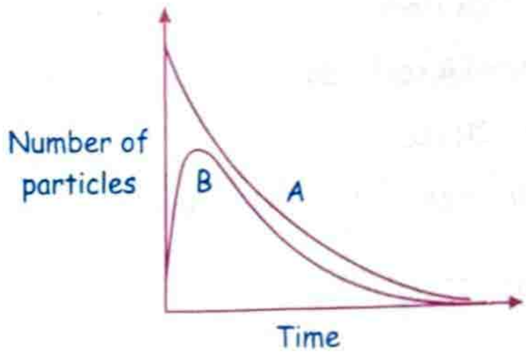
Hence,

$$N_B e^{\lambda_B t} = \frac{\lambda_A N_0}{\lambda_B - \lambda_A}\left[e^{(\lambda_B - \lambda_A)t} - 1\right]$$

$$\Rightarrow N_B = \frac{\lambda_A N_0}{\lambda_B - \lambda_A}\left[e^{-\lambda_A t} - e^{-\lambda_B t}\right]$$

Suppose the parent nucleus A is long lived i.e. the half life of the parent nucleus A is much larger in comparison to the half life of the daughter nucleus B

$\Rightarrow T_{1/2,A} \gg T_{1/2,B} \Rightarrow \lambda_A \ll \lambda_B \Rightarrow \lambda_B - \lambda_A \approx \lambda_B$



$\Rightarrow e^{-\lambda_B t}$ is negligible in comparison to $e^{-\lambda_A t}$.

$$\Rightarrow N_B = \frac{\lambda_A}{\lambda_B} N_0 e^{-\lambda_A t}$$

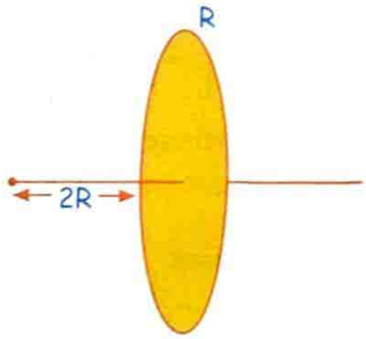
$$\Rightarrow N_B = \frac{\lambda_A}{\lambda_B} N_A$$

$$\Rightarrow N_A \lambda_A = N_B \lambda_B$$

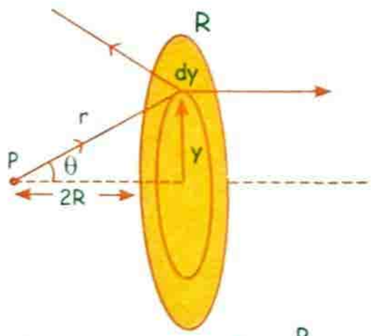
i.e., after a time much longer in comparison to the half life of the daughter nucleus B but much shorter in comparison to the half life of parent nucleus A, we have $N_A \lambda_A = N_B \lambda_B$. This state is called secular equilibrium.

FEW IMPORTANT QUESTION

Q. Point source P. Find four applied by light on plate (assume perfectly reflecting r = 1)



Sol.



$$I = \frac{P}{4\pi r^2}$$

$$\tan\theta = \frac{y}{2R}$$

$y = 2R\tan\theta$

$dy = 2R\sec^2\theta\, d\theta$

$r = 2R\sec\theta$

$$dF = PdA = \frac{I}{C}(1+r)\cos^2\theta\ 2\pi y dy$$

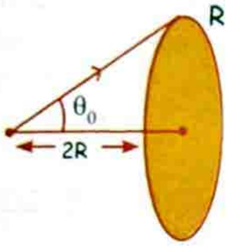
$$dF = \frac{2I}{C}\cos^2\theta\ \ 2\pi y\, dy$$

$$F_{net} = \int df = \int_0^{\theta} \frac{2I}{C}\cos^2\theta.\ 2\pi.\ 2R\tan\theta\, 2R\sec^2\theta\, d\theta$$

$$= \int \frac{2}{C}.\frac{P}{4\pi r^2}\cos^2\theta.\ 2\pi.2R\tan\theta\ 2R\sec^2\theta\, d\theta$$

$$= \frac{4PR^2}{C}\int\frac{\cos^2\theta.\tan\theta\sec^2\theta\, d\theta}{4R^2\sec^2\theta} = \frac{P}{C}\int_0^{\theta_0}\sin\theta\cos\theta\, d\theta$$

$$\frac{P}{C}\int_0^{\theta_0}\sin\theta\cos\theta\, d\theta$$

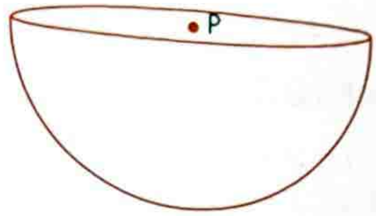


$$\sin\theta_0 = \frac{R}{R\sqrt{5}}$$

$$\frac{P}{C}\int t\,dt = \frac{P}{C}\frac{\sin^2\theta}{2}\Bigg|_0^{\theta_0} = \frac{P}{2C}\left(\sin^2\theta_0\right) = \frac{P}{2C}\left(\frac{1}{\sqrt{5}}\right)^2 = \frac{P}{10C}$$

Q. Find force on hemisphere due to light falling on it if power of point source is P (r = 1)

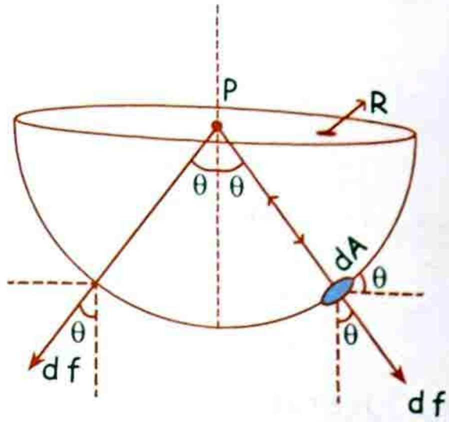
Sol. $\frac{P}{2C}$ ans ये याद करलो

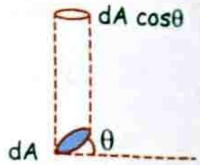


Sol. $F_{net} = \int dF\cos\theta$

$$= \int\frac{2P}{4\pi r^2}\cdot\frac{1}{C}dA\cos\theta = \frac{2P}{4\pi r^2 C}\int dA\cos\theta$$

$$= \frac{2P}{4\pi r^2 C}.\pi r^2 = \frac{P}{2C}$$





dF = (Pressure)dA

$$dF = \frac{2I}{C}.dA = 2.\frac{P}{4\pi r^2}\frac{1}{C}.dA$$

11 Semiconductor Electronics

$0 \rightarrow$ off, false, low voltage, low signal, 0 volt

$1 \rightarrow$ on, true, high voltage, high signal, +5 volt

BOOLEAN ALGEBRA

- $0 + 0 = 0$
- $0 + 1 = 1$
- $1 + 0 = 1$
- $1 + 1 = 1$
- $A + 1 = 1$
- $1 \cdot 1 = 1$
- $1 \cdot 0 = 0$
- $0 \cdot 1 = 0$
- $A \cdot 1 = A$
- $A + 1 = 1$

If $A = 1$ then $\bar{A} = 0$
If $\bar{A} = 1$ then $A = 0$

$A \cdot \bar{A} = 0$ $\quad$ $A + \bar{A} = 1$

A	$\bar{A}$	$A \cdot \bar{A}$	$A + \bar{A}$
0	1	0	1
1	0	0	1

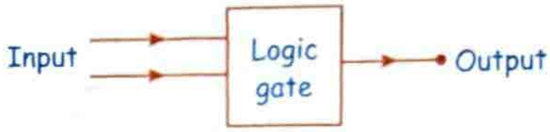
- $A + B = B + A$
- $A \cdot B = B \cdot A$
- $(A + B) + C = A + (B + C)$
- $A \cdot (B + C) = A \cdot B + A \cdot C$
- $A \cdot A = A$
- $A + A = A$
- $\overline{\overline{A}} = A$
- $A \cdot 0 = 0$
- $A \cdot \bar{A} = 0$
- $A + \bar{A} = 1$

$\overline{A + B} = \bar{A} \times \bar{B}$
$\overline{A \cdot B} = \bar{A} + \bar{B}$

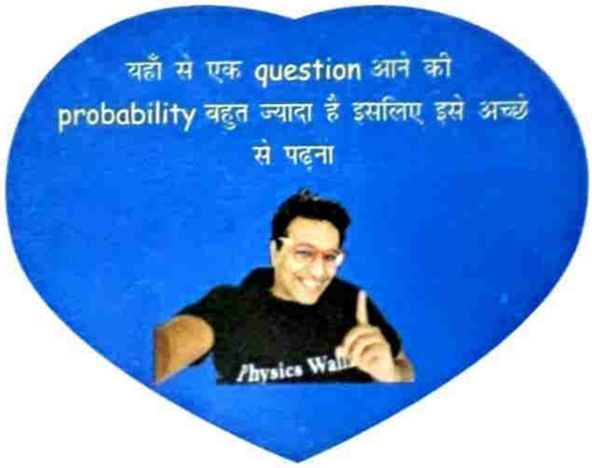
1. $A + A \cdot B = A(1 + B) = A \cdot 1 = A$
2. $A \cdot (A + B) = A \cdot A + A \cdot B = A + A \cdot B = A$
3. $\bar{A} \cdot (A + B) = \bar{A} \cdot A + \bar{A}B = 0 + \bar{A}B = \bar{A}B$
4. $(A + B)(A + C) = A + A \cdot C + B \cdot A + B \cdot C$
   $= A(1 + C) + A \cdot B + B \cdot C = A + B \cdot C$
5. $\overline{\overline{C} + \overline{D}} = \overline{\overline{C}} \cdot \overline{\overline{D}} = C \cdot D$ $\qquad$ $\overline{\overline{A} + \overline{B}} = A \cdot B$
6. $\overline{\overline{C} \cdot \overline{D}} = \overline{\overline{C}} + \overline{\overline{D}} = C + D$
7. $(A + B) \cdot (\bar{A} + \bar{B}) = 0 + A\bar{B} + B\bar{A} + 0 = A\bar{B} + B\bar{A}$
8. $(\bar{A} + B)(A + \bar{B}) = 0 + \bar{A} \cdot \bar{B} + BA + 0$
   $= \bar{A} \cdot \bar{B} + BA$

LOGIC GATE

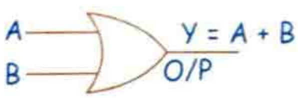
- Logic gates are digital circuit that follow's certainlogical relationship between input & output voltage.
- They control the information
- The are integral part of digital electronics
- They works on principle of boolen algebra.

