PRACHAND NEET

ONE SHOT

PHYSICS

Electromagnetic Induction

(EMI)

By - TANUJ BANSAL SIR (TBS)

Topics *to be covered*

+ 2 ones → Expected

1. Magnetic Flux
2. Faraday's Law, Lenz Law
3. AC Generator, Motional EMF
4. Inductance, Energy Stored, RL Circuit


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Introduction

eg: Infinite wire

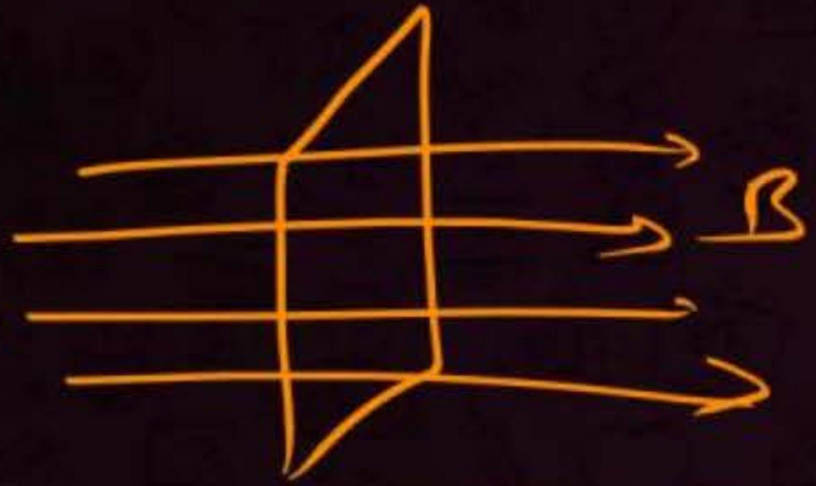
$B = \frac{\mu_0 i}{2\pi r} \Rightarrow B \propto i$

- Moving electric charges (current) produce magnetic fields.
- So, moving magnets must also produce electric currents.
- The experiments done by Michael Faraday in England and Joseph Henry in USA, conducted around 1830.

Magnetic Flux

(ϕ_B or ϕ)

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

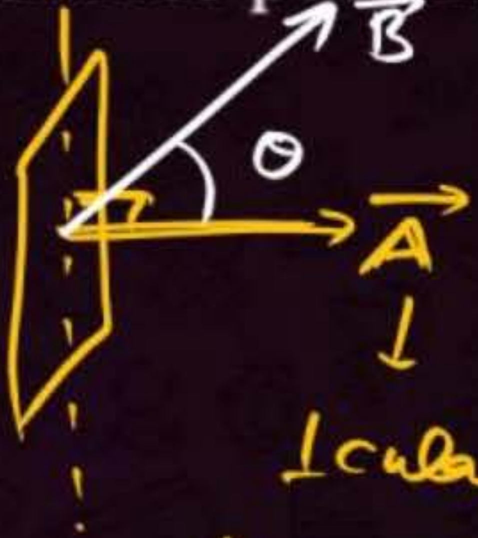


$$\phi = \vec{B} \cdot \vec{A}$$

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

$\theta \Rightarrow$ angle b/w $\vec{B}$ & $\vec{A}$

eg:-



$\vec{A}$ ⊥cular to surface

cgs unit → Maxwell

$1\,Wb = 1\,T\text{-}m^2$

$1\,Wb = 10^4\,G \times 10^4\,cm^2$

$1\,Wb = 10^8\,G\text{-}cm^2 = 10^8$ Maxwell

SI units ⇒ $T\text{-}m^2$ ⇒ Wb (Weber)

$B \Rightarrow$ Tesla (T) ⇒ $\frac{Wb}{m^2}$

Ques

Area = A

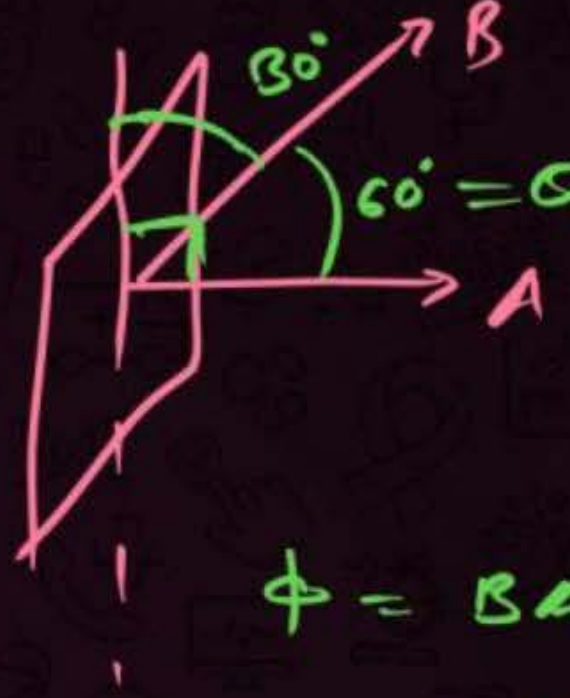
$\phi = ?$

A) BA

B) Zero

C) $\frac{BA}{2}$

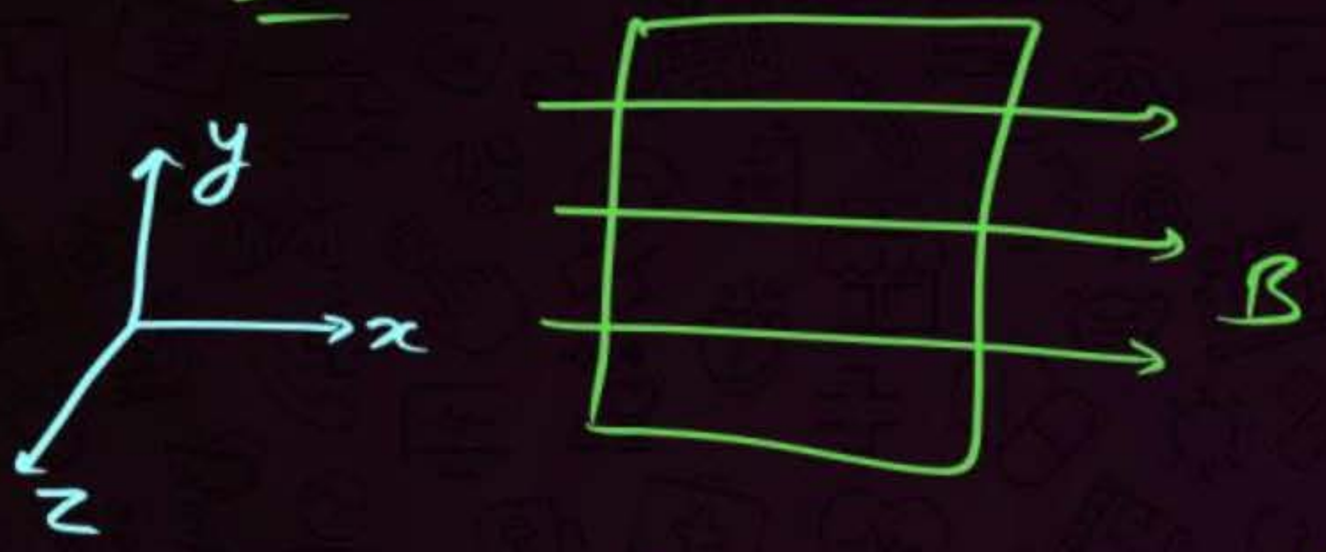
D) $\sqrt{3}\frac{BA}{2}$



$\phi = BA\cos 60°$

$= \frac{BA}{2}$

Ques



Area = A

$\phi = ?$

$\vec{A} \Rightarrow z$ $\quad \phi = BA\cos 90^\circ$

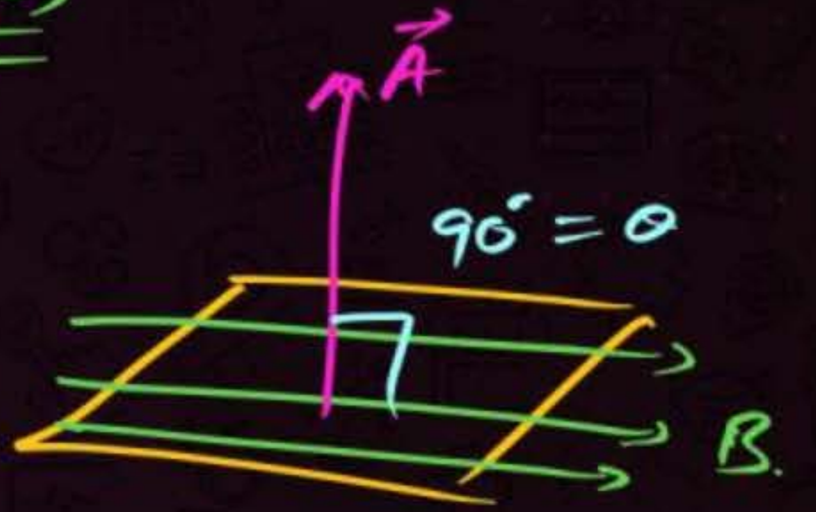
$\vec{B} \Rightarrow x$ $\quad \phi = 0$

TBS

B ||el to surface

$\phi = 0$

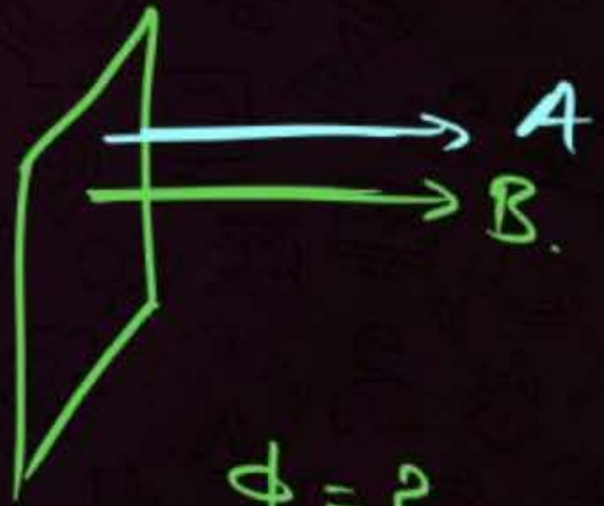
Ques



$90^\circ = \theta$

$\phi = 0$

Ques



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

$\phi = BA$ → maxm

$\phi = ?$

QUESTION

A coil of area $\vec{A} = 2\hat{\imath} + 4\hat{k}$ is placed in magnetic field $\vec{B} = 2\hat{\imath} + 5\hat{\jmath} + 6\hat{k}\ T$. Then find flux passing from the coil.

$0\hat{j}$

A) 24

B) 28

C) 20

D) None

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

$$= 2 \times 2 + 0 \times 5 + 4 \times 6$$

$$= 4 + 24 = 28 \text{ Wb.}$$

QUESTION

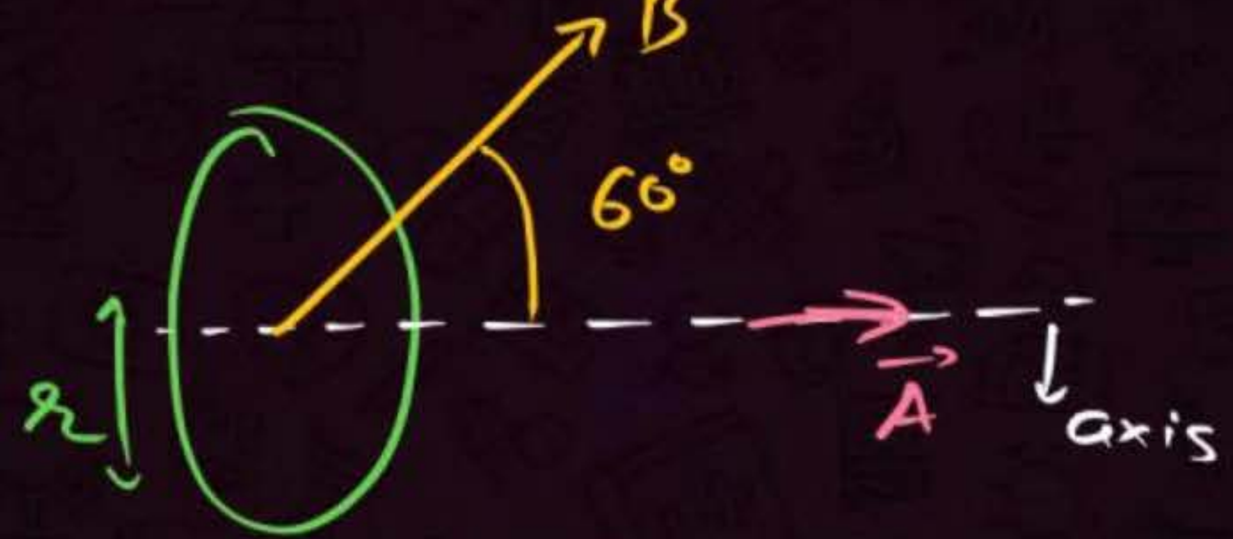
A circular disc of radius 0.2 metre is placed in a uniform magnetic field of induction $\frac{1}{2\pi}\left(\frac{Wb}{m^2}\right)$ in such a way that its axis makes an angle of 60° with $\vec{B}$. The magnetic flux linked with the disc is

(1) 0.08 Wb

(2) 0.01 Wb

(3) 0.02 Wb

(4) 0.06 Wb



$\phi = BA\cos 60°$

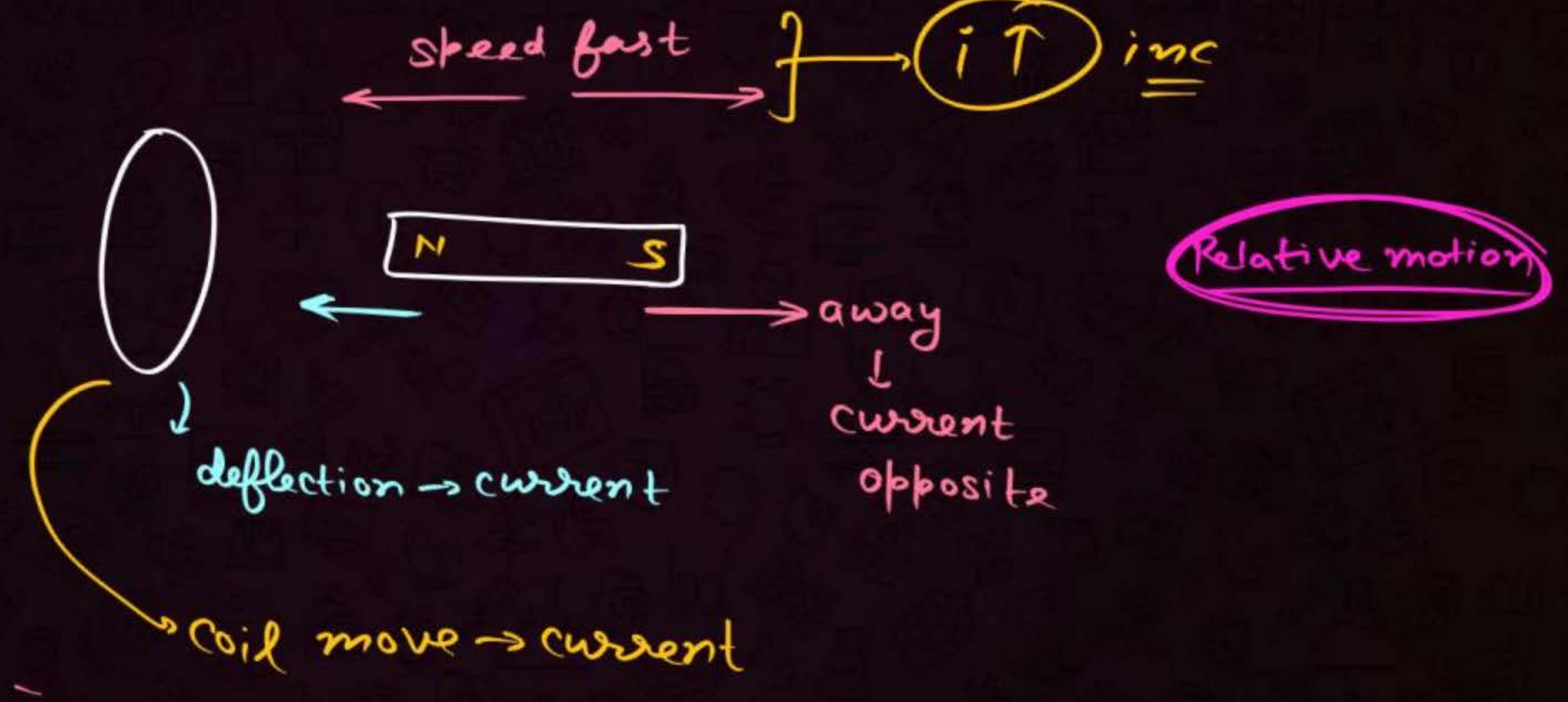
$= B \times \pi r^2 \times \frac{1}{2}$

$= \frac{1}{2\pi} \times \pi \times 0.2 \times 0.2 \times \frac{1}{2}$ (0.1 × 0.1)

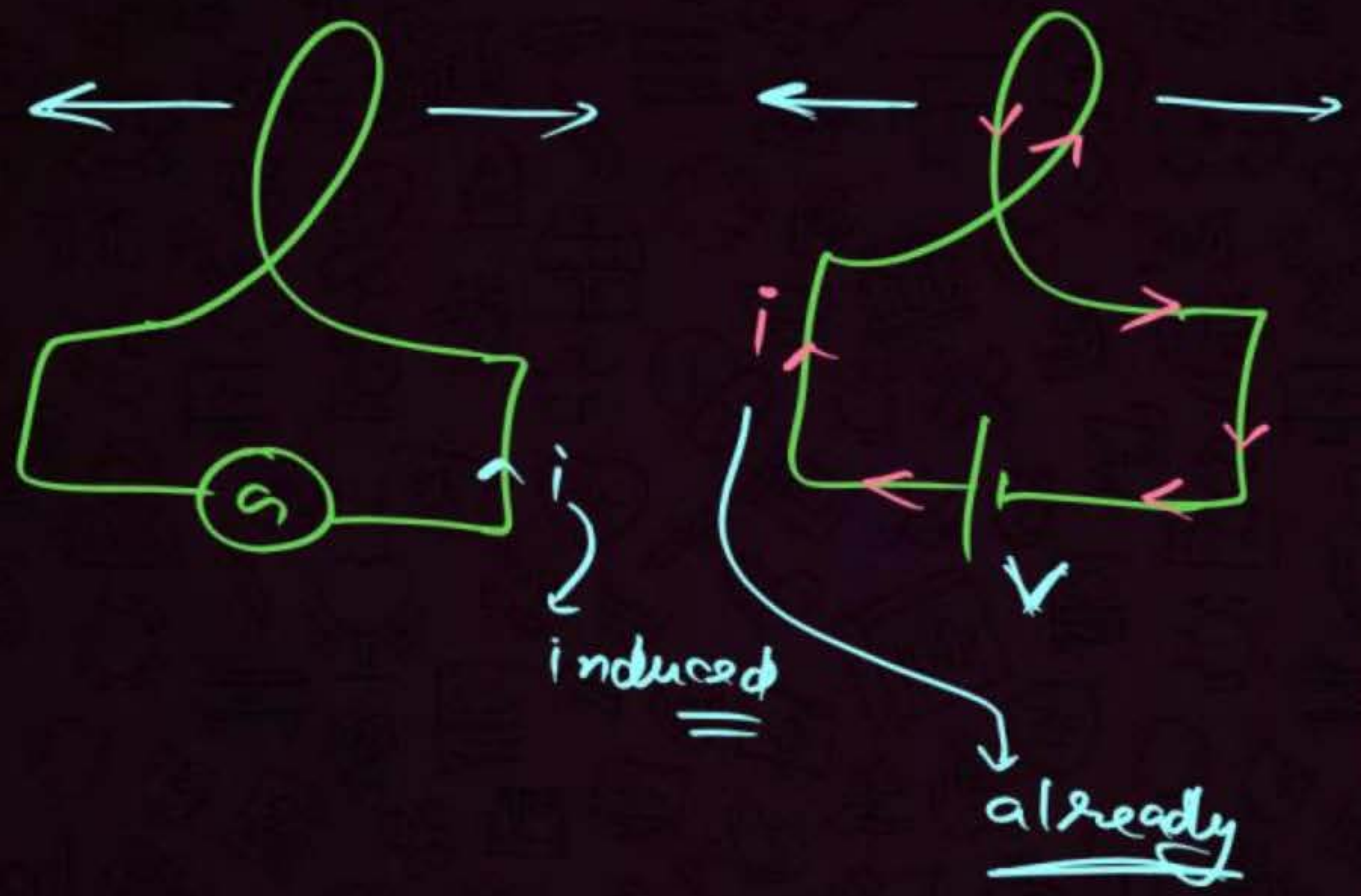
$= 0.01$

Faraday and Henry Experiments → Theory

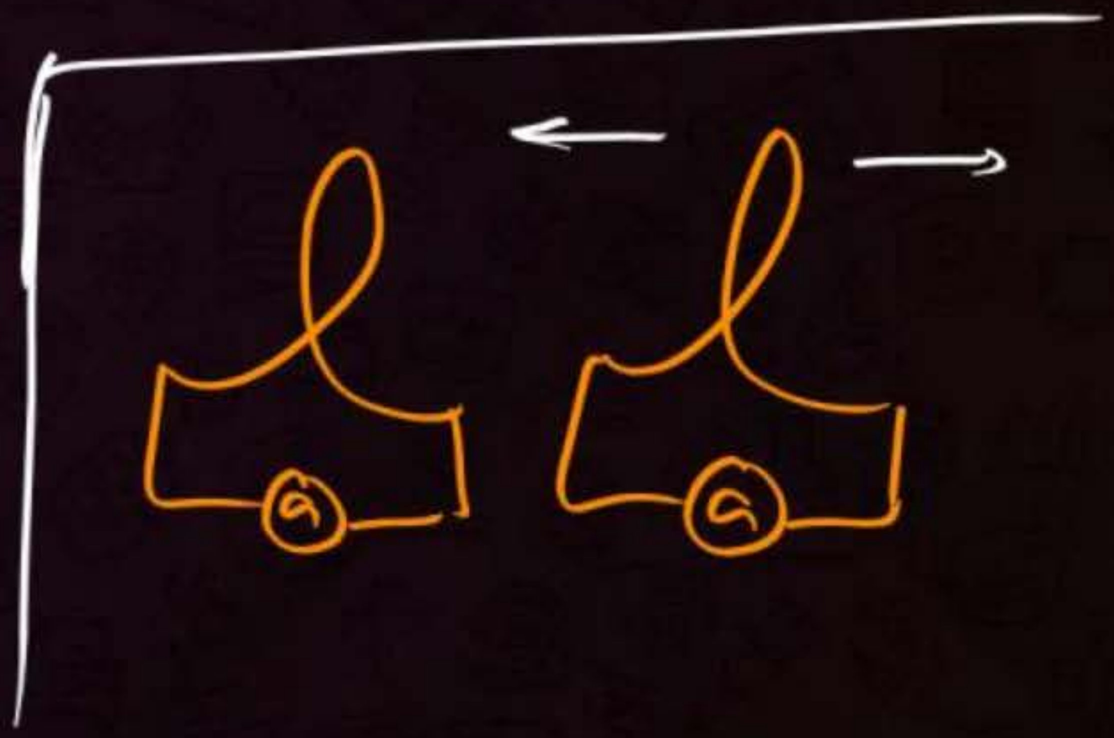
Experiment 1



Experiment 2

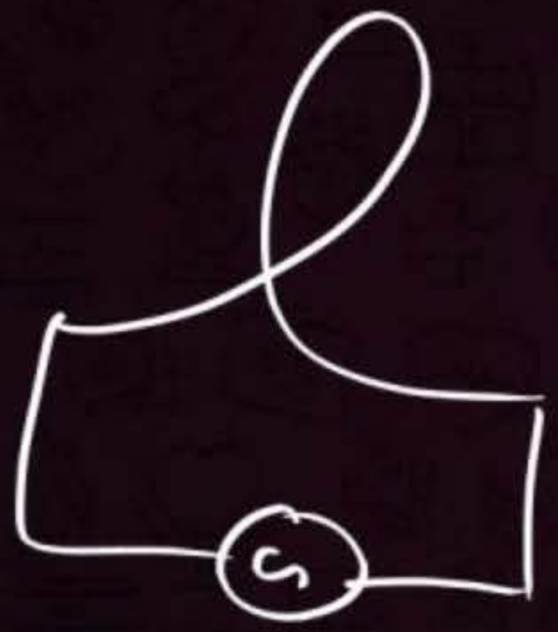


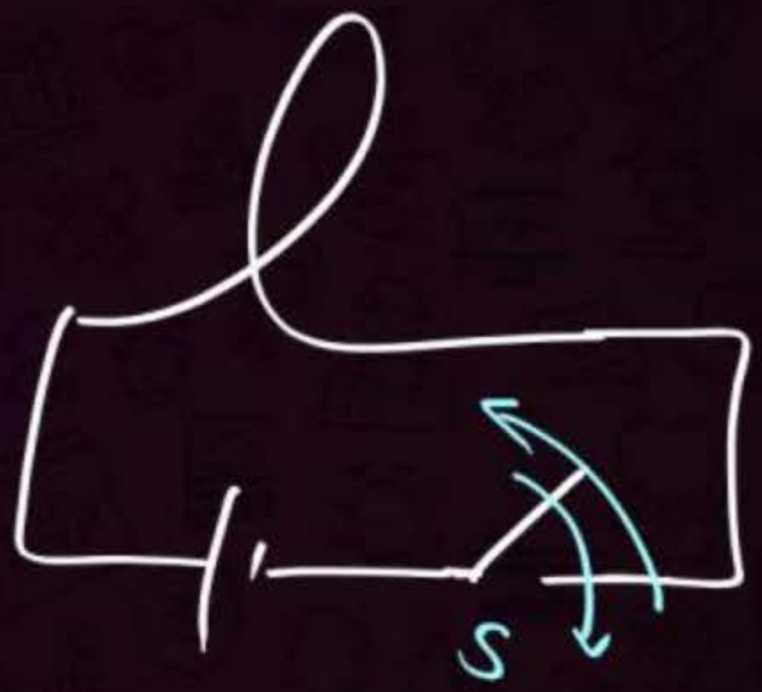
Relative motion b/w coils



Experiment 3

Relative motion ×



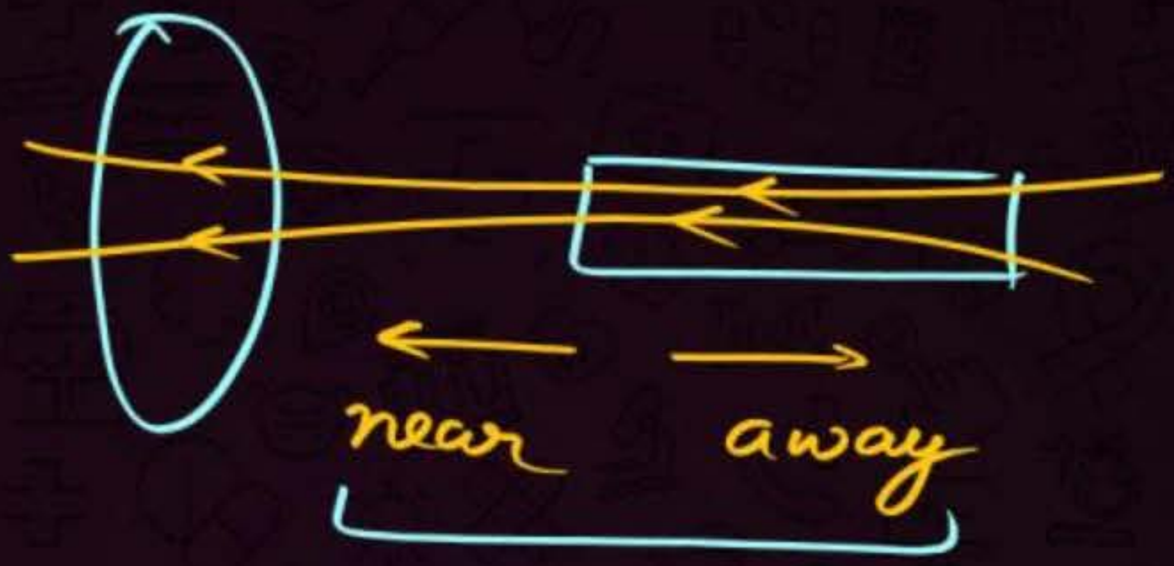


Switch on → Temporary deflection

Switch off → " "

In opp. direction

Cause



↓

magnetic flux

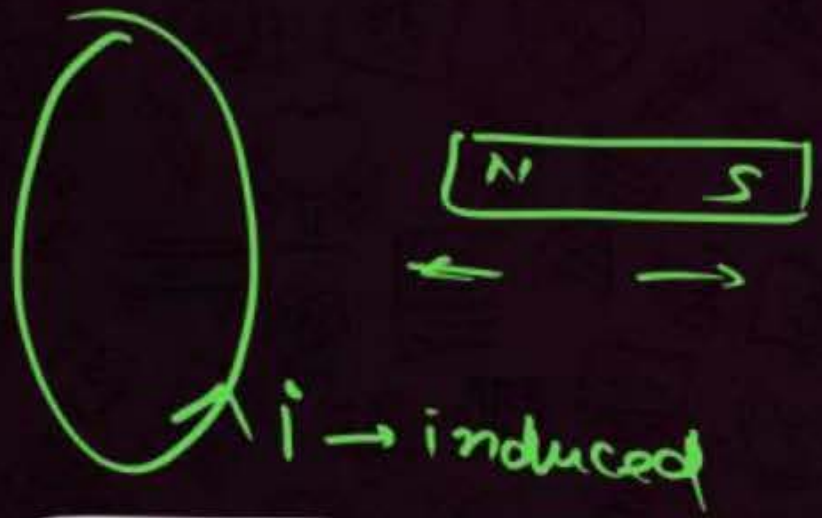
Change

Faraday's Law of Electromagnetic Induction

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

$$i = \frac{e}{R}$$

R = Resistance of coil



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

Units → volt

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

↓ instantaneous value.

N-turns ⟶ $e = -N\frac{d\phi}{dt}$

$$e_{av} = -\frac{\Delta\phi}{\Delta t}$$

N-turns ⟶ $e_{av} = -N\frac{\Delta\phi}{\Delta t}$

QUESTION

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

$\phi \rightarrow$ const $\Rightarrow e = -\frac{d\phi}{dt} = 0$

$\phi \rightarrow$ change

1. Must decrease ×
2. May increase or decrease ✓
3. Must remain constant ×
4. Must increase ×

QUESTION

Assertion: Only a change in magnetic flux will maintain an induced current in the coil.

Reason: The presence of large magnetic flux through a coil maintains a current in the coil if the circuit is continuous.

[AIIMS 1999, 2018]

1. If both assertion and reason are true and reason is the correct explanation of the assertion.
2. If both assertion and reason are true but reason is not correct explanation of the assertion.
3. If assertion is true, but reason is false.
4. Assertion is false, reason is true

QUESTION

The magnetic flux through a coil perpendicular to its plane is varying according to the relation $\phi = (5t^3 + 4t^2 + 2t - 5)$ Weber. If the resistance of the coil is 5 Ω, then the induced current through the coil at $t = 2$ s will be,

[26 June, 2022 (Shift-I)]

(JEE Mains)

(1) 15.6 A

(2) 16.6 A

(3) 17.6 A

(4) 18.6 A

$$|e| = \frac{d\phi}{dt} = 5 \times 3t^2 + 4 \times 2t + 2 \times 1 - 0$$

$$|e| = 15t^2 + 8t + 2$$

$$|e| = 15 \times 2^2 + 8 \times 2 + 2$$

$$|e| = 60 + 16 + 2 = 78\text{ V}$$

$$i = \frac{78}{5} = 15.6\text{ A}$$

QUESTION

Magnetic flux (in weber) in a closed circuit of resistance 20 Ω varies with time t(s} as $\phi = 8t^2 - 9t + 5$. The magnitude of the induced current at $t = 0.25$ s will be ____ mA.

[25 July, 2022 (Shift-II)]

(1) 4

(2) 1/4

(3) 250

(4) 25

$|e| = \frac{d\phi}{dt} = 8\times 2t - 9\times 1 + 0$ (JEE Mains)

$e = 16t - 9$

Put $t = 0.25$ sec $= \frac{1}{4}$ sec

$e = 16\times\frac{1}{4} - 9 = 4 - 9 = -5V$

$i = \frac{e}{R} = \frac{5}{20} = \frac{1}{4} A$

$\frac{1}{4}\times 1000$ mA

$= 250$ mA

QUESTION

HW

A coil of resistance 400Ω is placed in a magnetic field. If the magnetic flux ϕ(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)

(1) 0.5 A

(2) 0.1 A

(3) 2 A

(4) 1 A

QUESTION

HW

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

(1) 33 V

(2) 43 V

(3) 108 V

(4) 10 V

Ques

$\phi = 5\ Wb$ at $t = 3\ sec$

$\phi = 17\ Wb$ at $t = 5\ sec$.

Find e_{av} in the interval.

$t = 3$ to 5 sec

$$|e_{av}| = \frac{\Delta\phi}{\Delta t} = \frac{\phi_2 - \phi_1}{t_2 - t_1} = \frac{17-5}{5-3}$$

$$= \frac{12}{2} = 6V$$

Ques

$\phi = 2\ Wb$ at $t = 1\ sec$

$\phi = -2\ Wb$ at $t = 1.5\ sec$.

$e_{av} = ?$ in interval.

$$|e| = \frac{-2-(2)}{1.5-1}$$

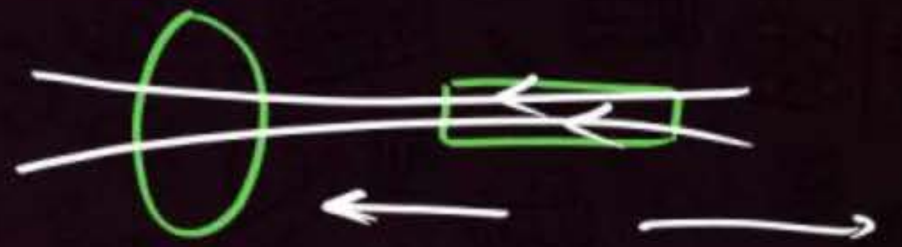
$$= \frac{-4}{0.5} = -8V$$

$|e| = 8V$

Methods to change Magnetic Flux

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

a) B change → inc. / → dec.



$B\uparrow$ $\phi\uparrow$

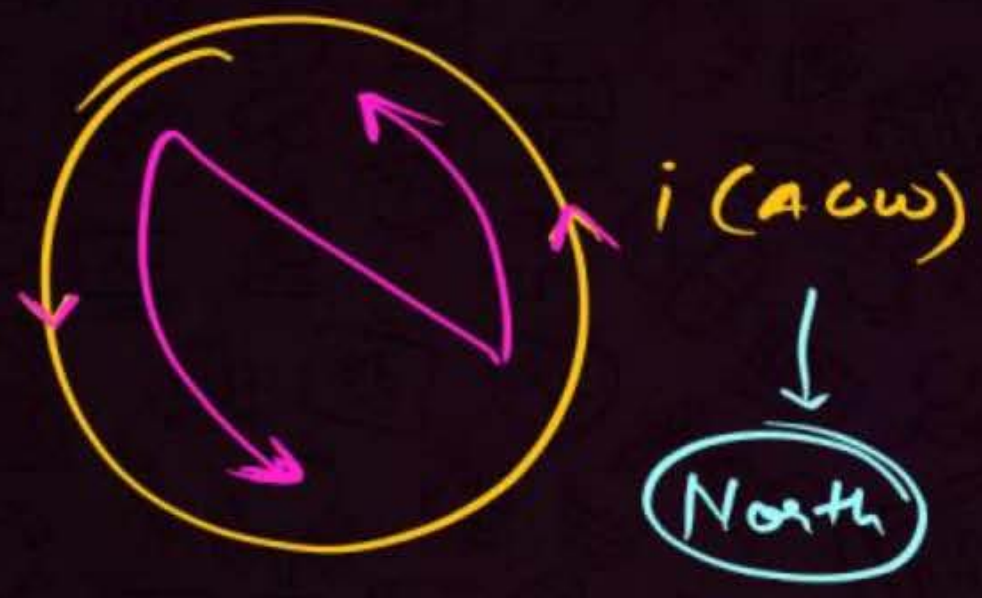
$B\downarrow$ $\phi\downarrow$.

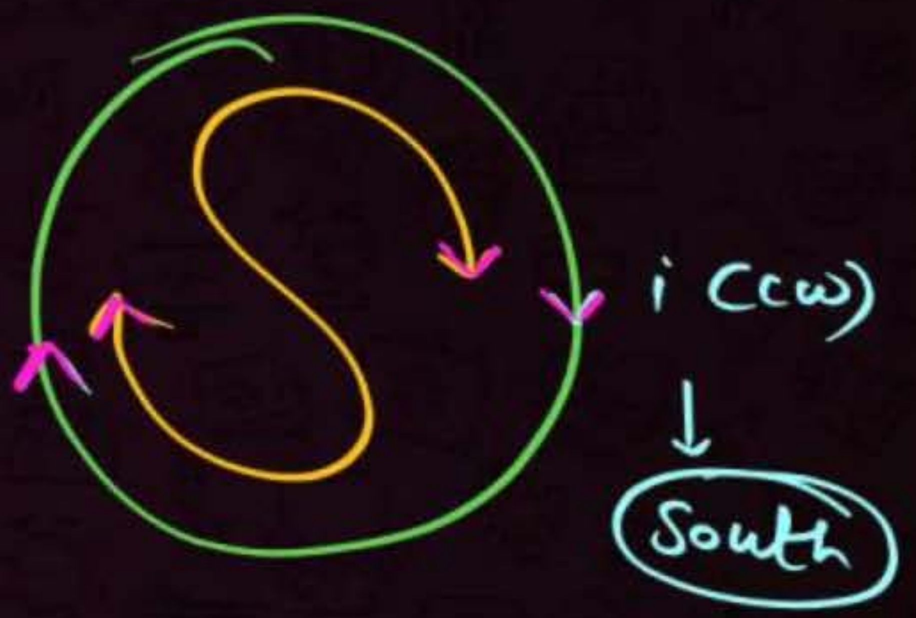
b) A change
↓
Through which flux passes

Shrink or expand

c) θ change
→ eg :- AC Generator
→ coil rotate

Sign Conventions for direction of current





Lenz Law

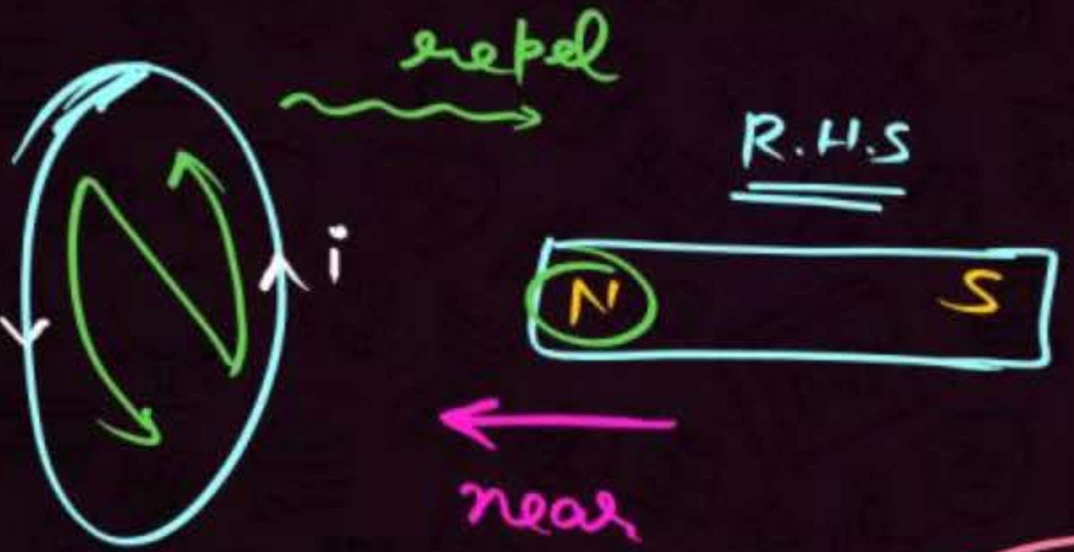
→ Jis Thaali Mein Khaye, Usi Mein Hath Dhoye !!!

