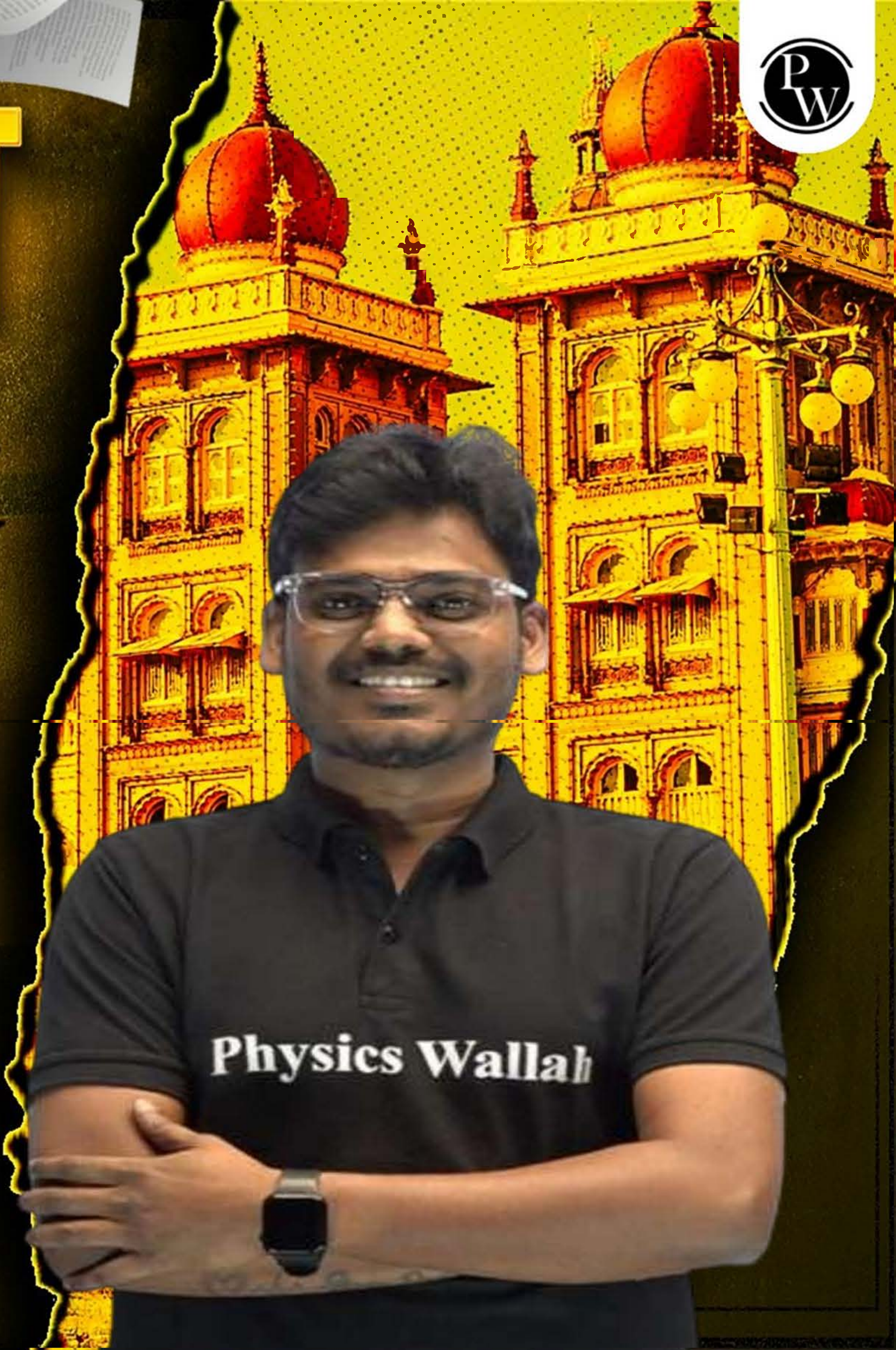
ULTIMATE KCET

CRASH COURSE 2026

PHYSICS | Lecture - 01

ELECTROMAGNETIC INDUCTION

By – AK SIR



Recap *of previous lecture*

1. TORQUE ON A CURRENT CARRYING COIL IN A MAGNETIC FIELD
2. CONVERSION OF A GALVANOMETER INTO AMMETER AND VOLTMETER
3. BAR MAGNET AND MAGNETIC FIELD LINES
4. QUESTIONS

Topics *to be covered*

1. CLASSIFICATIONS OF MAGNETIC MATERIALS
2. MAGNETIC FLUX AND FARADAY'S LAW
3. MOTIONAL AND ROTATIONAL EMF
4. INDUCTANCE AND AC GENERATOR

Question

A magnet of magnetic moment $50\hat{\imath}$ A-m^2 is placed along the x-axis in a magnetic field $\vec{B} = (0.5\hat{\imath} + 3.0\hat{\jmath})$T. The torque acting on the magnet is

A. $175\hat{k}$ N-M

B. $150\hat{k}$ N-m

C. $75\hat{k}$ N-m

D. $25\sqrt{37}\hat{k}$ N-m

$\vec{\tau} = \vec{m} \times \vec{B}$

$\vec{\tau} = 50\hat{i} \times (0.5\hat{i} + 3\hat{j})$

$\vec{\tau} = 25(\hat{i} \times \hat{i}) + 150(\hat{i} \times \hat{j})$, where $\hat{i} \times \hat{i} = 0$

$\vec{\tau} = 150\hat{k}$

Question

The pole strength of a bar magnet is 48 ampere-metre and the distance between its poles is 25 cm. The magnitude of the couple by which it can be placed at an angle of 30° with the uniform magnetic intensity of flux density 0.15 Newton /ampere-metre will be

(A) 12 Newton × metre

(B) 18 Newton × metre

(C) 0.9 Newton × metre

(D) None of the above

$\tau = M B \sin\theta$

$\tau = (m l) B \sin\theta$

$\tau = 48 \times 25 \times 10^{-2} \times 0.15 \times \sin 30^\circ$

$\tau = 90 \times 10^{-2}$

$\tau = 0.90$ N-m

Question

A bar magnet is hung by a thin cotton thread in a uniform horizontal magnetic field and is in the equilibrium state. The energy required to rotate it by 60° is W. Now the torque required to keep the magnet in this new position is:

(A) $\frac{W}{\sqrt{3}}$

(B) $\sqrt{3}W$

(C) $\frac{\sqrt{3}W}{2}$

(D) $\frac{2W}{2}$

$W = -MB[\cos\theta_2 - \cos\theta_1]$

$W = -MB[\cos 60° - \cos 0°]$

$W = -MB\left[\frac{1}{2} - 1\right] = \frac{MB}{2}$

$MB = 2W$

$\tau = MB\sin\theta_2 = MB\sin 60° = MB \times \frac{\sqrt{3}}{2}$

$\tau = 2W \times \frac{\sqrt{3}}{2} \Rightarrow \tau = \sqrt{3}W$

Question

$\theta_i = 0$ W

A magnetic needle suspended parallel to a magnetic field requires $\sqrt{3}$ J of work to turn it through 60°. The torque needed to maintain the needle in this position will be

θ_f

(A) $2\sqrt{3}$ J

(B) 3 J

(C) $\sqrt{3}$ J

(D) 3/2 J

$\tau = \sqrt{3}\, W$

$\tau = \sqrt{3} \times \sqrt{3}$

$\tau = 3$ N·m

Question

A magnet of magnetic moment 4 Am^2 is held in a uniform magnetic field 5×10^{-4} T with the magnetic moment vector makes an angle 30° with the field. Work done in increasing the angle from 30° to 45°: [H.W]

(A) 3.2×10^{-4} J

(B) 1.6×10^{-4} J

(C) 1.6×10^{-3} J

(D) 3.2×10^{-3} J

Question

A bar magnet has a magnetic moment 2.5 $A\text{-}m^2$ and it is placed in a magnetic field of 0.2T. Calculate the Work done in turning the magnet from parallel to antiparallel position relative to the field direction: [H.W]

(A) 0.1 J

(B) 1 J

(C) 2 J

(D) 5 J

Question

A short bar magnet of magnetic moment 0.4 J/T is placed in a uniform magnetic field of 0.16 T. The magnet is in stable equilibrium when the potential energy is:

$\theta = 0^\circ$

(A) 0.064 J

(B) zero

(C) –0.082 J

(D) –0.064 J

$U = -MB\cos\theta$

$U = -0.4 \times 0.16 \times \cos 0^\circ$

$U = -0.064\,J$

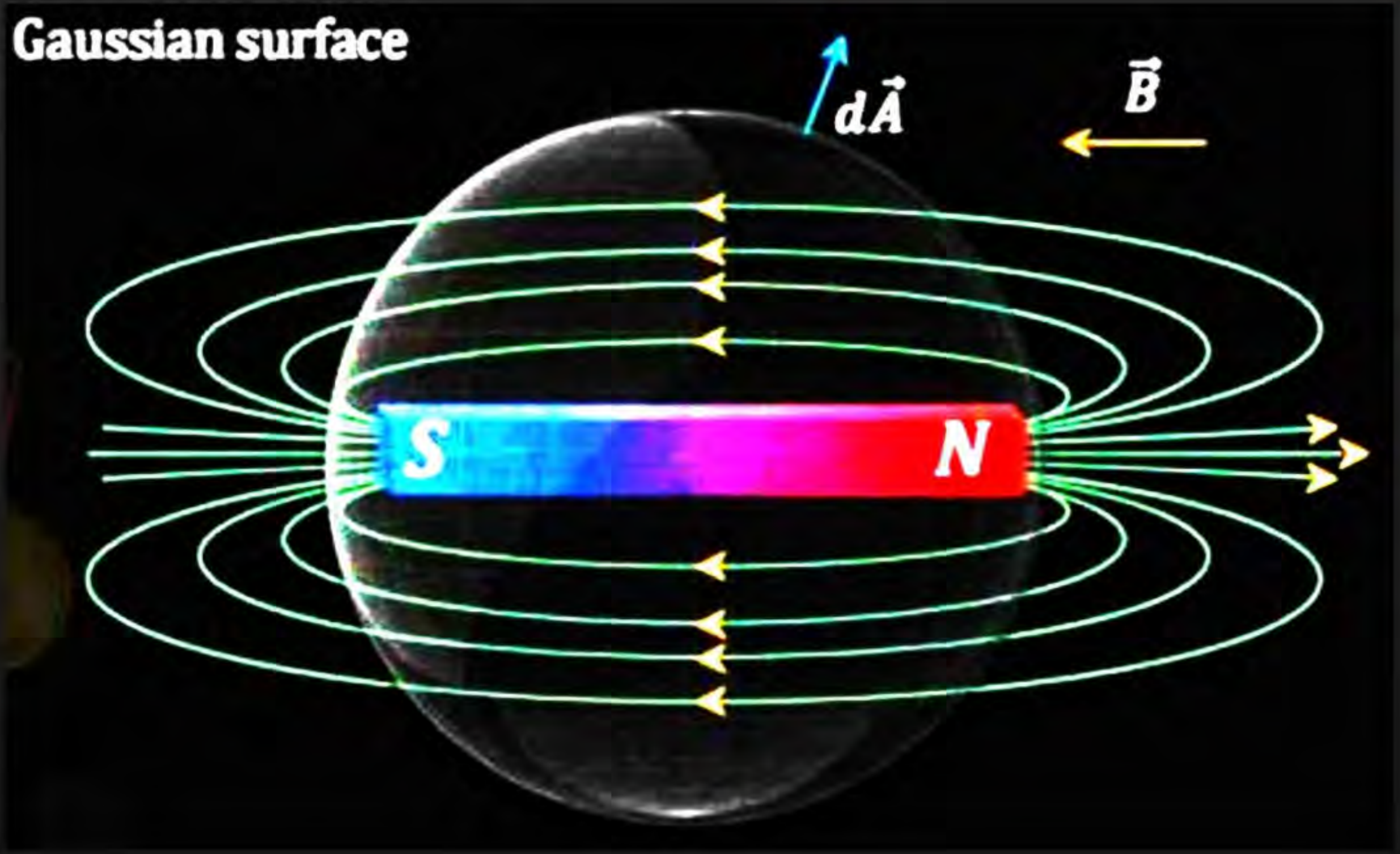
Magnetism and Gauss Law

$\phi_E = \frac{q}{\varepsilon_0} = \vec{E}\cdot\vec{A} \Rightarrow \oint \vec{E}\cdot d\vec{A}$

$\phi_B = \frac{m}{\mu_0} = \vec{B}\cdot\vec{A} \Rightarrow \oint \vec{B}\cdot d\vec{A} = 0$

Electric Dipole, $\phi = 0$, $Q_T = q - q = 0$

Bar magnet, $\phi_B = 0$, $m_T = +m - m = 0$



$$\oint \vec{B}\cdot d\vec{A} = 0$$

- Magnetic field lines exist in closed loop. Hence, the magnetic flux through any closed surface is always zero

Magnetism and Gauss Law

Note :

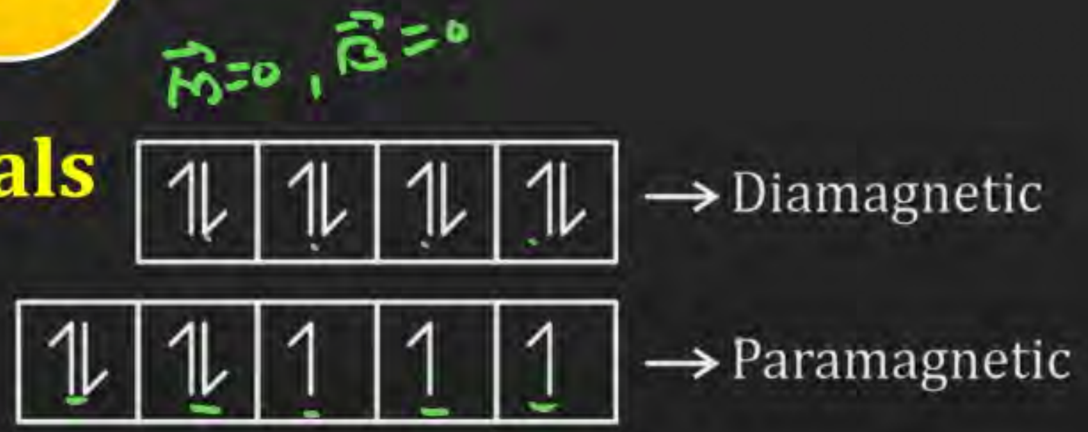
(a) An isolated magnetic pole do not exist i.e Monopole do not exist.