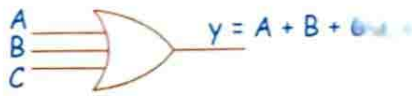


- It may have more than two input also.



OR gate

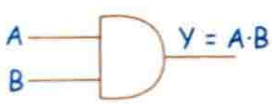


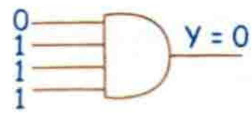


A	B	$y = A + B$
0	0	0
0	1	1
1	0	1
1	1	1

A	B	C	Y
0	0	0	0
0	0	1	1
0	1	0	1
1	1	0	1

AND gate



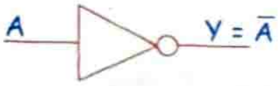


A	B	$Y = A \cdot B$
0	0	0
0	1	0
1	0	0
1	1	1

#SKC
OR gate में output zero तभी मिलेगा जब सारे input zero हो वरना output 1 मिलेगा।

#SKC
AND gate में output 1 तभी मिलेगा जब सारे input 1 हो वरना output 0 मिलेगा।

NOT gate (यह तो उलटा कर देगा रे बाबा)

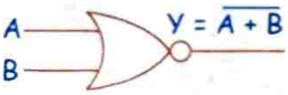


A	$Y = \overline{A}$
0	1
1	0

Universal gate

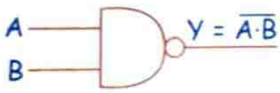
NOR NAND

NOR

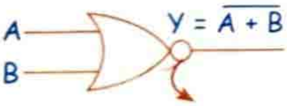


A	B	A + B	$Y = \overline{A + B}$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

NAND gate

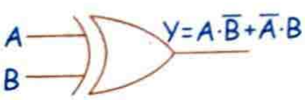


A	B	A · B	$Y = \overline{A \cdot B}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0



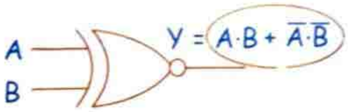
यह गुल्ला OR gate को reverse करके उसे NOR gate बना दे रहा है

XOR gate



A	B	$y = A \cdot \overline{B} + \overline{A} \cdot B$
0	0	0
0	1	1
1	0	1
1	1	0

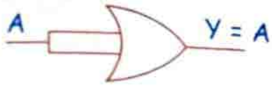
X NOR gate

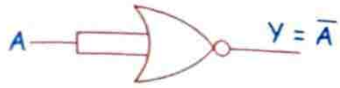


A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

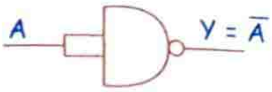
Q. Find expression for output in following question.

1 

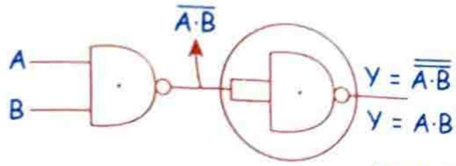
2 

3 

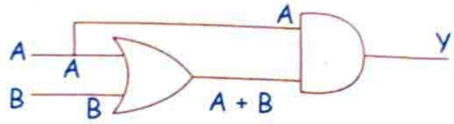
(NOT Gate बन गया)

4 

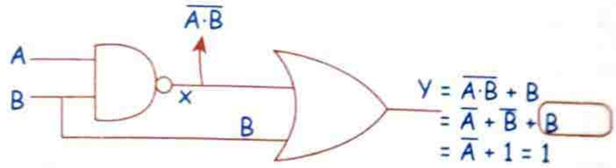
(Not Gate बन गया)

5 

(AND Gate बन गया)

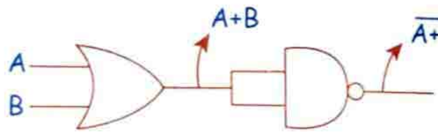
6 

$Y = A \cdot (A + B) = A \cdot A + A \cdot B = A + A \cdot B = A(1 + B) = A$

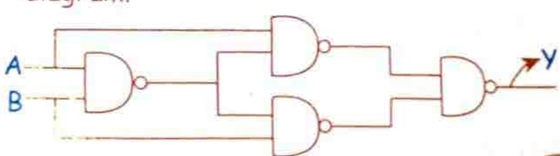
7 

IF $A = 0$ $x = 1$
$B = 0$, $Y = 1$

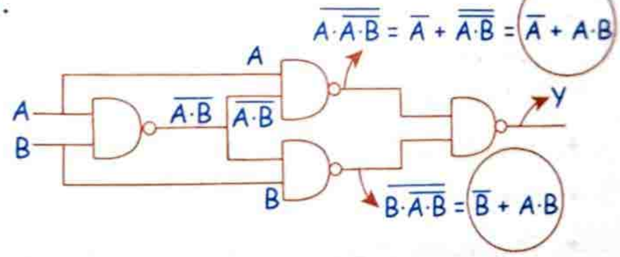
If $A = 0$, $x = 1$,
$B = 1$, $Y = 1$



Q. Find expression for output Y in following diagram.



Sol.



$$Y = \overline{(\bar{A} + AB)\cdot(\bar{B} + AB)}$$

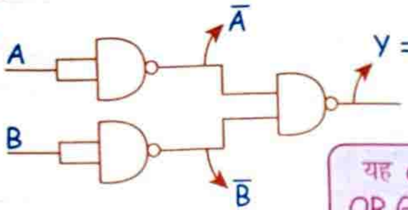
$$= \overline{\bar{A}\cdot\bar{B} + O + O + AB} = \overline{\bar{A}\cdot\bar{B} + AB} = \overline{\bar{A}\cdot\bar{B}}\cdot\overline{AB}$$

$$= (A + B)\cdot(\bar{A} + \bar{B})$$

$$= A\bar{B} + B\bar{A}$$

Q. Find expression for output Y in following diagram.

(a)

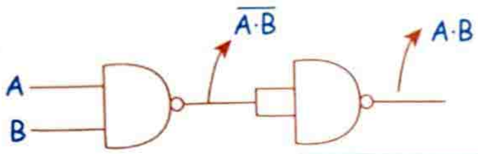


$Y = \overline{\bar{A}\cdot\bar{B}} = \bar{\bar{A}} + \bar{\bar{B}}$

$= A + B$

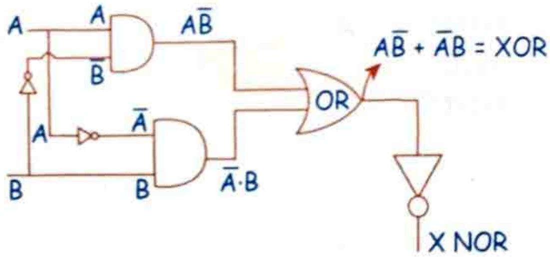
यह overall एक OR Gate बन गया।

(b)



यह overall एक AND Gate बन गया।

(c)



$\overline{A\bar{B} + \bar{A}B} = ?$

$= \overline{A\bar{B}}\cdot\overline{\bar{A}B}$

$= (\bar{A} + \bar{\bar{B}})\cdot(\bar{\bar{A}} + \bar{B})$

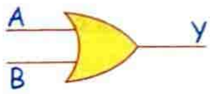
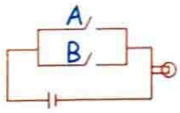
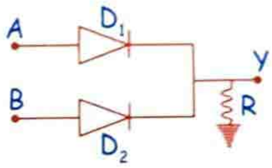
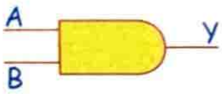
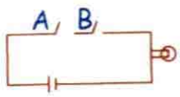
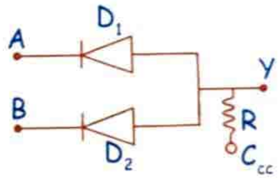
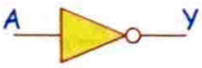
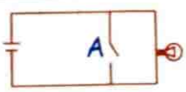
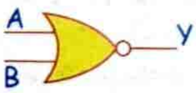
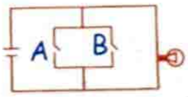
$= (\bar{A} + B)\cdot(A + \bar{B})$

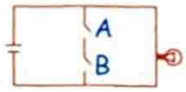
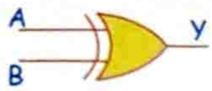
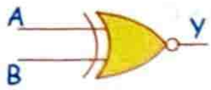
$= 0 + \bar{A}\cdot\bar{B} + AB + 0$

$= AB + \bar{A}\cdot\bar{B}$

अब JEE Mains PYQ के LOGIC GATE के सारे सवाल लगाओ।

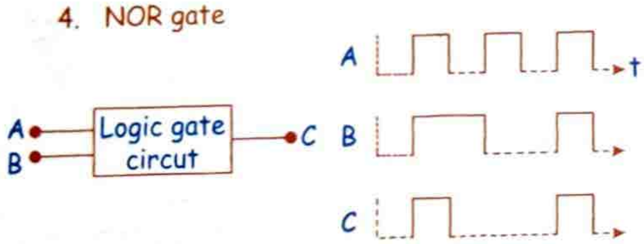
SUMMARY OF LOGIC GATES

Names	Symbol	Boolean Expression	Truth table	Electrical analogue	Circuit diagram (Practical Realisation)
OR		$Y = A + B$	A B Y 0 0 0 0 1 1 1 0 1 1 1 1		
AND		$Y = A\cdot B$	A B Y 0 0 0 0 1 0 1 0 0 1 1 1		
NOT Inverter		$Y = \bar{A}$	A Y 0 1 1 0		
NOR (OR + NOT)		$Y = \overline{A + B}$	A B Y 0 0 1 0 1 0 1 0 0 1 1 0		

NAND (AND + NOT)		$Y = \overline{A \cdot B}$	A B Y 0 0 1 0 1 1 1 0 1 1 1 0		
XOR (Exclusive OR)		$Y = A \oplus B$ or $Y = \overline{A} \cdot B + A\overline{B}$	A B Y 0 0 0 0 1 1 1 0 1 1 1 0	$Y = A \oplus B$ exoR	
XNOR (Exclusive NOR)		$Y = A \odot B$ or $Y = A \cdot B + \overline{A} \cdot \overline{B}$ or $Y = \overline{A \oplus B}$	A B Y 0 0 1 0 1 0 1 0 0 1 1 1		

Q. The follo wing figure shows a logic gate circuit with two input A and B output C. The voltage waveforms of A, B and C are as shown in second figure below. The logic gate is:?

