PARISHRAM

2026

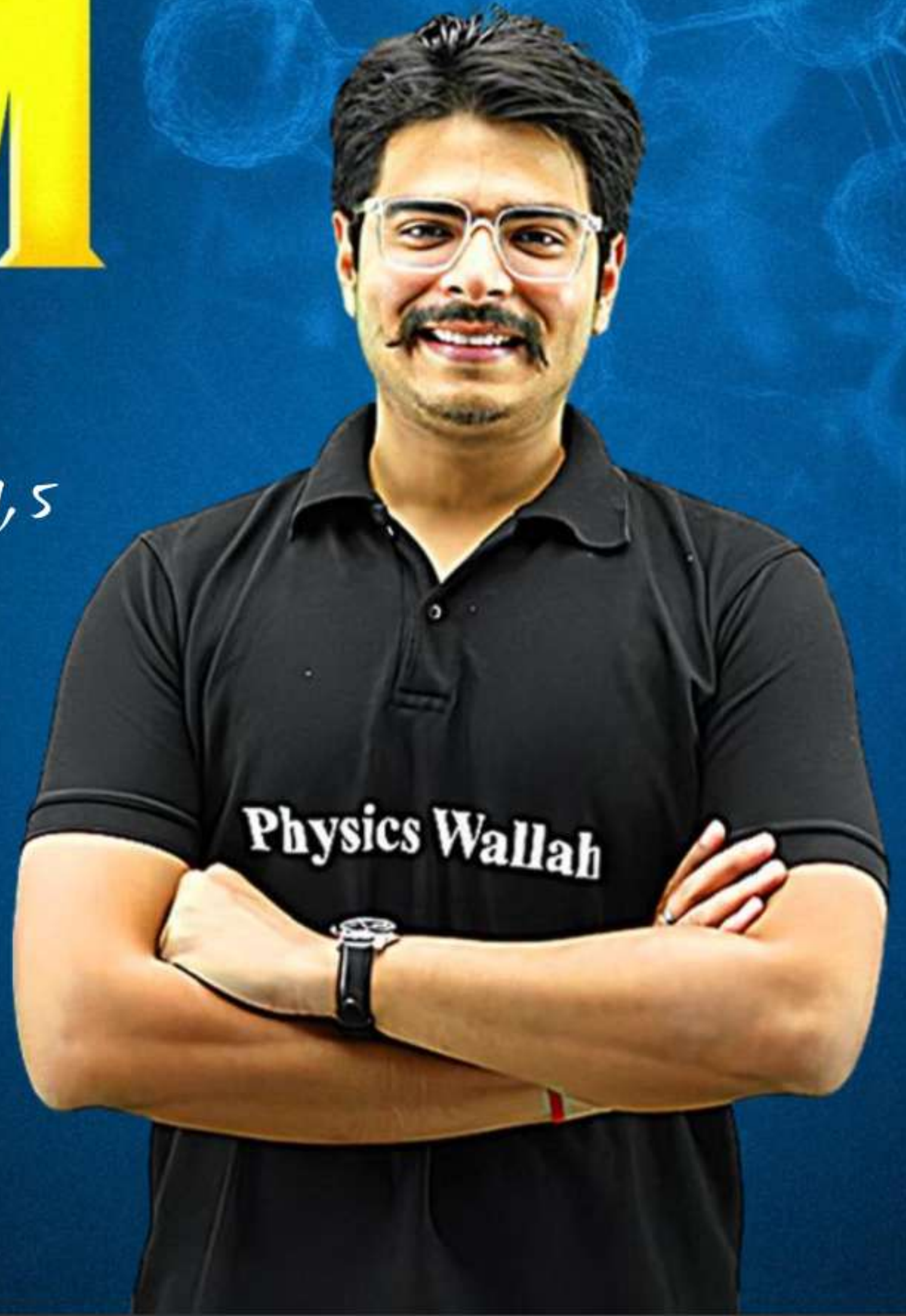
Ch- 1,2,3,4,5

Lecture - 01

Electromagnetic Induction

PHYSICS LECTURE - 1

BY - RAKSHAK SIR



Topics *to be covered*

- **A** Magnetic Flux ✓
- **B** Faraday's Laws ✓
- **C**
- **D**

Unit-III	**Magnetic Effects of Current and Magnetism**	17
	Chapter–4: Moving Charges and Magnetism	
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Unit IV: **Electromagnetic Induction and Alternating Currents**

Chapter–6: Electromagnetic Induction (EMI)

Electromagnetic induction; Faraday's laws, induced EMF and current; Lenz's Law, (Self and mutual induction), AC Generator.

Introduction

moving charge (current) ⟶ Magnetism

Ampere and a few others established the fact that electricity and magnetism are inter-related. They found that # moving electric charges produce magnetic fields. For example, an electric current deflects a magnetic compass needle placed in its vicinity.

This naturally raises the questions like: Is the converse effect possible? Can moving magnets produce electric currents? Does the nature permit such a relation between electricity and magnetism? The answer is resounding yes!

The experiments of Michael Faraday in England and Joseph Henry in USA, conducted around 1830, demonstrated conclusively that electric currents were induced in closed coils when subjected to changing magnetic fields.

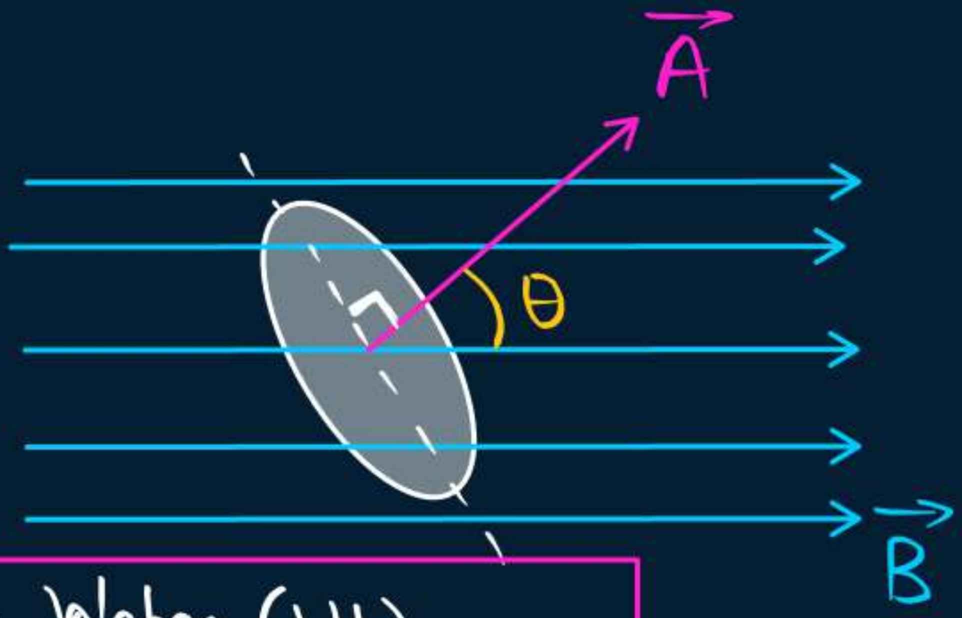
moving magnets ⟶ Electricity

Magnetic Flux

$\phi_B = \vec{B}\cdot\vec{A}$

$= BA\cos\theta$

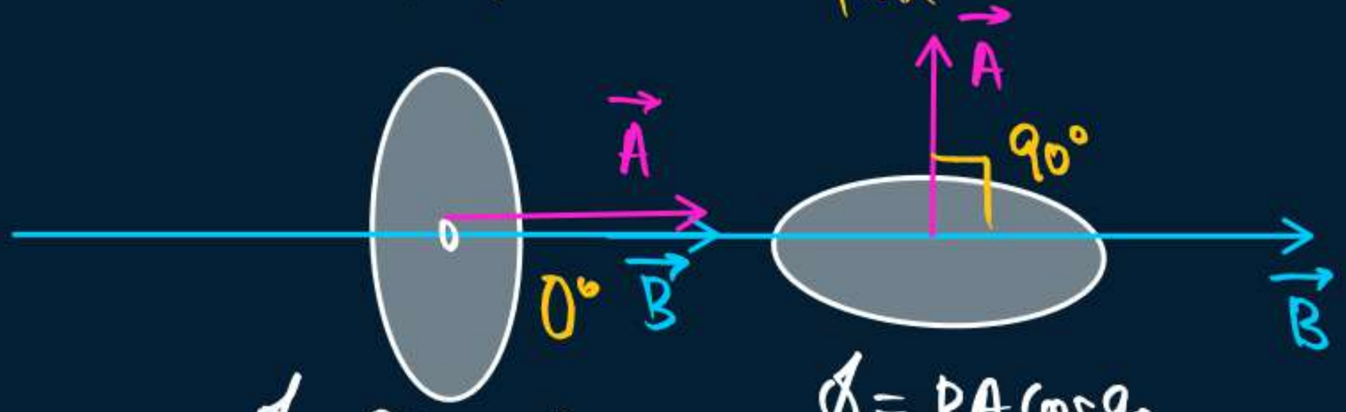
It measures the number of magnetic field lines passing through a given area.



$$\boxed{\begin{aligned}\phi_B &= \vec{B}\cdot\vec{A}\\ &= BA\cos\theta\end{aligned}}$$

Maximum flux

Minimum flux



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

$\phi_{max} = BA$

$\phi = BA\cos 90$

$\phi = 0$

* SI unit :- Weber (Wb)

Tesla-(metre)^2 = $\boxed{Tm^2}$ = $\boxed{\text{Weber (Wb)}}$

* CGS unit :- MaxWell

$\vec{B} \rightarrow$ Unit : $\boxed{\frac{Wb}{m^2}}$

$\boxed{1\,Wb = 10^8\,\text{MaxWell}}$

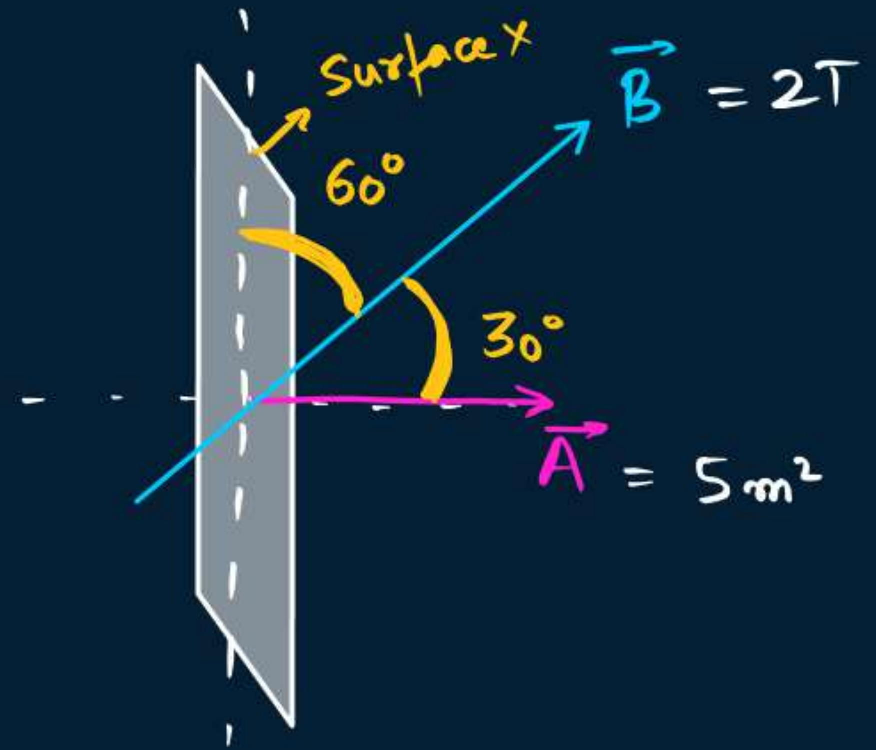
Y.K.B.

Ch-1

$\phi_e = \vec{E}\cdot\vec{A}$

$= EA\cos\theta$

Examples : Magnetic Flux



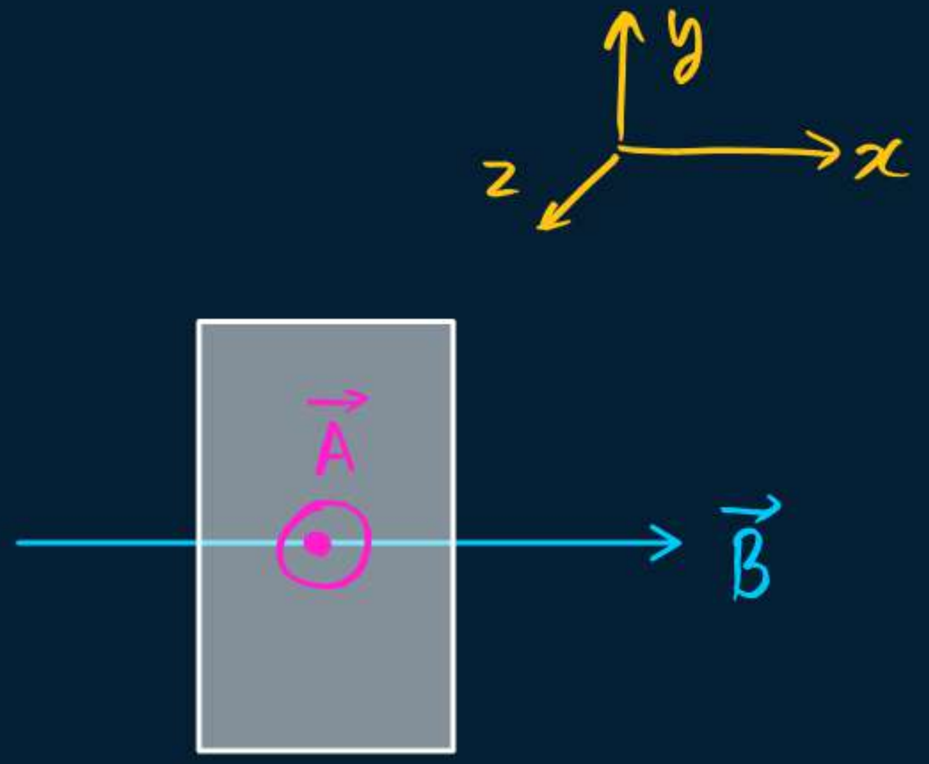
$\phi_B = \vec{B}\cdot\vec{A}$

$= BA\cos\theta$

$= 2\times 5\times \cos 30^\circ$

$= 2\times 5\times \frac{\sqrt{3}}{2}$

$= 5\sqrt{3}$ Wb.



$\phi = BA\cos\theta$

$= BA\cos 90$

$\phi = 0$

QUESTION

A coil of area $\vec{A} = 2\hat{\imath} + 3\hat{k}$ is placed in magnetic field $\vec{B} = 2\hat{\imath} + 3\hat{\jmath} + 4\hat{k}T$. Then find flux passing from the coil.

$$\vec{A} = 2\hat{i} + 3\hat{k}$$

$$\vec{B} = 2\hat{i} + 3\hat{j} + 4\hat{k}$$

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

$$= (2\hat{i} + 3\hat{j} + 4\hat{k}) \cdot (2\hat{i} + 3\hat{k})$$

$$= 2 \times 2 + 3 \times 0 + 4 \times 3$$

$$= 4 + 12$$

$$= 16 \text{ Wb.}$$

QUESTION

A circular disc of radius 0.2 metre is placed in a uniform magnetic field of induction $\frac{1}{\pi}\left(\frac{Wb}{m^2}\right)$ in such a way that its axis makes an angle of 60° with $\vec{B}$. The magnetic flux linked with the disc is

(A) 0.08 Wb

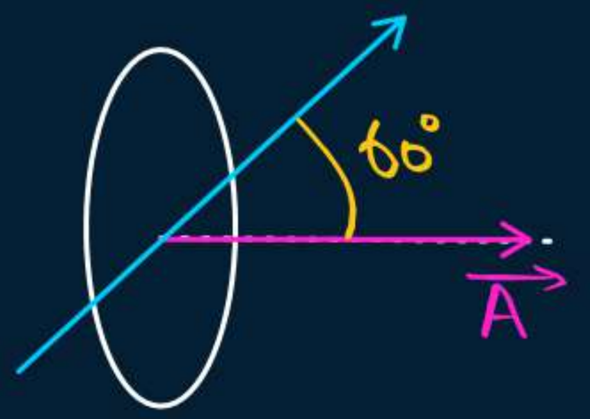
(B) 0.01 Wb

(C) 0.02 Wb

(D) 0.06 Wb

$r = 0.2\ m$

$B = \frac{1}{\pi}\frac{Wb}{m^2} = \frac{1}{\pi}\ T$



$\phi = BA\cos\theta$

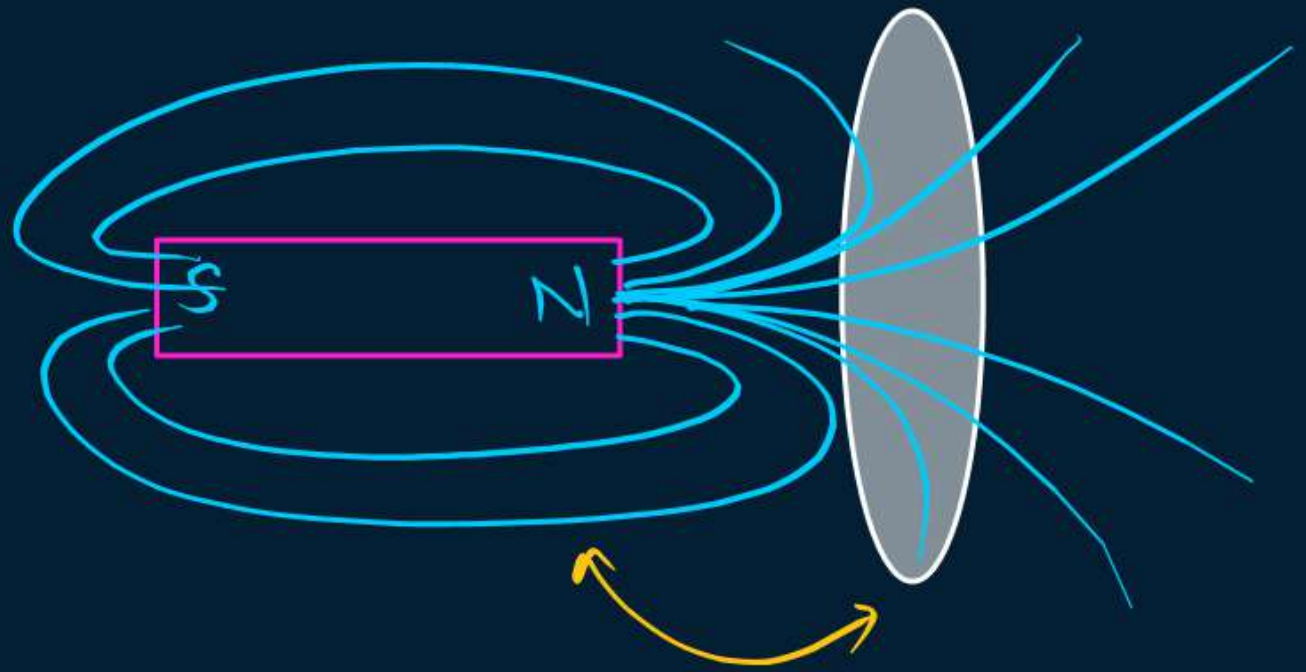
$= \frac{1}{\cancel{\pi}} \times \cancel{\pi} \times \frac{0.2}{10} \times \frac{0.2}{10} \times \cancel{\cos 60°}$