(b) Always magnetic dipole exist.

(c) Numbers of magnetic field line entering a surface is equal to number of field lines leaving the closed surface.

Classifications of Materials

Magnetic Materials



Diamagnetic

- All paired electrons.
- Magnetic moment of individual atom is zero.
- They weakly repel the magnetic field.

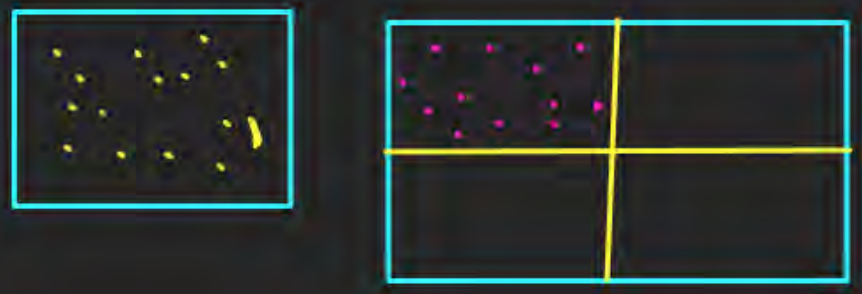
Paramagnetic

- They have unpaired electron
- Magnetic moment of individual atoms is non-zero.
- They weakly attract the magnetic field.

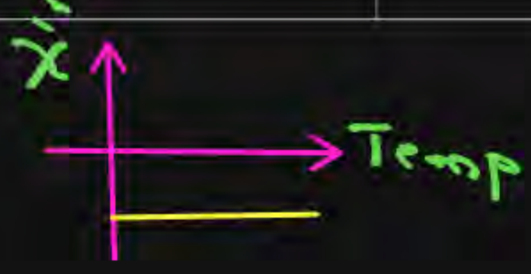
Ferro magnetic material

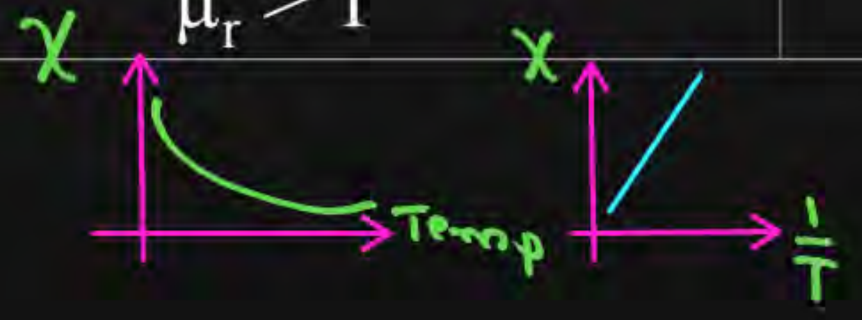
- They have unpaired electrons
- They have domain characteristic.
- Magnetic moment of individual atoms is non-zero.
- They strongly attract the magnetic field.

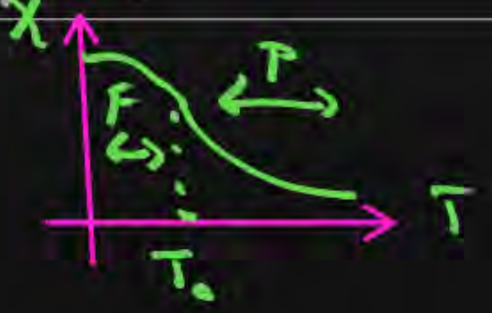
Classifications of Materials



Diamagnetic	Paramagnetic	Ferromagnetic
All paired electrons (spin) Strong region - weak region	unpaired electron (spin) weak region → strong region	unpaired electron (spin) + Domain characteristic
Due to orbital motion	spin motion	spin motion
Weakly repels in M.F.	weekly attracts the M.F.	strongly attract the M.F.
susceptibility is small (–ve) e.g $\chi = -0.04$	Susceptibility is small (+ve) e.g. $\chi = +0.04$	susceptibility high (+ve) e.g. $\chi = 998$
$\mu_r = (1 + \chi) < 1$	$\mu_r > 1$	$\mu_r >> 1$







Curie Temperature

The temperature above which a ferro magnetic substance becomes paramagnetic is called 'Curie temperature' of the substance.

Ex : The curie temperature of Iron is 770^0C and that of nickel is 358^0C

Curie's Law

The magnetisation I of paramagnetic substance is directly proportional to the magnetic intensity H of the magnetising field and inversely proportional to the kelvin temperature T,

$$I \propto \frac{H}{T}$$

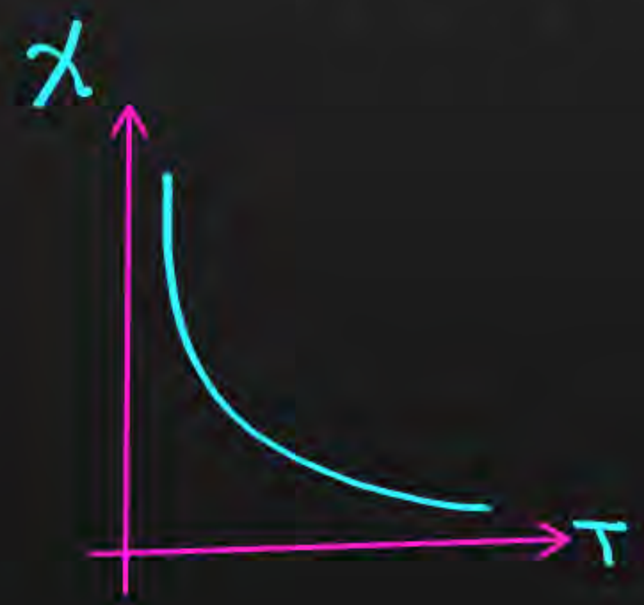
$$I = C\frac{H}{T}$$

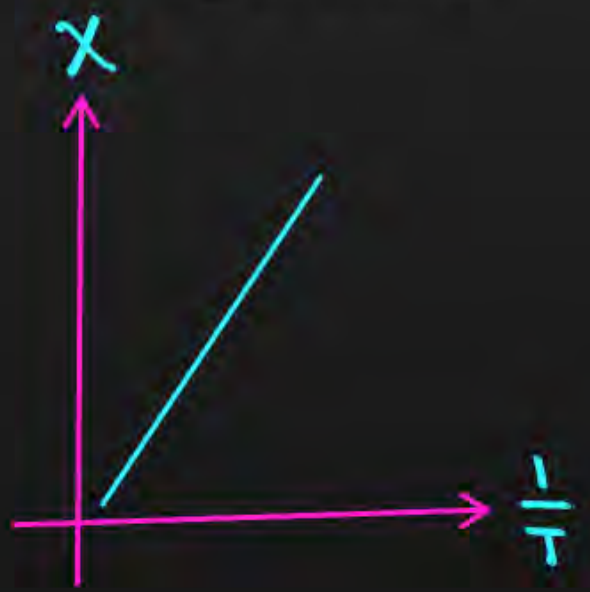
$$\frac{I}{H} = \frac{C}{T}$$

$$\chi = \frac{I}{H}$$

$$\chi = \frac{C}{T}$$

$$\chi \propto \frac{1}{T}$$





Curie's Weiss Law

$$\chi = \frac{C}{T} \rightarrow \text{para}$$

$$\chi = \frac{C}{T - T_c} \rightarrow \text{Ferro}$$

C - curie constant

χ - mag. susceptibility

T - Kelvin Temp

T_c - curie temp

Question

Which of the following statements is true in respect of diamagnetic substances?

(A) Susceptibility decreases with temperature.

(B) Susceptibility is small and negative.

(C) They are feebly attracted by magnets.

(D) Permeability is greater than 1000

Question

Magnetic susceptibility of Mg at 300 K is 1.2×10^{-5} .What is its susceptibility at 200 K?

(A) 18×10^{-5}

(B) 180×10^{-5}

(C) 1.8×10^{-5}

(D) 0.18×10^{-5}

$\chi = \frac{C}{T}$

$C_1 = C_2$

$\chi_1 T_1 = \chi_2 T_2$

$1.2 \times 10^{-5} \times 300 = \chi_2 \times 200$

$\chi_2 = 1.8 \times 10^{-5}$

Question

The Curie temperature of cobalt and iron are 1400 K and 1000 K respectively. At T = 1600K the ratio of magnetic susceptibility of cobalt to that of iron is

A 1/3

B 3

C 7/5

D 5/7

$$\chi = \frac{C}{T - T_C}$$

$$\frac{\chi_C}{\chi_I} = \frac{C}{T - T_{C\,(cob)}} \times \frac{T - T_{C\,(Iron)}}{C}$$

$$= \frac{1600 - 1000}{1600 - 1400} = \frac{600}{200} = 3$$

$$\frac{\chi_C}{\chi_I} = 3$$

Question

A paramagnetic sample shows a net magnetisation of $8\,A\,m^{-1}$ when placed in an external magnetic field of 0.6 T at a temperature of 4K. When the same sample is placed in an external magnetic field of 0.2 T at a temperature of 16 K, the magnetisation will be

(A) $\frac{32}{3}\,\text{Am}^{-1}$

(B) $\frac{2}{3}\,\text{Am}^{-1}$

(C) $6\,\text{Am}^{-1}$

(D) $2.4\,\text{Am}^{-1}$

$$I \propto \frac{H}{T} \Rightarrow I = \frac{CH}{T}$$

$$\frac{I_2}{I_1} = \frac{CH_2}{T_2} \times \frac{T_1}{CH_1} = \frac{T_1 H_2}{T_2 H_1}$$

$$\frac{I_2}{8} = \frac{4\times 0.2}{16\times 0.6} = \frac{0.2}{4\times 0.6} = \frac{2}{6}$$

$$I_2 = \frac{8\times 2}{6\times 4} = \frac{2}{3}\,A/m$$

Question

Needles N_1, N_2 and N_3 are made of a ferromagnetic, a paramagnetic and a diamagnetic substance, respectively. A magnet when brought close to them will

(A) attract all three of them

(B) attract N_1 strongly, N_2 weakly and repel N_3 weakly

(C) attract N_1 strongly but repel N_2 and N_3 weakly

(D) attract N_1 and N_2 strongly but repel N_3

Question

The susceptibility of a ferromagnetic substance is

(A) Zero

(B) >1

(C) <1

(D) >>1

Question

χ_1 and χ_2 are susceptibility of a paramagnetic material at temperatures T_1 K and T_2 respectively, then

(A) $\chi_1 = \chi_2$

(B) $\chi_1 T_1 = \chi_2 T_2$

(C) $\chi_1 T_2 = \chi_2 T_1$

(D) $\chi_1 \sqrt{T_1} = \chi_2 \sqrt{T_2}$

$\chi = \frac{C}{T}$ → same

$C_1 = C_2$

$\chi_1 T_1 = \chi_2 T_2$

Question

$\rightarrow T_1 = 273 - 73 = 200K$

The magnetic susceptibility of a paramagnetic material at –73°C is 0.0075 and its value at – 173°C will be

$\hookrightarrow T_2 = 273 - 173 = 100K$

$\chi_1 T_1 = \chi_2 T_2$

$0.0075 \times 200 = \chi_2 \times 100$

$\chi_2 = 0.0150$

(A) 0.015

(B) 0.0045

(C) 0.0075

(D) 0.0030

Question

A susceptibility of a certain magnetic material is 400. What is the class of the magnetic material?