1. OR gate
2. NAND gate
3. AND gate
4. NOR gate



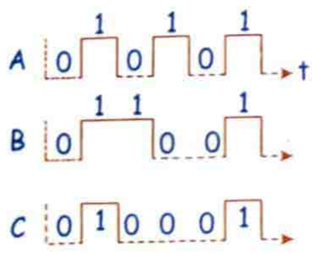
Sol. सबसे पहले input A, B की सुकून से value लिखो फिर देखो output क्या है।

A = 0 1 0 1 0 1

B = 0 1 1 0 0 1

A·B 0 1 0 0 0 1

Ans. is AND gate.



CLASSIFICATION OF CONDUCTORS, INSULATORS AND SEMICONDUCTOR

- On the basis of the relative values of electrical conductivity and energy bands the solids are broadly classified into three categories

  (i) Conductor

  (ii) Semiconductor → Conductivity of S.C. can be heavily controlled by external factor:

  (iii) Insulator

- Electron in outermost shell of an atom are called valence e^- and this shell called valence shell.

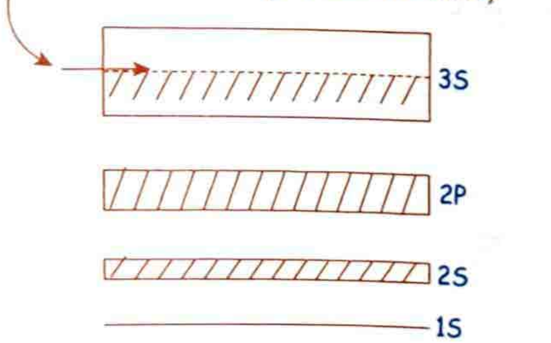
Valence band

$Na \rightarrow 1s^2, 2s^2, 2p^6, 3s^1$

completely filled

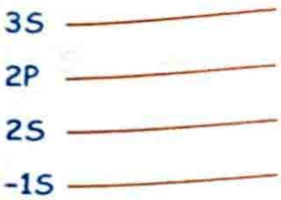
half filled incomplete

Fermi energy LEVELS (top most energy level where e^- filled)

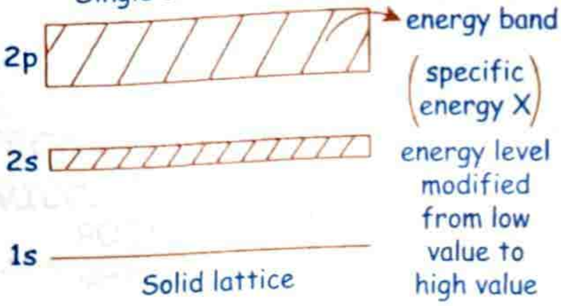


- In an isolated atom there are well define energy level
- But in case of solid state, when atoms are very close to each other, their energy values slightly changes. hence in large no. of atoms in a sample we will have a continuous range of energy level for particular energy state,

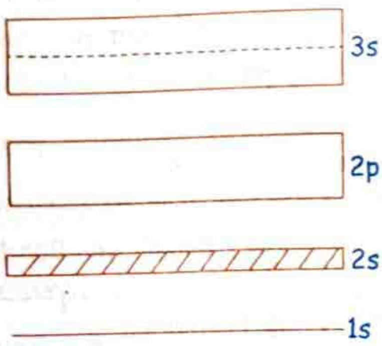
- Range of energy possessed by e^- in a solid is known as energy bond.



Single atom



Solid lattice



#SKC

देख भाई bohr model में हमने electron का interaction केवल nucleus से माना था तो वहाँ definite energy होती थी

$$E = -\frac{13.6z^2}{n^2} \text{ (अबे याद तो है ना)}$$

अब lattice में electron के चारों तरफ बहुत ही सारे atoms हैं तो कायदे में electron पड़ोस के nucleus and electron से भी interact करेगा तो अब उसकी energy में change आ जायेगा और energy की band बन जायेगी i mean energy band बन जायेगी

ENERGY BANDS

Range of energy possessed by electron in a solid is known as energy band.

Valence Band (VB)

Range of energies possessed by valence electron is known as valence band.

→ Have bonded electron.
→ No flow of current due to such electron.
→ Always fulfill by electron.
→ which are completely filled with e^- at 0 K
→ never empty
→ e^- are not capable of gaining energy from Ex. E.F. they donot contribute to electric current.

Conduction Band (CB)

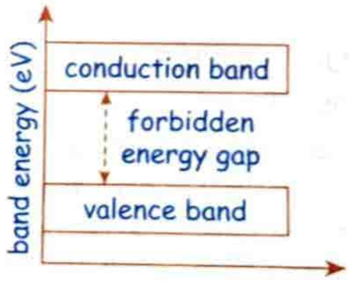
Range of energies possessed by free electron is known as conduction band.

→ Band which are partially filled or completely vacant
→ It has conducting electrons.
→ Current flows due to such electrons.
→ If conduction band is fully empty then current conduction is not possible.
→ Electrons may exist or not in it.
→ e^- gain every from Ex. E.F.
→ they contribute to electric current.

FORBIDDEN ENERGY GAP (FEG) (ΔEg)

$$\Delta E_g = (CB)_{min} - (VB)_{max}$$

Energy gap between conduction band and valence band, where no free electron can exist.



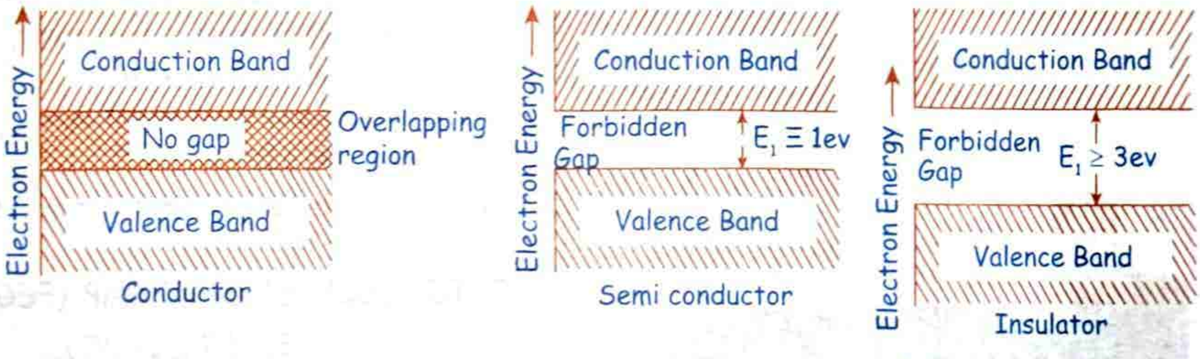
- Width of forbidden energy gap depends upon the nature of substance.
- Width is more, then valence electrons are strongly attached with nucleus
- As temperature increases forbidden energy gap decreases (very slightly).

#SKC
Valence band में electron का मतलब जैसे आप घर में bounded रहते हो और conduction band में electron का मतलब जैसे आप कोटा में आगये हो कोटा में आकर जैसे आप आजाद हो जाते हो घूमना शुरू कर देते वैसे ही electron अगर conduction band में है तो घूम सकता है मतलब current में participate कर सकता है।

COMPARISON BETWEEN CONDUCTOR, SEMICONDUCTOR AND INSULATOR

Properties	Conductor	Semiconductor	Insulator
Resistivity	10^{-2} - 10^{-8} Ωm	10^{-5} - 10^{6} Ωm	10^{11} - 10^{19} Ωm
Conductivity	10^{2} - 10^{8} mho/m	10^{5} - 10^{-6} mho/m	10^{-11} - 10^{-19} mho/m
Temp. Coefficient of resistance (α)	Positive	negative	negative
Current	Due to free electrons	Due to electrons and holes	No current

Energy band diagram

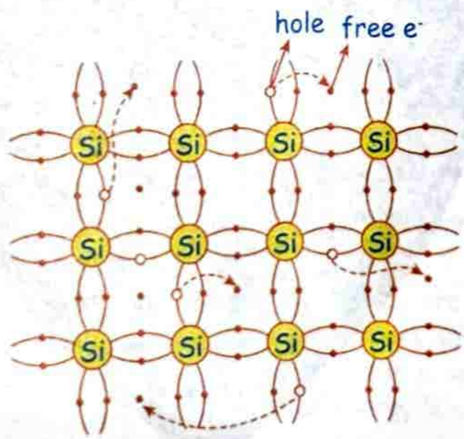


Properties	Conductor	Semiconductor	Insulator
Forbidden energy gap	$\div$ 0 eV	$\div$ 1 eV	$\geq$ 3 eV
Example:	Pt, Al, Cu, Ag	Ge, Si, GaAs, GaF	Wood, Plastic, Diamond, Mica

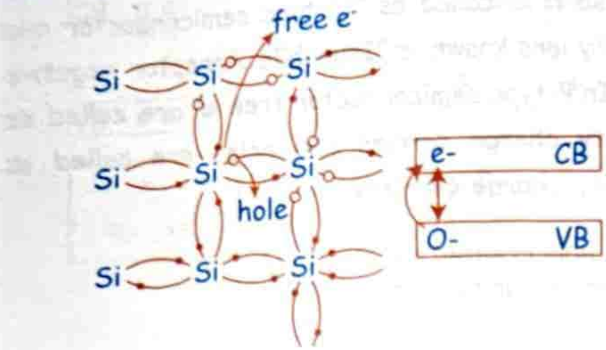
CONCEPT OF "HOLES" IN SEMICONDUCTORS

Due to external energy (temp. or radiation) when electron goes from valence band to conduction band (*i.e.* bonded electrons becomes free) a vacancy of free e^- creats in valence band, which has same charge as electron but positive. This positively charged vacancy is termed as hole and shown in figure.

- It is deficiency of electron in VB.
- It acts as positive charge carrier.
- It's effective mass is more than electron.
- It's mobility is less than electron.



Note: Hole acts as virtual charge carrier, although it has no physical significance.