$= 0.02\ Wb$

Faraday and Henry Experiments

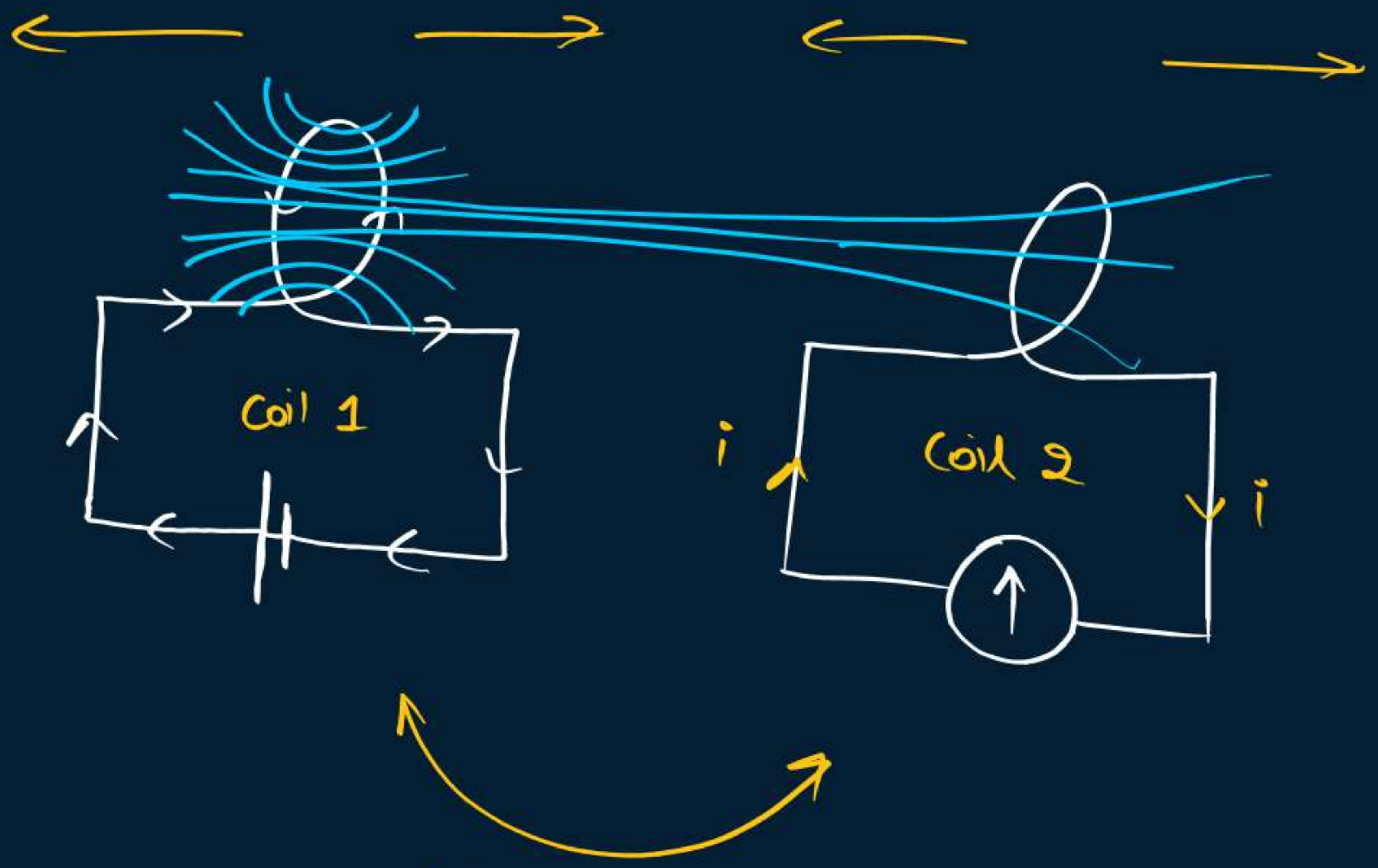
Change = inc/dec

Experiment 1



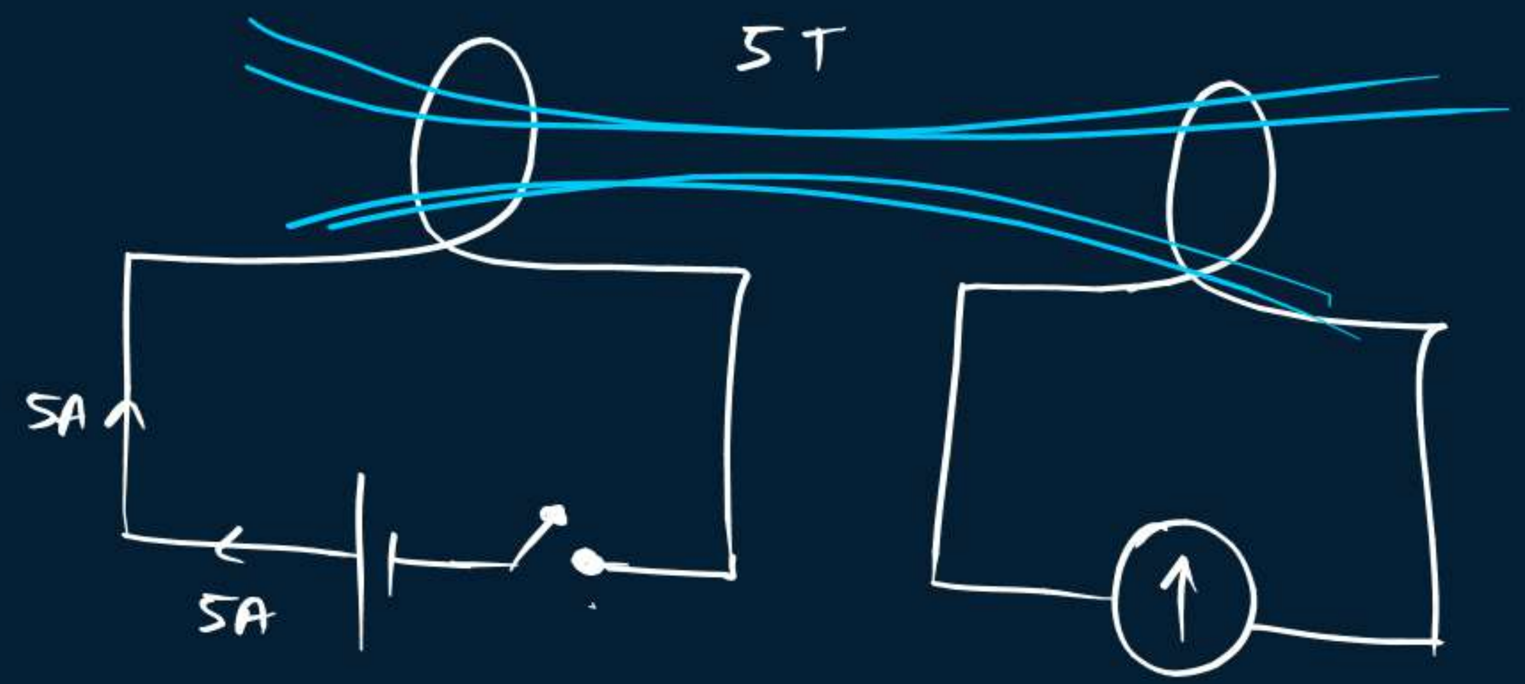
relative motion
b/w magnet
&
coil → Current is induced (Jagrit)
inside the coil

Experiment 2



relative motion b/w coils → flux change → i induced in coil 2

Experiment 3



I Absent	⟸	① Key is opened (Steady)	① No Current induced
I rise	⟸	② Key is just closed (Transition)	② Current is induced
I Constant	⟸	③ Key is closed (Steady)	③ No current induced
I decay	⟸	④ Key is just opened (Transit)	④ current is induced

Faraday's Law of Electromagnetic Induction

'EMI'

Voltage

Whenever there is change in the magnetic flux linked with the coil, emf or current is induced in the coil. The magnitude of the induced emf in a circuit (coil) is equal to the time rate of change of magnetic flux through the circuit

SI unit

Volts = $\frac{\text{Weber}}{\text{Second}}$

$V = Wb\,s^{-1}$

$$\left|\mathcal{E}_{ind}\right| = \frac{\text{Change in Magnetic flux}}{\text{time interval}}$$

Avg. Value of emf

$$\boxed{\mathcal{E}_{ind} = -\frac{\Delta\phi}{\Delta t}}$$

"instant" emf

$$\boxed{\mathcal{E}_{ind} = -\frac{d\phi}{dt}}$$

$$\left|\mathcal{E}_{ind}\right| = \frac{d\phi}{dt}$$

Y.K.B.

$a_{av} = \frac{\Delta v}{\Delta t}$

$a_{inst} = \frac{dv}{dt}$

$i_{av} = \frac{\Delta q}{\Delta t}$

$i_{inst} = \frac{dq}{dt}$

QUESTION

To Induce an e.m.f. in a coil, the linking magnetic flux

A. Must Decrease

B. Must Increase

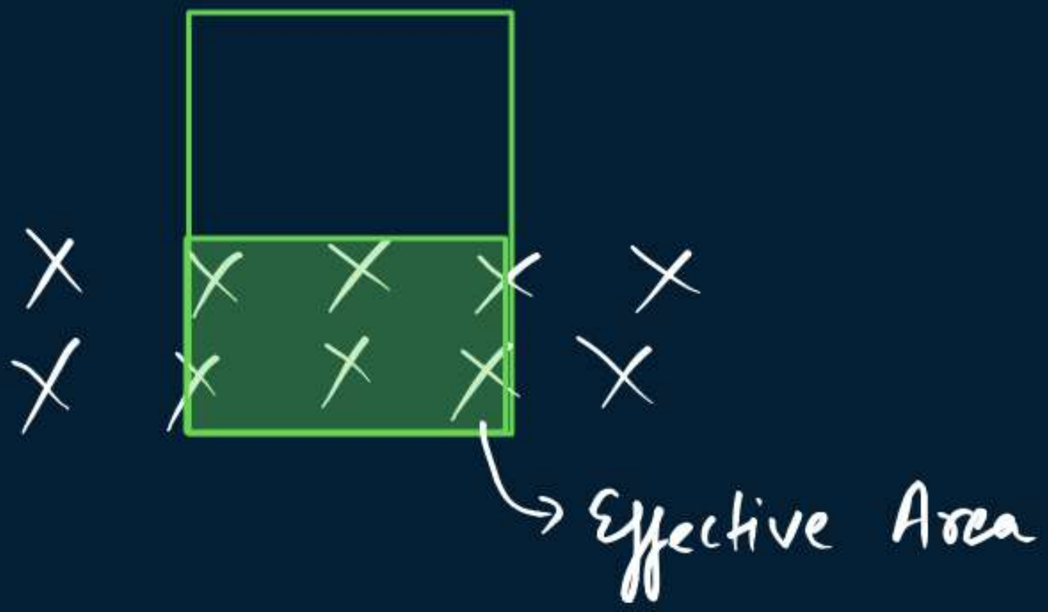
C. May increase or decrease

D. Must remain constant

Methods to change Magnetic Flux

$$\phi_B = \vec{B}\cdot\vec{A}$$

$$\phi_B = BA\cos\theta$$



B

$$\varepsilon = \frac{d\phi}{dt}$$

$$\varepsilon = \frac{d}{dt}(BA\cos\theta)$$

$$\boxed{\varepsilon = A\cos\theta\left(\frac{dB}{dt}\right)}$$

A

$$\varepsilon = \frac{d\phi}{dt}$$

$$\varepsilon = \frac{d}{dt}(BA\cos\theta)$$

$$\boxed{\varepsilon = B\cos\theta\left(\frac{dA}{dt}\right)}$$

θ

$$\varepsilon = \frac{d\phi}{dt}$$

$$\varepsilon = \frac{d}{dt}(BA\cos\theta)$$

$$\boxed{\varepsilon = BA\frac{d}{dt}(\cos\theta)}$$

QUESTION

A coil of resistance 400Ω is placed in a magnetic field. If the magnetic flux $\phi(\mathrm{Wb})$ linked with the coil varies with time $t(s)$ as $\phi = 50t^2 + 4$, the current in the coil at $t = 2$ s is [2012]

A 0.5 A

B 0.1 A

C 2 A

D 1 A

$R = 400\Omega$

$\phi = (50t^2 + 4)$ Wb

$t = 2s$

$i_{ind} = ?$

$\varepsilon_{ind} = \frac{d\phi}{dt}$

$= \frac{d(50t^2+4)}{dt}$

$= 50(2t) + 0$

$\varepsilon_{ind} = 100t$

$\varepsilon_{at\,t=2s} = 100 \times 2 = 200$ V

$\varepsilon_{ind} = i_{ind} R$

$200 = i \times 400$

$\frac{\cancel{200}^{1}}{\cancel{400}_{2}} = i$

$i = 0.5$ A

QUESTION

H.W.

The magnetic flux linked with a coil (in Wb) is given by the equation $\phi = 5t^2 + 3t + 16$ The magnitude of induced emf in the coil at the $t = 4$ sec will be

A 33 V

B 43 V

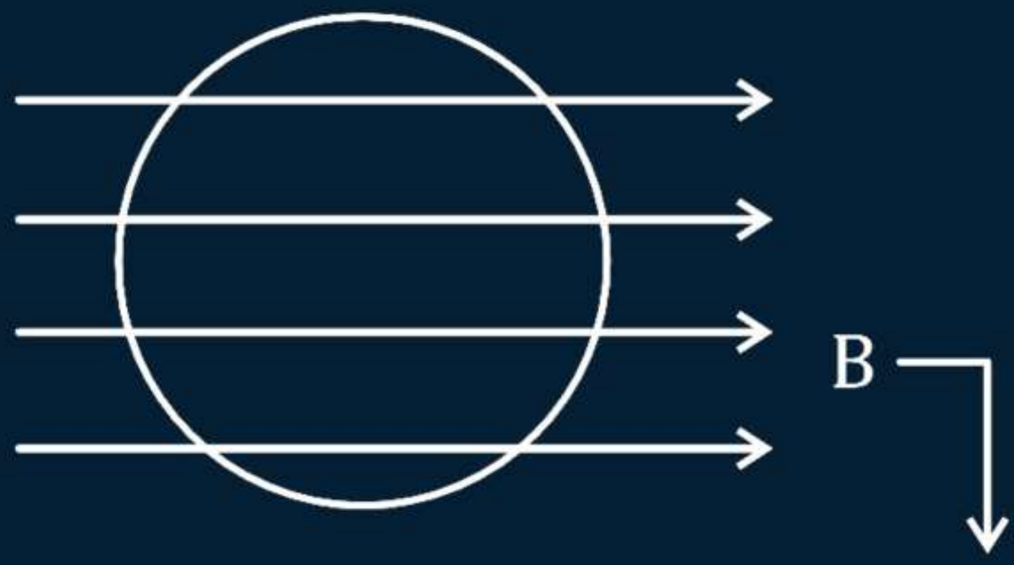
C 108 V

D 10 V

QUESTION

H.W.

i = ? (Direction)



llel to loop.

% increasing.

Homework

Notes

Revision

PARISHRAM

2026

Lecture - 02

Electromagnetic Induction

PHYSICS LECTURE - 2

BY - RAKSHAK SIR

Topics *to be covered*

- **A** # Lenz Law
- **B** # Motional Emf
- **C** #
- **D** #

QUESTION

H.W.

The magnetic flux linked with a coil (in Wb) is given by the equation $\phi = 5t^2 + 3t + 16$ The magnitude of induced emf in the coil at the $t = 4$ sec will be

(A) 33 V

(B) 43 V

(C) 108 V

(D) 10 V

$$\phi = 5t^2 + 3t + 16$$

$$\varepsilon_e = \frac{d\phi}{dt}$$

$$= 5(2t) + 3(1) + 0$$

$$\varepsilon_e = 10t + 3$$

$$\varepsilon_{e\,\text{at}\,t=4s} = 10 \times 4 + 3$$

$$= 40 + 3 = 43\,V$$

QUESTION H.W.

$i = ?$ (Direction)

zero

There is No flux through loop

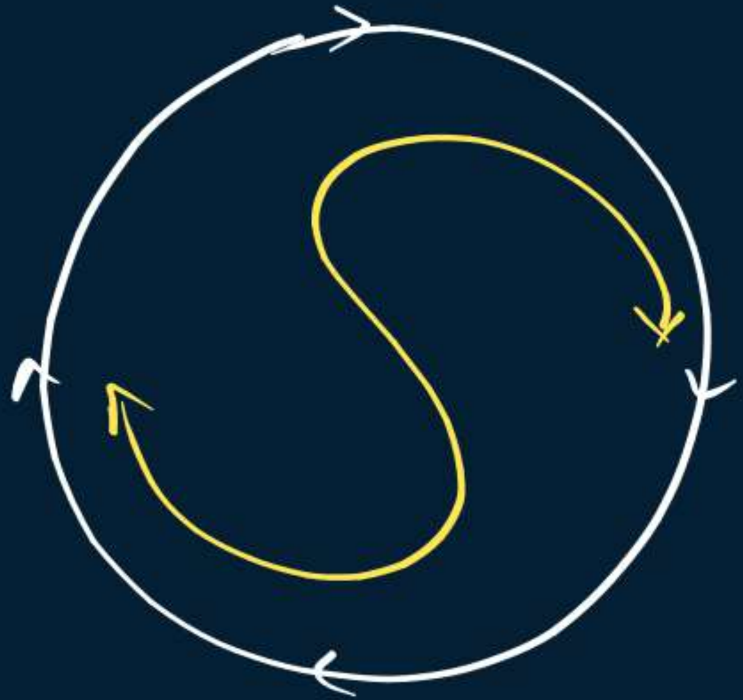
$\Delta\phi = 0$

$\varepsilon = 0$

$i = 0$

Sign Conventions for direction of current

$i \rightarrow$ ACW $\Rightarrow$ North Pole



$i \rightarrow$ CW $\Rightarrow$ South Pole

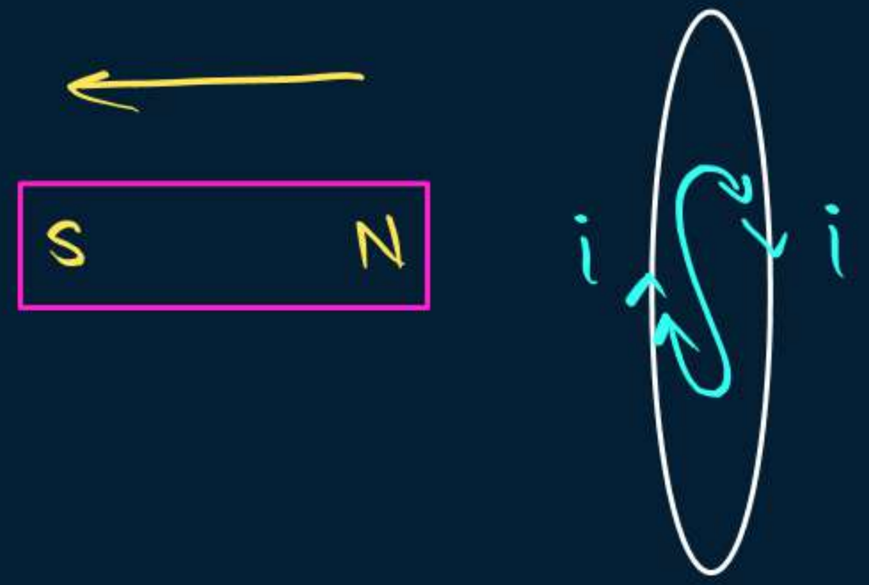
Lenz Law

Ehsaanfaramoshi

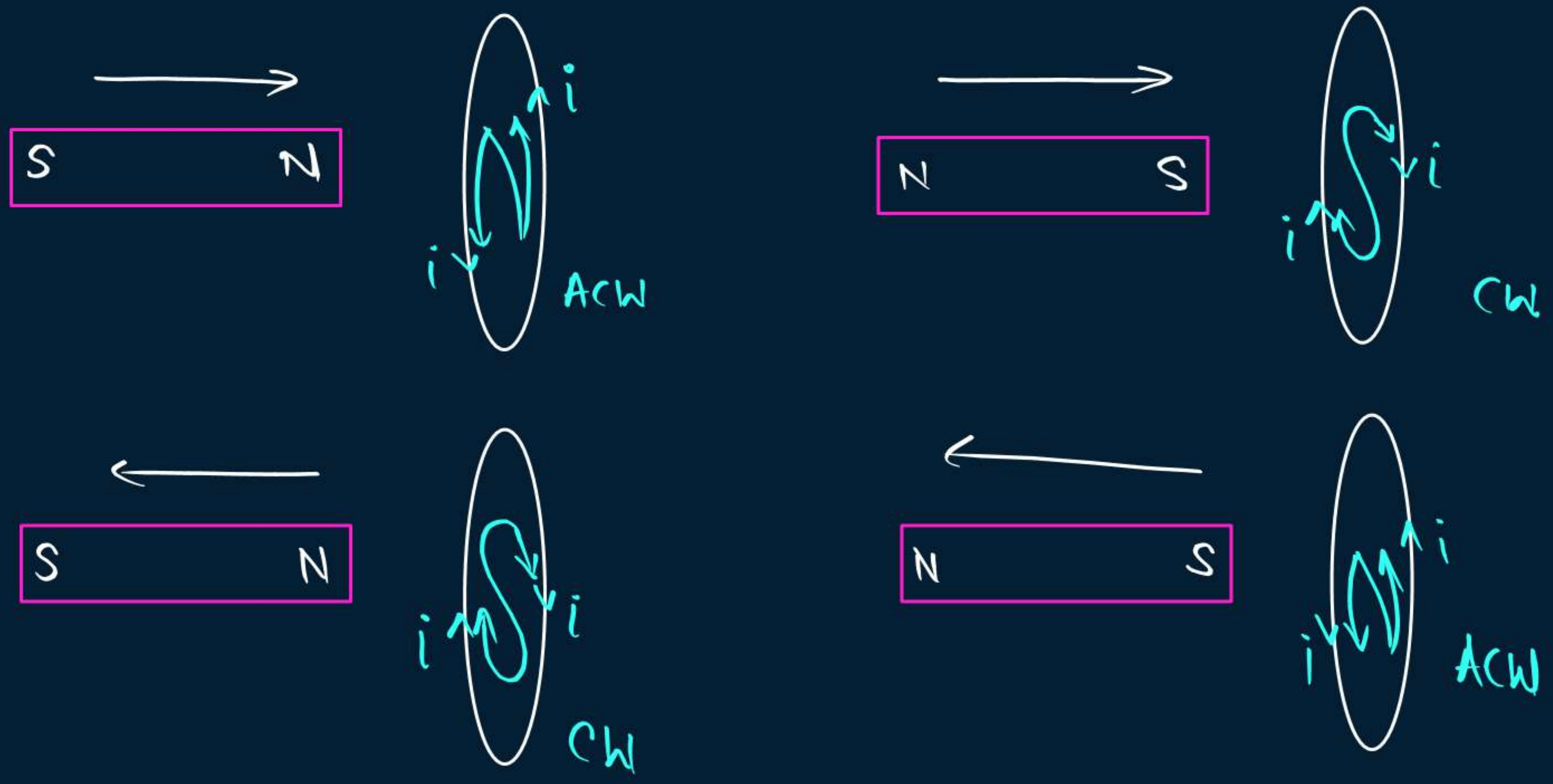
The polarity of induced emf is such that it produces a current which opposes the change in magnetic flux that produced it

$$\mathcal{E}_{ind} = -\frac{d\phi}{dt}$$

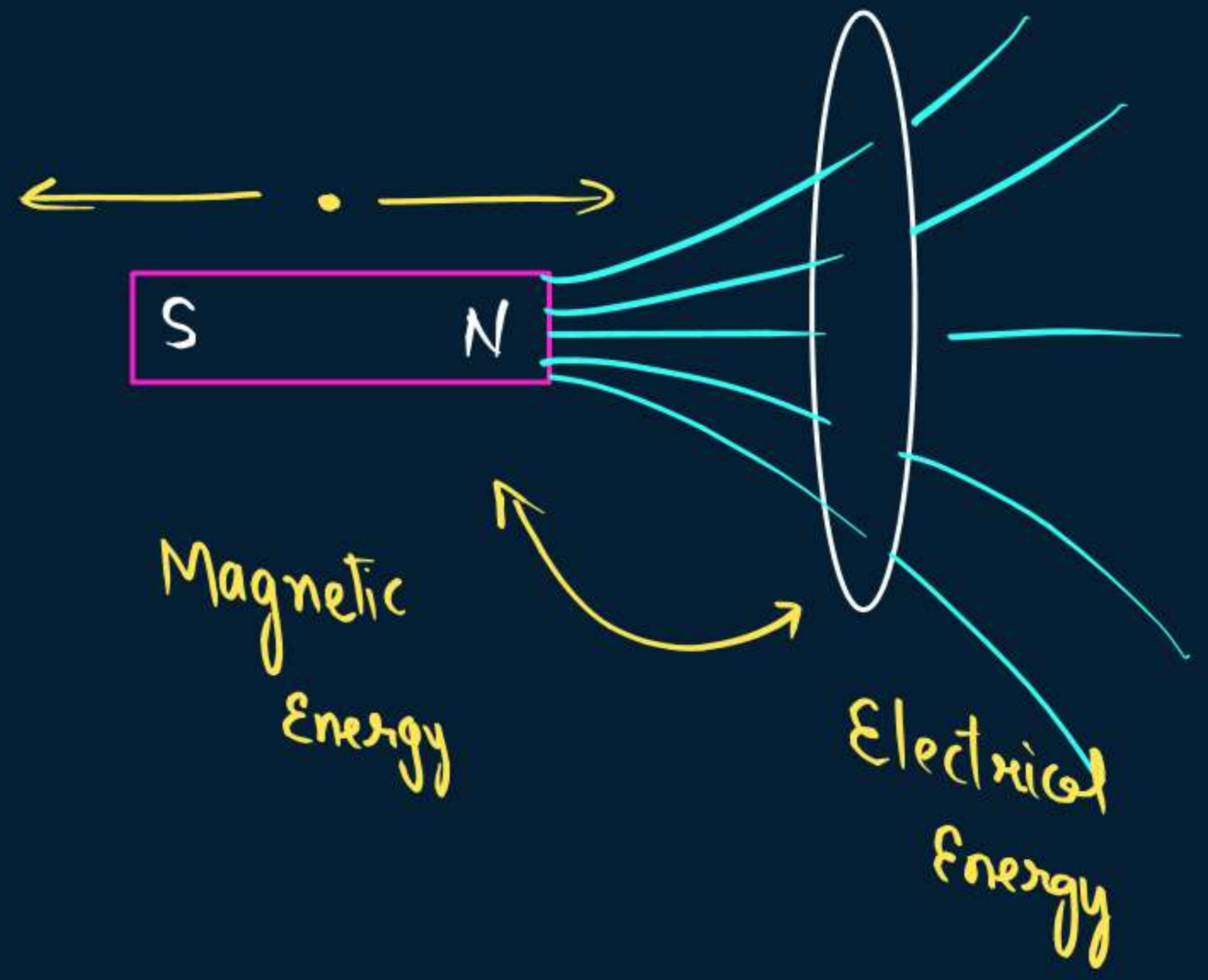
$$\left|\mathcal{E}_{ind}\right| = \frac{d\phi}{dt}$$