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

current → Hath Dhona (Beta)

change in magnetic flux → Thaali (Baap)

Ours LHS → $i \to CW$



$N \to ACW$

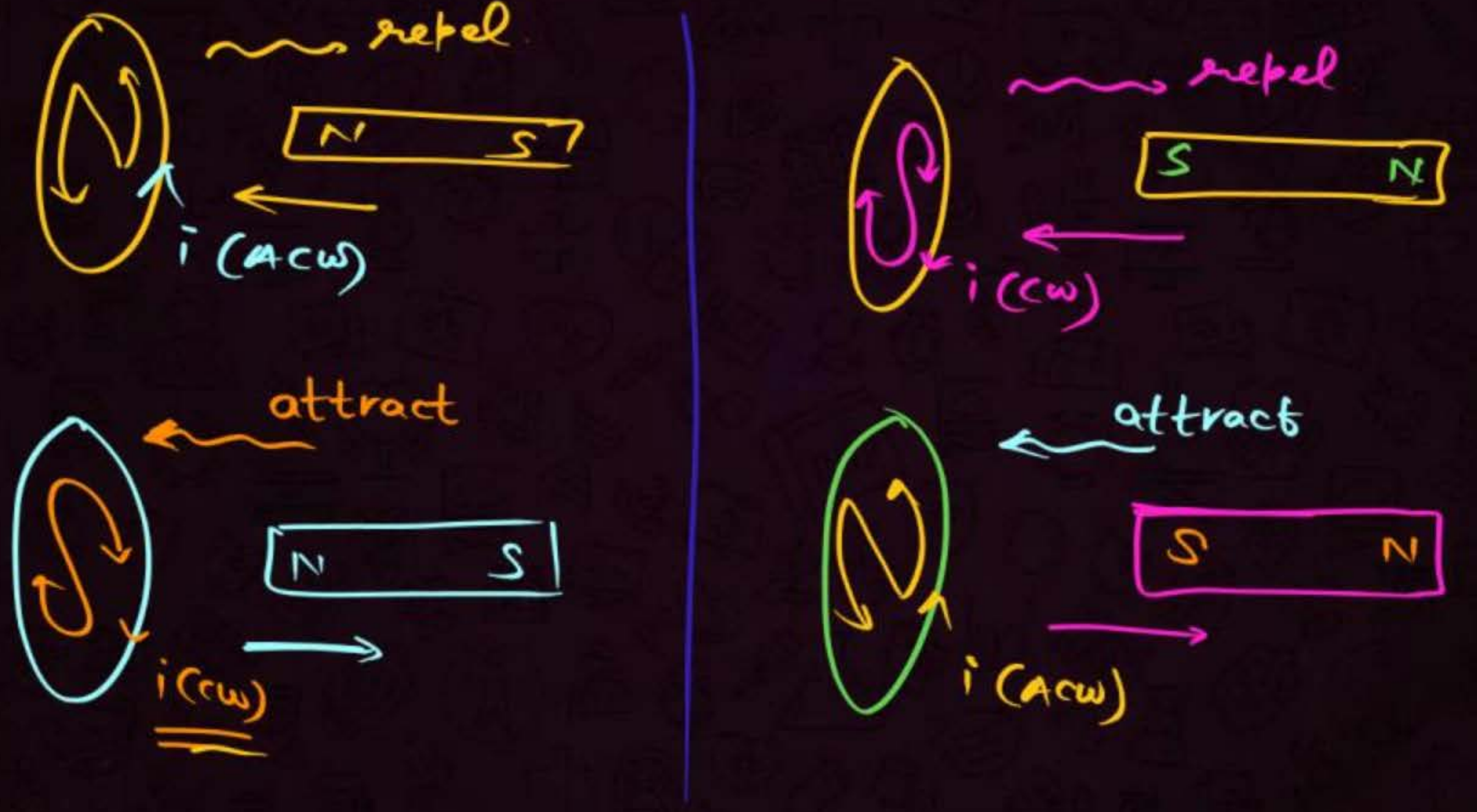
$i \to ACW \to$ as seen from magnet's side

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

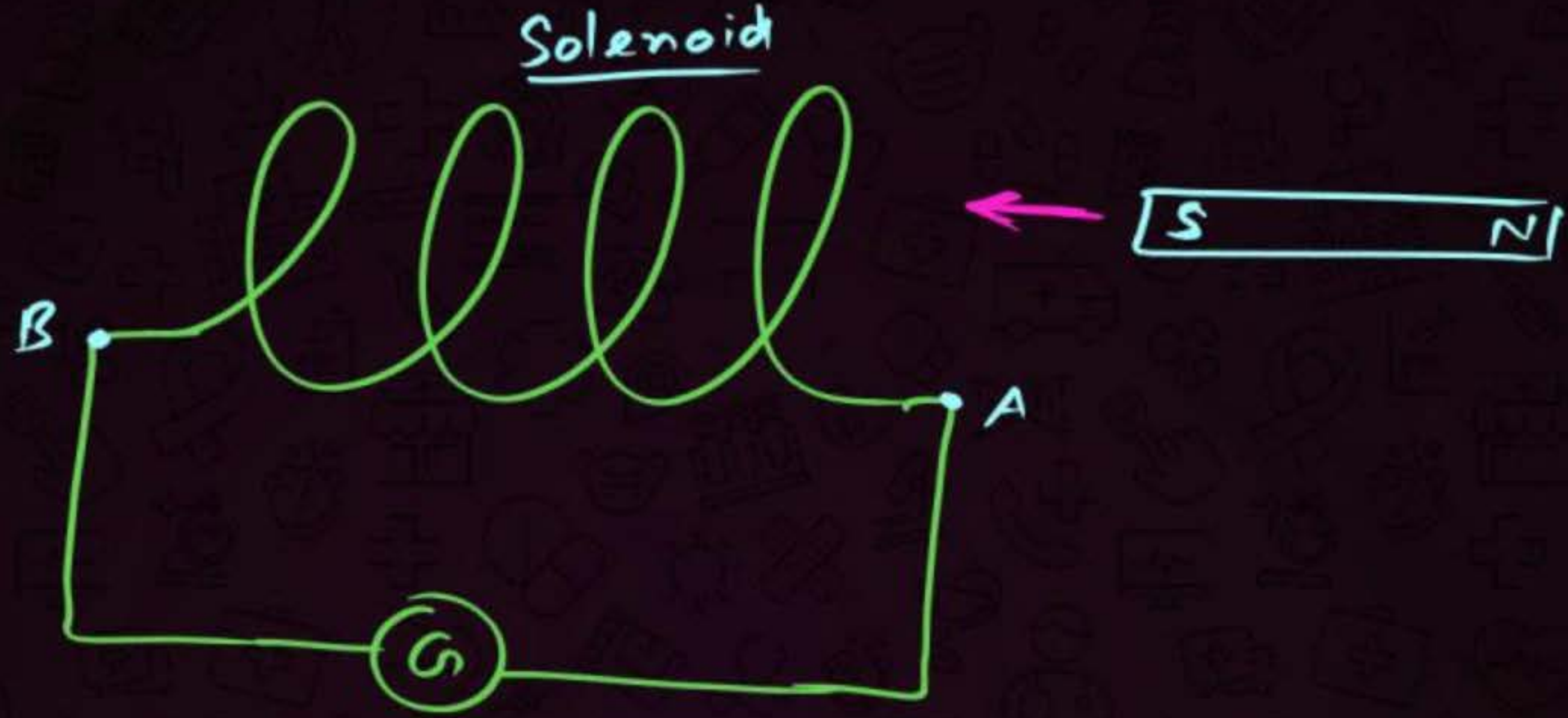
↓ Lenz Law

Examples on motion of magnet

Magnet's side



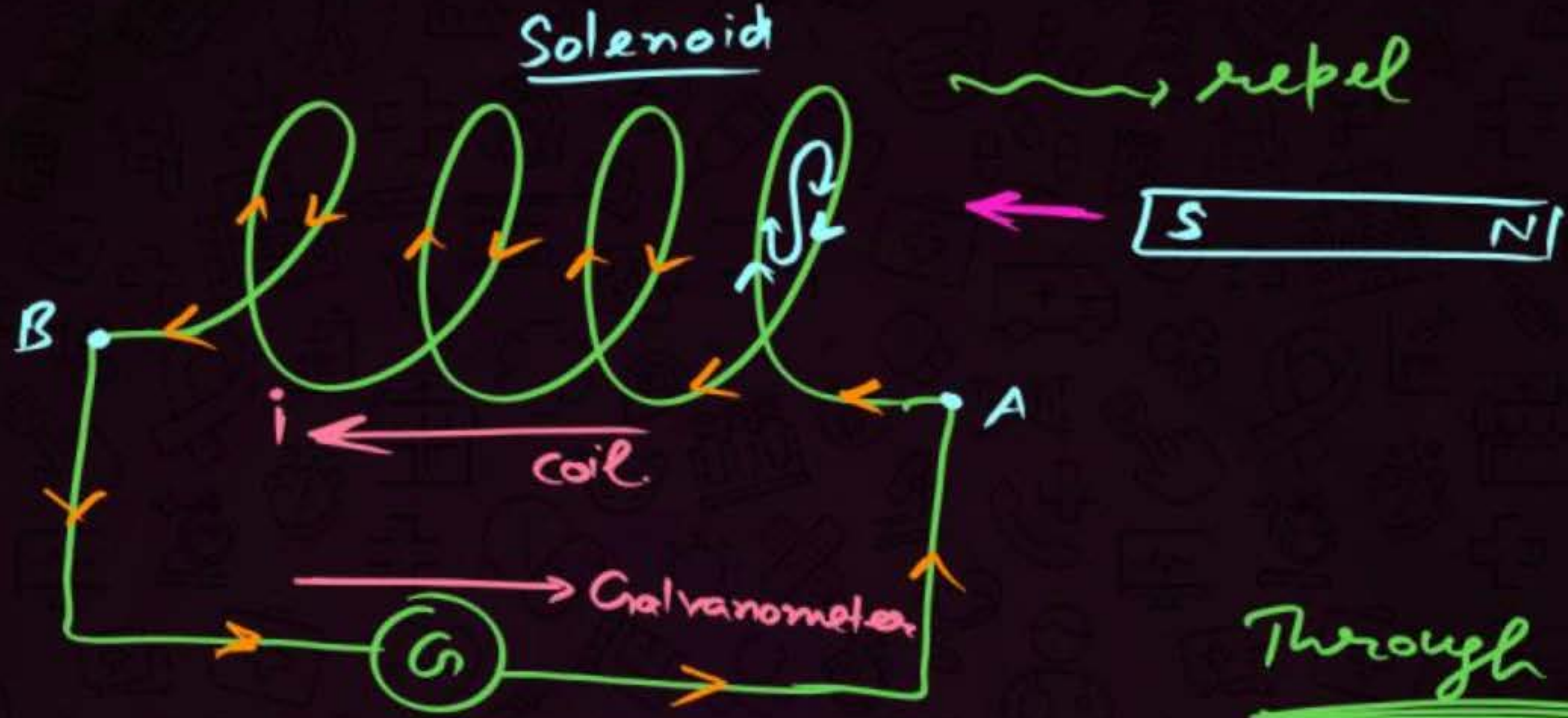
Ques



Direction of current through galvanometer?

- A to B
- B to A

Ques



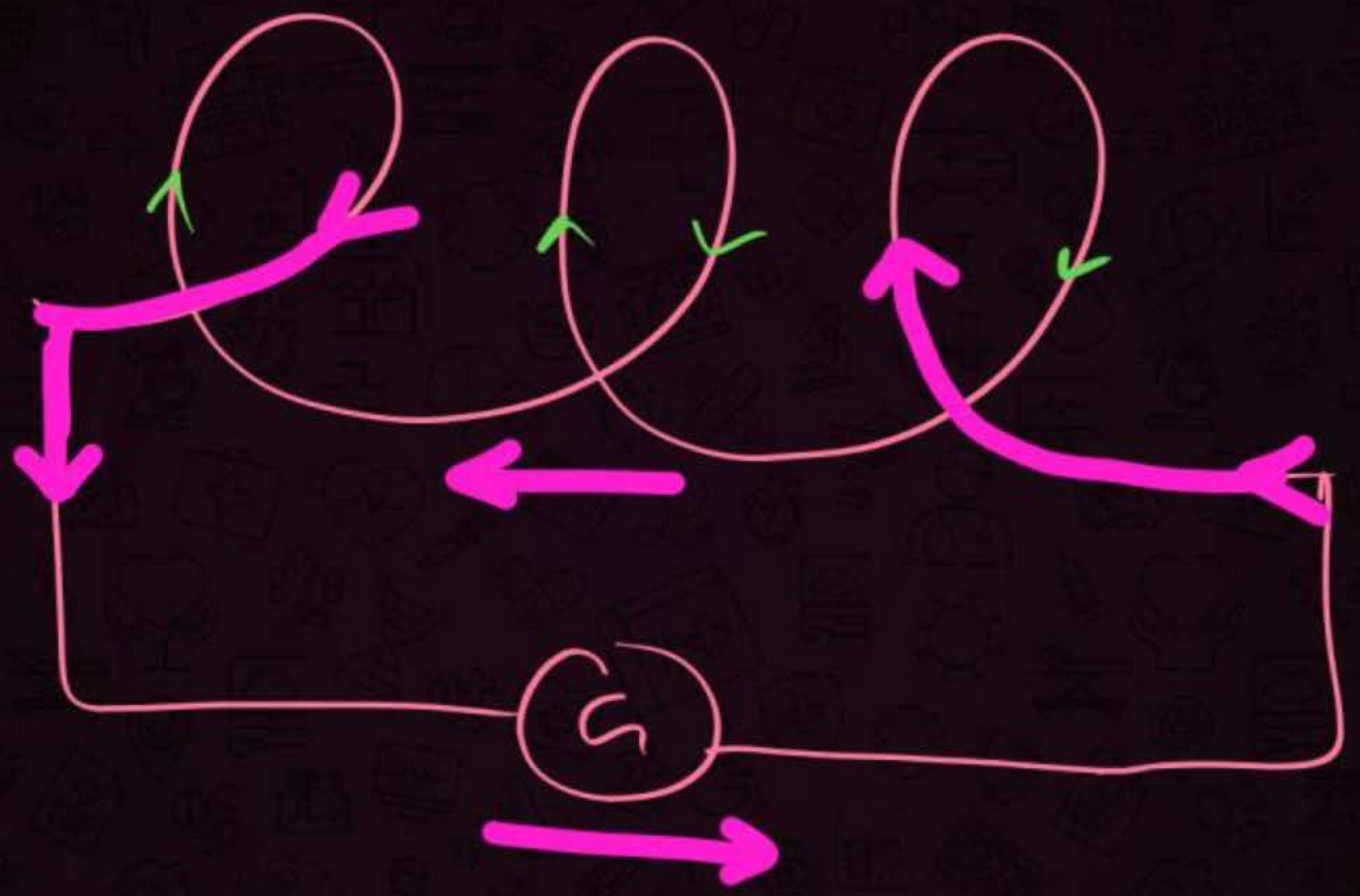
Direction of current through galvanometer?

- A to B
- B to A

Through coil

A to B

B to A


G

QUESTION

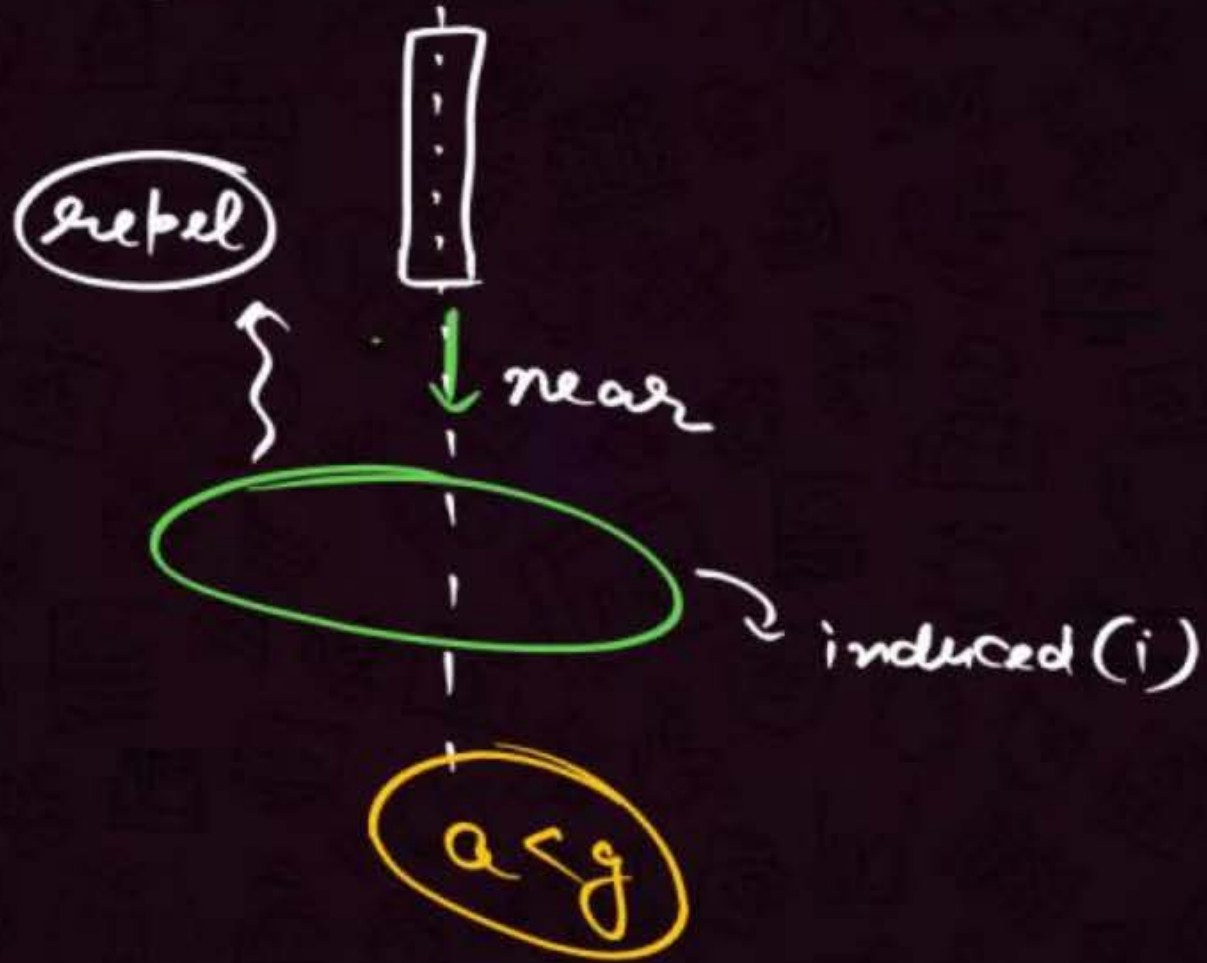
A metal ring is held horizontally and bar magnet is dropped through the ring with its length along the axis of the ring. The acceleration of the falling magnet is

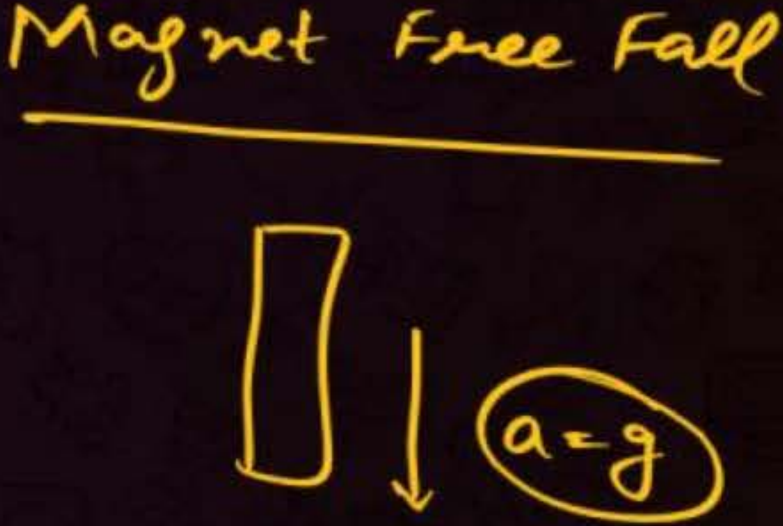
(1) more than g

(2) equal to g

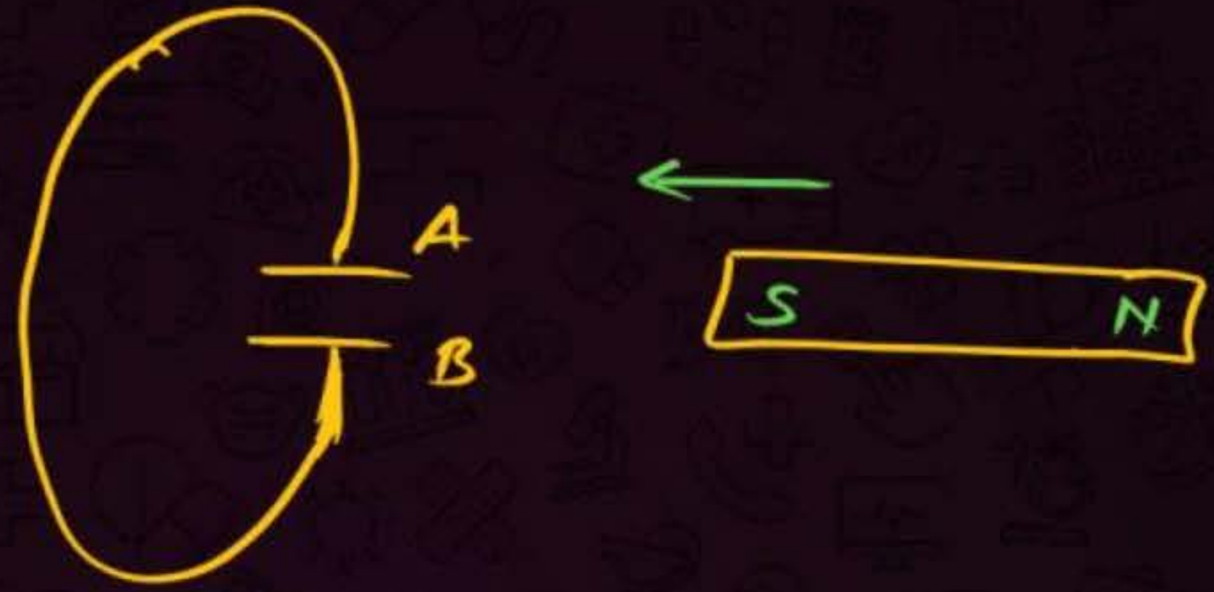
(3) less than g

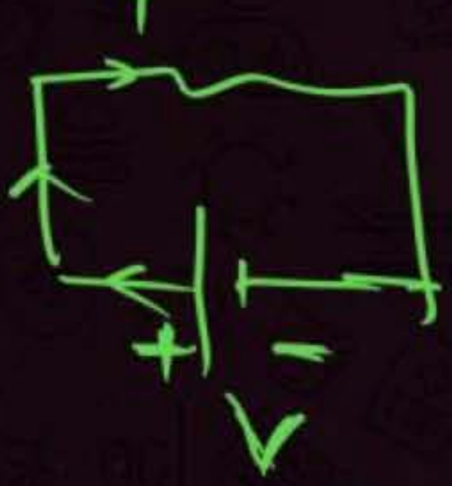
(4) either (A) or (C)



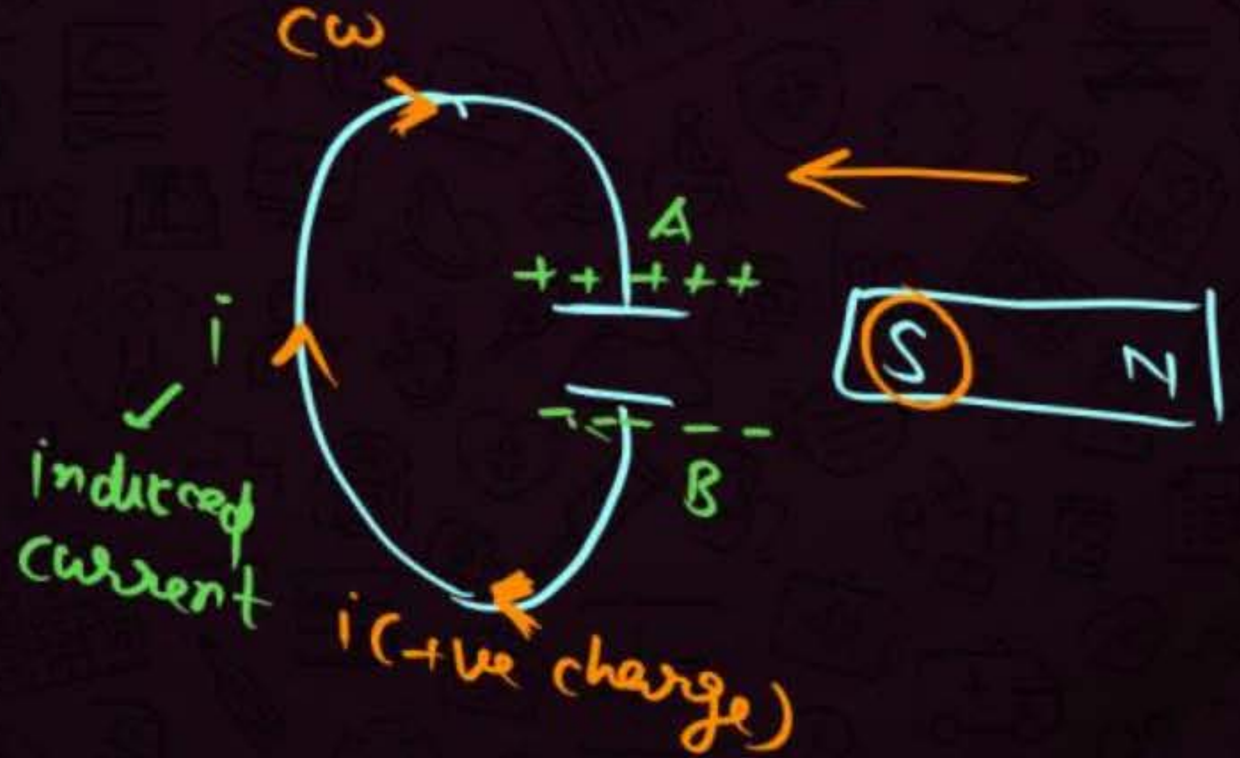


Ques





Which capacitor plate is at higher potential?



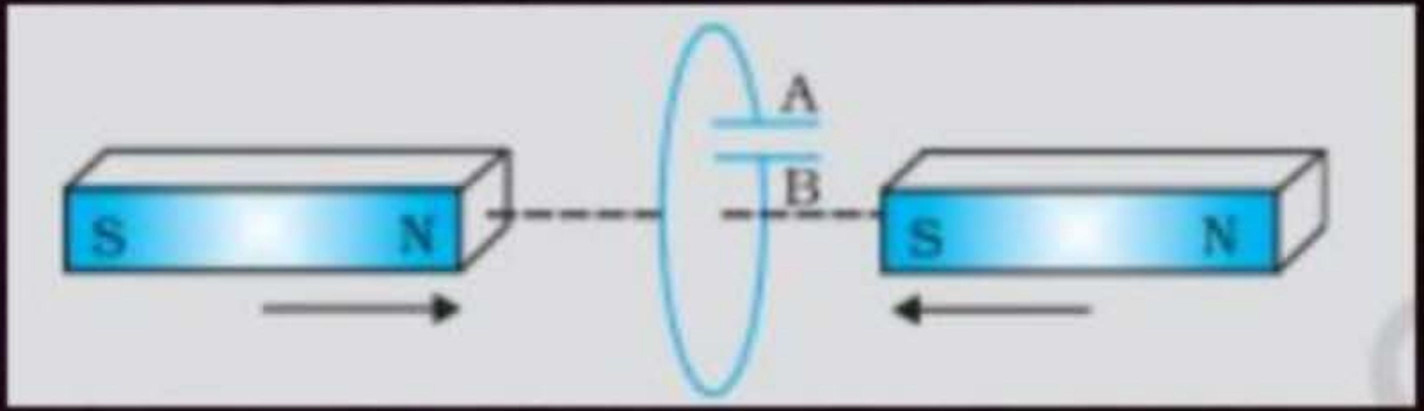
$V_A > V_B$

QUESTION

Predict the polarity of the capacitor in the situation described. Which capacitor plate will be at higher potential

HW

(NCERT Example)



QUESTION

Faraday Law

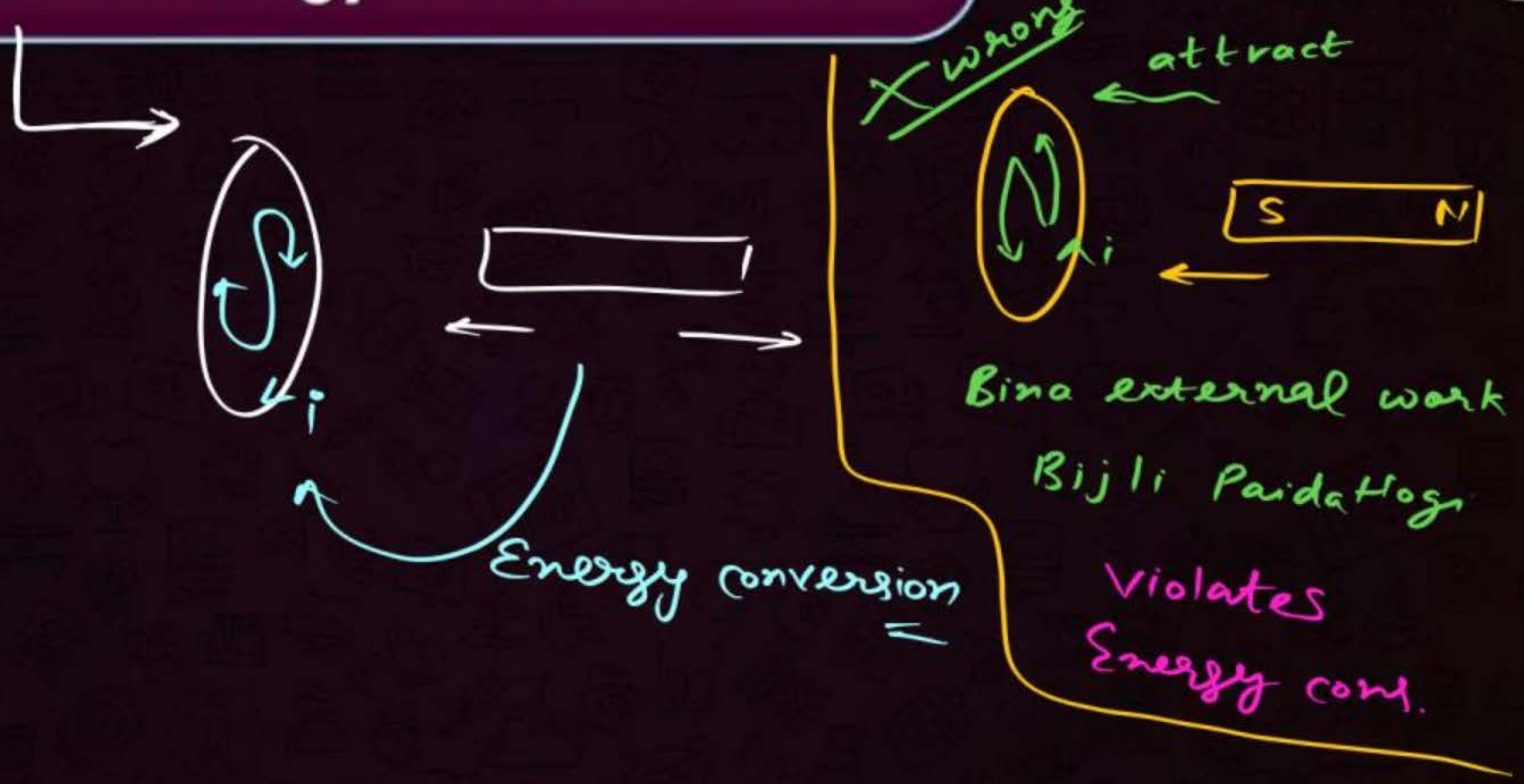
Assertion: Whenever magnetic flux linked with the coil changes with respect to time, then an emf is induced in it.

Lenz Law.

Reason: According to lenz law, the direction of induced current in any coil in such a way that it always opposes the cause by which it produced.