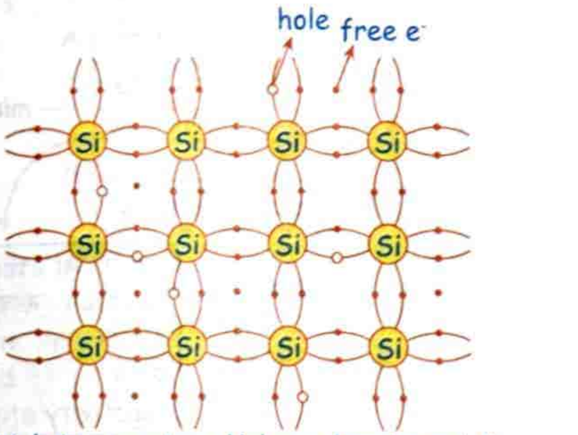
EFFECT OF TEMPERATURE ON SEMICONDUCTOR

At absolute zero kelvin temperature

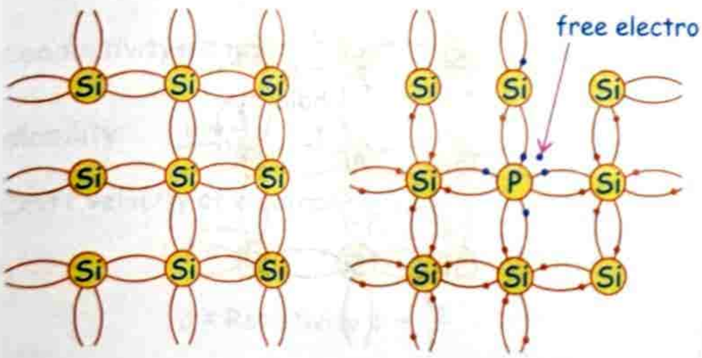
At this temperature covalent bonds are very strong and there are no free electrons and hence semiconductor behaves as perfect insulator.

Above absolute temperature

With increase in temperature few valence electrons jump into conduction band and hence it behaves as poor conductor.



at high temperature Valence band partially empty Conduction band partially filled



EFFECT OF IMPURITY IN SEMICONDUCTOR

Doping is a method of addition of "desirable" impurity atoms to pure semiconductor to increase conductivity of semiconductor.

Added impurity atoms are called dopants.

The impurity added may ≈ **1 part per million (ppm)**.

- The dopant atom should **take the position of semiconductor** atom in the lattice.
- The presence of the dopant atom should not distort the crystal lattice.
- The size of the dopant atom should be almost the same as that of the crystal atom.
- The concentration of dopant atoms **should not be** large (not more than 1% of the crystal atom).

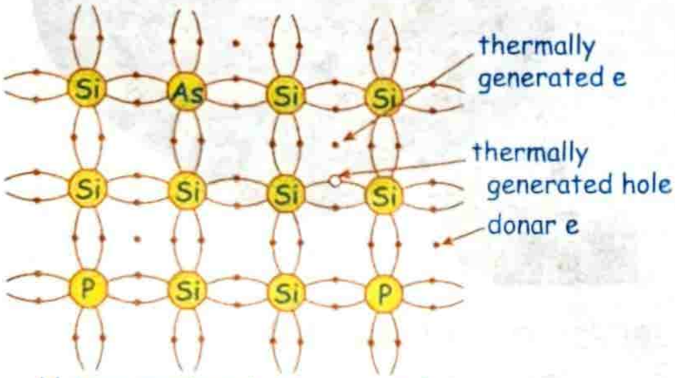
It is to be noted that the doping of a semiconductor increases its electrical conductivity to a great extent.

- The concentration of dopant atoms be very low, doping ratio is vary from impure : pure :: $1 : 10^6$ to $1 : 10^{10}$ In general it is $1 : 10^8$

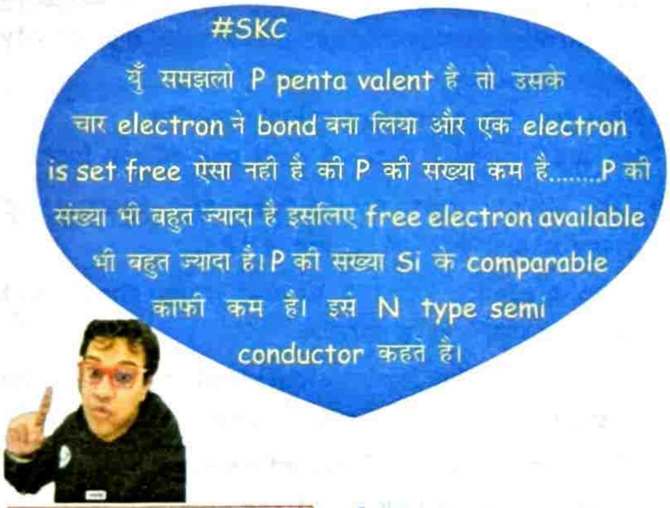
N TYPE SEMICONDUCTOR

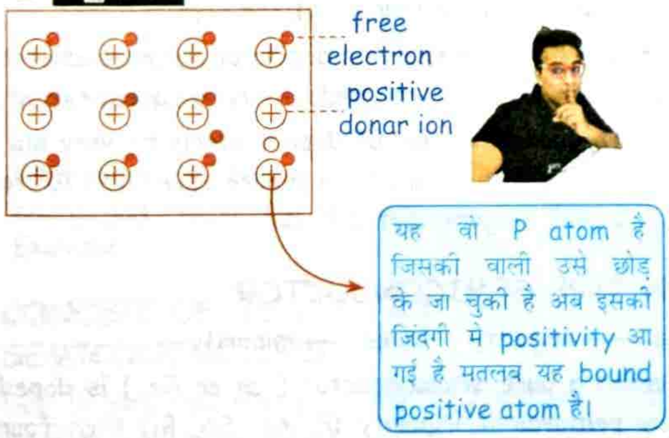
$e^- \longrightarrow$ majority   holes $\longrightarrow$ minority---

When a pure semiconductor (Si or Ge) is doped by pentavalent impurity (P, As, Sb, Bi) then four electrons out of the five valence electrons of impurity take part, in covalent bonding, with four silicon atoms surrounding it and **the fifth electron is set free**. These impurity atoms which donate free e^- for conduction are called as Donar impurity (N_D). Due to donar impurity free e^- increases very much so it is called as "N" type semiconductor. By donating e^- impurity atoms get positive charge and hence known as "**Immobile Donar positive Ion**". In N-type semiconductor free e^- are called as "majority" charge carriers and "holes" are called as "minority" charge carriers.



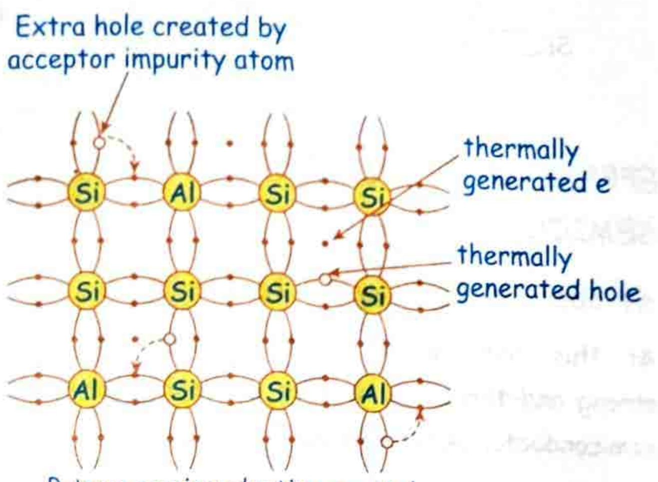
N-type semiconducting crystal



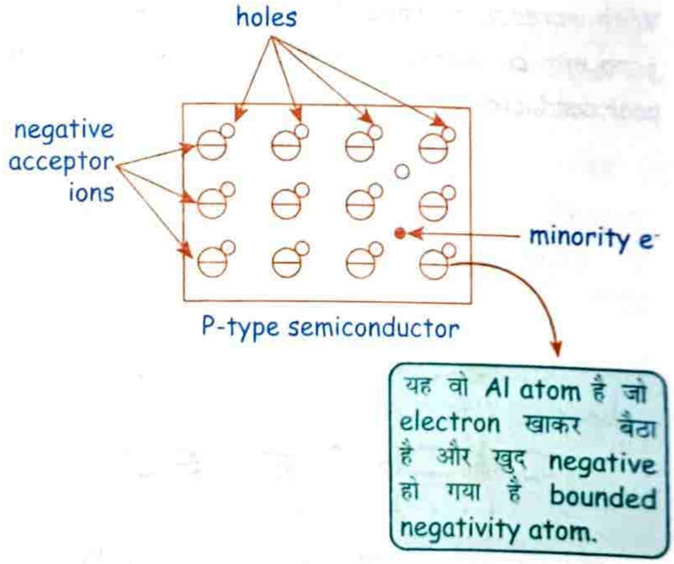


P TYPE SEMICONDUCTOR

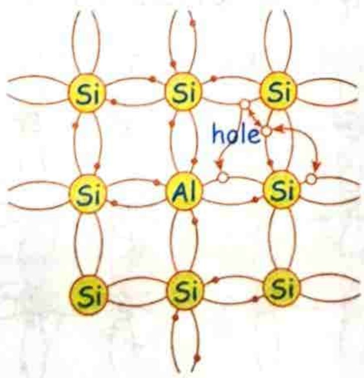
When a pure semiconductor (Si or Ge) is doped by trivalent impurity (B, Al, In, Ga) then outer most three electrons of the valence band of impurity take part, in covalent bonding with four silicon atoms surrounding it and accept one electron from semiconductor and make hole in semiconductor. These impurity atoms which accept bonded e^- from valance band are called as Acceptor impurity(N_A). Here holes increases very much so it is called as "P" type semiconductor and impurity ions known as "**Immobile Acceptor negative Ion**". In P-type semiconductor **free e^- are called as minority charge carries and holes are called as majority charge carriers**.

