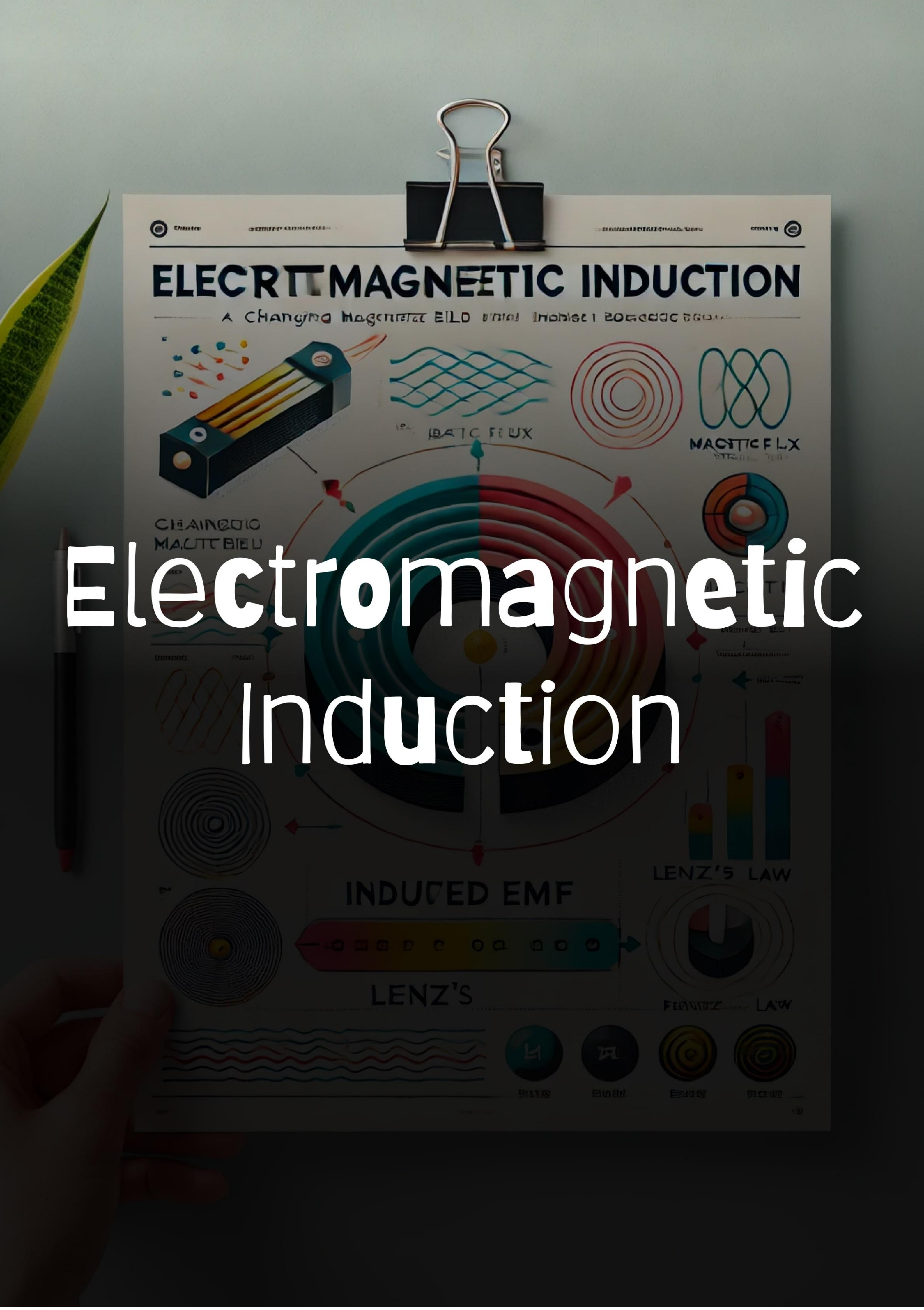
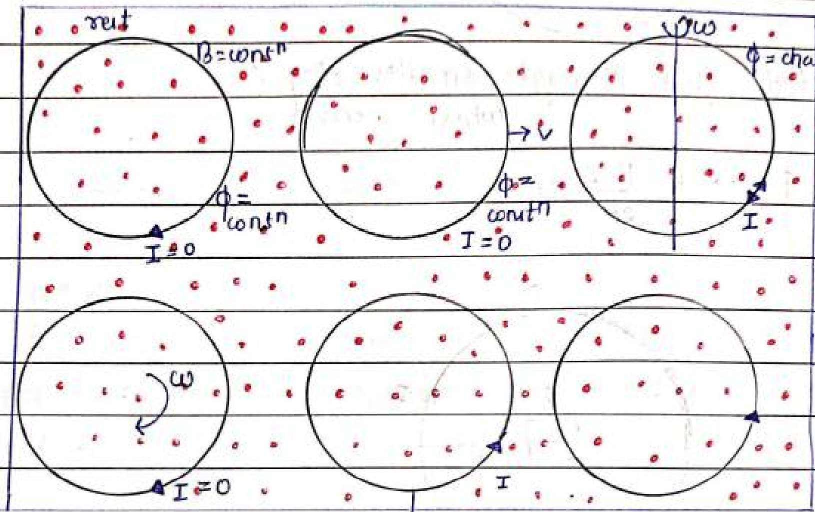


Electromagnetic Induction

ELECTROMAGNETIC INDUCTION

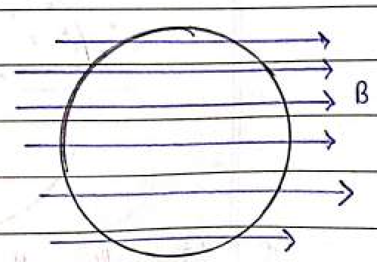


MAGNETIC FLUX

Like electric flux, magnetic flux is proportional to the number of magnetic field lines passing through a surface. It is donated by ϕ_B.

~~Magne~~ Mathematically → $\vec{B}\cdot\vec{A} = \phi_B = BA\cos\theta$

θ = angle between $\vec{B}$ and $\vec{A}$



Area → Vector

direction perpendicular to plane

$\phi = AB\cos 90° = 0$

\# ϕ_B → Real quantity

B → Magnetic line of force → imaginary

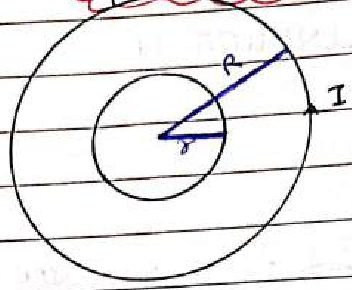
Gyan ki baat

$\phi_B = \boxed{B}\boxed{A}\cos\boxed{\theta}$

If B changes → Static EMI

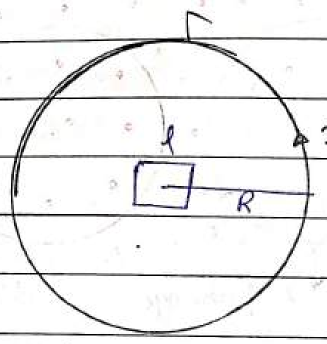
If A changes then ϕ_B also changes → Motional EMI

If θ changes → ϕ_B changes → Periodic EMI → dynamo



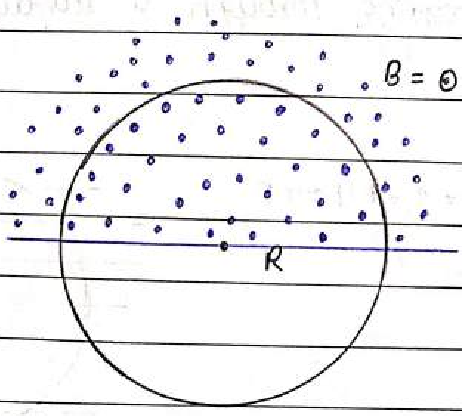
Q Find flux through smaller ring? where $r <<<< R$

$\Rightarrow \phi = B.A = \frac{\mu_0 I}{2R} \pi r^2$



Q Flux through square loop $(R >>>> l)$??

$\Rightarrow \phi = B.A = \frac{\mu_0 I}{2R} l^2$



Q Find flux through ring

$\Rightarrow B.A = \frac{B \pi R^2}{2}$

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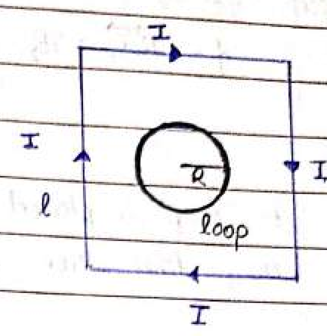
Q Find flux through ring. $(R \lll l)$



→ $\phi = B.A$

$\Rightarrow \frac{2\sqrt{2}\mu_0 I}{\cancel{\pi} l} \cancel{\pi} R^2 = \frac{2\sqrt{2}\mu_0 I R^2}{l}$

SI unit of magnetic flux is weber (Wb) $1 Wb = 1 tesla\ m^2$

CGS unit of magnetic flux is maxwell (1 maxwell = 1 gauss cm^2)

1 Weber = 10^8 maxwell

Magnetic flux is a scalar quantity.

Magnetic flux can also be calculated by integration method

$$\phi = \int d\phi_B = \int \vec{B}\cdot\vec{dA}$$

The dimensional formula of magnetic flux is $[ML^2T^{-2}A^{-1}]$ (from $F = BIL$)

Q A uniform magnetic field exists in the space $\vec{B} = B_1\hat{i} + B_2\hat{j} - B_3\hat{k}$. Find the magnetic flux through an area $\vec{S}$ if area $\vec{S}$ is in.

(i) x-y plane
(ii) y-z plane
(iii) z-x plane

(i) $\vec{S_1} = S\hat{k}$

$\phi = \vec{B}.\vec{S_1} = -SB_3$

(ii) $\vec{S_2} = S\hat{i}$

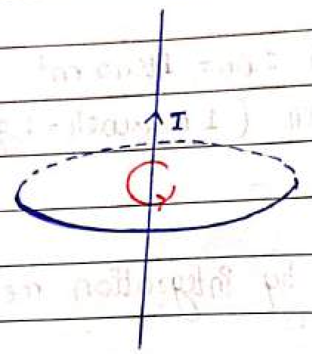
$\phi = \vec{B}.\vec{S_2} = SB_1$

(iii) $S_3 = S\hat{j}$

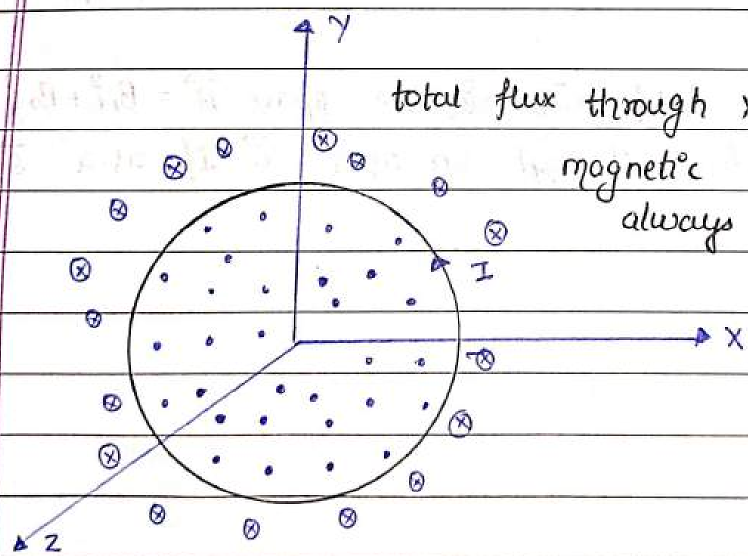
$\phi = \vec{B}\cdot\vec{S_2} = SB_2$

Q A loop is placed perpendicular to the current carrying wire then find flux passing through loop.

Ans



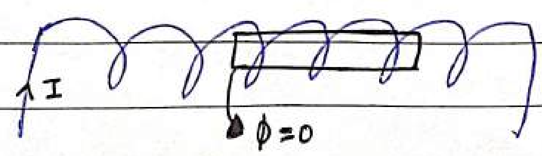
Q Current carrying circular loop is placed in x-y plane then find flux through complete x-y plane.



total flux through x-y plane = 0

magnetic field lines always form close loops.

Q A rectangular loop placed parallel to axis of solenoid then flux through loop



LENTZ LAW → Based on law of conservation of energy

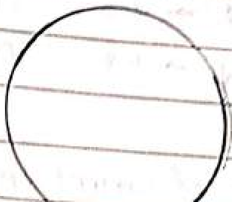
$\phi = \vec{B}.\vec{A}$

ϕ = constant → $I = 0$

ϕ = variable → $I \neq 0$

$I \neq 0$:

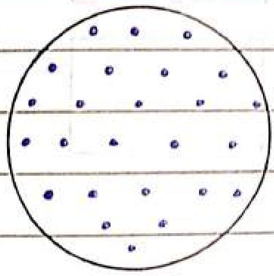
- I (magnitude) ↓ Faraday's law of emf for magnitude.
- I (direction) ↓ Lenz law for direction



loop (coil)
↓
flux ke inertia me hai

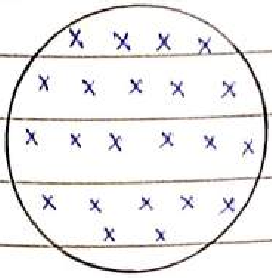
ϕ → change hone par
↓
coil change ko oppose karta hai

ϕ → same rakhna chahta hai

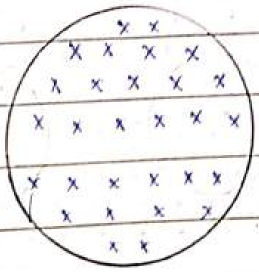


$B \otimes$ induced (clockwise current will induce)

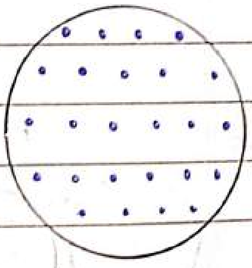
$B_{ext} \odot \uparrow$



$B_{ext} \otimes \uparrow \rightarrow B \odot$ induced
↓
I (Anti)



$B_{ext} \otimes \downarrow \rightarrow B \otimes$ induced
↓
I (clockwise)



$B \odot \downarrow$
↓
$B \odot$ (induced)
↓
I (Anti)

$B\odot\uparrow \rightarrow B\otimes$ [I → clockwise]

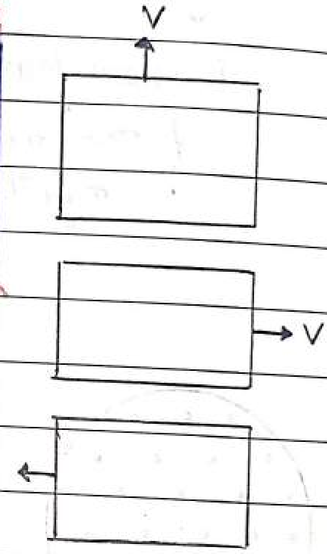
$B\odot\downarrow \rightarrow B\odot$ [I → Anti]

$B\otimes\uparrow \rightarrow B\odot$ [I → Anti]

$B\otimes\downarrow \rightarrow B\otimes$ [I → clockwise]

* Direction of current in a coil due to change in flux such that it oppose the cause due to which it is induced.

Q Find direction of induced current in



a) loop A

→ ϕ = constant

$I = 0$

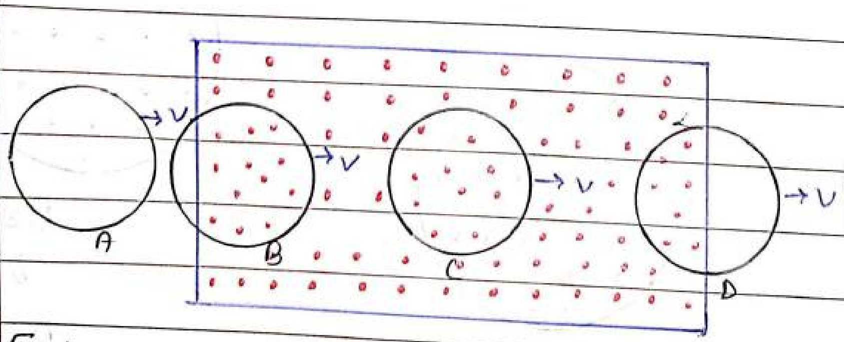
b) loop B

$\phi_B = \otimes\downarrow \rightarrow \otimes\uparrow \rightarrow$ clockwise current

c) loop C

→ $\phi_c = \otimes\uparrow \rightarrow \odot \rightarrow$ Anticlockwise current

Q

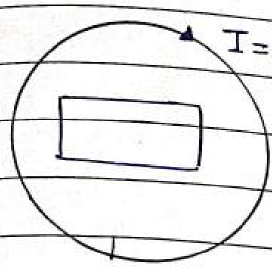


Q Find direction of induced current

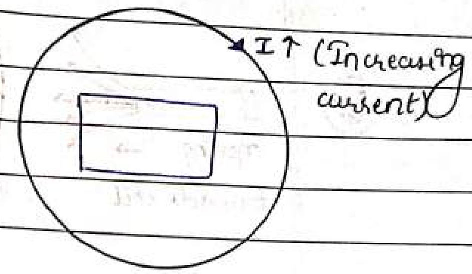
→ $A \rightarrow 0$ $C \rightarrow 0$

$B \rightarrow \odot\uparrow \rightarrow \otimes$ $D \rightarrow \odot\downarrow \rightarrow \odot$

I [clockwise] I [Anti clockwise]

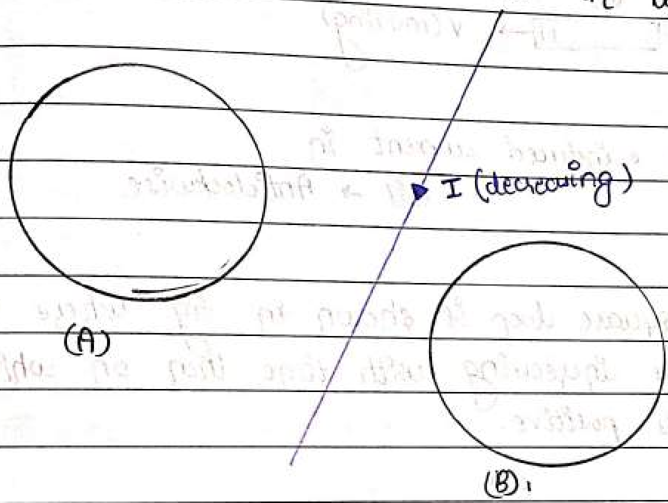


direction of induced current in square loop = 0



Ans ~ $\otimes\uparrow \rightarrow \odot$ Induced
↓
anti-clockwise current

Q Find direction of induced current in both the coil.

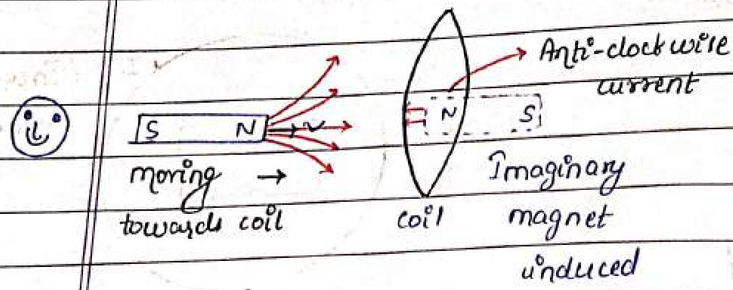


For coil A

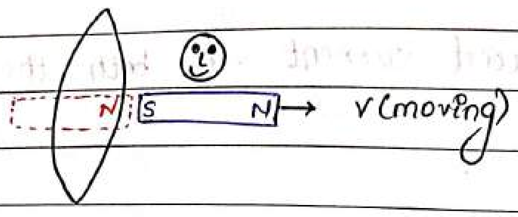
→ $\otimes\downarrow \rightarrow \otimes$ (induced)
↓
clockwise current.

For coil B

$\odot\downarrow \rightarrow \odot$ (induced)
↓
Anticlockwise current.