Examples on motion of magnet



Lenz Law and Energy Conservation



QUESTION

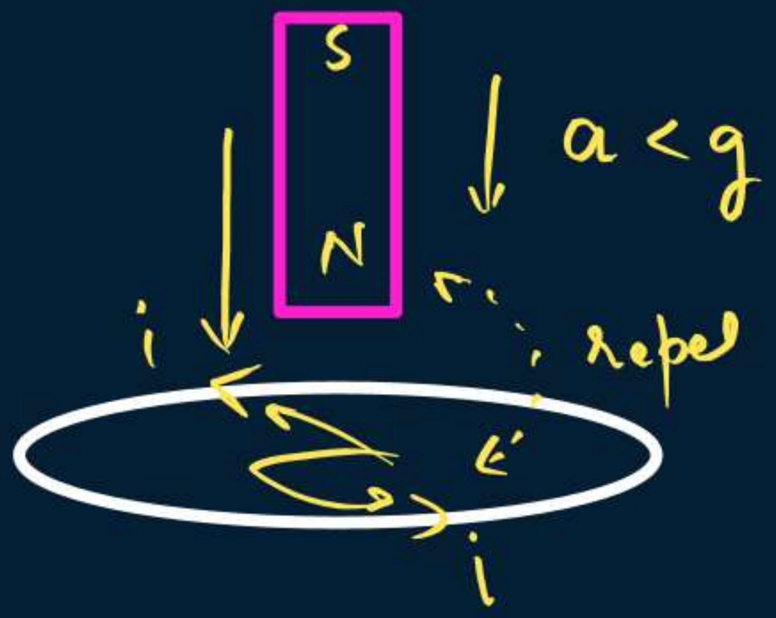
A metal ring is held horizontally and bar magnet is dropped through the ring with its length along the axis of the ring. The acceleration of the falling magnet is

A more than g

B equal to g

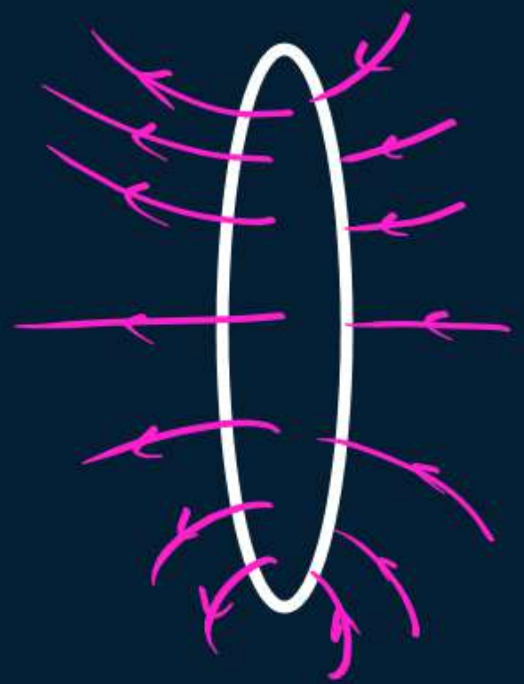
C less than g

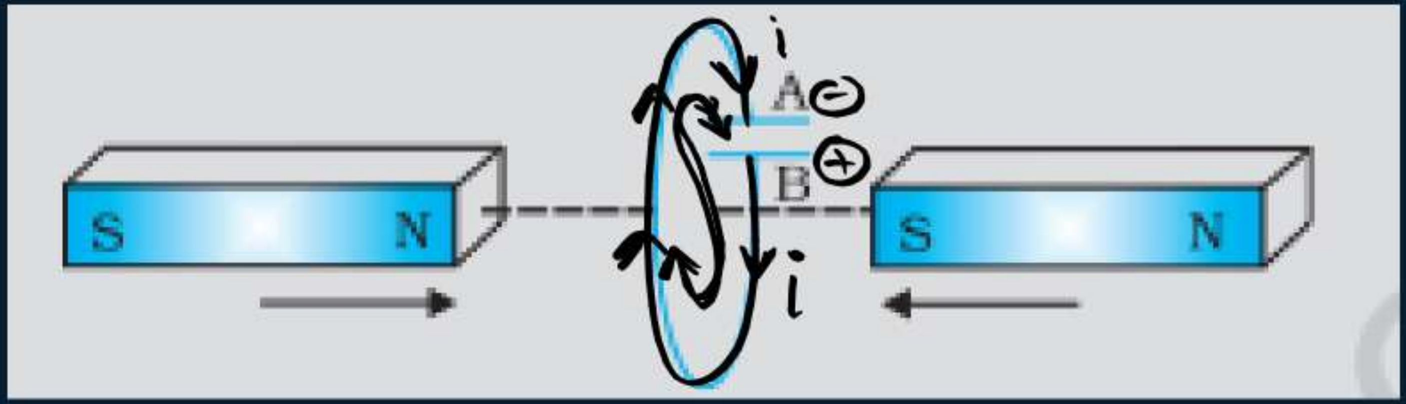
D either (A) or (C)



QUESTION

Predict the polarity of the capacitor in the situation described. Which capacitor plate will be at higher potential → 'B' **[NCERT Example]**





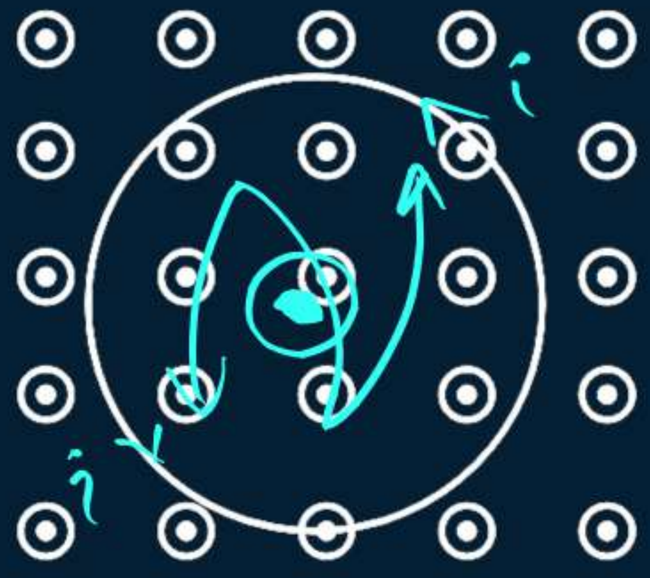
QUESTION

Find:

Shrink $\rightarrow$ $A\downarrow$ $\phi\downarrow$

$i = ?$

CW



Shrink $\rightarrow$ $A\downarrow$ $\phi\downarrow$

$i = ?$

ACW

Expand $\rightarrow$ $A\uparrow$ $\phi\uparrow$

$i \rightarrow$ ACW

Expand $\rightarrow$ $A\uparrow$ $\phi\uparrow$ $i \rightarrow$ CW

QUESTION

A rectangular coil of 20 turns and area of cross-section 25 sq. cm has a resistance of 100 Ω. If a magnetic field which is perpendicular to the plane of coil changes at a rate of 1000 tesla per second, the current in the coil is [1992]

(A) 1 A

(B) 50 A

(C) 0.5 A

(D) 5 A

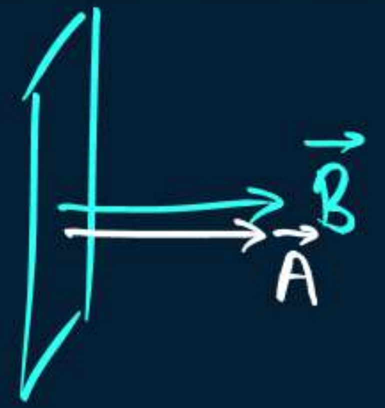
$N = 20$

$A = \frac{25}{10000} \, m^2$

$R = 100 \, \Omega$

$\theta = 0^\circ$

$\frac{dB}{dt} = 1000 \, T/s$



$\varepsilon_{ind} = N\frac{d\phi}{dt}$

$iR = N\frac{d}{dt}(BA\cos\theta)$

$iR = NA\frac{dB}{dt}$

$i = \frac{NA}{R}\frac{dB}{dt}$

$i = \frac{20}{100} \times \frac{25}{10000} \times 1000 = \frac{1}{2} = 0.5A$

QUESTION

$10^{-3} \rightarrow$ milli

$10^{-6} \rightarrow$ micro(μ)

A conducting circular loop is placed in uniform magnetic field, B = 0.025 T with its plane perpendicular to the loop. The radius of the loop is made to shrink at a constant rate of 1 mm s^{-1}. The induced e.m.f. when radius is 2 cm, is [2010]

A) 2 μV

B) 2 πμ V

C) π μV

D) π/2 μV

$B = 0.025\,T$

$\theta = 0^\circ$

$\frac{dr}{dt} = \frac{1}{1000}\,m/s$

$r = \frac{2}{100}\,m$

$\varepsilon_{ind} = \frac{d\phi}{dt}$

$= \frac{d(BA\cos\theta)}{dt}$

$= B.\frac{d(\pi R^2)}{dt}$

$= B.\pi\frac{d(r^2)}{dt}$

$= B\pi 2r.\frac{dr}{dt}$

$= \frac{0.025}{1000}\times\pi\times 2\times\frac{2}{100}\times\frac{1}{1000}$

$\frac{\pi}{10^6}\,V$

$\pi\times 10^{-6}\,V$

$\pi\mu V$

$\frac{dy}{dx} = \frac{d(x^2)}{dx}$

$= 2x$

$\frac{d(r^2)}{dr} = 2r$

$\frac{d(r^2)}{dt} = 2r\frac{dr}{dt}$

QUESTION

H.W.

A conducting circular loop is placed in a uniform magnetic field of 0.04 T with its plane perpendicular to the magnetic field. The radius of the loop starts shrinking at 2 mm/s. The induced emf in the loop when the radius is 2 cm is **[2009]**

A. $4.8\ \pi\mu V$

B. $0.8\ \pi\mu V$

C. $1.6\ \pi\mu V$

D. $3.2\ \pi\mu V$

Examples on motion of loop in magnetic field

i) $i_{ind} \neq 0$

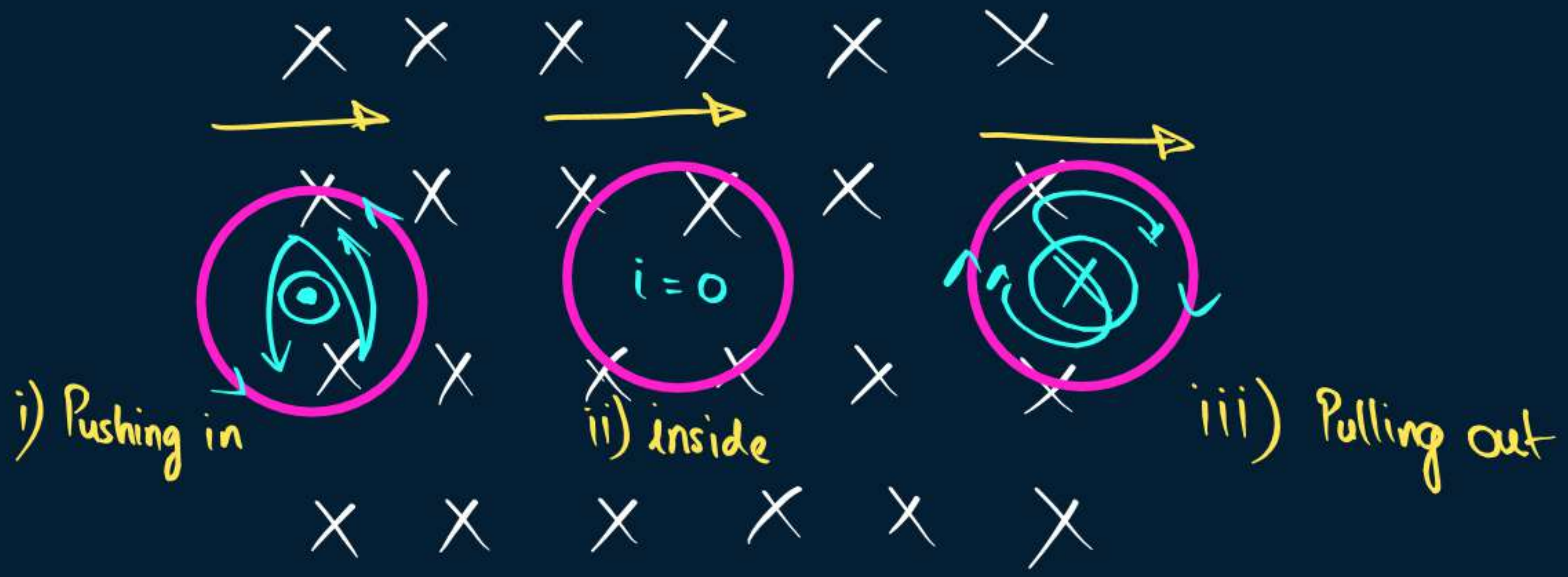
(ACW)

ii) $i_{ind} = 0$

$\phi \rightarrow$ const.

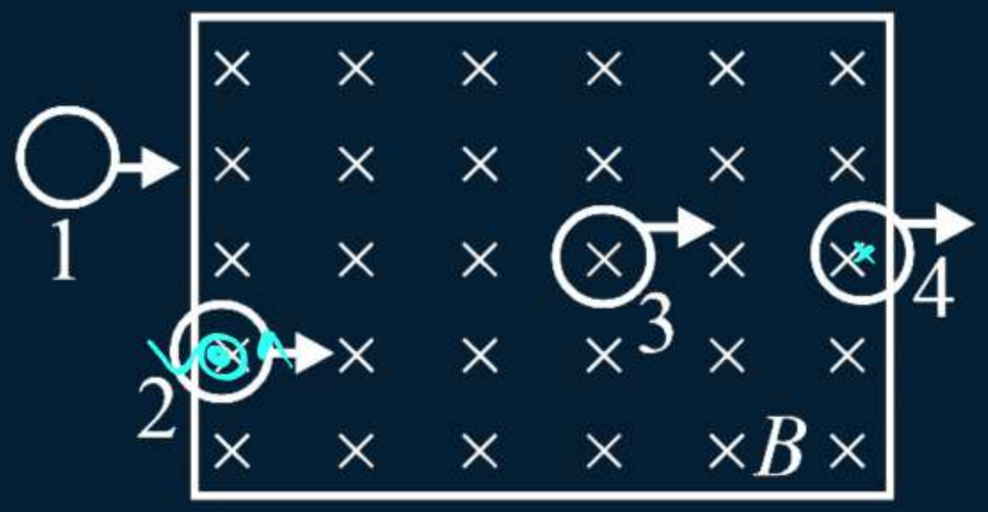
iii) $i_{ind} \neq 0$

(CW)



QUESTION

A conducting loop is moving from left to right through a region of uniform magnetic (B) field. Its four positions are shown below. Show the direction of induced current in all four positions.



$1 \rightarrow i_{ind} = 0$

$2 \rightarrow i_{ind} \neq 0$ (ACW)

$3 \rightarrow i_{ind} = 0$

$4 \rightarrow i_{ind} \neq 0$ (CW)

QUESTION

H.W.

A rectangular, a square, a circular and an elliptical loop, all in the *xy*-plane, are moving out of a uniform magnetic field with a constant velocity, $v = v\hat{i}$. The magnetic field is directed along the negative *z*-axis direction. The induced emf, during the passage of these loops, out of the field region, will not remain constant for

[2009]

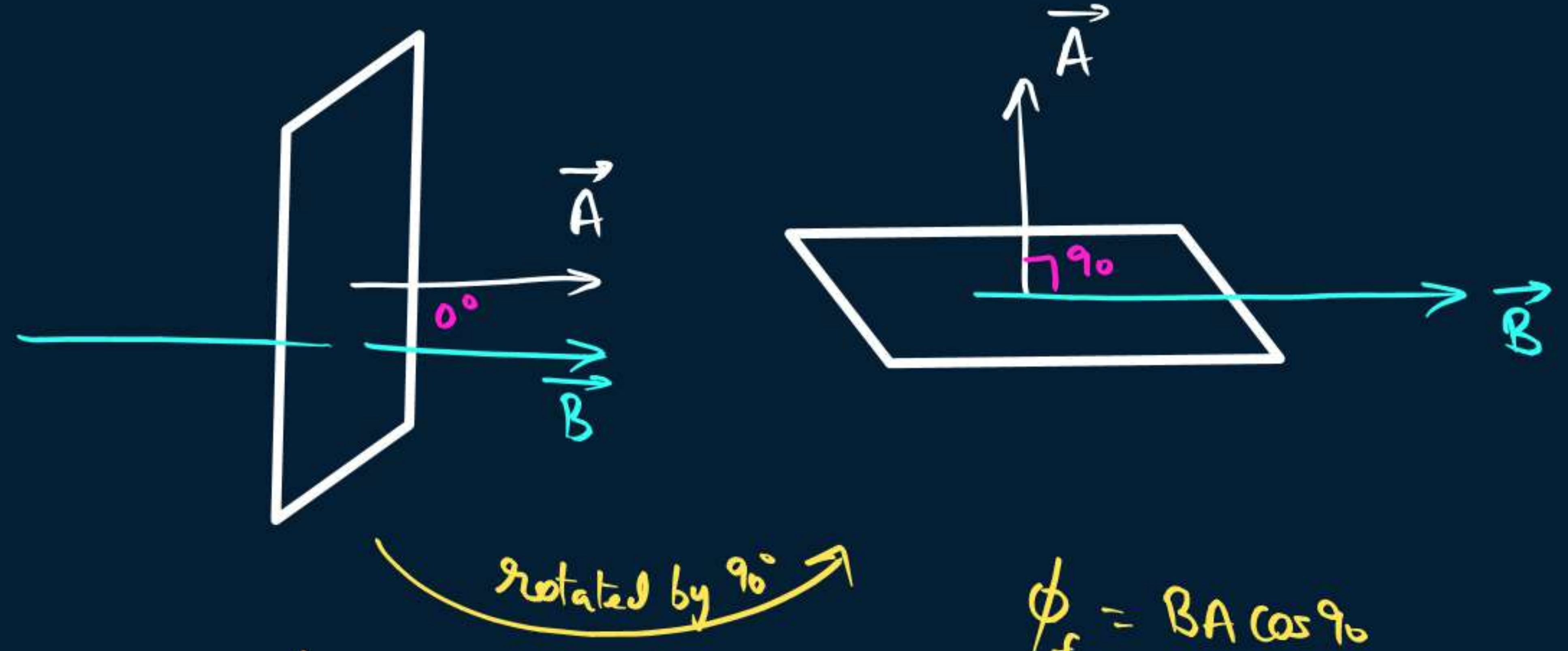
A. the rectangular, circular and elliptical loops

B. the circular and the elliptical loops

C. only the elliptical loop

D. any of the four loops

Examples on changing angle



$\phi_i = BA\cos 0^\circ$

$\phi_i = BA$

$\phi_f = BA\cos 90$

$\phi_f = 0$

$$\boxed{\varepsilon_{ind} = -\frac{\Delta\phi}{\Delta t}}$$

$$= -\frac{(\phi_f - \phi_i)}{\Delta t}$$

$$= -\frac{(0 - BA)}{t}$$

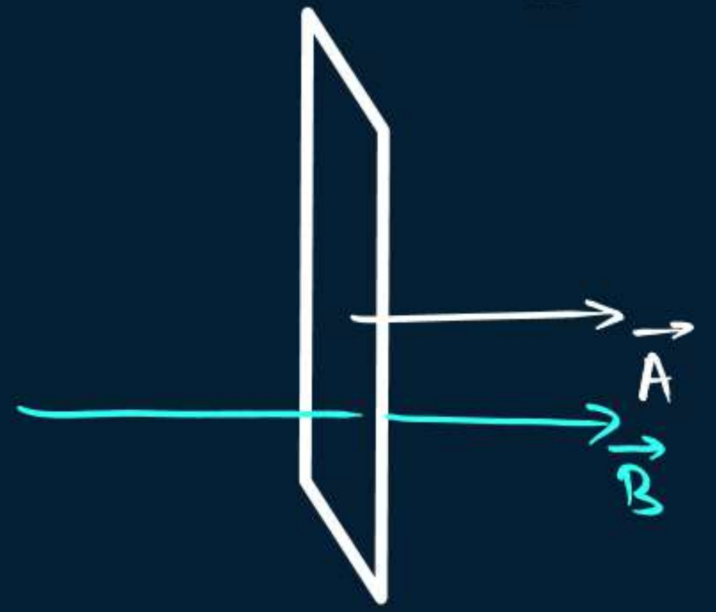
$$\boxed{\varepsilon_{ind} = \frac{BA}{t}}$$

for N-turns

$$\boxed{\varepsilon_{ind} = \frac{NBA}{t}}$$

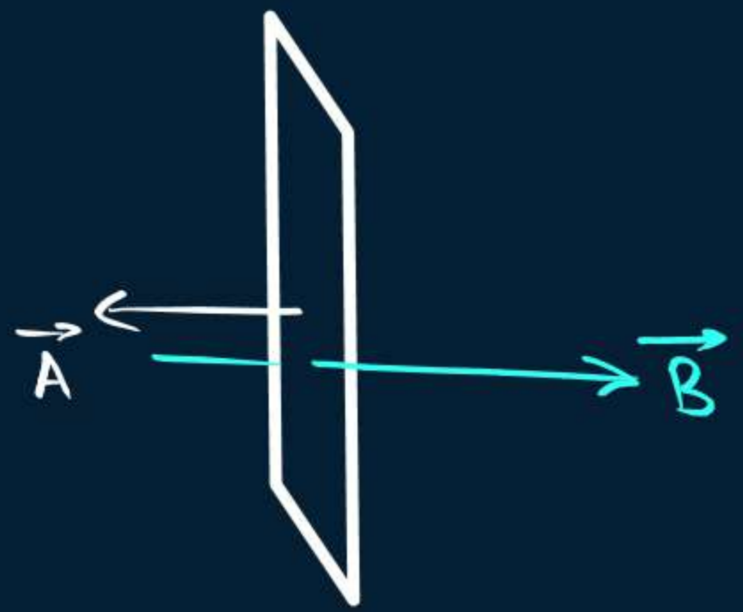
QUESTION

If loop is rotated by 180 degrees, find the induced emf.