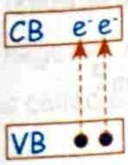
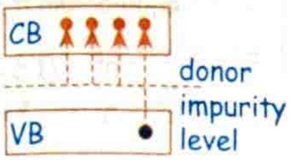
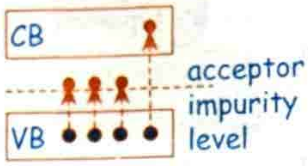
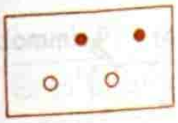
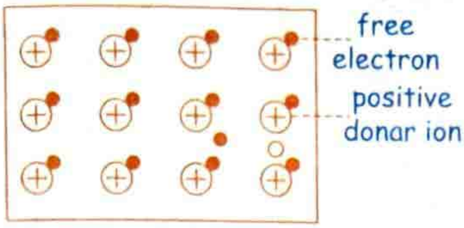
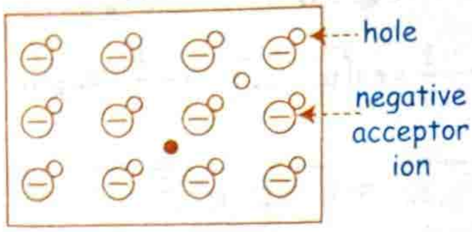


P-type semiconducting crystal



P-type semiconductor



Pure Intrinsic Semiconductor	N-type (Pentavalent impurity)	P-type (Trivalent impurity)
1. 		
2. 		
3. Current due to electron and hole	Mainly due to electrons	Mainly due to holes
4. $n_e = n_h = n_i$	$\boxed{n_h \ll n_e}(N_D \simeq n_e)$	$n_h \gg n_e\ (N_A \simeq n_h)$
5. $I = I_e + I_h$	$I \simeq I_e$	$I \simeq I_h$
6. Entirely neutral	Entirely neutral	Entirely neutral
7. Quantity of electrons and holes are equal	Majority - Electrons Minority - Holes	Majority - Holes Minority - Electrons

RESISTIVITY AND CONDUCTIVITY OF SEMICONDUCTOR

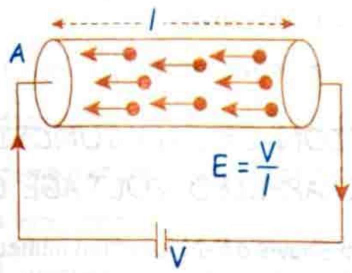
Conduction in conductor

Relation between current (i) and drift velocity (v_d)

$I = neAv_d$ n = number of electron in unit volume

A= cross sectional area

$i = neA v_d$



Current density $J = \frac{I}{A}\,amp/m^2 = nev_d$

$J = ne\,\mu E$

Conductivity $\sigma = ne\mu = \frac{1}{\rho}$

Mobility $\mu = \frac{v_d}{E}$

Drift velocity of electron $v_d = \mu E$

$J = \sigma E$

ρ = Resistivity $\mu = \frac{v_d}{E}$

Total current $= I_e + I_h$

$$I = n_e eAv_e + n_h eAv_h$$

$$\frac{I}{A} = e(n_e v_e + n_h v_h)$$

$$\frac{E}{\rho} = e(n_e v_e + n_h v_h)$$

$$\frac{\cancel{E}}{\rho} = e(n_e \mu_e \cancel{E} + n_h \mu_h \cancel{E})$$

$$\boxed{\frac{1}{\rho} = \sigma = e(h_e \mu_e + h_h \mu_h)}$$

$$\frac{i}{A} = J = \sigma E = \frac{1}{\rho}E$$

$\mu_e \rightarrow$ mobility of $e^- = \frac{v_e}{E}$

$$\boxed{V_e = \mu_e E}$$

$T\uparrow, n_e\uparrow, n_h\uparrow, \sigma\uparrow, \rho\uparrow$

Electric current

$I = eA(n_e v_e + n_h v_h)$

Electrical conductivity $\sigma = \frac{1}{\rho} = e(n_e \mu_e + n_h \mu_h)$

Conduction in Semiconductor

Intrinsic semiconductor	P-type	N-type
$n_e = n_h$	$n_h \gg n_e$	$n_e \gg n_h$
$J = ne\,[v_e + v_h]$	$J \cong en_h v_h$	$J \cong en_e v_e$
$\sigma = \frac{1}{\rho} = en\left[\mu_e + \mu_h\right]$	$\sigma = \frac{1}{\rho} \cong en_h \mu_h$	$\sigma = \frac{1}{\rho} \cong en_e \mu_e$

यह याद रखना है pure semi conductor में $n_e = n_h$. P type semi conductor में $n_e \ll n_h$ और N type semi conductor में $n_e \gg n_h$. That's why N type में electron are majority carrier or P type में holes are majority carrier.

Q. What is the conductivity of a semiconductor if electron density = $5 \times 10^{12}/cm^3$ and hole density = $8 \times 10^{13}/cm^3$ ($\mu_e = 2.3\ m^2V^{-1}s^{-1}$, $\mu_h = 0.01\ m^2V^{-1}s^{-1}$)

Sol. Electron density = $n_e = 5 \times 10^{12}/cm^3 = 5 \times 10^{18}/m^3$

Hole density = $n_h = 8 \times 10^{13}/cm^3 = 8 \times 10^{19}/m^3$

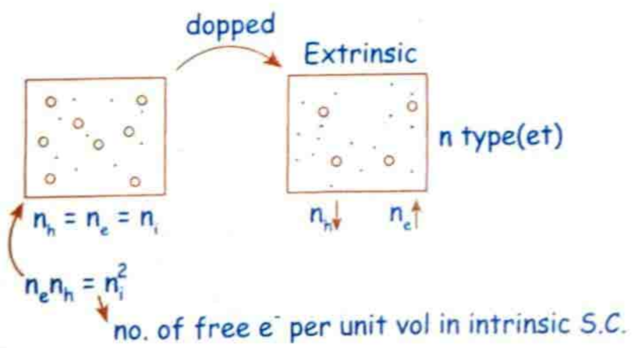
The conductivity of the semiconductor

$= e(\mu_e n_e + \mu_h n_h)$

$= 1.6 \times 10^{-19}[(2.3)(5 \times 10^{18}) + (0.01)(8 \times 10^{19})]$

$= 1.968\ \Omega^{-1}m^{-1}$.

Mass Action Law

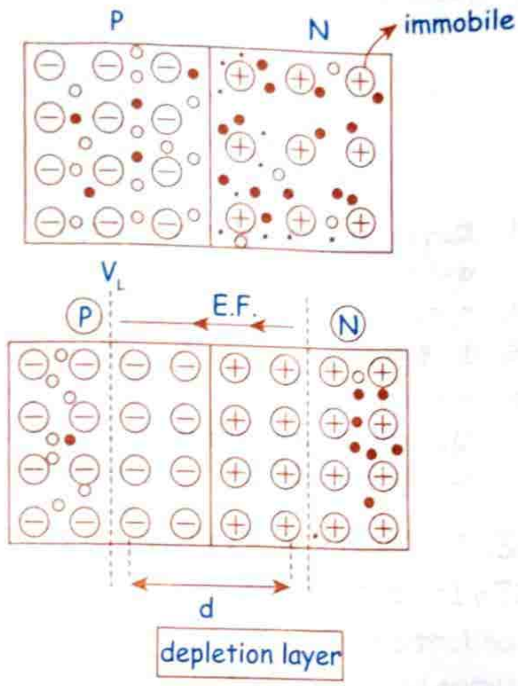


Q. Pure Si at 300 K has equal electron (n_e) and hole (n_h) concentrations of $1.5 \times 10^{16}\ m^{-3}$. Doping by indium increases n_h to $3 \times 10^{22}\ m^{-3}$. Calculate n_e in the doped Si.

Sol. For a doped semi-conductor in thermal equilibrium $n_e n_h = n_i^2$ (Law of mass action)

$$n_e = \frac{n_i^2}{n_h} = \frac{(1.5 \times 10^{16})^2}{3 \times 10^{22}} = 7.5 \times 10^9\ m^{-3}$$

P - N junction



majority carrier

P $\longrightarrow$ Hole

N $\longrightarrow$ e^-,

P to N $\Rightarrow$ holes move

N to P $\Rightarrow$ e^- move

DESCRIPTION OF P-N JUNCTION WITHOUT APPLIED VOLTAGE OR BIAS

Given diagram shows a P-N junction immediately after it is formed.

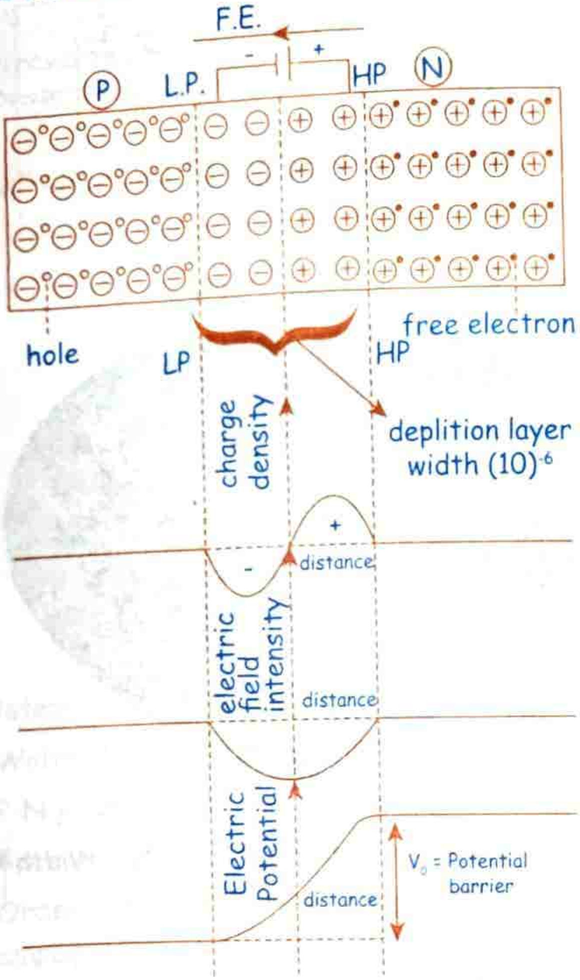
P region has mobile majority holes and immobile negatively charged impurity ions.

N region has mobile majority free electrons and immobile positively charged impurity ions.

Due to concentration difference diffusion of holes starts from P to N side and diffusion of e-s starts N to P side.

Due to this a layer of only positive (in N side) and negative (in P-side) started to form which generate an electric field (N to P side) which oppose diffusion process, during diffusion magnitude of electric field

increases due to this diffusion it gradually decreased and ultimately stop. The layer of immobile positive and negative ions, which have no free electrons and holes called as depletion layer as shown in diagram.



- Width of depletion layer $\cong 10^{-6}$ m.
  - (a) As doping increases depletion layer decreases.
  - (b) As temperature is increased depletion layer also increases.
  - (c) P-N junction → nonohmic, due to nonlinear relation between I and V .
- $\boxed{\text{Potential Barrier}}$ or contact potential

  $\boxed{Ge \rightarrow 0.3V}$ $\qquad$ $\boxed{Si \rightarrow 0.7\ V}$
- Electric field, produce due to potential barrier

  $E = \frac{V}{d} = \frac{0.5}{10^{-6}} \Rightarrow E \cong 10^5\ V/m;$

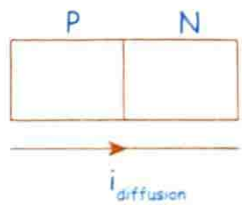
  This field prevents the respective $\boxed{\text{majority carrier}}$ from crossing barrier region.