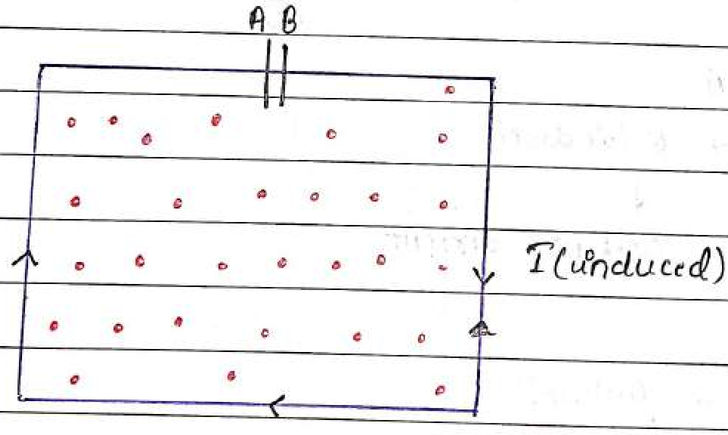


Q



direction of induced current in coil → Anticlockwise.

Q A conducting square loop is shown in fig where magnetic field outside is increasing with time then on which plate charge is positive.

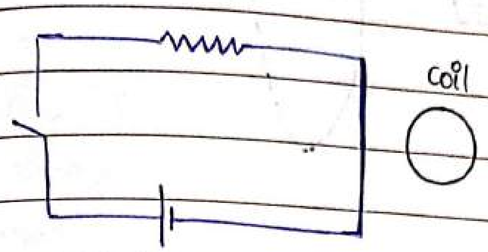


→ According to Lenz law change in flux lead to flow of current.

B ⊙ ↑ → B ⊗ induced → I
clockwise

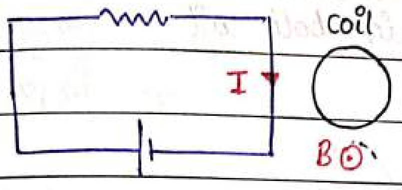
→ charge on A is positive.

Q Find direction of induced current in circular loop,(i) just after key is closed? (ii) just after key is opened.



ANS

(i)



B⊙ banega

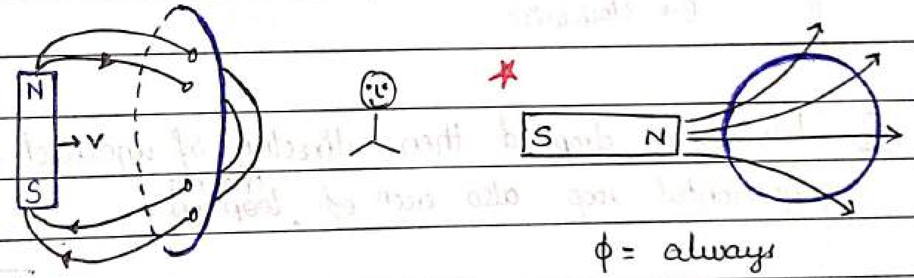
I → clockwise current.

(ii) I = 0

B⊙ banega

I → anticlockwise current.

Q Direction of induced current in loop.



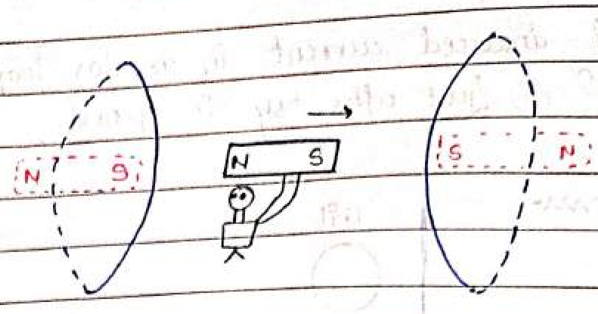
ϕ = always zero → I = 0 (induced

→ No current will be induced

↓

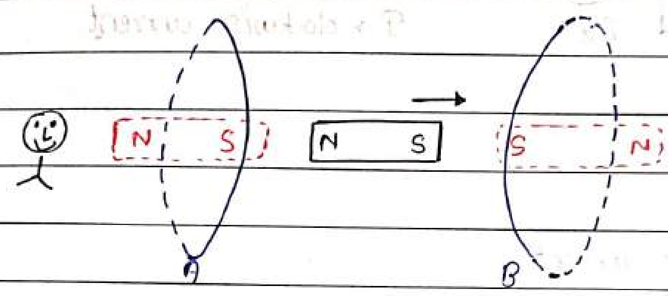
ϕ = always zero

Q Find direction of induced current in coil 'A' & 'B' with respect to observer.



Ans → Both clockwise.

Q Direction of induced current in both coil.



A → Anticlockwise

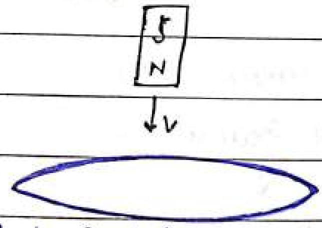
B → clockwise

Q Magnet is dropped then direction of induced current in the horizontal loop, also accⁿ of magnet is.

a) a<g

b) a>g

c) a=g



Fixed horizontal non conducting loop.

ϕ is changing but no current will induce due to plastic loop.

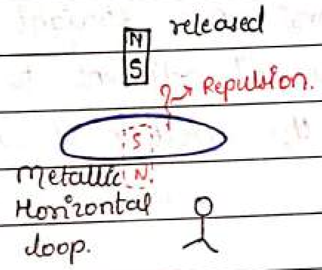
Q. A metallic ring with a cut is ~~cut~~ kept horizontally and a magnet is allowed to fall vertically through the ring, then the acceleration of this magnet is.

a) equal to g
b) More than g
c) Less than g
d) Some times less and sometimes more than g.

→ $\phi \rightarrow$ changing
$I = 0$, open loop.

Q. Magnet is dropped then direction of induced current in the horizontal loop, also accn of magnet is.

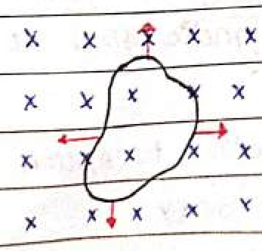
a) $a < g$
b) $a > g$
c) $a = g$



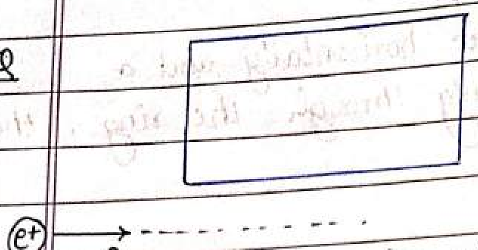
Induced current → anticlockwise
→ $a < g$ always.

Q. A loop of magnet irregular shape of conducting wire PQRS (as shown in figure) placed in uniform magnetic field perpendicular to the plane of the paper changes into a circular shape. The direction of induced current will be

a) Clockwise ~~b)~~ Anti-clockwise
c) No current d) None of these



Ans $B \otimes \uparrow \rightarrow B \odot$ (induced) → I (Anti)

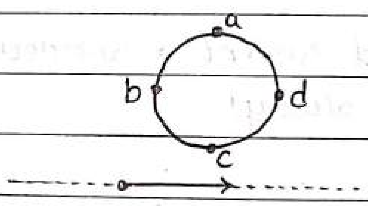
Q 

proton — One proton is moving along a straight line then direction of induced current in a loop.

Ans Initially B ⊙ will be increased
∴ B ⊗ will be induced
↓
clockwise current induced

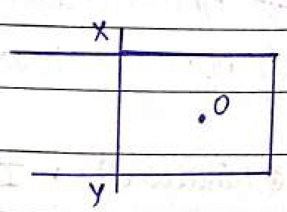
After some time
B ⊙ will decrease
∴ B ⊙ will be induced
↓
Anti-clockwise current.

Q An electron moves on a straight line path XY as shown. The abcd is a coil adjacent to the path of the electron. What will be the direction of current, if any, induced in the coil?



a) No current induced
b) abcd
c) adcb
d) The current will reverse its direction as the electron goes past the coil

Q When a conducting wire XY is moved towards the right, a current flows in the anti-clockwise direction. Direction of magnetic field at point O is.

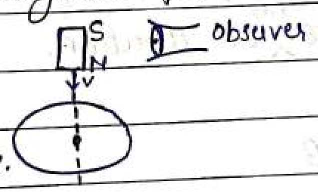


a) Parallel to motion of wire
b) Along XY

c) Perpendicular outside the paper.
d) Perpendicular inside the paper.

Ans Induced current → Anticlockwise ⟶ B ⊙
↓
Bana hoga
when the flux is decreasing
↓
so the flux would be definately inward at point O.

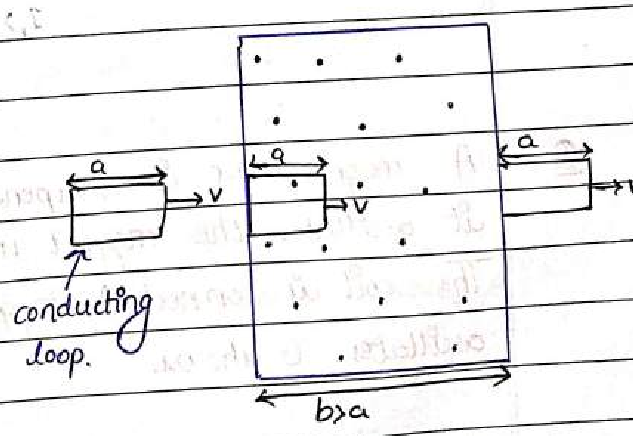
Q A bar magnet is dropped through a horizontal aluminium ring along the axis of the ring. What will be the direction of induced current in the loop for the observer shown? What will be the direction of magnetic force experienced by the bar magnet?



→ Direction ⇝ upward (always)
→ Direction of current → Anticlockwise.

★ Q Time for which current will induce (b>a)

Ans total time = $t = \frac{a}{v} + \frac{a}{v} = \frac{2a}{v}$

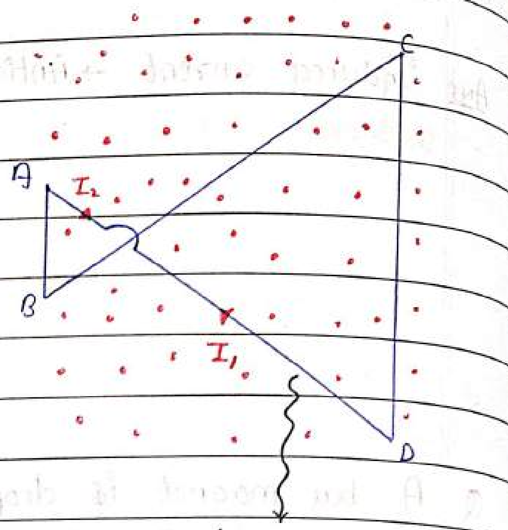


Q ★ If B⊙ magnetic field is increasing then find direction of induced current in the wire AB.

~~a)~~ A to B

b) B to A

c) No current will flow.



Always refer to bigger area

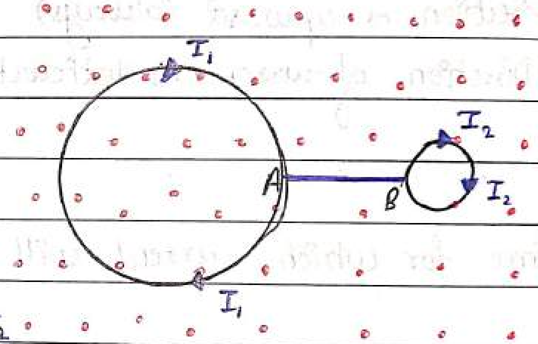
$\phi \Rightarrow$ more $\rightarrow$ change more $\rightarrow I_1 > I_2$

Q ★★★ Magnetic flux is increasing then current will flow in wire AB in direction.

a) $A \rightarrow B$

b) $B \rightarrow A$

~~c)~~ No current.



Q A magnet N-S is suspended from a spring and when it oscillates the magnet moves in and out of the coil. C. The coil is connected to galvanometer G. Then as the magnet oscillates, G shows.

a) No deflection

~~b)~~ Deflection to the left and right but the amplitude steadily decreases

c) Deflection to the left and right with constant amplitude.

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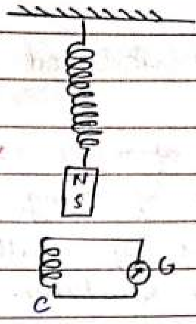
d) Deflection on one side.



FARADAYS LAW OF INDUCTION

The magnitude of the induced emf in a circuit is equal to the time rate of change of magnetic flux through the circuit.

$\phi \rightarrow$ changing

emf

In time 't' — At time 't'

direction.

$emf_{Avg} = \frac{-\Delta\phi}{\Delta t}$

direction

$emf = \frac{-d\phi}{dt}$

$|emf|_{(inst)} = \frac{d\phi}{dt}$

Slope of flux-time graph is instantaneous emf.
Area of emf-time graph is total change in flux.
Unit $\rightarrow$ wb/s = Tesla m^2/s
If ϕ is constant then emf induced will be zero.
Does not depend on nature of coil but flow of current depends on nature of coil.

Scalar

$\phi = BA$

(Plastic, wood, Iron ...)

ϕ = change

$emf = \frac{\Delta\phi}{\Delta t}$

Q The induced emf of a coil does not depend upon.

a) No of turns. → $\phi = NBA$
b) Rate of change of magnetic flux
c) Time of rotation
~~d)~~ The resistance of the circuit.

Avg emf

$$|emf|_{Avg} = \frac{\Delta\phi}{\Delta t}$$

"divide by resistance"

$$\frac{(e.m.f)_{Avg}}{R} = \frac{\Delta\phi}{R\Delta t}$$

$$I_{avg} = \frac{\Delta\phi}{R\Delta t}$$

$$\frac{\Delta q}{\cancel{\Delta t}} = \frac{\Delta\phi}{R\cancel{\Delta t}}$$

$$\Delta q = \frac{\Delta\phi}{R}$$

Avg induced charge.

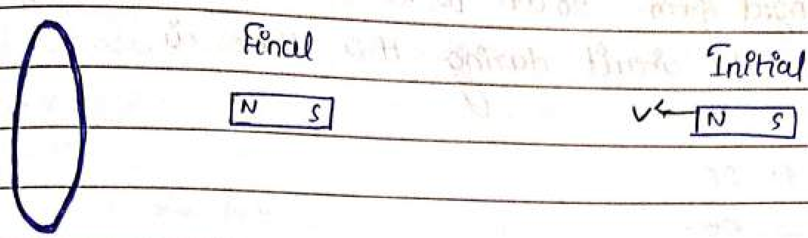
does not depend on time taken.

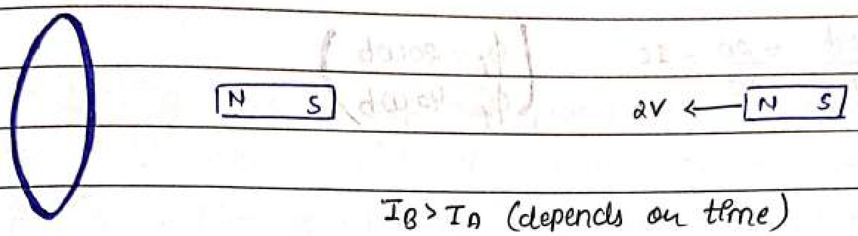
Q The magnetic flux through a circuit of resistance R changes by an amount $\Delta\phi$ in time Δt. Then the total quantity of electric charge Q that passes any point in the circuit during the time Δt is represented by,

a) $Q = \frac{1}{R}\frac{\Delta\phi}{\Delta t}$ ~~(b)~~ $Q = \frac{\Delta\phi}{R}$

c) $Q = \frac{\Delta\phi}{\Delta t}$ (d) $Q = R\frac{\Delta\phi}{\Delta t}$

Q Compare value of induced current and charge. (IIT 2002)





$I_B > I_A$ (depends on time)

$Q_A = Q_B$ (independent of time)

Q If magnetic flux $\phi = 2t^2 + t^3 - 3t + 4$ then find emf at time $t = 2$ sec.

Ans $|emf|_{at\ t=2} = 4t + 3t^2 - 3$

$\Rightarrow 8 + 12 - 3 = 17$ Ans

Q A conducting ring of radius r is placed perpendicularly inside a time varying magnetic field given by $B = B_0 + \alpha t$. B_0 and α are positive constants. Emf induced in the ring is.

a) $-\pi \alpha r$ (b) $-\pi \alpha r^2$
c) $-\pi \alpha^2 r^2$ (d) $-\pi \alpha^2 r$

Ans $emf = -\frac{d\phi}{dt} = -\frac{d(B.A)}{dt} = -\frac{d\, \pi R^2 (B_0 + \alpha t)}{dt} = -\pi R^2 (0 + \alpha)$

$\Rightarrow -\pi R^2 \alpha$

Q Magnetic flux through a circuit of resistance 20Ω is changed from 20 wb to 40 wb in 5ms. Charge passed through the circuit during this time is.

a) 1C (b) 2C

c) 1.05 (d) 0.5C

ANS $q = \frac{\Delta\phi}{R} = \frac{20}{20} = 1C$ $\begin{pmatrix}\phi_i = 20wb \\ \phi_f = 40wb\end{pmatrix}$

Q A coil having 500 square loops each of side 10cm is placed with its plane perpendicular to a magnetic field which increases at a rate of 1.0 tesla/s. The induced emf (in volts) is.

a) 0.5 (b) 1.0

c) 0.1 (d) 5

ANS $\phi = BAN = 500 \times 10 \times 10 \times 10^{-4} \times B \Rightarrow 5B$

$emf = \frac{\Delta\phi}{\Delta t} = \frac{d\phi}{dt} = 5\frac{dB}{dt} = 5 \times 1 = 5$ volt

Q Radius of a circular loop placed in a perpendicular uniform magnetic field is increasing at a constant rate of r_0 m/s⁻¹. If at any instant radius of the loop is r, then emf induced in the loop at that instant will be.

a) $-2B r r_0$ (b) $-2B\pi r$

c) $-B\pi r_0 r$ (d) $-2B\pi r r_0$

Ans $emf = -\frac{d\phi}{dt}$

$\phi = BA\cos\theta = BA\cos 0° = BA = B\pi r^2$

$emf = -\frac{d\,\pi r^2 B}{dt}$

$= -B\pi \frac{dr^2}{dt}\frac{dr}{dr} = -B\pi \frac{dr^2}{dr}\frac{dr}{dt} = -2B\pi r r_0$ Ans

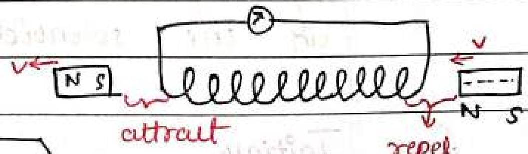
Q A conducting circular loop is placed in a uniform magnetic field, B = 0.025 T with its plane perpendicular to the loop field. The radius of the loop is made to shrink at a constant rate of 1mm/s. The induced emf when the radius is 2 cm is.

a) $2\pi\mu V$ ~~(b)~~ $\pi\mu V$

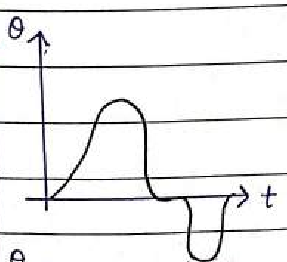
c) $\frac{\pi}{2}\mu V$ (d) $2\mu V$

Ans $emf = -2B\pi r r_0 = 2\times 0.025\times\pi\times 10^{-3}\times 2\times 10^{-2} = \pi\mu V$ Ans

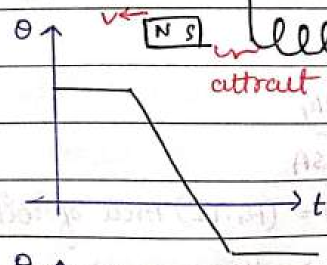
Q A short bar magnet passes at a steady speed right through a long solenoid. A galvanometer is connected across the solenoid. Which graph best represents the variation of the galvanometer deflection θ with time t?