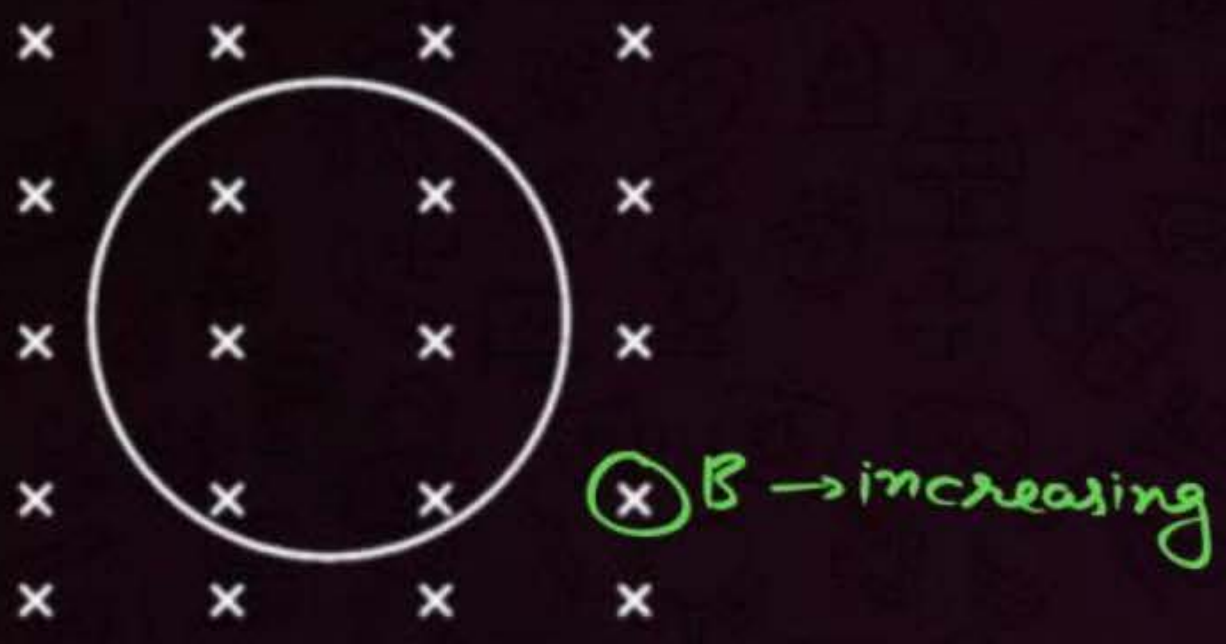
1. If both assertion and reason are true and reason is the correct explanation of the assertion.
2. If both assertion and reason are true but reason is not correct explanation of the assertion.
3. If assertion is true, but reason is false.
4. Assertion is false, reason is true

Lenz Law and Energy Conservation



QUESTION

Find direction of current in each case:



(I) → B ⊗

(II) → (inc.) or dec.

to decrease ⊗ B,

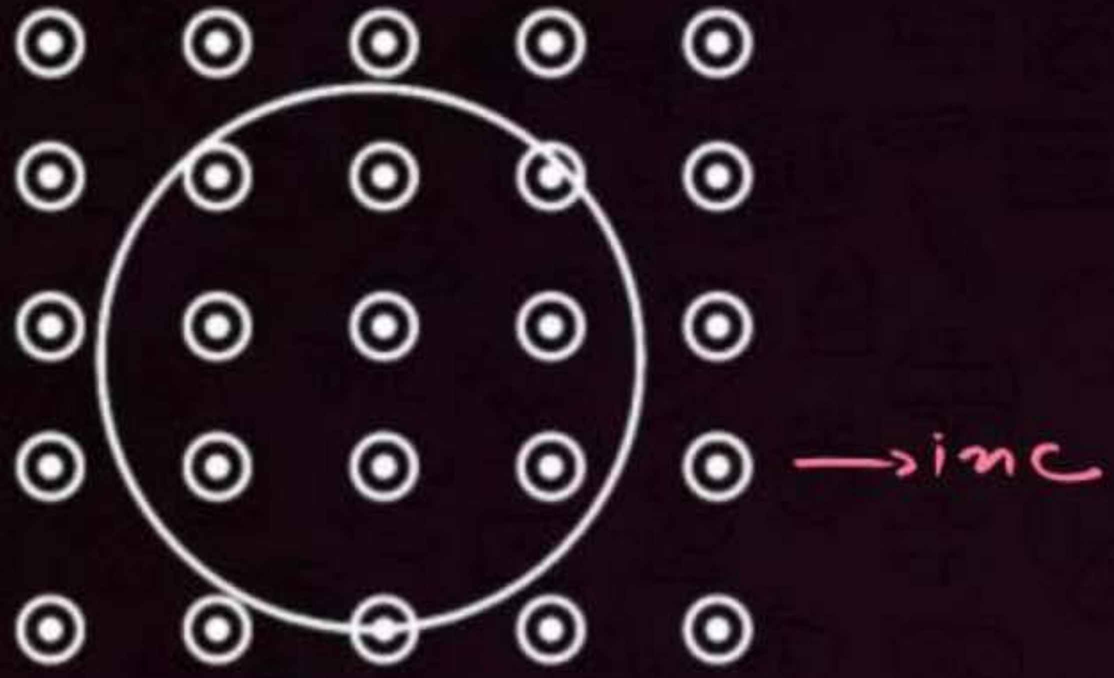
⊙ B should be produced

(ACW)

I → B ⊗

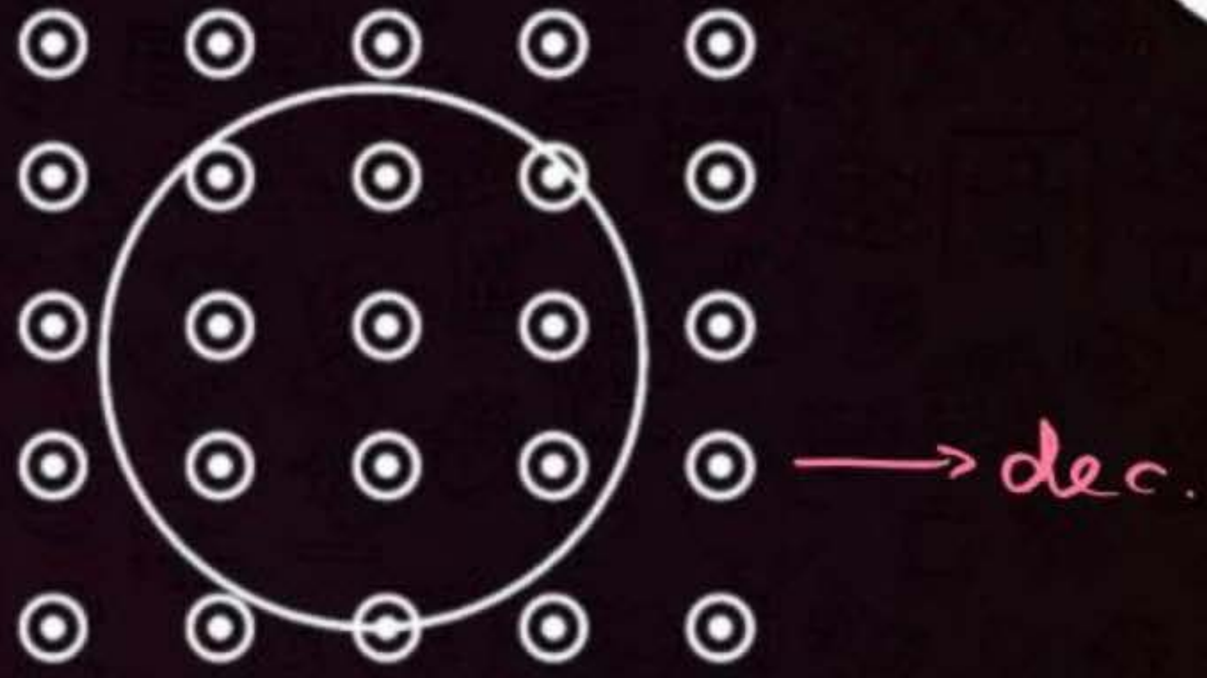
II → dec.

i (CW)



(I) B ⊙

(II) inc



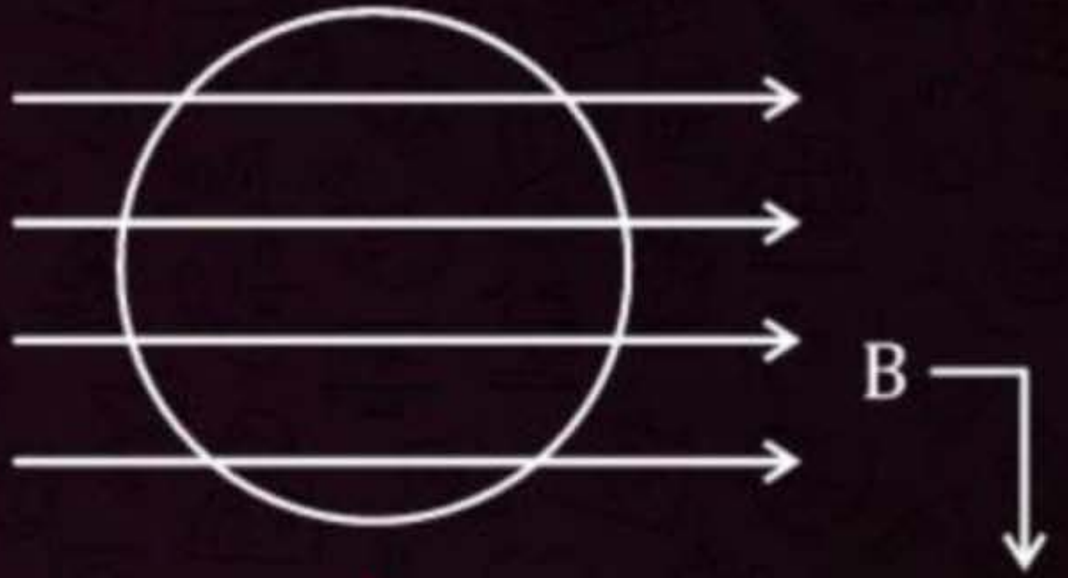
(I) → B ⊙

(II) → dec

QUESTION

$i = ?$ (Direction)

$i = 0$



llel to loop.

B is increasing.

No flux is passing

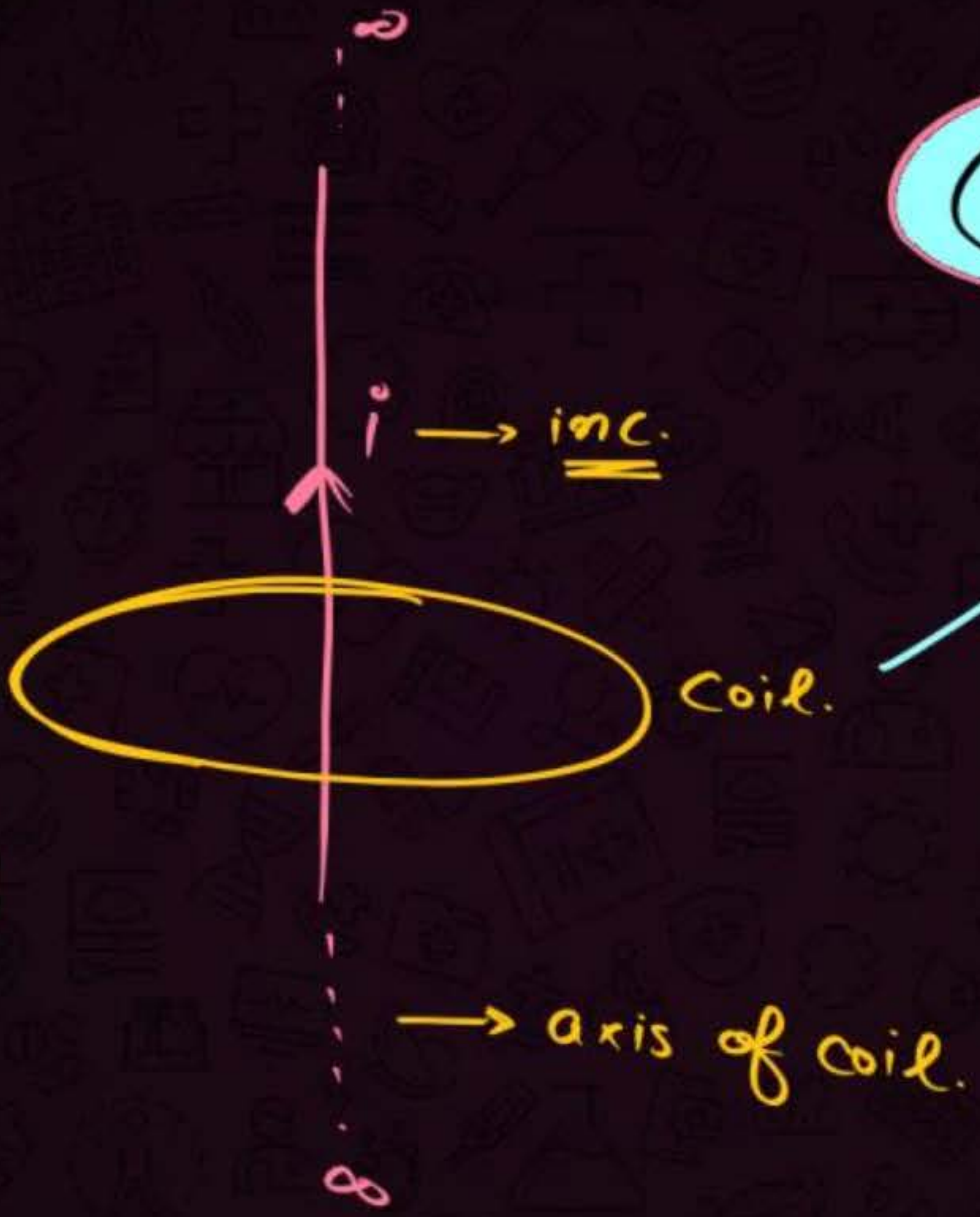
$\phi = 0$

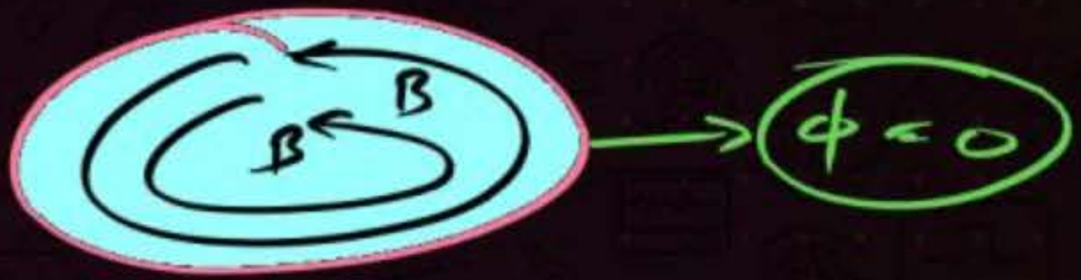
const.

$\phi = BA\cos 90^\circ$

$\phi = 0$

Ques





Induced current

a) Yes

b) No

A coil is placed in a magnetic field $\vec{B}$ shown below : A current is induced in the coil because $\vec{B}$ is (JEE Main 2021)

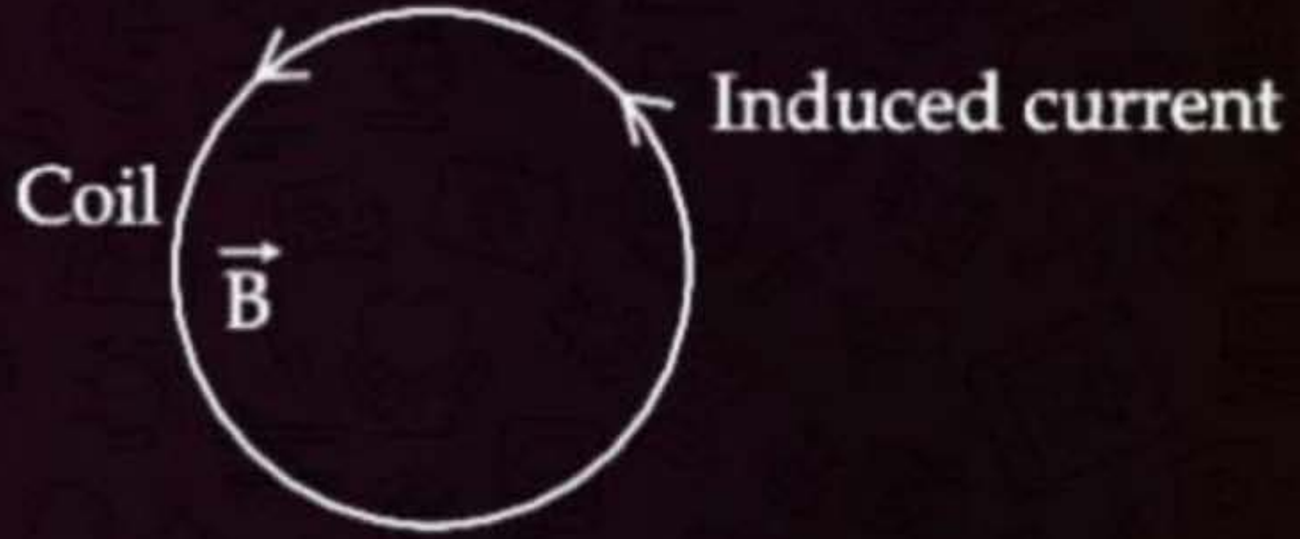
HW

(a) parallel to the plane of coil and increasing with time

(b) outward and increasing with time

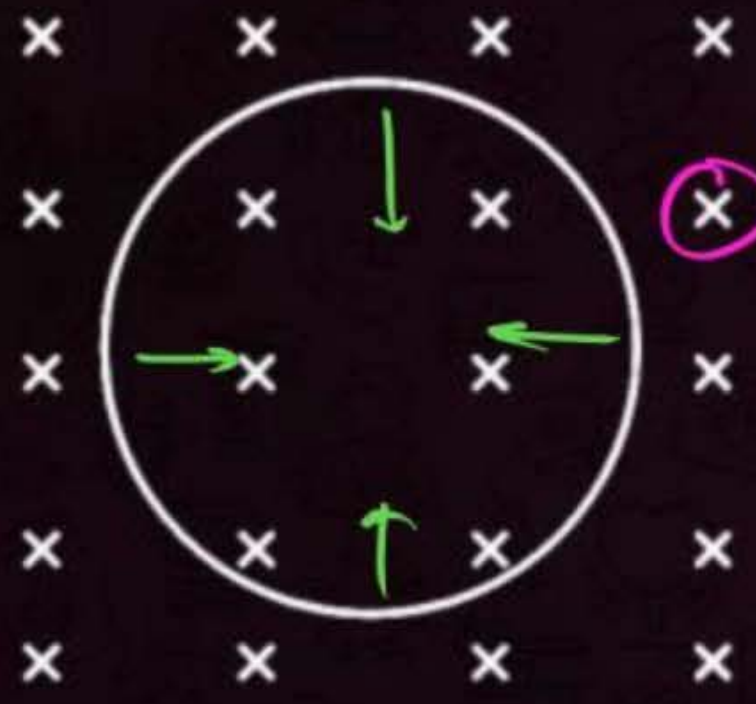
(c) outward and decreasing with time

(d) parallel to the plane of coil and decreasing with time

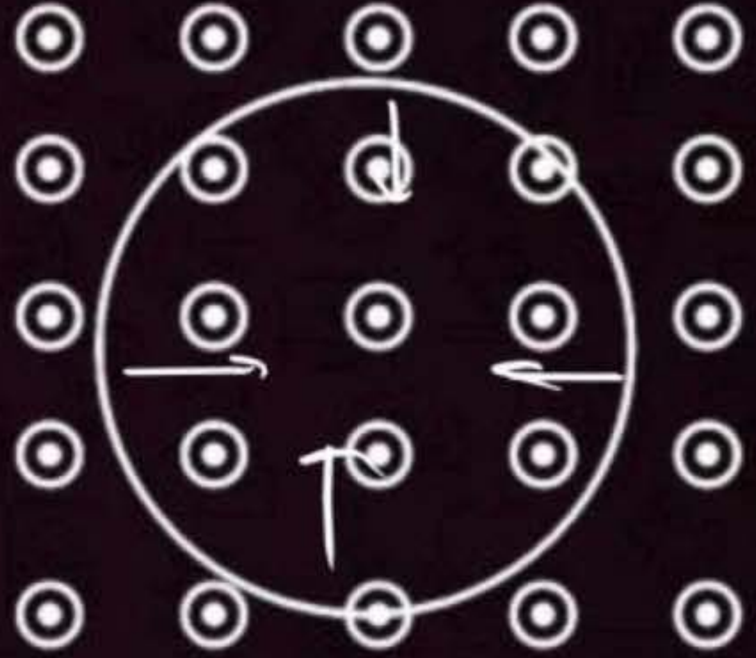


QUESTION

Find direction of current in each case:



Shrink
$i = ?$



Shrink
$i = ?$

Inside /Outside of Magnetic Field

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 → outside the B ⇒ $\phi = 0$

$i = 0$

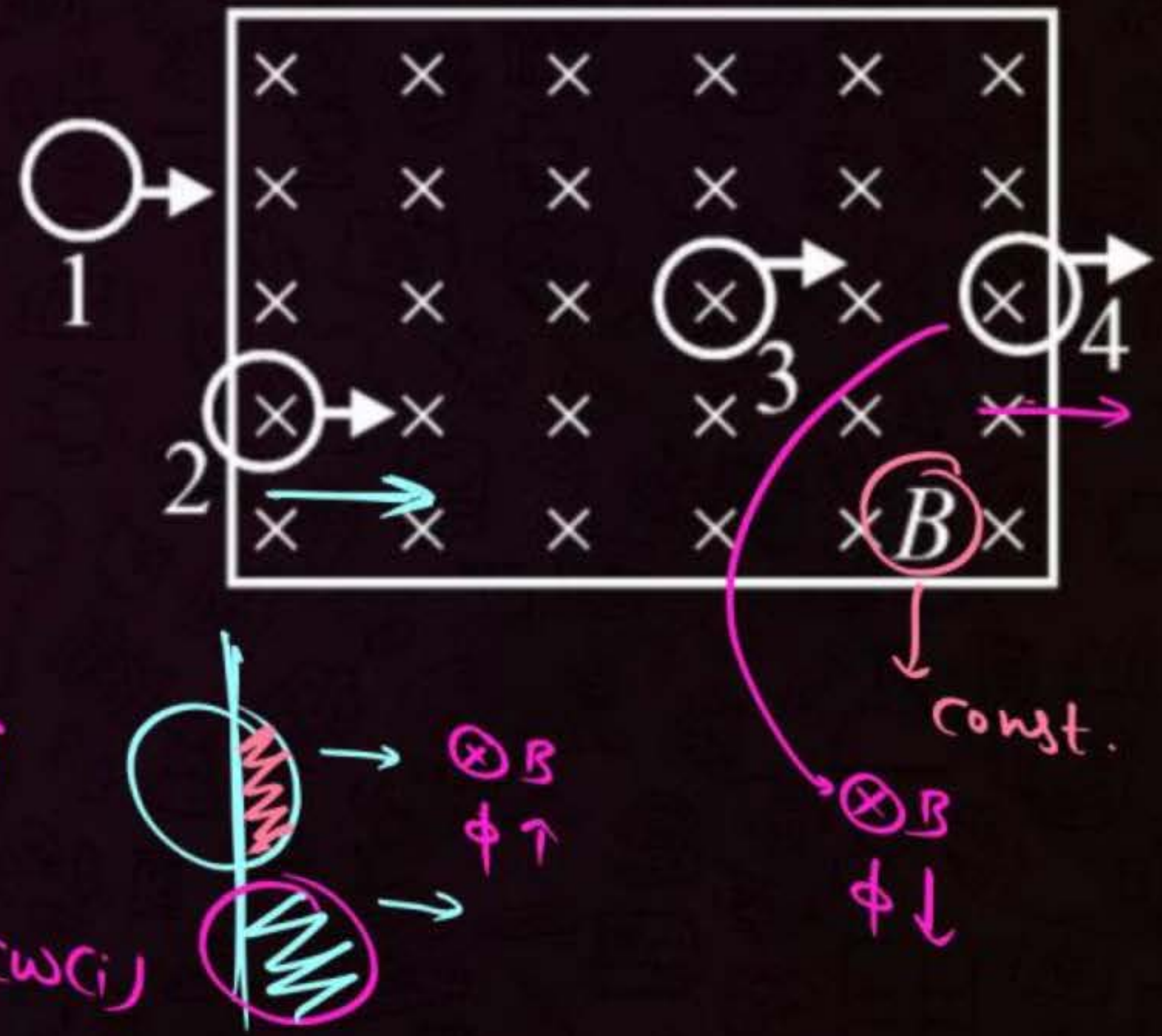
3 → completely inside B.

B, A, θ → const.

ϕ → const ⇒ $i = 0$

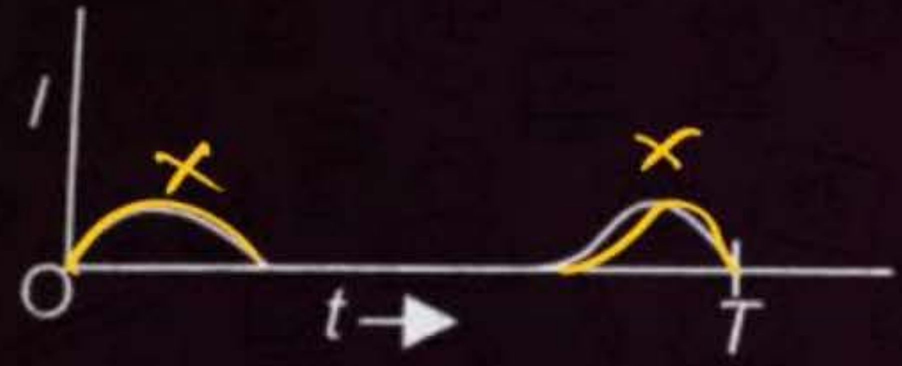
2 → ACW

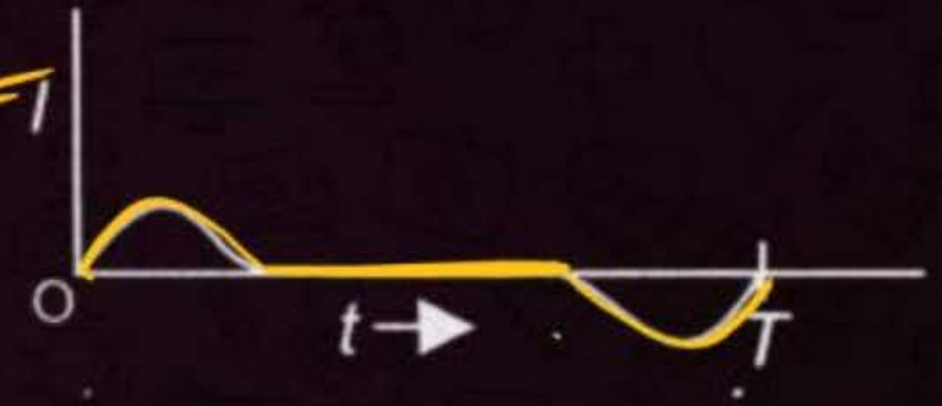
4 → CW

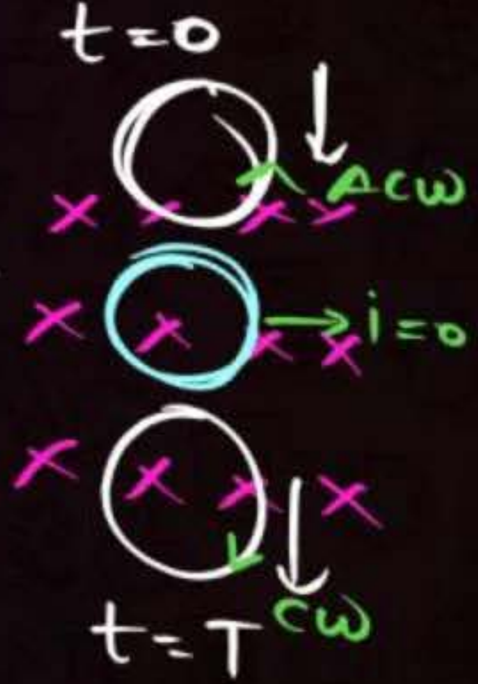


QUESTION

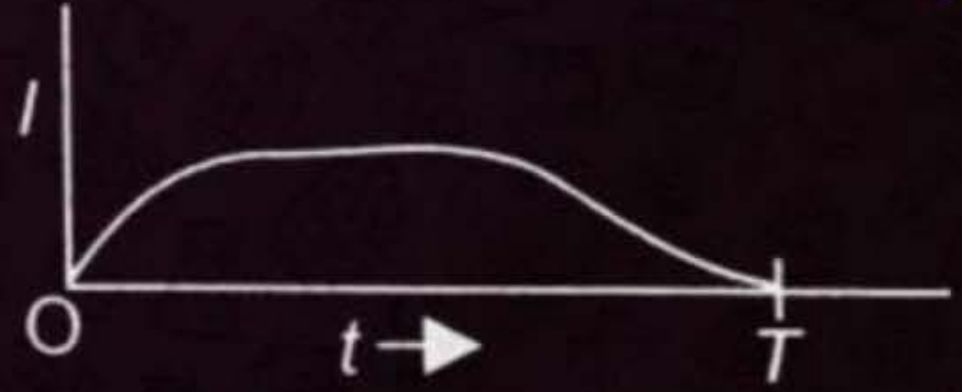
A metallic ring is dropped down, keeping its plane perpendicular to a constant and horizontal magnetic field. The ring enters the region of magnetic field at $t = 0$ and completely emerges out at $t = \mathrm{T}$ sec. The current in the ring varies as (AIIMS 2006)

(1)


(2)




(3)


(4)


Expression for magnetic field or area changing with time

$\phi = BA\cos\theta$

- Let $\theta = 0°$

$\phi = BA$

- $|e| = \frac{d\phi}{dt} = \frac{d(BA)}{dt}$

If $A \to$ const, $B \to$ change $\Rightarrow |e| = A\frac{dB}{dt} \longrightarrow NA\frac{dB}{dt}$

If $B \to$ const., $A \to$ change: $|e| = B\frac{dA}{dt} \longrightarrow NB\frac{dA}{dt}$

QUESTION

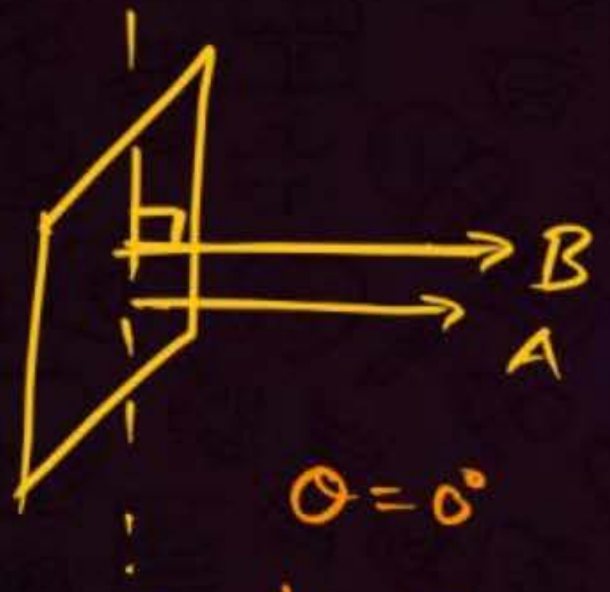
A rectangular coil of 20 turns and area of cross-section 25 sq. cm has a resistance of 100 Ω. If a magnetic field which is perpendicular to the plane of coil changes at a rate of 1000 tesla per second, the current in the coil is (1992)

(1) 1 A

(2) 50 A

(3) 0.5 A

(4) 5 A



$\theta = 0^\circ$

$\phi = BA$

$e = NA\frac{dB}{dt}$ (given) $= 20 \times (25 \times 10^{-4}) \times 1000$

$= 500 \times 10^{-4} \times 1000$

$= 50\,V$

$i = \frac{50}{100} = 0.5\,A$

QUESTION

At a place earth's magnetic field, 5×10^{-5} Wb/m^2 is acting perpendicular to a coil of radius R = 5 cm. If $\mu_0/4\pi = 10^{-7}$ T m A^{-1}, then how much current is induced in circular loop?

(AIIMS 2001)

B → const.

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

(1) 0.2 A

(2) 0 A

(3) 4 A

(4) 40 A

QUESTION

A conducting loop of radius $10/\sqrt{\pi}$ cm is placed perpendicular to a uniform magnetic field of 0.5 T. The magnetic field is decreased to zero in 0.5 s at a steady rate. The induced emf in the circular loop at 0.25 s is:

[24 Jan, 2023 (Shift-I)]

(JEE Mains)

1. $emf = 1$ mV
2. $emf = 10$ mV
3. $emf = 100$ mV
4. $emf = 5$ mV

$B_f = 0$

$r = \frac{10}{\sqrt{\pi}}$ cm

$B_i \rightarrow 0.5$ T

$\Delta t = 0.5$ sec.

$e = NA\frac{\Delta B}{\Delta t}$

$\Delta B = B_f - B_i$

$= 0 - 0.5$

$\Delta B = -0.5$

$|\Delta B| = +0.5$

$e = 1 \times \pi r^2 \times \frac{0.5}{0.5}$

$= \pi \times \frac{10}{\sqrt{\pi}} \times \frac{10}{\sqrt{\pi}} \times 10^{-4}$

$= 10^{-2}$ V

$= 10^{-2} \times 1000$ mV

$= 10$ mV

each time

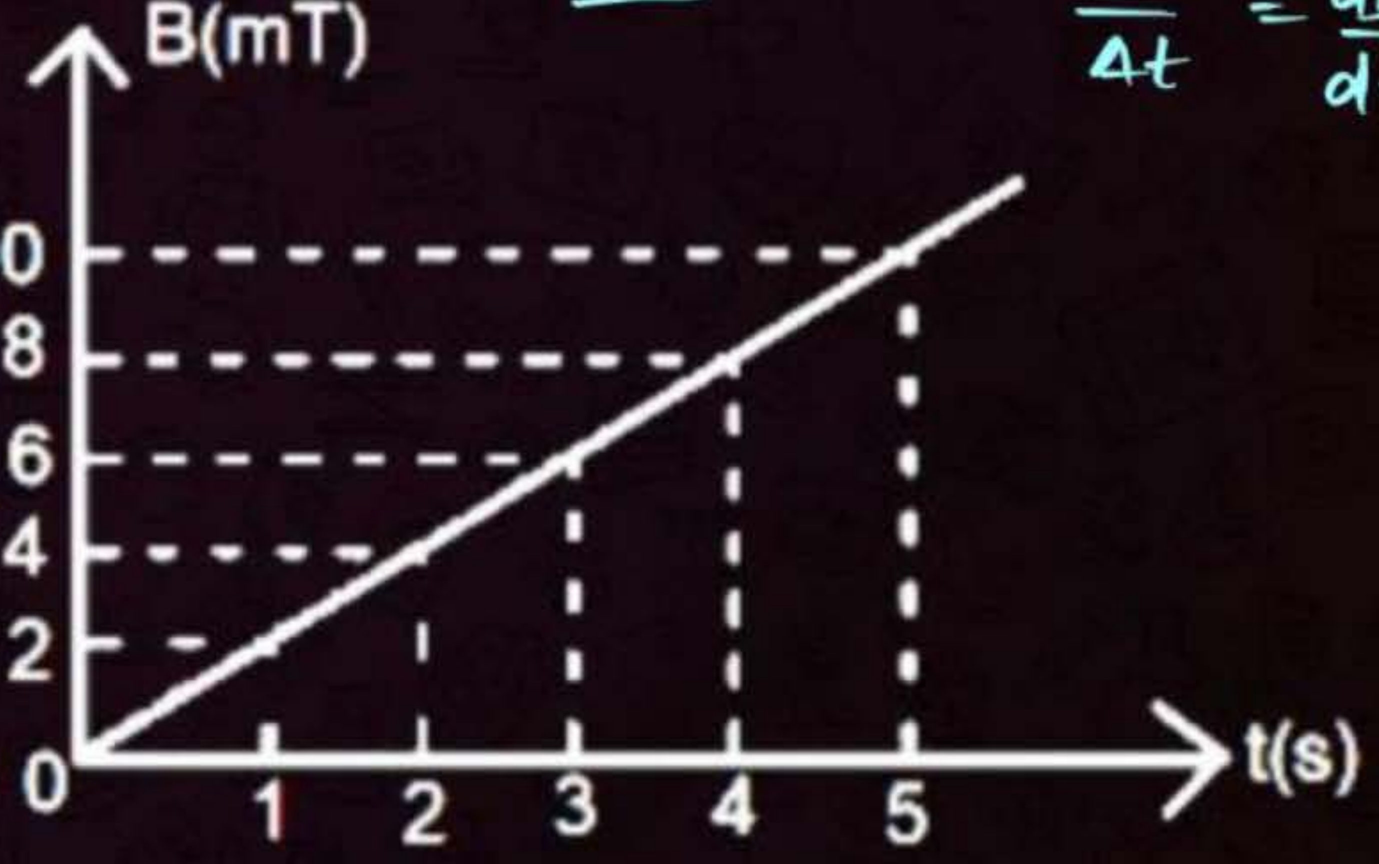
QUESTION

The magnetic field B crossing normally a square metallic plate of area 4 m^2 is changing with time as shown in figure. The magnitude of induced emf in the plate during $t = 2$ s to $t = 4$ s, is ______ mV

[11 April, 2023 (Shift-I)]

HW

Hint Slope $= \frac{\Delta B}{\Delta t} = \frac{dB}{dt}$



QUESTION

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

(2016)

1. Zero in loop 1 and zero in loop 2
2. $-\frac{dB}{dt}\pi r^2$ in loop 1 and $-\frac{dB}{dt}\pi r^2$ in loop 2
3. $-\frac{dB}{dt}\pi R^2$ in loop 1 and zero in loop 2
4. $-\frac{dB}{dt}\pi r^2$ in loop 1 and zero in loop 2

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

$= -\pi r^2 \frac{dB}{dt}$

$\phi = 0 \rightarrow e = 0$

Coil area $= \pi R^2$

Flux passing area $= \pi r^2$

$\frac{dr}{dt}$

Area $= \pi r^2$

$\frac{dA}{dt}$

$A = \pi r^2$

$\frac{dA}{dr} = \pi \times 2r = 2\pi r$

$dA = 2\pi r \, dr$

$$\boxed{\frac{dA}{dt} = 2\pi r \frac{dr}{dt}}$$

→ circular loop.

QUESTION

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)

1. $2\,\mu V$
2. $2\pi\,\mu V$
3. $\pi\,\mu V$
4. $\frac{\pi}{2}\,\mu V$

$B = 0.025 = \frac{25}{1000}\,T$

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

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

$e = NB\frac{dA}{dt} = NB\,2\pi r\frac{dr}{dt}$

$= 1 \times \frac{25}{1000} \times 2\pi \times \frac{2}{100} \times \frac{1}{1000}$

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

$= \pi\,\mu V$

QUESTION

HW

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)

1. $4.8\,\pi\mu V$
2. $0.8\,\pi\mu V$
3. $1.6\,\pi\mu V$
4. $3.2\,\pi\mu V$

Inside /Outside of Magnetic Field

HW

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)

1. the rectangular, circular and elliptical loops
2. the circular and the elliptical loops
3. only the elliptical loop
4. any of the four loops

Inside /Outside of Magnetic Field

For MRI, a patient is slowly pushed in a time of 10 s within the coils of the magnet where magnetic field is B = 2.0 T. If the patient's trunk is 0.8 m in circumference, the induced emf around the patient's trunk is **(AIIMS 2017)**

→ Magnetic Resonance Imaging

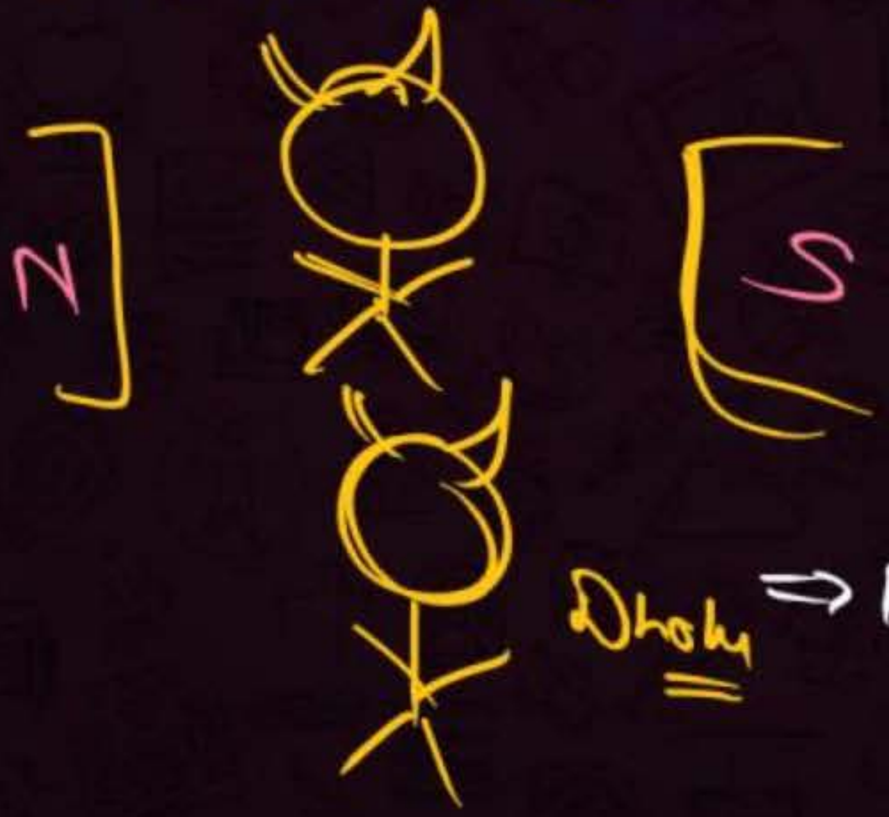
(1) 10.18×10^{-2} V

(2) 9.66×10^{-2} V

(3) 10.18×10^{-3} V ✓

(4) 1.51×10^{-2} V

$\Delta t = 10$ sec.