(A) Diamagnetic

(B) Paramagnetic

(C) Ferromagnetic

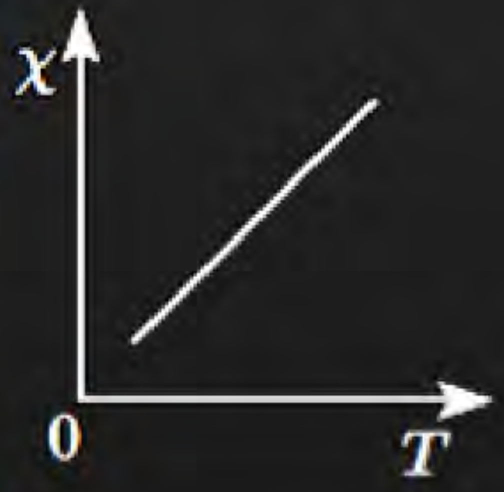
(D) Ferroelectric

Question

The best suited curve showing the variations of susceptibility (x) of a paramagnetic material in free space with temperature (T) is:

$\chi \propto \frac{1}{T}$

A



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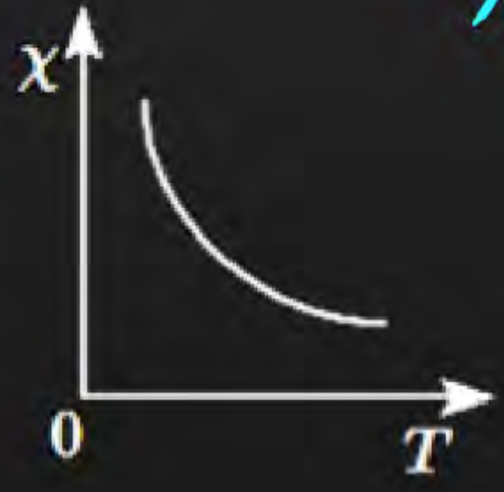

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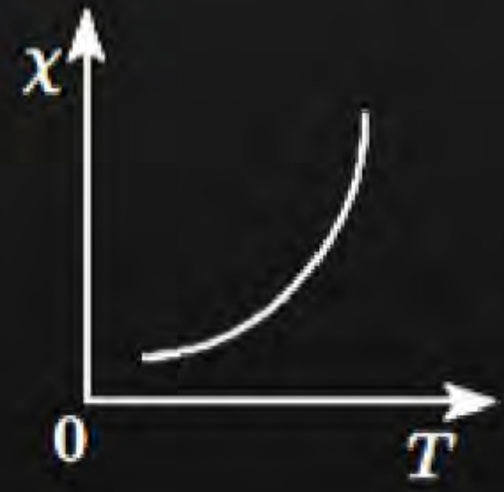

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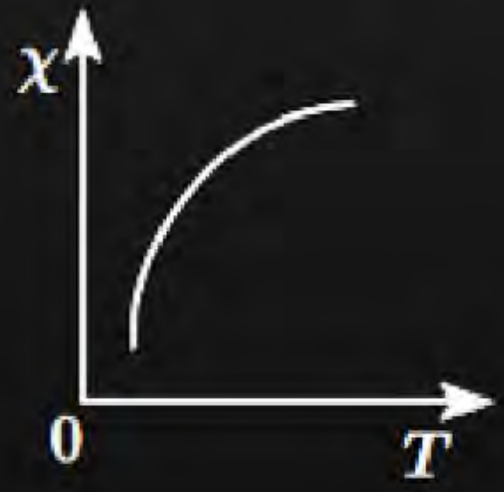
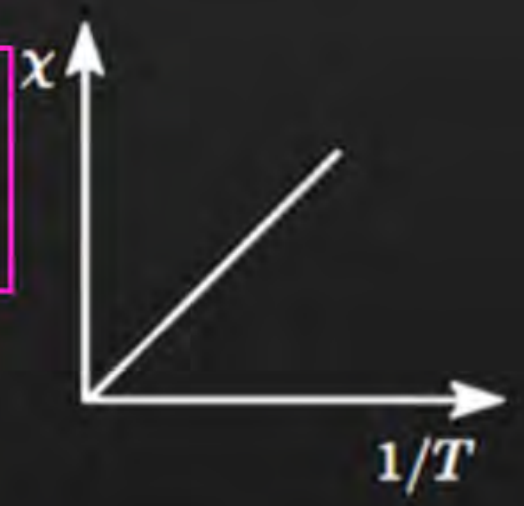


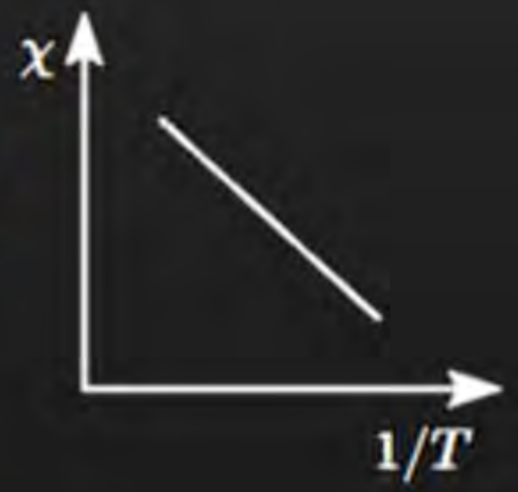
Question

The variation of susceptibility (χ) with absolute temperature (T) for a paramagnetic material is represented as:

A



B



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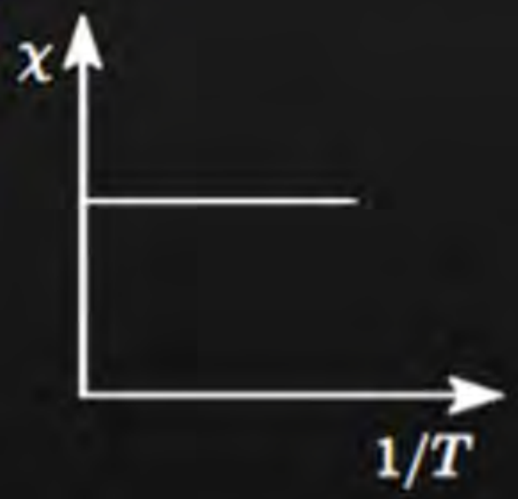
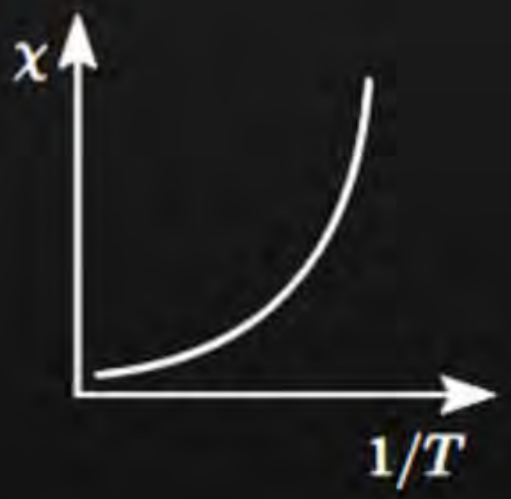


D



Question

The net magnetic flux through any closed surface is:

(A) Negative

(B) Zero

(C) Positive

(D) Infinity

Question

Given below are two statements:

Assertion (A): Gauss's law for magnetism states that the net magnetic flux through any closed surface is zero. Reason (R): The magnetic monopoles do not exist. North and South poles occur in pairs, allowing vanishing net magnetic flux through the surface.

A is True but (R) is False.

B (A) is False but (R) is True.

C Both (A) and (R) are True and (R) is the correct explanation of (A).

D Both (A) and (R) are True but (R) is not the correct explanation of (A).

Question

An iron rod of susceptibility 599 is subjected to a magnetizing field of 1200 A m^{-1}. The permeability of the material of the rod is: ($\mu o = 4\pi \times 10^{-7}$ T mA^{-1})

(A) 8.0×10^{-5} T mA^{-1}

(B) 2.4×10^{-5} T mA^{-1}

(C) 2.4×10^{-7} T mA^{-1}

(D) $2.4\pi \times 10^{-4}$ T mA^{-1}

$\mu_r = 1 + \chi = 1 + 599 = 600$

$\frac{\mu_m}{\mu_0} = 600$

$\mu_m = 600 \times 4\pi \times 10^{-7}$

$\mu_m = 2400\pi \times 10^{-7}$

$\mu_m = 2.4\pi \times 10^{-4}$

Question

The magnetic susceptibility is negative for

(A) Paramagnetic material only

(B) Ferromagnetic material only

(C) Paramagnetic and ferromagnetic materials

(D) Diamagnetic material only

Question

unpaired Electron, m = 0

The magnetic moment of a diamagnetic atom is:

(A) Much greater than one.

(B) One.

(C) Between zero and one.

(D) Equal to zero.

Question

Curie temperature is the temperature above which:

A) Ferromagnetic material becomes paramagnetic material.

B) Paramagnetic material becomes diamagnetic material.

C) Paramagnetic material becomes ferromagnetic material. → Below T_c

D) Ferromagnetic material becomes diamagnetic material.

Question

Nickel shows the ferromagnetic property at room temperature. If the temperature is increased beyond Curie's temperature, then it will show:

A. paramagnetism

B. anti-ferromagnetism

C. no magnetic property

D. diamagnetism

Question

The substances which have the tendency to move from stronger to weaker part of external magnetic field are

(A) Diamagnetic

(B) Ferromagnetic

(C) Paramagnetic

(D) Ferro and Paramagnetic

Question

A small compass needle of magnetic dipole moment 'm' is placed in uniform magnetic field 'B' at an angle θ, then the magnetic potential energy of the needle is

A. $+mB \sin\theta$

B. $-mB \sin\theta$

C. $+mB \cos\theta$

D. $-mB \cos\theta$

ELECTROMAGNETIC INDUCTION

KCET analysis of chapter - Marks weightage

Year	Topic
2025 (2Q)	Bar magnet pushed towards the coil, Magnetic flux
2024(4Q)	Magnetic flux(2), Lenz law, Mutual Inductance
2023(3Q)	Motional emf(2) and Self Inductance
2022(3Q)	Magnetic flux, Motional emf and Magnetic field due to solenoid
2021(1Q)	Self Inductance

KCET analysis of chapter - Marks weightage

Year	Topic
2020(2Q)	Motional emf and Average induced emf
2019(1Q)	Motional emf
2018(1Q)	Magnetic flux
2017(2Q)	Eddy current and Lenz law
2016(1Q)	-
2015(2Q)	Motional emf and Induced emf

Magnetic Flux

$\phi = -ve \Rightarrow$ Inward Flux.

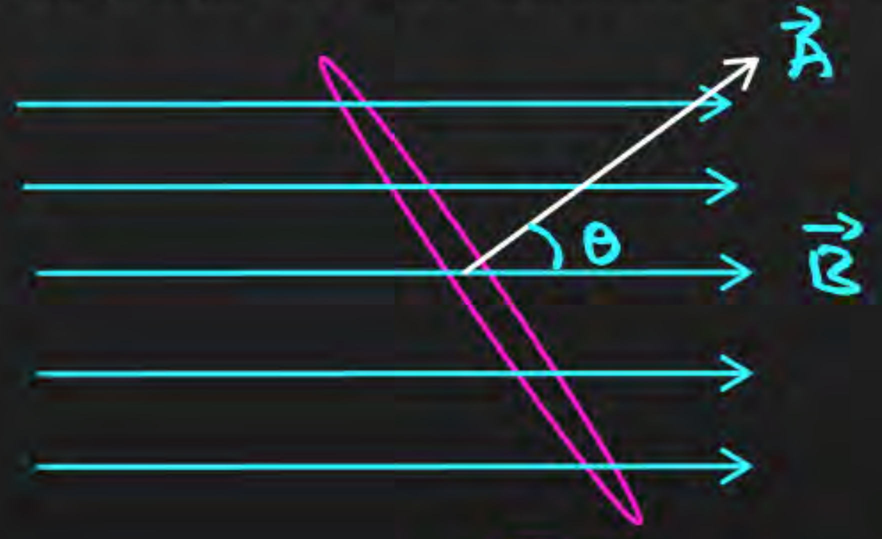
$\phi = +ve \Rightarrow$ Outward Flux

The number of magnetic field lines passing perpendicular to the surface area is called Magnetic flux

$$\phi = \vec{B} \cdot \vec{A} \Rightarrow \frac{Wb}{m^2} \times m^2$$

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

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



plane $\Rightarrow 90^\circ - \text{Angle} = \theta$

Ex: 30° $\quad 90^\circ - 30^\circ = 60^\circ = \theta$

Formula :

SI Unit : Wb

Quantity : Scalar.

Question

A square loop with a side length of 1 m and resistance of 1Ω is placed in a uniform magnetic field of 0.5 T. The plane of the loop is perpendicular to the direction of the magnetic field. The magnetic flux through the loop is

(A) zero

(B) 2 Wb

(C) 0.5 Wb

(D) 1 Wb

$\theta = 90^\circ - 90^\circ = 0^\circ$

$\phi = BA\cos\theta$

$\phi = 0.5 \times (1)^2 \times \cos 0^\circ$

$\phi = 0.5 \times 1 \times 1$

$\phi = 0.5\ Wb$

Question

A circular disc of the radius 0.2 m 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 to the disc will be

(A) 0.02 Wb

(B) 0.06 Wb

(C) 0.08 Wb

(D) 0.01 Wb

$\phi = BA\cos\theta$

$\phi = B \times \pi r^2 \cos\theta$

$\phi = \frac{1}{\pi} \times \pi \times (0.2)^2 \cos 60^\circ$

$\phi = 0.04 \times \frac{1}{2}$

$\phi = 0.02\ Wb$

Question

A square loop of side 2 m lies in the Y-Z plane in a region having a magnetic field $B = ((5\hat{\imath} - 3\hat{\jmath} - 4\hat{k}))$ T. The magnitude of magnetic flux through the square loop is