$\phi_i = BA\cos 0^\circ$

$\phi_i = BA$



$\phi_f = BA\cos 180^\circ$

$\phi_f = -BA$

$$\varepsilon_{ind} = -\frac{\Delta\phi}{\Delta t}$$

$$\varepsilon_{ind} = -\frac{(\phi_f - \phi_i)}{t}$$

$$= -\left(\frac{-BA - BA}{t}\right)$$

$$= +\left(+\frac{2BA}{t}\right)$$

$$\boxed{\varepsilon_{ind} = \frac{2BA}{t}}$$

for N-turns

$$\boxed{\varepsilon_{ind} = \frac{2NBA}{t}}$$

QUESTION

A 800 turn coil of effective area 0.05 m^2 is kept perpendicular to a magnetic filed 5×10^{-5} T. When the plane of the coil is rotated by 90° around any of its coplanar axis in 0.1 s, the e.m.f. induced in the coil will be: **[2019]**

(A) 2×10^{-3} V

(B) 0.02 V

(C) 2 V

(D) 0.2 V

$N = 800$

$A = 0.05\ m^2$

$\theta_i = 0°$

$B = 5 \times 10^{-5}$

$\theta_f = 90°$

$t = 0.1\ s$

$$\boxed{\mathcal{E}_{ind} = N\frac{BA}{t}}$$

$$= \frac{5 \times 10^{-5} \times 0.05}{0.1} \times \frac{10}{100} \times 800$$

$$= 200 \times 10 \times 10^{-5}$$

$$= \frac{2000}{100000}$$

$$= 0.02\ V$$

Induced Charge Flow through the coil

$$\boxed{\varepsilon_{ind} = \frac{d\phi}{dt}}$$

by ohm's law..

$$i_{ind} R = \frac{d\phi}{dt}$$

$$\boxed{i_{ind} = \frac{1}{R}\frac{d\phi}{dt}}$$

$$\frac{dq_{ind}}{\cancel{dt}} = \frac{1}{R}\frac{d\phi}{\cancel{dt}}$$

$$\boxed{dq_{ind} = \frac{d\phi}{R}} \quad \text{OR} \quad \boxed{\Delta Q_{ind} = \frac{\Delta\phi}{R}}$$

QUESTION

The magnetic flux through a circuit of resistance R changes by an amount $\Delta\phi$ in a time Δt. Then the total quantity of electric charge Q that passes any point in the circuit during the time Δt is represented by [2004]

$$\boxed{\Delta Q = \frac{\Delta \phi}{R}}$$

(A) ~~$Q = R.\frac{\Delta\phi}{\Delta t}$~~

(B) ~~$Q = \frac{1}{R}.\frac{\Delta\phi}{\Delta t}$~~

(C) $Q = \frac{\Delta\phi}{R}$

(D) ~~$Q = \frac{\Delta\phi}{\Delta t}$~~

QUESTION

The total charge induced in a conducting loop when it is moved in magnetic field depends on

A) ~~the rate of change of magnetic flux~~ $\rightarrow \frac{d\phi}{dt}$

B) ~~initial magnetic flux~~

C) the total change in magnetic flux $\Delta\phi$

D) ~~final magnetic flux~~

$dq = \frac{d\phi}{R}$

QUESTION

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: **[2012]**

A 8

B 2

C 6

D 4

$R = 10\Omega$

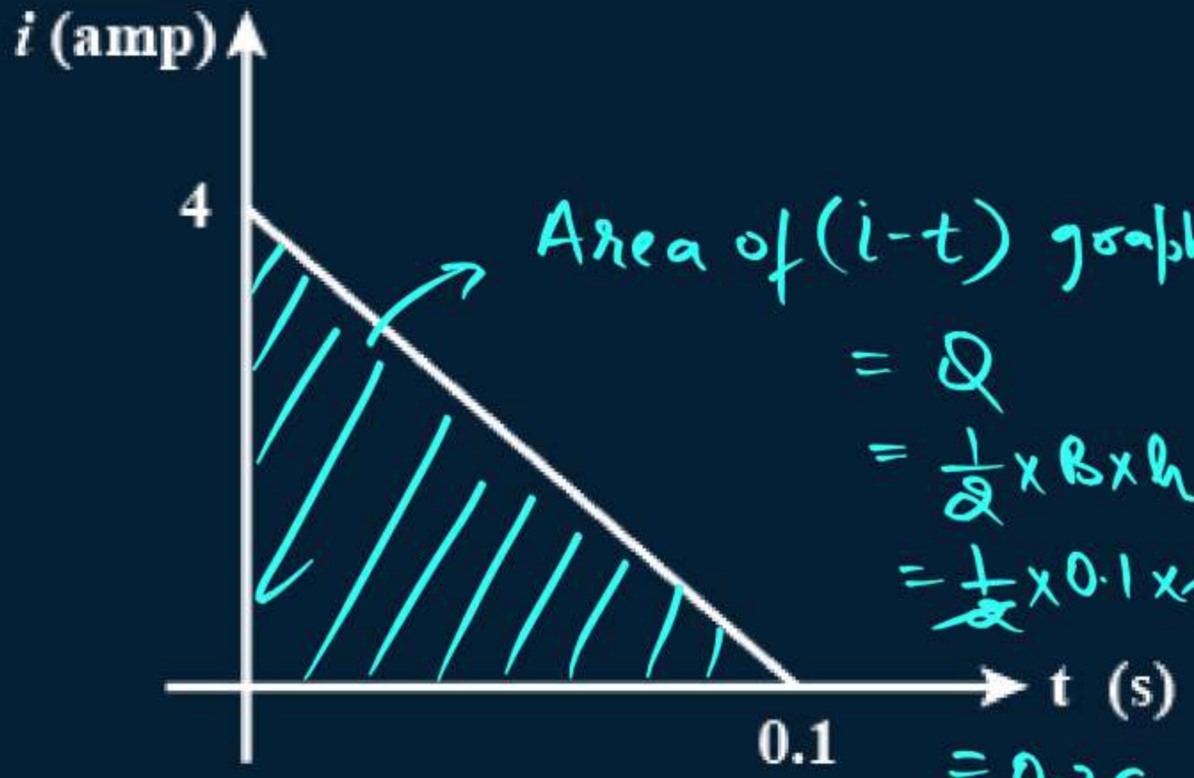
$\Delta\phi = ?$

$\Delta Q = \dfrac{\Delta\phi}{R}$

$\Delta\phi = R\Delta Q$

$= 10 \times 0.2$

$\Delta\phi = 2\ Wb$



Area of (i-t) graph

$= Q$

$= \frac{1}{2} \times B \times h$

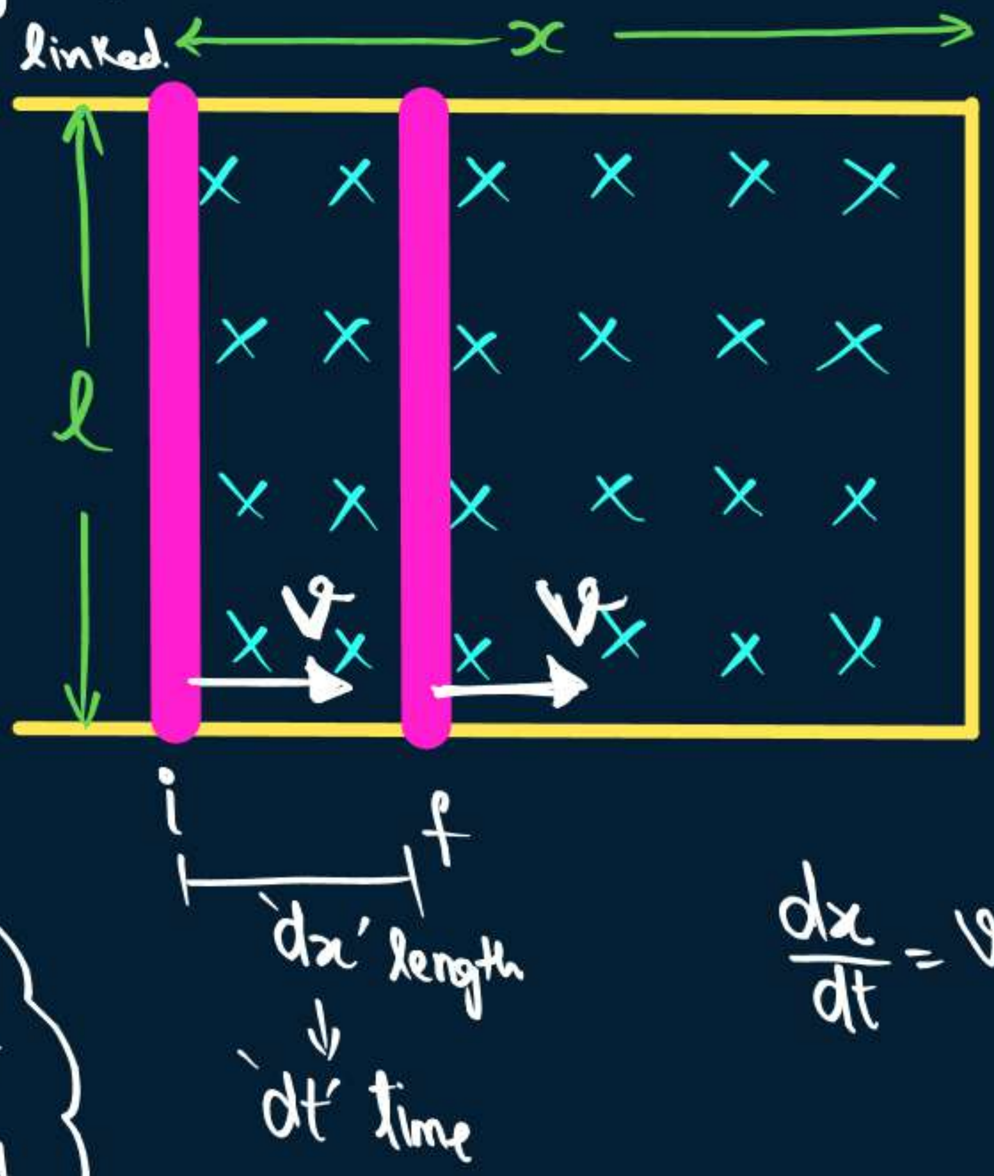
$= \frac{1}{2} \times 0.1 \times 4$

$= 0.2C$

Motional EMF

The EMF induced due to motion of conductor in magnetic field.

let the distance 'dx' be travelled by a rod of length 'l' in a uniform m.f. 'B' in 'dt' time. which ultimately changes the Area and the flux linked.



$$\mathcal{E}_{ind} = \frac{d\phi}{dt}$$

$$= \frac{d}{dt}(BA\cos\theta)$$

$$= B\frac{dA}{dt} \quad [\theta = 0^\circ]$$

* $\boxed{\mathcal{E}_{ind} = Bl v}$

effective length as a component $\perp$ to velocity

RD*

$$= B\frac{d(l \times x)}{dt}$$

$$= Bl\left(\frac{dx}{dt}\right)$$

$$\mathcal{E}_{ind} = Blv$$

$$\frac{dx}{dt} = v$$

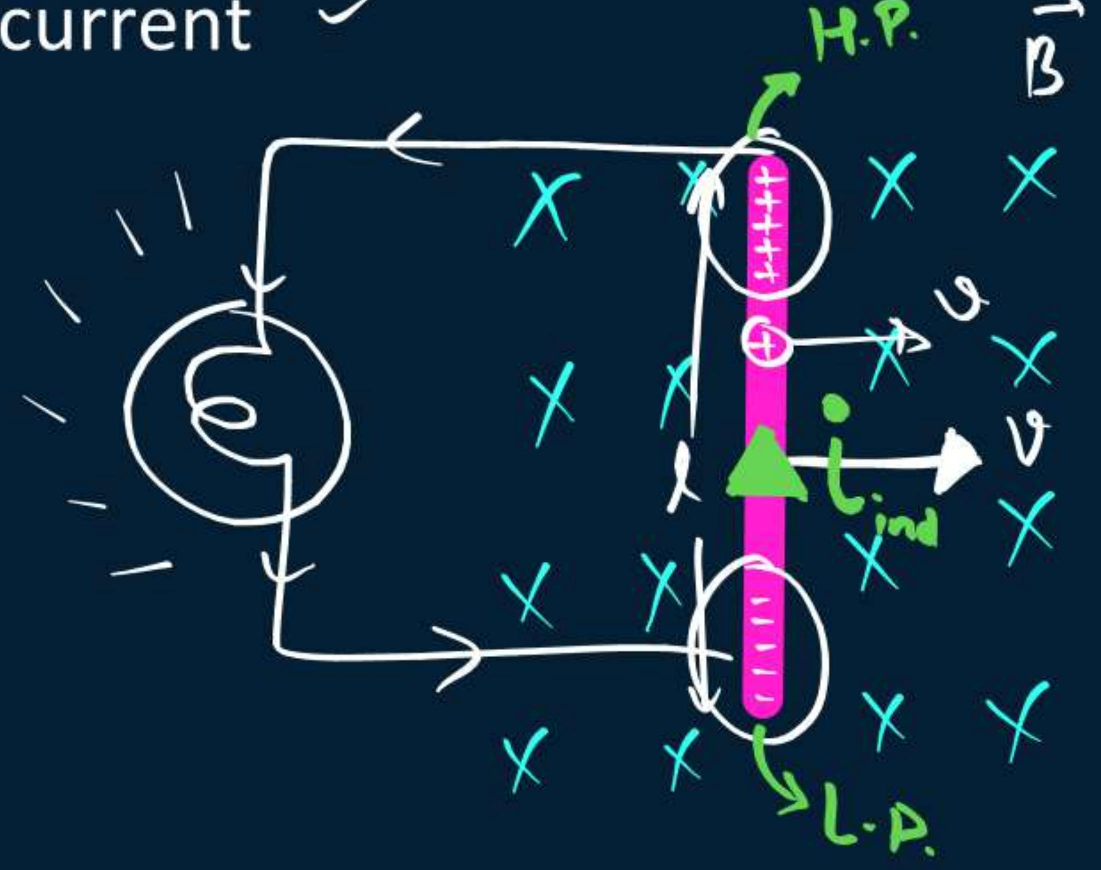
Fleming right hand rule

$$\varepsilon_{ind} = Blv$$

First finger – Magnetic Field ✓

Middle (Central) Finger - Induced current ✓

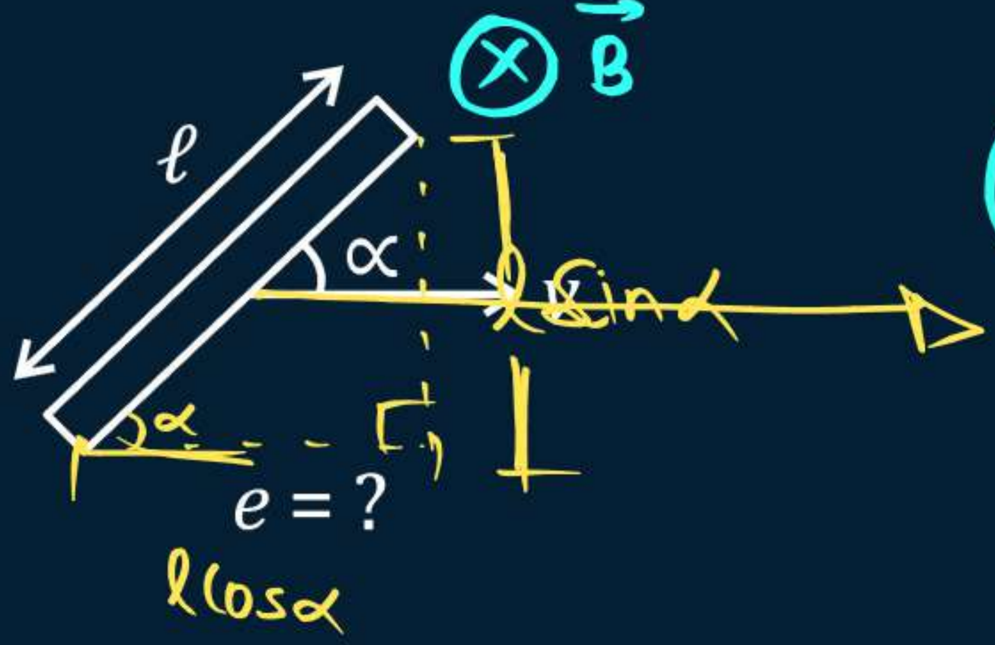
Thumb - Motion of conductor ✓



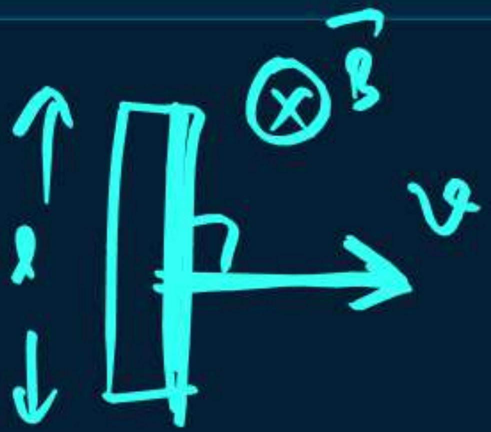
$$\vec{F} = q(\vec{v} \times \vec{B})$$

QUESTION

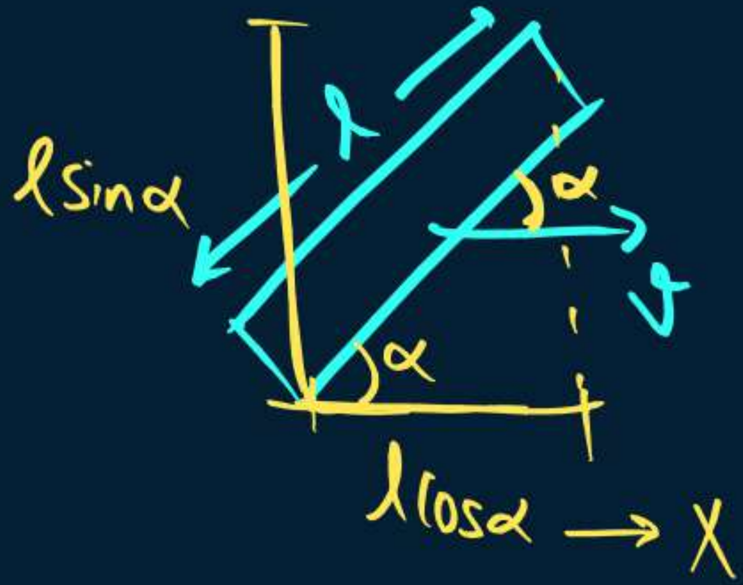
Find:



$$\mathcal{E}_e = Blv$$



$l \perp v$

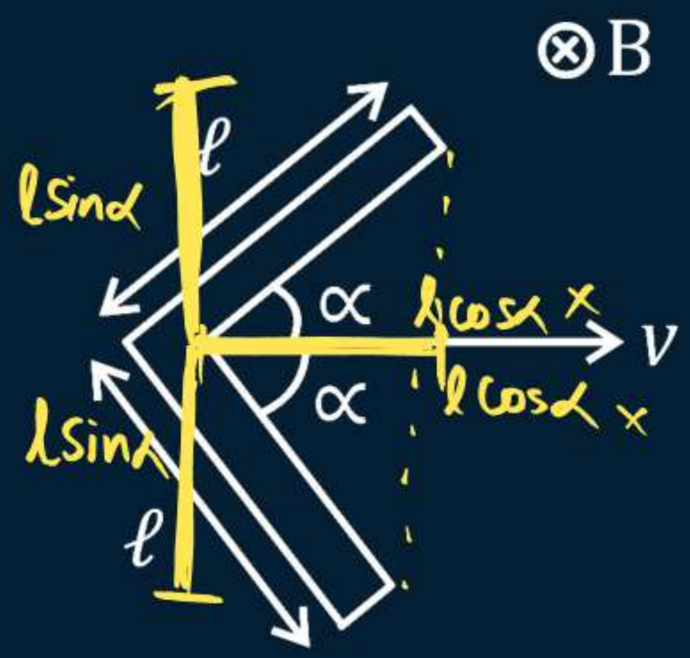


$$\mathcal{E}_e = B(l\sin\alpha)v$$

$$\mathcal{E}_{ind} = Blv\sin\alpha$$

QUESTION

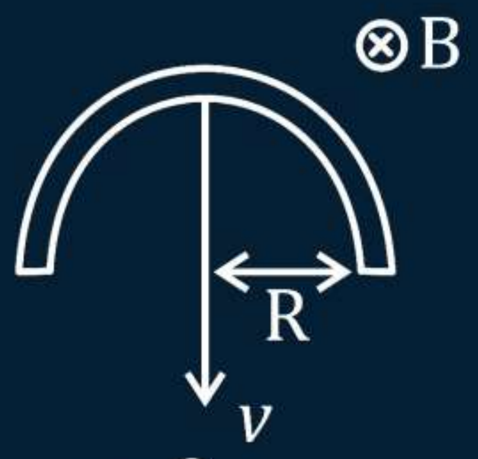
Find:



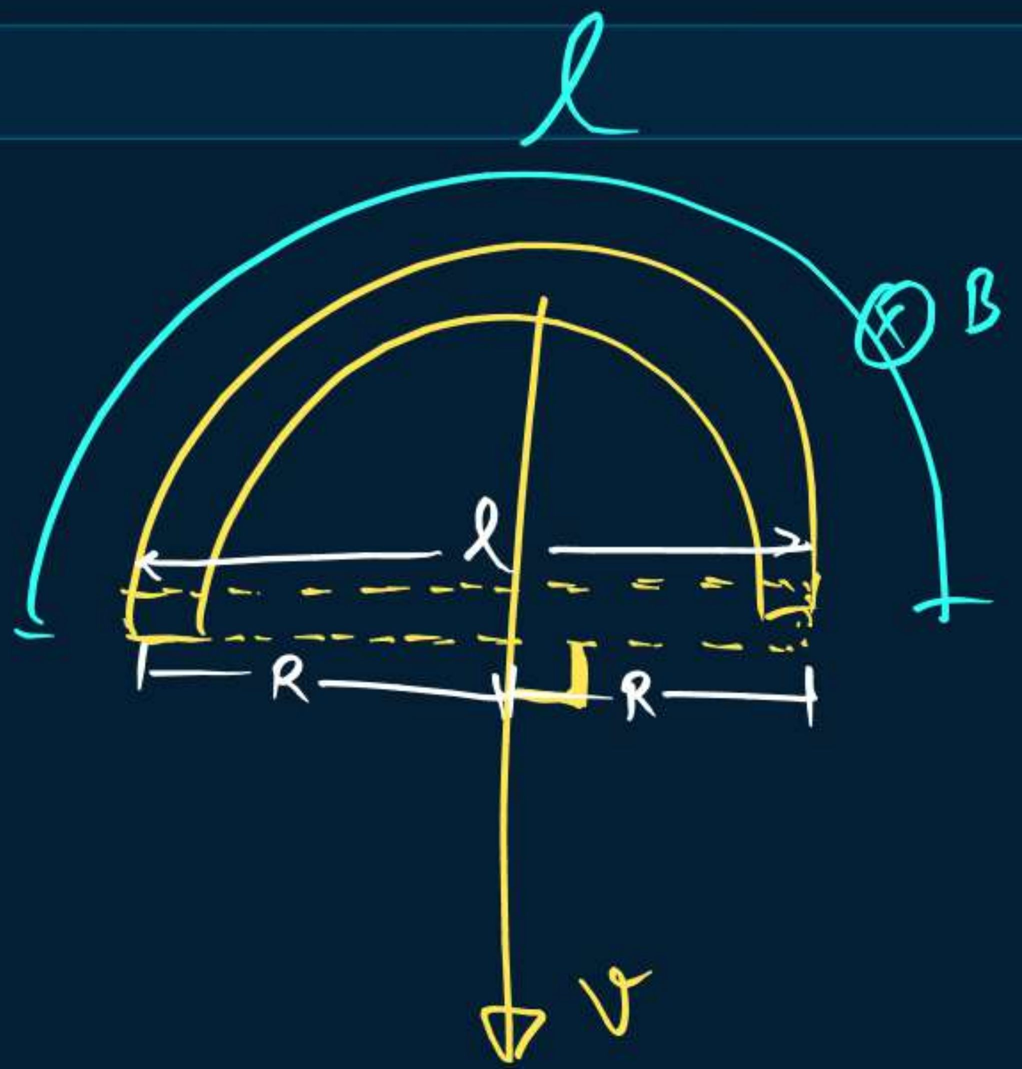
$$\varepsilon_{ind} = B(2l\sin\alpha)v$$

QUESTION

Find:



$e = ?$



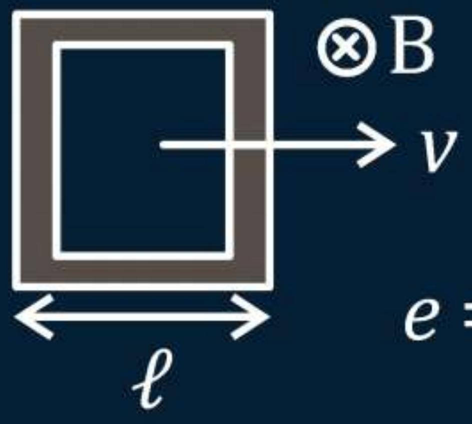
$\varepsilon_e = B(2R)v$

$= 2BRv$

QUESTION

H.W.