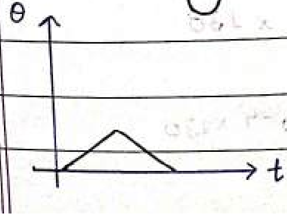
a)



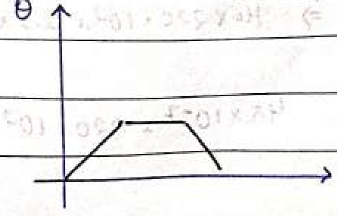
(b)



(c)

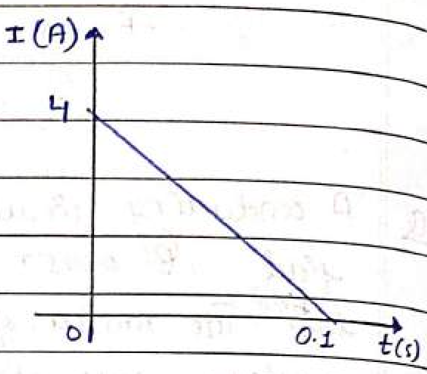


(d)



Q In a coil of resistance 10 Ω the induced current developed by changing magnetic flux through it, is shown in figure as a function of time. The magnitude of change in flux through the coil in Weber is.

a) 8 ~~b)~~ 2
c) 6 d) 4



Ans $emf \cdot dt = d\phi$

$R\int I\,dt = \int d\phi$

$R \times \left(\frac{1}{2} \times 0.1 \times 4\right) = \Delta\phi$

$\Rightarrow 0.2 \times 10 = \Delta\phi$

$\Delta\phi = 2$

Q A current $I = 1.5A$ is flowing through a long solenoid of diameter 3.2 cm, having 220 turns per cm. At its centre, a 130 turn closely placed packed coil of diameter 2.1 cm is placed such that the coil is coaxial with the long solenoid. The current in the solenoid is reduced to zero at a steady rate in 25 ms. What is the magnitude of emf induced in the coil while the current in the solenoid is changing?

Ans Initially

$I = 1.5A$

flux $\phi = (\mu_0 n I)$ Area of coil × No. of its turn

$\Rightarrow \mu_0 \times 220 \times 10^2 \times 1.5 \times \pi \times \frac{2.1}{2} \times \frac{2.1}{2} \times 10^{-4} \times 130$

$4\pi \times 10^{-7} \times 220 \times 10^2 \times 1.5 \times \pi \frac{2.1}{2} \times \frac{2.1}{2} \times 10^{-4} \times 130$

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$\cancel{4} \times 22 \times 1.5 \times \frac{2.1}{\cancel{2}} \times \frac{2.1}{\cancel{2}} \times 10^{-7} \times 130$

$\Rightarrow 33 \times 4.41 \times 10^{-7} \times 130$

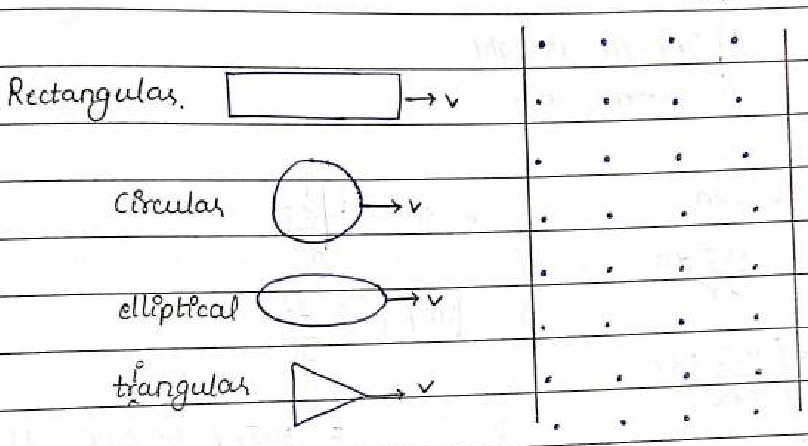
$14553 \times 10^{-7} \times 130$

$\Rightarrow 1.4553 \times 10^{-5}$ Ans $\times 130$

$\text{emf} = \frac{-\Delta\phi}{\Delta t}$

$\Delta\phi = \frac{1.4553 \times 130 \times 10^{-5}}{25 \times 10^{-3}}$

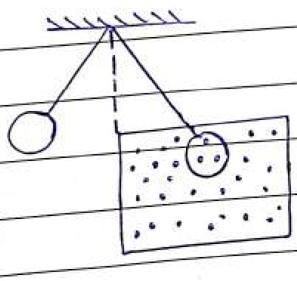
Q In which case induced current is in constant magnitude.



Ans $(\text{emf}) = -\frac{d\phi}{dt} = -B\frac{dA}{dt}$

$\frac{dA}{dt}$ is constant for rectangle therefore current induced in it will be ~~same~~ constant.

Q Conducting loop released then its oscillation will ??



damped oscillation with decreasing amplitude

due to change in flux

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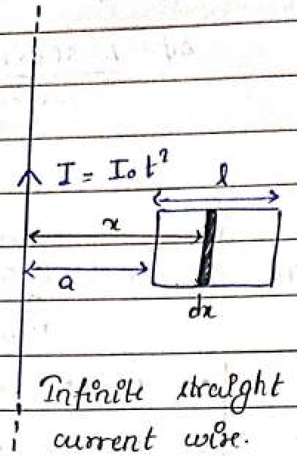
Q Find emf in square loop due to current in infinite wire.



ANS

$$d\phi = B.dA$$

$$d\phi = \frac{\mu_0 I}{2\pi x} dA$$

$$\int d\phi = \int \frac{\mu_0 I}{2\pi x} l\,dx$$

at time t

$$\phi = \frac{\mu_0 I l}{2\pi} \int \frac{1}{x} dx$$

$$\phi = \frac{\mu_0 I l}{2\pi} \ln \frac{a+L}{a}$$

$$emf = -\frac{d\phi}{dt}$$

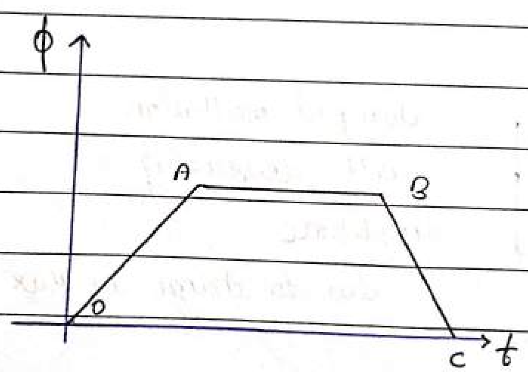
$$|emf| = \frac{d\phi}{dt}$$

$$= \frac{\mu_0 I_0 l}{2\pi} \ln \frac{a+l}{a} \frac{dt^2}{dt}$$

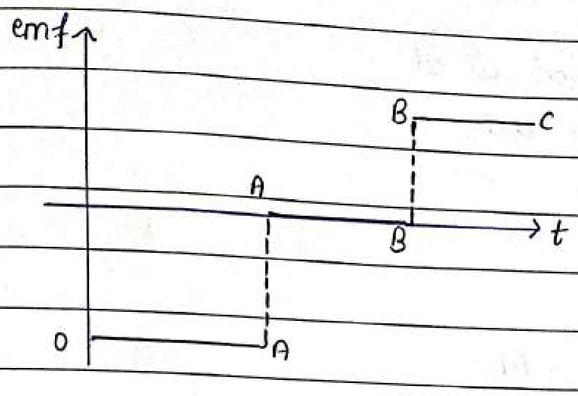
$$= \frac{t \mu_0 I_0 l}{\pi} \ln \frac{a+l}{a} \quad \underline{Ans}$$

Q Convert ϕ / t graph into emf time graph.

a)

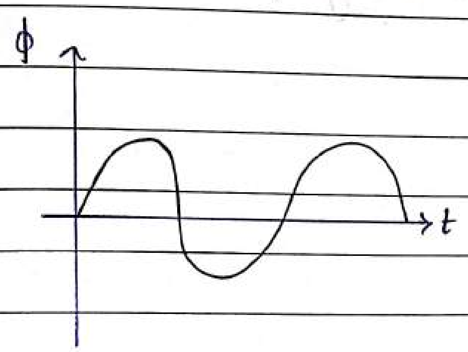


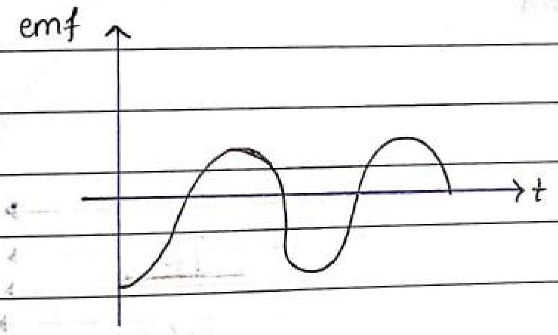
ANS



$$emf = -\frac{d\phi}{dt} = -\,slope$$

b)





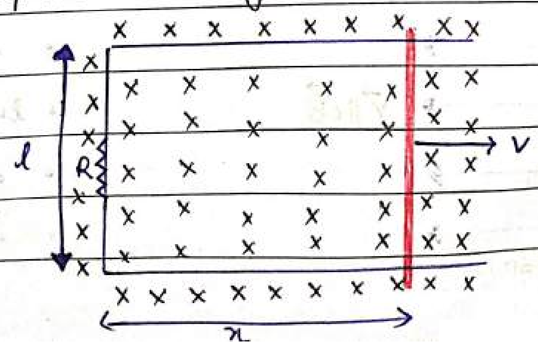
$\phi \propto \sin \omega t$

$emf = -\frac{d \sin(\omega t)}{dt} = -\cos(\omega t)$

Q If ϕ is zero then emf must be zero → false

MOTIONAL ELECTROMOTIVE FORCE → Rail Problem

Let us consider a straight conductor moving in a uniform and time independent magnetic field.



at time 't', let rod is at distance x from one end

Area $= x l$

$\phi = BA = Blx$

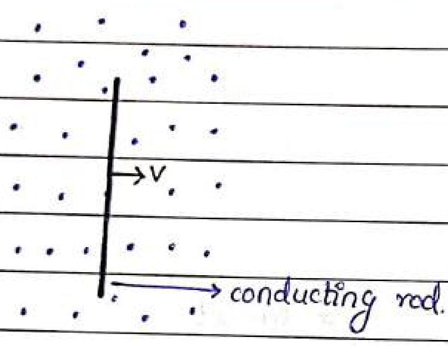
$|emf| = \frac{d\phi}{dt} = \frac{d\,Blx}{dt} = Blv$

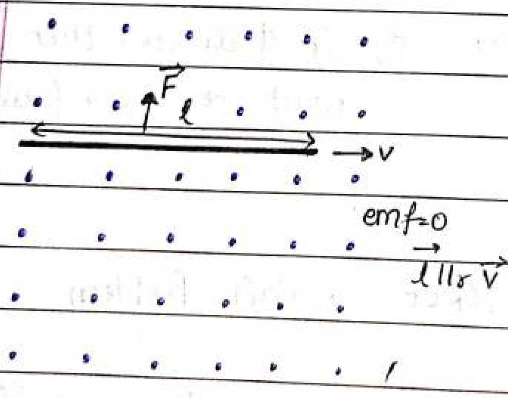
MIT

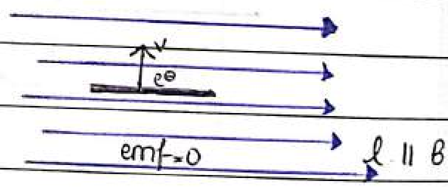
$\boxed{emf = Blv}$ $\quad l \rightarrow$ length of rod

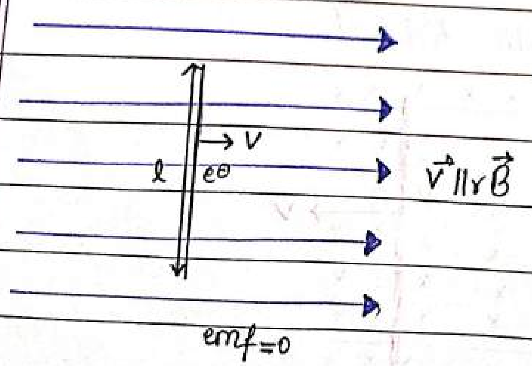
$v \rightarrow$ velocity of rod

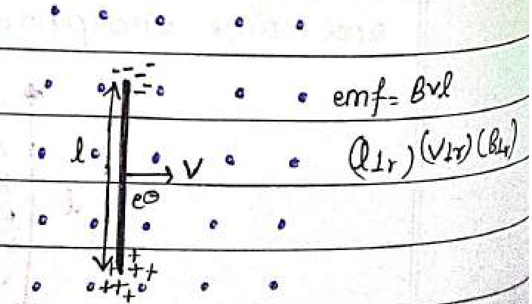
$I = \frac{emf}{R} = \frac{Blv}{R}$

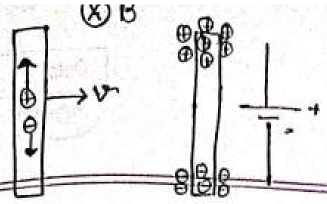




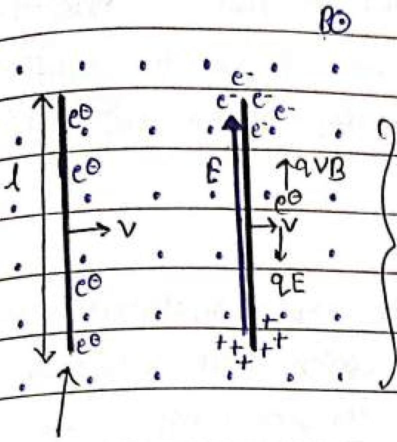








HALL EFFECT



This represent inside of battery.

Conducting rod having large no of free electrons.

At equilibrium.

$\cancel{q}E = \cancel{q}(v \times B)$

$\frac{\Delta V}{l} = \vec{v} \times \vec{B}$

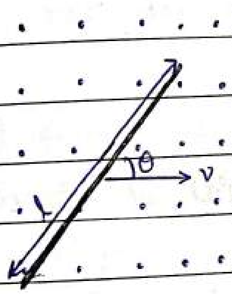
$\Delta V = Bvl \Rightarrow (\vec{v} \times \vec{B}) \cdot \vec{l}$

ΔV → potential difference across the rod.

scalar triple product.

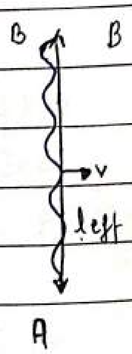
emf will be zero if any two is parallel

Q Find induced emf in Rod ??



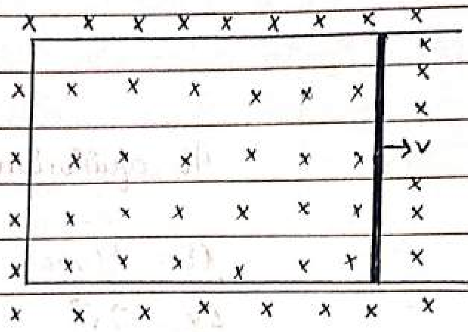
$emf = (B_{\perp r})(v_{\perp r})(l_{\perp r})$

$\Rightarrow Bvl \sin\theta$



$emf = Bv\,(l_{eff})$

l_{eff} → perpendicular to magnetic field



MTT

$emf = Blv$

$$I_{induced} = \frac{emf}{R} = \frac{Blv}{R}$$

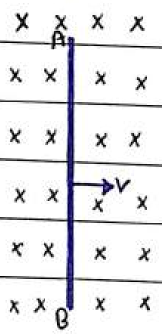
$$Force = BIl = Bl\left(\frac{Blv}{R}\right) = \frac{B^2l^2v}{R}$$

$$(Force)_{ext} = -Force = -\frac{B^2l^2v}{R}$$

$$Power\ delivered = F.v = \frac{B^2l^2v^2}{R}$$

How to find in which direction Potential is higher ??

↳ Higher Potential is along the direction of force on +ve charge.



$V_A > V_B$

Q The current carrying wire and the rod AB are in same plane. The rod moves parallel to the wire with a velocity v. Which of the following ~~sta~~ statement is true

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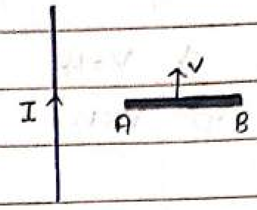
Shivalal

a) End A will be at lower potential with respect to B
b) A and B will be at same potential
c) There will be no induced emf in the rod
~~d)~~ Potential at A will be higher than that at B



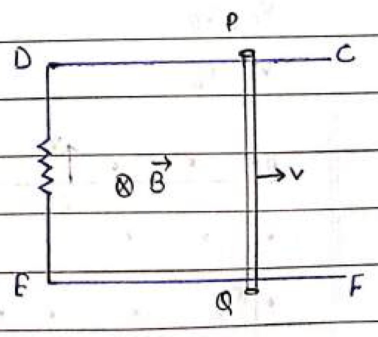
Q An aeroplane rises vertically with a speed of 100 m/s. The aeroplane has wings span 10 m and horizontal component of earth's magnetic field perpendicular to wings is 5×10^{-3} wb/m². The induced emf across the ends of wing is.

a) 50V (b) 0.5V
~~c)~~ 5V (d) 25V

Ans emf = $Bvl = 5\times10^{-3}\times100\times10 = 5V$ Ans

Q A frame CDEF is placed in region where a magnetic field $\vec{B}$ is present. A rod of length one metre moves with constant velocity 20 m/s and strength of magnetic field is one tesla. The power spent in the process is (take $R = 0.2\,\Omega$ and all other wires and rod have zero resistance)

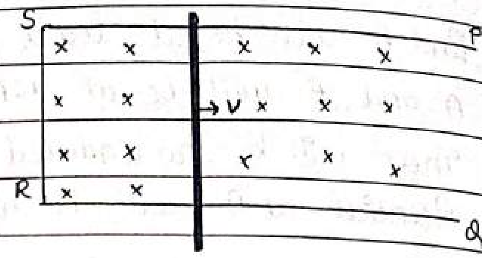
a) 1 kW ~~(b)~~ 2kW
c) 3kW (d) 4kW



$\Rightarrow P = \frac{B^2v^2l^2}{R} = \frac{(1)^2\times20\times20\times(1)^2}{0.2} = \frac{\cancel{4000}\ 2000}{\cancel{2}}$

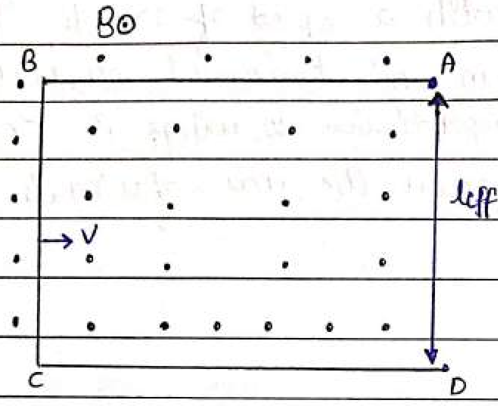
$\Rightarrow$ 2kW

Q A conducting rod AB of length l is projected on a frictionless frame PSRQ with velocity v_0 at any instant. The velocity of the rod after time t is



1) $V = V_0$ 2) $V > V_0$

3) $V < V_0$ 4) None of these



Q Find induced emf in
(i) complete wire
(ii) in length AB
(iii) in length BC
(iv) CD
(v) BD

(i) $(emf)_{compt\ wire} = Bv\,l_{eff} = Bvl$

(ii) $(emf)_{AB} = 0$

(iii) $(emf)_{BC} = Bvl$

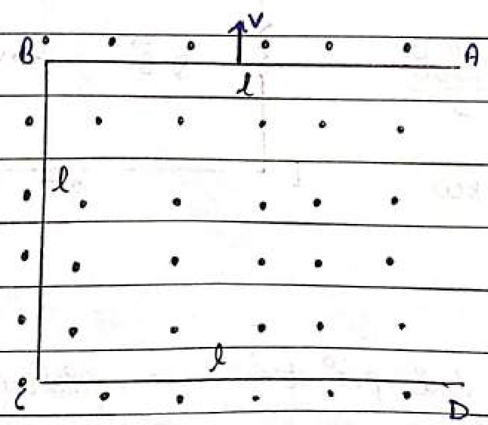
(iv) $(emf)_{CD} = 0$

(v) $(emf)_{BD} = Bvl \quad \left[Bv\sqrt{2}\,l \times \frac{1}{\sqrt{2}} \right] = Bvl$

⇒ $V_C > V_B$

$V_A = V_B$

$V_C = V_D$



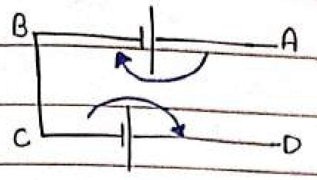
Q Find induced emf in (i) complete wire (ii) AB (iii) BC (iv) CD