(A) 16 Wb

(B) 10 Wb

(C) 20 Wb

(D) 12 Wb

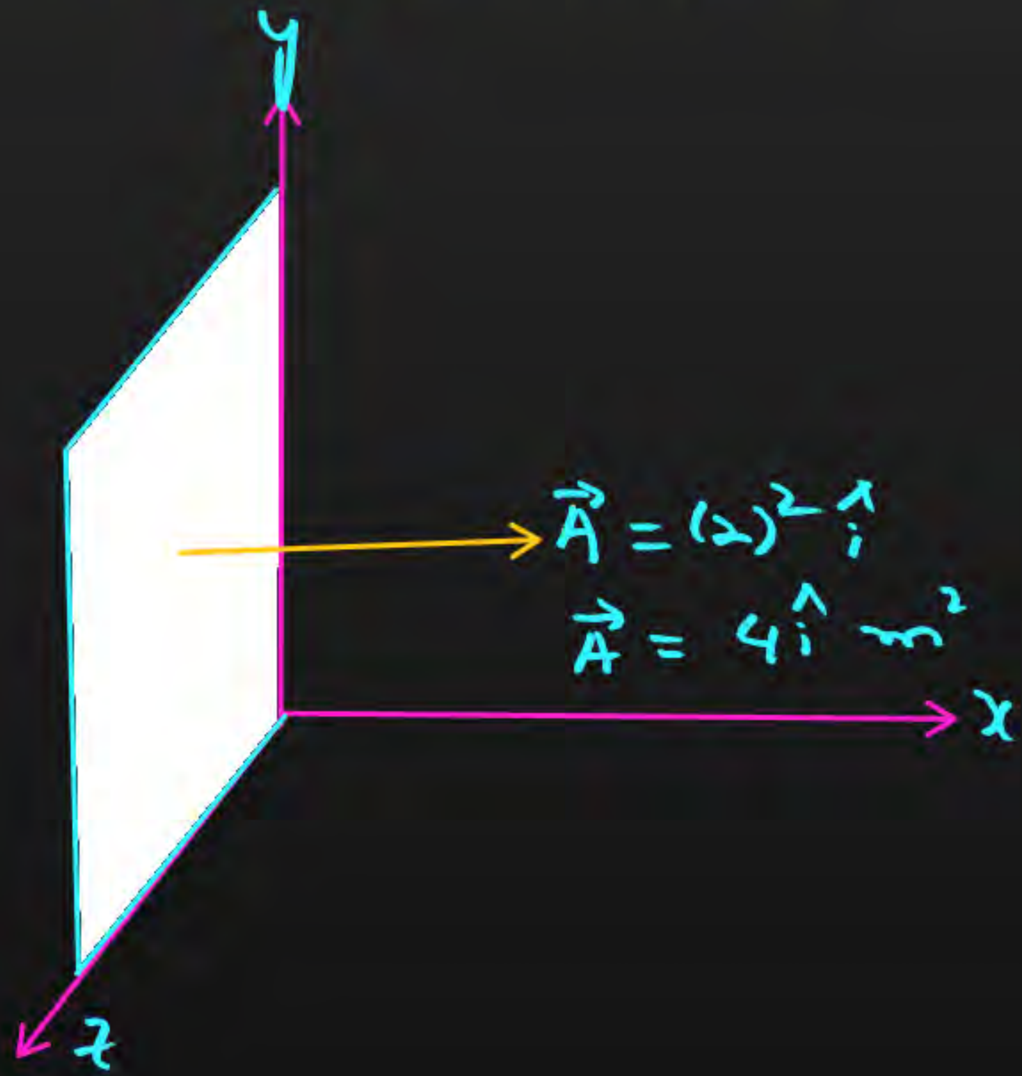
$\phi = \vec{B}\cdot\vec{A}$

$\phi = (5\hat{i} - 3\hat{j} - 4\hat{k})\,4\hat{i}$

$\phi = 20(\hat{i}\cdot\hat{i}) - 12(\underbrace{\hat{j}\cdot\hat{i}}_{0}) - 16(\underbrace{\hat{k}\cdot\hat{i}}_{0})$

$\phi = 20(1)$

$\phi = 20\ Wb$



Question

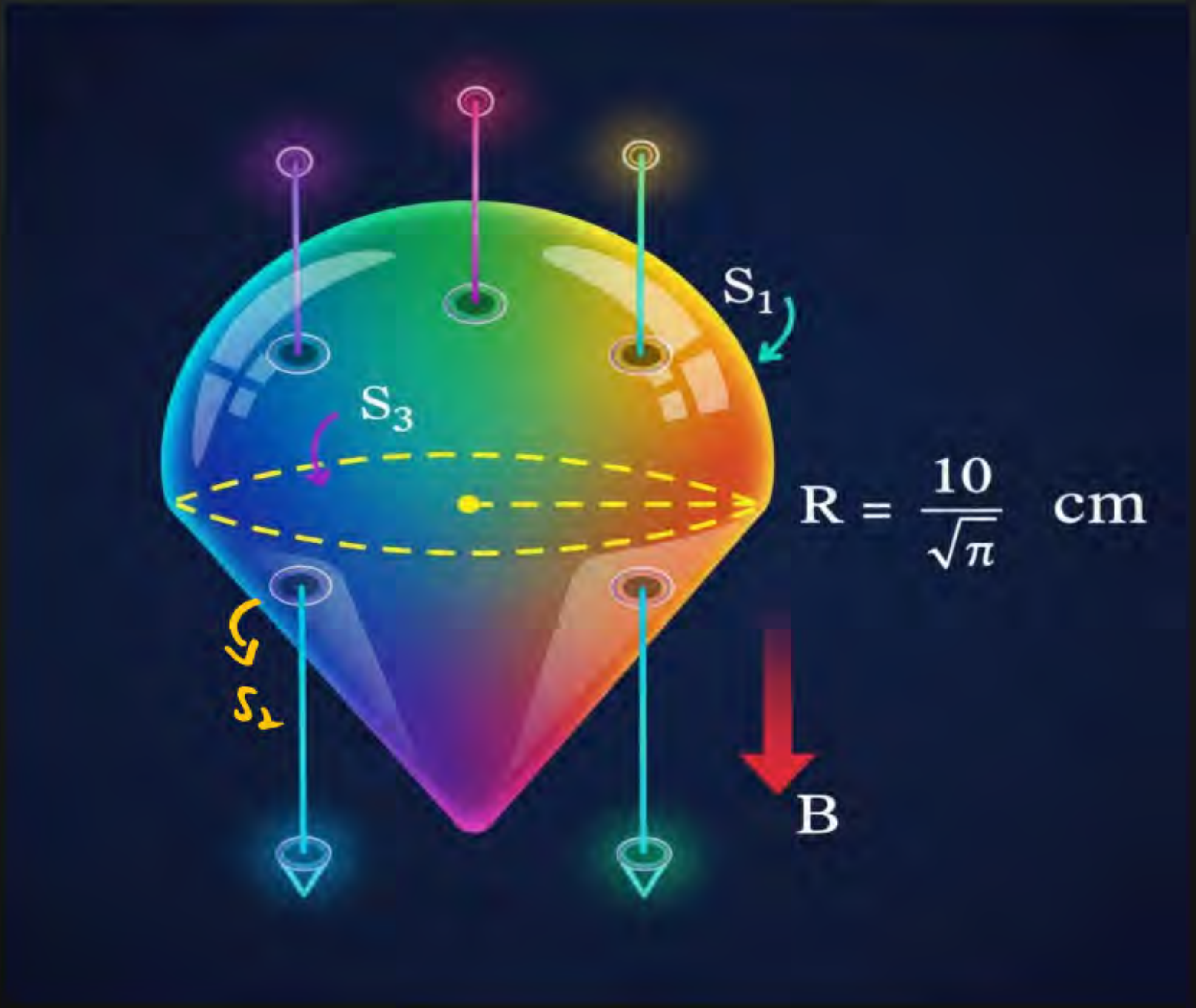
A uniform magnetic field of strength B = 2 mT exists vertically downwards. These magnetic field lines pass through a closed surface as shown in the figure. The closed surface consists of a hemisphere S_1, a right circular cone S_2 and a circular surface S3. The magnetic flux through S_1 and S_2 are respectively

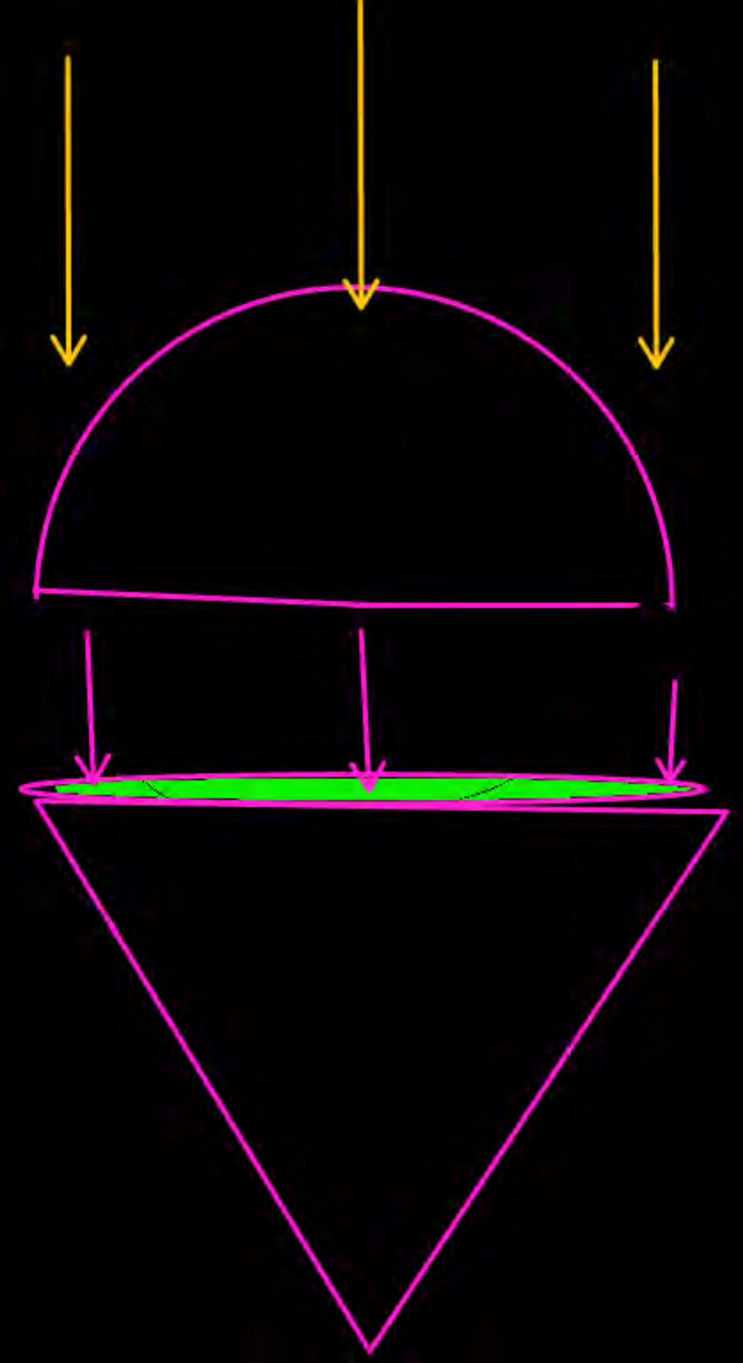
(A) $\Phi S_1 = -20\mu$ Wb, $\Phi S_2 = +20\ \mu$ Wb

(B) $\Phi S_1 = +20\ \mu$Wb, $\Phi S_2 = -20\ \mu$ Wb

(C) $\Phi S_1 = -40\ \mu$Wb, $\Phi S_2 = +40\ \mu$Wb

(D) $\Phi S_1 = +40\ \mu$Wb, $\Phi S_2 = -40\ \mu$Wb





$$\phi = -BA = -B \times \pi r^2$$

$$\phi = -2\times10^{-3} \times \pi \times \left(\frac{10}{\sqrt{\pi}} \times 10^{-2}\right)^2$$

$$\phi = -2\times10^{-3} \times \frac{\pi}{\pi} \times 10^{-2}$$

$$\phi = -2\times10^{-5}$$

$$\phi = -20\times10^{-6}$$

$$\phi_I = -20\,\mu Wb$$

$$\phi_0 = +20\,\mu Wb$$

Faraday's Law of Induction

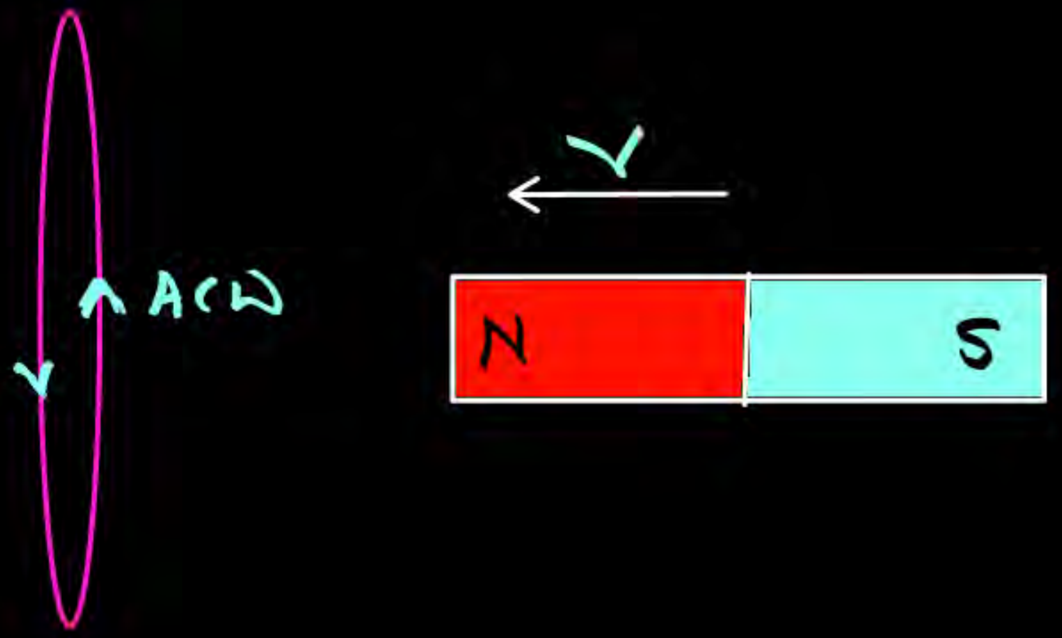
First Law : The magnitude of the induced emf in a circuit is equal to time rate of change of magnetic flux linked with the circuit. This is also known as " Neumann's Law"

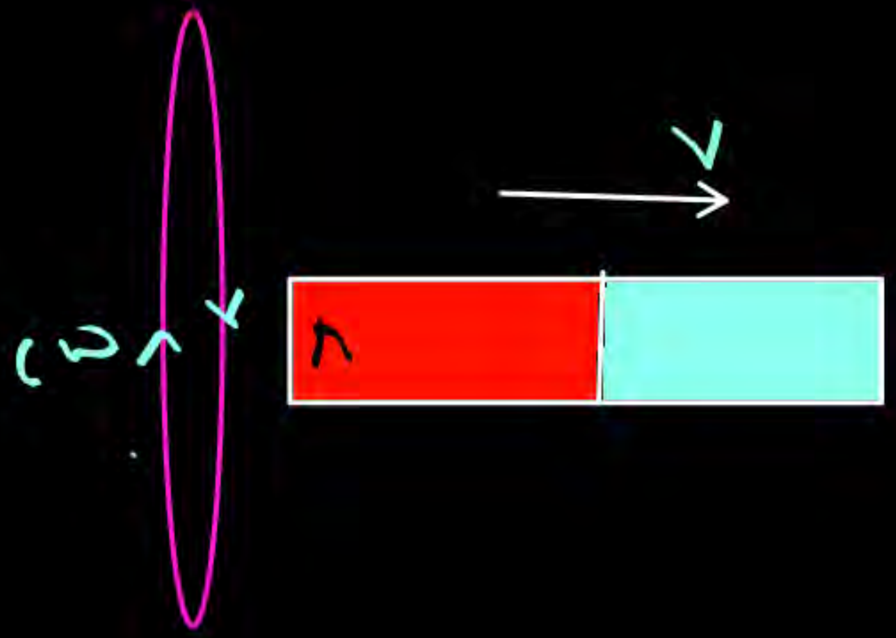
$$e = -N\frac{d\phi}{dt} = -N\frac{\Delta\phi}{\Delta t}$$

N - No. of turns.