$\Rightarrow B_f = 2$

Dholu $\Rightarrow B_i = 0$

$2\pi r = 0.8$ m

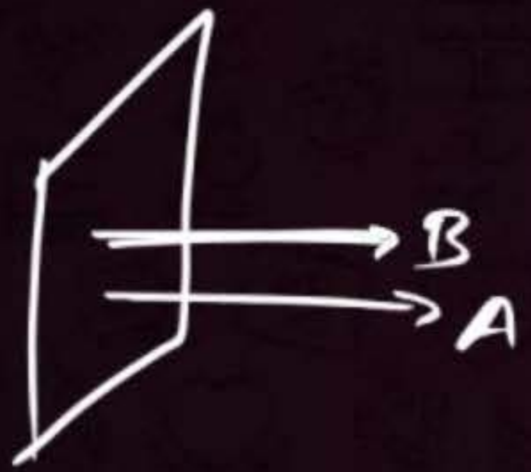
$r = \frac{0.8}{2\pi} = \frac{0.4}{\pi}$

$A = \pi r^2$

$e = A \frac{\Delta B}{\Delta t}$

$= \frac{\pi r^2 (B_f - B_i)}{\Delta t}$

Expressions for changing angle



$\theta = 0^\circ$

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

$\phi_i = BA$

Rotate by 90°

$\theta = 90^\circ$

$\phi_f = 0$

$e = -\dfrac{\Delta\phi}{\Delta t}$

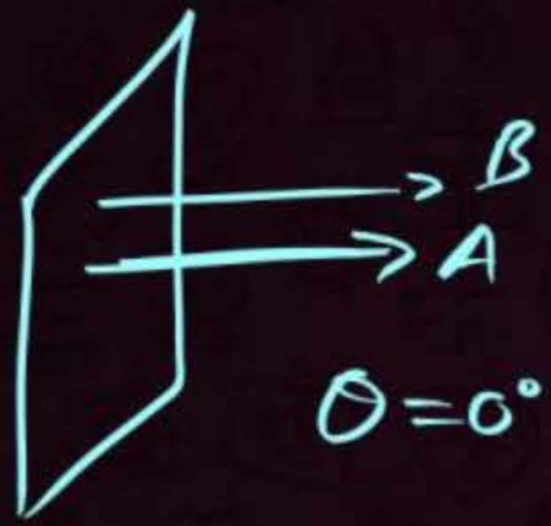
$e = -\dfrac{(\phi_f - \phi_i)}{t}$

$e = -\dfrac{(0 - BA)}{t}$

$\boxed{e = \dfrac{BA}{t}} \longrightarrow \dfrac{NBA}{t}$

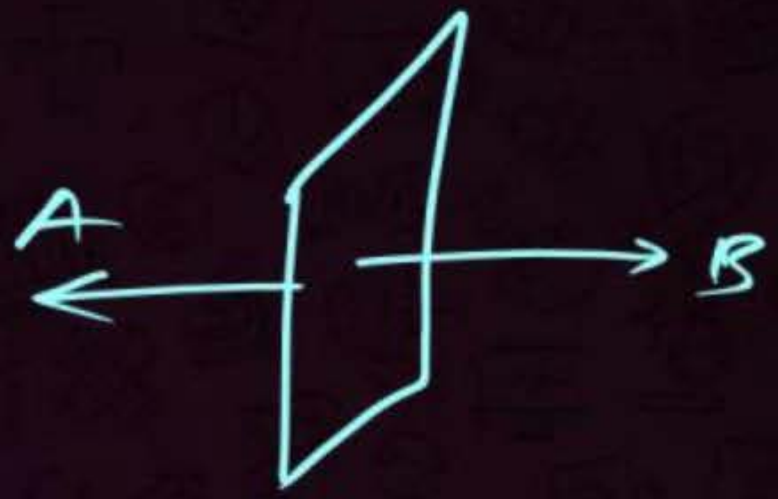
QUESTION

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



$\theta = 0^\circ$

$\phi_i = BA$



$\theta = 180^\circ$

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

$= -BA$

$$e = -\frac{\Delta\phi}{\Delta t} = -\frac{(-BA - BA)}{t}$$

$$e = -\frac{(-2BA)}{t}$$

$$\boxed{e = \frac{2BA}{t}} \Rightarrow \frac{2NBA}{t}$$

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)

(1) 2×10^{-3} V

(2) 0.02 V

(3) 2 V

(4) 0.2 V

$$e = \frac{NBA}{t} = \frac{800 \times 5 \times 10^{-5} \times 0.05}{0.1}$$

$$= 0.02\,V$$

QUESTION

HW

A circular coil of radius 10 cm, 500 turns and resistance $2\ \Omega$ is placed with its plane perpendicular to the horizontal component of the earth's magnetic field. It is rotated about its vertical diameter through 180° in 0.25s . The current induced in the coil is (Horizontal component of the earth's magnetic field at that place is 3.0×10^{-5} T)

(AIIMS 2017)

(1) 1.9×10^{-3} A

(2) 2.9×10^{-3} A

(3) 3.9×10^{-3} A

(4) 4.9×10^{-3} A

$$e = \frac{2NBA}{t}$$

$$i = \frac{e}{R}$$

AC Generator

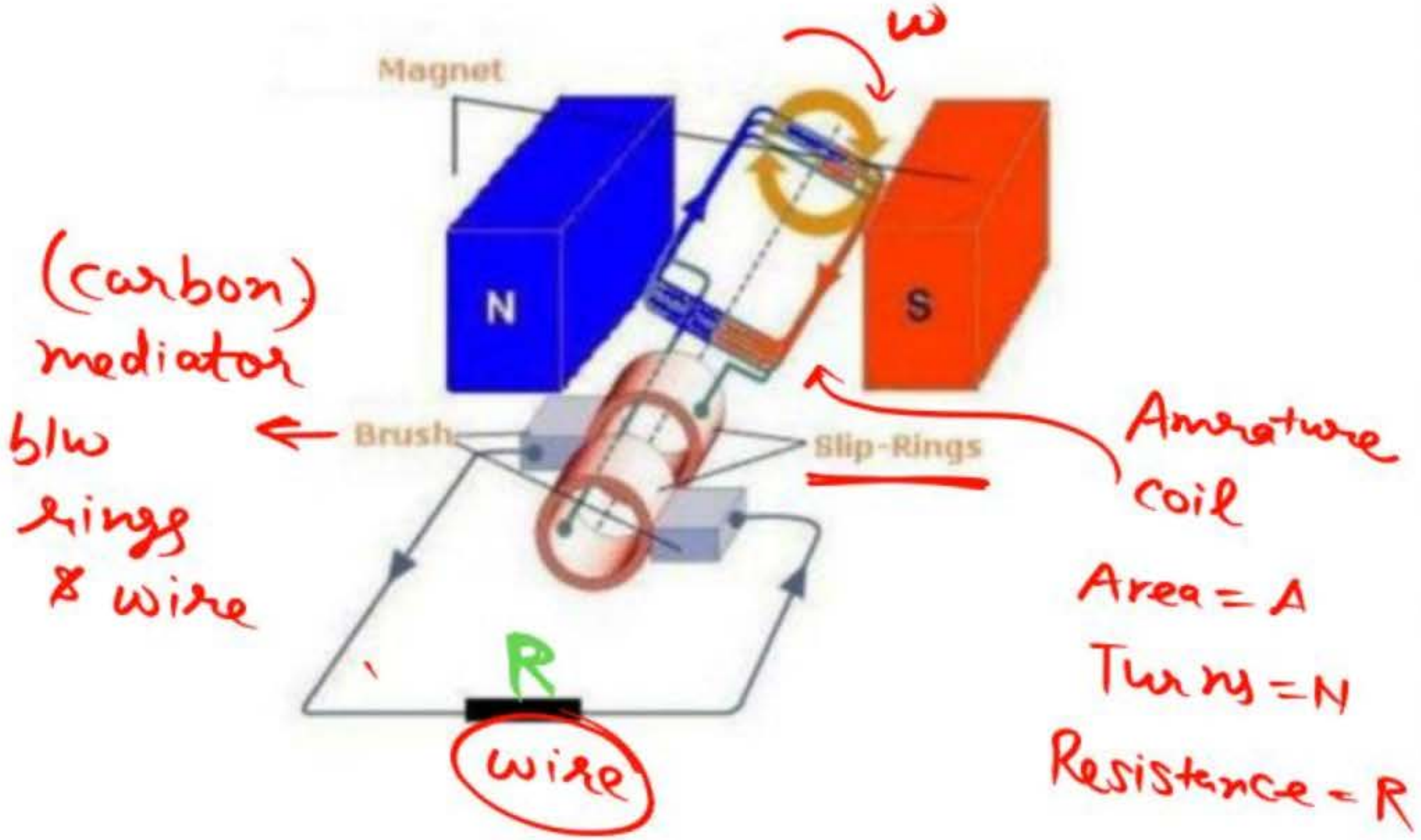
It is a device which changes mechanical energy into electrical energy.

↳ kinetic

Principle - It works on the principle of electromagnetic induction. The angle between the magnetic field and the area vector continuously changes.

↳ θ always changes

Alternating Current Generator



$$e = -N\frac{d\phi}{dt}$$

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

$$\boxed{e = e_0 \sin\omega t}$$

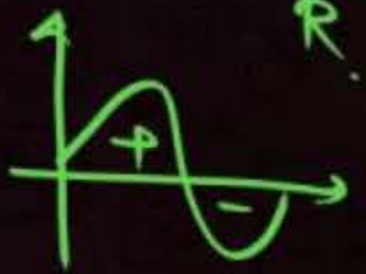
$\downarrow$

maxm $= NBA\omega$

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

$\downarrow$

$$i_0 = \frac{e_0}{R}$$



QUESTION

A wire loop is rotated in a magnetic field. The frequency of change of direction of the induced emf is (or current)

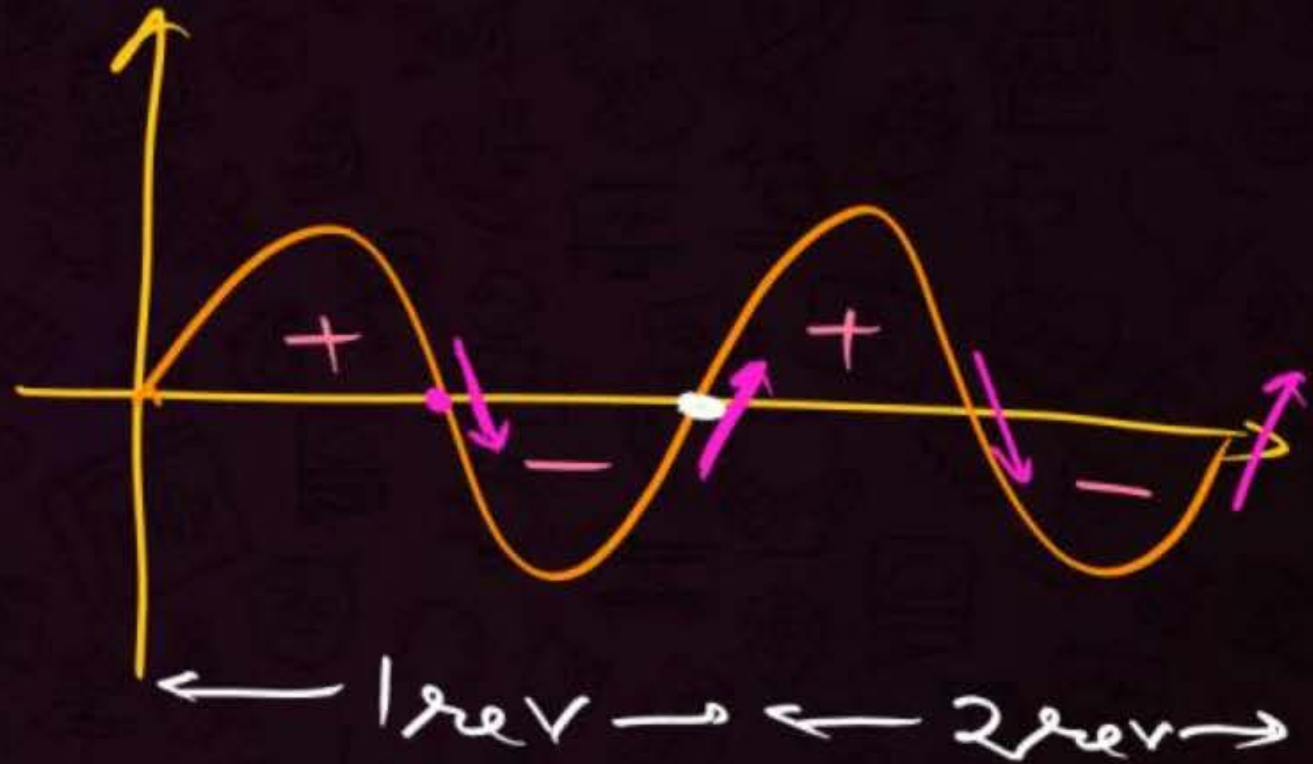
[NEET 2013]

(1) once per revolution

(2) twice per revolution (Learn)

(3) four times per revolution

(4) six times per revolution



QUESTION

$r = \frac{30}{100}$ m

In a region of uniform magnetic induction $B = 10^{-2}$ T, a circular coil of radius 30 cm and resistance π^2 ohm is rotated about an axis which is perpendicular to the direction of B and which forms a diameter of the coil. If the coil rotates at 200 rpm the amplitude of the alternating current induced in the coil is [CBSE AIPMT 1988]

(max^m value)

1. $4\pi^2$ mA
2. 30 mA
3. 6 mA
4. 200 mA

$i_0 = ?$

$$i_0 = \frac{e_0}{R} = \frac{NBA\omega}{R}$$

$B = 10^{-2}$ T $N = 1$

$A = \pi r^2$

$R = \pi^2 \Omega$.

rpm → rev/min.

$$\frac{200}{60} = f \text{ (rev/sec)}$$

$$\omega = 2\pi f = 2\pi \times \frac{200}{60} \text{ rad/sec}$$

Induced Charge Flow through the coil

$$i = \frac{e}{R}$$

$$\frac{dq}{\cancel{dt}} = \frac{d\phi/\cancel{dt}}{R}$$

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

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

Δq ↓ induced charge flow.

$$\boxed{R \propto \Delta q = \Delta \phi}$$

* $\Delta q \rightarrow$ independent of time (Δt)

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)

$\rightarrow \Delta q$

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

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

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

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

QUESTION

$r = 10\,cm = \frac{1}{10}\,m.$

A circular ring of diameter 20 cm has a resistance of 0.01 Ω. The charge that will flow through the ring if it is turned from a position perpendicular to a uniform magnetic field of 2.0 T to a position parallel to the field is about (AIIMS 2018)

(1) 63 C

(2) 0.63 C

(3) 6.3 C

(4) 0.063 C

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

90° rotation

$\Delta\phi = BA$

$$= \frac{B \times \pi r^2}{R}$$

$$= \frac{2 \times \pi \times \frac{1}{10} \times \frac{1}{10}}{0.01}$$

$$= 2\pi = 2 \times 3.14 = 6.28 \simeq 6.3$$

QUESTION

(HW)

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

(1) the rate of change of magnetic flux

(2) initial magnetic flux

(3) the total change in magnetic flux

(4) final magnetic flux

In a coil of resistance 100 Ω, a current is induced by changing the magnetic flux through it as shown in the figure. The magnitude of change in flux through the coil is (JEE Main 2017)

(a) 250 Wb

(b) 275 Wb

(c) 200 Wb

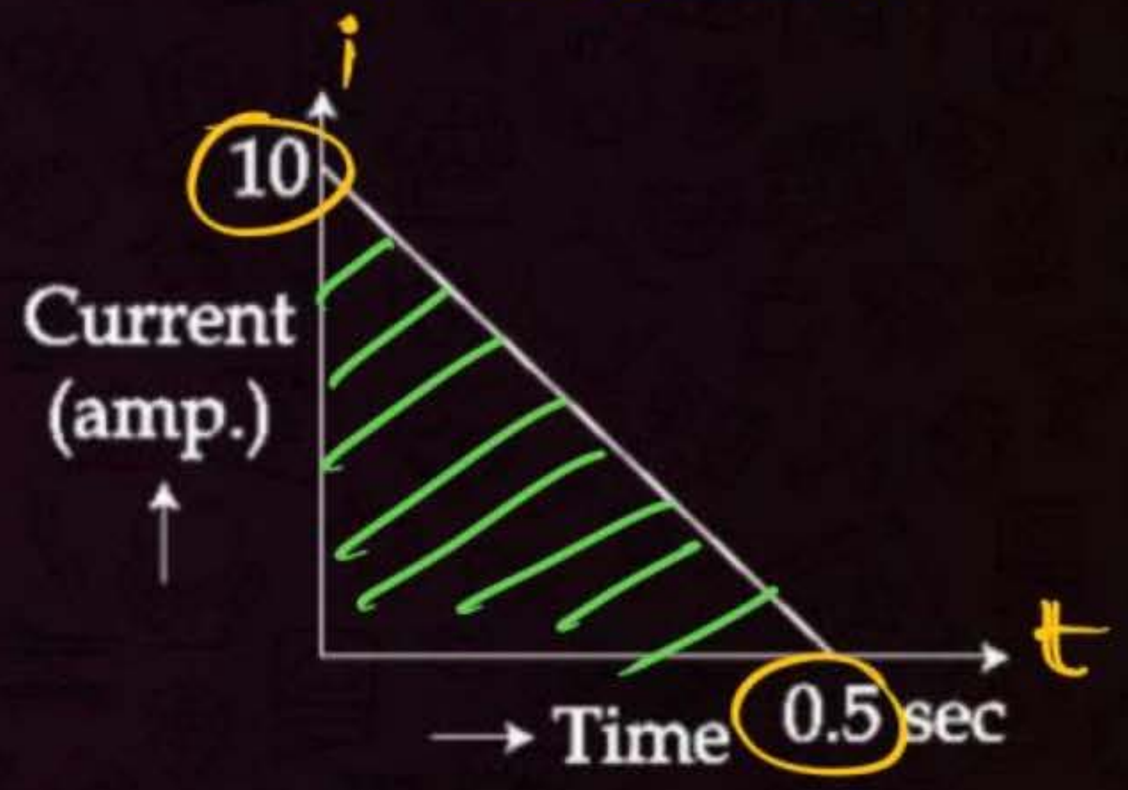
(d) 225 Wb

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

$\Delta \phi = \Delta q \times R$

$= 2.5 \times 100$

$= 250$ Wb.



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

$= 2.5$.

QUESTION

HW

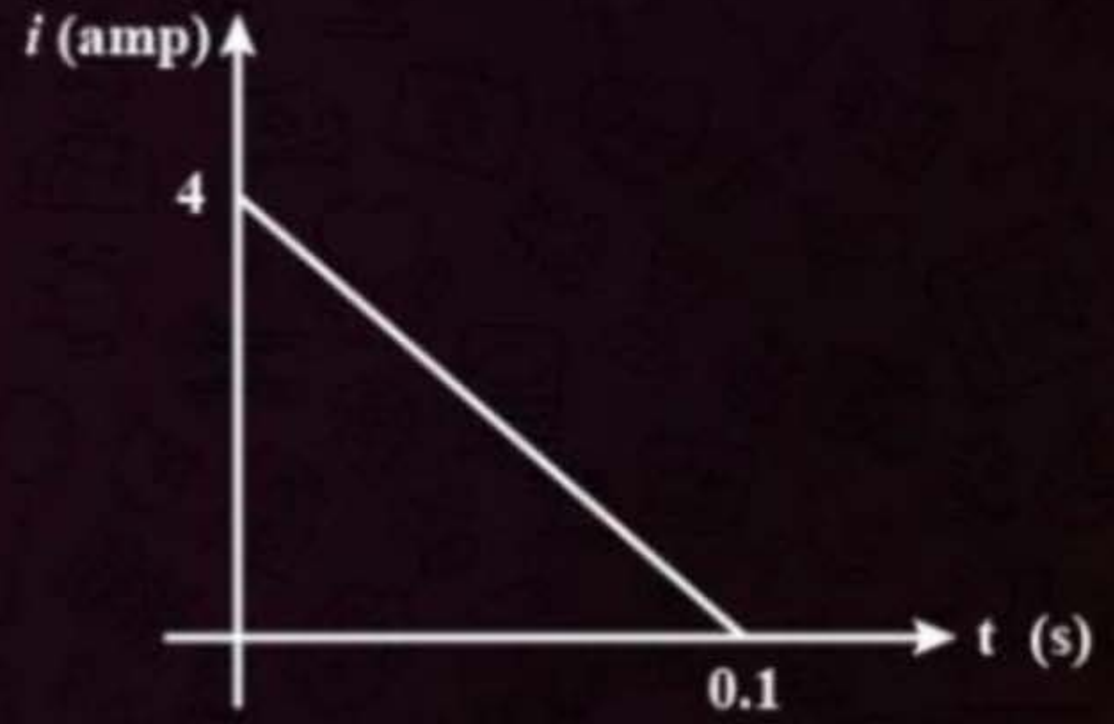
In a coil of resistance 10 Ω, the induced current developed by changing magnetic flux through it, is shown in figure as a function of time. The magnitude of change in flux through the coil in Weber is: (2012)

(1) 8

(2) 2

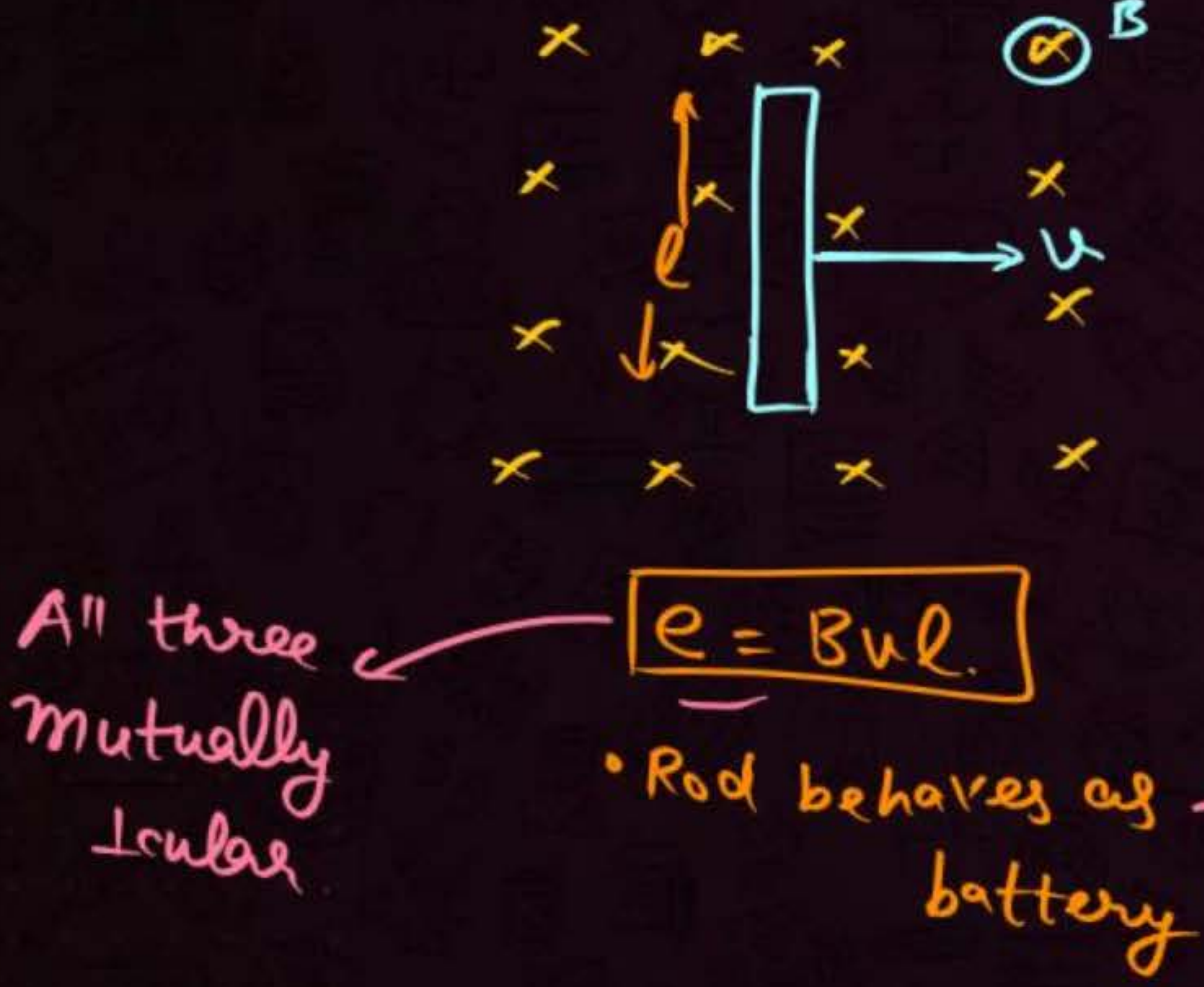
(3) 6

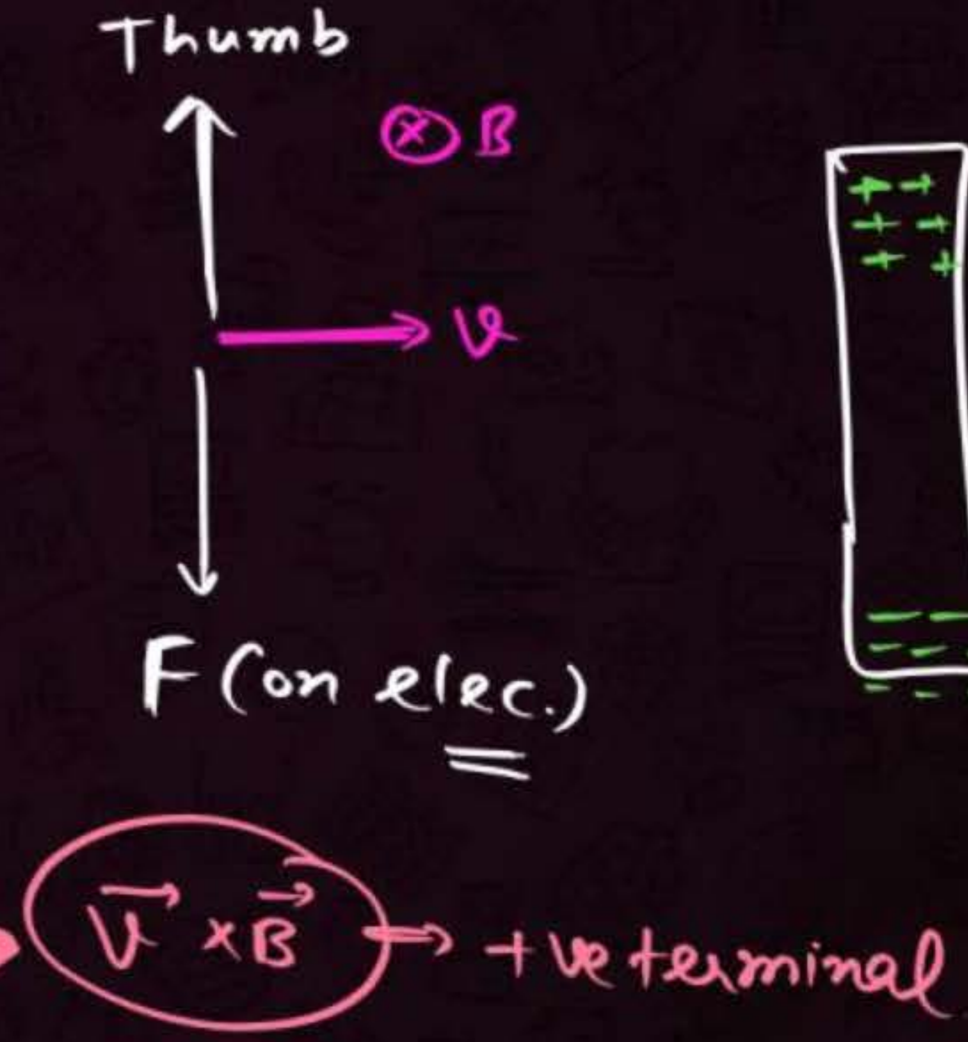
(4) 4

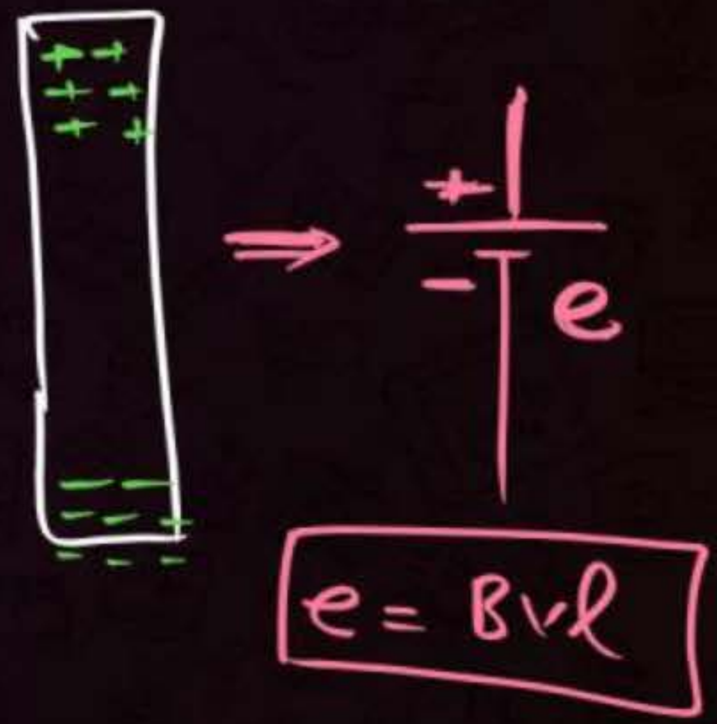


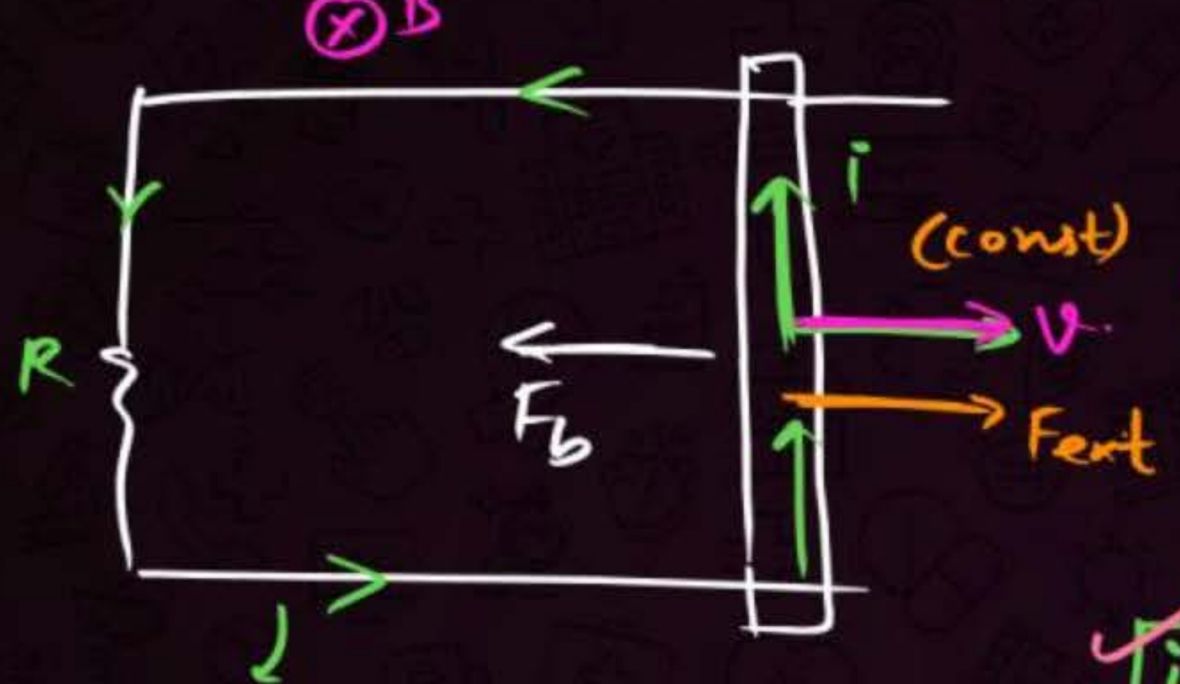
Motional EMF

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

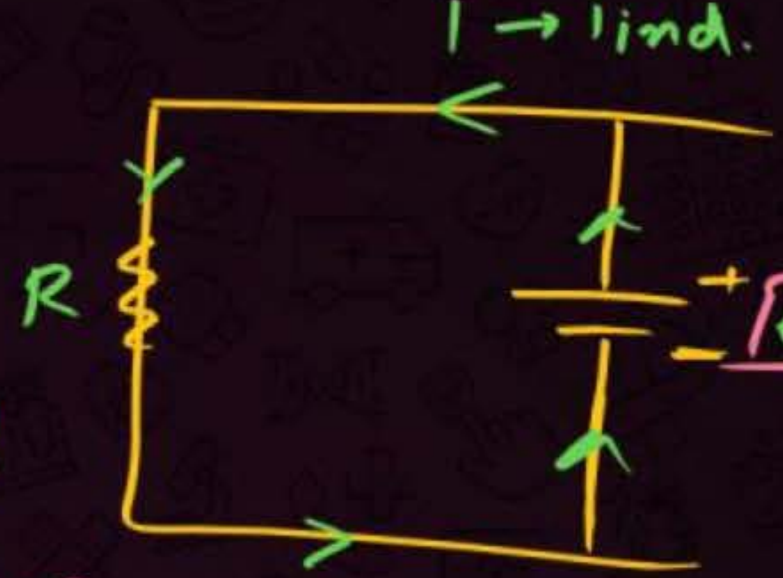








conducting rails.
(frictionless)



$e = Bvl$

$$i_{ind} = \frac{e}{R} = \frac{Bvl}{R}$$

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

$$F_{ext} = F_b = \frac{B^2 l^2 v}{R}$$

v → const.

TBS : Whole mechanical work converted into electrical energy & then into heat

$$\vec{F_b} = i(\vec{l} \times \vec{B})$$

$$F_b = ilB\sin\theta$$

$$F_b = ilB = Bil$$

$$P_{ext} = F_{ext}\, v = \frac{B^2 l^2 v^2}{R}$$

$$P_{diss} = i^2 R$$

Fleming right hand rule

→ Rare Use

First finger – Magnetic Field

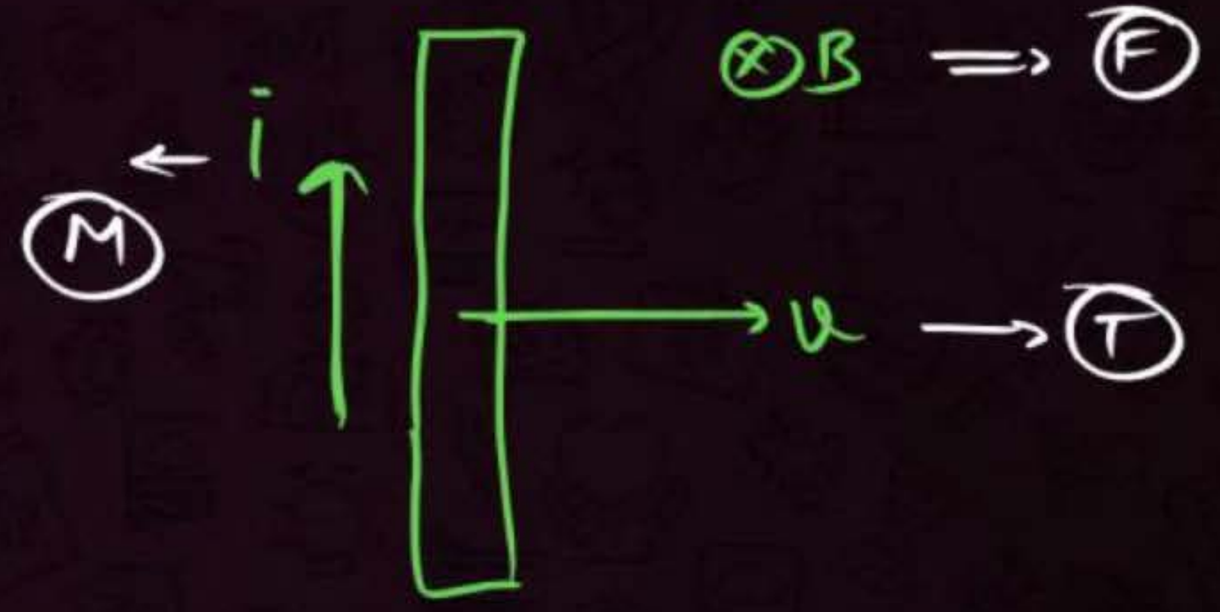
Middle (Central) Finger - Induced current

Thumb - Motion of conductor

F → B

M → i

T → v



Vector Form

$$e = (\vec{v} \times \vec{B}) \cdot \vec{l}$$

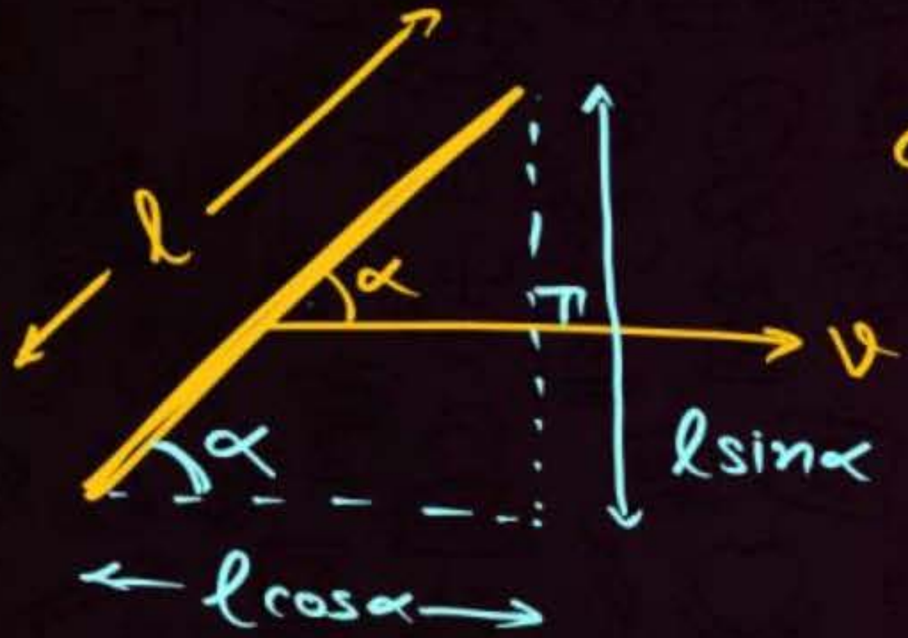
QUESTION

(TBS) ⟶ Take component of length ⊥cular to v.
(leff or $\vec{l}$)

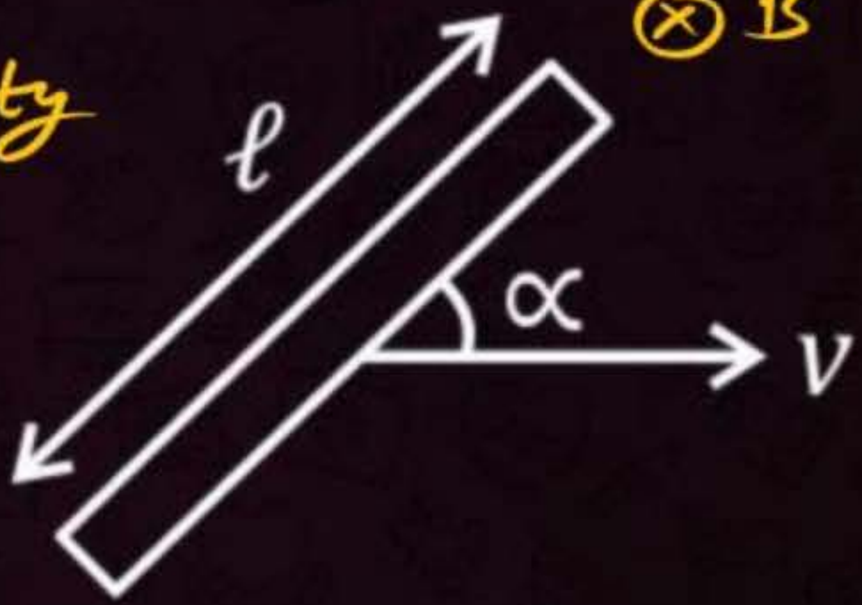
OR

component of velocity ⊥cular to length

Find:



$$e = Bvl\sin\alpha$$



$e = ?$

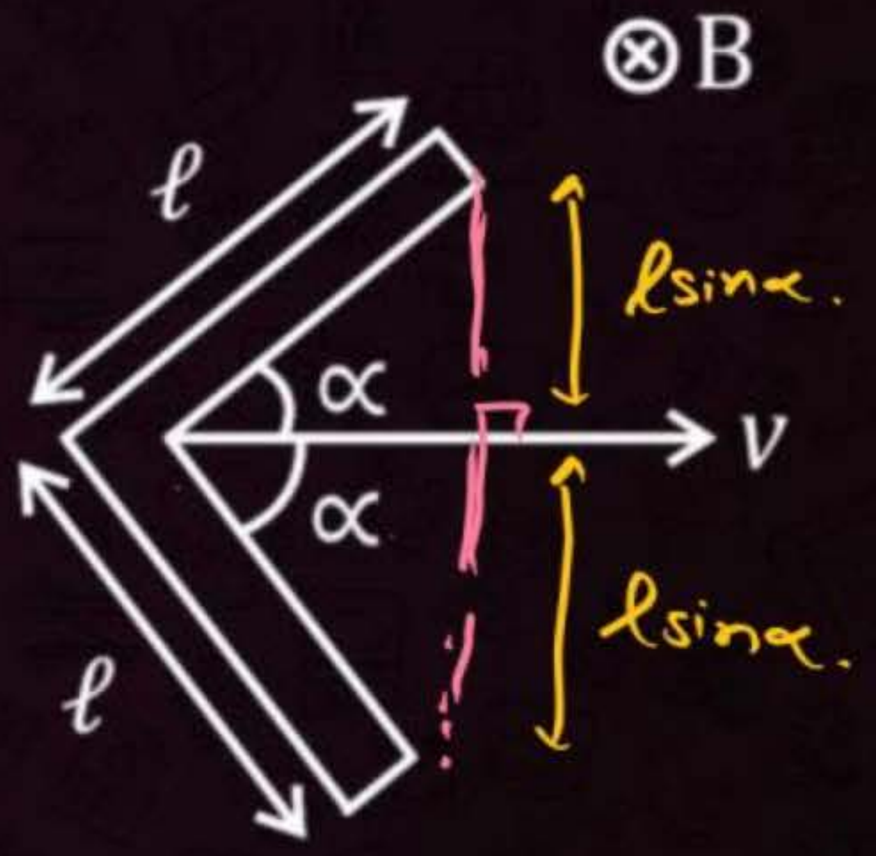
QUESTION

Find:

$l_{eff} = 2l\sin\alpha$.