Ans ⇒ $(emf)_{AB} = Bvl = V_A - V_B$

$(emf)_{BC} = 0$

$(emf)_{CD} = Bvl$

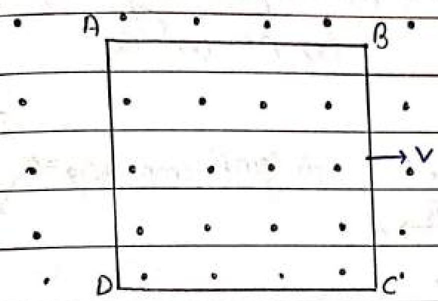
$(emf)_{compt\ wire} = 2vBl$ ✗



$V_A - Bvl + Bvl = V_D$

$V_A - V_D = 0$
↓
emf of complete wire

Q. Find induced emf in
(i) loop (ii) AB (iii) BC (iv) CD (v) DA



Ans. in square loop ϕ = constant, emf = 0
(faraday)

By Hall effect

$(emf)_{AB} = 0$

$(emf)_{BC} = Blv$

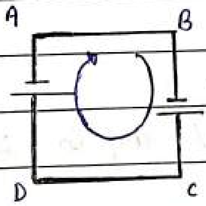
$V_C - V_B = Bvl$

$(emf)_{CD} = 0$

$(emf)_{DA} = Blv$

$V_D - V_A = Bvl$

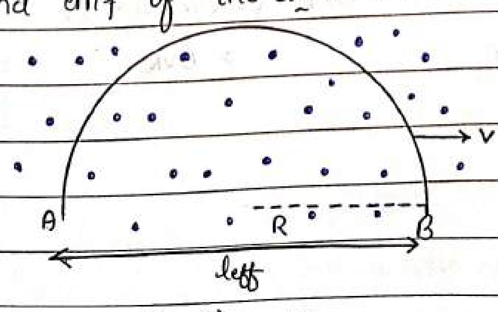
$(emf)_{loop} = 0 \quad \because l_{eff} = 0$



$\cancel{V_B} + \cancel{Bvl} - \cancel{Bvl} = \cancel{V_A}$

$(emf)_{loop} = 0$

Q. Find emf of the across AB



$(emf)_{AB} = 0$

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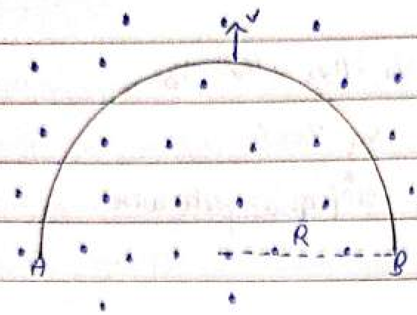
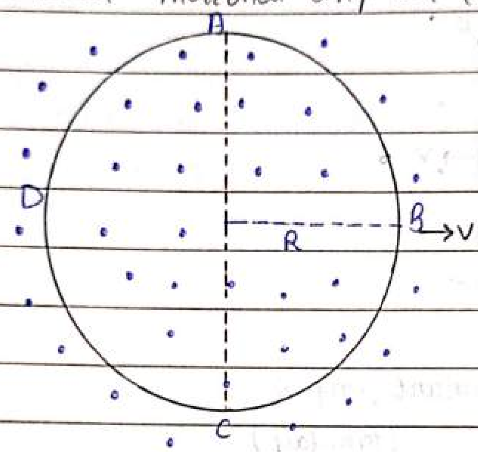
Q



→ $(emf)_{AB} = 2BvR$

Q Find induced motional emf in (i) complete ring (ii) AC (iii) BD (iv) AB (v) BC



(i) $(emf)_{compt\ ring} = 0$ → $\phi = $ const, $emf = 0$ faraday; $l_{eff} = 0$, $emf = 0$ Hall

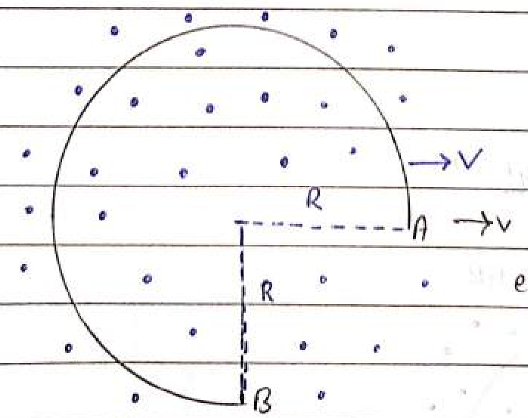
(ii) $(emf)_{AC} = 2RBv$

(iii) $(emf)_{BD} = 0$

(iv) $(emf)_{AB} = BvR$

(v) $(emf)_{BC} = BvR$

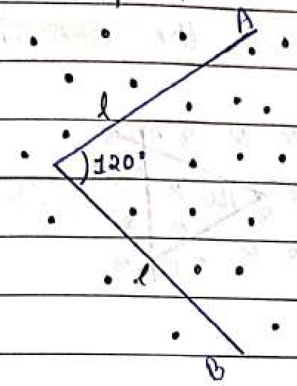
Q Find induced emotional emf in (i) complete ring (ii) AC across AB



$emf = \sqrt{2}R\cos 45° Bv$

$\Rightarrow BvR$

Q Find induced emf in wire 'AB'



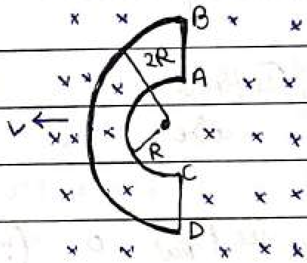
$\Rightarrow$ $l_{eff} = 2l\sin 60° = \frac{\cancel{2}l\sqrt{3}}{\cancel{2}} = \sqrt{3}l$

$emf = \sqrt{3}Bvl = \sqrt{3}Bvl$

Q If given arrangement is moving towards left with speed v then potential difference between B and D and current in the loop are respectively.

a) BvR and non zero (b) 2BvR and zero

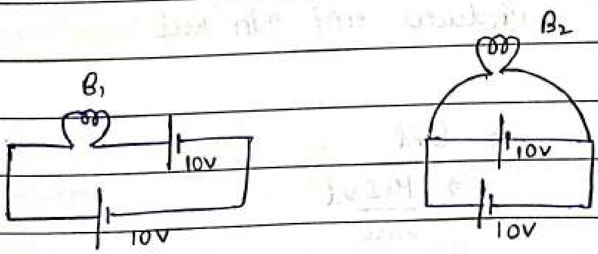
c) 4BvR and non zero (d) 4BvR and zero



Ans $(emf)_{BD} = Bvl_{eff}$

$\Rightarrow Bv4R = 4BvR$

Current = 0 since emf induced = 0



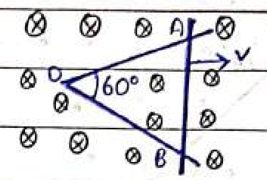
B_2 will glow

but B_1 will not glow

Q A rod AB slides on a V shaped wire with speed v as shown, such that at any time $OA = OB = l$. Magnetic field in the field region is perpendicular downwards and has strength B, induced emf in the rod is.

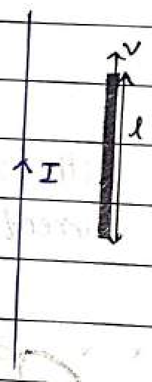
a) Zero ~~(b)~~ Bvl

c) $\frac{\sqrt{3}\,Bvl}{2}$ (d) $\frac{Bvl}{2}$



Ans length of $AB = l$

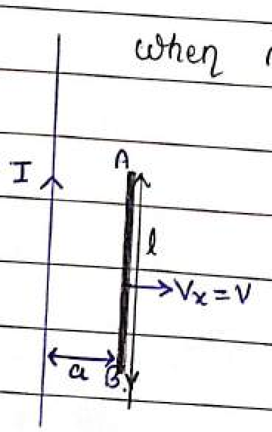
Q



Infinite wire

$\Rightarrow (emf)_{Rod} = 0 \quad (\because \vec{v} \parallel \vec{l})$

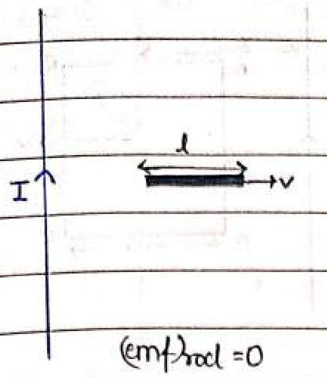
Q when moving rod is at 'a' then find induced emf in Rod.



$\Rightarrow Bvl$

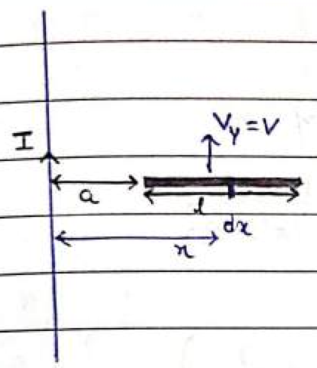
$\Rightarrow \frac{\mu_0 I v l}{2\pi a}$

Q



$(emf)_{rod} = 0$

Q



$\Rightarrow dB = \dfrac{\mu_0 I}{2\pi x}$

$$emf = \int \frac{\mu_0 I}{2\pi x} v\,dx$$

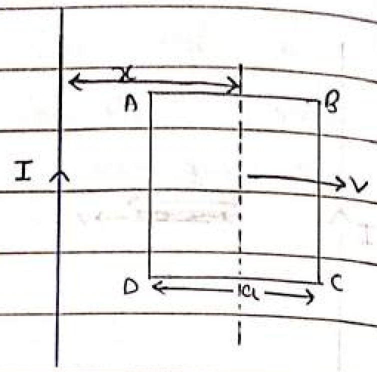
$$\frac{\mu_0 I v}{2\pi} \ln \frac{a+L}{a} \quad \text{Ans}$$

Q A conducting square frame of side a and a long straight wire carrying current I are located in the same plane as shown in the figure. The frame moves to the right with a constant velocity v. The emf induced in the frame will be proportional to.

(a) $\dfrac{1}{(2x-a)(2x+a)}$ (b) $\dfrac{1}{x^2}$ (c) $\dfrac{1}{(2x-a)^2}$ (d) $\dfrac{1}{(2x+a)^2}$

ANS (emf) induced in AB and DC = 0

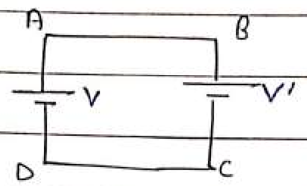
(emf) induced in AD $= \dfrac{\mu_0 I v l}{2\pi(x-\frac{a}{2})}$



$V_A > V_D$

$(emf)_{BC} = \dfrac{\mu_0 I v l}{2\pi(x+\frac{a}{2})}$

$V_B > V_C$



$V > V'$

$V - V' =$ emf of loop

$$\Rightarrow \frac{\mu_0 I v l}{2\pi(x-\frac{a}{2})} - \frac{\mu_0 I v l}{2\pi(x+\frac{a}{2})}$$

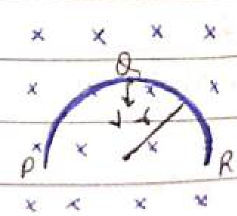
$$\Rightarrow \frac{\mu_0 I v l}{2\pi}\left(\frac{2}{2x-a} - \frac{2}{2x+a}\right)$$

$$\Rightarrow \frac{\mu_0 I v l}{\pi}\left[\frac{\cancel{2x}+a-\cancel{2x}+a}{(2x-a)(2x+a)}\right]$$

$$\Rightarrow \frac{2\mu_0 I v l a}{\pi(2x-a)(2x+a)}$$

$$\text{Emf} \propto \frac{1}{(2x-a)(2x+a)}$$

Q A thin semicircular conducting ring (PQR) of radius r is falling with its plane vertical in a horizontal magnetic field B, as shown in figure. The potential difference developed across the ring when its speed is v is.

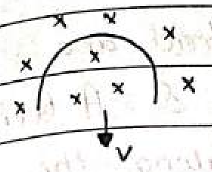


a) Zero

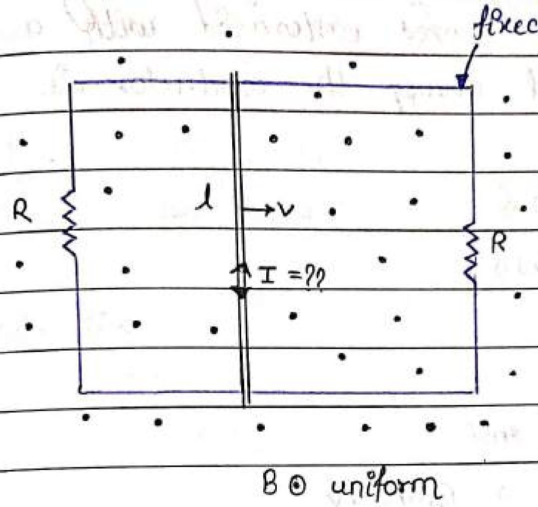
b) $Bv\pi r^2/2$ and P is at higher potential

c) $\pi r B v$ and R is at higher potential

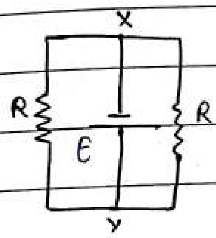
d) $2rBv$ and R is at higher potential



★ **Q**



ANS



$E = Bvl$

$R_{eq} = \frac{R}{2}$ $\quad I = \frac{V}{R} = \frac{2Bvl}{R}$ **ANS**

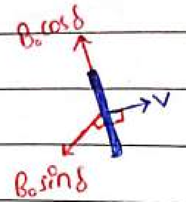
Q A long horizontal metallic rod with length along the east-west direction is falling under gravity. The potential difference between its two ends will,

a) Be zero (b) Be constant
~~c)~~ Increases with time (d) Decreases with time.

If Rod was vertical and falling downward then emf always zero ($\because v \parallel$ length)

Q. The magnitude of the earth's magnetic field at a place is B_0 and the angle of dip is δ. A horizontal component conductor of length (l) lying along the magnetic north-south moves eastwards with a velocity v. The emf induced across the conductor is.

a) Zero ~~(b)~~ $B_0 l v \sin\delta$
c) $B_0 l v$ (d) $B_0 l v \cos\delta$

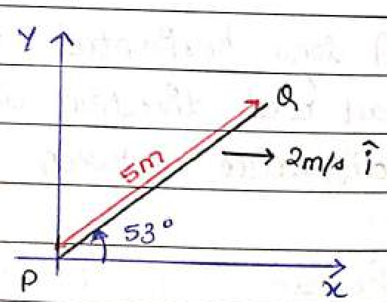
ANS


emf

$\Rightarrow B_0 \sin\delta\, l v$

Q. A conducting rod PQ of length 5m oriented as shown in figure is moving with velocity $(2m/s)\hat{i}$ without rotation in a uniform magnetic field $(3\hat{j} + 4\hat{k})$ Tesla. Emf induced in the rod is.

~~a)~~ 32 volt (b) 50 volt
c) 40 volt (d) none



ANS emf $= (B)_\perp (v)_\perp (l)_\perp$

emf $= 5 \sin 53^\circ \times 4 \times 2$

$\Rightarrow 32$ volt

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Q. A straight conductor of length 0.4m is moved with a speed of 7m/s perpendicular to the magnetic field of intensity of 0.9wb/m²? The induced emf across the conductor will be.

a) 7.25 V (b) 3.75V

c) 1.25 V ~~(d)~~ 2.52 V

Ans emf = Bvl

$\Rightarrow 0.9 \times 0.4 \times 7$

$\Rightarrow 2.52V$

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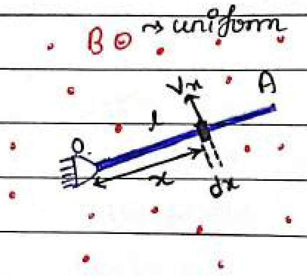
ROTATIONAL E.M.F.

Q. A rod of length l is rotating about one end with angular velocity ω, then find potential difference about two ends of rod.

Ans



$d\varepsilon = B v_x dx$

$\varepsilon \Rightarrow \int B x \omega dx$

$\varepsilon = B\omega\left(\frac{x^2}{2}\right)_0^l$

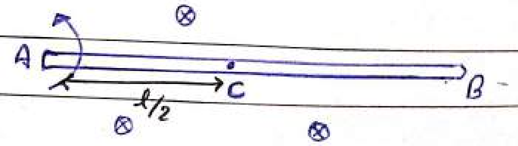
$\varepsilon = \frac{1}{2} B\omega l^2 = \frac{B\omega l^2}{2}$ Ans

$\varepsilon = V_A - V_0 = \frac{B\omega l^2}{2}$

$\downarrow$

only valid when one end is fixed.

Q. A copper rod AB of length l, pivoted at one end A, rotates at constant angular velocity ω, at right angles to a uniform magnetic field of induction B. The emf, developed between the mid point C of the rod and the end B is.



a) $\frac{B\omega l^2}{8}$ (b) $\frac{3}{4}B\omega l^2$

c) $\frac{B\omega l^2}{4}$ (d) $\frac{3B\omega l^2}{8}$

ANS $(emf)_{AB} = \frac{1}{2}B\omega l^2$

$(emf)_{AC} = \frac{1}{2}B\omega\left(\frac{l}{2}\right)^2 = \frac{1}{2}\frac{B\omega l^2}{4}$

$(emf)_{AB} = (emf)_{AC} + (emf)_{CB}$

$\frac{1}{2}B\omega l^2 = \frac{B\omega l^2}{8} + (emf)_{CB}$

$(emf)_{CB} = \frac{3B\omega l^2}{8}$ Ans

Method two

$(emf) = \frac{B\omega x^2}{2}$

so from $\frac{1}{2}$ to l

$emf = \frac{B\omega}{2}\left(l^2 - \frac{l^2}{4}\right) = \frac{3B\omega l^2}{8}$ Ans

Method-3

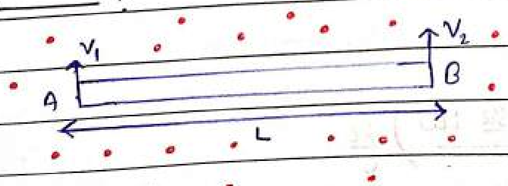
$emf = B\left(\frac{v_1+v_2}{2}\right)l$

v_1 and v_2 are the velocity of edges

l is the distance between the edges.

$emf = B\left(\frac{\frac{l\omega}{2} + l\omega}{2}\right)\frac{l}{2} = \frac{3Bl^2\omega}{8}$ Ans

Q $E_{AB} = $ ______ ?