Find:



$e = ?$

QUESTION

A conductor of length 0.4 m is moving with a speed of 7 m/s perpendicular to a magnetic field of intensity 0.9 Wb/m^2. The induced emf across the conductor is

[CBSE AIPMT 1995]

A. 1.26 V

B. 2.52 V

C. 5.04 V

D. 25.2 V

$l = 0.4\ m$

$v = 7\ m/s$

$B = 0.9\ Wb/m^2$ or T

$\varepsilon_e = Blv$

$= 0.9 \times 0.4 \times 7$

$= \frac{9 \times 4 \times 7}{100} = \frac{280}{100}$

$= 2.8$

Homework

- Notes
- Revision
- DPP - 1

PARISHRAM

2026

Lecture - 03

Electromagnetic Induction

PHYSICS LECTURE - 3

BY - RAKSHAK SIR

Topics *to be covered*

- **A** # Rotational Emf
- **B** # Self Inductance
- **C** # Mutual Inductance
- **D** #

QUESTION

H.W.

A conducting circular loop is placed in a uniform magnetic field of 0.04 T (B) with its plane perpendicular to the magnetic field. The radius of the loop starts shrinking at 2 mm/s. The induced emf in the loop when the radius is 2 cm (r) is [2009]

A) $4.8\ \pi\mu V$

B) $0.8\ \pi\mu V$

C) $1.6\ \pi\mu V$

D) $3.2\ \pi\mu V$

$$\varepsilon = \frac{d\phi}{dt}$$

$$= \frac{d(BA\cos\theta)}{dt}$$

$$= B\frac{d(\pi r^2)}{dt}$$

$$= B\pi\frac{d(r^2)}{dt}$$

$$= B\pi\, 2r \cdot \frac{dr}{dt}$$

$$= \frac{0.04}{100} \times \pi \times 2 \times \frac{2}{100} \times \frac{2}{1000}$$

$$= \frac{32\pi}{1000000\cancel{0}}$$

$$= \frac{3.2\pi}{10^6}$$

$$= 3.2\pi\, 10^{-6}$$

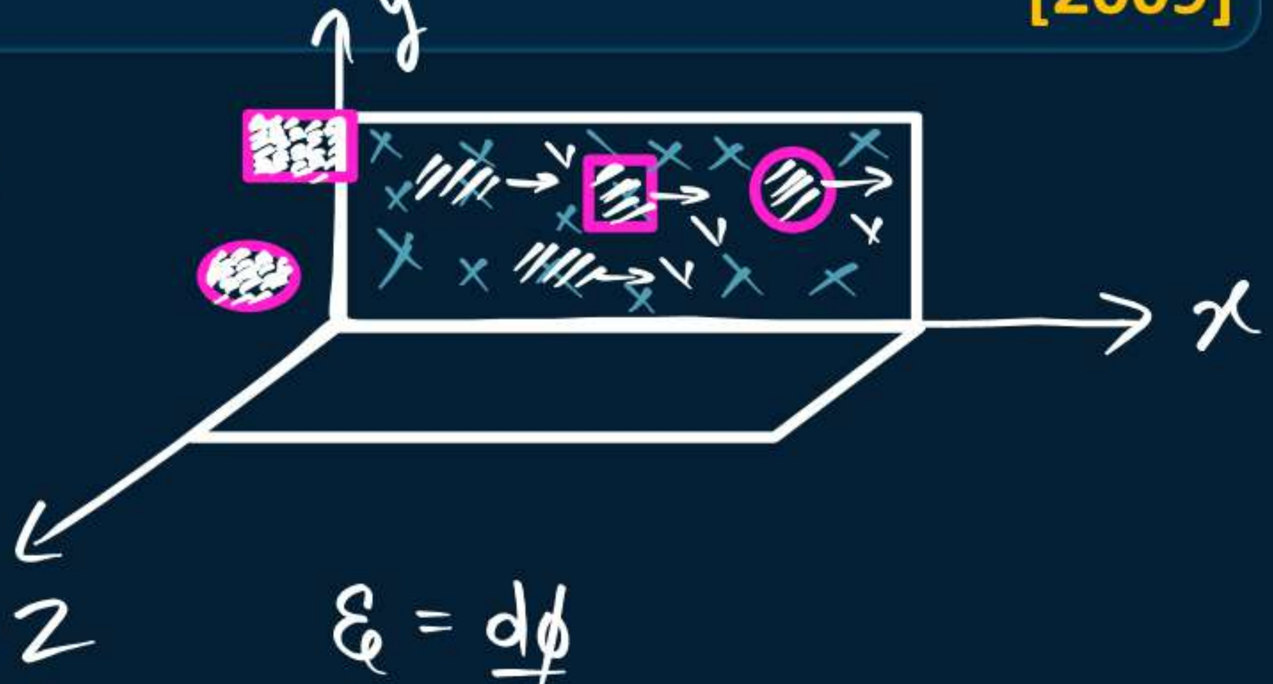
$$\varepsilon = 3.2\pi\mu V$$

QUESTION

H.W.

A rectangular, a square, a circular and an elliptical loop, all in the *xy*-plane, are moving out of a uniform magnetic field with a constant velocity, $v = v\hat{\imath}$. The magnetic field is directed along the negative *z*-axis direction. The induced emf, during the passage of these loops, out of the field region, will not remain constant for

[2009]



A the rectangular, circular and elliptical loops

B the circular and the elliptical loops

C only the elliptical loop

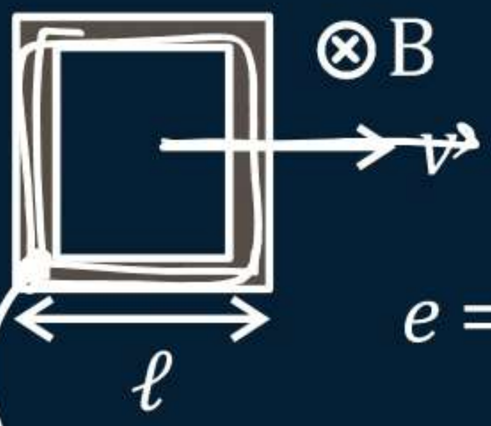
D ~~any of the four loops~~

$\varepsilon = \frac{d\phi}{dt}$

QUESTION

H.W.

Find:



$e = ?$

$\ell_{eff} = 0$

$\varepsilon = 0$

$\varepsilon = B\ell v$

$\varepsilon = 0$

$i = 0$

ind emf $\leftarrow$ $\boxed{\varepsilon_{ind} = Blv}$

$$iR = Blv$$

ind. current $\leftarrow$ $\boxed{i_{ind} = \frac{Blv}{R}}$

$$F = Bi_{ind}l$$

$$F = B\frac{Blv}{R}l$$

Force $\leftarrow$ $\boxed{F = \frac{B^2l^2v}{R}}$

$$P = Fv$$

$$P = \frac{B^2l^2v}{R}\cdot v$$

$$\boxed{P = \frac{B^2l^2v^2}{R} \qquad P = \frac{(Blv)^2}{R}}$$

Y.K.B.

$$P = \frac{W}{t}$$

$$= F\cdot\left(\frac{s}{t}\right)$$

$$P = \vec{F}\cdot\vec{V}$$

$$P = Fv\cos\theta$$

Rotational EMF

let a rod of length 'l' is rotating in a uniform m.f. B, with angular speed 'ω'

$\mathcal{E}_{ind} = B l v$

let's take an element of length 'dx' at a dist. 'x' from pivot.

$d\mathcal{E}_{ind} = B\, dx\, v$

$d\mathcal{E} = B\, dx\, x\omega \quad [\because v = x\omega]$

$d\mathcal{E} = B\omega\, x \cdot dx$

Int. both sides

$\int d\mathcal{E} = \int B\omega\, x \cdot dx$

$\int_0^{\mathcal{E}} d\mathcal{E} = B\omega \int_0^{l} x \cdot dx$

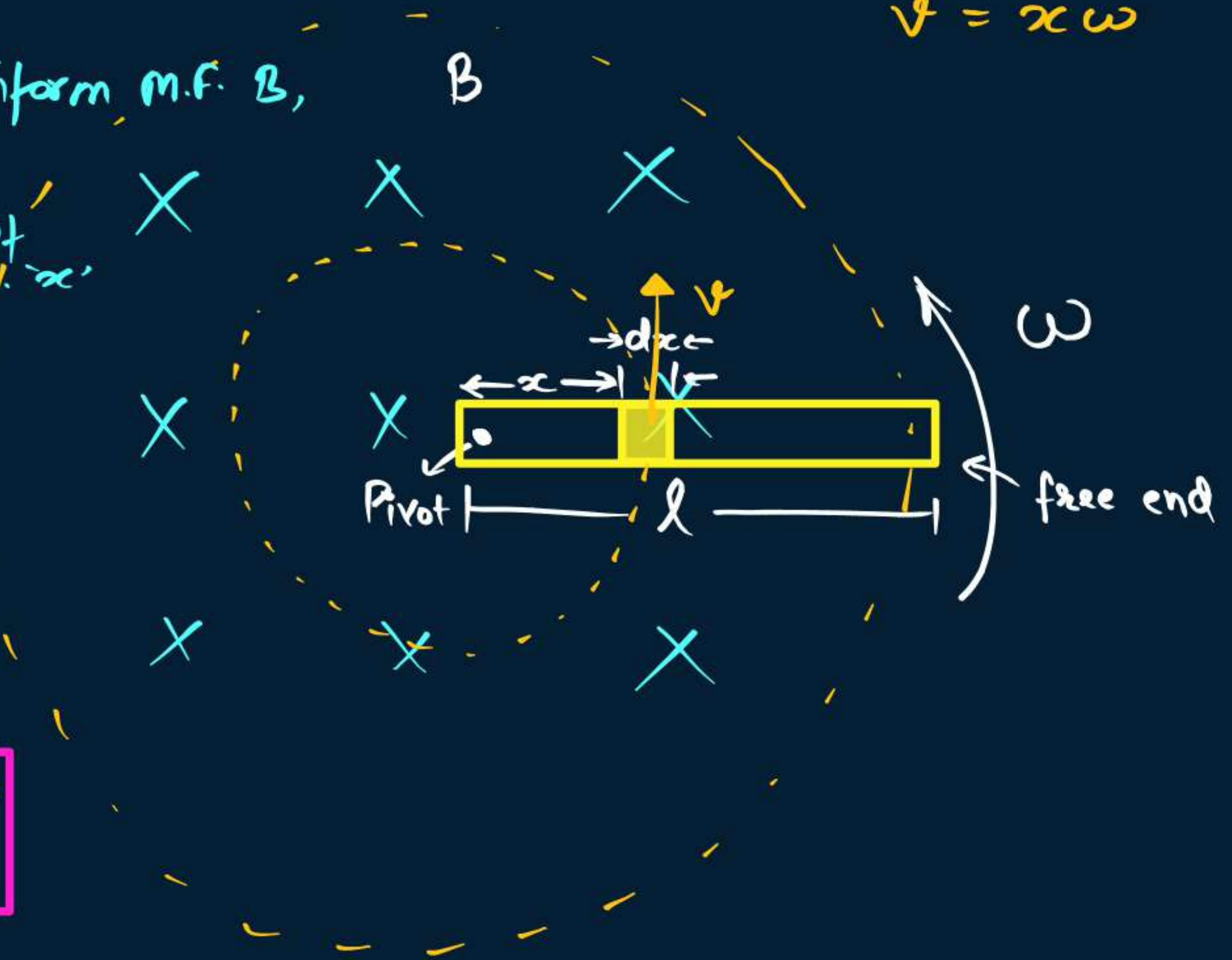
$(\mathcal{E} - 0) = B\omega \left[\frac{x^2}{2}\right]_0^{l}$

$\mathcal{E}_{ind} = B\omega \frac{l^2}{2}$

$\boxed{\mathcal{E}_{ind} = \frac{1}{2} B\omega l^2}$

$v = R\omega$

$v = x\omega$



QUESTION

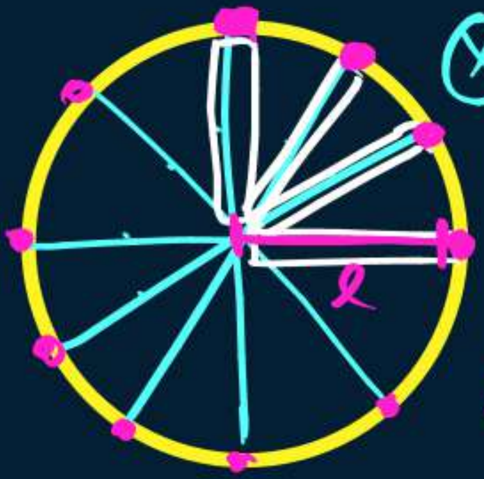
H.W.

$\omega = \frac{2\pi}{T} = \frac{2\pi}{60}$

$1T = 10^4 G$

A wheel of 10 spokes is rotating in a cross magnetic field of 0.4 gauss with 120 rev/min. The radius of wheel = 0.5 m. Find emf induced between center and rim of the wheel.

[Similar to NCERT Example]



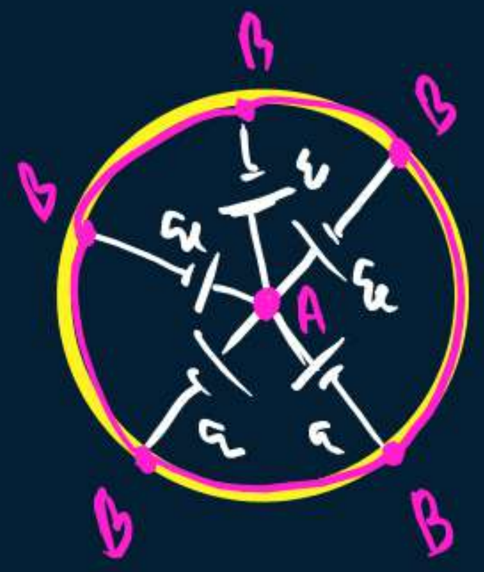
$\otimes \vec{B} = 0.4G$

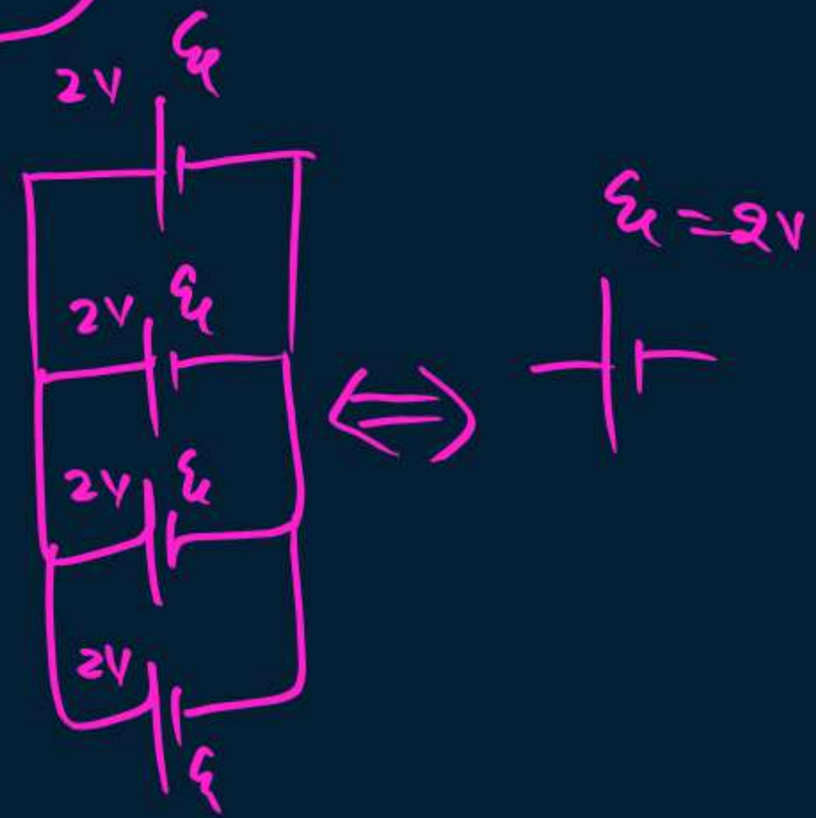
$rpm = 120$

$l = r = 0.5\,m$

$\varepsilon_{ind} =$

$$\boxed{\varepsilon_{ind} = \frac{1}{2} B \omega l^2}$$





QUESTION

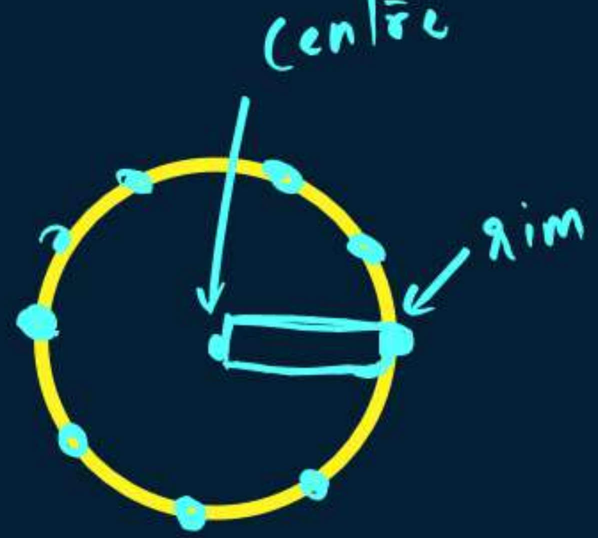
A cycle wheel of radius 0.5 m is rotated with constant angular velocity of 10 rad/s in a region of magnetic field of 0.1 T which is perpendicular to the plane of the wheel. The EMF generated between its centre and the rim is **[NEET (Odisha) 2019]**

(A) 0.25 V

(B) 0.125 V

(C) 0.5 V

(D) zero



$\varepsilon_{ind} = \frac{1}{2} B\omega l^2$

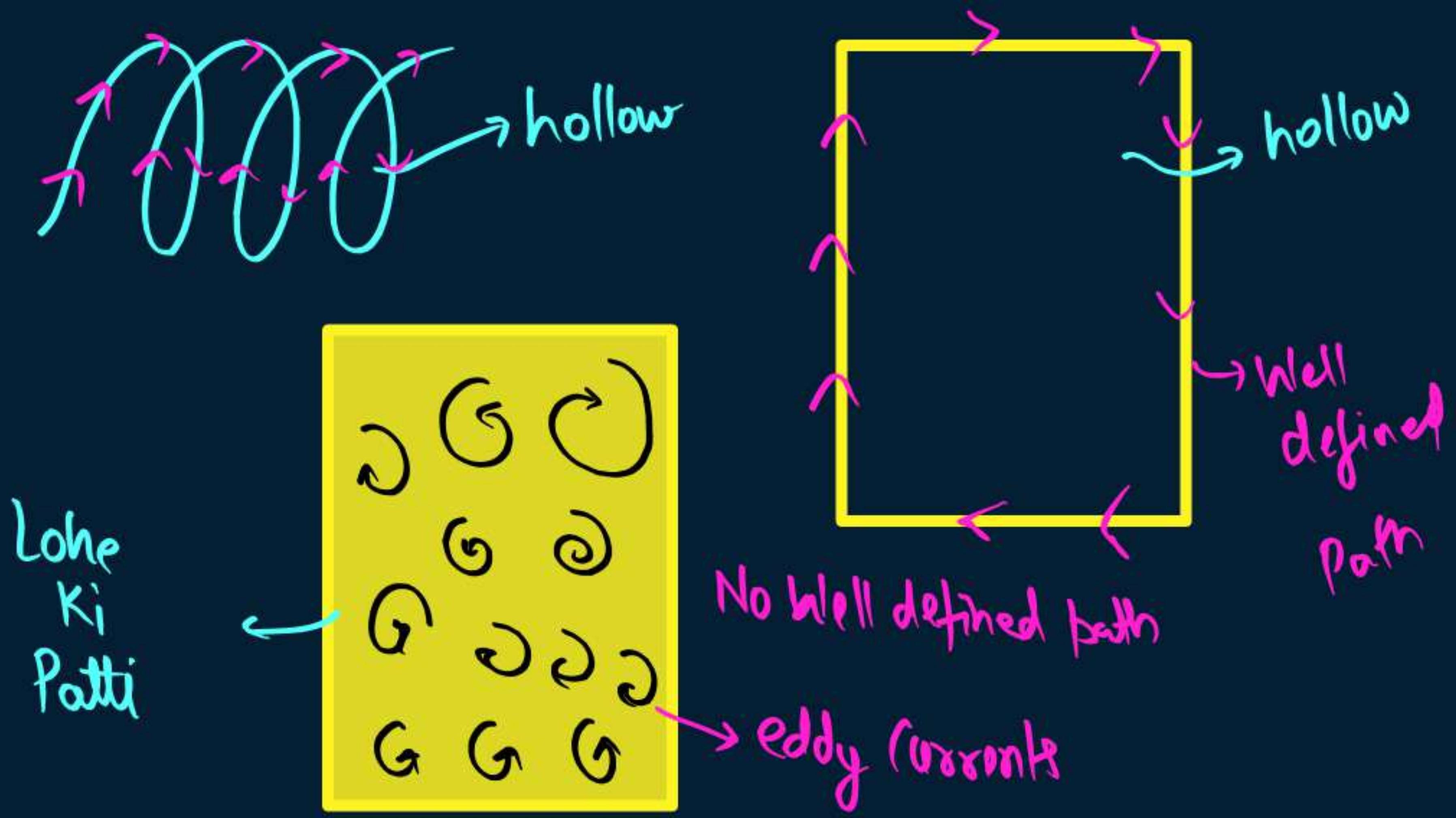
$= \frac{1}{2} \times 0.1 \times 10 \times 0.5 \times 0.5$