$e = Bv(2l\sin\alpha)$

$e = 2Bvl\sin\alpha$

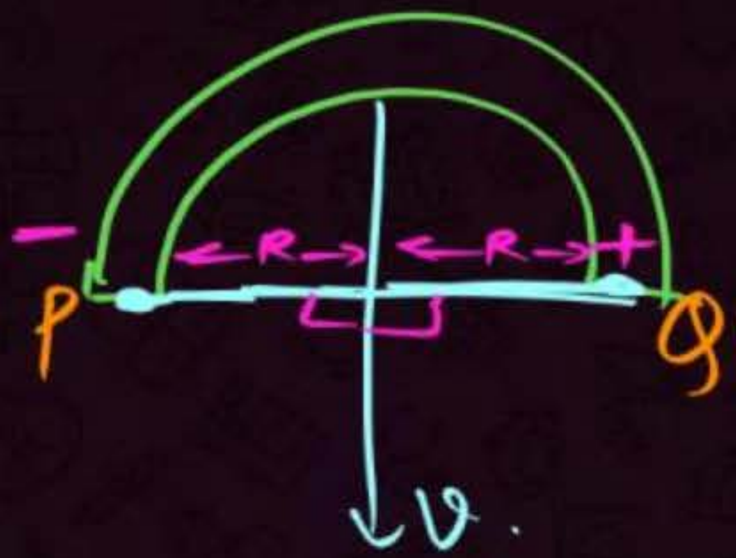


QUESTION

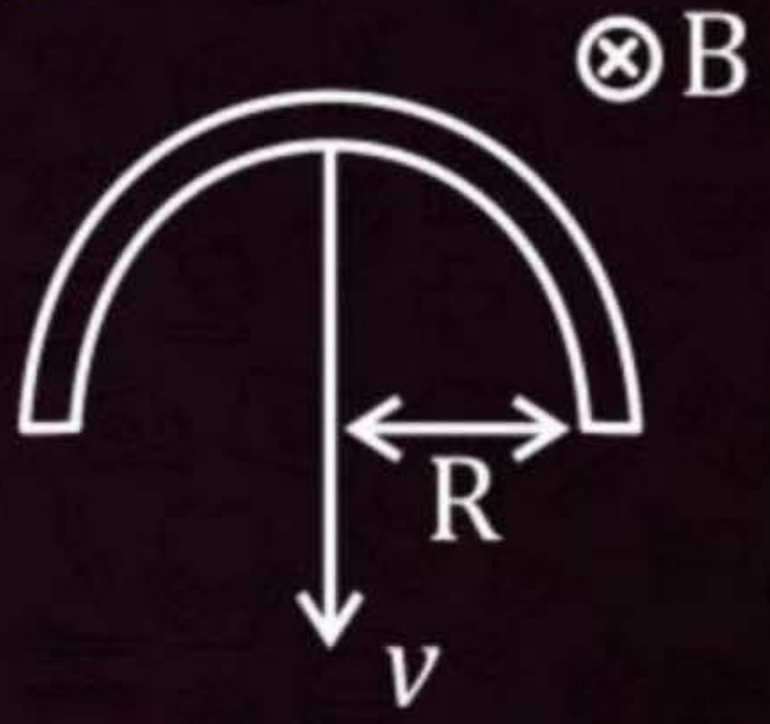
Find:

$e = Bv(2R)$

$= 2BvR$



$P \neq Q$



$e = ?$

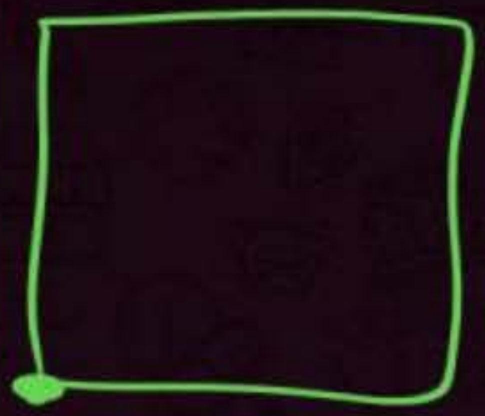
$\vec{v} \times \vec{B} \Rightarrow$ +ve terminal

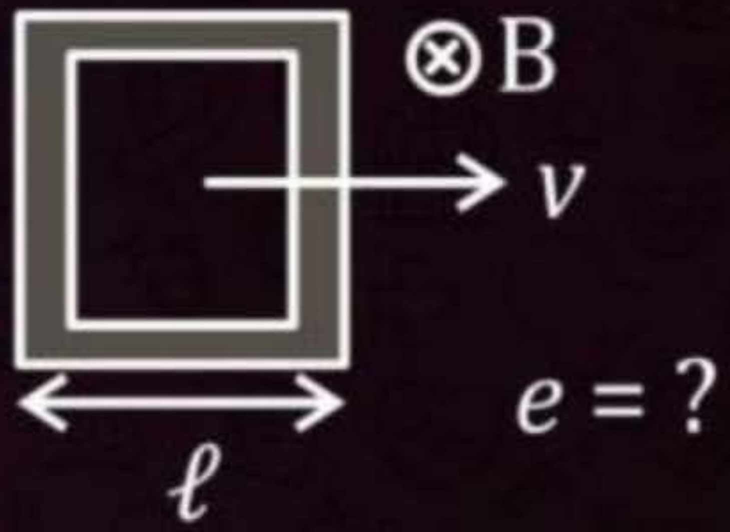
→ Right.

QUESTION

Find: $e = ?$

Square loop





$l_{eff} = 0$

$\vec{l} = 0$

$e = 0 \rightarrow i = 0$

QUESTION

A wire of length 1 m is moving with a velocity of 8 m/s at right angles to a magnetic field of 2 T. The magnitude of induced emf, between the ends of wire the will be

[25 Jan, 2023 (Shift-II)]

(JEE Mains)

1. 20 V
2. 8 V
3. 12 V
4. 16 V ✓

$$e = Bvl$$
$$= 2 \times 8 \times 1$$
$$= 16$$

QUESTION

HW

An emf of 0.08 V is induced in a metal rod of length 10 cm held normal to a uniform magnetic field of 0.4 T, when moves with a velocity of: [8 April, 2023 (Shift-II)]

1. $2\ ms^{-1}$
2. $3.2\ ms^{-1}$
3. $0.5\ ms^{-1}$
4. $20\ ms^{-1}$

A solid metal cube of edge length 2 cm is moving in a positive y direction at a constant speed of 6 m/s. There is a uniform magnetic field of 0.1 T in the positive z-direction. The potential difference between the two faces of the cube perpendicular to the x-axis, is (JEE Main 2019)

HW

(a) 6 mV

(b) 1 mV

(c) 12 mV

(d) 2 mV

QUESTION

HW

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]

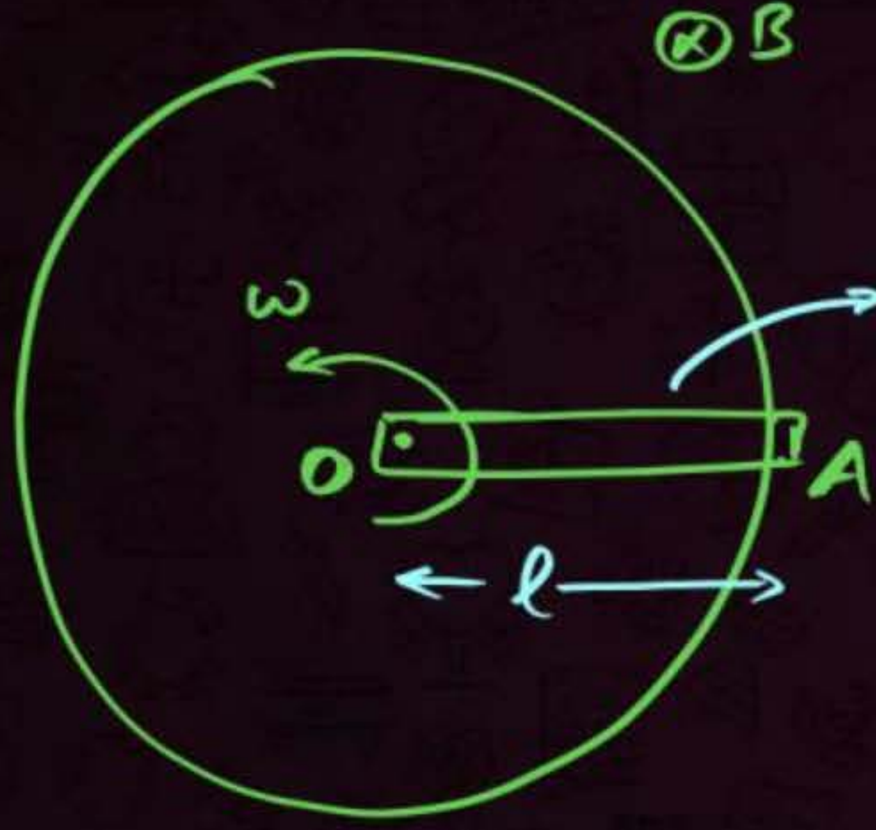
(1) 1.26 V

(2) 2.52 V

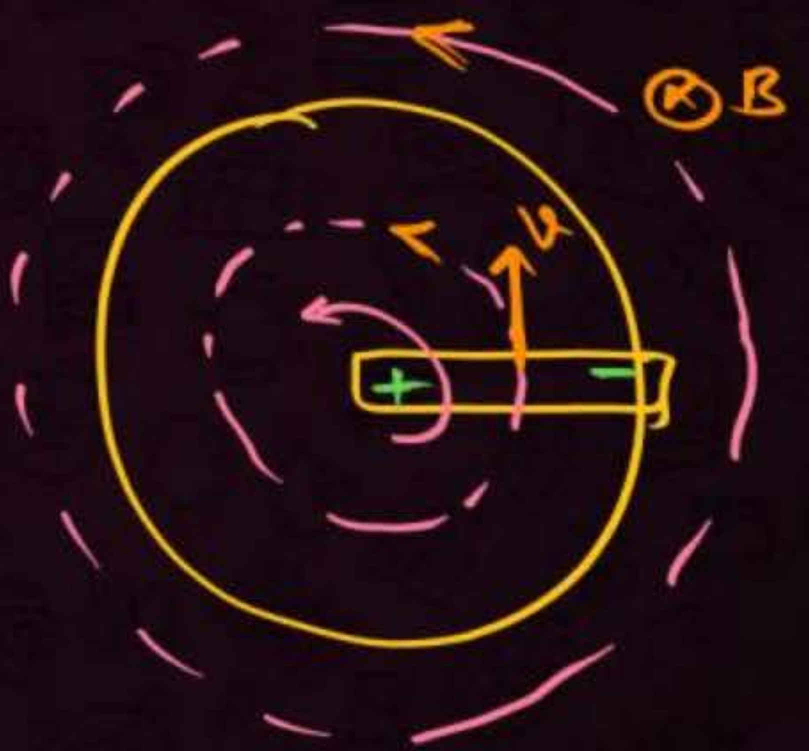
(3) 5.04 V

(4) 25.2 V

Rotational EMF

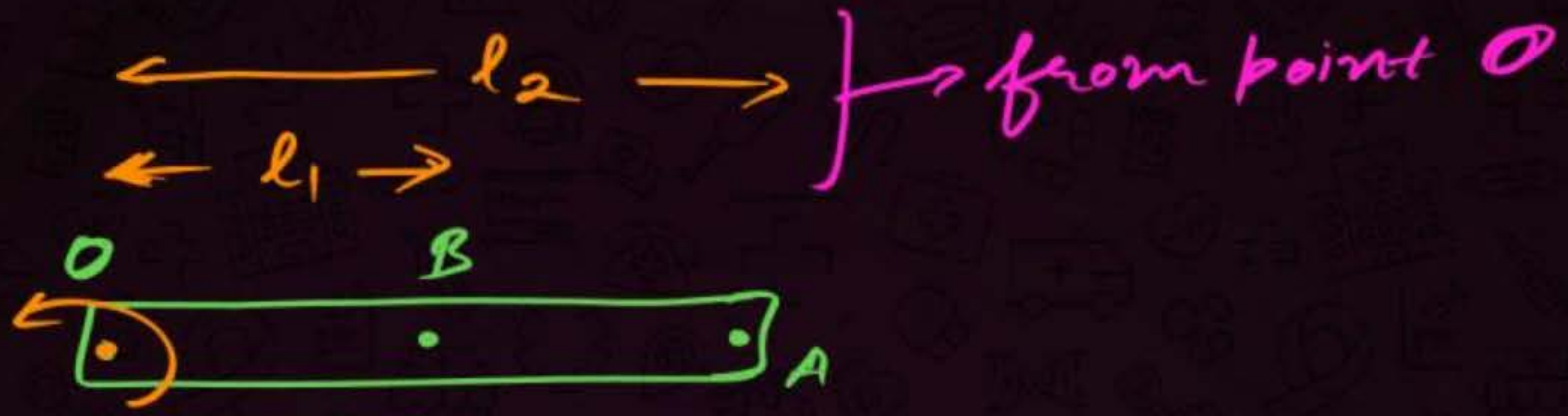


$$e = \frac{1}{2} B \omega l^2$$ → B/w center & rim (O A)



$\vec{v} \times \vec{B}$

Center ⇒ +ve



$e \Rightarrow$ b/w $\underline{\underline{AB}}$ $\Rightarrow$ $\boxed{e = \frac{1}{2}B\omega(l_2^2 - l_1^2)}$

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]**

(1) 0.25 V

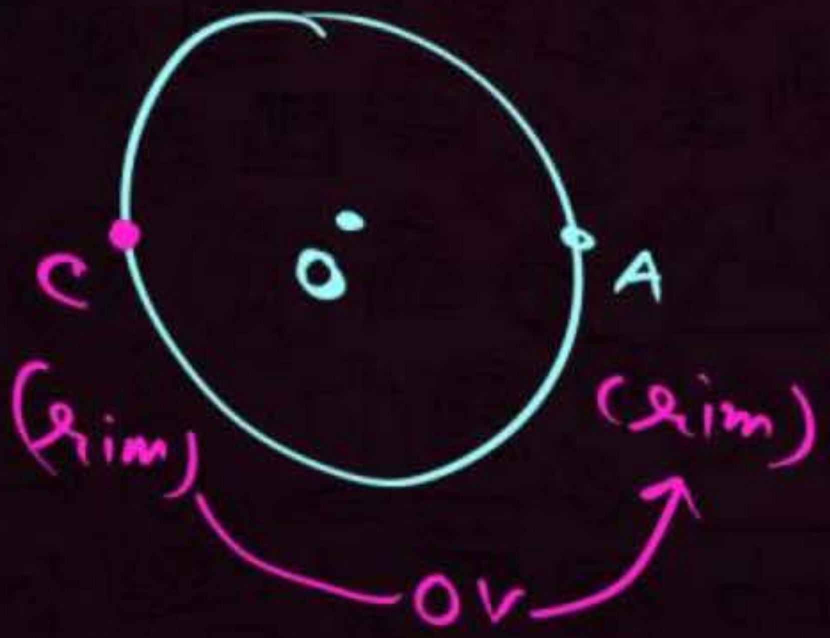
(2) 0.125 V ✓

(3) 0.5 V

(4) zero

$$e = \frac{1}{2} B\omega l^2 = \frac{1}{2} \times 0.1 \times 10 \times 0.5 \times 0.5$$

$$= 0.125 \text{ V}$$



QUESTION

(HW)

A 20 cm long metallic rod is rotated with 210 rpm about an axis normal to the rod passing through its one end. The other end of the rod is in contact with a circular metallic ring. A constant and uniform magnetic field 0.2 T parallel to the axis exists everywhere. The emf developed between the centre and the ring is ______ mV.

Take $\pi = 22/7$

[15 April, 2023 (Shift-I)]

convert in rad/sec

(1) 22

(2) 44

(3) 66

(4) 88

QUESTION

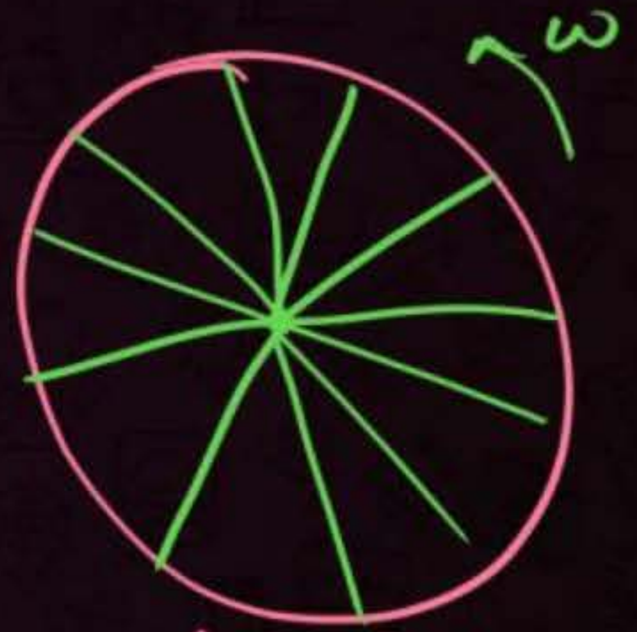
(HW)

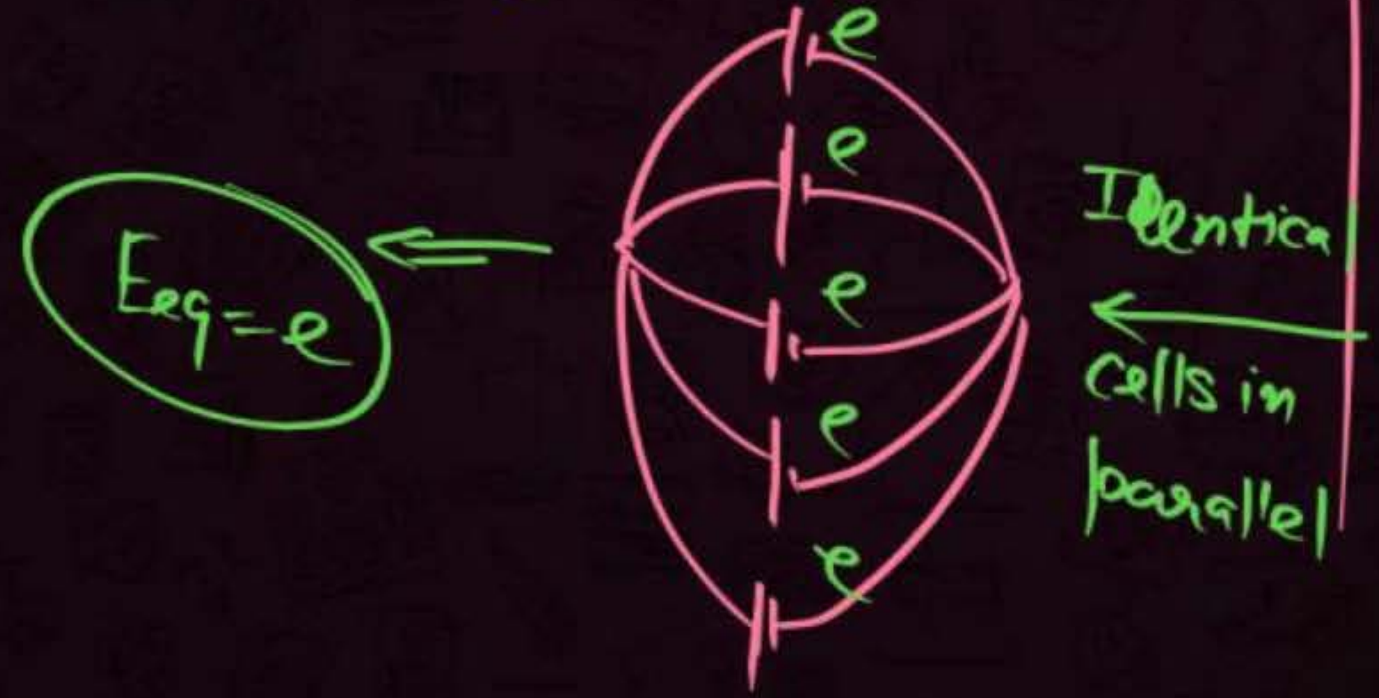
A wheel of 10 spokes is rotating in a cross magnetic field of 0.4 gauss with 120 rev/min. The radius of wheel = 0.5 m. Find emf induced between center and rim of the wheel.

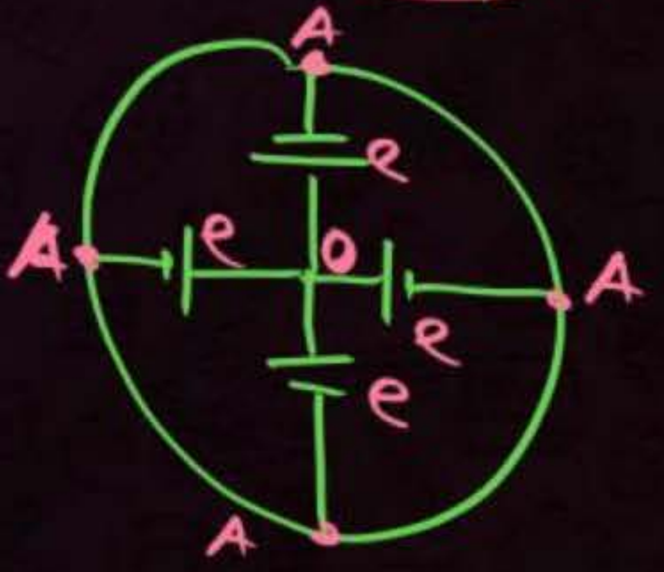
(Similar to NCERT Example)

$$e = \frac{1}{2} B \omega l^2 \times 10 \quad \times$$

$$e = \frac{1}{2} B \omega l^2 \quad \checkmark$$







QUESTION

HW

A wheel with 20 metallic spokes each 1 m long is rotated with a speed of 120 rpm in a plane perpendicular to a magnetic field of 0.4 G. The induced emf between the axle and rim of the wheel will be ($1\ G = 10^{-4}\ T$) [NEET (Oct.) 2020]

(1) 2.51×10^{-4} V

(2) 2.51×10^{-5} V

(3) 4.0×10^{-5} V

(4) 2.51 V

QUESTION

(HW)

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 end B is

(1) $\frac{B\omega l^2}{8}$

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

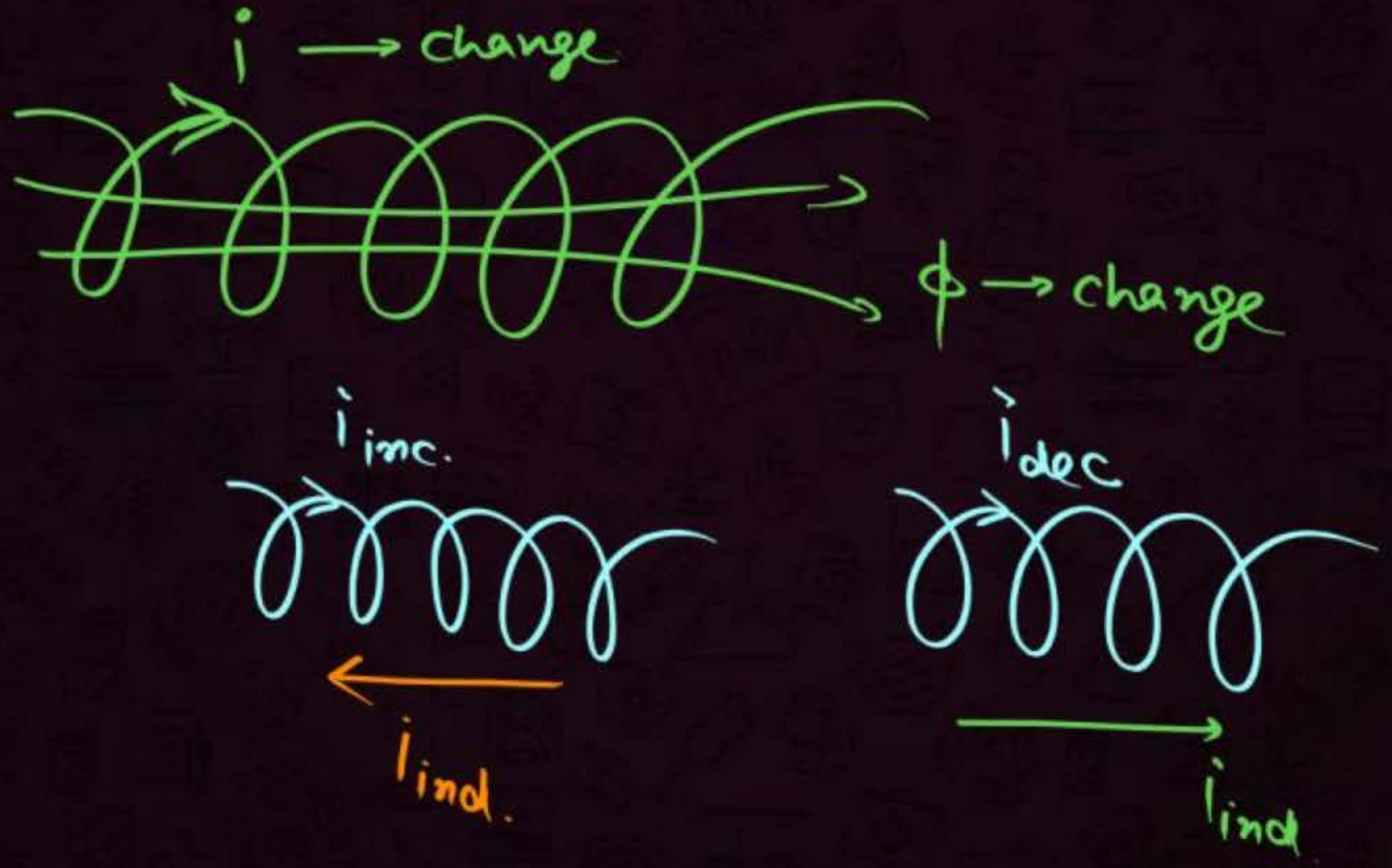
(3) $\frac{B\omega l^2}{4}$

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

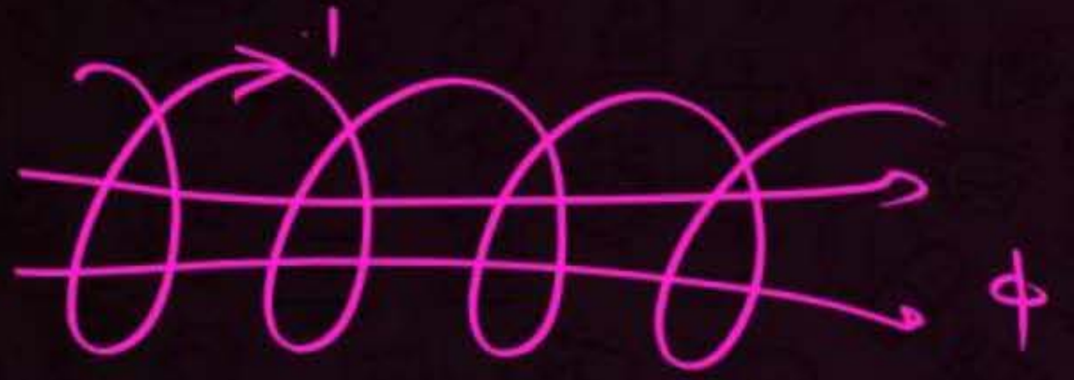
$e = \frac{1}{2}B\omega(l_2^2 - l_1^2)$

Self Induction

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



Self Inductance (L) or Coefficient of Self Induction



$\phi \propto i$

N-turns

$\boxed{\phi = Li} \Rightarrow \boxed{N\phi = Li}$

SI units → Henry (H)

$\boxed{L = \dfrac{\phi}{i}}$

⇓

doesn't depend on i ✗

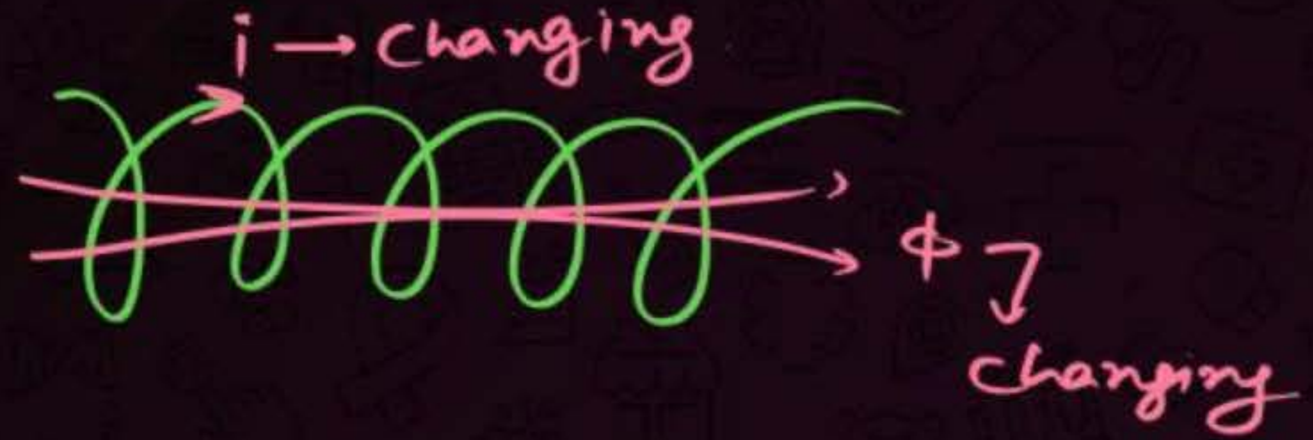
ϕ ✗

$V \propto i$

$V = iR$ (V ✗, i ✗)

$Q \propto V$

$Q = CV$ (Q ✗, V ✗)



$$\phi = Li$$

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

$$e = -L\frac{di}{dt}$$

$$|e| = L\frac{di}{dt}$$

$$|e| = L\frac{\Delta i}{\Delta t}$$

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)

(1) 0.5 Wb

(2) 12. 5 Wb

(3) Zero

(4) 2 Wb

$$\phi = Li$$

$$\phi = 5 \times 2.5$$

$$= 12.5$$

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)

Total ×

(1) 1.0 henry

(2) 4.0 henry

(3) 2.5 henry

(4) 2.0 henry

$$N\phi = Li$$

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

$$2000 \times 10^{-3} = L \times 2$$

$$1 = L$$

QUESTION

Assertion (A): Inductance coil are made of copper.

conductance ↑.
resistance ↓.

Reason (R): Induced current is more in wire having less resistance.

$i = \frac{e}{R} \Rightarrow R\downarrow \Rightarrow i\uparrow$

(1) Assertion is True, Reason is True; Reason is a correct explanation for Assertion.

(2) Assertion is True, Reason is True; Reason is not a correct explanation for Assertion.

(3) Assertion is True, Reason is False.

(4) Assertion is False, Reason is True.

QUESTION

Assertion: Due to high inductance of any coil, the current attains it peak value relatively late in it.

Reason: Due to self induction, coil opposed the flow of current through it.

1. If both assertion and reason are true and reason is the correct explanation of the assertion.
2. If both assertion and reason are true but reason is not correct explanation of the assertion.
3. If assertion is true, but reason is false.
4. Assertion is false, reason is true

QUESTION

The current in self inductance L = 40 mH is to be increased uniformly from 1 amp to 11 amp in 4 milliseconds. The emf induced in inductor during process is (1990)

(1) 100 volt

(2) 0.4 volt

(3) 4.0 volt

(4) 440 volt

$|e| = L\frac{\Delta i}{\Delta t}$

$\Delta i = 11 - 1 = 10$

$= 40 \times 10^{-3} \times \frac{10}{4 \times 10^{-3}}$

$= 100\ V.$

QUESTION

HW

A 12 V battery connected to a coil of resistance 6 Ω through a switch, drives a constant current in the circuit. The switch is opened in 1 ms. The emf induced across the coil is 20 V. The inductance of the coil is: [15 April, 2023 (Shift-I)]

(1) 5 mH

(2) 12 mH

(3) 8 mH

(4) 10 mH

QUESTION

HW

When the current changes from +2 A to −2 A in 0.05 second, an emf of 8 V is induced in a coil. The coefficient of self-induction of the coil is :

(1) 0.2 H

(2) 0.4 H

(3) 0.8 H

(4) 0.1 H

QUESTION

Assertion: The possibility of an electric bulb fusing is higher at the time of switching on and off.

V → high i → high

Reason: Inductive effects produce a surge at the time of switch-off and switch-on.