ANS $(emf)_{AB} = B\left(\dfrac{\vec{v_1}+\vec{v_1}}{2}\right)l$

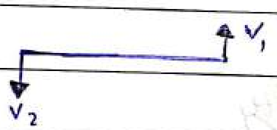
$v_1 = v_2 = v$	$v_1 = 0$, $v_2 = l\omega$
Motional	Rotational
$emf = Bvl$	$emf = \dfrac{Bl\omega l}{2} = \dfrac{B\omega l^2}{2}$

Q A copper rod of length l is rotating about mid-point of rod, perpendicular to the magnetic field B with constant angular velocity ω. The induced emf between the two rod's ends is.

a) $\dfrac{B\omega l^2}{2}$ (b) $B\omega l^2$

c) $2B\omega l^2$ ~~(d)~~ zero

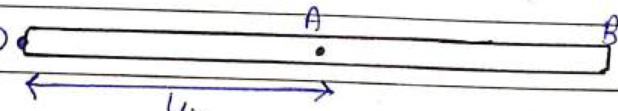
ANS



$\vec{v_1} = -\vec{v_2}$

$\therefore\ emf = B\left(\dfrac{\vec{v_1}+\vec{v_2}}{2}\right)l = 0$

Q $(EMF)_{AB} = ?$



ANS MR*

$emf = B\left(\dfrac{l\omega/4 + \cancel{\ } l\omega}{2}\right)\dfrac{3l}{4}$

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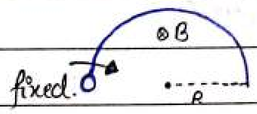
$\frac{15BL^2\omega}{32}$

Q A semicircular wire of radius R is rotated with constant angular velocity ω about an axis passing through one end and perpendicular to the plane of the wire. There is a uniform magnetic field of strength B. The induced emf between the ends is:-

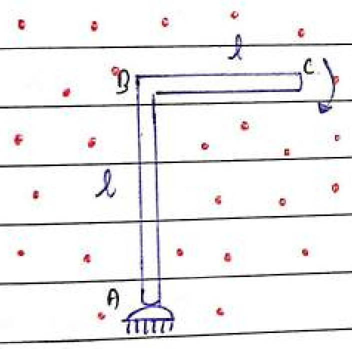
a) $\frac{B\omega R^2}{2}$ ~~(b)~~ $2B\omega R^2$



c) is variable (d) none of these

Ans emf $= \frac{1}{2}B\omega(2R)^2 = 2B\omega R^2$

Q



Find $(emf)_{BC} = ?$

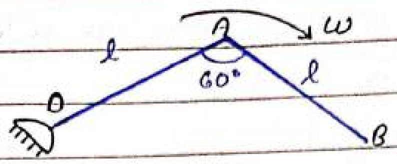
Ans $(emf)_{AB} = \frac{1}{2}B\omega l^2$

$(emf)_{AC} = \frac{1}{2}B\omega(\sqrt{2}l)^2 = B\omega l^2$

$(emf)_{BC} = (emf)_{AC} - (emf)_{AB}$

$\Rightarrow B\omega l^2 - \frac{1}{2}B\omega l^2 = \frac{1}{2}B\omega l^2$

Q



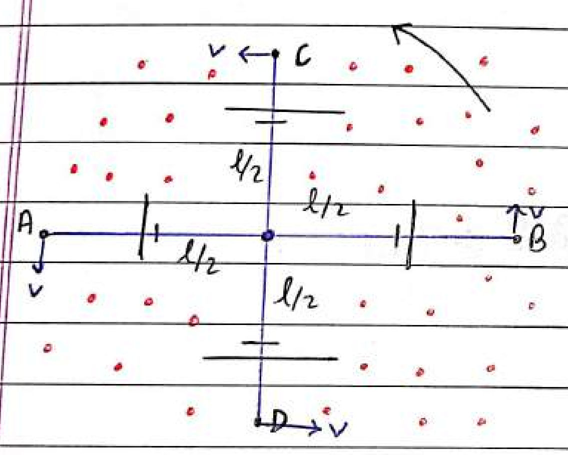
Find emf of AB

ANS $(emf)_{OA} = \frac{1}{2} B\omega l^2$

$(emf)_{OB} = \frac{1}{2} B\omega l^2$

$(emf)_{AB} = 0$

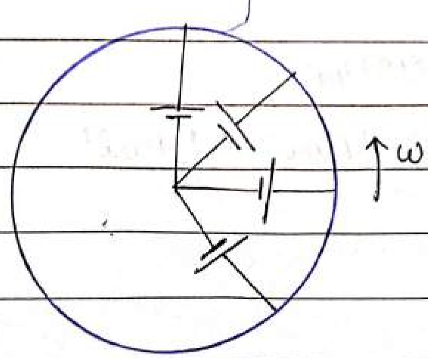
Q



$V_A = V_C$

$V_C = V_D = V_A = V_B$ —①

all (emf) induced are parallel to each other.



Q. A copper disc of radius 0.1 m rotates about its centre with 10 revolutions per second in a uniform magnetic field of 0.1 tesla. The emf induced across the radius of the disc is.

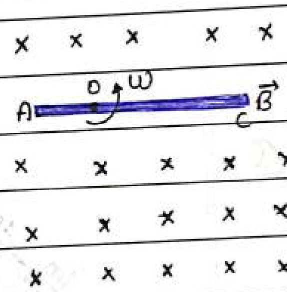
a) $\pi/10$ V (b) $2\pi/10$ V
(c) 10π mV (d) 20π mV

Ans emf = ~~$B v R$~~ $\quad B\omega R^2/2 \Rightarrow \frac{B \times 10 \times \cancel{2}\pi \times 0.1 \times 0.1}{\cancel{2}}$

$\Rightarrow$ ~~$0.1 \times 0.1 \times 2\pi \cdot 0.1 \times 10$~~

$\Rightarrow$ ~~20π mV~~ $\Rightarrow 10\pi$ mV

Q A conducting rod AC of length 4L is rotated about a point O in a uniform magnetic field $\vec{B}$ directed into the paper. AO = L , OC = 3L



1) $V_A - V_O = \frac{3B\omega L^2}{2}$ (2) $V_O - V_C = \frac{5B\omega L^2}{2}$

3) $V_A - V_C = 4B\omega L^2$ (4) $V_C - V_O = \frac{3B\omega L^2}{2}$

$\Rightarrow V_A - V_O = B\left(\frac{\omega L + 0}{2}\right) L = -\frac{B\omega L^2}{2}$

$V_A - V_C = B\left(\frac{3\omega L - \omega L}{\cancel{2}}\right) 4L$

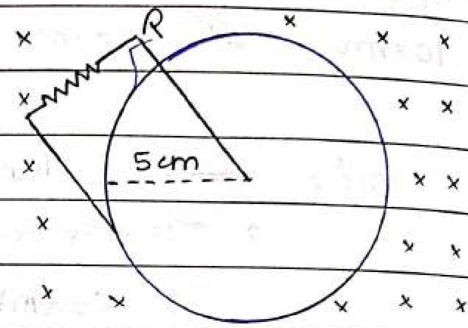
$\Rightarrow 2B\,2\omega L^2$

$\Rightarrow 4B\omega L^2$

$V_O - V_C = B\left(0 + \frac{3\omega L}{2}\right)3L = \frac{9B\omega L^2}{2}$

~~$V_C - V_O = B($~~ $V_C - V_O = -\frac{9B\omega L^2}{2}$

Q Figure shows a conducting disc rotating about its axis in a perpendicular magnetic field B. A resistor of resistance R is connected between the centre and the rim. The radius of the disc is 5.0 cm, angular speed $\omega = 40$ rad/s, $B = 0.10\,T$ and $R = 1\Omega$. The current through the resistor is.



a) 5mA (b) 50A

c) 5A (d) 10mA

ANS emf across resistor = $\cancel{B v R}\ B\omega R^2/2$

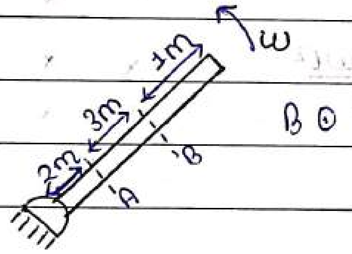
$$\Rightarrow 0.1 \times \omega R^2/2$$

$$\Rightarrow 0.1 \times 40 \times 5 \times 5 \times 10^{-4}/2$$

$$\Rightarrow 1000 \times 10^{-5} = 10^{-2}/2$$

$$\text{Current } (I) = \frac{V}{R} = \frac{10^{-2}}{1} = 10mA/2 = 5mA \text{ Ans}$$

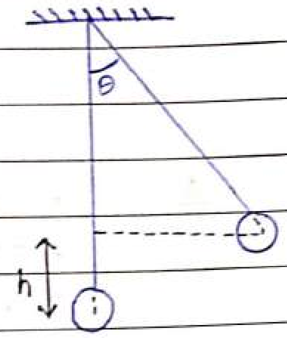
Q Find induced emf between A and B ?



ANS $$\text{emf} = B\left(\frac{\vec{V_1}+\vec{V_2}}{2}\right)3m$$

$$\Rightarrow B\left(\frac{2\omega+5\omega}{2}\right)3m = \frac{21B\omega}{2} \text{ Ans}$$

Q A simple pendulum with bob of mass m and conducting wire of length L swings under gravity through an angle 2θ. The earth's magnetic field component in the direction perpendicular to swing is B. The maximum potential difference induced across the pendulum is.



a) $2BL \sin\frac{\theta}{2}\sqrt{gL}$ ~~(b)~~ $BL \sin\frac{\theta}{2}\sqrt{gL}$

c) $BL \sin\frac{\theta}{2}(gL)^{3/2}$ (d) $BL \sin\frac{\theta}{2}.(gL)^2$

Ans By MR*

$$emf = B\left(\frac{\vec{V_1}+\vec{V_2}}{2}\right)L$$

$$V_1 = 0$$

$$(emf)_{max} = B\frac{(V_2)_{max}}{2}L$$

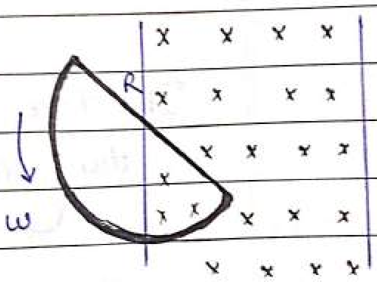
$$(emf)_{max} = \frac{B\sqrt{2gh}L}{2} \quad [V_{max} \text{ at mean position}]$$

$$(emf)_{max} = \frac{BL}{2}\sqrt{2gL(1-\cos\theta)}$$

$$(emf)_{max} = \frac{BL}{2}\sqrt{2gL\,2\sin^2\frac{\theta}{2}}$$

$$\Rightarrow BL\sin\frac{\theta}{2}\sqrt{gL} \quad \text{Ans}$$

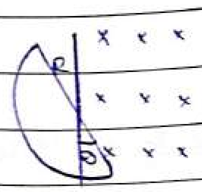
Q A semicircular loop of radius R is rotated with an angular velocity to perpendicular to the plane of a magnetic field B as shown in the figure. Emf induced in the loop is.



a) $B\omega R^2$ ~~(b)~~ $\frac{1}{2}B\omega R^2$

c) $\frac{3}{2}B\omega R^2$ (d) $\frac{B\omega R^2}{4}$

Ans



flux at time 't'

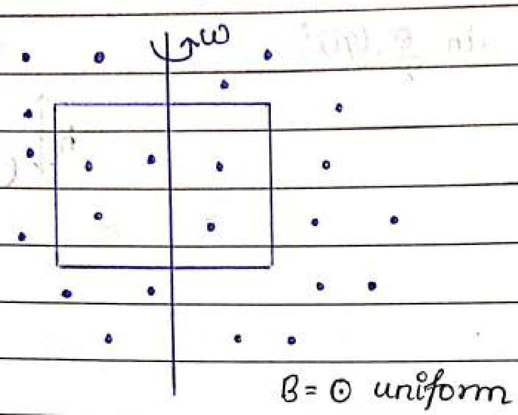
$$\phi = B\,Area$$

$$\phi = B\frac{1}{2}R^2\theta$$

$$emf = \frac{d\phi}{dt} = \frac{1}{2}R^2B\frac{d\theta}{dt}$$

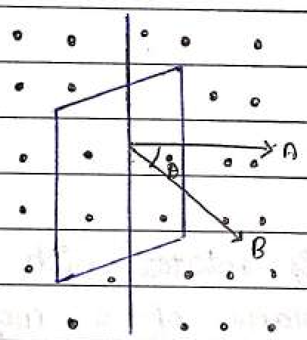
$$\Rightarrow \frac{BR^2\omega}{2} \quad \underline{Ans}$$

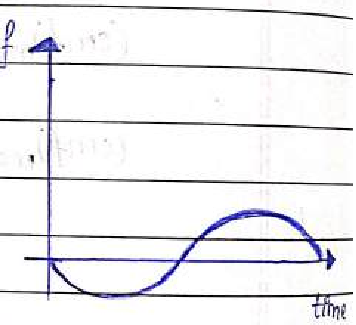
Q



Find induced emf in square loop?

Ans At any instant





Flux $(\phi) = \vec{B}\cdot\vec{A}$

$\Rightarrow BA\cos\theta$

$\phi = BA\cos\omega t$

diff. wrt time

$\underline{emf} = \frac{d\phi}{dt} = -BA\omega\sin\omega t$

$emf = -BA\omega\sin\omega t$

$(emf)_{max} = BA\omega$

If there are N loops

then $emf = -NBA \cancel{\cos t}\, \omega \sin(\omega t)$

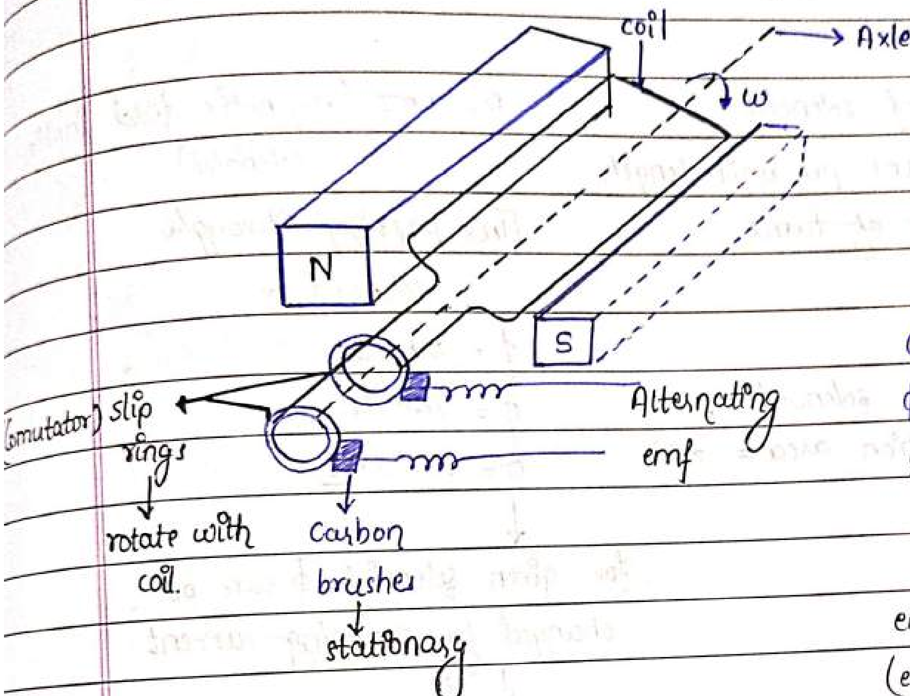
↳ AC Generator.

OR $emf = NBA\omega\cos(\omega t)$

↳ when $\phi = BA\sin\omega t$ $(\theta = \omega t)$

↳ when θ = angle b/w plane and magnetic field.

AC GENERATOR. {Mechanical energy converted into electrical energy}



$A \rightarrow$ Area of coil

$N \rightarrow$ No of coil.

$$\phi = BA\cos\theta$$

$$\phi = BA\cos(\omega t)N$$

$$\frac{d\phi}{dt} = -BA\sin(\omega t)\,\omega N$$

$$\Rightarrow -BA\omega\sin(\omega t)\,N$$

$$\Rightarrow -BAN\omega\sin\omega t$$

$$emf = +NBA\omega\sin\omega t$$

$$(emf)_{max} = NBA\omega$$

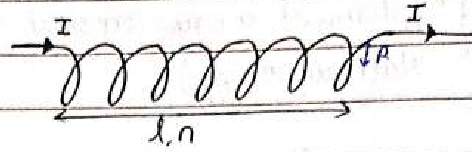
$$I = \frac{emf}{R} = \frac{NBA\omega}{R}\sin(\omega t)$$

$$I = I_0\sin(\omega t)$$

Q What is an AC Generator?

→ AC generator is a machine that converts mechanical energy into electrical energy. The AC Generator's input supply is mechanical energy supplied by steam turbines, gas turbines and combustion engines. The output is an alternating electrical power in the form of alternating voltage and current.

long solenoid ($l >>> R$)



$l \rightarrow$ length of solenoid
$n \rightarrow$ no. of turns per unit length
$N \rightarrow$ Total no. of turns.

$$n = \frac{N}{l}$$

$I \rightarrow$ current in solenoid
$A \rightarrow$ Cross section area $= \pi R^2$

$B = \mu_0 n I$ (magnetic field inside solenoid)

Flux passing through solenoid =

$$\phi = B.\text{Area}$$
$$\phi = \mu_0 n I A N$$
$$\phi = \mu_0 n^2 l A I$$

for given solenoid ϕ can be changed by changing current

due to change in current there is induced emf.

$$\text{emf} = -\frac{d\phi}{dt} = \underbrace{\{-\mu_0 n^2 A l\}}_{\text{constant for given solenoid}} \frac{dI}{dt}$$

$$\text{emf} = \underbrace{-}_{\text{direction}} \underbrace{L}_{\text{self inductance}} \frac{dI}{dt}$$

$$\underbrace{L}_{\text{self inductance}} = \mu_0 n^2 A l \qquad L = \mu_0 l A n^2$$

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Another method

$\phi \propto I$

$\phi = LI$

$emf = -\frac{d\phi}{dt} = -L\frac{dI}{dt}$

$L = \mu_0 n^2 A l$

Important formula

$L = \mu_0 n^2 A l \longrightarrow L \propto l \; [n = const^n]$

$L = \frac{\mu_0 N^2 A}{l} \longrightarrow L \propto \frac{1}{l} \; [N \Rightarrow const^n]$

Q Is self inductance $\left(L = \frac{\phi}{I}\right)$ depends on flux and current?

$\phi = LI$

$L = \frac{\phi}{I}$ → proportional constant [L → depends on nature of conductor]

Is self inductance $\propto$ flux (ϕ) ✗
depends upon ratio of flux & current.

Unit

$L = \frac{\phi}{I} = \frac{weber}{Ampere} = Henry$

$E = \frac{1}{2} L I^2$

Unit $\left[L = \frac{E}{I^2} = J/Amp^2 = Henry\right.$

Dimension → $ML^2T^{-2}A^{-2}$

Scalar quantity

Q If length of inductor becomes doubled then its self inductance become?

→ wrong question, can't say

Q If no. of turns per unit length becomes double then

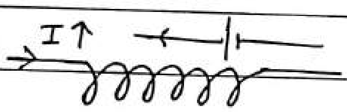
Soln $L = \mu_0 n^2 A l$

$L \propto n^2$

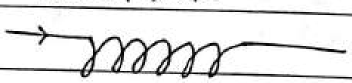
$L = 4$ times

inductor (solenoid)

$I\uparrow$



I = constant



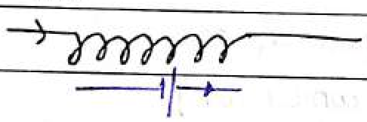
$\uparrow\phi = LI\uparrow$

emf (Potential diff) = $L\dfrac{dI}{dt}$

$\phi = LI$ = constn

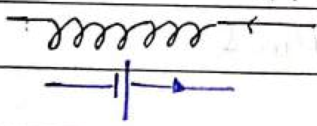
emf = $L\dfrac{dI}{dt} = 0$

$I\downarrow$

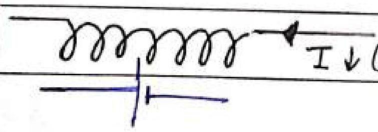


Behave as simple wire for constant current (dc current)

$I\uparrow$ (increasing)



emf = $L\dfrac{dI}{dt}$



$I\downarrow$ (decreasing)

emf = $L\dfrac{dI}{dt}$

Q Why inductor behave as simple wire for D/C voltage supply or D/C current?

Ans $emf = L\frac{dI}{dt}$

$I = \text{constant}, \frac{dI}{dt} = 0$

emf (across conc) = 0

Q The current passing through a choke coil of self inductance 5H is decreasing at the rate of 2A/s. The emf developed across the coil is.

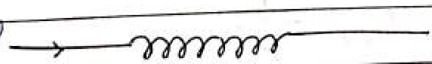
~~a)~~ 10V (b) 10V
c) -2.5V (d) 2.5V

Ans $emf = -L\frac{dI}{dt}$

$= -5 \times -2 = 10V$

Q Find {back emf} in given inductor

induced emf



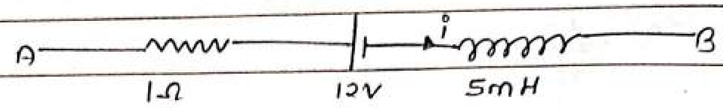
$I = 5A$ $L = 30H$

$\frac{dI}{dt} = 0.2 A/s$

Ans $emf = L\frac{dI}{dt} = 30 \times 0.2 = 6V$

does not depend on current flowing

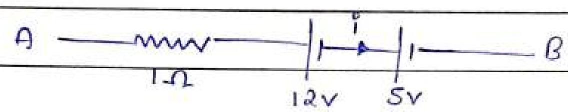
Q The network shown in figure is a part of a complete circuit. If at a certain instant, the current i is 4A and is increasing at a rate of 10^3 A/s. Then $V_B - V_A$ will be.