2nd Law : The direction of induced emf or current in any circuit is such as to oppose the cause that produces it. This is also know as Lenz's Law

↳ polarity





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

Question

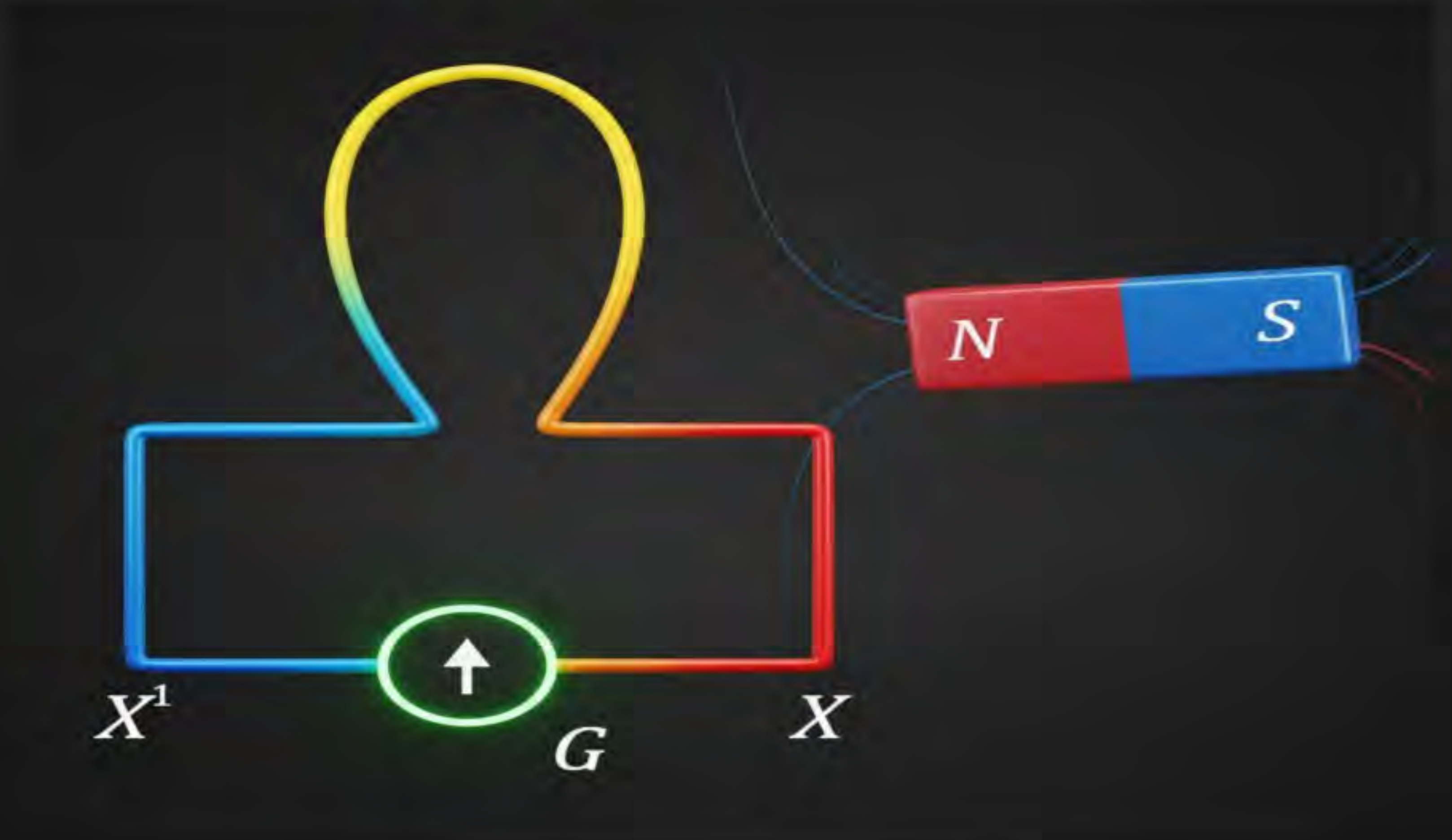
When a bar magnet is pushed towards the coil, along its axis, as shown in the figure, the galvanometer pointer deflects towards X. When this magnet is pulled away from the coil, the galvanometer pointer

(A) oscillates

(B) deflects towards X

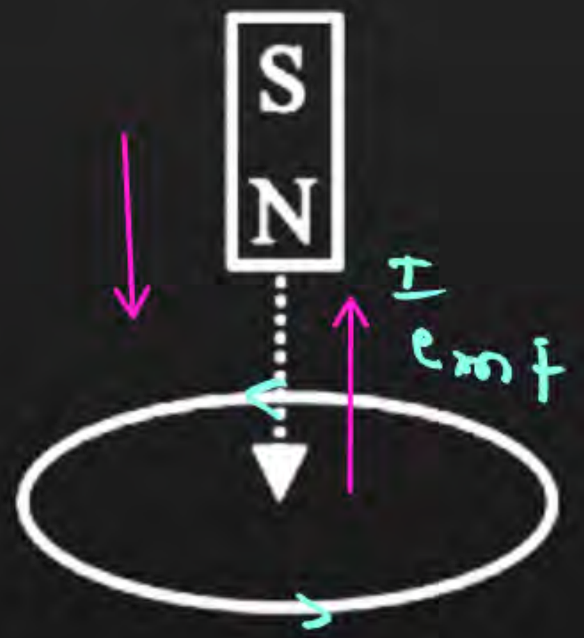
(C) deflects towards X’

(D) does not deflect



Question

A bar magnet is allowed to fall vertically through a copper coil placed in a horizontal plane. The magnet falls with a net acceleration, is



(A) Zero

(B) $=g$

(C) $<g$

(D) $>g$

Question

$e \to V$

An induced current of 2 A flows through a coil. The resistance of the coil is 10 ohm. What is the change in magnetic flux associated with the coil in 1 ms?

(A) 0.2×10^{-2} Wb

(B) 2×10^{-2} Wb

(C) 22×10^{-2} Wb

(D) 0.22×10^{-2} Wb

$$e = -N\frac{\Delta\phi}{\Delta t}$$

$$IR = N\frac{\Delta\phi}{\Delta t}$$

$$2 \times 10 = (1)\frac{\Delta\phi}{1 \times 10^{-3}}$$

$$\Delta\phi = 20 \times 10^{-3}\ \text{Wb}$$

$$\boxed{\Delta\phi = 2 \times 10^{-2}\ \text{Wb}}$$

Question

A magnetic field of flux density 1.0 Wb m^{-2} acts normal to a 80 turn coil of 0.01 m^2 area. If this coil is removed from the field in 0.2 s, then the emf induced in it is

(A) 8 V

(B) 0.8 V

(C) 5 V

(D) 4 V

$$e = N\frac{\Delta\Phi}{\Delta t} = N\frac{\Delta(BA)}{\Delta t}$$

$$e = 80 \times \frac{(1 \times 0.01)}{0.2}$$

$$e = 4V$$

Question

The magnetic flux linked with a coil varies as $\phi = 3t^2 + 4t + 9$. The magnitude of the emf induced at $t = 2$ s is

(A) 8 V

(B) 16 V

(C) 32 V

(D) 64 V

$e = \frac{d\phi}{dt} = 3 \times 2t + 4(1) + 0$

$e = 6t + 4$

At $t = 2s$, $e = 6(2) + 4$

$e = 12 + 4$

$e = 16\,V$

Question

Direction of current induced in a wire moving in a magnetic field is found using

(A) Right hand clasp rule → $\vec{B}$

(B) Fleming's left hand rule → $\vec{F}$

(C) Fleming's right hand rule

(D) Ampere's rule → $\vec{B}$

Question

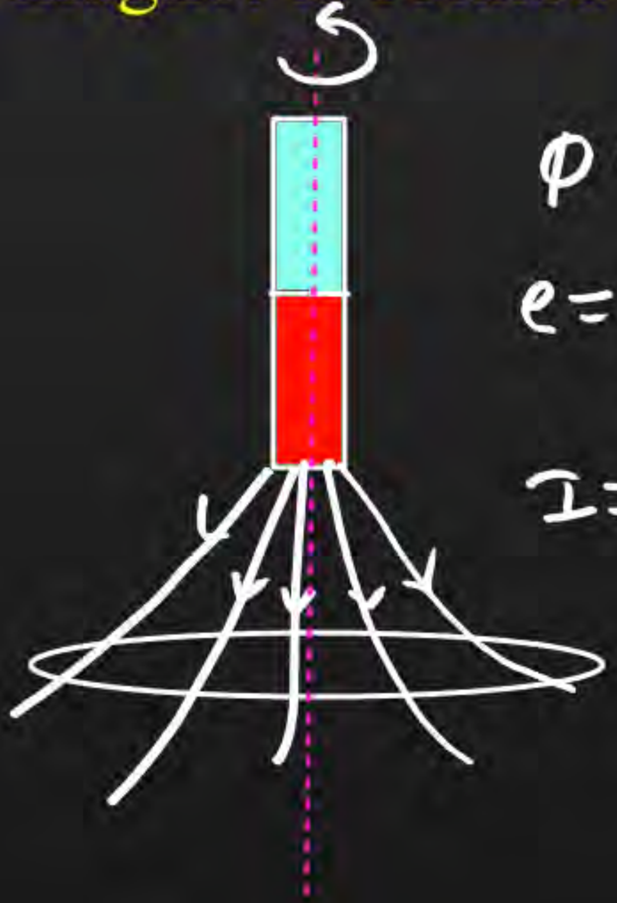
A bar magnet is kept along the axis of a circular coil. If the magnet is rotated about its axis, then

(A) A current will be induced in the coil

(B) No current will be induced in the coil

(C) An emf and current both will be induced in the coil

(D) Only an emf will be induced in the coil



$\phi = \text{const}$

$e = \frac{d\phi}{dt} = 0$

$I = \frac{e}{R} = 0$

Question

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

A. Gauss's law in magnetism

B. Faraday's law

C. Ampere's circuital law

D. Blot-Savart's law

Question

The Polarity of induced emf is given by

A. Faraday's law

B. Lenz's law

C. Gauss's law in magnetostatics

D. Ampere's circuital law

Question

Lenz's law is a consequence of conservation of

(A) Energy

(B) Linear momentum

(C) Angular momentum

(D) Charge

Question

A conducting circular loop of face area $2.5 \times 10^{-3}\ m^2$ is placed perpendicular to a magnetic field which varies as $B = 0.5 \sin(100\pi t)$ T. The magnitude of induced EMF at time $t = 0$ s is

(A) 0.125π m V

(B) 125π m V

(C) 125π v

(D) 12.5π m V

$e = N \frac{d\phi}{dt} = (1) \frac{d}{dt}(BA)$

$e = A \frac{dB}{dt} = A \times 0.5 \cos(100\pi t) \times 100\pi$

$e = 0.5 \times 100\pi \times A \times \cos(100\pi t)$

$t = 0s$ $\quad e = 0.5 \times 100\pi \times 2.5 \times 10^{-3} \times (1)$

$e = 125\pi \times 10^{-3}$ V

MOTIONAL ELECTROMOTIVE FORCE

The emf induced across the ends of a conductor due to its motion in a uniform magnetic Field is called Motional emf.

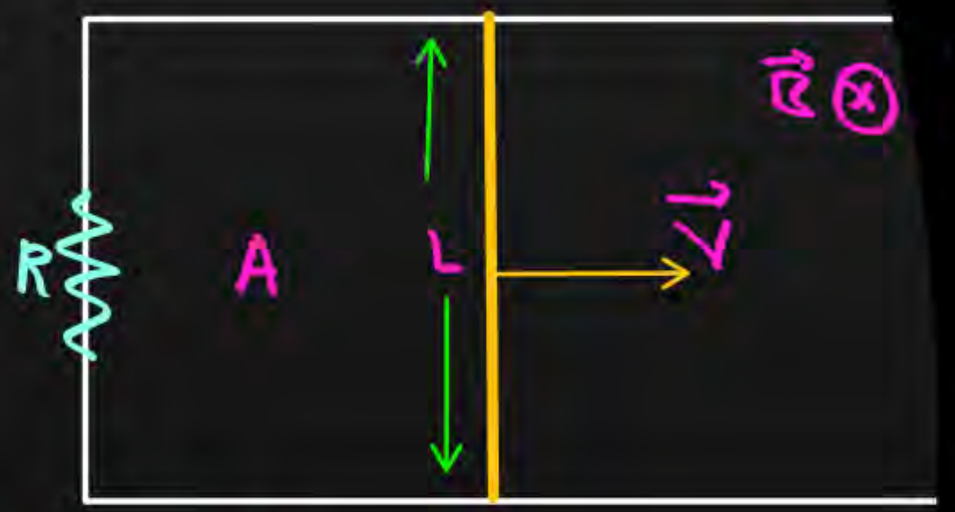
When a conducting rod move in a static magnetic field such that length of the conducting rod (L), Velocity/speed of the rod (V) and magnetic field (B) mutually perpendicular.