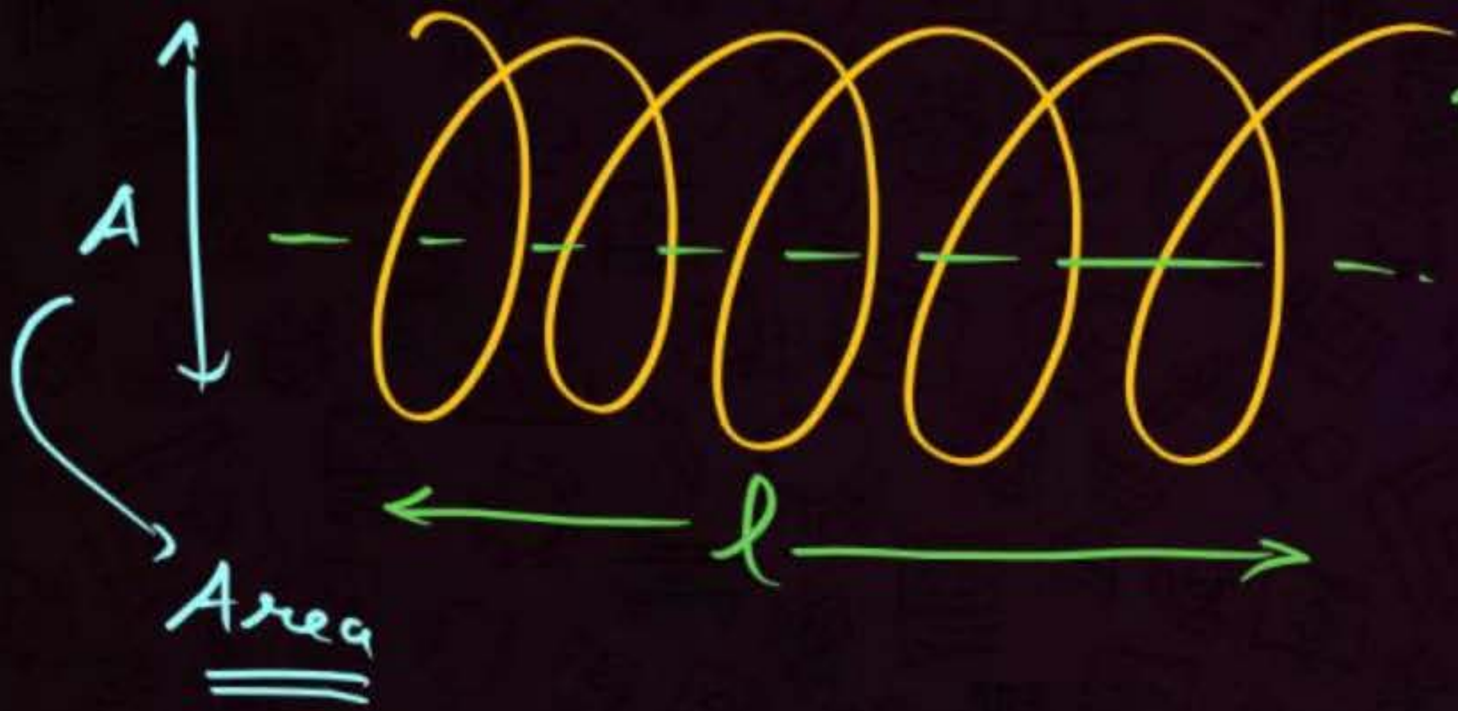
(L)

[AIIMS 2003]

1. If both assertion and reason are true and reason is the correct explanation of the assertion.
2. If both assertion and reason are true but reason is not correct explanation of the assertion.
3. If assertion is true, but reason is false.
4. Assertion is false, reason is true

L → electrical inertia

Self Inductance of Solenoid



N = No. of turns

n = no. of turns/length

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

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

$$L \propto N^2$$

QUESTION

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

[CBSE AIPMT 1993]

(1) N^0

(2) N

(3) N^2

(4) N^{-2}

QUESTION

BPU

A coil of wire of a certain radius has 100 turns and a self inductance of 15 mH. The self inductance of a second similar coil of 500 turns will be [AIIMS 2009]

1. 75 mH
2. 375 mH
3. 15 mH
4. None of these

$L \propto N^2$

$N = 100 \rightarrow 500$

5 times

$L \rightarrow 25L$

$5^2 = 25$

$L' = 25L$

$= 25 \times 15$

$= 375\ mH$

QUESTION

HW

If the number of turns per unit length of a coil of solenoid is doubled, the self-inductance of the solenoid will [CBSE AIPMT 1991]

(1) remain unchanged

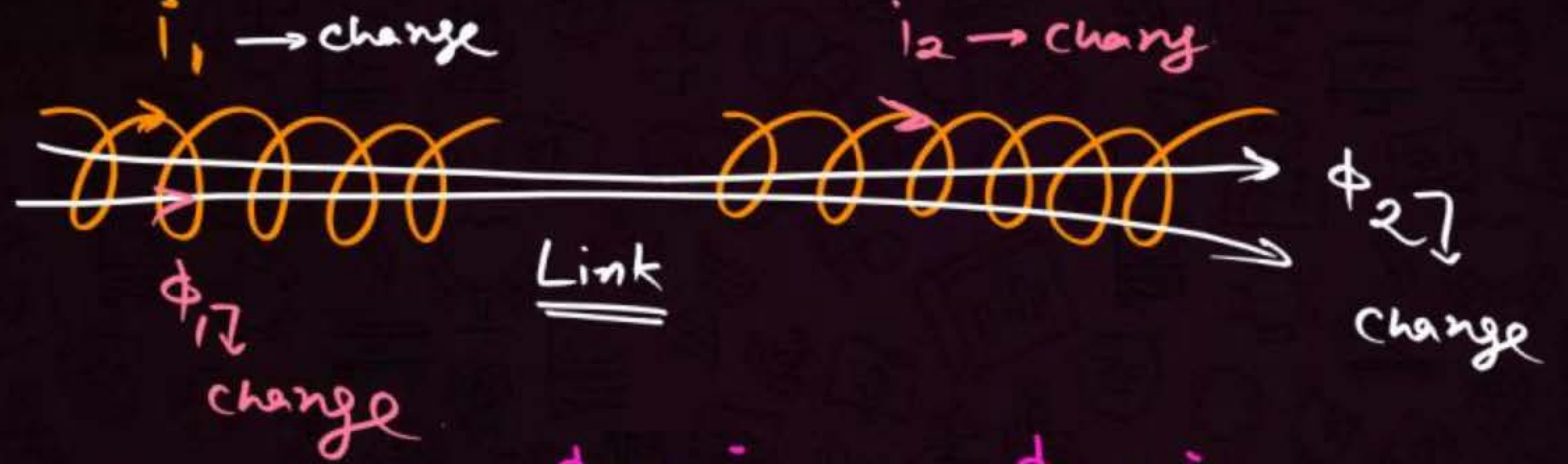
(2) be halved

(3) be doubled

(4) become four times

Mutual induction (M)

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



$\phi_2 \propto i_1$

$\phi_1 \propto i_2$

$\phi_2 = M i_1$

$\phi_1 = M i_2$

$N_2 \phi_2 = M i_1$

$N_1 \phi_1 = M i_2$

$M_{12} = M_{21} = M$ → Theorem of reciprocity

SI unit → (Henry)

Induced EMF in terms of Mutual Inductance

$$e_2 = -M\frac{di_1}{dt}$$

$$e_1 = -M\frac{di_2}{dt}$$

$$|e_2| = M\frac{\Delta i_1}{\Delta t}$$

$$|e_1| = M\frac{\Delta i_2}{\Delta t}$$

QUESTION

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.

(1) 0.1 H

(2) 0.05 H

(3) 0.01 H

(4) 1 H

$e = 0.5V$

$\Delta i_1 = 2 - 5 = -3$

$= 3$

$\Delta t = 300\ ms$

$= 300 \times 10^{-3}\ s$

$e = M \frac{\Delta i}{\Delta t}$

$0.5 = M \times \frac{3}{300 \times 10^{-3}}$

$0.5 = \frac{M}{0.1}$

$M = 0.05\ H$

QUESTION

Two coils have a mutual inductance of 0.005 H. The current changes in the first coil according to equation $i = i_0 \sin \omega t$, $i_0 = 10A$ and $\omega = 100\pi$ rad/s. The maximum value of emf in the second coil is

(CBSE AIMPT 1998)

(1) 2π

(2) 5π

(3) π

(4) 4π

$e_2 = M \frac{di_1}{dt}$

$e_2 = 0.005 \times i_0 \omega \cos \omega t$

e_2 → maxm; $0.005 \times i_0 \omega$ → e_0; $\cos \omega t$ → $1 \Rightarrow$ maxm

$e = \frac{5}{1000} \times 10 \times 100\pi$

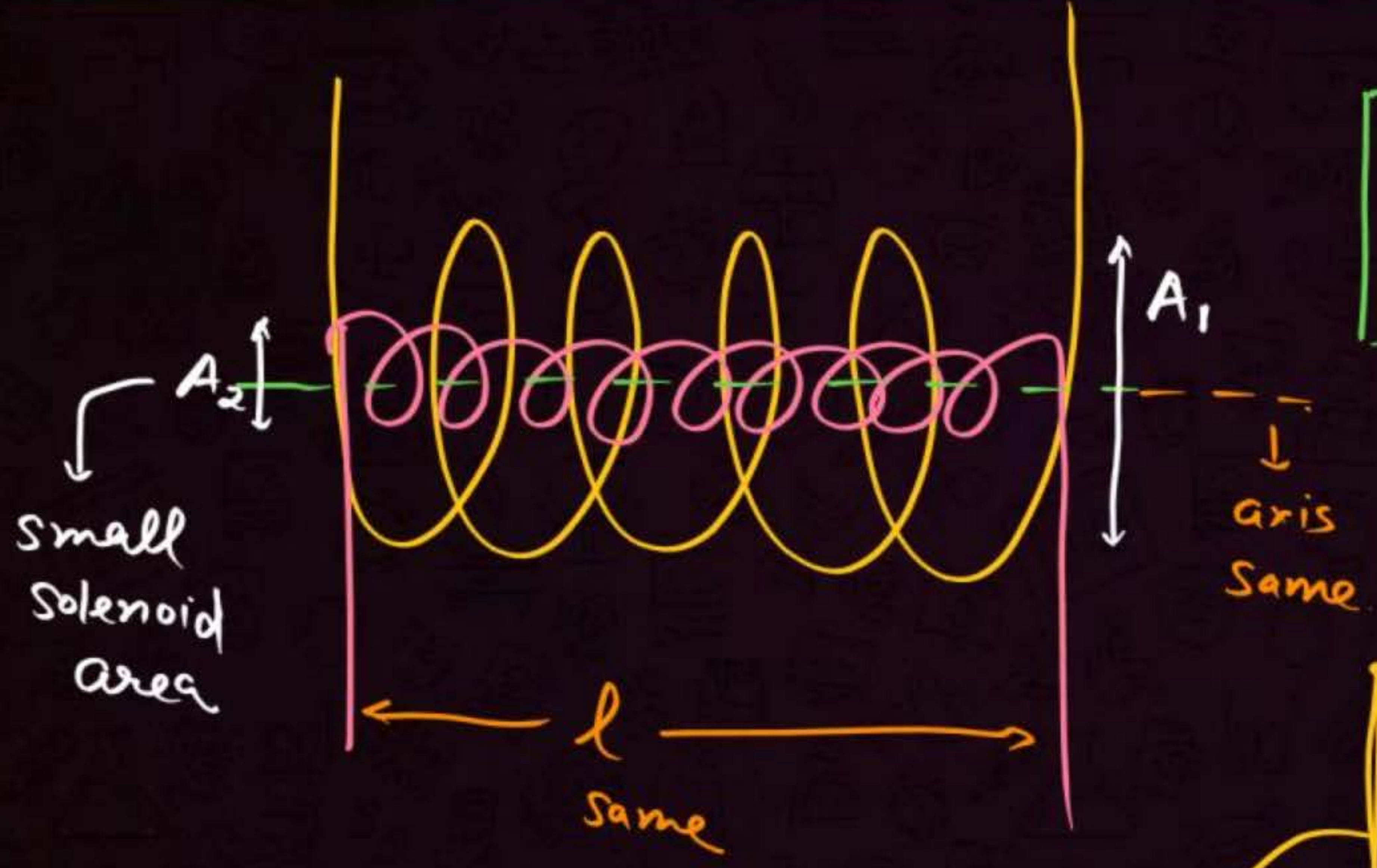
$= 5\pi$

$i_1 = i_0 \sin \omega t$

$\frac{di_1}{dt} = i_0 \cos \omega t \times \omega$

$= i_0 \omega \cos \omega t$

Mutual Inductance of two coaxial solenoids



$$M = \frac{\mu_0 N_1 N_2 A_2}{\ell} = \mu_0 n_1 n_2 A_2 \ell$$

$$L = \frac{\mu_0 N^2 A}{\ell} = \mu_0 n^2 A \ell.$$

$L \rightarrow$ depend shape/size (geometry, configuration)
(N, ℓ, A)
& medium (μ_0)

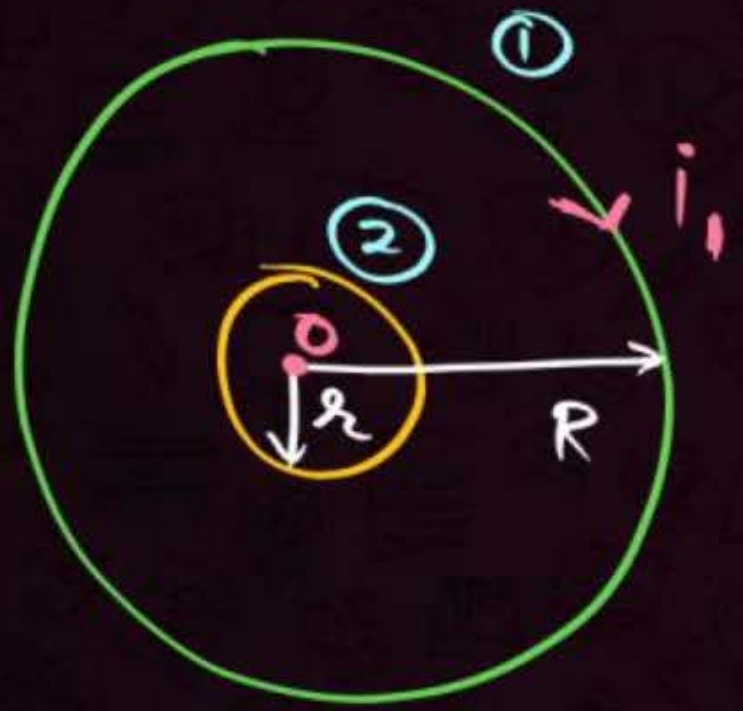
$M \rightarrow$ extra.
Orientation of coils

How to find mutual inductance

TBS
- $i \rightarrow$ Bde
- $B \rightarrow$ Bde
- $A \rightarrow$ chhote
- $\phi \rightarrow$ chhote

$N_1 N_2 \rightarrow$ multiply

Ques Circular coil.



* $r << R$

$$B_1 = \frac{\mu_0 i_1}{2R}$$

$$\phi_2 = B_1 A_2$$

$$\phi_2 = \frac{\mu_0 i_1}{2R} \times \pi r^2 = M i_1$$

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

Ques

$$M = \frac{\mu_0}{2R_1} \times \pi R_2^2 \times N_1 N_2$$

QUESTION

Two conducting circular loops of radii R_1 and R_2 are placed in the same plane with their centers coinciding. If $R_1 >> R_2$, the mutual inductance M between them will be directly proportional to

[NEET 2021]

AIIMS

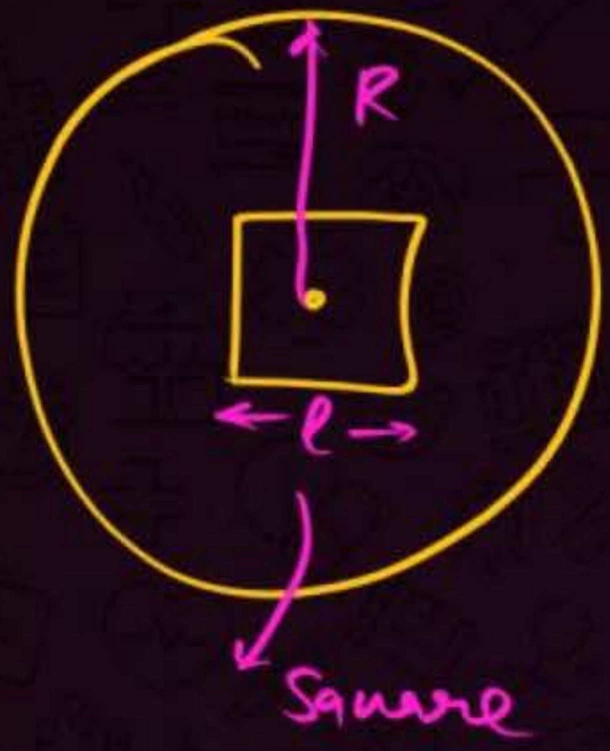
1. $\frac{R_1}{R_2}$
2. $\frac{R_2}{R_1}$
3. $\frac{R_1^2}{R_2}$
4. $\frac{R_2^2}{R_1}$

$$M = \frac{\mu_0}{2R_1} \times \pi R_2^2$$

$$M \propto \frac{R_2^2}{R_1}$$

Ques

Same plane



* $l << R$

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

Ans

QUESTION

Two concentric circular coils with radii 1 cm and 1000 cm, and number of turns 10 and 200 respectively are placed coaxially with centers coinciding. The mutual inductance of this arrangement will be ______ $\times 10^{-8}$ H. (Take, $\pi^2 = 10$)

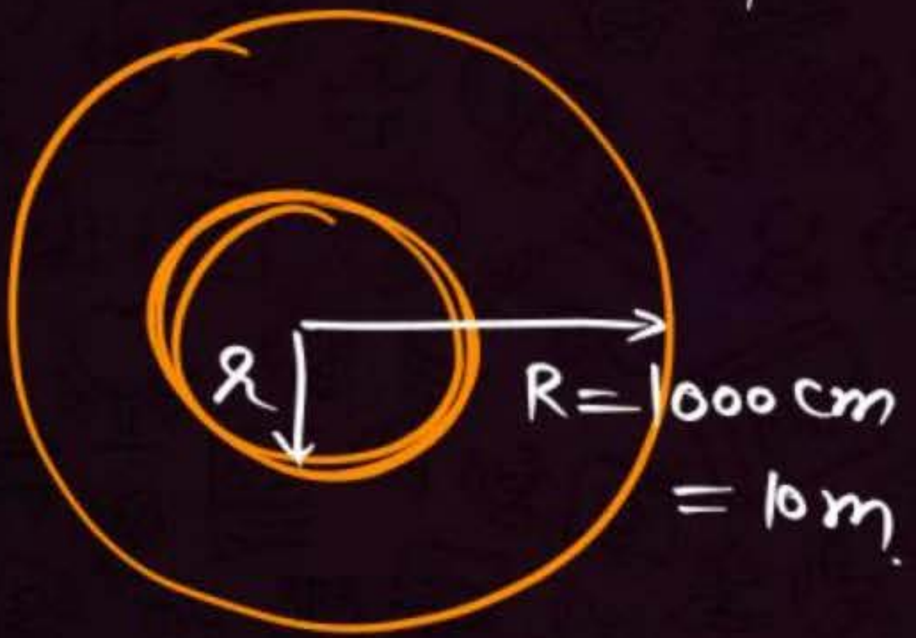
[6 April, 2023 (Shift-II)]

(1) 2

(2) 4

(3) 6

(4) 8



$r = 1\text{cm} = \frac{1}{100}\text{m}$

$N_1 N_2 = 10 \times 2000$

$M = \frac{\mu_0}{2R} \times \pi r^2 \times N_1 N_2$

$= \frac{4\pi \times 10^{-7}}{2 \times 10} \times \pi \times \frac{1}{100} \times \frac{1}{100} \times 10 \times 200$

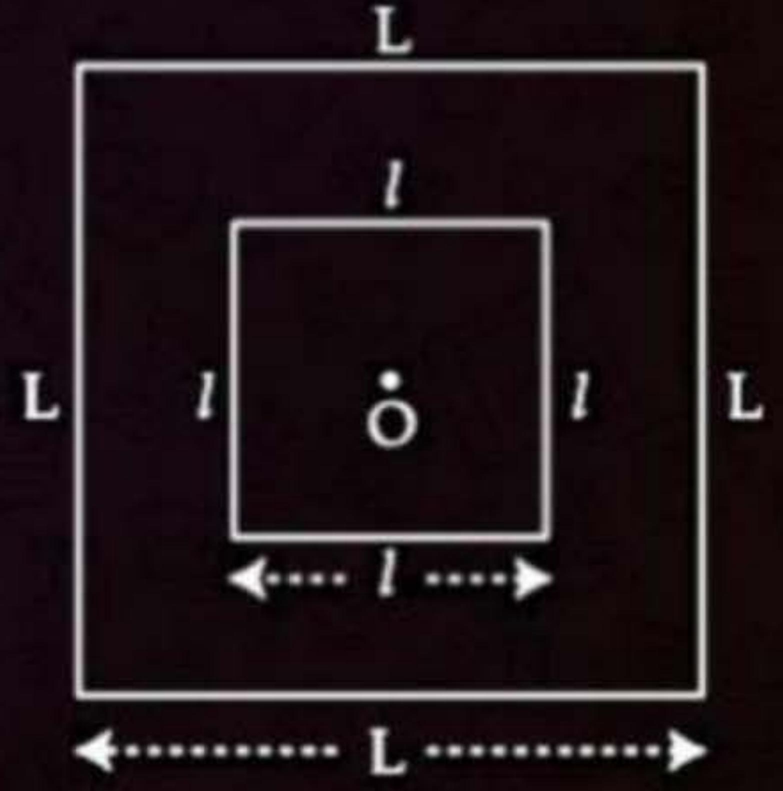
$= \frac{4\pi^2 \times 10^{-7}}{100} = 4\pi^2 \times 10^{-9}$

$= 40 \times 10^{-9}\,H = 4 \times 10^{-8}\,H$

QUESTION

(HW)

A small square loop of wire of side l is placed inside a large square loop of wire. $L(L >> l)$. Both loops are coplanar and their centres coincide at point O as shown in figure. The mutual inductance of the system is: [25 July, 2022 (Shift-I)]



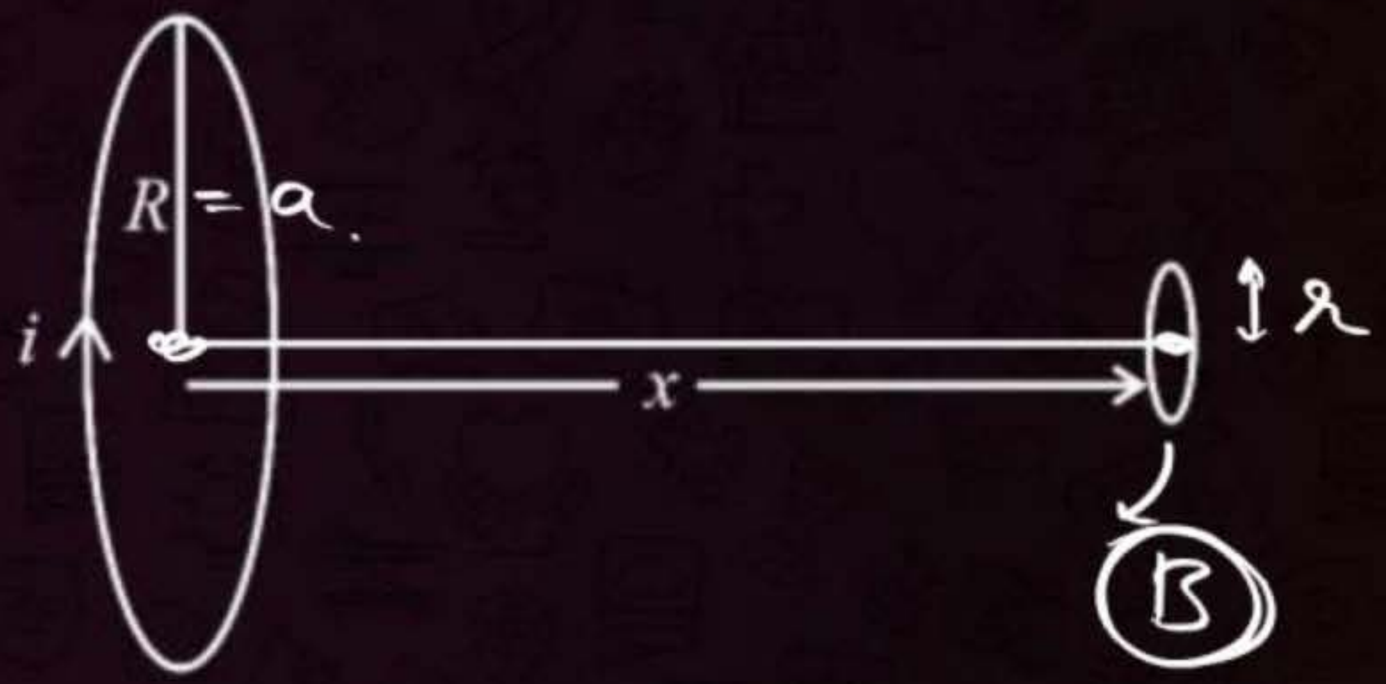
1. $\frac{2\sqrt{2}\mu_0 L^2}{\pi\ell}$
2. $\frac{\mu_0 \ell^2}{2\sqrt{2}\pi\ell}$
3. $\frac{2\sqrt{2}\mu_0 \ell^2}{\pi L}$
4. $\frac{\mu_0 L^2}{2\sqrt{2}\pi\ell}$

QUESTION

Find the mutual inductance between the loop. (Assume $r << R$)

$$M = \frac{\mu_0 R^2}{2(x^2+R^2)^{3/2}} \times \pi r^2$$

Ans



QUESTION

HW

There are two long co-axial solenoids of same length l. The inner and outer coils have radii r_1 and r_2 and number of turns per unit length n_1 and n_2 respectively. The ratio of mutual inductance to the self-inductance of the inner-coil is **[11 Jan, 2019 (S-I)]**

(1) $\frac{n_1}{n_2}$

(2) $\frac{n_2}{n_1}\frac{r_1}{r_2}$

(3) $\frac{n_2}{n_1}\frac{r_2^2}{r_1^2}$

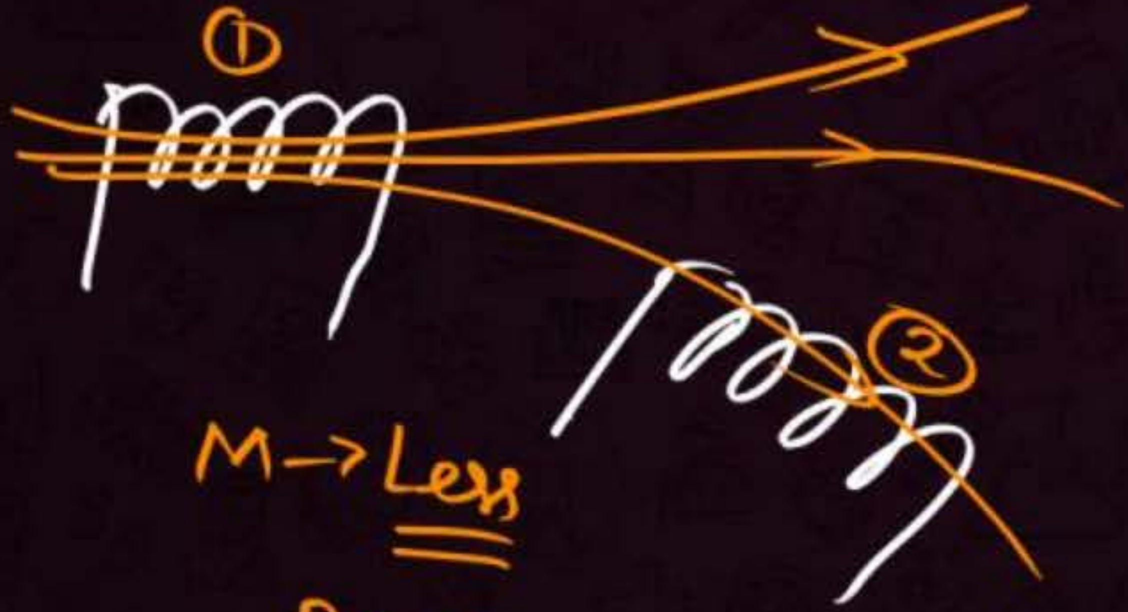
(4) $\frac{n_2}{n_1}$

Coefficient of Coupling

$$M = k\sqrt{L_1 L_2}$$

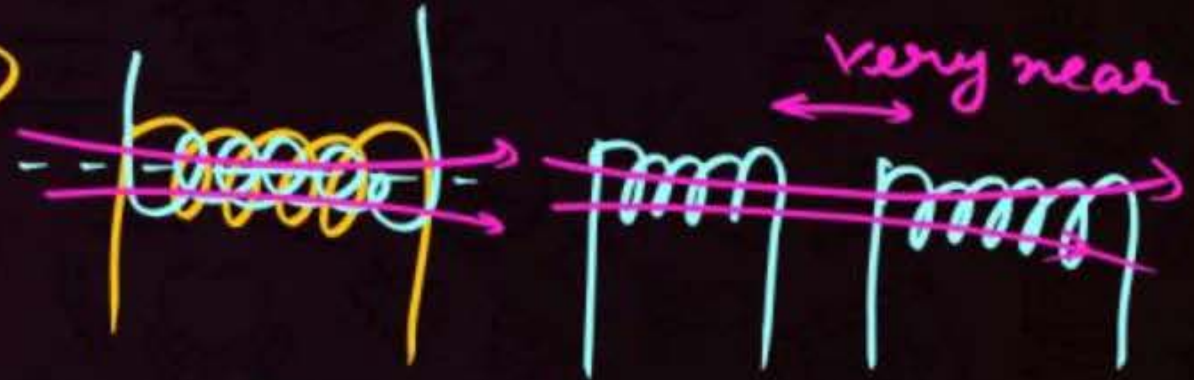
k = coeff of coupling

k ⇒ B/w 0 and 1



Relative orientation

①

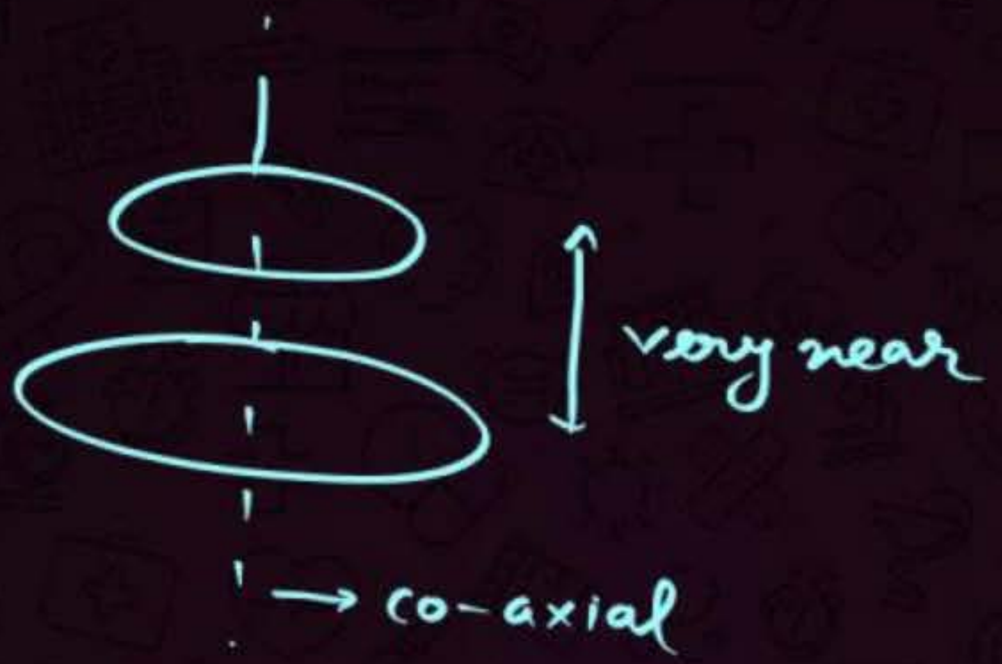


Flux Linkage maxm. (k = 1)

$$M = \sqrt{L_1 L_2}$$ → maxm

②

ans



$M \rightarrow max^m$

ans

$k = 0$

$M = 0$

QUESTION

Two coils of self-inductances 2 mH and 8 mH are placed so close together that the effective flux in one coil is completely linked with the other. The mutual inductance between these coils is

(CBSE AIMPT 2006)

$M = \sqrt{2 \times 8} = \sqrt{16} = 4$

(1) 10 mH

(2) 6 mH

(3) 4 mH

(4) 16 mH

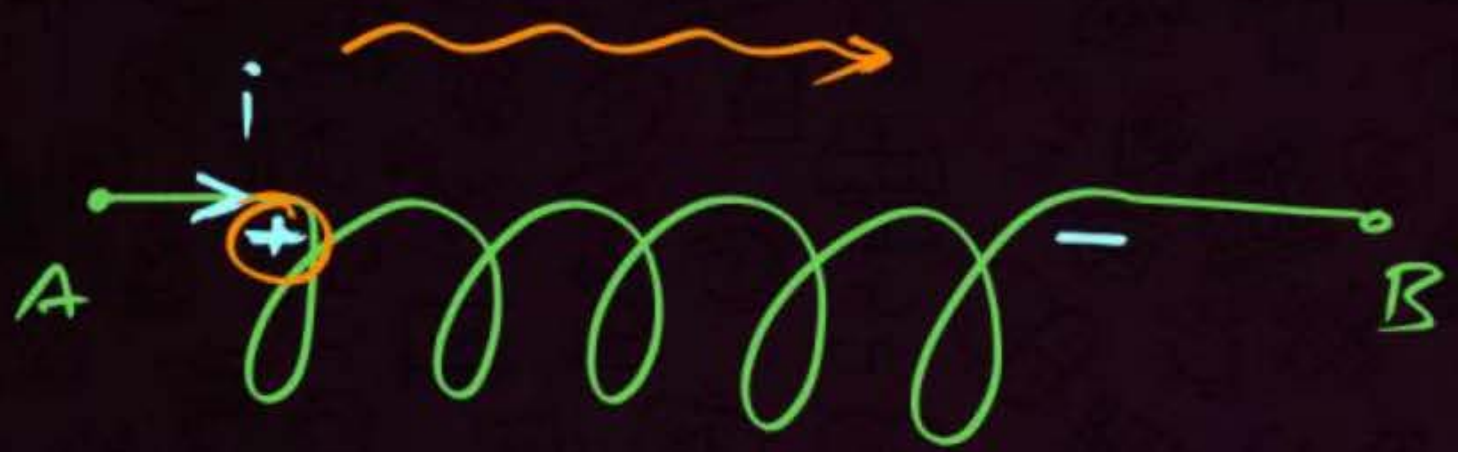
QUESTION

Assertion (A): When two coils are wound on each other, the mutual induction between the coils is maximum.

Reason (R): Mutual induction does not depend on the orientation of the coils.

1. Assertion is True, Reason is True; Reason is a correct explanation for Assertion.
2. Assertion is True, Reason is True; Reason is not a correct explanation for Assertion.
3. Assertion is True, Reason is False.
4. Assertion is False, Reason is True.

Inductors in Circuits



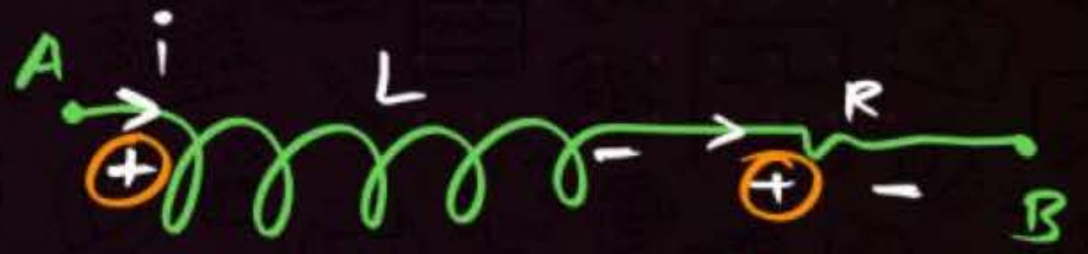
$$V_A - L\frac{di}{dt} = V_B$$

$i \rightarrow \text{inc} \Rightarrow \frac{di}{dt} = +ve$

$i \rightarrow \text{dec.} \Rightarrow \frac{di}{dt} = -ve$

Ques

- $i = 4A$
- $i \to$ inc. at rate $1\ A/sec.$
- $V_A - V_B = ?$



$$V_A - L\frac{di}{dt} - iR = V_B$$

$$V_A - V_B = L\frac{di}{dt} + iR$$

$$= 3\times(+1) + 4\times 2$$

$$= 3 + 8 = 11 \text{ volts}$$

If $i \to$ dec. $\to$

$$V_A - V_B = 3\times(-1) + 4\times 2$$

$$= -3 + 8 = 5 \text{ volts}$$

QUESTION

HW

$R = 0.2\ \Omega$. At a certain instant $V_A - V_B = 0.5$ V, I = 0.5 A and current is increasing at the rate of 8 A/s. Find inductance of the coil.

(1) 0.01 H

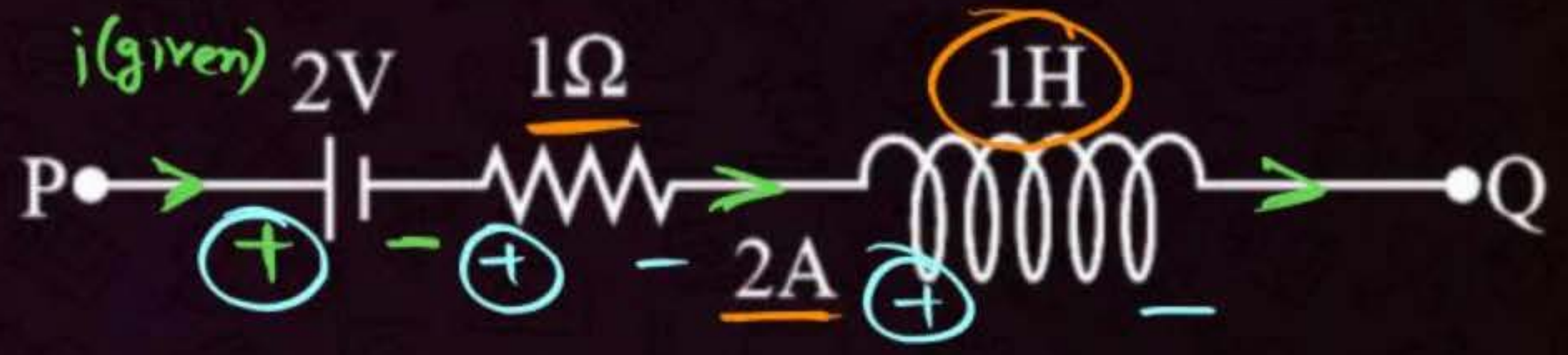
(2) 2 H

(3) 0.05 H

(4) 5 H

QUESTION

Network shown in the diagram is part of an electric circuit. The current is 2 A and is decreasing at the rate of 2 A/s then $V_P - V_Q$ equals



1. 2 V
2. −2 V
3. 4 V
4. −4 V

$$V_P - 2 = V_Q$$
$$V_P - V_Q = +2$$

$$V_P - 2 - iR - L\frac{di}{dt} = V_Q$$
$$V_P - 2 - 2\times1 - 1\times(-2) = V_Q$$
$$V_P - 2 - 2 + 2 = V_Q$$
$$V_P - V_Q = 2.$$

Soch Bhai Soch

What is the induced emf in a coil if current in it is constant.

1. Zero ✓
2. Non-zero

$i \rightarrow$ const.