(a) −11V (b) 11V

(c) −21V (d) 21V

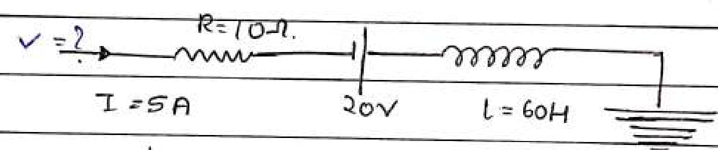
ANS $emf = L\frac{dI}{dt} = 5\times10^{-3}\times10^{3} = 5V$



$V_B + 5 + 12 + 4 = V_A$

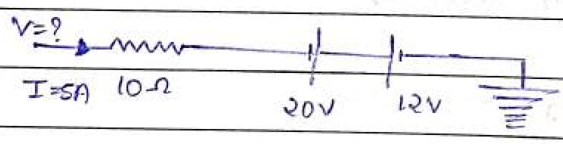
$V_B - V_A = -21V$

Q



$\frac{dI}{dt} = 0.2\ A/s$

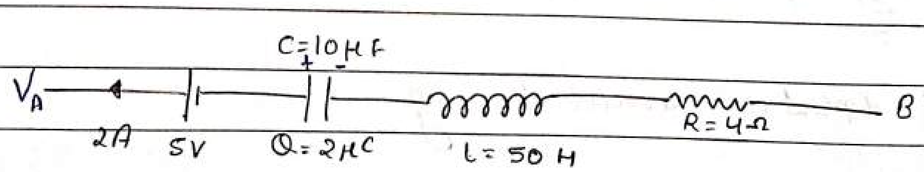
ANS



$V - 50 + 20 - 12 = 0$

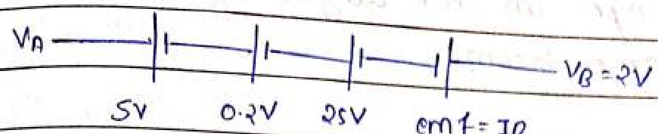
$V = 42V$ Ans

Q



$\frac{dI}{dt} = -0.5\ A/s$. Find $V_A = ?$ if $V_B = 2\ volt$

Ans



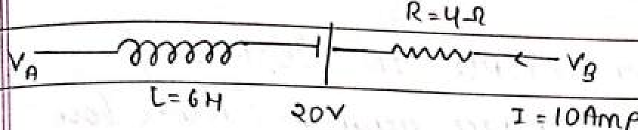
emf = IR

= 8V

$\Rightarrow 2 - 8 + 25 + 0.2 + 5 = V_A$

$\Rightarrow 24.2V$ Ans

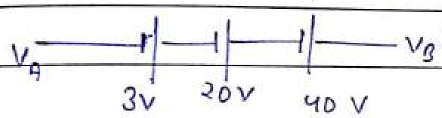
Q



$\frac{dI}{dt} = 0.5\ Amp$

Find $V_A - V_B = ?$

Ans



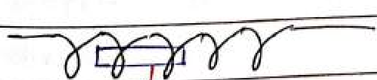
$V_A + 3 + 20 + 40 = V_B$

$V_A - V_B = -63V$ Ans

If iron is placed inside solenoid then its inductance will be.

$L = \mu_0 n^2 A l$

↳ medium = air



iron.

$L = \mu_m n^2 A l$

↳ increase

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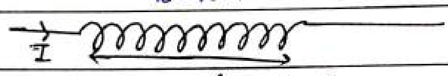
Q. When the numbers of turns in a solenoid are doubled without any change in the length of the solenoid, its self inductance becomes.

(a) Half — (b) Double

(c) Four times — (d) Eight times.

MAGNETIC ENERGY STORED IN SOLENOID / Magnetic energy density / Power loss.

$B = \mu_0 n I$



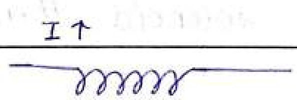
I = constⁿ l, n, A, N

↓

there is magnetic energy stored in solenoid.

$E = \frac{1}{2} L I^2$

Derivation.



$\text{emf} = L \frac{dI}{dt}$

Power loss = VI

$$\frac{dE}{\cancel{dt}} = L \frac{dI}{\cancel{dt}} I$$

$$\int dE = L \int_0^I I \, dI$$

$$E = L \frac{I^2}{2} = \frac{1}{2} L I^2$$

↓

Energy stored.

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$E = \frac{1}{2} L I^2$

$L = \mu_0 n^2 A l$

$E = \frac{1}{2} \mu_0 n^2 A l I^2$

$E = \frac{1}{2} \mu_0 n^2 I^2 A l \frac{\mu_0}{\mu_0}$

$E = \frac{1}{2} \frac{\mu_0^2 n^2 I^2 A l}{\mu_0} = \frac{1}{2\mu_0} B^2 A l$

$\frac{1}{2\mu_0} B^2 A l$

$\text{Energy} = \frac{1}{2\mu_0} B^2 A l$

$\text{Energy} = \frac{1}{2\mu_0} B^2 V$

$\frac{\text{Energy}}{\text{Volume}} = \text{Energy density} = \frac{B^2}{2\mu_0}$

Just like in Capacitor

$\frac{E}{V} = \frac{1}{2} \epsilon_0 E^2$

Q A long solenoid has self inductance L. If its length is doubled keeping total number of turns constant then its self inductance will be

a) $\frac{L}{2}$ (b) $2L$

c) L (d) $\frac{L}{4}$

Ans $L = \frac{\mu_0 N^2 A}{l}$

$L \propto \frac{1}{l}$

Q A coil of resistance 20 ohms and inductance 5H has been connected to a 100 volt battery. The energy stored in the coil is

a) 31.25 J (b) 62.5 J

c) 125 J (d) 250 J

Ans $I = \frac{V}{R} = \frac{100}{20} = 5A$

$E = \frac{1}{2}LI^2 = \frac{1}{2} \times 5 \times 25 = 62.5\ J$

Q The magnetic energy stored in a long solenoid of area A and cross section length in a small region of length l is.

a) $\frac{B^2Al}{2\mu_0}$ (b) $\frac{Al}{2\mu_0}$

c) $\frac{\mu_0 B^2 Al}{2}$ ~~(d)~~ $\frac{B^2Al}{2\mu_0}$

Q A long solenoid has 1000 turns. When a current of 4A flows through it, the magnetic flux linked with each turn of the solenoid is 4×10^{-3} wb. The self inductance of the solenoid is.

~~a)~~ 1H (b) 2H

c) 3H (d) 4H

Ans $\phi = LI$

$\phi = 1000 \times 4 \times 10^{-3} = L \times 4$

$L = 1H$

Q The magnetic potential energy stored in a certain inductor is 25 mJ, when the current in the inductor is 60mA. This inductor is of inductance

a) 0.138H (b) 138.88H

~~c)~~ 13.89 H (d) 1.389H

$E = 25\times10^{-3}\,J$

$I = 60\times10^{-3}$

$E = \frac{1}{2}LI^2$

$25\times10^{-3} = \frac{1}{2}\times L\times 3600\times10^{-6}$

$L = \frac{25\times2\times10^{3}}{3600} \Rightarrow \frac{50\times10}{36} = \frac{500}{\cancel{36}}\ 13.88 = 13.88\,H$

CHARGING OF INDUCTOR

At $t=0$, key is just close

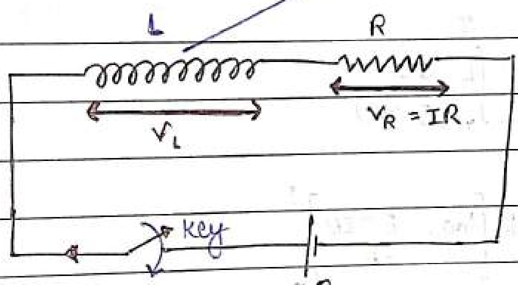
$I=0$ — inductor, oppose the change

$V_R=0$

Inductor behave as open wire

$V_L = E$

$[\,E = V_L + \cancel{V_R}^{\,0}\,]$ at $t=0$



$I=0$ At $t=0$

$\left[\,E = V_L = L\frac{dI}{dt}\,\right]$

At steady state $(t=\infty)$

I = constant

$V_L = 0$

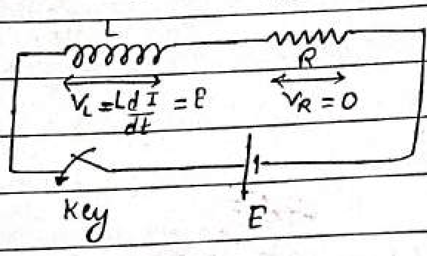
Inductor will behave as simple wire.

$I_{max} = \frac{E}{R}$ $[V_L=0]$

$(\text{energy})_{max} = \frac{1}{2}L(I_{max})^2$

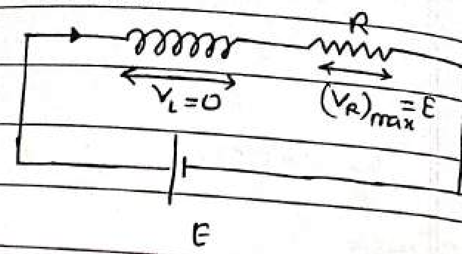
At $t=0$

$I=0$ Inductor as open wire

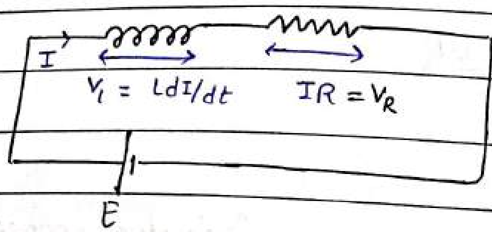


At steady state ($t=\infty$)

$I = \text{const}^n$



At time 't'



$$E = L\frac{dI}{dt} + IR$$

$$E - IR = L\frac{dI}{dt}$$

$$\int_0^t dt = \int_0^I L\frac{dI}{(E-IR)}$$

$$t = L\left[\frac{\log_e (E-IR)}{-R}\right]_0^I$$

$$t = \frac{-L}{R}\left[\log_e (E-IR) - \log E\right]$$

$$-t = \frac{L}{R}\left[\log_e \frac{E-IR}{E}\right]$$

$$\log_e\left(\frac{E-IR}{E}\right) = \frac{-tR}{L}$$

Now taking antilog

$$\frac{E-IR}{E} = e^{-tR/L}$$

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$$1 - \frac{IR}{E} = e^{-tR/L}$$

$$1 - e^{-tR/L} = \frac{IR}{E}$$

$$I = \frac{E}{R}\left[1 - e^{-tR/L}\right]$$

$$I = I_{max}\left[1 - e^{-tR/L}\right]$$

$$Q = Q_{max}\left[1 - e^{-t/RC}\right]$$

$$Q = Q_{max}\left[1 - e^{-t/\tau}\right]$$

time constant $= RC = \tau$

Charging of Inductor

$$I = I_0\left(1 - e^{-t/\tau}\right)$$

$$I = I_{max}\left(1 - e^{-tR/L}\right)$$

$$\Rightarrow I = I_{max}\left(1 - e^{-t/LR}\right)$$

$\tau = \frac{L}{R}$ = time constant

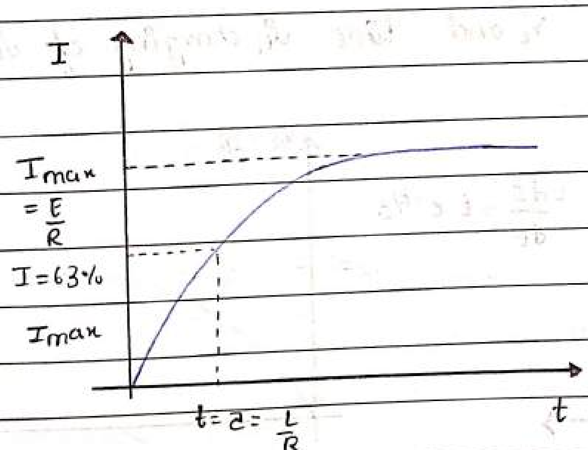
If $t = 0$ (open wire)

$I = 0$

$I = I_0(1-1) = 0$

If $t = \infty$ $e^{-\infty} = 0$

$I = I_{max}(1-0) = I_{max} = \frac{E}{R}$



$$I = I_{max}\left(1 - e^{-tR/L}\right) \Rightarrow I = I_{max}\left(1 - e^{-t/\tau}\right)$$

$$I = I_{max}\left(1 - e^{-1}\right) = \left(\frac{e-1}{e}\right) I_{max}$$

Q. Draw graph between $\frac{dI}{dt}$ and time

$\Rightarrow$ $I = I_{max}(1 - e^{-t/\tau})$

differentiate w.r.t. time.

$$\frac{dI}{dt} = I_{max}\left[0 - \left(-\frac{1}{\tau}\right)e^{-t/\tau}\right]$$

$$\frac{dI}{dt} = \frac{E}{\cancel{R}}\frac{\cancel{R}}{L}e^{-t/\tau}$$

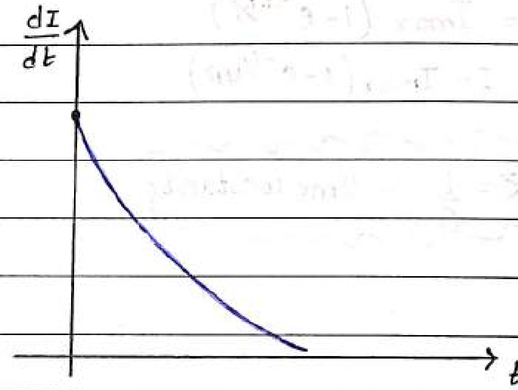
$$\frac{dI}{dt} = \frac{E}{L}e^{-t/\tau}$$

At $t = 0$

$$\frac{dI}{dt} = \frac{E}{L}$$

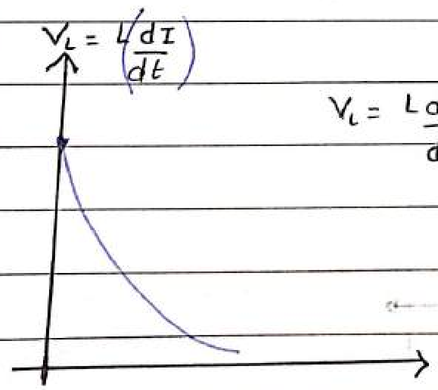
At $t = \infty$

$$\frac{dI}{dt} = 0$$

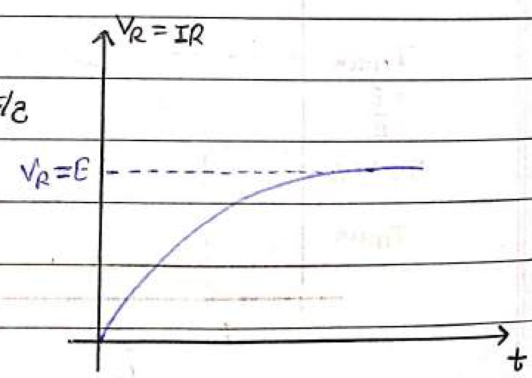


Q. Draw graph between V_L and time in charging of inductor

$\Rightarrow$



$$V_L = L\frac{dI}{dt} = E\,e^{-t/\tau}$$



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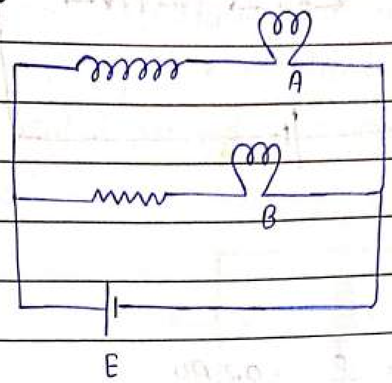
Shivalal

Q Compare Brightness of Bulb at t=0 and t=∞ (steady state)



⇒ At t=0

Inductor open wire

(Bulb A will not glow)

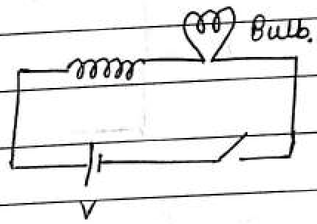
Bulb B will glow

At t=∞

Both bulb will glow but brightness of A will be greater than bulb B.

because at t=∞ E is across A but P.D. across B is <E since some of it is dropped across resistor.

Q The current circuit, bulb will become suddenly bright, if



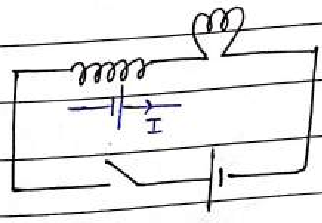
a) Switch is closed or opened

b) Switch is closed

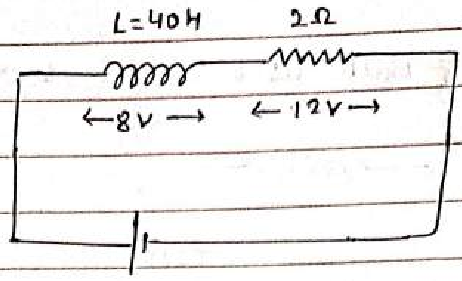
~~c)~~ Switch is just opened

d) None of these.

Ans



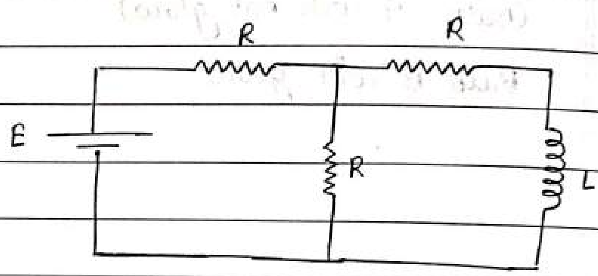
Q Find $\frac{dI}{dt}$ in the circuit at a given instant?



Ans $V = L\frac{dI}{dt}$

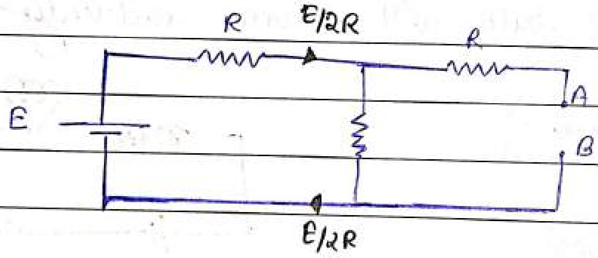
$$\frac{dI}{dt} = \frac{V}{L} = \frac{8}{40} = 0.2 \ A/s$$

Q Find rate of change of current across inductor in
(i) $t=0$
(ii) $t=$ steady current



Ans At $t=0$

inductor will behave as open wire



$$I = \frac{E}{2R}$$

emf across $AB = \frac{E}{2R} \times R = \frac{E}{2}$

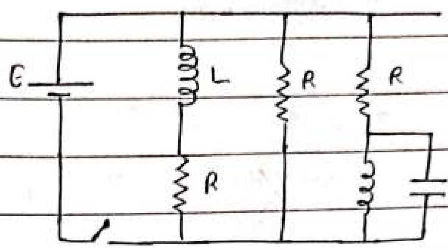
$$V = L\frac{dI}{dt}$$

$$\frac{dI}{dt} = \frac{V}{L} = \frac{E}{2L}$$

At $t=\infty$

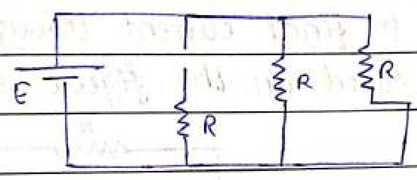
$\frac{dI}{dt} = 0$ for any circuit

Q Figure shows a circuit containing three identical resistors with resistances $R = 9.0\,\Omega$ each, two identical inductors with inductance $L = 2.0\,mH$ each, and a ideal battery with emf $\mathcal{E} = 18\,V$. The current i through the battery just after the switch is closed.