rim and rim

$(\varepsilon = 0)$

Eddy Currents

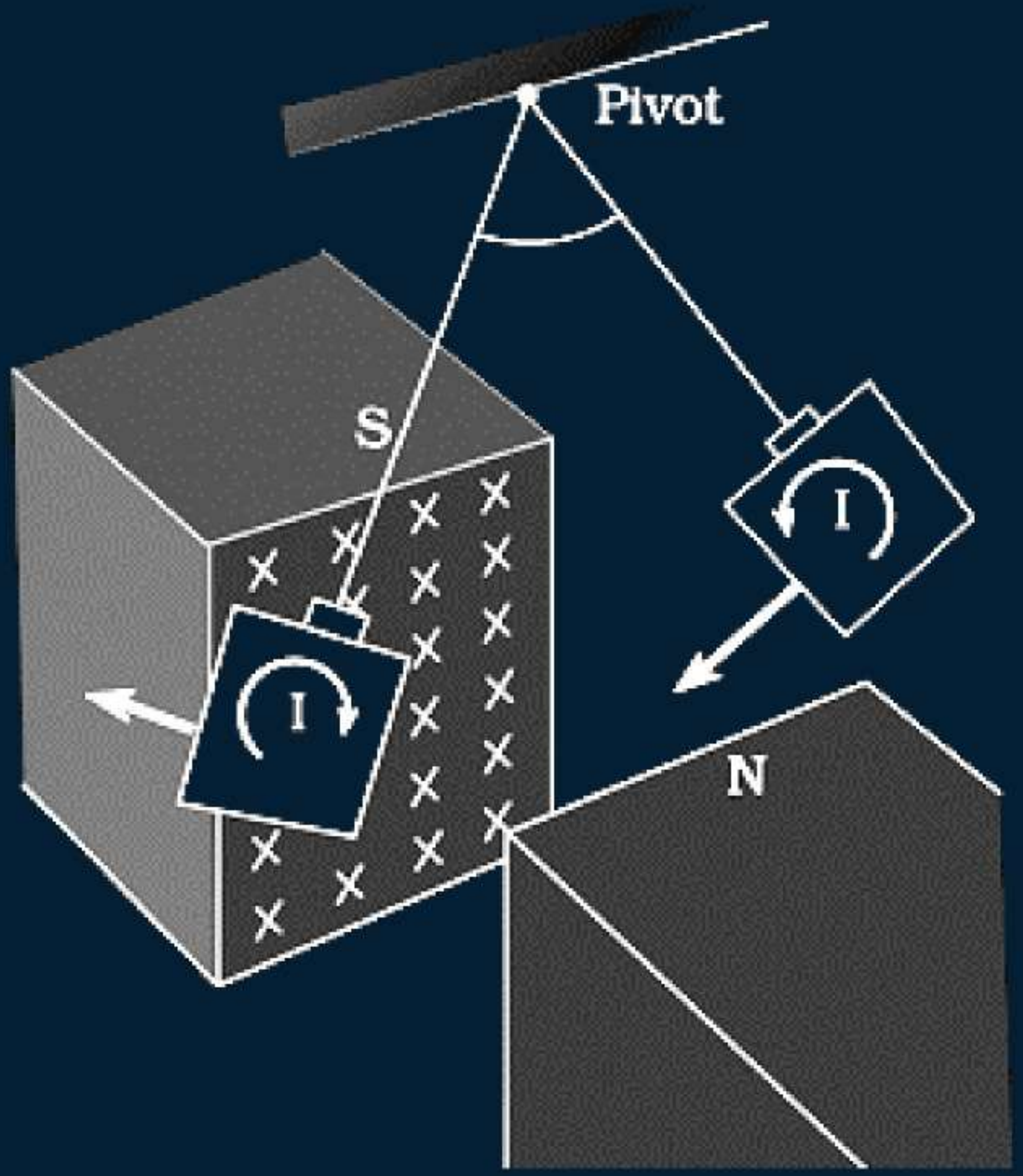
The induced currents produced in the bulk pieces of conductors.



- Current is not in well defined paths.
- Their flow patterns resemble swirling eddies in water and these currents are called eddy currents.

Applications of Eddy Currents

1. Electromagnetic Damping



A copper plate is allowed to swing like a simple pendulum two magnets.

Motion is damped and in a little while the plate comes to rest.

↳ Weak

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 opposite when the plate swings into the region between the poles and when it swings out of the region.

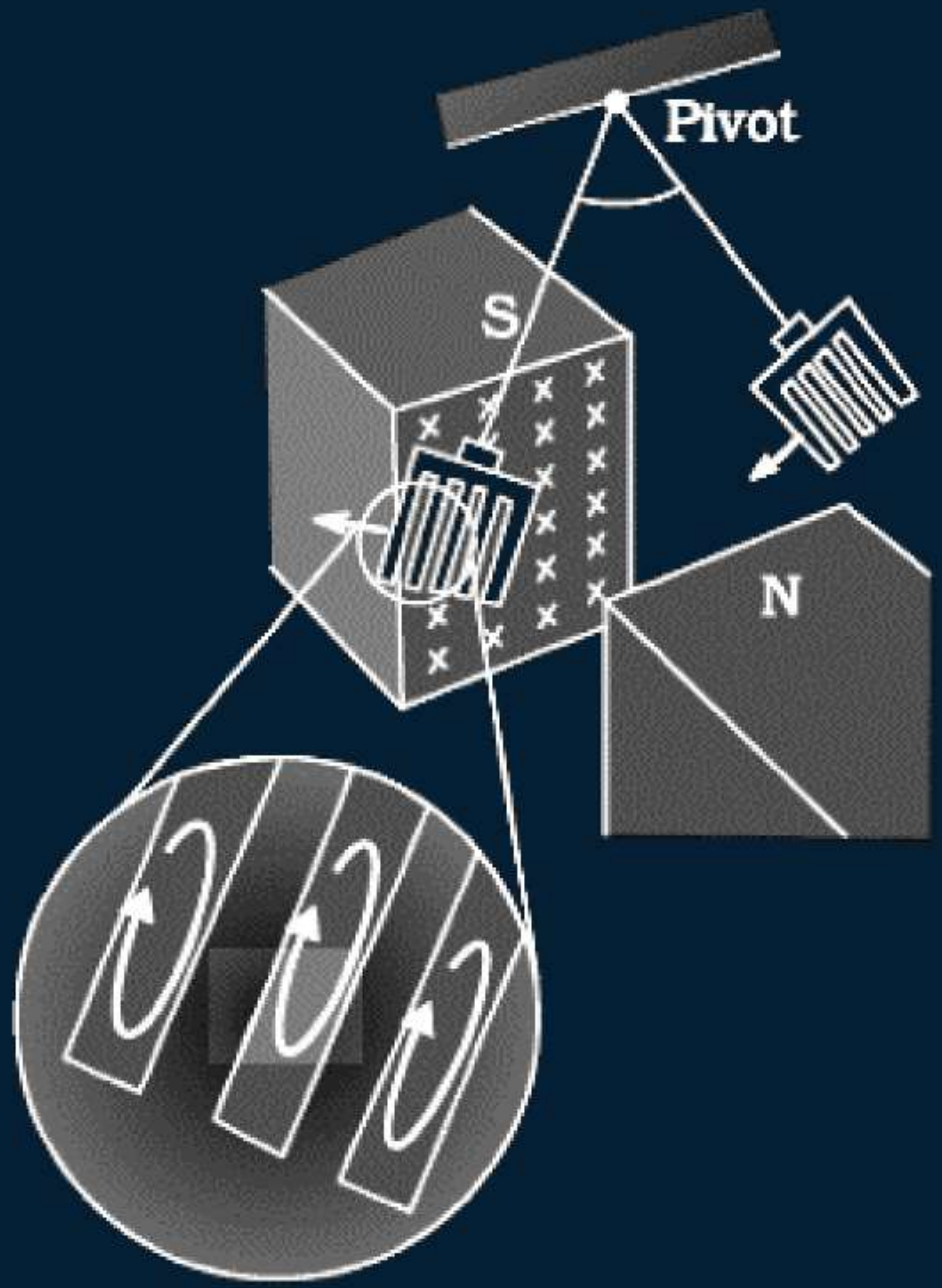
- If rectangular slots are made in the copper plate, area available to the flow of eddy currents is less and damping is reduced.

- Used in the metallic cores of transformers, electric motors and other such devices.

- Eddy currents are undesirable since they heat up the core and dissipate electrical energy in the form of heat.

$R\uparrow \propto l\uparrow$

$i\downarrow$



Dead Beat Galvanometers

When the coil oscillates, the eddy currents generated in the core oppose the motion and bring the coil to rest quickly.

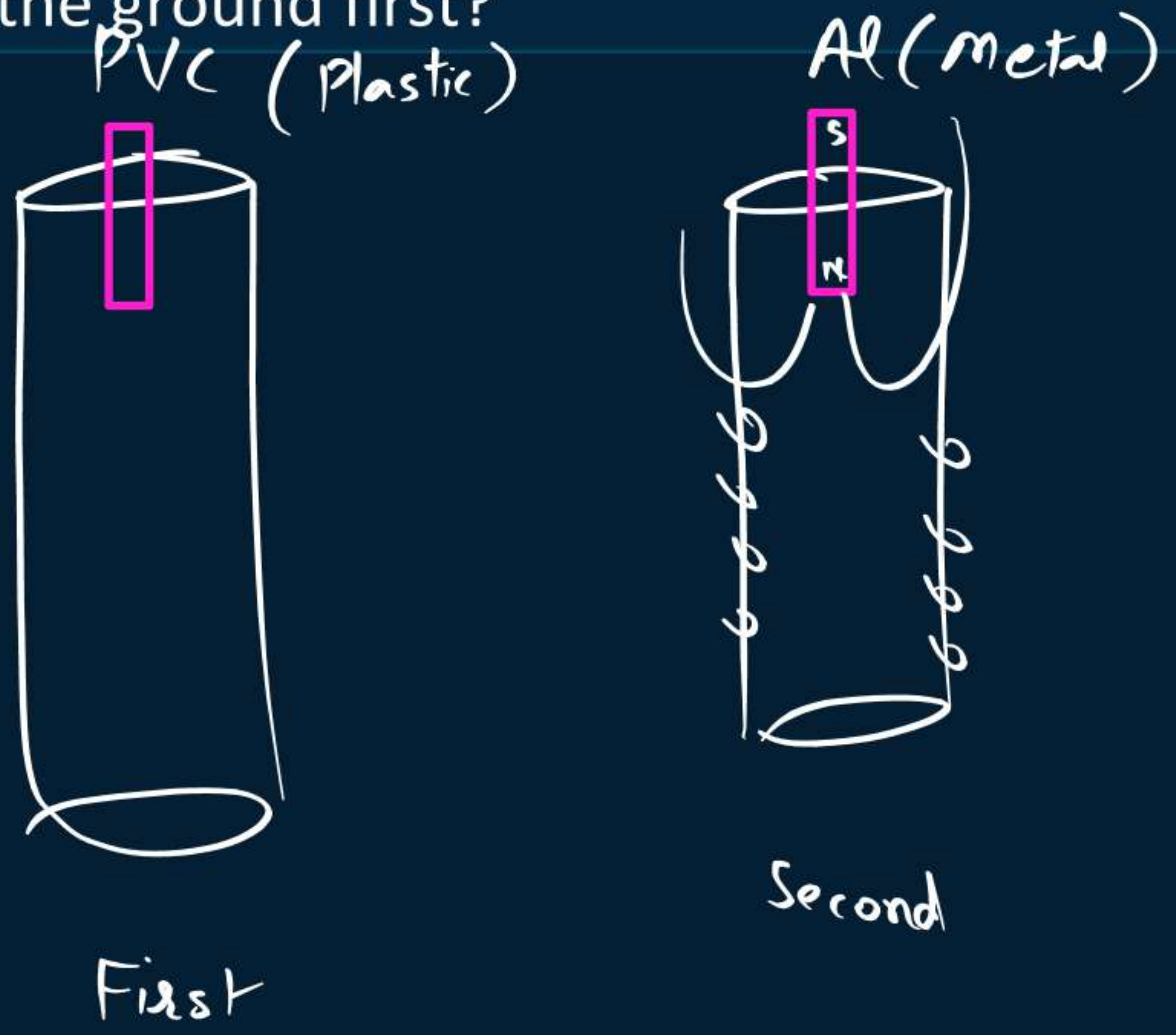
* Magnetic Braking in trains :

Smooth Braking

* Induction Chulha

QUESTION

A magnet is dropped from same height through the PVC and Aluminium pipes each. In which case, the magnet will reach the ground first?



2. Magnetic Braking in trains

The eddy currents induced in the rails oppose the motion of the train.

As there are no mechanical linkages, the braking effect is smooth.

Bhatti

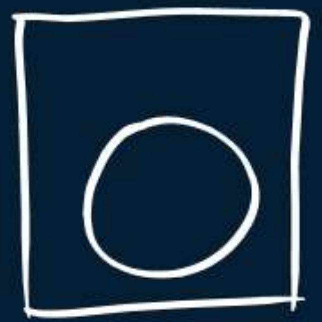
3. Induction furnace

Used to melt metals by producing high temperatures.

A high frequency alternating current is passed through a coil which surrounds the metals to be melted. The eddy currents generated in the metals produce high temperatures sufficient to melt it.

4. Electric Power Meters

The shiny metal disc in the electric power meter (analogue type) rotates due to the eddy currents.



5. Induction Cooktop

QUESTION

In which of the following devices, the eddy current effect is not used?

A. Induction furnace

B. Magnetic braking in train

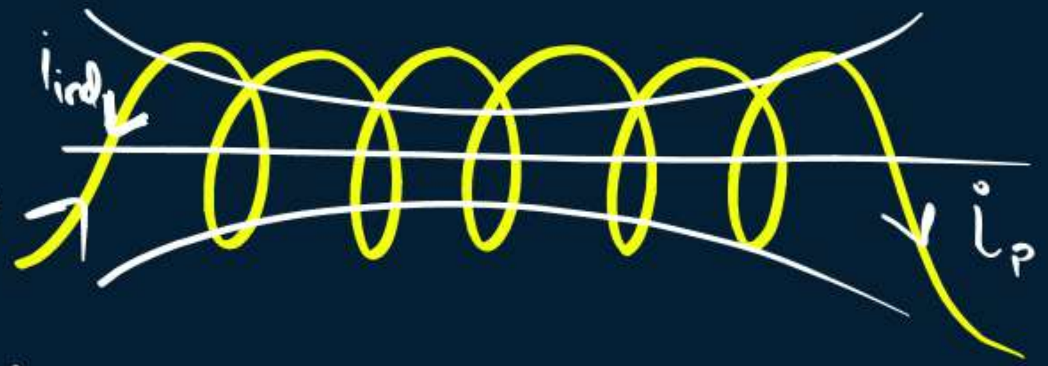
C. electromagnet

D. electric heater

Self Induction

Khudse Khud ki Jung

The property of coil by which it opposes the change in flux in itself is called self induction.



$i_p \uparrow$

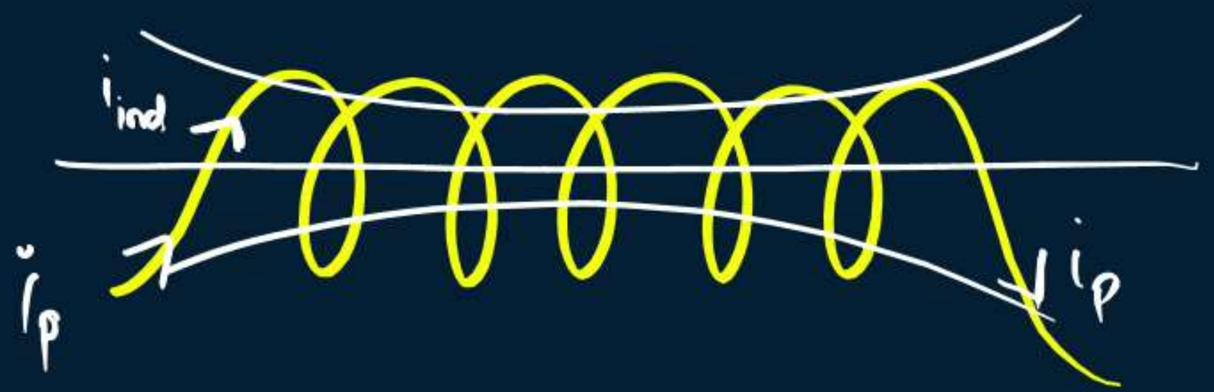
$B \uparrow$

$\phi \uparrow$

$\varepsilon_{ind} \neq 0$

$i_{ind} \neq 0$

$$i_{net} = i_p - i_{ind}$$



$i_p \downarrow$

$B \downarrow$

$\phi \downarrow$

$\varepsilon_{ind} \neq 0$

$i_{ind} \neq 0$

$$i_{net} = i_p + i_{ind}$$

Self Inductance (L) or Coefficient of Self Induction

$\phi \propto i$

$\boxed{\phi = Li} \xrightarrow{\text{for N-turns}} \boxed{N\phi = Li}$

L → Constant (doesn't depend on 'i' or 'ϕ')

SI unit of L : Henry (H)

QUESTION

A current of 2.5 A flows through a coil of inductance 5 H. The magnetic flux linked with coil is **[Karnataka NEET 2013]**

(A) 0.5 Wb

(B) 12. 5 Wb

(C) Zero

(D) 2 Wb

$\phi = Li$

$\phi = 5 \times 2.5$

$= 12.5\ \text{Wb}$

QUESTION

A long solenoid has 500 turns. When a current of 2 ampere is passed through it, the resulting magnetic flux linked with the each turn of the solenoid is 4×10^{-3} Wb. The self inductance of the solenoid is [2008]

(A) 1.0 henry

(B) 4.0 henry

(C) 2.5 henry

(D) 2.0 henry

$N = 500$

$i = 2A$

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

$L = ?$

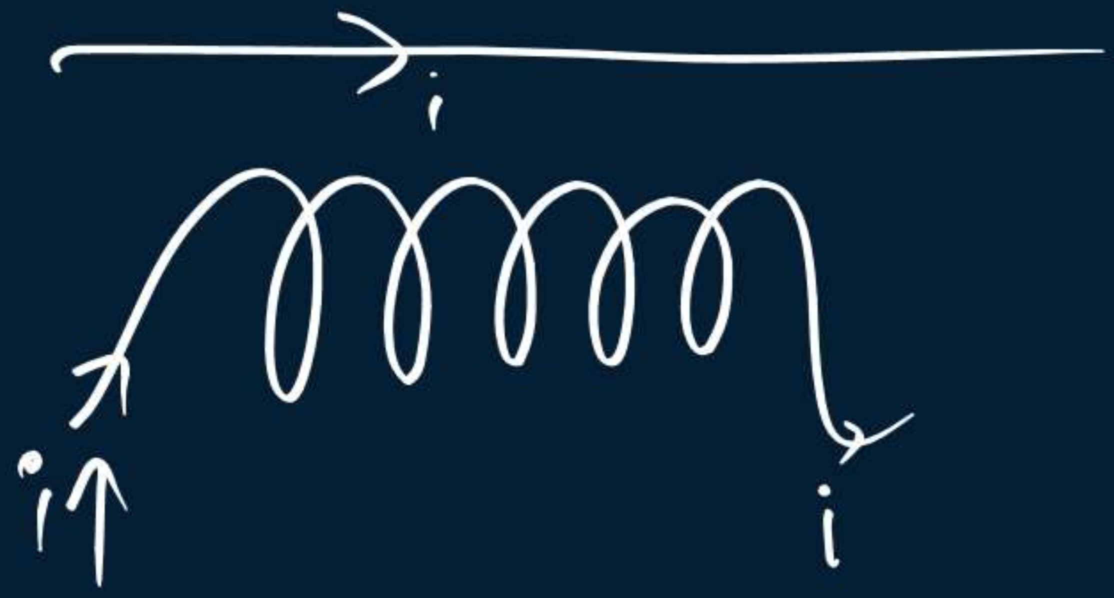
$N\phi = Li$

$500 \times \cancel{4} \times 10^{-3} = L \times \cancel{2}$
2

$\frac{\cancel{1000}}{\cancel{1000}} = L$

$L = 1H$

Induced emf in an inductor



$$\phi = Li$$

$$\varepsilon_{ind} = -\frac{d\phi}{dt}$$

$$= -\frac{d(Li)}{dt}$$

$$\boxed{\varepsilon_{ind} = -L\frac{di}{dt}}$$

$$\boxed{\varepsilon_{ind} = L\frac{di}{dt}}$$

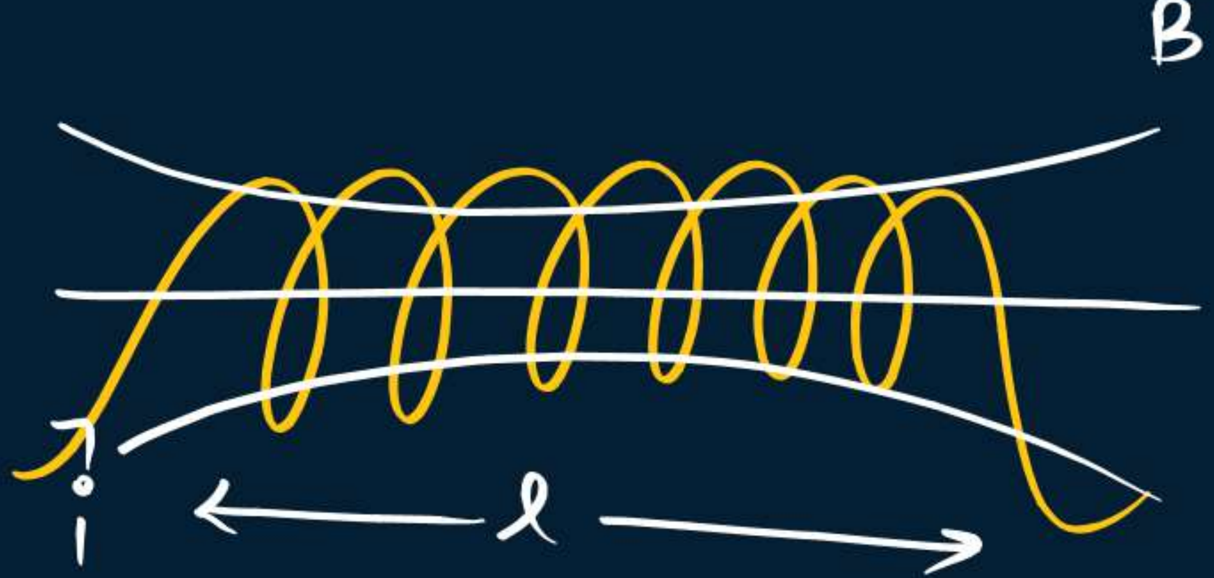
$$\varepsilon_{ind} = L\frac{di}{dt}$$

$$i_{ind}R = L\frac{di}{dt}$$

$$\boxed{i_{ind} = \frac{L}{R}\frac{di_p}{dt}}$$

Self Inductance of Solenoid

(L)



$n \rightarrow$ No. of Turns per unit length (Turn density)