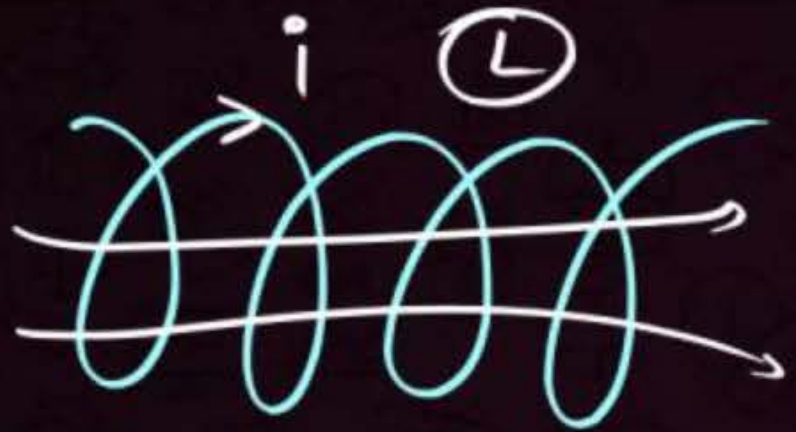
$\Longrightarrow$

we can assume it as conducting wire

$$\frac{di}{dt} = 0 \Rightarrow e = 0$$

$$V_A - V_B = 0$$

Energy Stored in an Inductor



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

$$U \propto i^2$$

Energy Density in an Inductor

Capacitor

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

$$u = \frac{U}{\text{Vol.}} = \frac{1}{2}\epsilon_0 E^2$$

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

$$u = \frac{1}{2}\frac{B^2}{\mu_0}$$

energy is stored in inductor in form of magnetic field lines.

QUESTION

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

(CBSE AIMPT 1991)

1. 0.5 J
2. 1 A
3. 0.05 J
4. 0.1 J

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

$$= \frac{1}{2} \times \frac{100}{1000} \times 1^2$$

$$= 0.05$$

QUESTION

The self produced emf of a coil is 25 volts. When the current in it is changed at uniform rate from 10 A to 25 A in 1 s, the change in the energy of the inductance is:

[10 Jan, 2019 (S-II)]

(1) 740 J

(2) 437.5 J

(3) 540 J

(4) 637.5 J

$e = 25$

$e = L\frac{\Delta i}{\Delta t}$

$\Delta i = 25 - 10 = 15$

$\Delta t = 1$

$L = \frac{5}{3}\,H$

$U = \frac{1}{2}Li_2^2 - \frac{1}{2}Li_1^2$

$= \frac{1}{2}L(i_2^2 - i_1^2)$

$= \frac{1}{2} \times \frac{5}{3}(25^2 - 10^2)$

QUESTION

HW

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)

(1) 1.389 H

(2) 138.88 H

(3) 0.138 H

(4) 13.89 H

QUESTION

An inductor may store energy in (CBSE AIMPT 1990)

(1) its electric field

(2) its coils

(3) its magnetic field

(4) Both in electric and magnetic fields

* P = Power = Vi = $\boxed{ei}$

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

$$\boxed{P = Li\frac{di}{dt}}$$

Inductors in Combination

→ same as resistors.

Series ⇒ $L_s = L_1 + L_2 + L_3 + \ldots$

↓

Shortcuts.

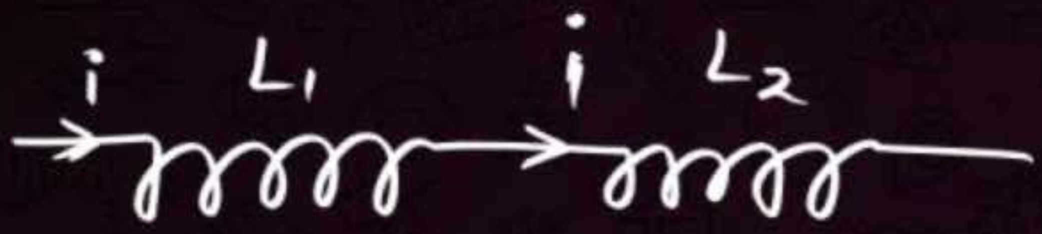
same

Parallel → $\frac{1}{L_p} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \ldots$

* Mutual inductance not considered

Rare chance

same dir i



$$L_{eff} = L_1 + L_2 + 2M.$$

opp. i

$$L_{eff} = L_1 + L_2 - 2M$$

QUESTION

Two inductor coils 20 H and 40 H combined in series to support each other so that the resultant inductance is 80 H. Find mutual inductance between them.

(1) 5 H

(2) 10 H

(3) 20 H

(4) 40 H

(+)

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

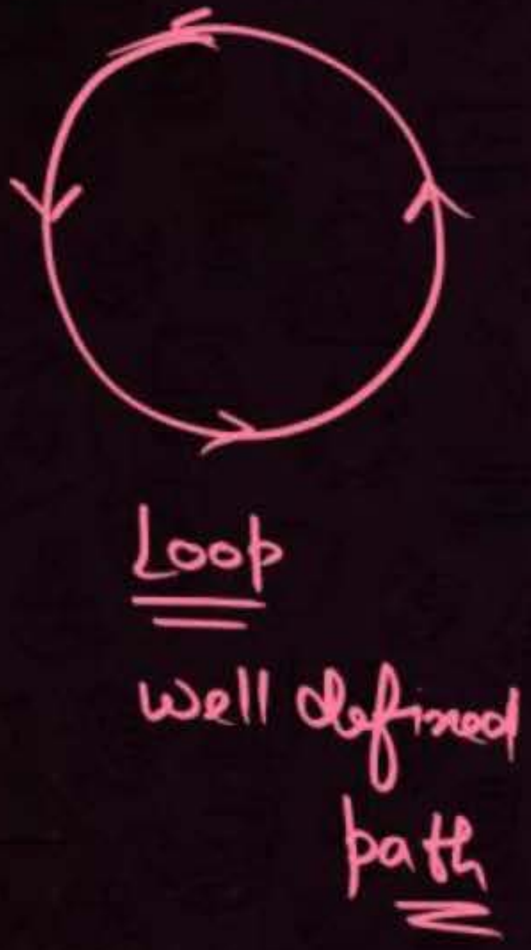
$$80 = 20 + 40 + 2M$$

$$20 = 2M$$

$$10 = M$$

Eddy Currents

The induced currents produced in the bulk pieces of conductors.

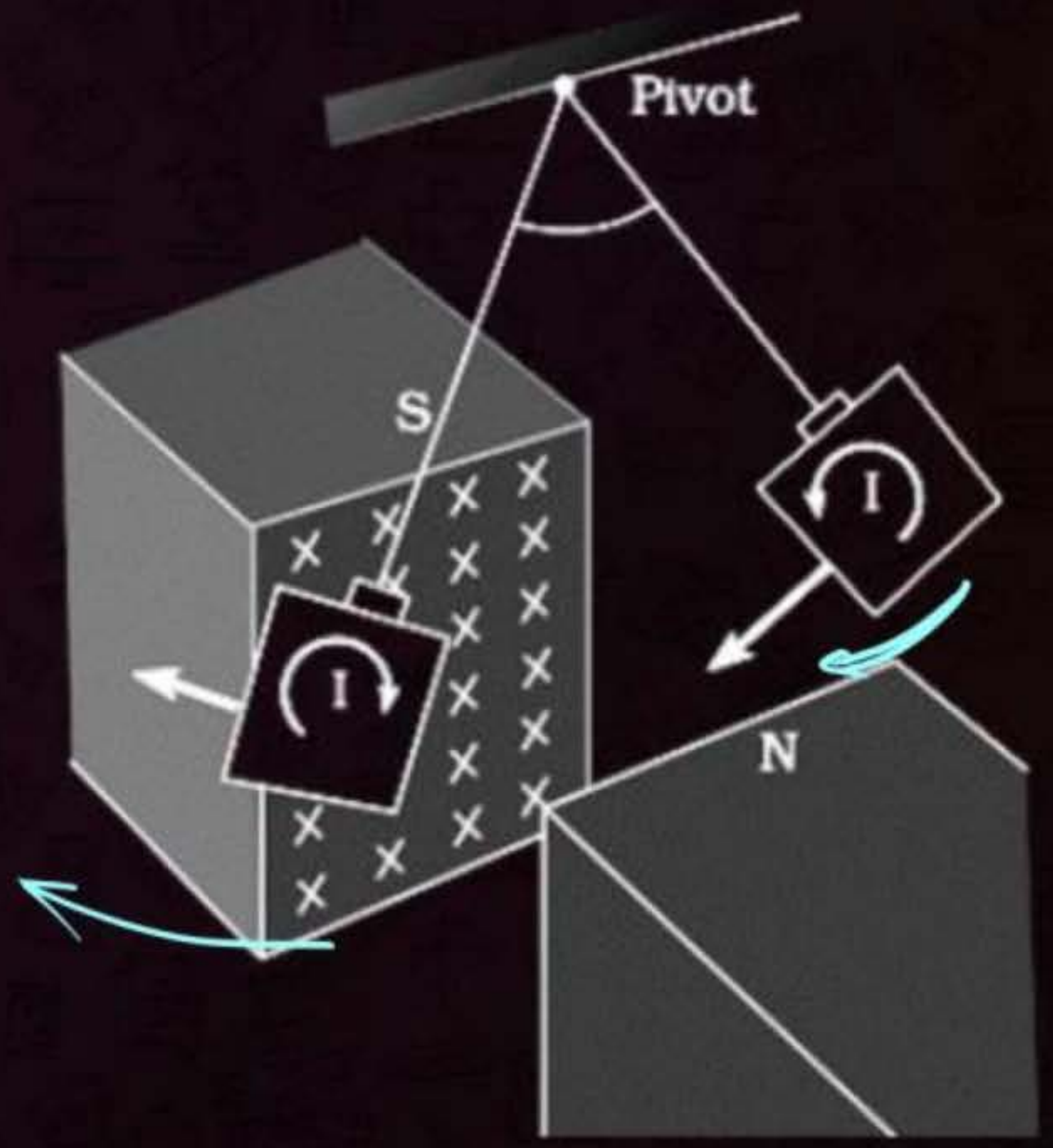


- Current is not in well defined paths.
- Their flow patterns resemble swirling eddies in water and these currents are called eddy currents.

Applications of Eddy Currents

1. Electromagnetic Damping

↳ Motion ko resist karna
↗ oppose



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.

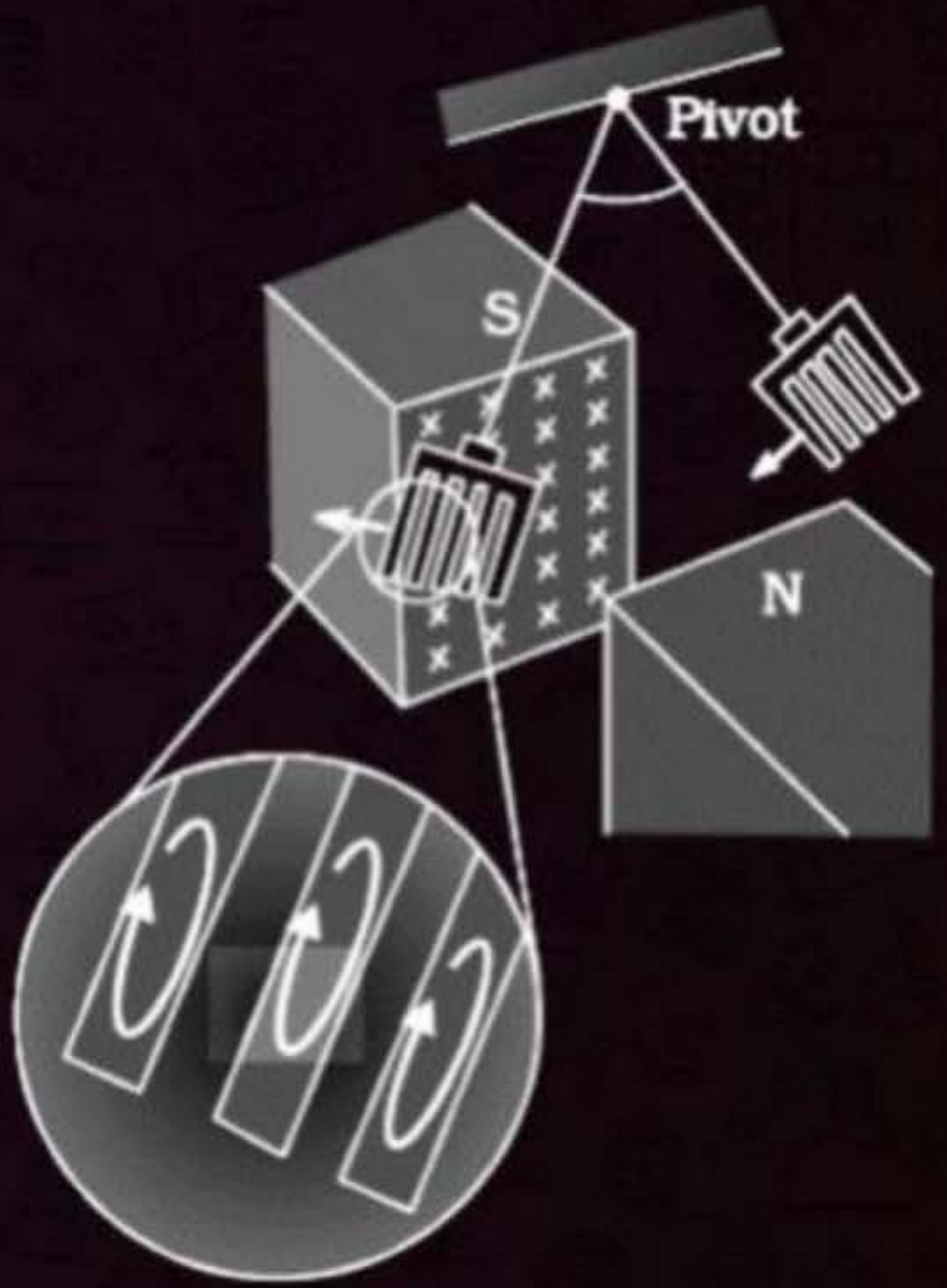
Magnetic flux associated with the plate keeps on changing as the plate moves in and out of the region.The flux change induces eddy currents in the plate.

Directions of eddy currents are opposite when the plate swings into and 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.

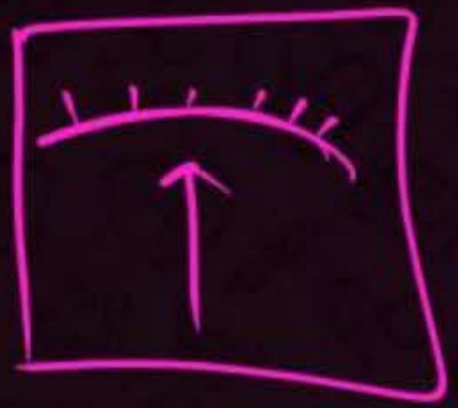
- Eddy currents are undesirable since they heat up the core and dissipate electrical energy in the form of heat.



Dead Beat Galvanometers

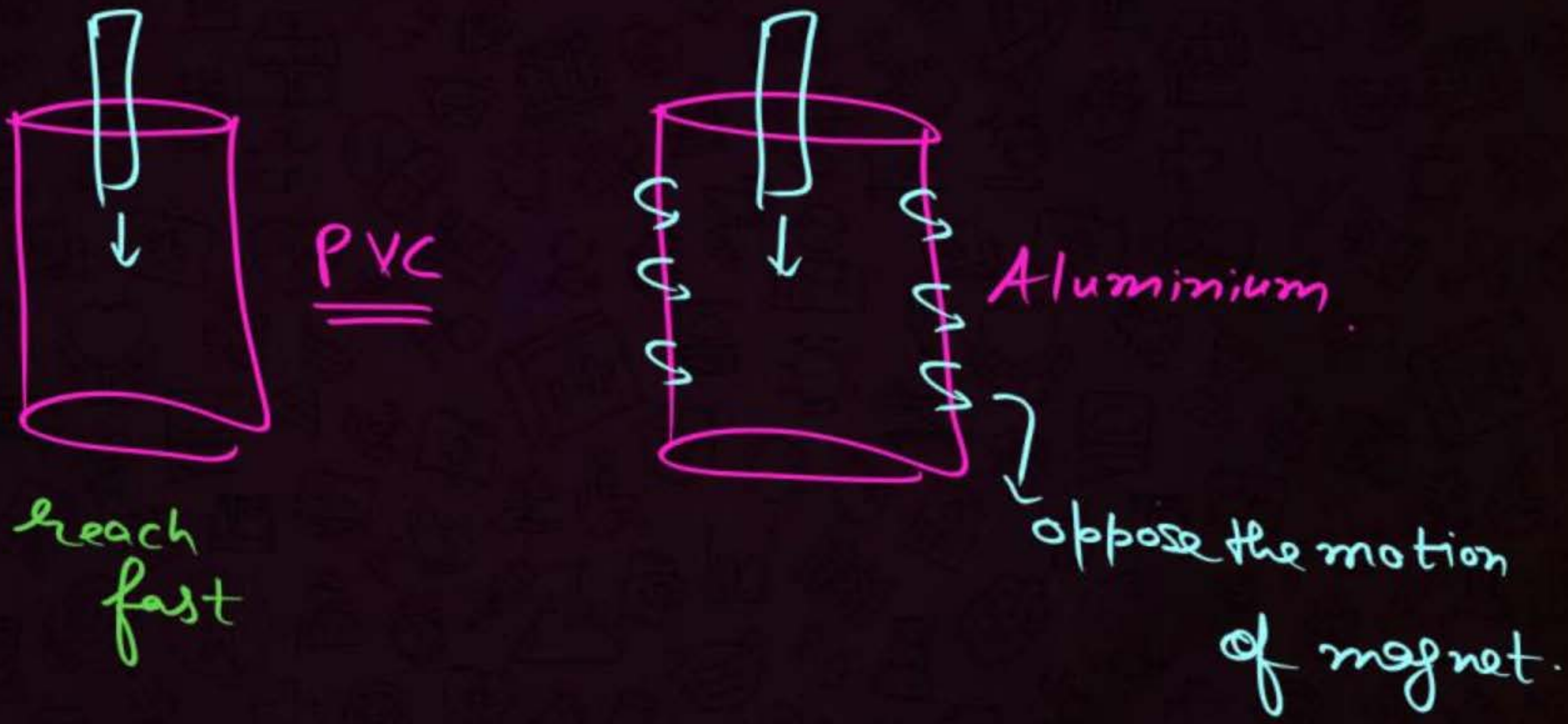
↳ instant reading

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



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.

3. Induction furnace

melts — melt

heat

i → variable

Used to melt metals by producing high temperatures.

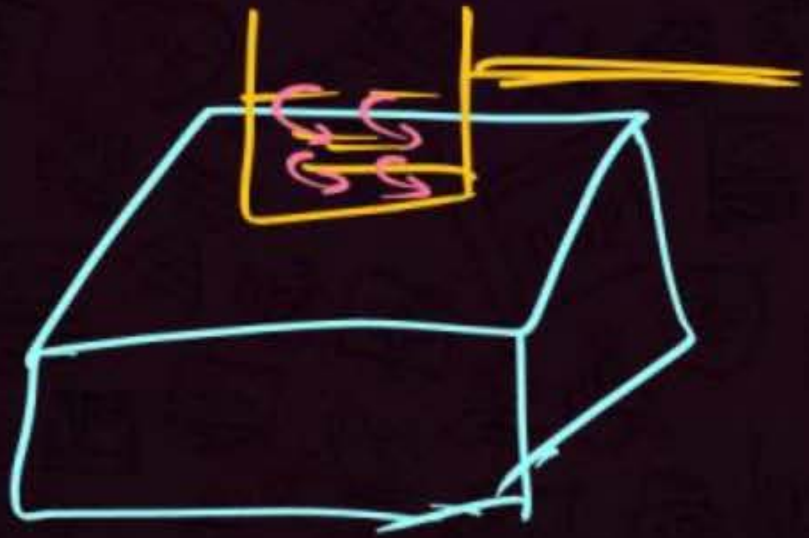
A high frequency alternating current is passed through a coil which surrounds the metals to be melted. The eddy currents generated in the metals produce high temperatures sufficient to melt it.

4. Electric Power Meters

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

5. Induction Cooktop

↓
eddy
currents



QUESTION

HW

Assertion: A metallic surface is moved in the moved out in a magnetic field, then emf is induced in it.

Reason: Eddy current generate heat.

(1) If both assertion and reason are true and reason is the correct explanation of the assertion.

(2) If both assertion and reason are true but reason is not correct explanation of the assertion.

(3) If assertion is true, but reason is false.

(4) Assertion is false, reason is true

QUESTION

HW

Eddy currents are produced when [AIIMS 2000]

(1) a metal is kept in varying magnetic field

(2) a metal is kept in the steady magnetic field

(3) a circular coil is placed in a magnetic field

(4) through a circular coil current is passed.

QUESTION

HW

Assertion: If current if flowing through a machine of iron eddy currents are produced.

Reason: Change in magnetic flux through an area causes eddy currents. [AIIMS 2000]

1. If both assertion and reason are true and reason is the correct explanation of the assertion.
2. If both assertion and reason are true but reason is not correct explanation of the assertion.
3. If assertion is true, but reason is false.
4. Assertion is false, reason is true

QUESTION

HW

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

(1) Induction furnace

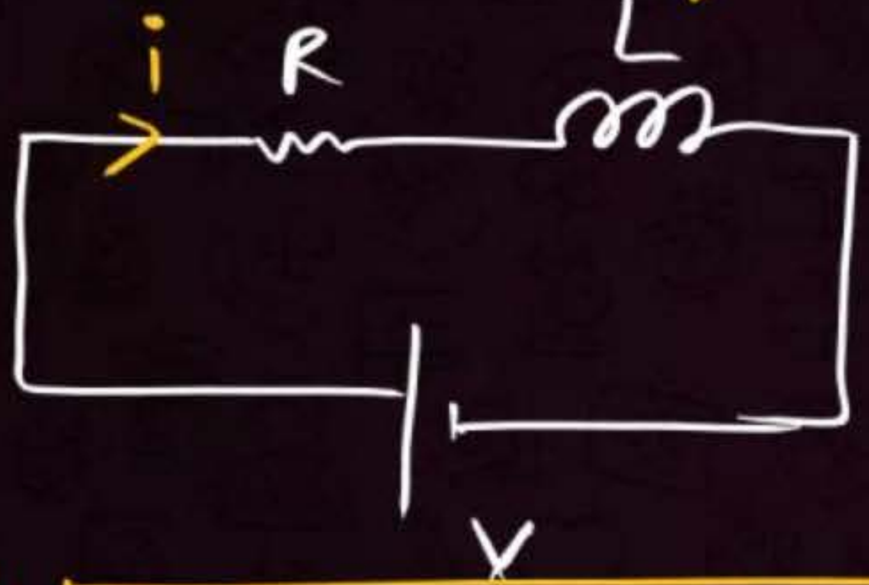
(2) Magnetic braking in train

(3) electromagnet

(4) electric heater

R-L Circuits

Charging circuit



→ oppose change in current

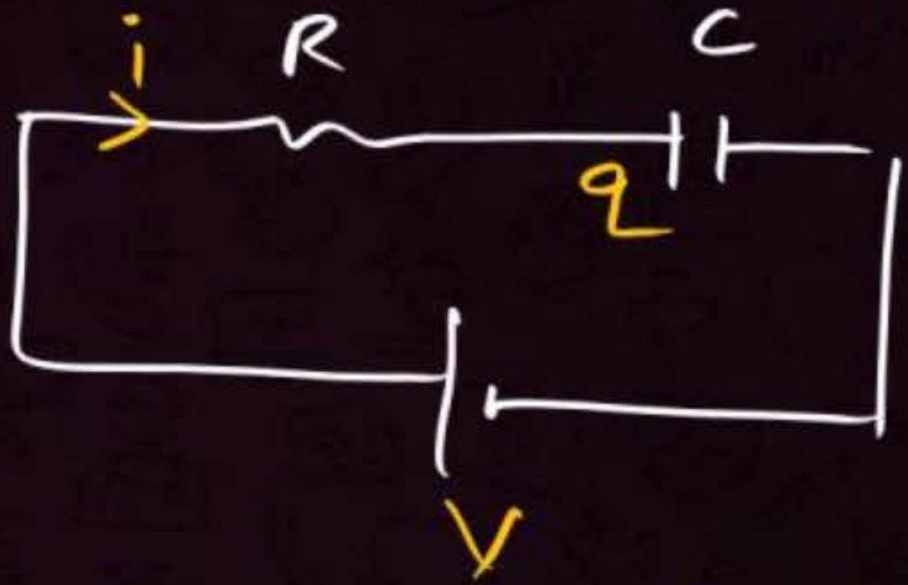
$\tau = \frac{L}{R}$

$$i = \frac{V}{R}\left(1 - e^{-Rt/L}\right)$$

$$i = i_0\left(1 - e^{-t/\tau}\right)$$

$$\frac{di}{dt} = \frac{V}{L} e^{-t/\tau}$$

$$\frac{di}{dt} = \left(\frac{di}{dt}\right)_{max} e^{-t/\tau}$$



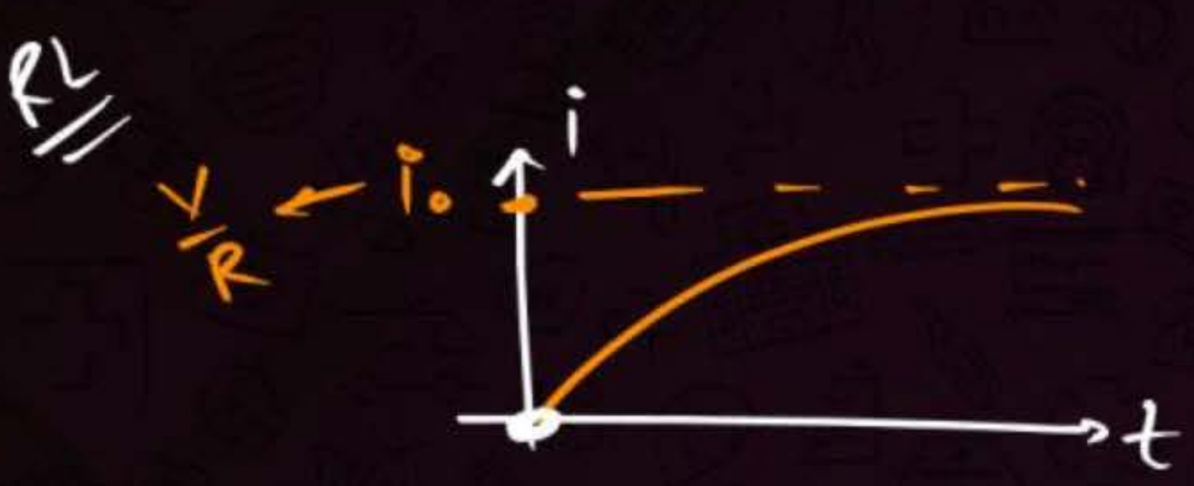
$$q = CV\left(1 - e^{-t/RC}\right)$$

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

$\tau = RC$

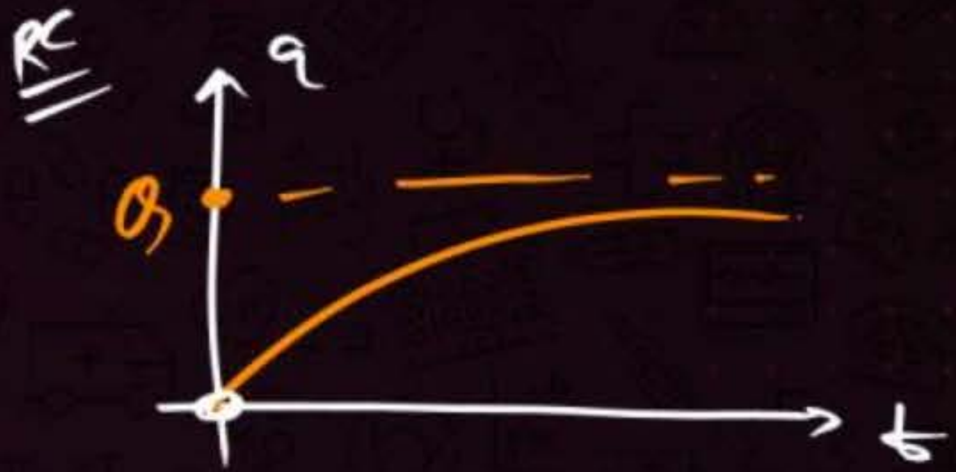
$$i = \frac{V}{R} e^{-t/RC}$$

$$i = i_0 e^{-t/\tau}$$



At $t=0 \Rightarrow i=0,\ \frac{di}{dt}=\frac{V}{L}$

At $t\to\infty \Rightarrow i=\frac{V}{R},\ \frac{di}{dt}=0$



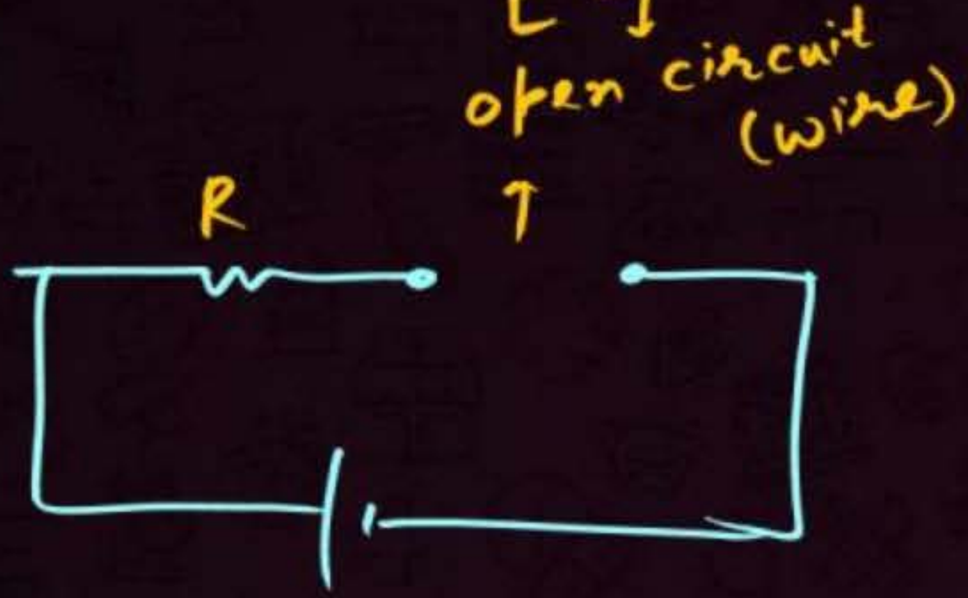
At $t=0 \Rightarrow q=0,\ i=i_0$

At $t\to\infty \Rightarrow q=Q,\ i=0$

TBS

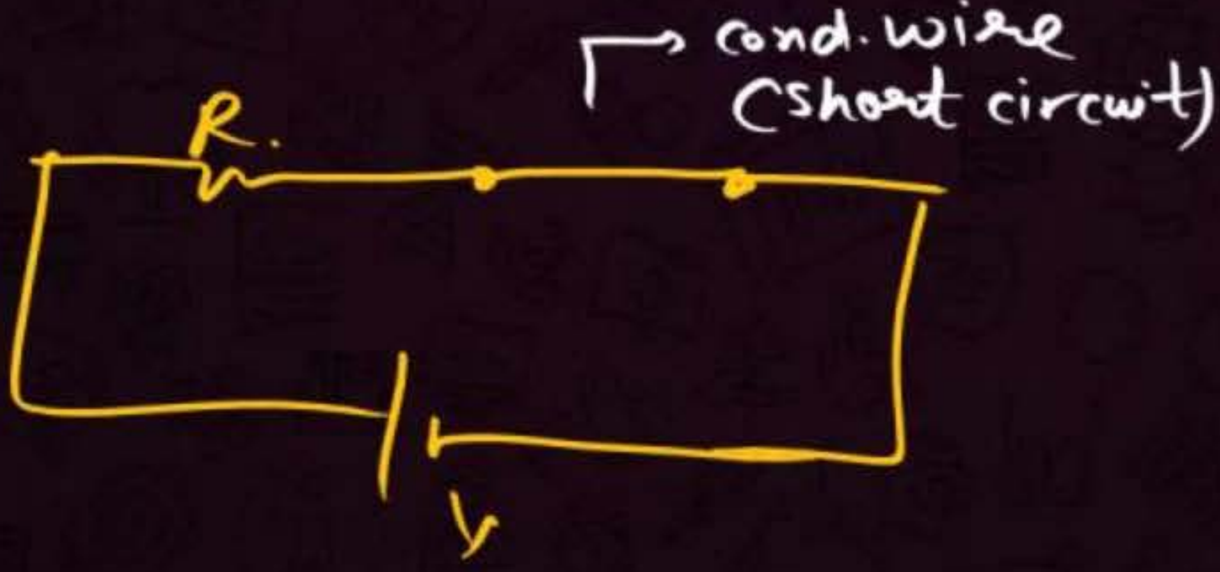
At $t=0$

$i=0$



At $t \to \infty$

$i = \frac{V}{R}$



(Ulta Tha)

capacitor

$t=0 \to$ wire

$t \to \infty \Rightarrow$ Verrado.

QUESTION

What is current in inductor at a time equals to one time constant.

RL

$t = \tau$

One τ: $i = 63\%$ of i_0

$i = 0.63 i_0$

$\frac{di}{dt} \Rightarrow 37\%$ of $\frac{V}{L}$

RC

One $\tau \Rightarrow q = 0.63 Q$

$\Rightarrow i = 37\%$ of i_0

QUESTION

HW

An ideal coil of 10 H is connected in series with a resistance of 5 Ω and a battery of 5V. After 2s, the connection is made, the current flowing (in ampere) in the circuit is

(1) $(1 - e)$

$$i = \frac{V}{R}\left(1 - e^{-Rt/L}\right)$$

(2) e

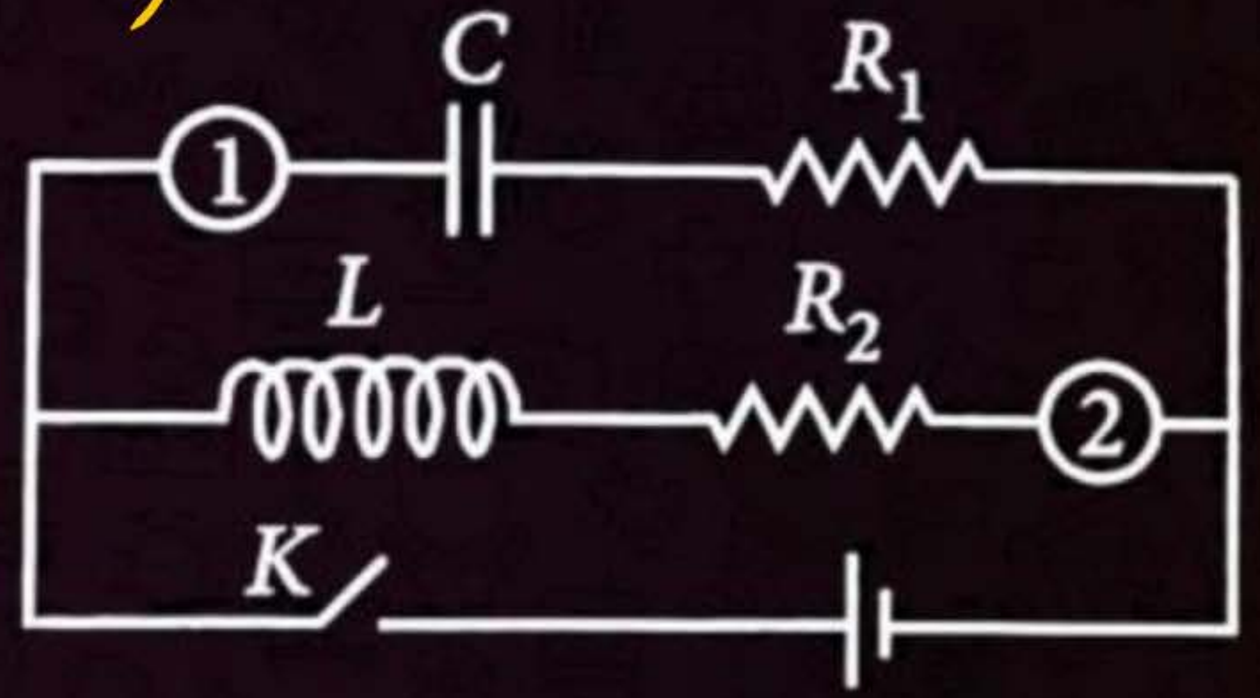
(3) e^{-1}

(4) $(1 - e^{-1})$

QUESTION

(HW)

In the circuit given in figure, 1 and 2 are ammeters. Just after key K is pressed to complete the circuit, the reading will be (1999)



1. zero in 1, max^m in 2
2. max^m in both 1 and 2
3. zero in both 1 and 2
4. max^m in 1, zero in 2

In the figure shown, a circuit contains two identical resistors with resistance $R = 5\ \Omega$ and an inductance with $L = 2$ mH. An ideal battery of 15 V is connected in the circuit. What will be the current through the battery long after the switch is closed ?