$\phi = BA$, $e = \frac{d\phi}{dt}$ A - vary

$$e = Blv$$

v - speed

l - Effective length (like Displacement)



MOTIONAL ELECTROMOTIVE FORCE

NOTE :

1. All three must be perpendicular to each other $\vec{B} \perp \vec{v} \perp l$, $e \neq 0$
2. If any two becomes parallel to each other, then emf becomes zero, $B \parallel v \parallel l$, $e = 0$
3. The length perpendicular to velocity vector and magnetic field vector independent of shape and length of wire,

MOTIONAL ELECTROMOTIVE FORCE

For the given circuit, If metal rod moves with uniform velocity 'V' by an external agent, Then

1. Induced emf in the circuit : $e = BLV$

2. Current flows through the circuit : $I = \frac{e}{R} = \frac{BLV}{R}$

3. Retarding/Opposing force exerted on the metal rod by action of induced current.

$$F = BIL = B\left[\frac{BLV}{R}\right]L = \boxed{\frac{B^2L^2V}{R}}$$

Question

A metallic rod of length 1 m held along east-west direction is allowed to fall down freely. Given horizontal component of earth's magnetic field $B_H = 3 \times 10^{-5}$ T, the emf induced in the rod at an instant $t = 2$ s after it is released is (Take, $g = 10\ \text{ms}^{-2}$)

A. 6×10^{-4} V

B. 3×10^{-3} V

C. 3×10^{-4} V

D. $6 \times 10^{-3} V$

$u = 0$

Free fall

$v = u + at$

$v = 0 + gt$

$v = 10 \times 2 = 20$ m/s

$e = BLv$

$e = 3 \times 10^{-5} \times 1 \times 20$

$e = 60 \times 10^{-5}$

$e = 6 \times 10^{-4}$ V

Question

A rod of length 2 m slides with a speed of 5 ms^{-1} on a rectangular conducting frame as shown in figure. There exists a uniform magnetic filed of 0.04 T perpendicular to the plane of the figure. If the resistance of the rod is 3 ohm. The current through the rod is

(A) 75 mA

(B) 133 mA

(C) 0.75 A

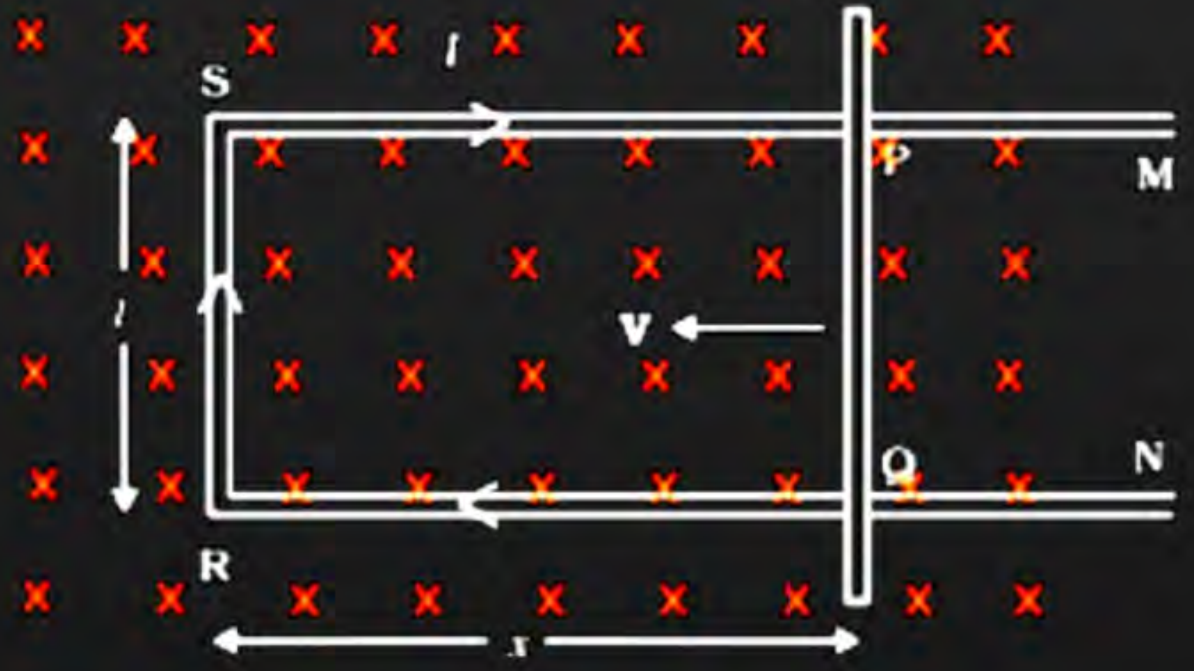
(D) 1.33 A

$$I = \frac{e}{R} = \frac{BLV}{R}$$

$$I = \frac{0.04 \times 2 \times 5}{3}$$

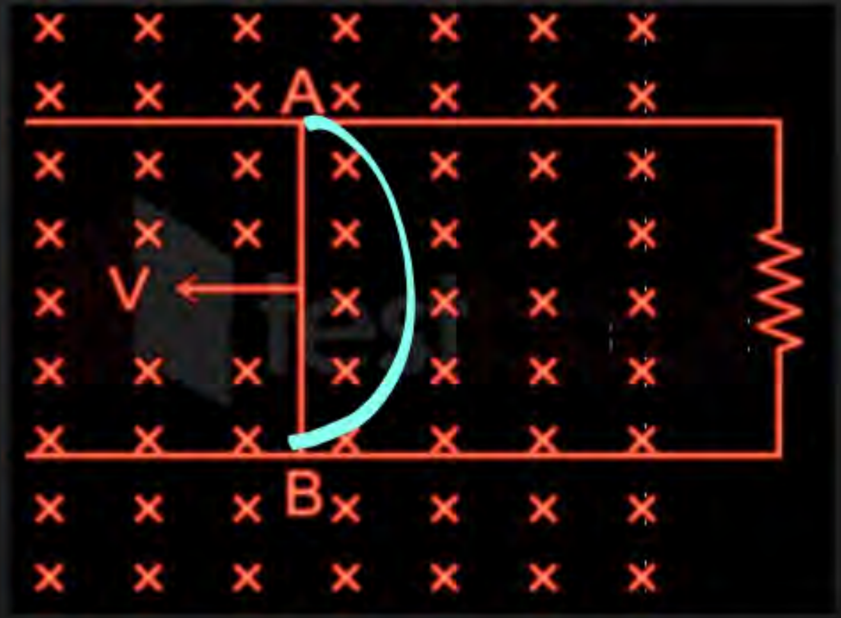
$$I = 0.1333\ A$$

$$I = 133.3\ mA$$



Question

Consider the situation given in figure. The wire AB is slid on the fixed rails with a constant velocity. If the wire AB is replaced by a semicircular wire, the magnitude of the induced current will



(A) Increase

(B) Remain same

(C) Decrease

(D) Increase or decrease depending on whether the semicircle bulges towards the resistance or away from it.

Question

A conducting rod AB of length $l = 1$ m is moving at a velocity $v = 4$ m/s making an angle 30° with it's length. A uniform magnetic field B = 2T exists in a direction perpendicular to the plane of motion. Then _____.

(A) $V_A - V_B = 8V$

(B) $V_A - V_B = 4V$

(C) $V_A - V_B = -8V$

(D) $V_A - V_B = -4V$

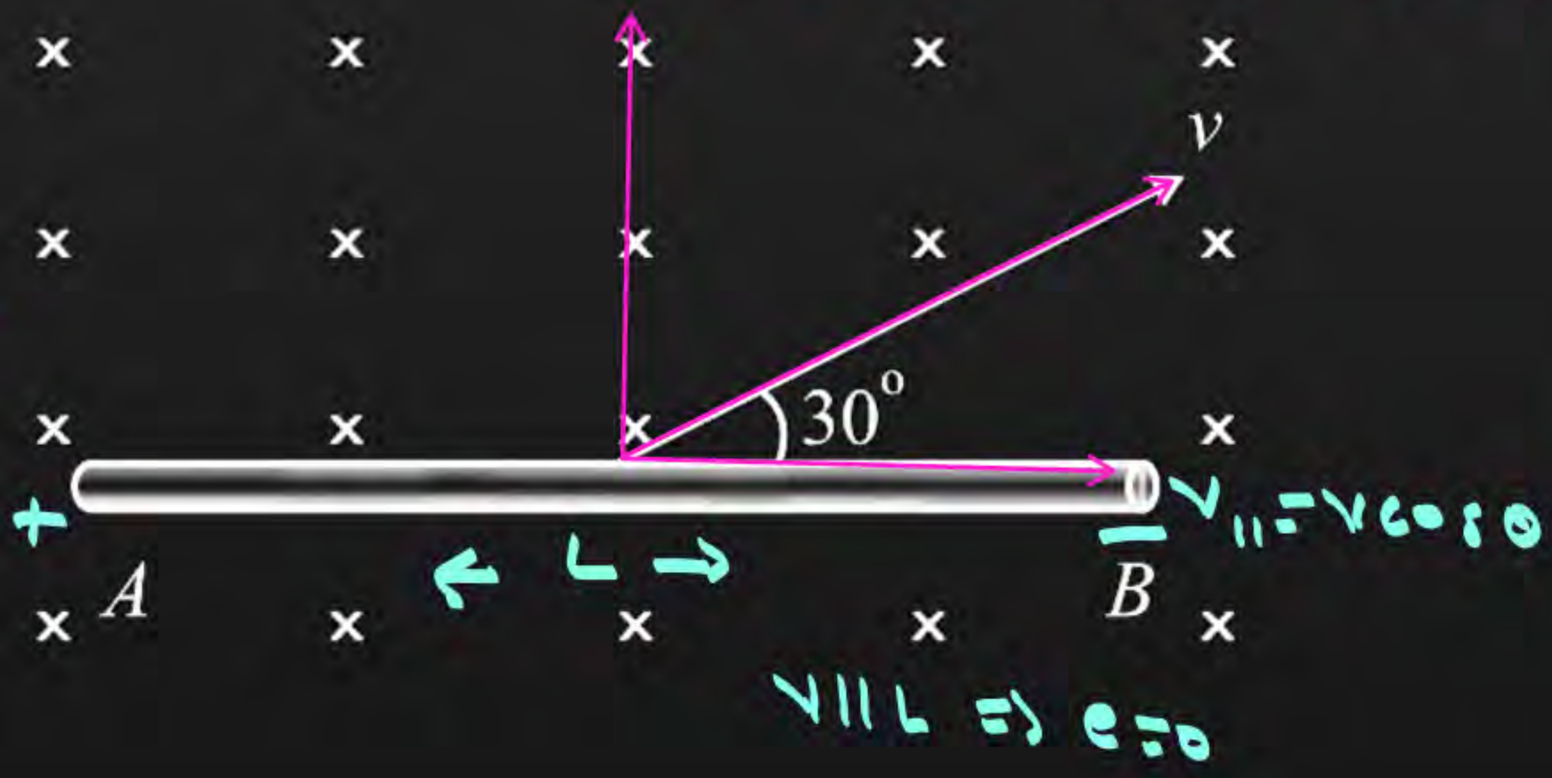
$e = BLV_\perp$

$V_A - V_B = BLV\sin\theta$

$V_A - V_B = 2 \times 1 \times 2$

$V_A - V_B = 4V$

$V_\perp = V\sin\theta = 4 \times \sin 30^\circ = 2$ m/s



ROTATIONAL ELECTROMOTIVE FORCE

The emf induced across the ends of a conductor due to its rotational motion in a uniform magnetic is called Rotational emf.

field

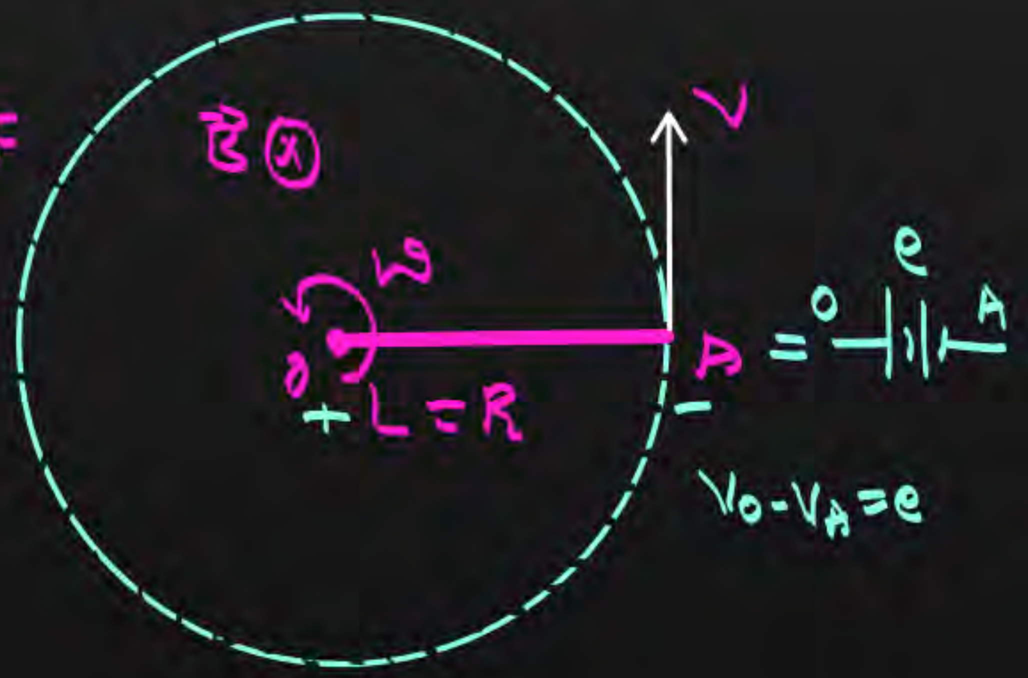
Rod of length 'L' is rotation about its corner with constant 'ω' in a magnetic field $\vec{B}$.