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

$N \rightarrow$ No. of turns

$l \rightarrow$ length

$N = nl$

$$N\phi = Li$$

$$NBA = Li$$

$$N\mu_0 n \cancel{i} A = L\cancel{i}$$

$$L = \frac{\mu_0 N N A}{l}$$

$$\boxed{L = \frac{\mu_0 N^2 A}{l}} = \frac{\mu_0 n^2 l^{\cancel{2}} A}{\cancel{l}}$$

$$\boxed{L = \mu_0 n^2 A l}$$

QUESTION

If N is the number of turns in a coil, the value of self-inductance varies as

[CBSE AIPMT 1993]

(A) N^0

(B) N

(C) N^2

(D) N^{-2}

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

$$L \propto N^2$$

Homework

→ Notes

→ Revision

PARISHRAM

2026

Lecture - 04

Electromagnetic Induction

PHYSICS **LECTURE - 4**

BY - RAKSHAK SIR

Topics *to be covered*

A # Mutual Inductance

B # A.C. Generator

C # Practice Questions (PYQs)

D #

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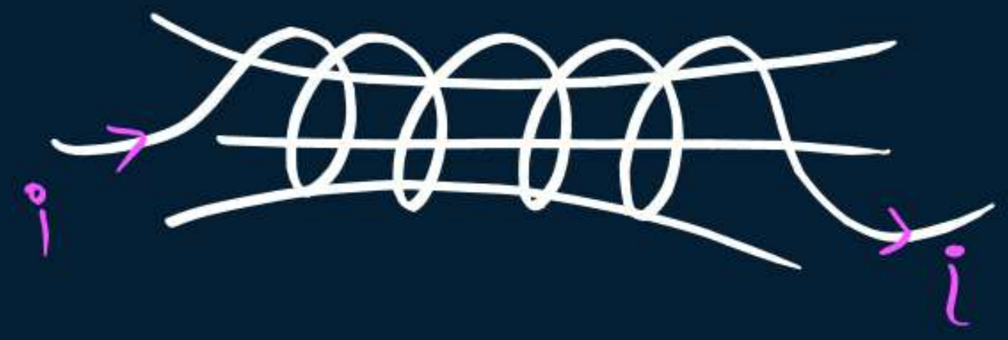
Energy Stored in an Inductor



$$\boxed{\mathcal{E}_{ind} = L\frac{di}{dt}}$$

$$[U]_0^U = L\left[\frac{i^2}{2}\right]_0^i$$

$$(U-0) = L\left(\frac{i^2}{2} - \frac{0^2}{2}\right)$$

$$* \ \boxed{U = \frac{1}{2}Li^2}$$

$$P = Vi$$

$$P = \mathcal{E}i$$

$$P = L\frac{di}{dt}i$$

$$\frac{dU}{\cancel{dt}} = Li\frac{di}{\cancel{dt}}$$

$$dU = Lidi$$

Int. both sides

$$\int dU = \int Lidi$$

$$\int_0^U dU = L\int_0^i idi$$

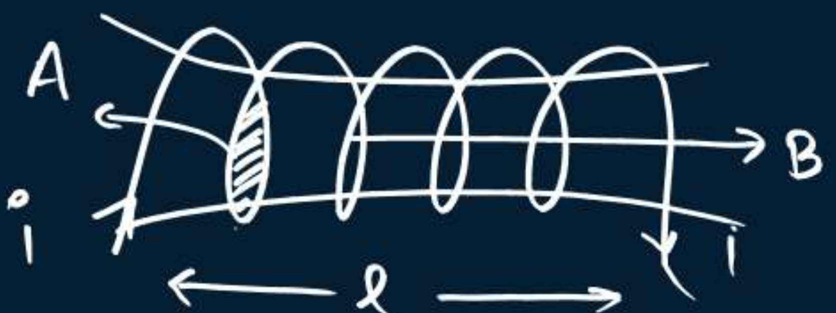
Y.K.B.

$$U = \frac{1}{2}CV^2$$

$$P = \frac{dW}{dt}$$

$$P = \frac{dU}{dt}$$

Energy Density in an Inductor



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

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

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

$$u_B = \frac{U}{\text{Volume}}$$

$$u_B = \frac{\frac{1}{2} L i^2}{A \times l}$$

$$u_B = \frac{1}{2} \frac{\mu_0 N^2 \cancel{Al}}{l^2 \times \cancel{A \times l}} i^2$$

$$u_B = \frac{1}{2} \mu_0 \frac{N^2}{l^2} i^2$$

$$u_B = \frac{1}{2} \mu_0 n^2 i^2 \times \frac{\mu_0}{\mu_0} \qquad n = \frac{N}{l}$$

$$u_B = \frac{(\mu_0 n i)^2}{2\mu_0}$$

$$\boxed{u_B = \frac{B^2}{2\mu_0}}$$

Y.K.B.

$$u_e = \frac{U}{\text{Vol.}}$$

$$\boxed{u_e = \frac{1}{2} \epsilon_0 E^2}$$

QUESTION

A 100 mH coil carries a current of 1 A. Energy stored in its magnetic field is

[CBSE AIMPT 1991]

(A) 0.5 J

(B) 1 A

(C) 0.05 J

(D) 0.1 J

$$U = \frac{1}{2} L i^2$$

$$= \frac{1}{2} \times 100 \times 10^{-3} \times 1^2$$

$$= \frac{1}{2} \times \frac{1\cancel{0}\cancel{0}}{10\cancel{0}\cancel{0}} = \frac{1}{20} = 0.05 \text{ J}$$

QUESTION

The magnetic potential energy stored in a certain inductor is 25 mJ, when the current in the inductor is 60 mA. This inductor is of inductance [NEET 2018]

A 1.389 H

B 138.88 H

C 0.138 H

D 13.89 H

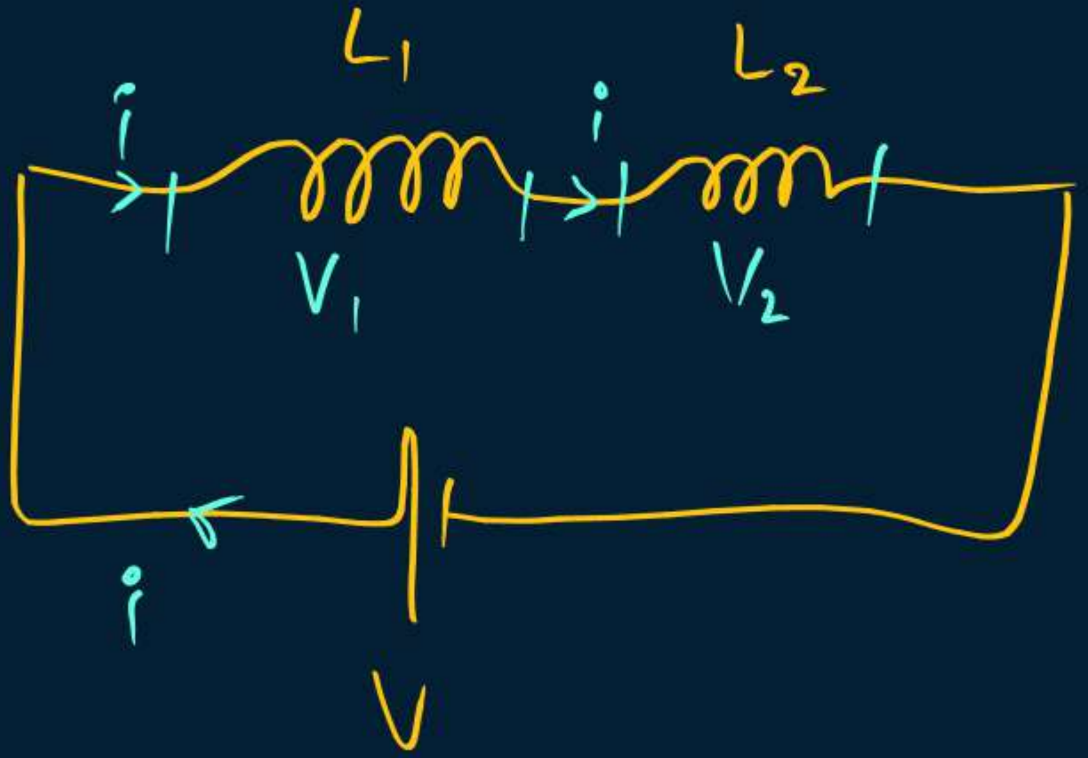
$$U = \frac{1}{2} L i$$

$$25 \times 10^{-3} = \frac{1}{2} L \; 60 \times 10^{-3}$$

$$L =$$

Inductors in Combination

Series :- $\begin{cases} V \text{ divide} \\ i \text{ same} \end{cases}$



$$V = V_1 + V_2$$

$$\varepsilon = L\frac{di}{dt}$$

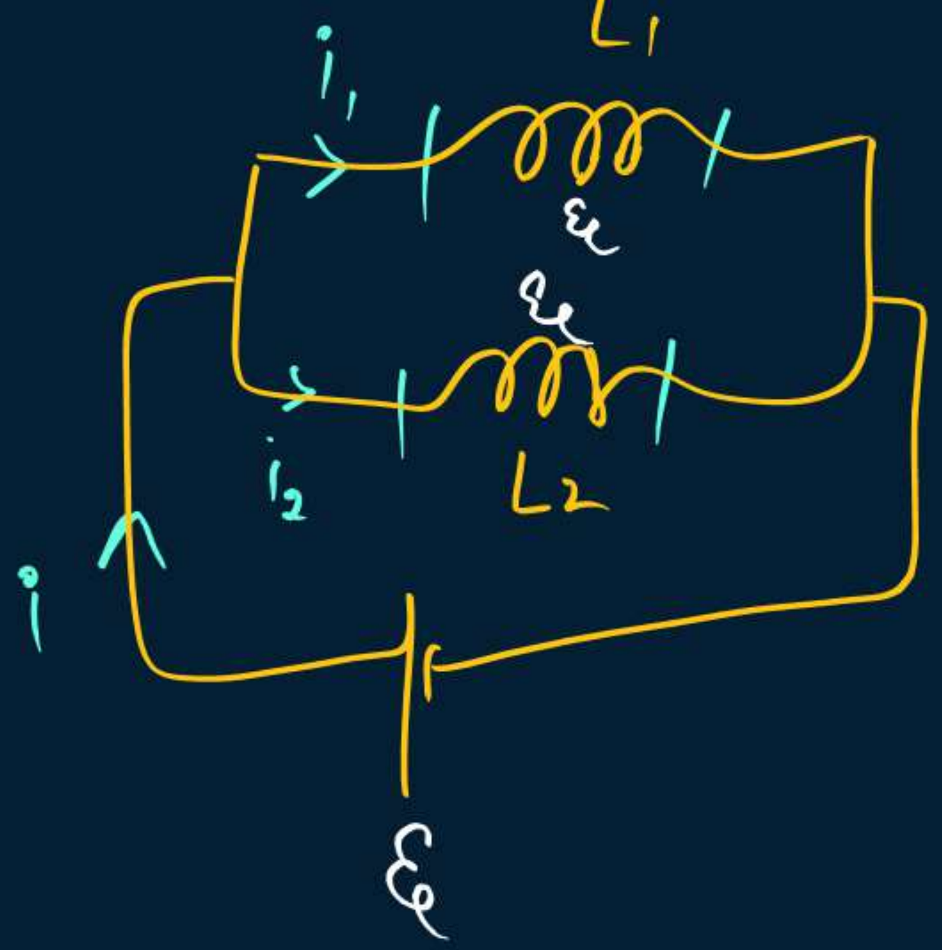
$$\varepsilon = \varepsilon_1 + \varepsilon_2$$

$$L_{eff}\cancel{\frac{di}{dt}} = L_1\cancel{\frac{di}{dt}} + L_2\cancel{\frac{di}{dt}}$$

$$\boxed{L_{eff} = L_1 + L_2}$$

Inductors in Combination

Parallel :- V same, i divide



$$i = i_1 + i_2$$

diff 'i' w.r.t. 't'

$$\frac{di}{dt} = \frac{di_1}{dt} + \frac{di_2}{dt}$$

$$\frac{\mathcal{E}}{L_{eff}} = \frac{\mathcal{E}}{L_1} + \frac{\mathcal{E}}{L_2}$$

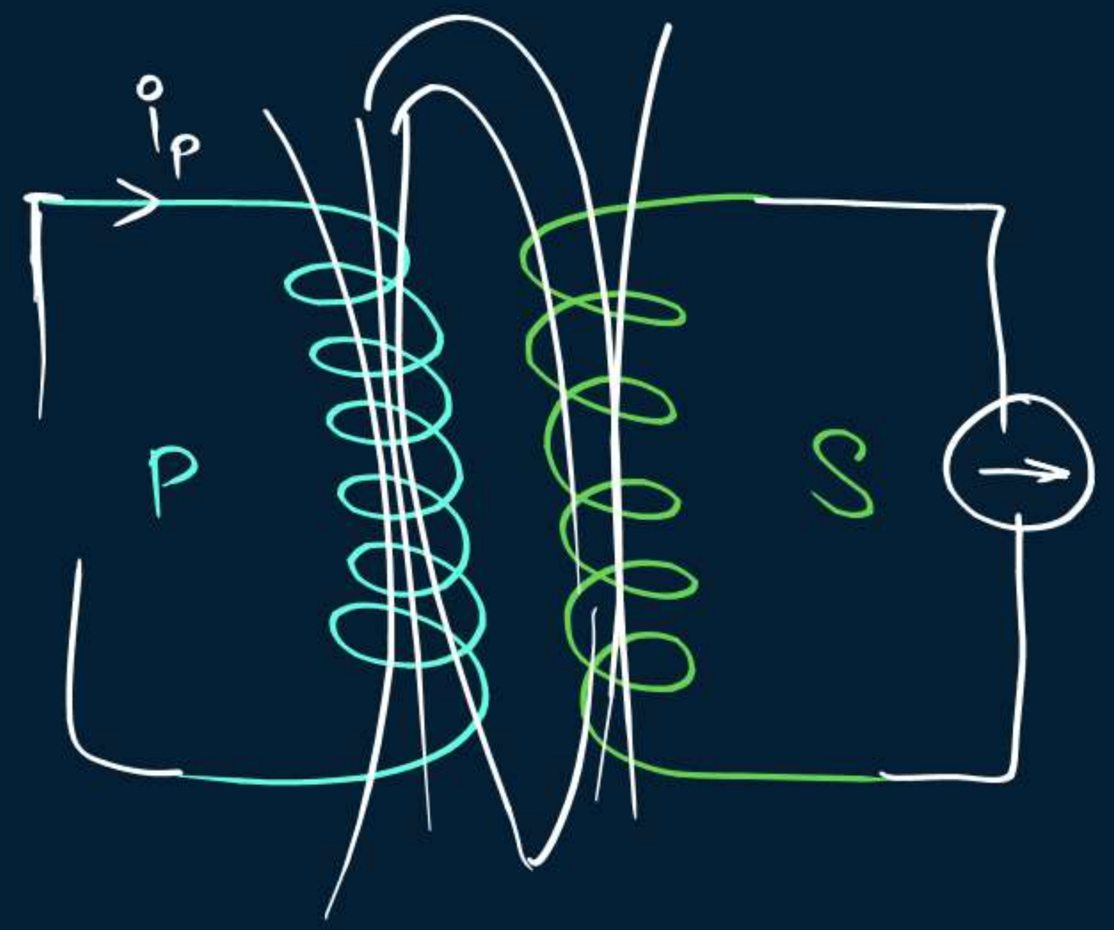
$$\boxed{\frac{1}{L_{eff}} = \frac{1}{L_1} + \frac{1}{L_2}}$$

$$\mathcal{E} = L\frac{di}{dt}$$

$$\frac{\mathcal{E}}{L} = \frac{di}{dt}$$

Mutual induction

The property of coil by which it opposes the change in flux due to change in the current in other coil



Induced EMF in terms of Mutual Inductance

$$\phi_2 \propto i_1$$

स्थिर $\leftarrow$ * $\boxed{\phi_2 = M_{21}\, i_1}$

for N_2 turns...

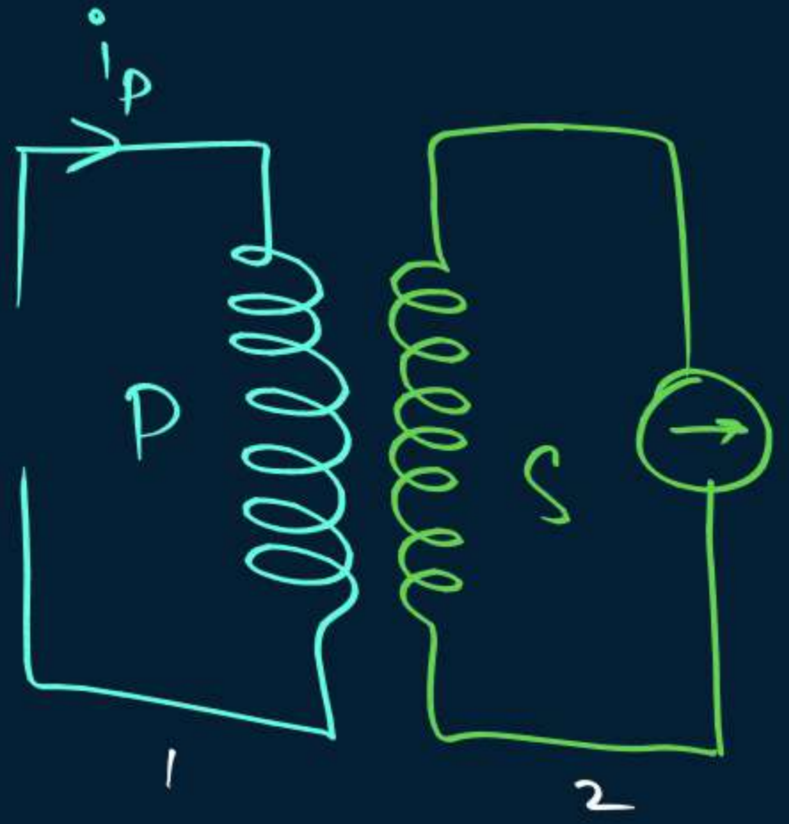
$$N_2 \phi_2 = M_{21}\, i_1$$

$$\boxed{M_{21} = \frac{N_2 \phi_2}{i_1}}$$

Henry (H)

$M_{21} \rightarrow$ Mutual Inductance of coil 2 w.r.t. 1

$M_{12} \rightarrow$ Mutual Inductance of coil 1 w.r.t. 2



$$\boxed{M_{21} = M_{12} = M}$$

$\hookrightarrow$ Theorem of Reciprocity

* Induced Emf :-

By Faraday's law —

$$\mathcal{E}_{ind} = \frac{d\phi}{dt}$$

$$\mathcal{E}_2 = \frac{d\phi_2}{dt}$$

$$= \frac{d(M_{21} i_1)}{dt}$$

induced emf in coil 2 due to 1

$$\boxed{\mathcal{E}_2 = M_{21} \frac{di_1}{dt}}$$

$$i_2 R_2 = M_{21} \frac{di_1}{dt}$$

$$\boxed{i_2 = \frac{M_{21}}{R_2}\left(\frac{di_1}{dt}\right)}$$

induced current in coil 2 due to 1

QUESTION

$\mathcal{E}_2 = 0.5\,V$

An emf of 0.5 V is developed in the secondary coil, when current in primary coil changes from 5.0 A to 2.0 A in 300 millisecond. Calculate the mutual inductance of the two coils.

M_{21}

A) 0.1 H

B) 0.05 H

C) 0.01 H

D) 1 H

$$\mathcal{E}_2 = M_{21}\frac{di_1}{dt}$$

$$\downarrow$$

$$\mathcal{E}_2 = M_{21}\frac{\Delta i_1}{\Delta t}$$

$$0.5 = M_{21}\frac{(5-2)}{300\times10^{-3}}$$

$$0.5 = M_{21}\,\frac{\cancel{3000}\,10}{\cancel{300}\,1} \longrightarrow M_{21} = \frac{0.5}{10} = 0.05\,H$$

Mutual Inductance of two coaxial solenoids

Let us take two solenoids of equal lengths 'l'

We are changing current i_1 in Primary coil and thus flux ϕ_2 is changing in Secondary coil

$$\phi_2 \propto i_1$$

$$\phi_2 = M_{21} i_1$$

where M_{21} is Mutual inductance of coil 2 w.r.t. 1

for N_2 turns . . .