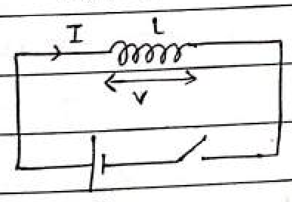
Ans At $t=0$

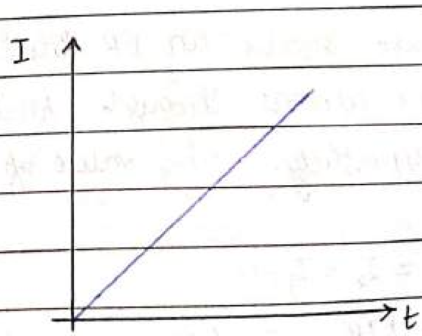
$i = ?$



$$i = \frac{2E}{R} = \frac{2\times 18}{9} = 4A \quad \underline{Ans}$$

Q If only inductor is connected with battery, then find current as a function of time





Ans $L\frac{dI}{dt} = E$

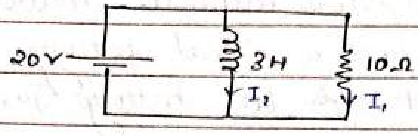
$$L\int_{I=0}^{I} dI = E\int_{t=0}^{t} dt$$

$$LI = Et$$

$$I = \frac{E}{L}t$$

$$I \propto t$$

Q Find current at 2sec in battery?



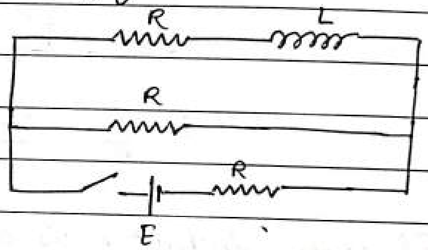
Ans $I_1 = \frac{20}{10} = 2A$

$I_2 = ?$

$V = \cancel{L}\frac{dI}{dt}$ $\qquad I = \frac{E}{L}t = \frac{20}{3} \times 2 = \frac{40}{3}$

$I_{net} = I_1 + I_2 = \left(\frac{40}{3} + 2\right) A$ Ans

Q The ratio of initial to final current through the battery when the switch is closed in the figure is



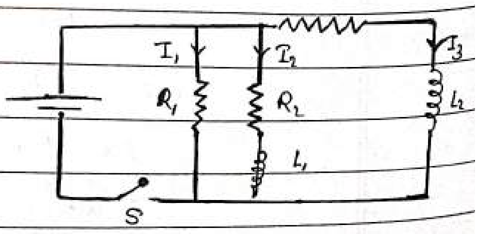
a) Zero (b) ∞
c) 4/3 ~~(d)~~ 3/4

Ans At $t=0$ $\qquad$ At $t=\infty$

$I_1 = \frac{E}{2R}$ $\qquad I_2 = \frac{2E}{3R}$

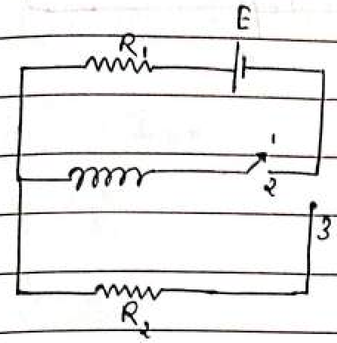
$\frac{I_1}{I_2} = \frac{3}{4}$

Q Figure shows an L-R circuit. When the switch is closed the current through resistor R_1, R_2 and R_3 are I_1, I_2, I_3 respectively. The value of I_1, I_2, and I_3 at $t=0$ is.



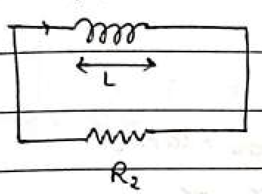
a) $I_1 = I_2 = I_3 = 0$
~~b)~~ $I_1 = E/R_1$, $I_2 = I_3 = 0$
c) $I_1 = 0$, $I_2 = E/R_2$, $I_3 = E/R_3$
d) $I_1 = E/R_1$, $I_2 = E/R_2 + L_1$, $I_3 = E/R_3 + L_3$

DISCHARGING OF INDUCTOR



After large time key ① is shifted from ~~②~~ ② to position ③.

$I = E/R_1$



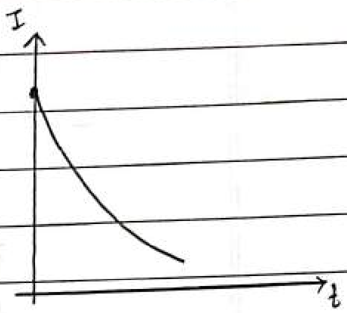
$V_L = V_R$

$-L\frac{dI}{dt} = IR$

$\int_{I_m}^{I} \frac{dI}{I} = -\frac{R}{L}\int_{t=0}^{t} dt$

$\ln \frac{I}{I_m} = -\frac{R}{L}t$

$e^{-Rt/L} = \frac{I}{I_m} \rightarrow I_m e^{-Rt/L} = I$ Ans



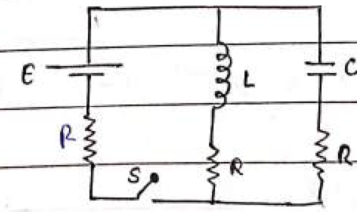
Q The switch shown in the circuit is closed at $t=0$, The current drawn from the battery by the circuit at $t=0$ and $t=\infty$ in the ratio.

a) 2:1

b) 1:2

c) 1:1

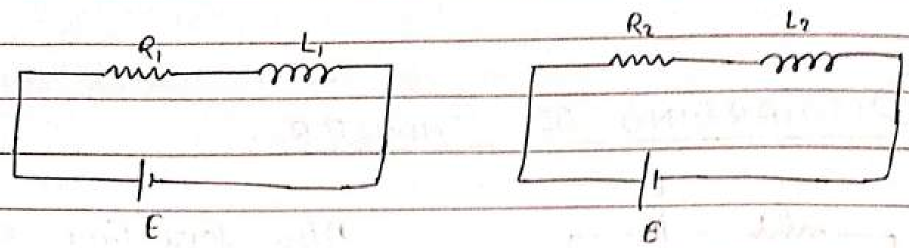
d) 1:4

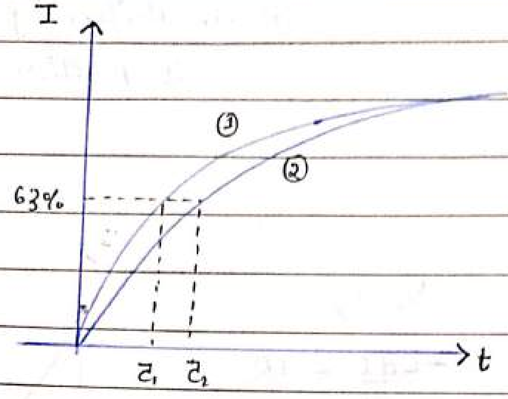


Ans At $t=0$ At $t=\infty$

$\frac{E}{2R} = I_1$ $I_2 = \frac{E}{2R}$

★ Q





I_{max} = same

$\tau_2 > \tau_1$

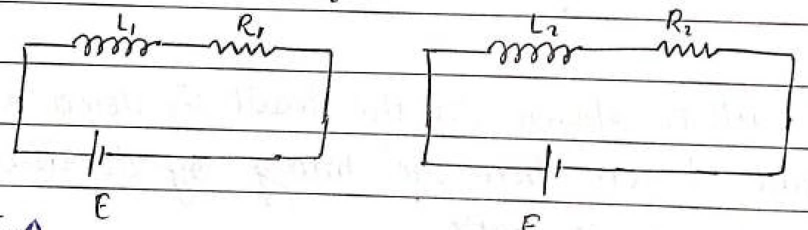
$\frac{\cancel{E}}{R_1} = \frac{\cancel{E}}{R_2}$

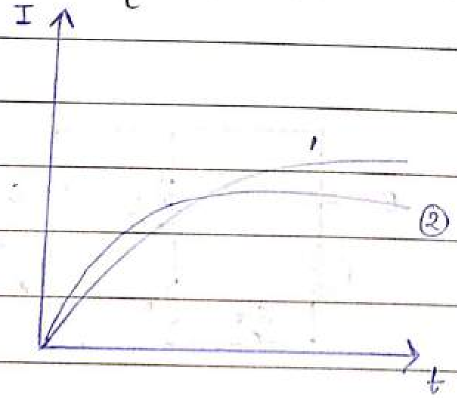
$\frac{L_1}{\cancel{R_1}} < \frac{L_2}{\cancel{R_2}}$

$\boxed{R_1 = R_2}$

$\boxed{L_2 > L_1}$

★ Q Compare R_1 & R_2 and L_1 & L_2





ANS At $t=0$ $\frac{dI}{dt}$ for 2nd is > $\left(\frac{dI}{dt}\right)_I$

$\frac{V}{L} = \frac{dI}{dt}$

$$\therefore \left(\frac{V}{L}\right)_2 > \left(\frac{V}{L}\right)_1$$

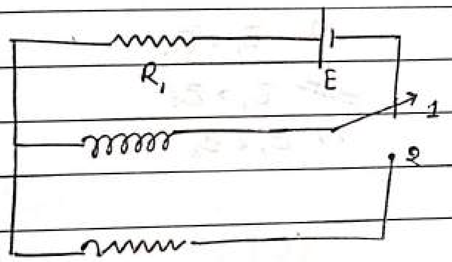
$$L_1 > L_2 \quad [V_1 = V_2]$$

$$I_{max1} > I_{max2}$$

$$\frac{\cancel{E}}{R_1} > \frac{\cancel{E}}{R_2}$$

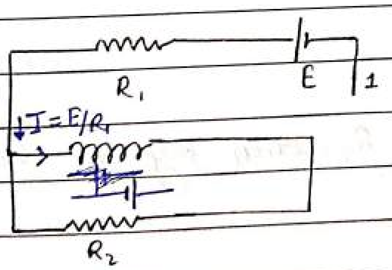
$$\boxed{R_2 > R_1}$$

DISCHARGING OF INDUCTOR.



After large time key is shifted from point ① to point ②

At $t=0$ $\quad I_{max} = \frac{E}{R_1}$



$$\text{Energy} = \frac{1}{2} L \left(\frac{E}{R_1}\right)^2$$

At time t'

$$V_L = V_R$$

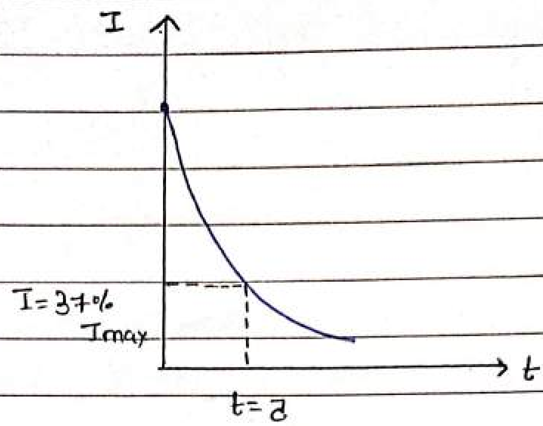
$$-L\frac{dI}{dt} = IR_2$$

$$-L\int_{I_{max}}^{I} \frac{dI}{IR_2} = \int_0^t dt$$

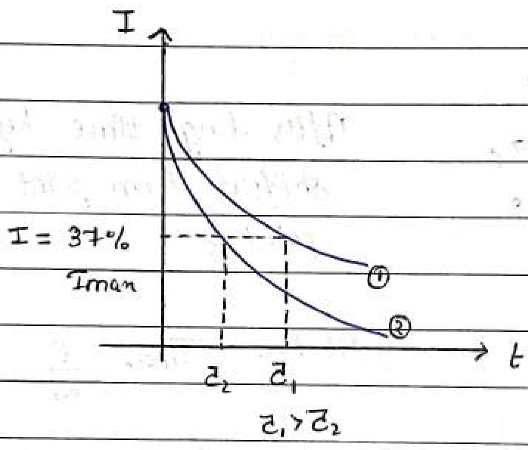
$$-\frac{L}{R_2} \ln \frac{I}{I_{max}} = t$$

$$\ln \frac{I}{I_{max}} = -\frac{R_2 t}{L}$$

$$I_{max}\, e^{-R_2 t/L} = I$$



For discharging of two inductor current vs time graph is given then compare time constant.

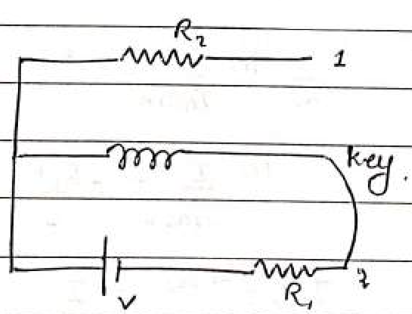


a) $\tau_1 = \tau_2$

~~b)~~ $\tau_1 > \tau_2$

c) $\tau_1 < \tau_2$

Q Find total heat loss across R_2 when key is shifted from ② to ①.



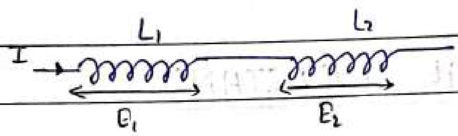
$\frac{1}{2} L \frac{V^2}{R_2^2}$

$\frac{1}{2} L \frac{V^2}{R_1^2}$

$\frac{1}{2} L \left(\frac{V}{R_1+R_2}\right)^2$

SERIES COMBINATION OF INDUCTOR.

Due to series combination



$I_1 = I_2$

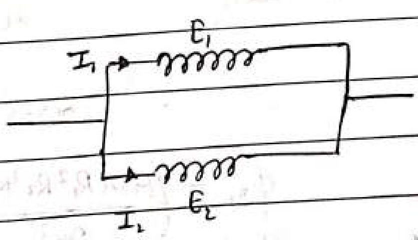
$\frac{dI_1}{dt} = \frac{dI_2}{dt}$

$E_{net} = E_1 + E_2$

$L_{net} \frac{d\cancel{I}}{\cancel{dt}} = L_1 \frac{d\cancel{I}}{\cancel{dt}} + L_2 \frac{d\cancel{I}}{\cancel{dt}}$

$L_{net} = L_1 + L_2$

PARALLEL COMBINATION



$I = I_1 + I_2$

$E_{net} = E_1 = E_2$

$E_1 = L_1 \frac{dI_1}{dt}$

$E_2 = L_2 \frac{dI_2}{dt}$

$E_{eq} = L_{eq} \frac{dI}{dt}$

$I = I_1 + I_2$

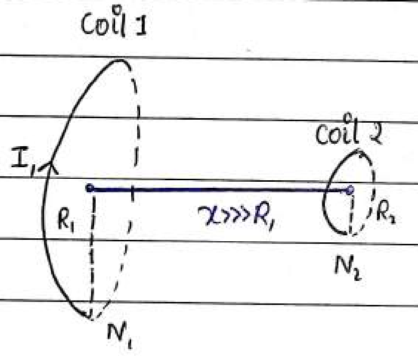
differentiate wrt. time

$$\frac{dI}{dt} = \frac{dI_1}{dt} + \frac{dI_2}{dt}$$

$$\frac{\cancel{E}}{L_{eq}} = \frac{\cancel{E}}{L_1} + \frac{\cancel{E}}{L_2}$$

$$\boxed{\frac{1}{L_{eq}} = \frac{1}{L_1} + \frac{1}{L_2}}$$

Mutual Inductance



Flux passing through 2nd coil due to 1st coil.

$$\phi_{21} = B_1 A_2$$

$$= \frac{\mu_0 I_1 R_1^2 N_1}{2(R^2+x^2)^{3/2}} \times \pi R_2^2 N_2$$

$x >>>> R_1 > R_2$

$$\phi_{21} = \left(\frac{\mu_0 \pi R_1^2 R_2^2 N_1 N_2}{2x^3}\right) I_1$$

ϕ_{21} → change in flux

$\left(\frac{\mu_0 \pi R_1^2 R_2^2 N_1 N_2}{2x^3}\right)$ → proportional constant for given arrangement.

$\phi_{21} = M_{21} I_1$

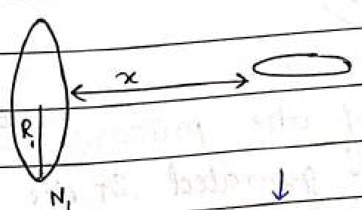
mutual inductance of second coil due to 1

$$M_{21} = \frac{\pi \mu_0 R_1^2 R_2^2 N_1 N_2}{2x^3}$$

RECIPROCITY THEOREM

$\boxed{M_{12} = M_{21}}$ → always.

$\phi_{21} = M_{21} I_1$	$\phi_{12} = M_{12} I_2$
diff. w.r.t. time	diff. w.r.t. time.
$\frac{d\phi_{21}}{dt} = M_{21} \frac{dI_1}{dt}$	$\frac{d\phi_{12}}{dt} = M_{12} \frac{dI_2}{dt}$
$(emf)_{21} = M_{21} \frac{dI_1}{dt}$	$(emf)_1 = M \frac{dI_2}{dt}$



$M = 0$

↓

therefore mutual inductance depends on orientation.

Mutual inductance does not depends on flux and current.

But mutual inductance depends upon.

1) Separation between them
2) Relative orientation
3) Geometry of coil
4) medium b/w them

$\phi_{12} = M_{12} I_2$

$M_{12} = \frac{\phi_{12}}{I_2}$

does not depend on flux and current.

Q Two coaxial coils are very close to each other and their mutual inductance is 5 mH. If a current of 50 sin 500 t is passed in one of the coils then the peak value of emf in second coil is.

a) 5000V (b) 500V

c) 150V (d) 125V

ANS $(emf)_2 = m \frac{dI_1}{dt}$

$= 5\times10^{-3} \frac{d\, 50 \sin 500t}{dt}$

$\Rightarrow 5\times10^{-3}\times 50 \,(\cos 500t)\times 500$

$\Rightarrow 125 \cos 500t$

$(Emf)_{max} = 125V$

Q With the decrease in current of the primary coil from 2A to zero in 0.01 s, the emf generated in the secondary coil is 1000V. The mutual inductance of the two coil is.

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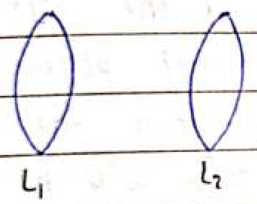
a) 1.25H (b) 2.50H
~~c)~~ 5.00H (d) 10.00H

Ans $\left(\frac{\Delta\phi}{\Delta t}\right)_1 = M \frac{\Delta I_2}{\Delta t}$

$\Rightarrow 1000 = M \frac{2}{0.01}$

$M = 5H$ Ans



$M = K\sqrt{L_1 L_2}$

↓

coupling constant(K)

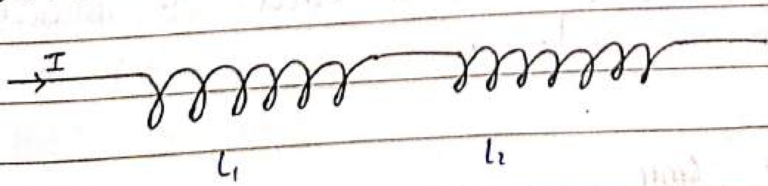
$0 \leq K \leq 1$

K → depends on orientation/ relative distance

$K_{max} = 1$

$M_{max} = \sqrt{L_1 L_2}$

SERIES COMBINATION OF INDUCTOR



equivalent inductance.

$$L_{eq} = L_1 + L_2 + 2M$$

$$L_{eq} = L_1 + L_2 + 2\sqrt{L_1 L_2} \qquad L_{eq} = L_1 + L_2 - 2\sqrt{L_1 L_2}$$

use this formula when the question is talking about mutual inductance

when they support each other.

when they oppose each other.

Q The coefficient of self inductance of two inductor coil are 20mH and 40mH respectively. If the coils are connected in series so as to support each other and the resultant inductance is 80mH then the value of mutual inductance between the coils will be.

a) 5mH (b) 10mH
c) 20mH (d) 40mH

Ans $L_{eq} = L_1 + L_2 + 2M$

$\Rightarrow 80 = 20 + 40 + 2M$

$M = 10\ mH$

Q Two coils of self inductance 2mH and 8mH are placed so closed together that the effective flux in one coil is completely linked with the other. The mutual inductance between these coils is. $\hookrightarrow K = 1$

a) 10mH c) 6mH
b) 4mH (d) 16mH

Ans $M = K\sqrt{L_1 L_2}$

$M = \sqrt{2 \times 8}$

$M = 4mH$

Q The equivalent inductance of two inductor is 2.4 H when connected in parallel and 10H when connected in series. The difference between two inductance is (Neglecting mutual inductance between coils)

a) 2H (b) 3H

c) 4H (d) 5H

Ans $\frac{L_1 L_2}{L_1 + L_2} = 2.4$

$L_1 + L_2 = 10$

$L_1 L_2 = 24$

$L_1 (10 - L_1) = 24$

$10L_1 - L_1^2 = 24$

$L_1^2 + 24 - 10L_1 = 0$

$L_1^2 - 10L_1 + 24 = 0$

$L_1^2 - 6L_1 - 4L_1 + 24 = 0$

$L_1(L_1 - 6) - 4(L_1 - 6) = 0$

$(L_1 - 4)(L_1 - 6) = 0$

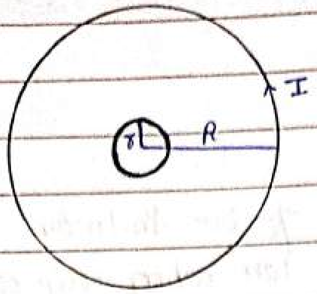
$L_1 = 4$

$L_1 = 6$

if $L_1 = 4$ then $L_2 = 6$

$L_2 - L_1 = 2$

Q Figure shows two concentric loops of radii R and r ($R \gg r$). A current i is passed through the outer loop. Find the flux linked with the inner loop and mutual inductance of the arrangement.