P-type or N-type को suitabiliy connect करने के बाद P-type के hole N-type के electron की तरफ move किए और N-type के electron P-type की तरफ move किए basically P-type के hole और N-type के electron के बीच setting हो रही है दोनों मिले और और...... समझ गए ना electron hole re-combination हुआ थोड़े समय बाद एक deplition region में electric field (Mogambo) create हो गई जो एक तरह से villian है अब Mogambo P-type के hole पर left side force लगा रहा है और N-type के electron पर right side force लगा रहा है। Mogambo ने electron hole को मिलने से रोक दिया।

DIFFUSION AND DRIFT CURRENT

(1) Diffusion current - **P to N side**

(2) Drift current - **N to P side**



If **there is no biasing** diffusion **current = drift current**

So total current is zero

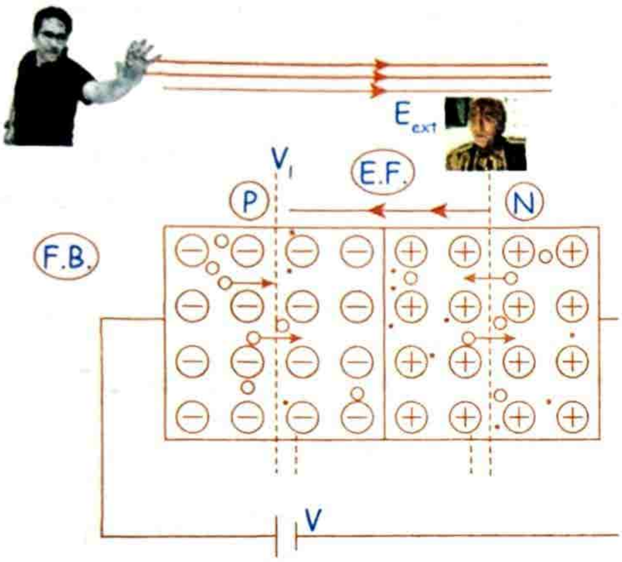
BEHAVIOUR OF P-N JUNCTION WITH AN EXTERNAL VOLTAGE APPLIED OR BIAS

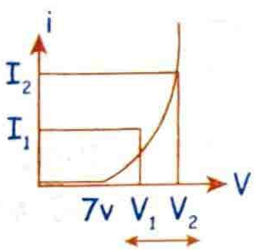
Forward Bias

If we apply a voltage "V" such that P-side is positive and N-side is negative as shown in diagram.

The applied voltage is opposite to the junction barrier potential. Due to this effective potential barrier decreases, **junction width also** decreases, so more majority carriers will be allowed to flow across junction. It means the current flow in principally **due to majority charge** carriers and it is in the order of mA called as forward Bias.

Basically forward bias में saleem bhaiya battery के form में आगए है External Battery का EMF बढ़ाने पर saleem bhaiya ने mogambo को खतम कर दिया current flow होना start हो गया। अब कुछ लोग आयेंगे और कहेंगे Saleem Bhaiya ने setting करवा दी।



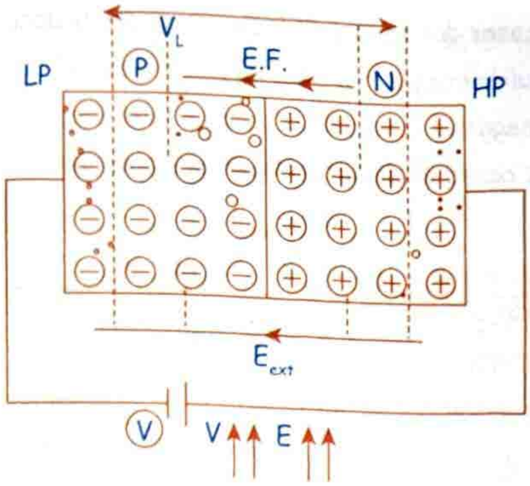


Reverse Bias

If we apply a voltage "V" such that P-side is negative and N-side is positive as shown in diagram. The applied voltage is in same direction as the junction barrier potential. Due to this **effective potential barrier increase** junction, **width also increases**, so **no majority carriers will be allowed to flow across junction.**

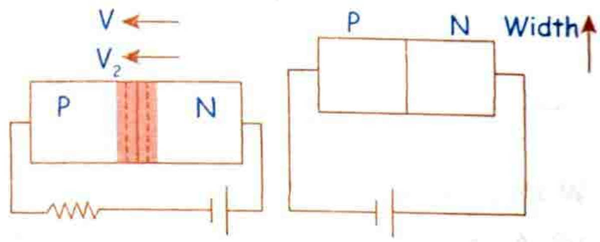
$P \xrightarrow{\text{joint}} -$ ve , L.P.

$N \xrightarrow{\text{joint}} +$ ve . H.P.



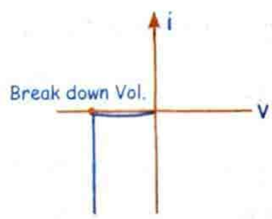
#SKC

Reverse bias में external battery की वजह से जो electric field आई उसने Mogambo को support किया इसलिए villain की power बढ़ गई और deplition layer increase कर गई। बाहर वाली battery का emf बढ़ाने पर deplition layer बढ़ती गई और एक moment पर breakdown हो गया।



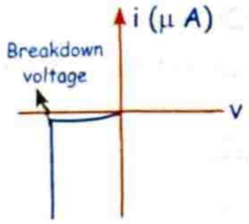
Only minority **carriers will drifted.** It means the current flow in principally due to **minority charge carriers and is very small (in the order of μA). This bias is called as reversed Bias.**

V↑, E↑, E_{xt} E.F.↑ d↑



If Electric field inside dep. layer become greater than Breakdown E.F dep. layer become conducting

(dielectric strength)

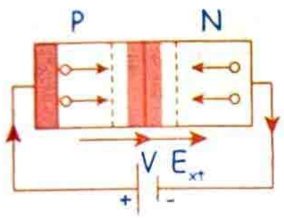


- **In reverse bias, the current is very small and nearly constant with bias (termed as reverse saturation** current). However interesting behaviour results in some special cases if the reverse bias is increased further beyond a certain limit, above particular high voltage breakdown of depletion layer started.
- Breakdown of a diode is of following two types:
  (i) Zener breakdown
  (ii) Avalanche breakdown

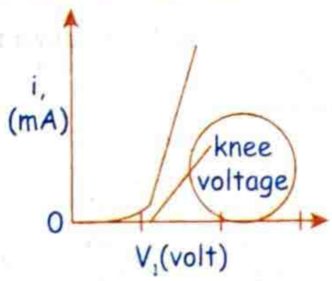
COMPARISON BETWEEN FORWARD BIAS AND REVERSE BIAS

Forward Bias

P → positive
N → negative



1. Potential Barrier reduces.
2. Width of depletion layer decreases
3. P-N jn. provide very small resistances
4. Forward current flows in the circuit.
5. Order of forward current is milli ampere.
6. Current flows mainly due **to majority careers.**
7. Forward characteristic curves.



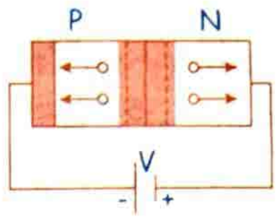
8. Forward resistance $R_f = \frac{\Delta V_f}{\Delta I_f} \cong 100\Omega$

9. **Order of knee or cut in voltage** $\boxed{\begin{array}{l} Ge \rightarrow 0.3V \\ Si \rightarrow 0.7V \end{array}}$

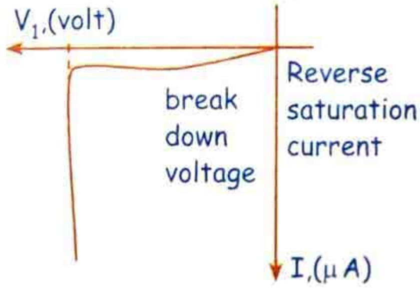
Special point: Generally $\frac{R_r}{R_f} = 10^3 : 1$ for Ge

Reverse Bias

P → negative
N → positive



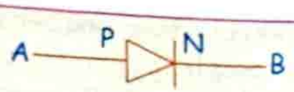
1. Potential Barrier increases.
2. Width of depletion layer increases.
3. P-N jn. provide high resistance
4. Very small current flows (μ, A).
5. Order of current is micro ampere for Ge or Neno ampere for Si .
6. Current flows mainly due **to minority Careers.**
7. Reverse characteristic curve



8. Reverse resistance $R_r = \frac{\Delta V_r}{\Delta I_r} \cong 10^6\Omega$

9. Breakdown voltage $\left.\begin{array}{l} Ge \rightarrow 25V \\ Si \rightarrow 35V \end{array}\right\}$

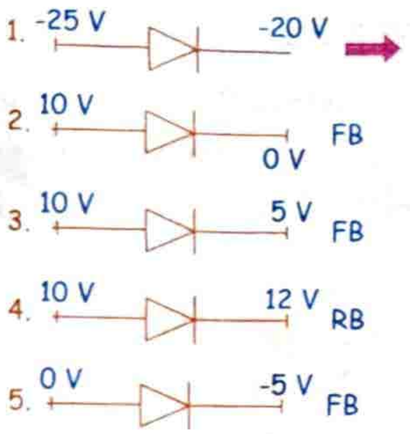
$\frac{R_r}{R_f} = 10^4 : 1$ for Si



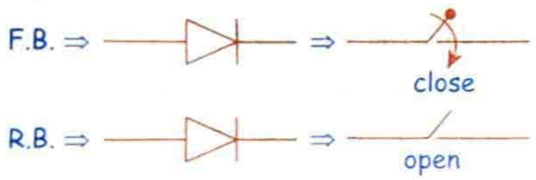
If $V_A > V_B \Rightarrow$ Forward Baise (FB)

$V_A < V_B \Rightarrow$ Forward Baise (RB)

Q. Identify which P-N junction diode is in FB and RB



Ideal Diode

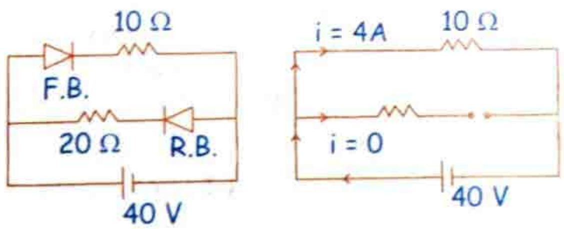


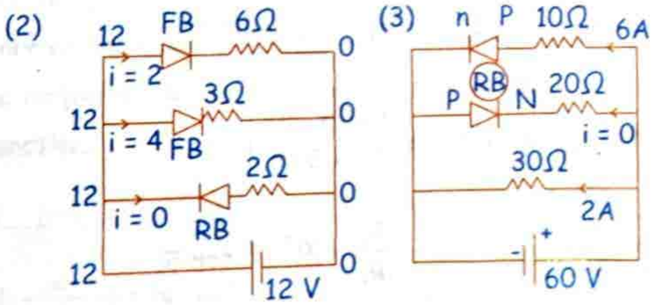
(applied voltage < Break down Voltage)