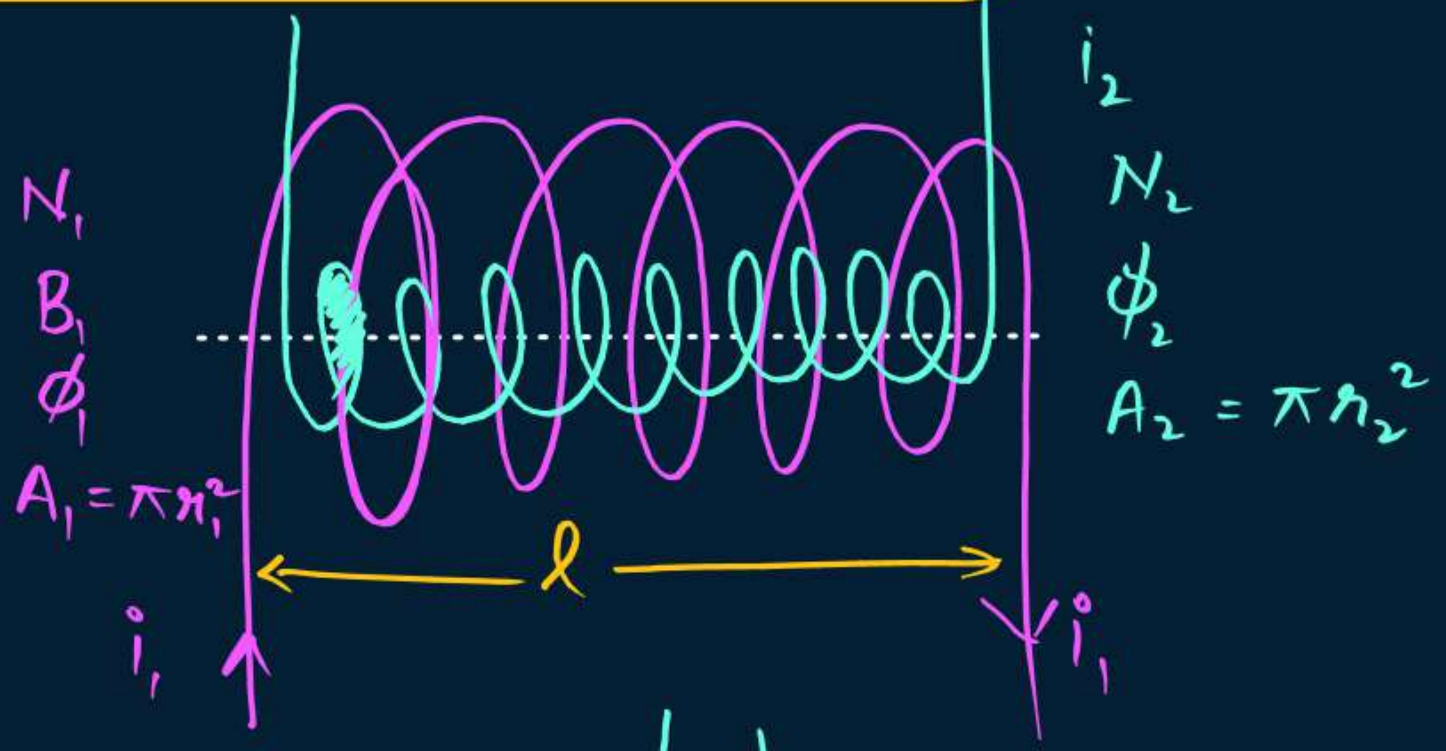
$$N_2 \phi_2 = M_{21} i_1$$

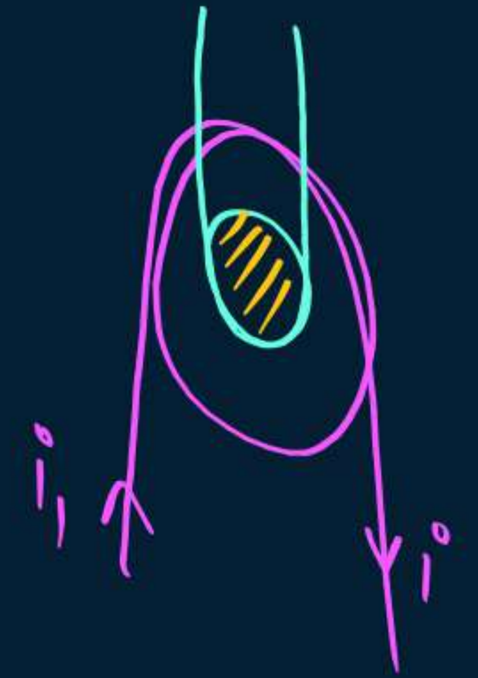
$$N_2 B_1 A_2 = M_{21} i_1 \qquad \left(\because \phi = \vec{B}\cdot\vec{A} = BA\right)$$

$$N_2 \mu_0 n_1 \cancel{i_1} A_2 = M_{21} \cancel{i_1}$$

$$M_{21} = \mu_0 N_2 n_1 A_2$$

$$\boxed{M_{21} = \frac{\mu_0 N_1 N_2 A_2}{l}} \qquad \left(\because n_1 = \frac{N_1}{l}\right)$$





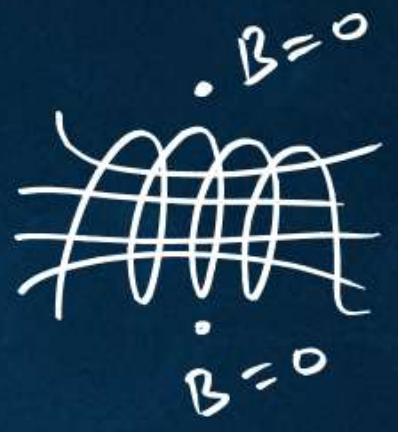
$$M_{21} = \frac{\mu_0 N_1 N_2 A_2}{l}$$

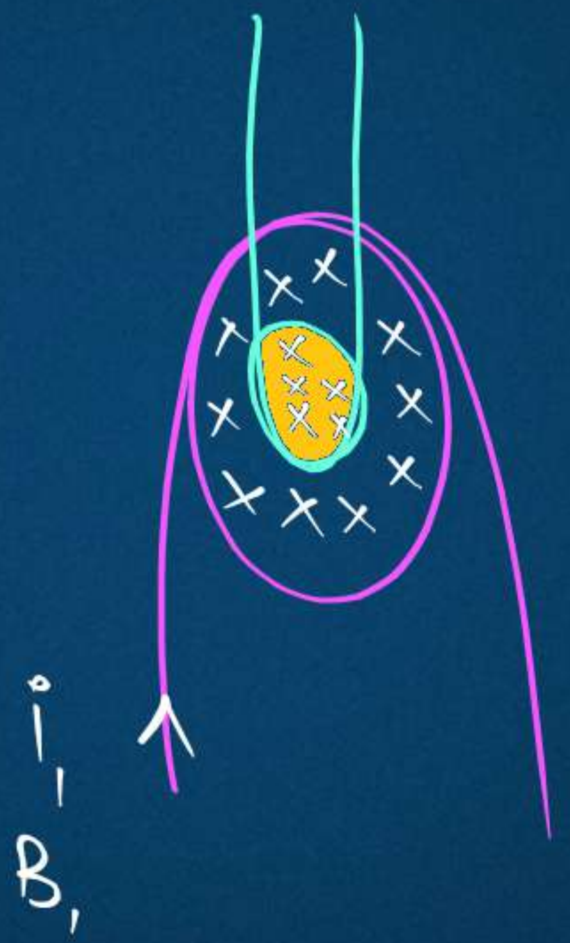
Similarily,

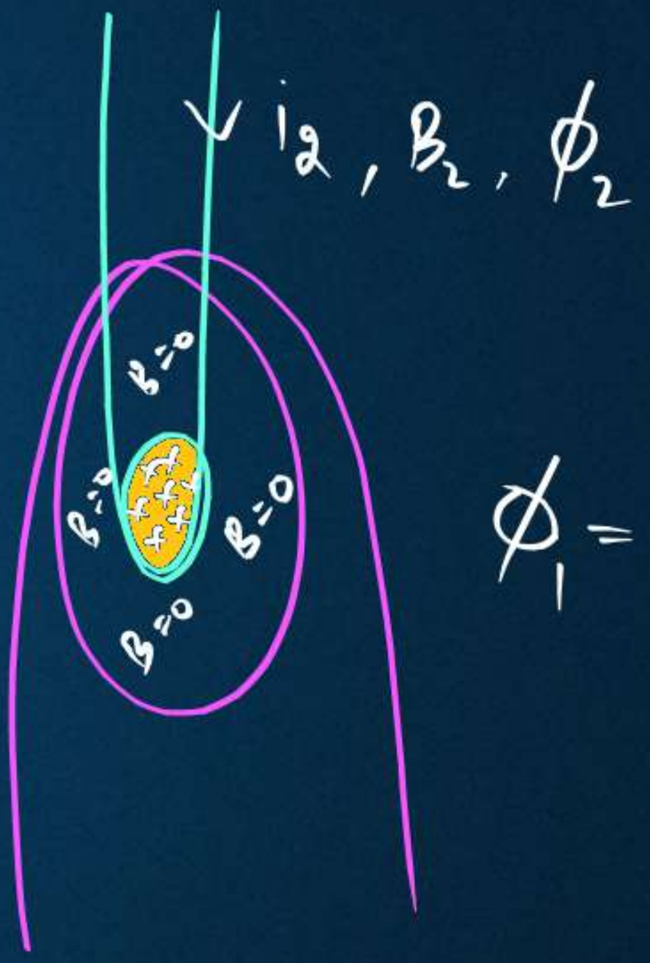
$$M_{12} = \frac{\mu_0 N_1 N_2 A_2}{l}$$

This shows from theorem of reciprocity,

$$\boxed{M_{12} = M_{21} = M}$$







$$\phi_1 = B_2 A_2$$

$$\boxed{M_{12} = M_{21} = \frac{\mu_0 N_1 N_2 A_2}{l}}$$

$$= \frac{\mu_0 \left(\frac{N_1}{l}\right)\left(\frac{N_2}{l}\right) A_2}{} \times l$$

for Air Core $\longrightarrow$ $\boxed{M = \mu_0 n_1 n_2 A l}$

for medium $\longrightarrow$ $\boxed{M = \mu_r \mu_0 n_1 n_2 A l}$

Coefficient of Coupling

Perfect coupling :-

1)

2)

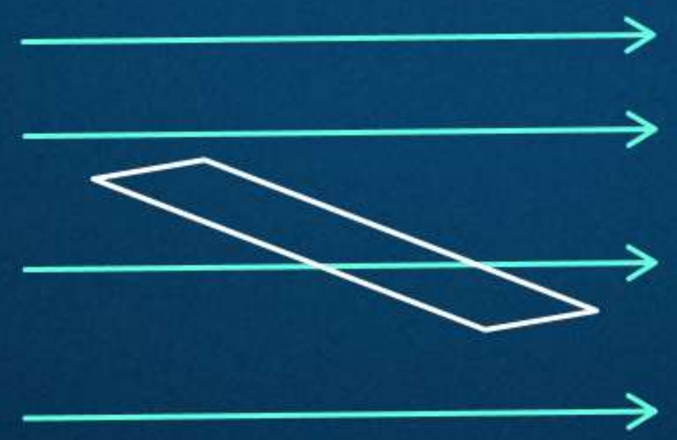
3)

$$\boxed{M = 0}$$

A.C. Generator → it converts Mechanical Energy into Electrical Energy

A → Alternating, C → current

* Principle :- The coil rotates within the magnetic field and the flux changes with time which induces emf in the coil.



* Calculations :-

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

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

from Faraday's law

$$\varepsilon_{ind} = -\frac{d\phi}{dt}$$

$$\varepsilon_e = -\frac{d}{dt}(BA\cos\theta)$$

The coil rotates with an angular speed 'ω' in time t, with charges the 'θ'

$$\omega = \frac{\theta}{t}$$

$$\theta = \omega t$$

$$\varepsilon_e = -\frac{d}{dt}(BA\cos\omega t)$$

$$\varepsilon_e = -BA\frac{d}{dt}(\cos\omega t)$$

$$\varepsilon_e = -BA \times -\sin\omega t \; \omega \frac{d(t)}{dt}$$

$$\varepsilon_e = \omega BA\sin\omega t$$

for N-turns ....

$$\boxed{\varepsilon_e = NBA\omega\sin\omega t}$$

$$\varepsilon_e = NBA\omega\sin\omega t$$

time varying emf.

Alternating Emf

$$iR = NBA\omega\sin\omega t$$

$$i = \left(\frac{NBA\omega}{R}\right)\sin\omega t$$

$$\boxed{i = i_0\sin\omega t}$$

A.C. time-varying current

$$\boxed{i = i_0 \sin\omega t}$$

$$y = A\sin(\omega t + \phi)$$

$$\boxed{\begin{aligned} V &= V_0 \sin\omega t \\ i &= i_0 \sin\omega t \end{aligned}}$$

QUESTION

T

Assertion (A): Lenz's law is a consequence of the law of conservation of energy.

Reason (R): There is no power loss in an ideal inductor. T [2024]

→ A.C.

A Both (A) and (R) are true and (R) is correct explanation of (A).

B Both (A) and (R) are true and (R) is not correct explanation of (A).

C (A) Is true, but (R) is false.

D (A) Is false and (R) is also false.

QUESTION

If both the number of turns and core length of an inductor is doubled keeping other factors constant, then its self-inductance will be [2021-2022]

(A) Unaffected

(B) Doubled

(C) Halved

(D) quadrupled

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

$$L' = \frac{\mu_0 (2N)^2 A}{2l}$$

$$= \cancel{4}^{2} \frac{\mu_0 N^2 A}{\cancel{2} l}$$

$$L' = 2L$$

QUESTION

A square shaped coil of side 10 cm, having 100 turns is placed perpendicular to a magnetic field which is increasing at 1 T/s. The induced emf in the coil is [2023]

(A) 0.1 V

(B) 0.5 V

(C) 0.75 V

(D) 1.0 V

$$\mathcal{E} = \frac{d\phi}{dt}$$

$$= \frac{d}{dt}(BA\cos\theta)$$

$$= N \times l^2 \times \frac{dB}{dt}$$

$$= 1\cancel{00} \times \frac{1\cancel{0}}{1\cancel{00}} \times \frac{1\cancel{0}}{1\cancel{00}} \times 1\,T/s$$

$$= 1\,V$$

QUESTION

Two coils C_1 and C_2 are placed close to each other. The magnetic flux ϕ_2 linked with the coil C_2 varies with the current I_1 flowing in coil C_1, as shown in the figure. Find

(i) the mutual inductance of the arrangement, and

(ii) the rate of change of current $\left(\frac{dI_1}{dt}\right)$ that will induce an emf of 100 V in coil C_2. **[2023]**

i) $\phi_2 \propto i_1$

$\phi_2 = M_{21} i_1$

$\frac{\phi_2}{i_1} = M_{21}$

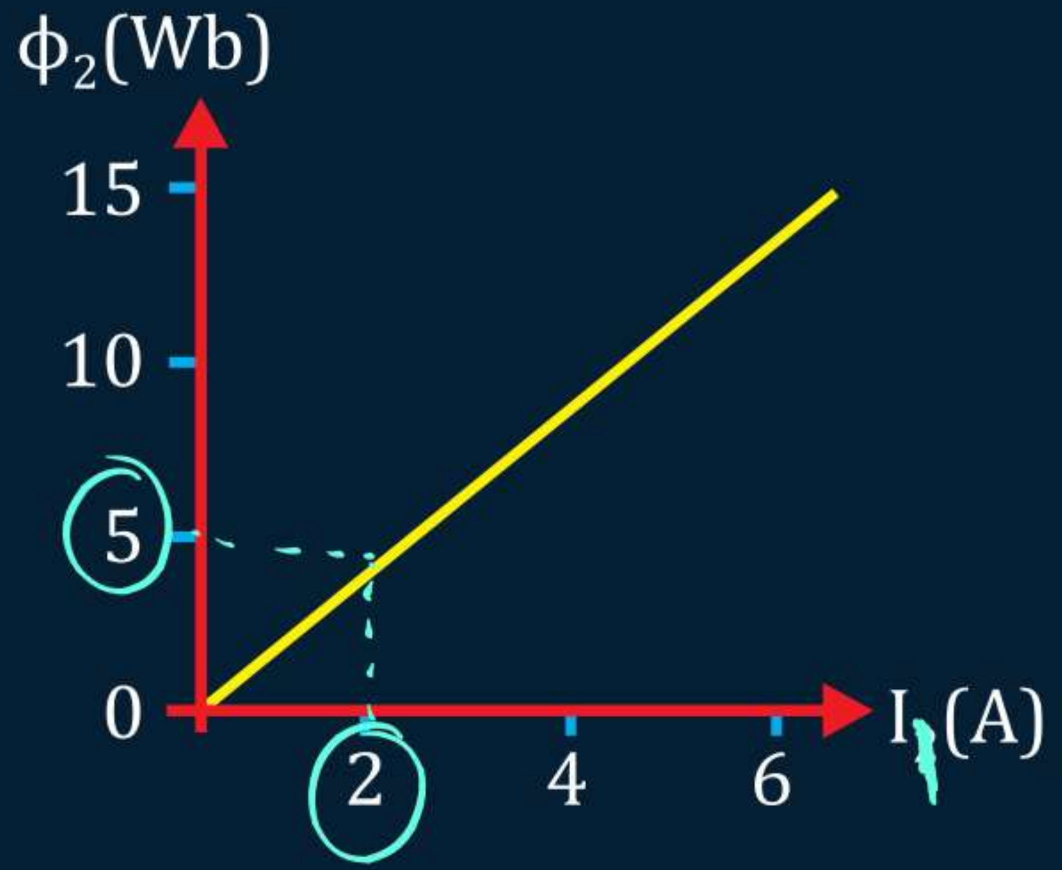
$\frac{5}{2} = M_{21}$

$2.5\,H = M_{21}$

ii) $\varepsilon_{ind} = M \frac{dI}{dt}$

$100 = 2.5 \times \frac{dI}{dt}$

$\frac{100}{2.5} = \frac{dI}{dt}$



QUESTION

(i) (1) What is meant by current sensitivity of a galvanometer? Mention the factors on which it depends. } 4th

(2) A galvanometer of resistance G is converted into a voltmeter of range (0 – V) by using a resistance R. Find the resistance, in terms of R and G, required to convert it into a voltmeter of range $\left(0-\frac{V}{2}\right)$. } 4th

(ii) The magnetic flux through a coil of resistance 5Ω increases with time as:

$\phi = (2.0t^3 + 5.0t^2 + 6.0t)$ m Wb

Find the magnitude of induced current through the coil at $t = 2$ s. **[2024]**

$\varepsilon = \frac{d\phi}{dt} = (6t^2 + 10t + 6)\,mV$

$\varepsilon_{t=2s} = 6(2)^2 + 10(2) + 6 \; mV$

$= 24 + 20 + 6$

$\varepsilon = 50\,mV$

$iR = 50\,mV$

$i = \frac{\cancel{50}\,10}{\cancel{5}}$

$i = 10\,mA$

QUESTION

A coil of area 100 cm^2 is kept at an angle of 30° with a magnetic field of 10^{-1}T. The magnetic field is reduced to zero in 10^{-4} s. The induced emf in the coil is [2021-2022]

(A) $5\sqrt{3}$ V

(B) $50\sqrt{3}$ V

(C) 5.0 V

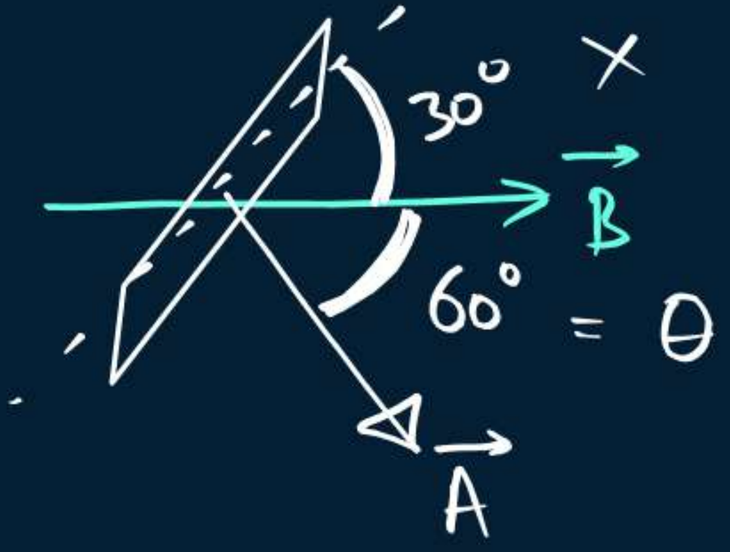
(D) 50.0 V

$$\mathcal{E}_e = \frac{d\phi}{dt}$$

$$= \frac{d}{dt}(BA\cos\theta)$$

$$= A \times \cos 60^\circ \times \frac{dB}{dt}$$

$$= \frac{100}{100\times 100} \times \frac{1}{2} \times \frac{(10^{-1} - 0)}{(10^{-4})}$$



QUESTION

$\theta = 0^\circ$

A coil of are of cross-section $0.5\ m^2$ is placed in a magnetic field acting normally to its plane. The field varies as $\boxed{B = 0.5t^2 + 2t,}$ where B is in tesla and t in seconds. The emf induced in the coil at $t = 1$ s is **[2024]**

A 0.5 V

B 1.0 V

C 1.5 V

D 3.0 V

$$\mathcal{E}_e = \frac{d\phi}{dt}$$

$$= \frac{d(BA\cos 0^\circ)}{dt}$$

$$= A\frac{dB}{dt}$$

$$= 0.5 \times (t+2)$$

$$= 0.5 \times (1+2)$$

$$= \frac{1}{2} \times 3 = 3/2 = 1.5\ V$$

QUESTION

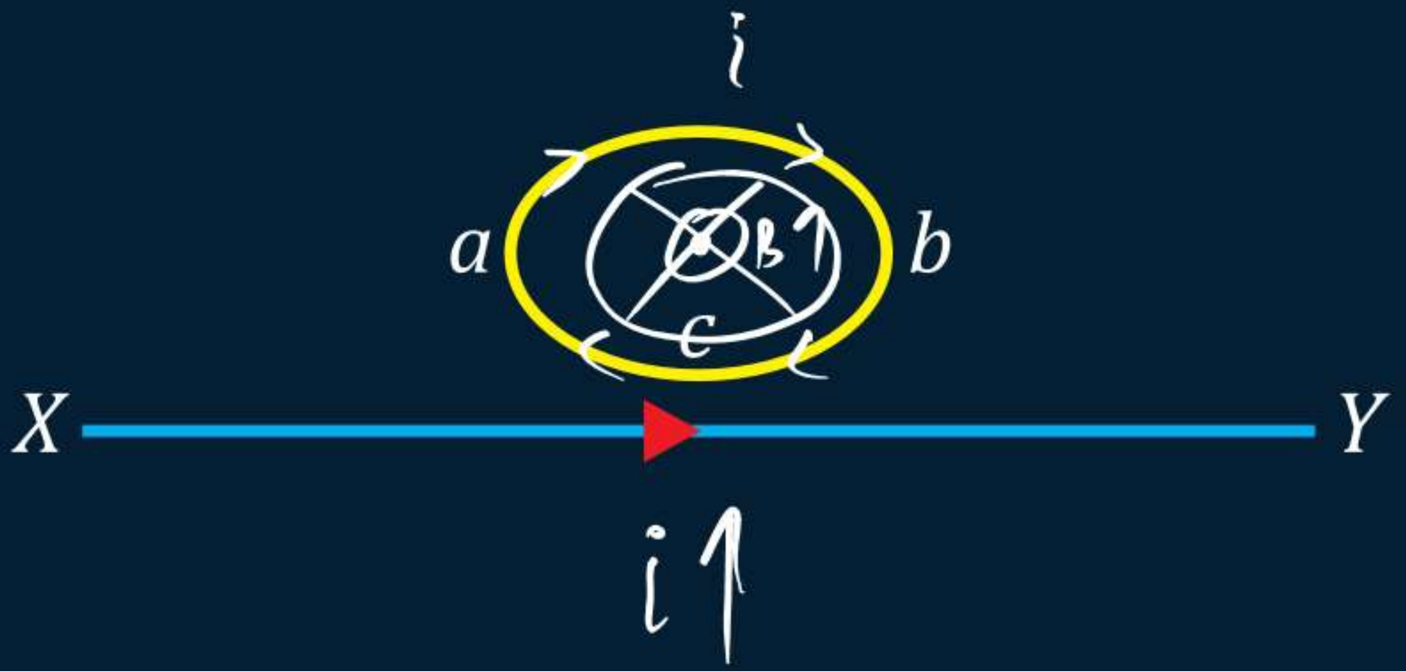
The direction of induced current in the loop *abc* is: [2023]

A. along *abc* if I decreases

B. along *acb* if I increases

C. along *abc* if I constant

D. along *abc* if I increases



QUESTION

The current in the primary coil of a pair of coils changes from 7 A to 3 A in 0.04 s. The mutual inductance between the two coils is 0.5 H. The induced emf in the secondary coil is: [2021-2022]

A) 50 V

B) 75 V

C) 100 V

D) 220 V

$$\varepsilon_e = M\frac{di}{dt}$$

$$\varepsilon_e = 0.5 \times \left(\frac{7-3}{0.04}\right)$$

$$= \frac{0.5}{10} \times \frac{4}{0.04} \times 100$$

$$= 50\,V$$

QUESTION

(i) State Lenz's law. In a closed circuit, the induced current opposes the change in magnetic flux that produced it as per the law of conservation of energy. Justify.

(ii) A metal rod of length 2 m is rotated with a frequency 60 rev/s about an axis passing through its centre an perpendicular to its length. A uniform magnetic field of 2 T perpendicular to its plane of rotation is switched onin the region. Calculate the e.m.f. induced between the centre and the end of the rod.

[2024]

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

$= \frac{1}{2} \times 2 \times 2\pi 60 \times (2)^2$

$l = 2m$

$\nu = 60 \text{ rev/s} \rightarrow \omega = 2\pi\nu$

$B = 2T$

$\varepsilon_i =$

Homework

Notes

Har sawaal laga ke dekhna!