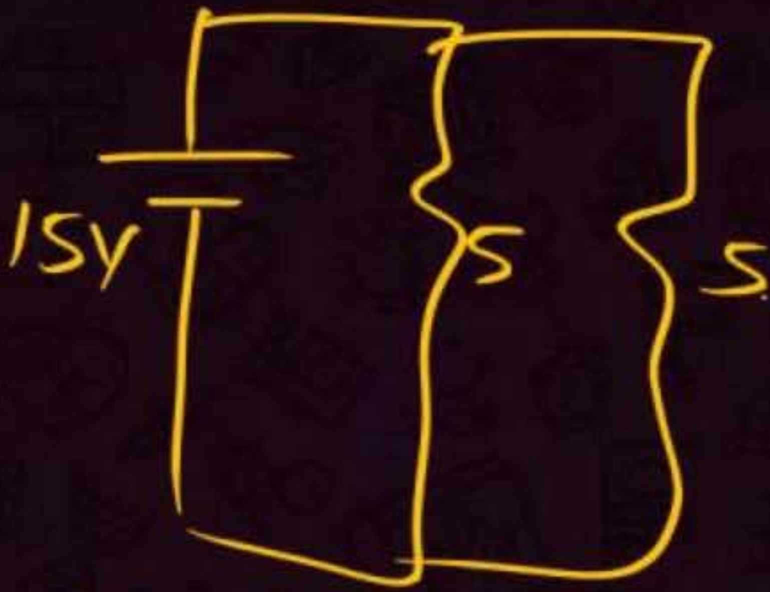
(JEE Main 2019)

(a) 6 A

(b) 7.5 A

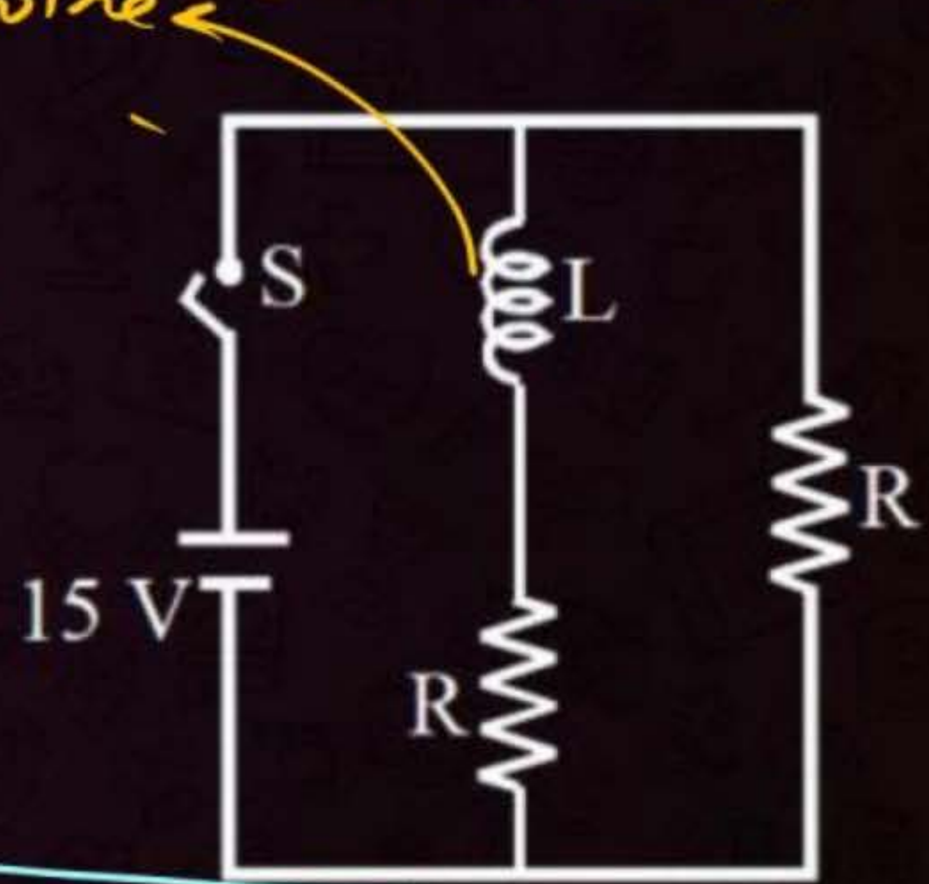
(c) 5.5 A

(d) 3 A



$R_{eq} = \frac{5}{2}\Omega$

$i = \frac{15}{5/2} = 6A$



At t=0

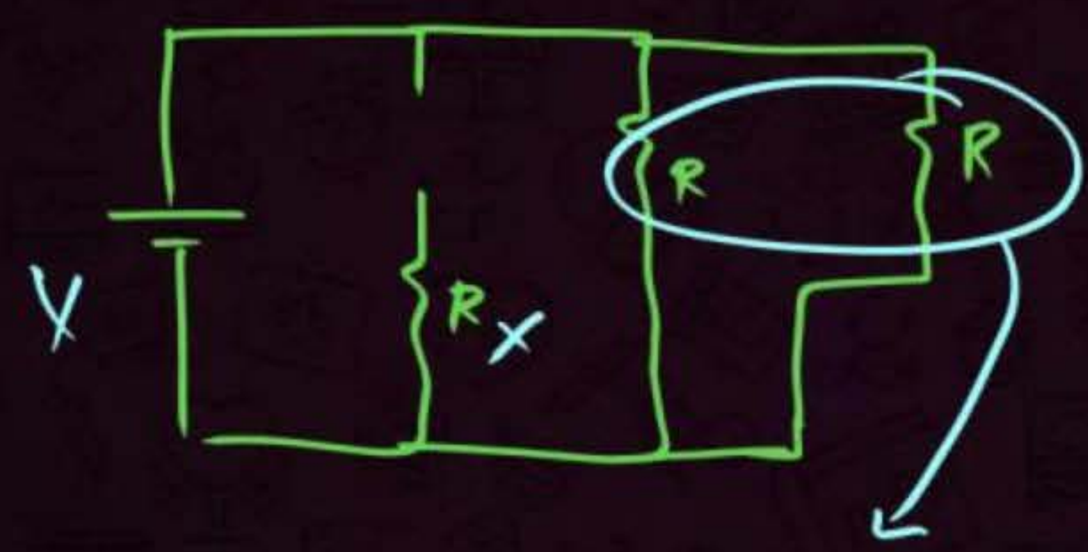
$i = \frac{15}{5} = 3A$

QUESTION

R = 9 Ω each and L = 2 mH each. Battery emf = 18 V. Find current through battery just after the switch is closed is **(NEET 2017)**

Bonus ←

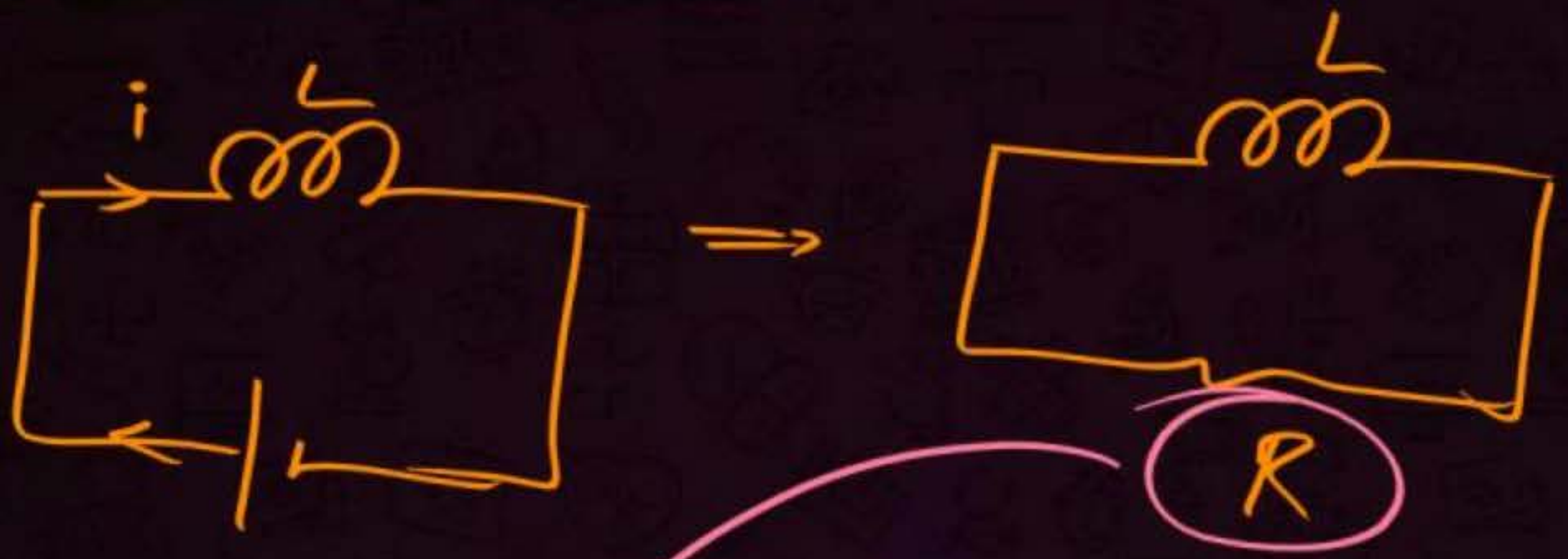
1. 0.2 A
2. 2 A
3. 0 ampere
4. 2 mA
5. 4 A ✓

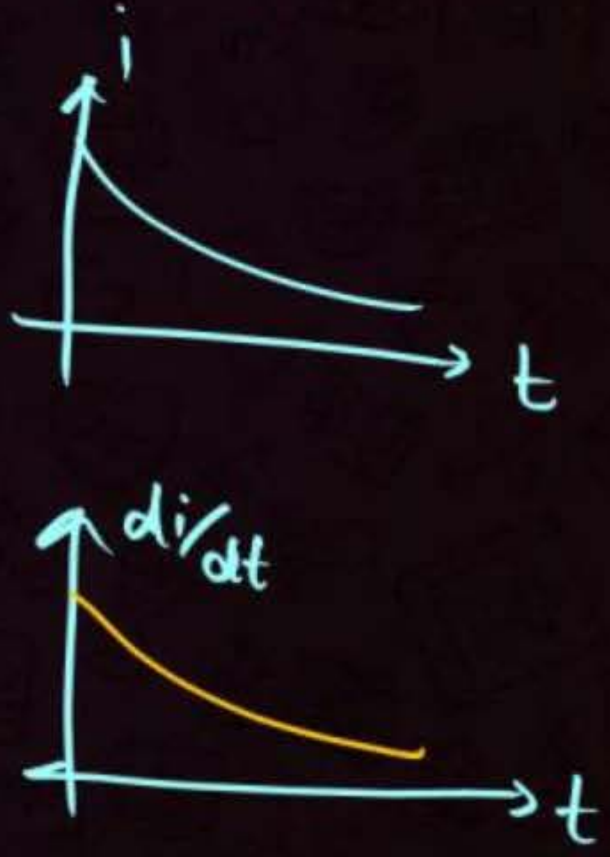


$R_{eq} = \frac{R}{2}$

$i = \frac{18}{9/2} = \frac{18 \times 2}{9} = 4\text{ A}$

Discharging Circuit





$$i = i_0 e^{-t/\tau}$$

$$\frac{di}{dt} = \left(\frac{di}{dt}\right)_{max} e^{-t/\tau}$$

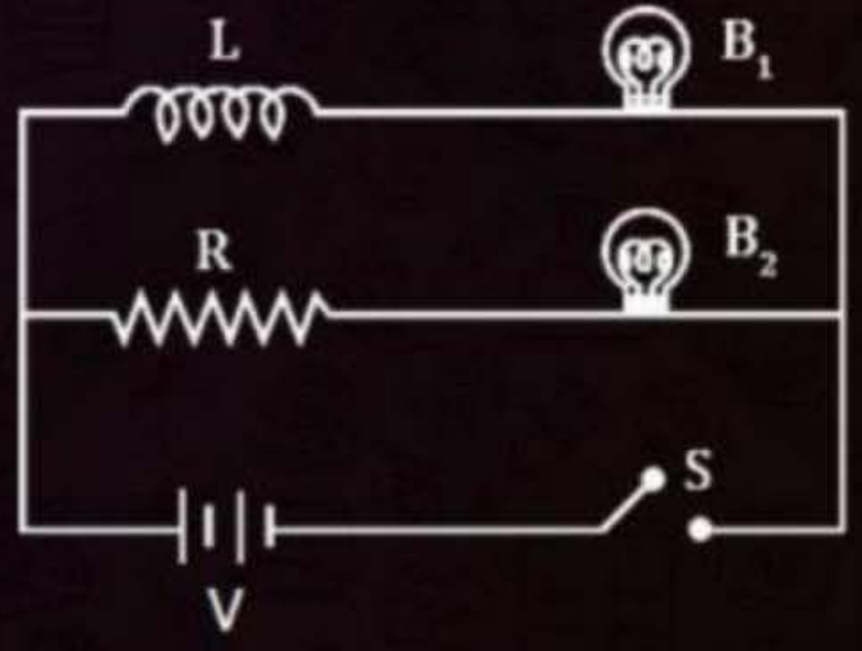
energy
Kha
Jaega
↓
Heat Mein.

QUESTION

HW

An inductor L, a resistance R and two identical bulbs, B_1 and B_2 are connected to a battery through a switch S as shown in the figure. Which of the following statements gives the correct description of the happening when the switch S is closed?

1. The bulb B_2 lights up earlier than B_1 and finally both the bulbs shine equally bright
2. B_1 lights up earlier and finally both the bulbs acquire equal brightness
3. B_2 lights up earlier and finally B_1 shines brighter than B_2
4. B_1 and B_2 light up together with equal brightness all the time




TBS Army – Tanuj Sir
TANUJ SIR
JOIN MY OFFICIAL TELEGRAM CHANNEL
Physics Wallah
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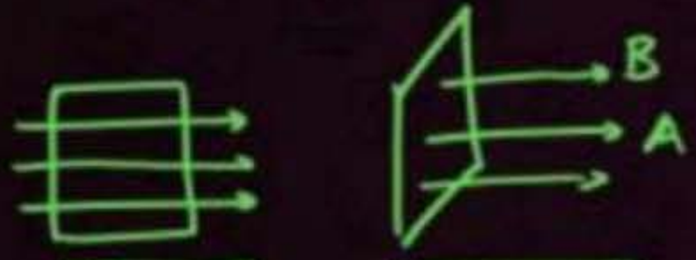
TBS Capsule ①

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

$\phi = BA\cos\theta$

$\theta \rightarrow$ angle b/w $\vec{B}$ & $\vec{A}$



$\boxed{\phi = 0}$ $\boxed{\phi = BA}$ ↓ max

- SI units
  ↳ $T\text{-}m^2$ (Wb)
- cgs unit ⇒ $G\text{-}cm^2$ (Maxwell)

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

Faraday's Law

* $e = -\dfrac{d\phi}{dt}$

$e = -N\dfrac{d\phi}{dt}$

$e_{av} = -\dfrac{\Delta\phi}{\Delta t}$

$e_{av} = -N\dfrac{\Delta\phi}{\Delta t}$

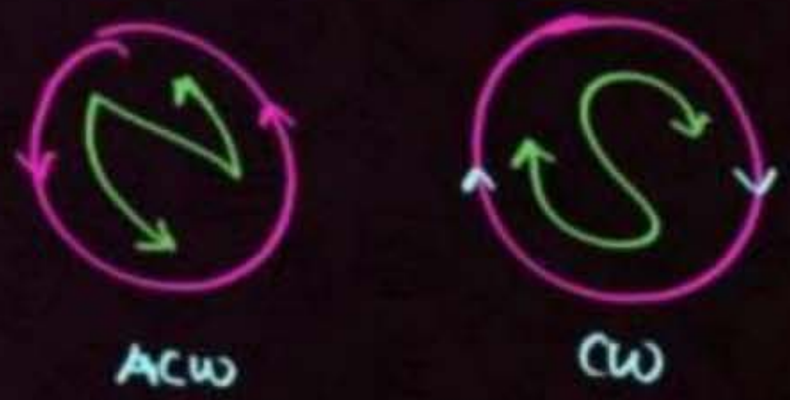
-ve is due to Lenz law
↓
opposes the $\Delta\phi$

- Based on cons. of energy.

* Methods to change ϕ

Change B, A or θ.
↳ Area through which flux passes.

- Sign Conventions

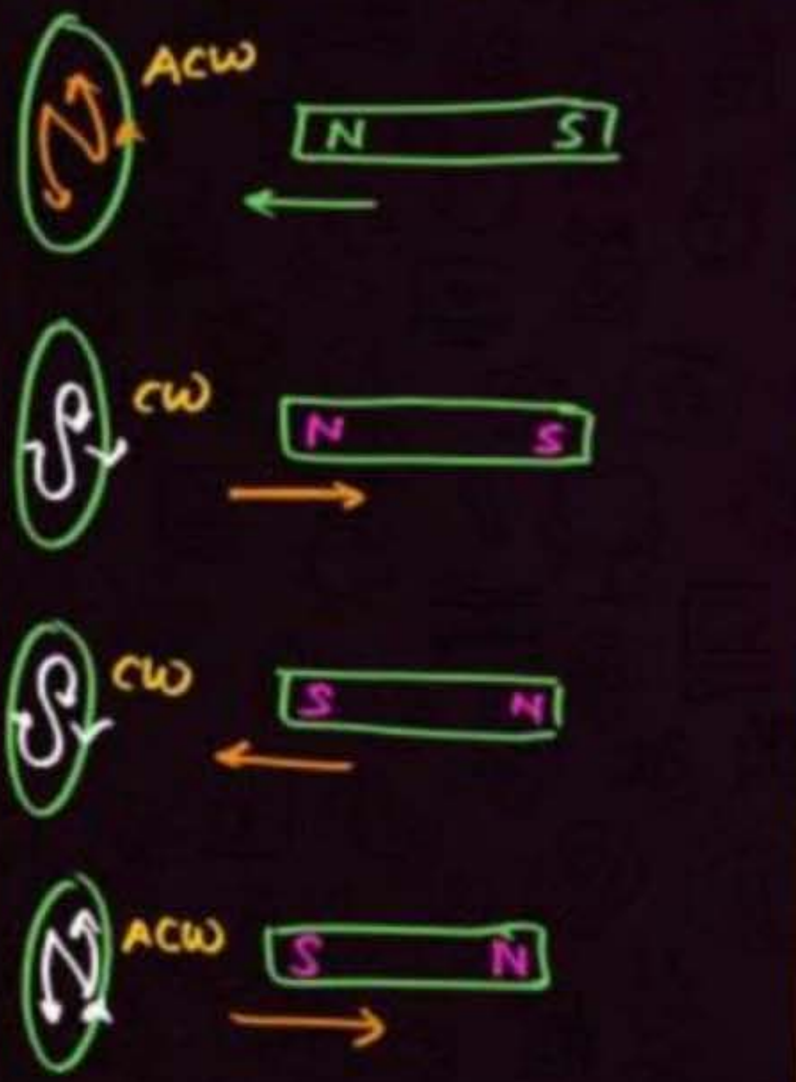


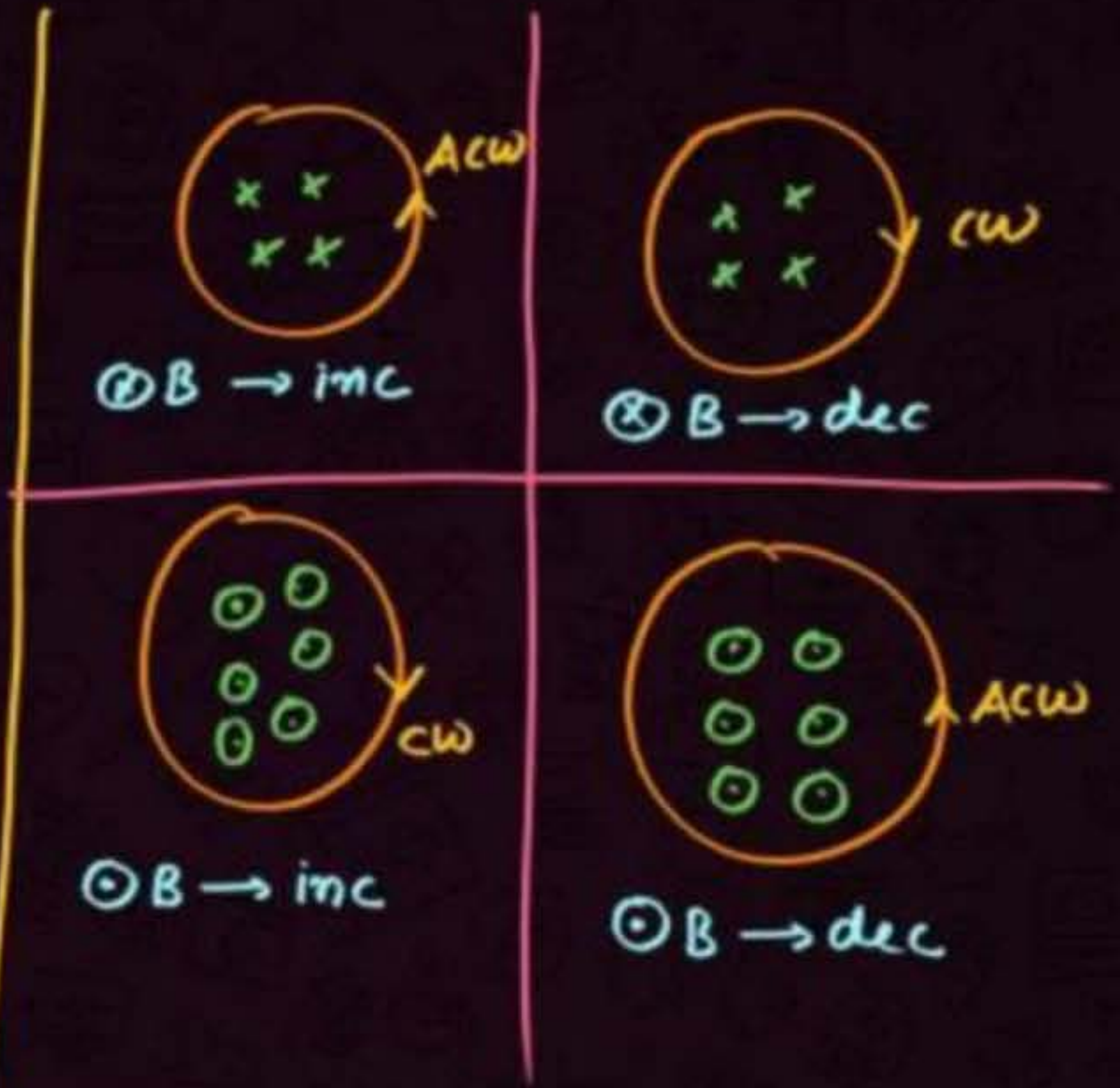
- Induced current (i) $= \dfrac{e}{R}$

R = Resistance

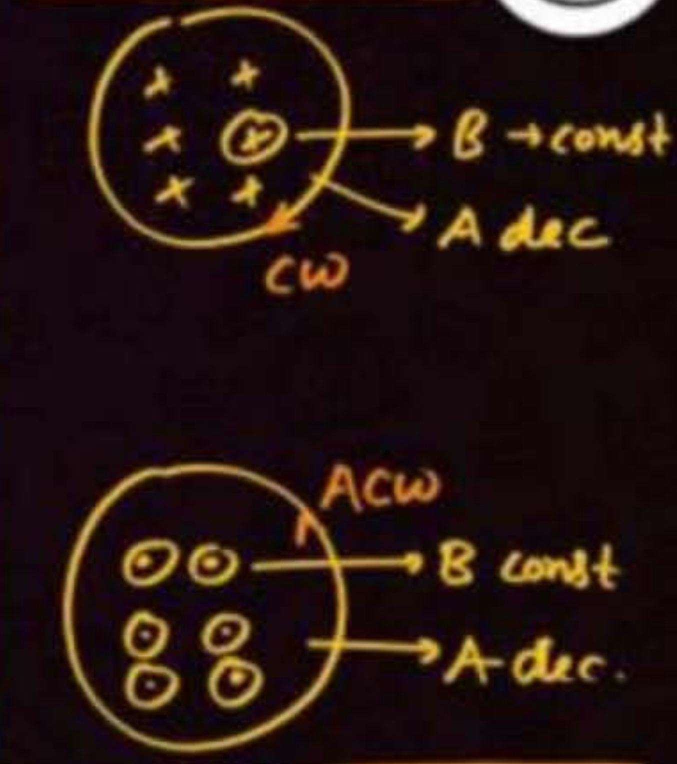
TBS capsule ②

From side of magnet





Shrinking loop



1) i = 0 3) i = 0

2) ACW 4) CW

TBS capsule (3)

- Let $\theta = 0^\circ \Rightarrow \phi = BA$
- If $A \rightarrow$ const

$$|e| = NA\frac{dB}{dt}$$

- If $B \rightarrow$ const

$$|e| = NB\frac{dA}{dt}$$

Circular loop $\rightarrow$ $\boxed{\frac{dA}{dt} = 2\pi r\frac{dr}{dt}}$

TBS

* Changing θ

a) 0° to 90°

$$e = \frac{NBA}{t} = \frac{\Delta\phi}{\Delta t}$$

b) 0° to 180°

$$e = \frac{2NBA}{t} = \frac{\Delta\phi}{\Delta t}$$

- Induced charge

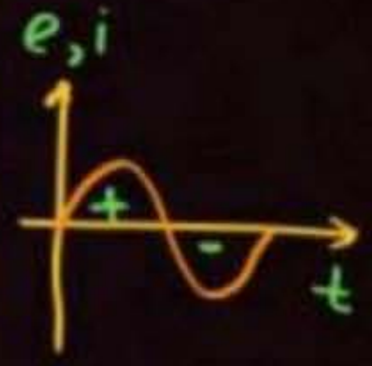
$$\boxed{\Delta q = \frac{\Delta\phi}{R}}$$

$\downarrow$ independent of time

AC Generator

- coil rotates continuously with uniform ω.

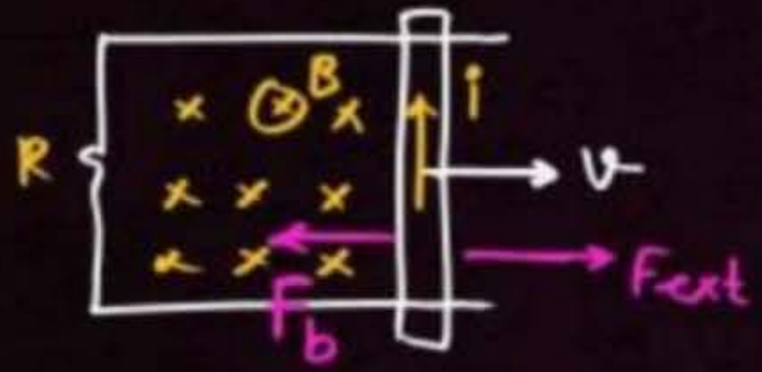
$$\boxed{\begin{aligned} e &= e_0 \sin\omega t \\ i &= i_0 \sin\omega t \end{aligned}}$$



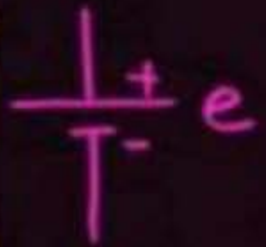
$\boxed{e_0 = NBA\omega}$ $\longrightarrow$ max^m emf

$\boxed{i_0 = \frac{e_0}{R}}$ $\longrightarrow$ max^m current

TBS Capsule (4)



$e = Bvl$



All mutually ⊥cular

* +ve terminal of rod by ⇒ R.H. Thumb Rule ($\vec{v} \times \vec{B}$)

* $i = \frac{Bvl}{R}$ • $F_{ext} = F_b = ilB = \frac{B^2 l^2 v}{R}$

* $P_{ext} = P_{diss} = \frac{B^2 l^2 v^2}{R}$

* whole work converted into heat

Fleming R.H. Rule

- First Fing → Mag. Field

  F → B

- Middle Fing → Ind. current

  M → i

- Thumb → Motion

  T → v.

- Vector form

  $e = (\vec{v} \times \vec{B}) \cdot \vec{l}$

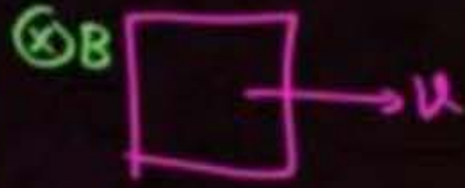
TBS

- Take vector length ⊥cular to velocity

  OR.

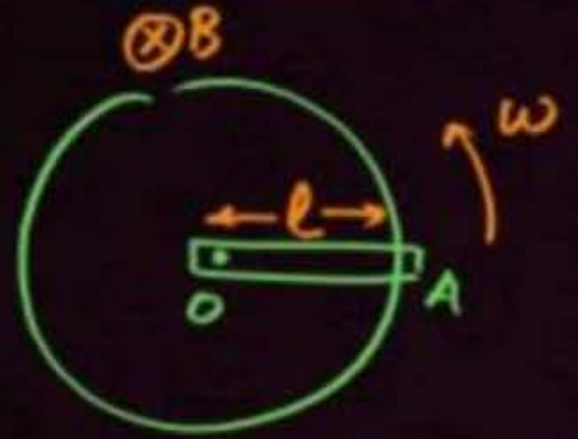
  velocity component ⊥cular to length.

$e = Bv(2R)$



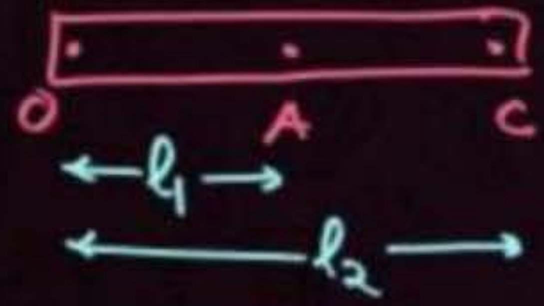
$e = 0$

Rotational emf

*


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

→ b/w OA.

*


B/w AC → $e = \frac{1}{2} B \omega (l_2^2 - l_1^2)$

- No effect of no. of spokes.

TBS Capsule ⑤

- L → inductance
- $\phi \propto i \Rightarrow \boxed{\phi = Li}$

$$\boxed{N\phi = Li}$$

SI units → Henry (H)

- $e = -L\dfrac{di}{dt}$
- $e_{av} = -L\dfrac{\Delta i}{\Delta t}$
- Solenoid ⇒ $L = \dfrac{\mu_0 N^2 A}{l}$
  - → $L = \mu_0 n^2 A l$.

- M → Mutual inductance
- $\phi_2 = M i_1 \Rightarrow N_2\phi_2 = M i_1$
- $\phi_1 = M i_2 \Rightarrow N_1\phi_1 = M i_2$
- $e_2 = -M\dfrac{di_1}{dt}$ | $e_1 = -M\dfrac{di_2}{dt}$

- Solenoids → Coaxial

$$\boxed{M = \frac{\mu_0 N_1 N_2 A_2}{l}}$$

$$\boxed{M = \mu_0 n_1 n_2 A_2 l}$$

- L → depends on shape/size & medium
- M → depends on shape/size, medium & orientation.
- How to find M

Assume current in Large coil & then find flux in smaller coil.

- $\boxed{M = k\sqrt{L_1 L_2}}$

a) $k = 1$ (Flux completely Linked)

→ very near or co-axial

b) $k = 0$ (zero Flux Linkage)

→ very far or ⊥cular

TBS capsule ⑥

$$V_A - L\frac{di}{dt} = V_B$$

$\frac{di}{dt}$ = +ve (i → inc.)

$\frac{di}{dt}$ = −ve (i → dec.)

- e = 0 if i const.

Inductor behaves as wire

- $U = \frac{1}{2}Li^2$
- $u = \frac{1}{2}\frac{B^2}{\mu_0}$
- energy stored in mag. field lines.
- $P = Li\frac{di}{dt} = ei$ → Power

- **Series**

$L_s = L_1 + L_2 + \ldots$

- **Parallel**

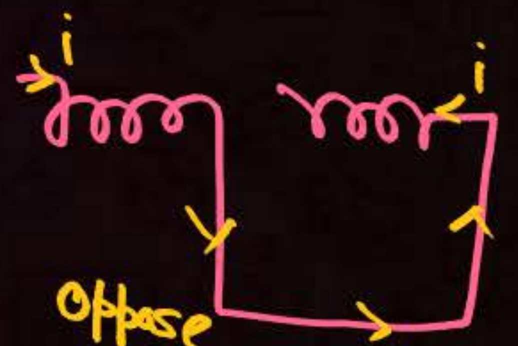
$\frac{1}{L_p} = \frac{1}{L_1} + \frac{1}{L_2} + \ldots$

Rare Chance

- If Mutual inductance is considered in series combination

Support

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

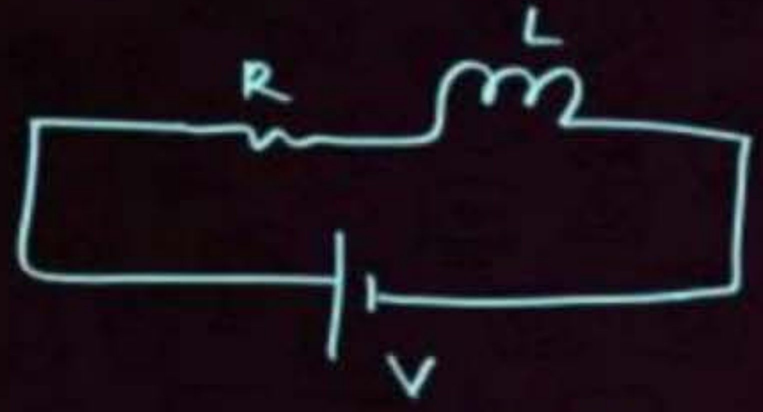


Oppose

$L_{eff} = L_1 + L_2 - 2M$

TBS Capsule (7)

R-L circuit



$$i = \frac{V}{R}\left(1 - e^{-Rt/L}\right)$$

$$i = i_0\left(1 - e^{-t/\tau}\right)$$

$$\frac{di}{dt} = \frac{V}{L} e^{-Rt/L}$$

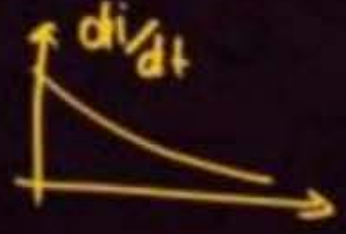
$$\frac{di}{dt} = \left(\frac{di}{dt}\right)_{max} e^{-t/\tau}$$

* $\boxed{\tau = \frac{L}{R}}$

• TBS

$t = 0 \rightarrow$ L open wire (circuit)

$t \rightarrow \infty \Rightarrow$ L $\rightarrow$ conducting wire (short circuit)

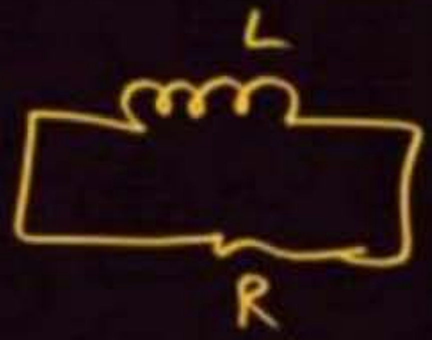


One τ

$i \rightarrow 63\%$

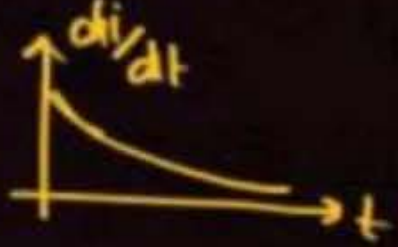
$\frac{di}{dt} \rightarrow 37\%$

Discharging



$$i = i_0 e^{-t/\tau}$$

$$\frac{di}{dt} = \left(\frac{di}{dt}\right)_{max} e^{-t/\tau}$$



TBS capsule ⑧

- **Eddy currents**

↓

induced currents in Bulk pieces of conductor

a) **Electromagnetic Damping**

↳ Slots are cut to reduce area & eddy currents

- Dead beat Galvanometers.

b) Magnetic braking in train

c) Induction furnace

d) Electric power meters

e) Induction Cook-top

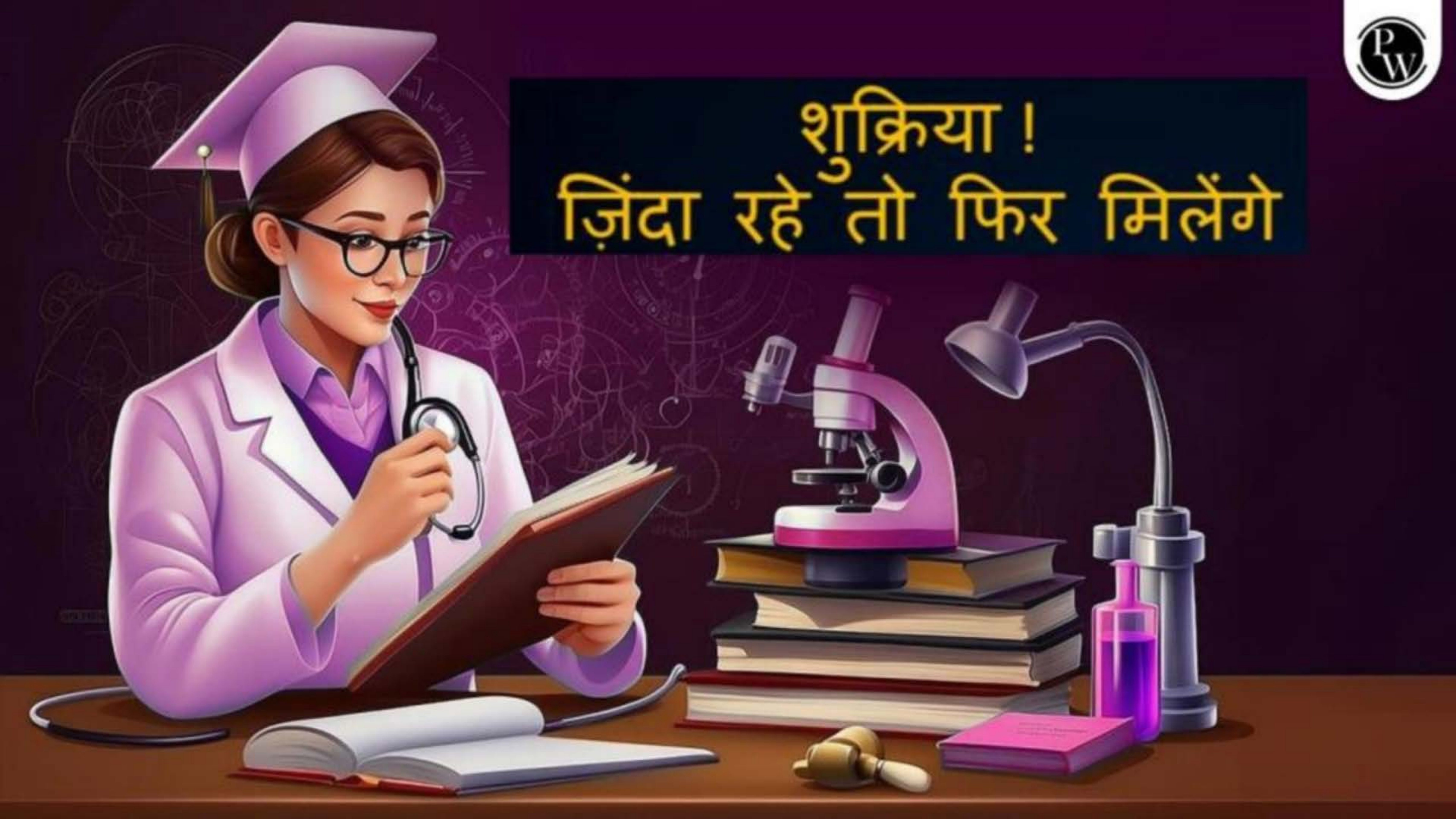
Homework

10 am Subah DPP Battle - Ground

* Next Lec → 9 Jan (10 am)

AC Circuits

Slide No.	option		
20	1	86	4
21	2	95	4
32	Plate A	96	4
39	C	101	4
47	8	111	3
51	4	113	4
52	2	120	3
57	1	127	4
65	3	141	2
67	2	142	1
77	1	143	4
78	C	144	4
79	2	149	4
83	4	150	4
85	1	154	3


शुक्रिया !
ज़िंदा रहे तो फिर मिलेंगे