#SKC

अगर ideal diode FB में है तो उसे तार बना दो और अगर RB में है तो breaking wire (टूटा तार) बना दो

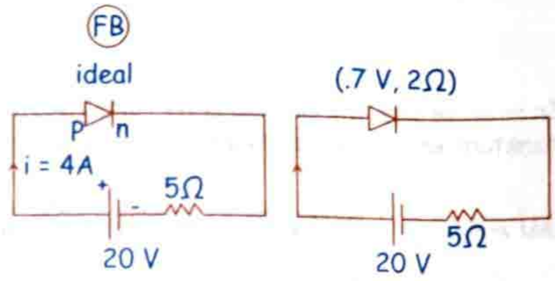
(1) Ideal diode





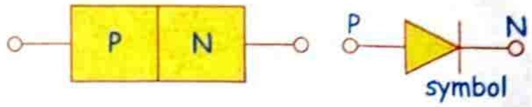
Important Question

Q. Find current through the battery in following circuit.



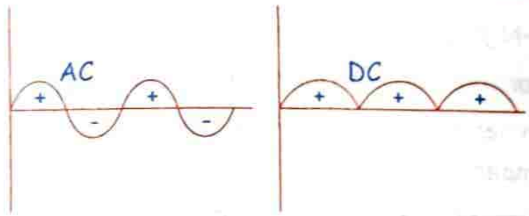
$$i = \frac{20 - .7}{5 + 2}$$

CHARACTERISTIC CURVE OF P-N JUNCTION DIODE



For Ideal Diode

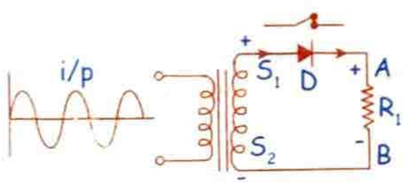
in forward bias	in reverse bias
$R_f = 0$ 'ON' switch	$R_f = \infty$ 'OFF' switch



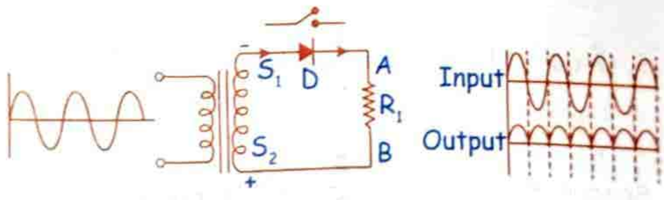
Rectifier

It is device which is used for converting **alternating** current into direct current.

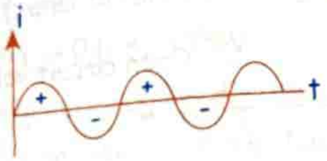
Half wave rectifier

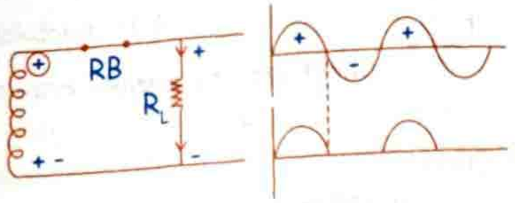


For positive half cycle



For negative half cycle

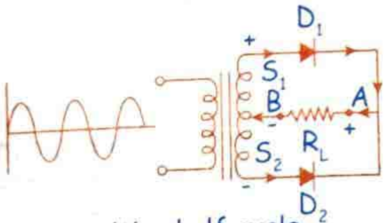




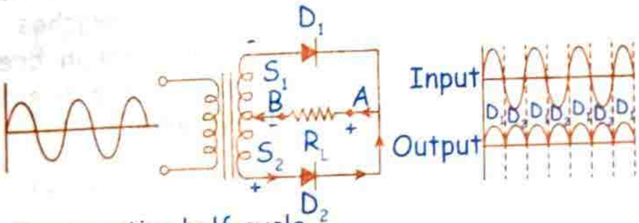
Full Wave Rectifier

When the diode rectifies the whole of the AC wave, it is called full wave rectifier. Figure shows the experimental arrangement for using diode as full wave rectifier. The alternating signal is fed to the primary a transformer. The output signal appears across the load resistance R_L.

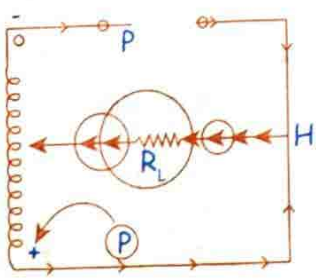
i/p $\longrightarrow$ 100 Hz o/p $\longrightarrow$ 200 kv

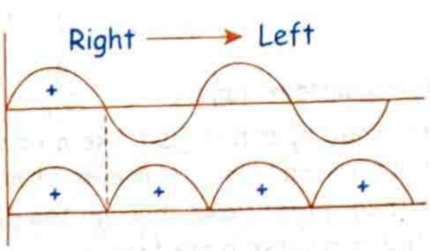


For positive half cycle

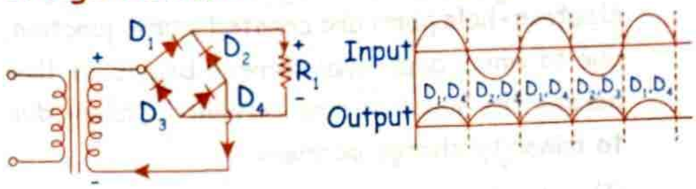


For negative half cycle





Bridge Rectifier



Light Emitting Diode (LED):

A light emitting diode is simply a forward biased p-n junction which emits spontaneous light radiation. When forward bias is applied, **the electron and holes at the junction recombine and energy released is emitted in the form of light. For visible radiation** phosphorus doped GaAs is commonly used. The advantages of LEDs are:

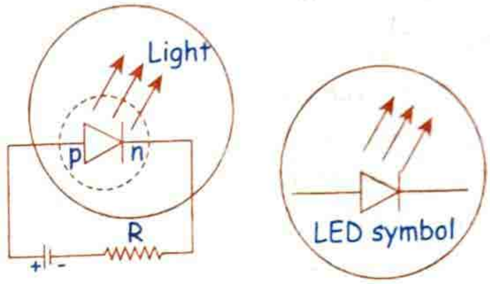
(i) Low operational voltage and less power

(ii) Fast action with no warm up time.

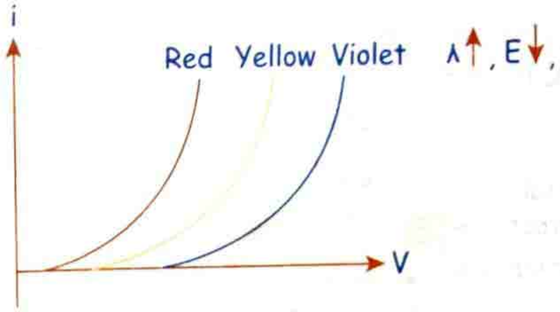
(iii) Emitted light is nearly monochromatic.

(iv) They have long life.

$$E_g = \frac{12400}{\lambda}$$



I-V characteristics of LED are similar to that of Si junction diode but the threshold voltages are much higher and slightly different for **each colour**. The reverse breakdown voltages of LED's are very low, about 5 V.



Photodiode:

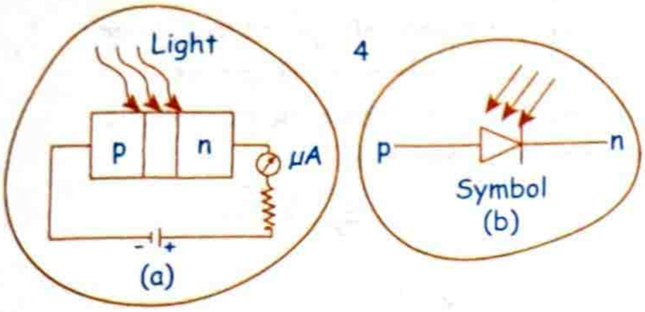
1. **It is a reversed-biased p-n junction,**
2. **illuminated by radiation**. When p-n junction is reversed biased with no current, a very small reverse saturated current flows across the junction called the dark current.

3. **When the junction is illuminated with light, electron-hole pairs are created at the junction,** due to which additional **current begins to flow across the junction;** the **current is solely due to minority charge carriers.**

(1) A photodiode is used in reverse bias, although in forward bias current is more than current in reverse bias because in reverse bias **it is easier to observe change in current with change in light intensity.**

(2) Photodiode is used to measure light intensity because reverse current increases with increase of intensity of light.

4

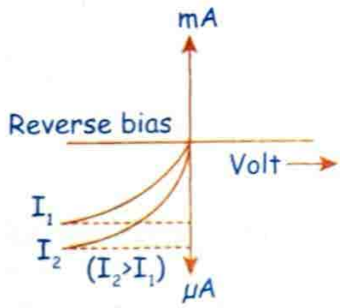


(a) (b)

The characteristic curves of a photodiode for two different illurninatios I_1 and I_2 ($I_2 > I_1$) are shown in figure.

5

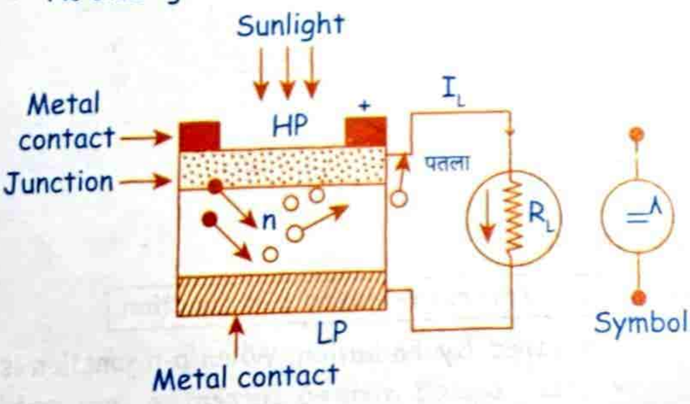
$I_2 > I_1$ $i\uparrow$



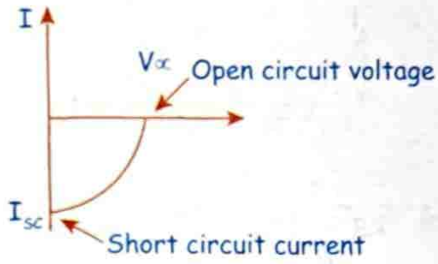
Solar Cell

A solar cell is a junction diode which converts light energy into electrical energy. A p-n junction solar cell consists of a large junction with $\boxed{\text{no external biasing.}}$

- No Biasing.