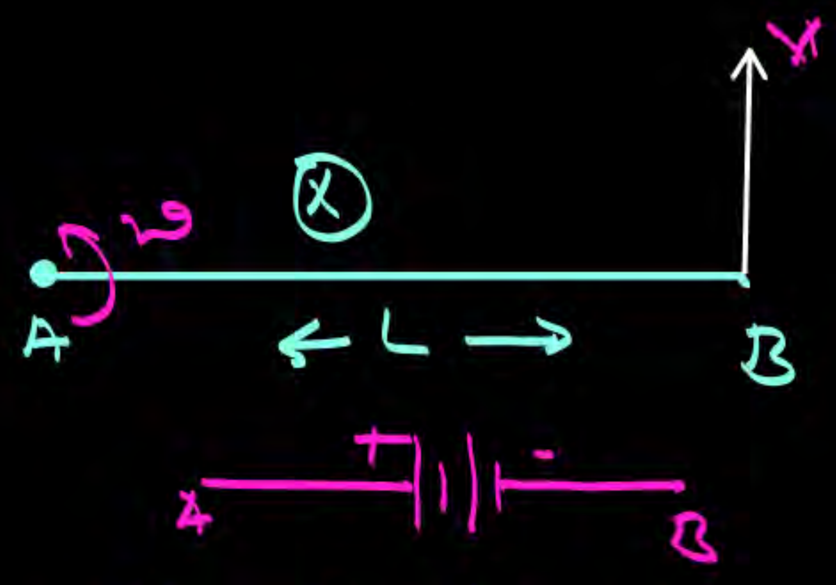
$e = BLv$ → Horizontal motional EMF

$e = BL\frac{\omega L}{2}$

$v = \omega x$.

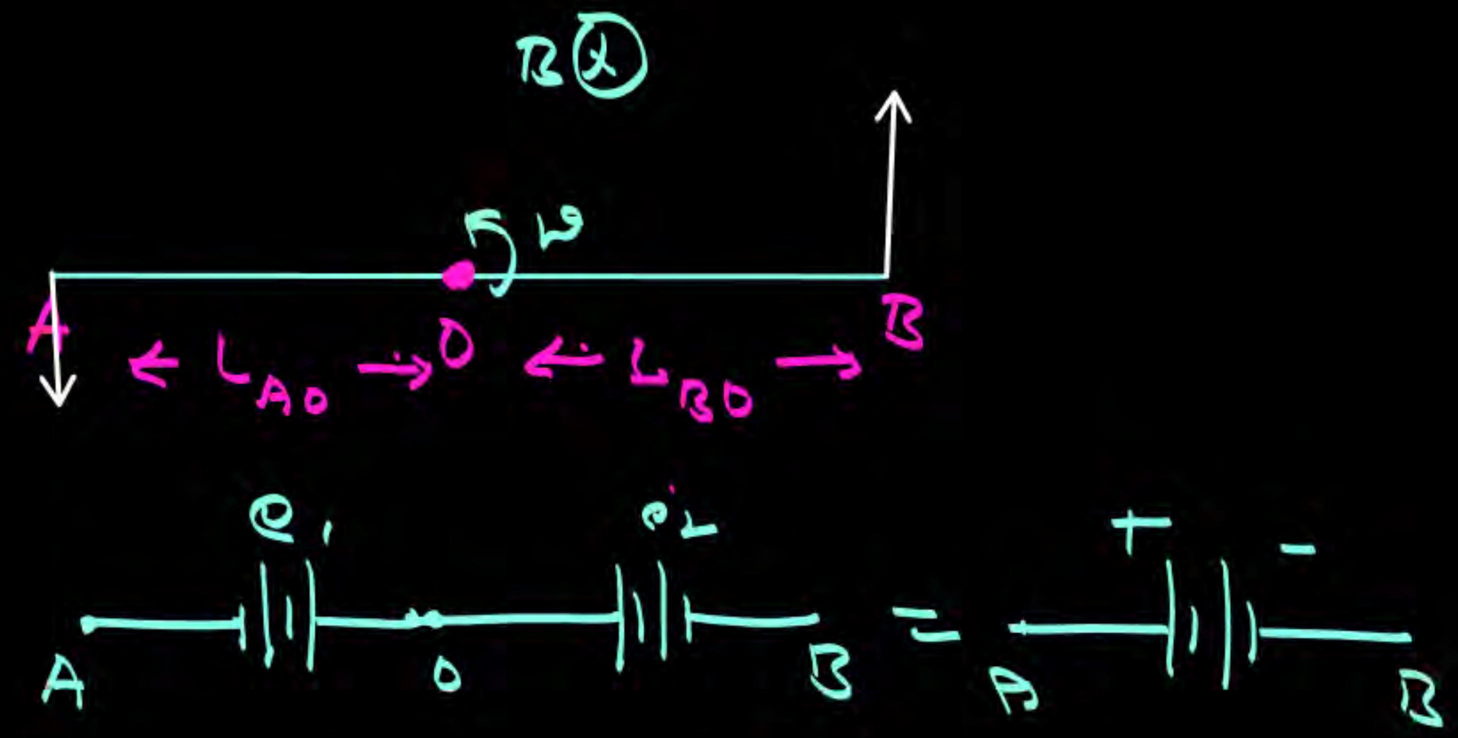
$$V_O - V_A = e = \frac{B\omega L^2}{2}$$ → Rotational EMF





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

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



$$e = \frac{B\omega}{2}\left(L_{BO}^2 - L_{AO}^2\right)$$

Question

A conducting rod AC of length $4l$ is rotated with angular velocity ω about a point O in a uniform magnetic field $\vec{B}$ directed into the plane of the paper. If $AO = l$ and $OC = 3l$, then potential difference between A and C, $V_A - V_C$ is

(A) $2B\omega l^2$

(B) $B\omega l^2$

(C) $3B\omega l^2$

(D) $4B\omega l^2$

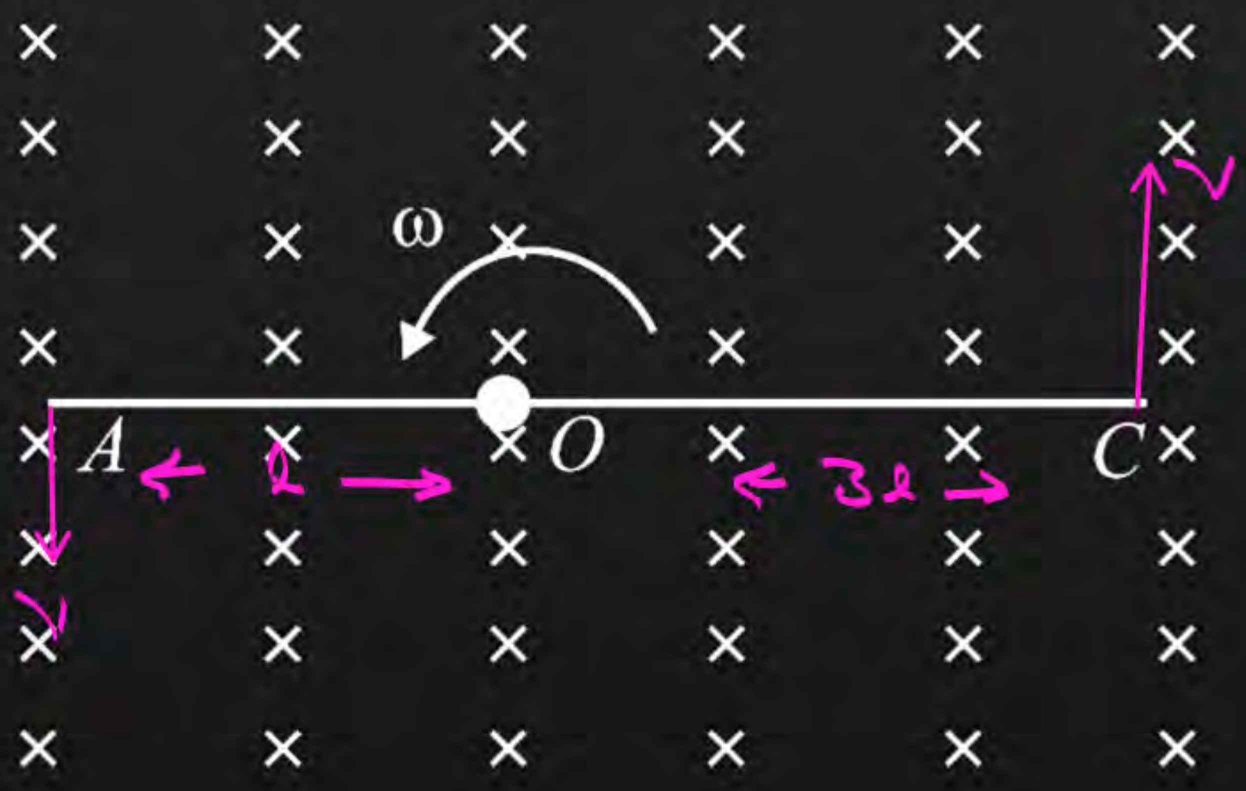
$e = \frac{B\omega}{2}[L_{OC}^2 - L_{AO}^2]$

$e = \frac{B\omega}{2}[(3l)^2 - (l)^2]$

$e = \frac{B\omega}{2}[9l^2 - l^2]$

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

$e = 4B\omega l^2$



Question

$R = L$ ω

A cycle wheel of radius 0.5 m is rotated with a constant angular velocity of 10 rad/s in a region of a 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

(A) 0.25 V

(B) 0.125 V

(C) 0.5 V

(D) zero

$$e = \frac{B\omega L^2}{2} = \frac{0.1 \times 10 \times (0.5)^2}{2}$$

$$e = 0.125\,V$$

INDUCTANCE

An electric current can be induced in a coil by flux change produced by another coil in its vicinity or flux change produced by the same coil.

Resistance :

Property to oppose the flow current

↳ Electrical Inertia

Inductance :

Growth
↑
Property to oppose the change in current

SELF INDUCTANCE

$B = \frac{\mu_0 I}{2r}$ $B \propto I$, $\phi \propto B \propto I$

$\phi = BA$ (A → const.)

$I\uparrow$ $B\uparrow$ $\phi\uparrow$

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

I_i

The phenomenon in which an emf is induced in a coil due to the change in the current through same coil is called self inductance.

$\phi \propto I$

Formula :

$N\phi \propto I \Rightarrow N\phi = LI$

$$L = \frac{N\phi}{I}$$

SI Unit :

→ unit $= \frac{Wb}{A} \Rightarrow$ Henry (H)

Dimensional Formula :

$$L = \frac{N\Phi}{I} = \frac{NBA}{I}$$

$$[L] = \frac{N}{A\text{-}m} \times \frac{m^2}{A}$$

$$= \frac{[M^1 \cancel{L^1} T^{-2}][L^2]}{[A^1 \cancel{L} A^1]}$$

$$L = [M^1 L^2 T^{-2} A^{-2}]$$

Question

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

(A) 2.5 H

(B) 2.0 H

(C) 1.0 H

(D) 4.0 H

$N\phi = LI$

$L = \frac{N\phi}{I} = \frac{500 \times 4 \times 10^{-3}}{2}$

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

$L = 1\,H$

SELF INDUCTANCE OF SOLENOID

When a current passes through a solenoid : I

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

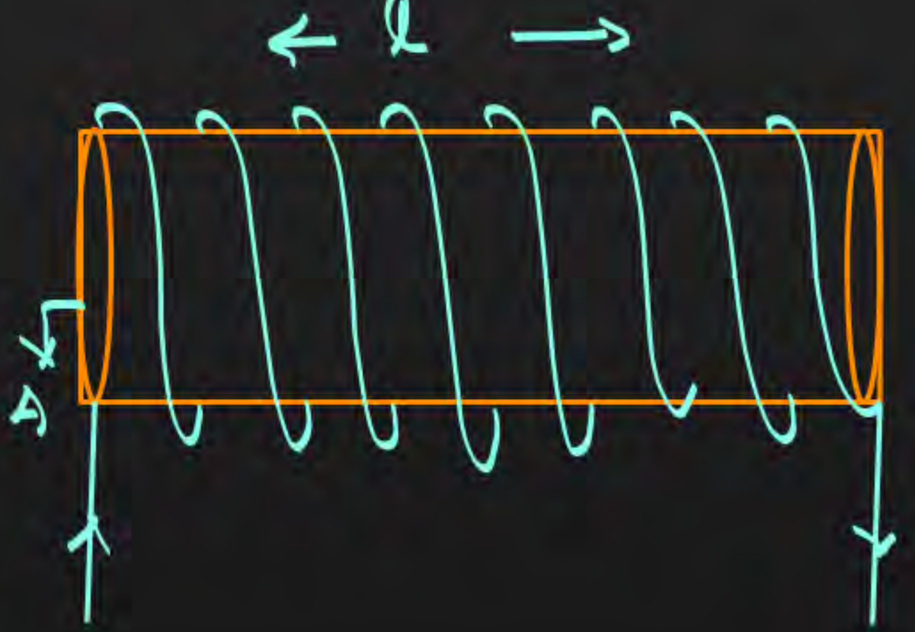
$$L = \mu_0 \frac{N^2}{l} A$$

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

A - Area

l - Length.