$\phi = B.A$

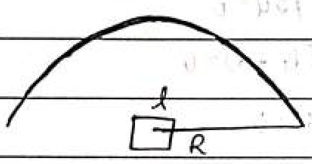
$\phi = \frac{\mu_0 I}{2R} \pi r^2$

$\phi = \left(\frac{\mu_0 I}{2R}\right) \pi r^2 \rightarrow \phi = \left(\frac{\mu_0 \pi r^2}{2R}\right) I$

$M = \frac{\mu_0 \pi r^2}{2R}$

$M \propto \frac{r^2}{R}$ Ans

Q



Find mutual Inductance ($R >>> l$)

$\phi = \frac{\mu_0 I}{4R} l^2$

$M = \frac{\mu_0 l^2}{4R}$

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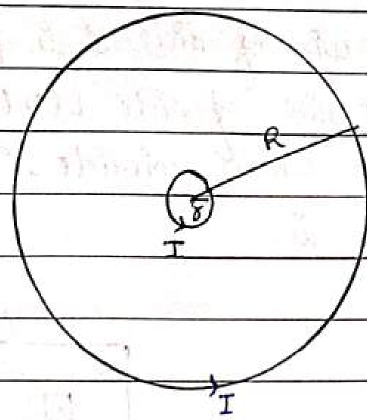
Shivalal

Q



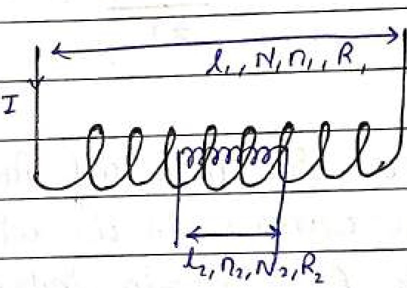
Find mutual inductance of the arrangement $(R >>> r)$

ANS Use reciprocity theorem

$$\phi = \frac{\mu_0 I}{2R} \pi r^2$$

$$M = \frac{\mu_0 \pi r^2}{2R}$$ Ans

Q Find flux in 2nd solenoid due to 1st solenoid



ANS $\phi_{21} = B_1 . A_2$

$\phi_{21} = (\mu_0 n_1 I_1) \pi R_2^2 N_1$

$\phi_{21} = (\pi \mu_0 n_1 n_2 l_2 R_2^2) I_1$

$\phi_{21} = M I_1$

$\boxed{M = \pi \mu_0 n_1 n_2 l_2 R_2^2}$

$\phi_{12} = B_2 A_2$

$\phi_{12} = \mu_0 I_2 n_2 \pi R_2^2 n_1 l_2$

$\phi_{12} = (\pi \mu_0 n_1 n_2 l_2 R_2^2) I_2$

$M = \pi \mu_0 n_1 n_2 l_2 R_2^2$

it is the mutual inductance of both coil.

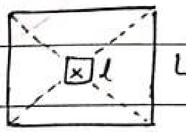
Trick to learn formula of L & M

$L = \mu_0 l A n^2$ $M = \mu_0 l A n^2$

$\Downarrow$

$\mu_0 l_2 A_2 n_2 n_1$

Q A small square loop of wire of side l is placed inside a large square loop of wire of side $L (\gg l)$. The loops are coplanar and their centres coincide. The mutual inductance of the system is.



a) $\frac{2\sqrt{2}\mu_0 L}{\pi I l}$ (b) $\frac{2\sqrt{2}\mu_0 L^2}{\pi I l}$

c) $\frac{2\sqrt{2}\mu_0 I l}{\pi L}$ (d) $\frac{2\sqrt{2}\mu_0 I l^2}{\pi L}$

ANS Let current I flows in outer loop

then ϕ of inner loop

$$\Rightarrow \frac{2\sqrt{2}\mu_0 I}{\pi l L} l^2$$

$$\phi = MI$$

$$M = \frac{2\sqrt{2}\mu_0 l^2}{\pi L}$$

Q Two coils have self inductance $L_1 = 4$ mH and $L_2 = 1$ mH respectively. The currents in the coils are increased at the same rate. At a certain instant of time both coils are given the same power. If I_1 and I_2 are the currents in the two coils, at that instant of time respectively. then the value of I_1/I_2 is.

a) 1/8 (b) 1/4

c) 1/2 (d) 1

ANS $E = V = L\frac{dI}{dt}$

$$P = VI = LI\frac{dI}{dt}$$

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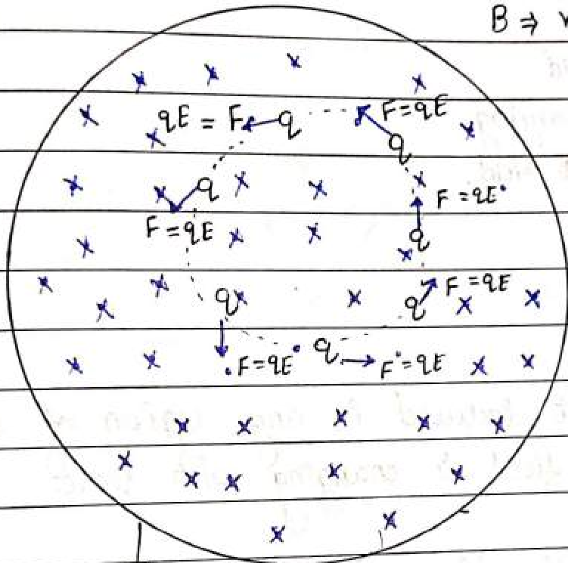
$$L_1 I_1 \frac{dI_1}{dt} = L_2 I_2 \frac{dI_2}{dt}$$

$$\frac{L_1}{L_2} = \frac{I_2}{I_1}$$

$$\frac{I_1}{I_2} = \frac{L_2}{L_1} = \frac{1}{4} \quad \text{Ans}$$

$B \Rightarrow$ variable



time varying magnetic field will induce electric field

↓

because only electric field can apply force on rest charge

This electric field is strange since electric field cannot form close loop.

cylindrical symmetric magnetic field

direction should be along induced current

ELECTRIC FIELD

असली → Electrostatic field (due to charge)

नकली → Induced electric field (due to time varying electromagnetic field)

Electrostatic field (due to charge)	Induced electric field (due to time varying electromagnetic field)
Conservative field	Non conservative field
$\oint \vec{E}\cdot\vec{dl} = 0 = \Delta V$	$\oint \vec{E}\cdot\vec{dl} \neq 0$
does not form close loop	always forms close loop
work done in close loop is zero.	Work done is not zero in close loop

Value of Induced electric field

Faraday law of E.M.I.

$$emf = -\frac{d\phi_m}{dt} \qquad E = -\frac{dv}{dl}$$

$$\cancel{-}\oint \vec{E}\cdot\vec{dl} = \cancel{-}\frac{d\phi_m}{dt}$$

$$\oint \vec{E}\cdot\vec{dl} = \frac{d\phi_m}{dt}$$

induced electric field
due to time varying
magnetic field.

$$\oint \vec{E}\cdot\vec{dl} = 0$$

electrostatic field

An electric field is induced in any region of space in which a magnetic field is changing with time.

* Space varying magnetic field does not induce electric field

A magnetic field is induced in any region of space in which an electric field is changing with time.

In each case, the strength of the induced field is proportional to the rate of change of the ~~induced~~ inducing field. Both fields are perpendicular to each other.

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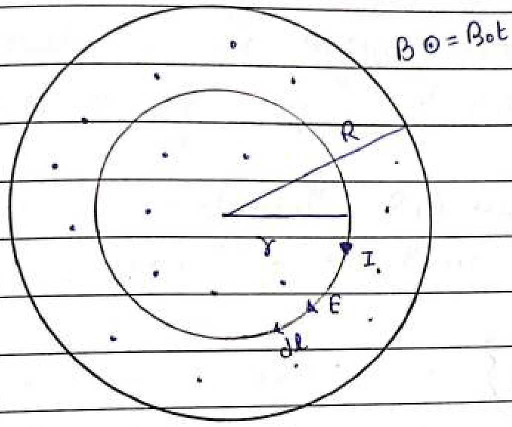
Q There exists a uniform magnetic field in a circular region of radius R centred at O. The field is perpendicular to and out of the plane of paper and its strength varies with time as $B = B_0 t$. Find the induced electric field at a distance r from the centre for (1) $r<R$ (2) $r>R$



$$\oint E_{in} \cdot dl = \frac{d\phi}{dt}$$

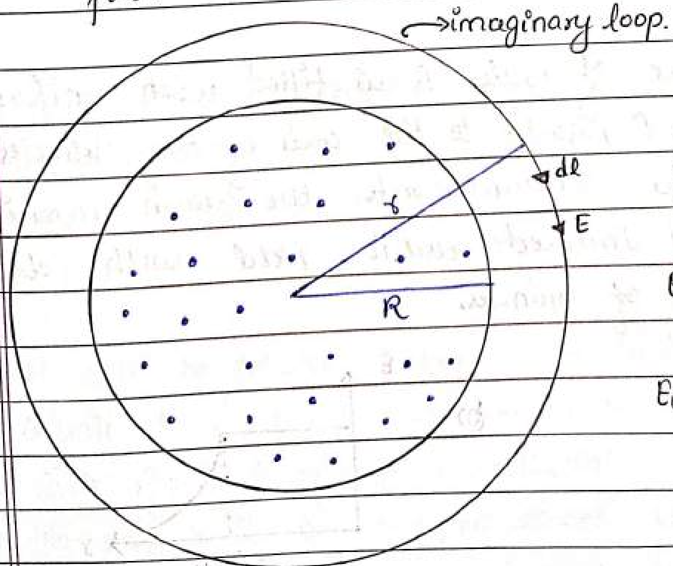
$$E_{in} \oint dl = \frac{d\phi}{dt}$$

$$E_{in}\ 2\pi r = \frac{d\pi r^2 B}{dt} = \pi r^2 \frac{dB_0 t}{dt}$$

$$E_{in}\ 2\cancel{\pi}\cancel{r} = \cancel{\pi} r^{\cancel{2}} B_0 \qquad E_{in} = \frac{r}{2}\frac{dB}{dt}$$

$$E_{in} = \frac{B_0 r}{2}$$

Induced electric field outside region of cylindrical magnetic field.



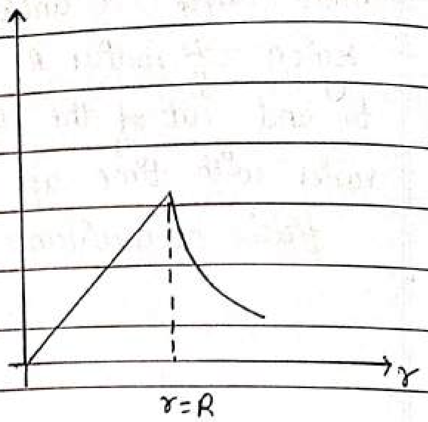
$$\oint E_{in} \cdot dl = \frac{d\phi}{dt}$$

$$E_{in}\ 2\pi r = \frac{d\,B\,\pi R^2}{dt}$$

$$E_{in}\ 2\cancel{\pi} r = B_0 \cancel{\pi} R^2$$

$$E_{in} = \frac{B_0 R^2}{2r}$$

$$E_{in} = \frac{R^2}{2r}\frac{dB}{dt}$$



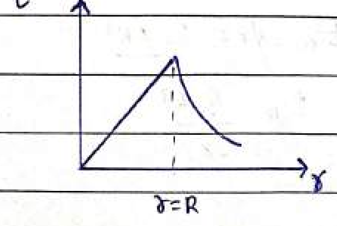
MIT

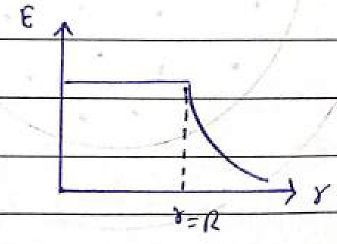
$$\boxed{E_{\text{induced electric inside magnetic field}} = \frac{r}{2}\frac{dB}{dt}}$$

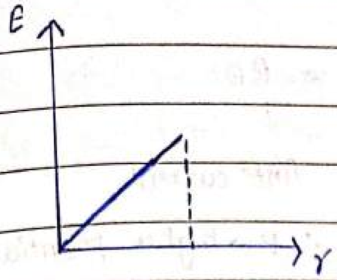
MIT

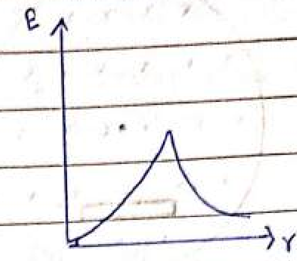
$$\boxed{E_{\text{induced electric field outside magnetic field}} = \frac{R^2}{2r}\frac{dB}{dt}}$$

Q A cylindrical space of radius R is filled with uniform magnetic induction B parallel to the axis of the cylinder. If B changes at a constant rate, the graph showing the variation of induced electric field with distance r from the axis of cylinder.

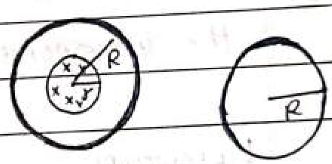
a) 

b) 

9) 



Q A uniform magnetic field is restricted within a region of radius r. The magnetic field changes with time at a rate of $\frac{d\vec{B}}{dt}$. Loop 1 of radius $R>r$ enclosed the region r and loop 2 of radius R is outside the region of magnetic field as shown in the figure below. Then the emf generated is



a) Zero in loop 1 and zero in loop 2

b) $-\frac{d\vec{B}}{dt}\pi r^2$ in loop 1 and $-\frac{d\vec{B}}{dt}\pi r^2$ in loop 2

c) $-\frac{dB}{dt}\pi R^2$ in loop 1 and zero in loop 2

d) $-\frac{dB}{dt}\pi r^2$ in loop 1 and zero in loop 2

Ans ⇒ emf $= \frac{-d\phi}{dt} = -\frac{d B\pi r^2}{dt} = -\pi r^2\frac{dB}{dt}$

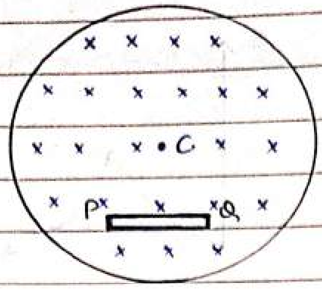
Q In a cylindrical region uniform magnetic field which is perpendicular to the plane of the figure is increasing with time and a conducting rod PQ is placed in the region. If C is the centre of the circle then.

a) P will be greater at higher potential than Q

b) Q will be at higher potential than P

c) Both P and Q will be equipotential

d) No emf will be developed across rod as it is not crossing / cutting any line of force.



$B \otimes \uparrow$

$B_{induced} \rightarrow B \odot$

$\downarrow$

Anti current

$\therefore$ P → higher potential.

Q How does an AC Generator produce electricity?

Ans AC generators work on the principle of Faraday's law of electromagnetic induction. When the armature rotates between the magnetic poles upon an axis perpendicular to the magnetic field, the flux linkage of the armature changes continuously. Due to this, an emf is induced in the armature. As a result, an electric current flows through the galvanometer and the slip rings and brushes.

ARMATURE

The part of an AC generator in which the voltage is produced is known as armature. This component primarily consists of coils of wire that are large enough to carry the full load current of the generator.

Primer mover.

The component used to drive the AC Generator is known as a prime mover. The prime mover could either be a diesel engine, a steam turbine, or a motor.

Rotor

The rotating component of the generator is known as a rotor. The generator's prime mover drives the rotor.

Q A 100 turn coil of area $0.1 m^2$ rotates at half a revolution per second. It is placed in a uniform magnetic field of 0.01T perpendicular to the axis of rotation of the coil. Calculate the maximum voltage generated in the coil?

a) 256.33 V (b) 89.12 V
c) 0.314 V (d) 3.1455 V

Ans $V = NBA\omega$

$\Rightarrow 100 \times 0.01 \times 0.1 \times \frac{1}{\cancel{2}} \times \cancel{2}\pi = 0.1\pi = 0.314 V$

Q In an AC generator electrical energy is converted to mechanical energy by electromagnetic induction.

a) True
b) False

Q An AC generator consists of a coil of 50 turns and an area of $2.5 m^2$ rotating at an angular speed of 60 rad/s. in a uniform magnetic field of 0.3 T between two fixed pole pieces. What is the flux through the coil, when the current is zero?

a) Maximum (b) Minimum
c) Zero (d) Independent of current

$\phi = BA\cos\theta$

$I = \frac{emf}{R} = \frac{d\phi}{R\,dt} \propto \sin\theta$

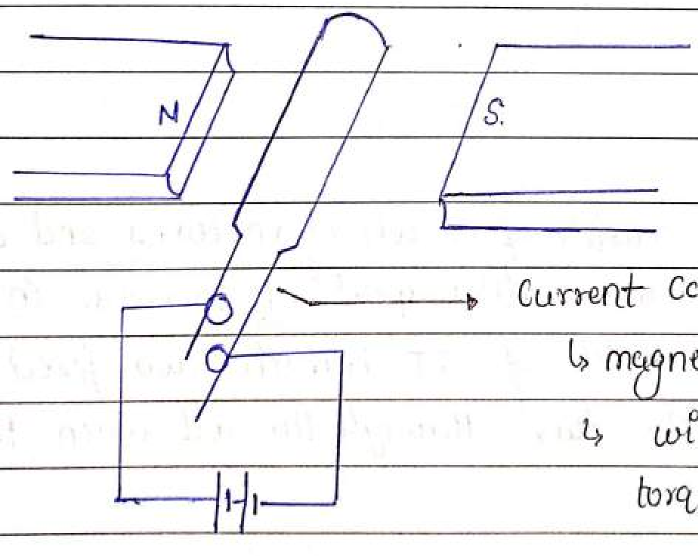
$I_{max} = \theta = 90^\circ$

$I_{min} \Rightarrow \theta = 0^\circ$

$\phi = BA\cos 0^\circ = BA = maxm$

D.C MOTOR

It is a device to convert electrical energy into mechanical energy. It is used to drive an electric car, a printing press, a sewing machine, machinery in factories and any other machinery requiring mechanical energy. Like an AC generator, the motor also consists of (1) field magnet (2) armature (3) commutator (4) brushes. The motor is connected to a battery or a DC line supply.



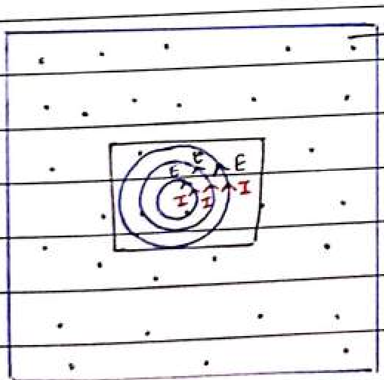
Current carrying loop
↳ magnetic dipole
↳ will experience torque in a magnetic field

PRINCIPLE

The principle of a DC motor is that of a moving coil galvanometer and revolves of the AC generator. When the current flows round the armature in the direction ABCD, the magnetic field exerts a couple on it and sets the armature into rotation.

EDDY CURRENT

Magnetic flux associated with the plate keeps on changing as the plate moves in and out of the region between magnetic poles. The flux change induces eddy currents in the plate. Directions of eddy currents are opposites when the plate swings into the region of between the plates the poles and when it swings out of the region.



time varying magnetic field induces electric field around conducting plate which has large no. of free e⁰, that

Applications.

a) Magnetic braking in trains
b) Electromagnetic damping
c) Induction furnace
d) Electric power meters.
e) Microwave oven