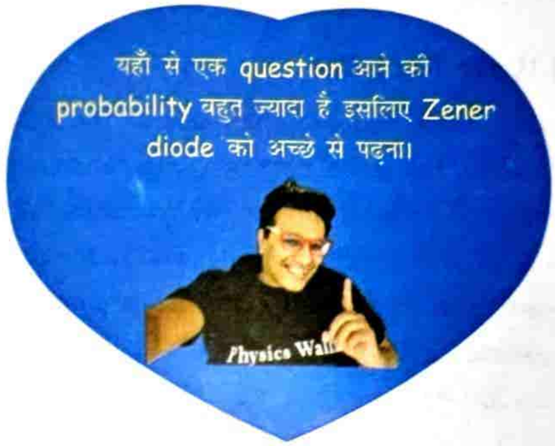


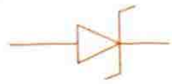
Construction and working
(a)



(b)

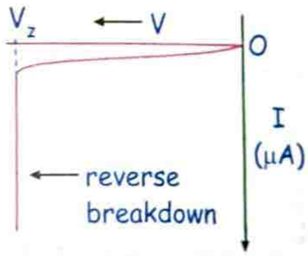
Zener Diode

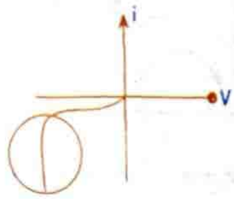


- 

A zener diode, also known as a breakdown diode, is a heavily doped semiconductor device that is designed to operate in the reverse direction.

When the voltage across the terminals of a zener diode is reversed and the potential reaches the Zener voltage (knee voltage), the junction breaks down and the current flows in the reverse direction. This effect is known as the Zener effect.

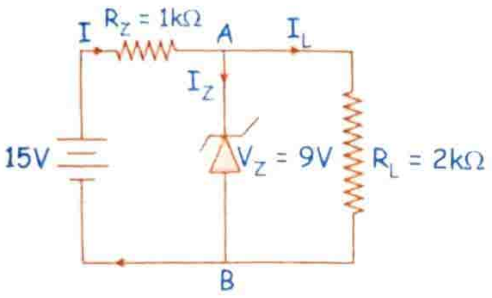




- Used to regulate voltage
- A zener diode operates just like a normal diode when it is forward biased. However a small leakage current (negligible) flows through the diode when connected in reverse biased mode.

- If $V_{ext} < V_Z$ (zener breakdown voltage) it will behave as open ckt $i \to 0$ (μA) order
- It is specially designed heavily doped P-N junction (thin depletion layer) which has very sharp breakdown voltage.
- It always operated in breakdown region.

Q. Find the current through the zener diode when the load resistance is 1kΩ Use diode approximation.



Sol. Voltage across AB is $V_Z = 9$ V

Voltage drop across $R_Z = 15 - 9 = 6$ V

Therefore current through the resistor R_Z,

$$I = \frac{6}{1 \times 10^3} = 6mA.$$

Voltage across the load resistor $R_L = V_{AB} = 9$ V

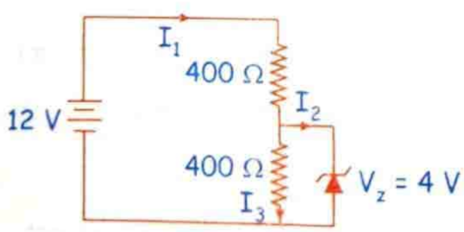
Current through load resistor

$$I_L = \frac{V_{AB}}{R_L} = \frac{9}{2 \times 10^3} = 4.5mA$$

The current through the Zener diode,

$I_Z = I - I_L = 6$ mA $- 4.5$ mA $= 1.5$ mA

Q. In the circuit shown in figure, Zener diode is properly biased. Power dissipated in diode is



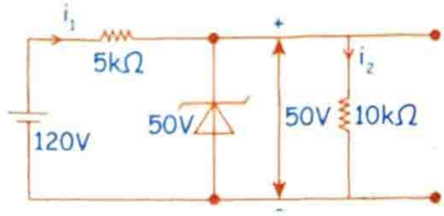
Sol. $400\, I_1 = 12 - 4 = 8$ V

$$\Rightarrow I_1 = \frac{8}{400} = 2 \times 10^{-2}\text{ A and } 400\, I_3 = 4\text{ V}$$

$\Rightarrow I_3 = 1 \times 10^{-2}$ A

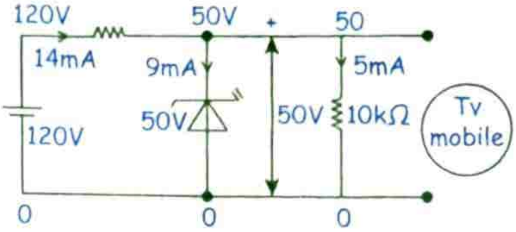
Hence $I_2 = I_1 - I_3 = 10^{-2}$ A $\Rightarrow P = V_z \times I_2 = 40$ mW

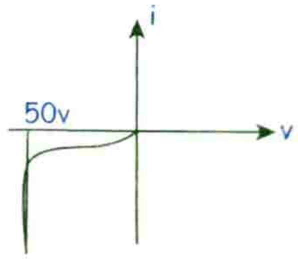
Q.



Find i_1 and i_2

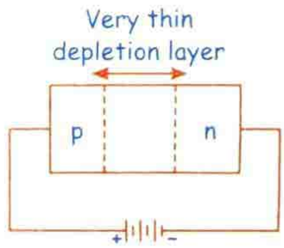
Sol.



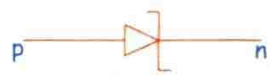


Zener Diode as a Voltage Regulator:

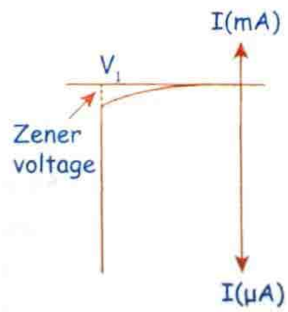
Zener diode may be used as a voltage regulator. The circuit of zener-diode is shown in figure.



Zener diode
(a)



Symbol
(b)

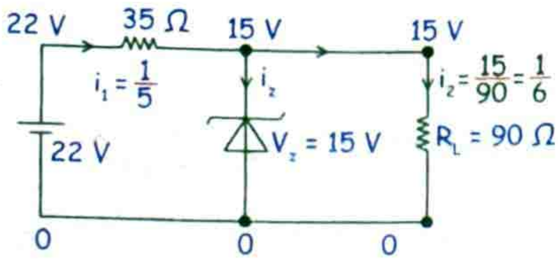


(c) characteristics

Q. (1) Find current through 35Ω, 90Ω and zener diode

(2) Power across zenerdiode in (mW) will be

Sol. (1) $i_1 = \frac{7}{35} = \frac{1}{5}$

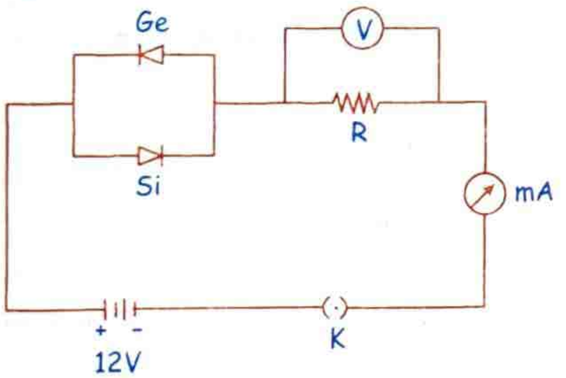


$$\boxed{i_Z = \frac{1}{5} - \frac{1}{6} = \frac{1}{30}}$$

(2) $P = Vi = 15 \times \frac{1}{30} = \frac{1}{2}$

= 500 mW

Q. Germanium and Silicon junction diodes are connected in parallel. These are connected in series with a resistance R, a milliammeter (mA) and a key (K) as shown in fig. When key (K) is closed a current begins to flow in the milliammeter. The potential drop across the germanium diode is

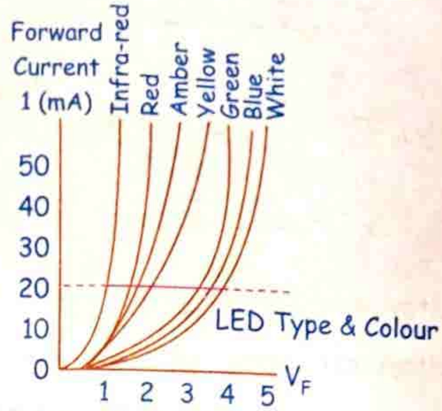


Sol. In fig. germanium diode is reverse biased and silicon diode is forward biased. Therefore, there will be no current in the branch of germanium diode. The potential barrier of silicon diode is 0.7V. Therefore, for conduction minimum potential difference across silicon is 0.7 V.

काम का डब्बा

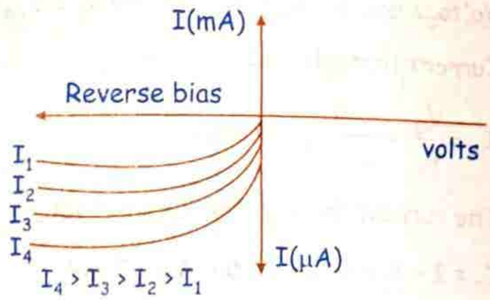
LED, photo diode, solar cell की biasing और इनके **graph** बहुत important है

- LED में pn junction diode को forward bias में रखते है।

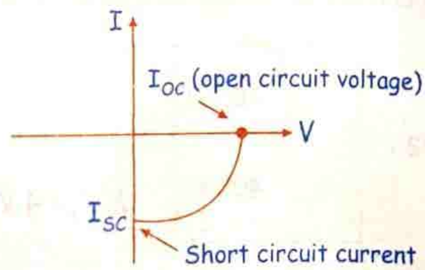


LED and its I-V characteristics

- Photo diode में pn junction diode को reverse bias में रखते है।



- Solar cell में no external biasing is applied.



So..... this beautiful journey is now going to......... i hope ये crush book काफी helpful रही होगी। Although हमारे Youtube channel JEE Wallah almost हर chapter की मेरी classes मौजूद है (search manzil series, percentile booster, mindmap series etc.) I wish आप अपने best potential तक पहुँचे और अच्छे से अच्छे college/मुकाम तक पहुँचे...... और भाई मुझे जरूर बताना। Insta id: saleem.nitt wish you all the best!