$L \propto N^2$



Question

If the number turns of a solenoid is doubled, the self inductance of the solenoid will

A. Remains unchanged

B. Be doubled

C. Be halved

D. Becomes four times

$L \propto N^2 \qquad N' = 2N$

$L' \propto N'^2 \propto (2N)^2 \propto 4N^2$

$L' \propto 4L$

INDUCED EMF IN THE COIL

Whenever there is change in current through a coil, then it opposes the change by developing an emf i.e back emf.

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

*

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

Question

The current in a coil changes from 2 A to 5 A in 0.3 s . The magnitude of emf induced in the coil is 1.0 V . The value of self-inductance of the coil is

(A) 1.0 mH

(B) 100 mH

(C) 0.1 mH

(D) 10 mH

$$e = -L\frac{dI}{dt} = -L\frac{\Delta I}{\Delta t}$$

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

$$1 = L \times \frac{(5-2)}{0.3} = L \times \frac{3}{0.3}$$

$$L = \frac{0.3}{3} = 0.1H$$

$$L = 0.1 \times \frac{1000}{1000} = 100mH$$

Question

The current in a coil of inductance 0.2 H changes from 5A to 2A in 0.5s. The magnitude of the average induced emf in the coil is

A. 0.6 V

B. 1.2 V

C. 30 V

D. 0.3 V

$e = L\frac{\Delta I}{\Delta t} = 0.2 \times \frac{(5-2)}{0.5}$

$e = \frac{2}{5} \times 3 = \frac{6}{5}$

$e = 1.2V$

Magnetic Energy Stored in an Inductor (Coil)

All the energy stored in the Inductor/coil is given by :

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

Cap → $U = \frac{1}{2} C V^2$

Ind → $U = \frac{1}{2} L I^2$

Magnetic Energy Density is magnetic energy per unit volume

$$E_{d} = \frac{1}{2} \frac{B^2}{\mu_0}$$

$u_E = \frac{1}{2} \varepsilon_0 E^2$

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

Question

The magnetic energy stored in an inductor of inductance 4 μH carrying a current of 2 A is

(A) 8 μJ

(B) 4 μJ

(C) 4 mJ

(D) 8 mJ

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

$U = \frac{1}{2} \times 4 \times (2)^2$

$U = 8 \mu J$

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:

(A) 0.138 H

(B) 138.88 H

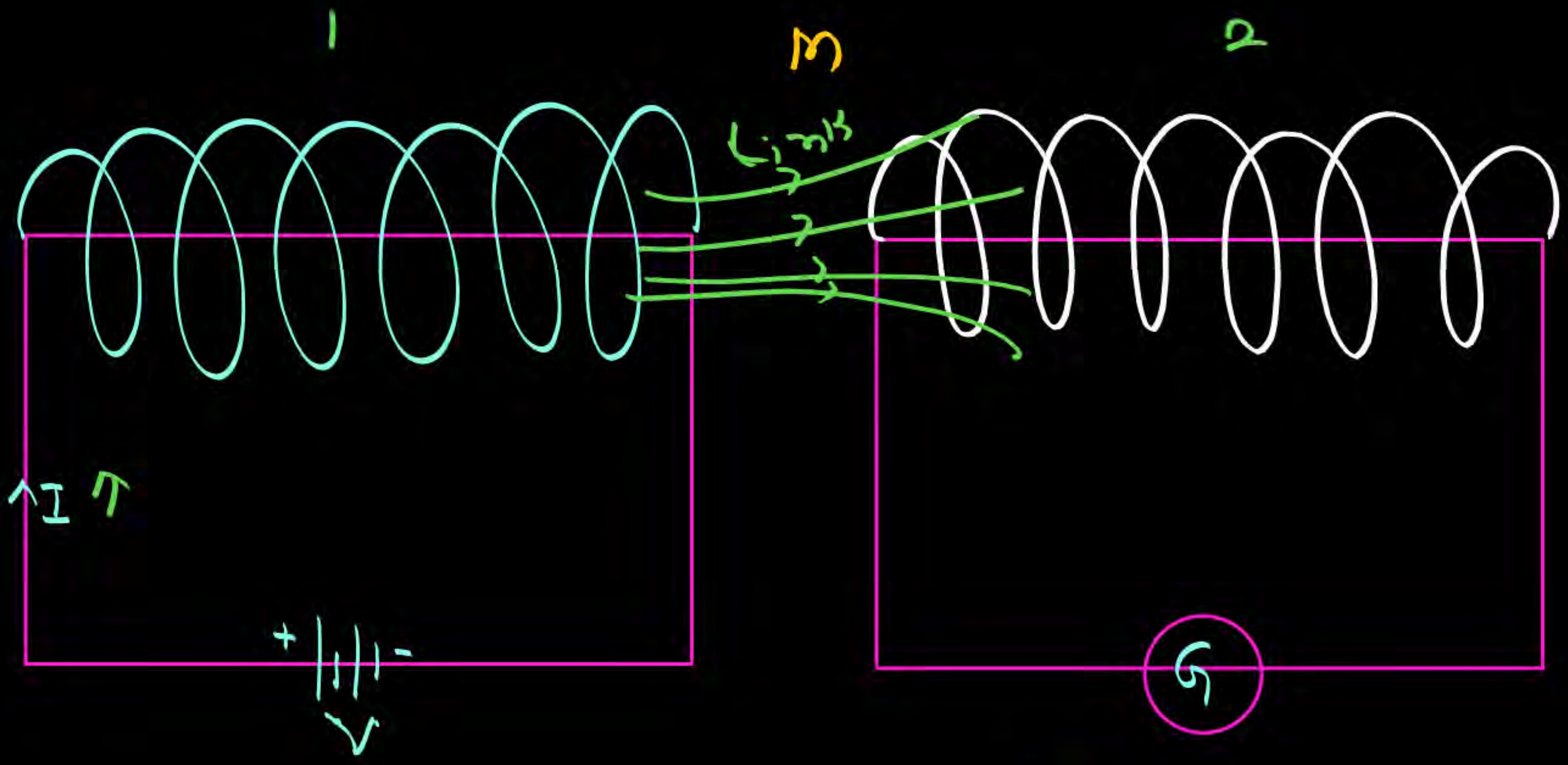
(C) 1.389 H

(D) 13.89 H

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

$$L = \frac{2U}{I^2} = \frac{2 \times 25 \times 10^{-3}}{(60 \times 10^{-3})^2} = \frac{50 \times 10^{-3}}{3600 \times 10^{-6}}$$

$$L = \frac{50 \times 10^{-3}}{3.6 \times 10^{-3}}$$



$$N_2 \phi_2 = M I_1$$

$$M = \frac{N_2 \phi_2}{I_1}$$

MUTUAL INDUCTANCE

Mutual Inductance (M) : It is property by which coil opposes change in flux due to change in current in second coil

Formula : $M = \frac{N\phi}{I}$

SI Unit : Henry

Dimensional Formula : $[M^1 L^2 T^{-2} A^{-2}]$

Question

The dimensions of mutual inductance (M) are

(A) $M^2LT^{-2}A^{-2}$

(B) $MLT^{-2}A^{-2}$

(C) $M^2L^2T^{-2}A^2$

(D) $ML^2T^{-2}A^{-2}$

Coupling constant

The coupling constant or coefficient of coupling (k) represents the fraction of magnetic flux produced by one coil that successfully links with the other coil.

i.e the relationship between L_1, L_2 (Self induction) and M (Mutual Induction)

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

$$0 \leq K \leq 1$$

Question

Two coils of self-inductance L_1 and L_2 are placed near each other so that the total flux in one coil is completely linked with the other. Their mutual inductance (M) will be given by _____.

$K = 1$

A $M = L_1 L_2$

$M = K\sqrt{L_1 L_2}$

B $M = \sqrt{L_1 L_2}$ completely $K = 1$, $M = \sqrt{L_1 L_2}$

C $M < \sqrt{L_1 L_2}$ partially

D $M > L_1 L_2$

Question

Two coils of self-inductance 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

$K = 1$

A) 10 mH

B) 6 mH

C) 4 mH

D) 16 mH

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

$$M = \sqrt{2\times10^{-3} \times 8\times10^{-3}}$$

$$M = \sqrt{16\times10^{-6}}$$

$$M = 4\times10^{-3}$$

$$M = 4\,mH$$

AC Generator

$e = e_0 \sin\omega t$

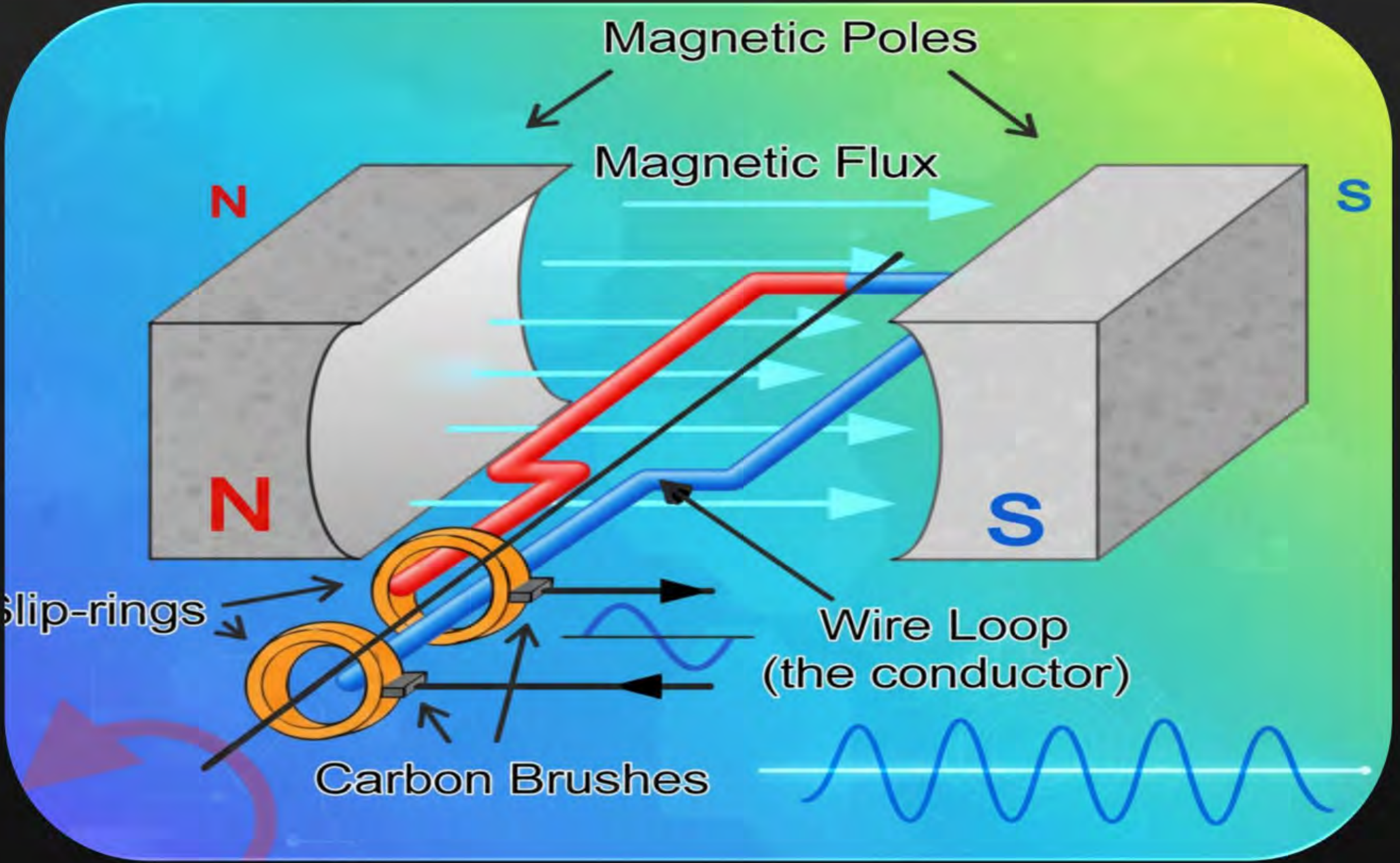
$e_0 = NA\omega B$

$e = e_0 \sin\omega t$

$e_0 = NA\omega B$

A device which converts mechanical energy to electrical energy is called AC Generator.

Working principle :
Electromagnetic Induction (EMI)



Question

Consider the following statements :

Statement – 1: A.C. Generator works on the principle of electromagnetic induction

Statement – 2: In an A.C. Generator , as the armature is rotated in a uniform magnetic field , the magnetic flux linked with the coil changes which induces an emf in the coil. Among the above two statements:

(A) Both statements are true

(B) Both statements are false

(C) Statement-1 is true and statement-2 is false

(D) Statement-1 is false and statement-2 is true

Question

An emf is generated by an ac generator having 100 turn coil, of loop area 1 m². The coil rotates at a speed of one revolution per second and placed in a uniform magnetic field of 0.05 T perpendicular to the axis of rotation of the coil. The maximum value of emf is:

(A) 3.14 v

(B) 31.4 V

(C) 62.8 v

(D) 6.28 V

$e = e_0 \sin \omega t$

$\sin \omega t = 1$

$e_{max} = e_0 = N \omega A B$

$= 100 \times 2\pi f \times 1 \times 0.05$

$= 100 \times 2 \times 3.14 \times 1 \times 1 \times 0.05$

$e = 31.4\,V$

Thank You