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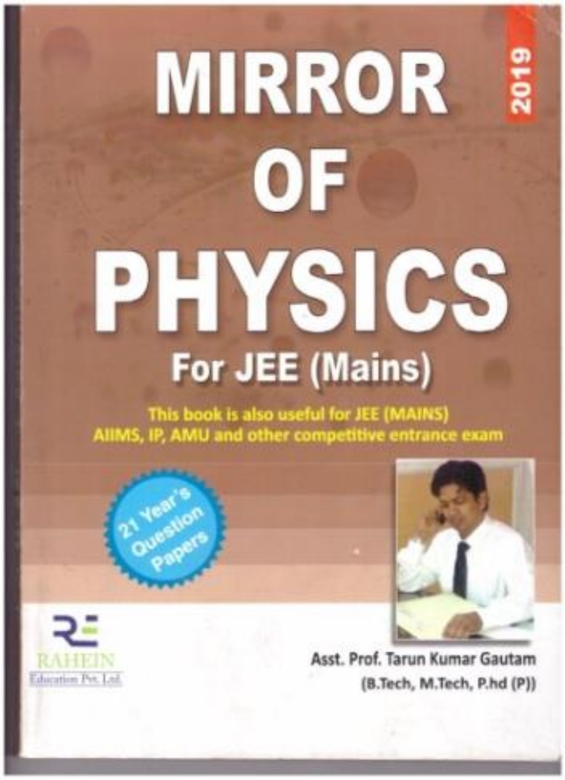
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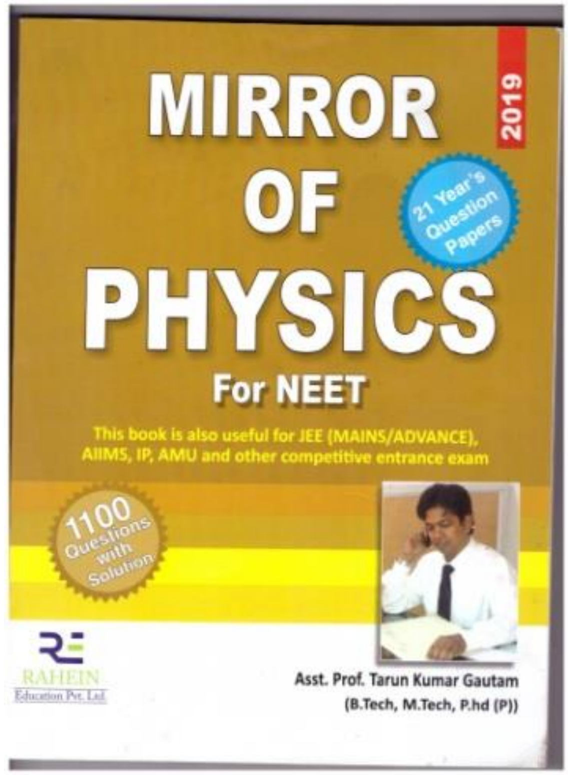
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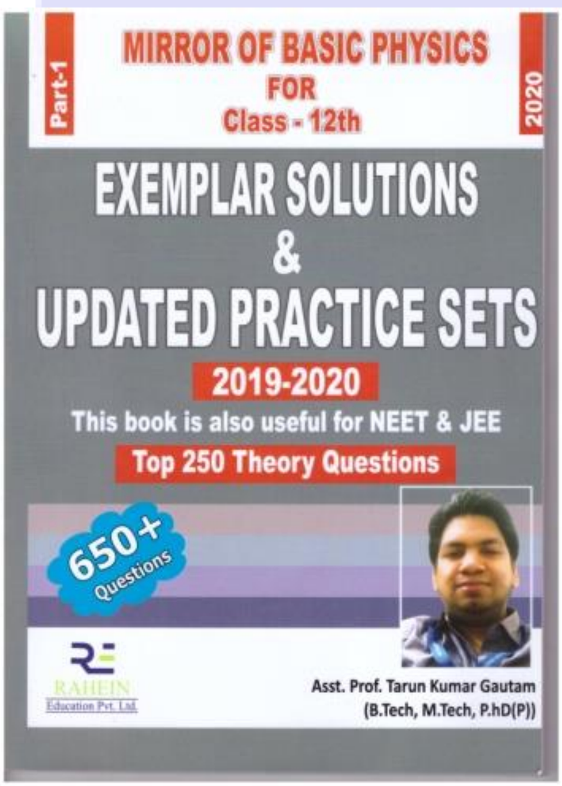
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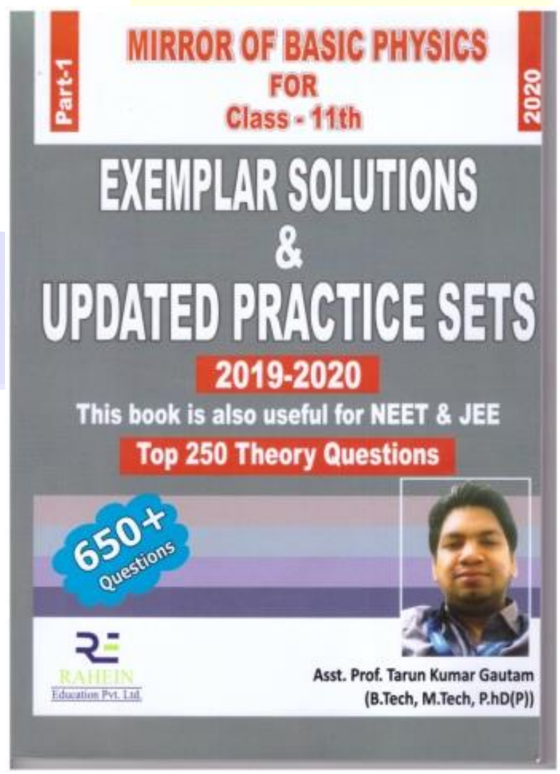
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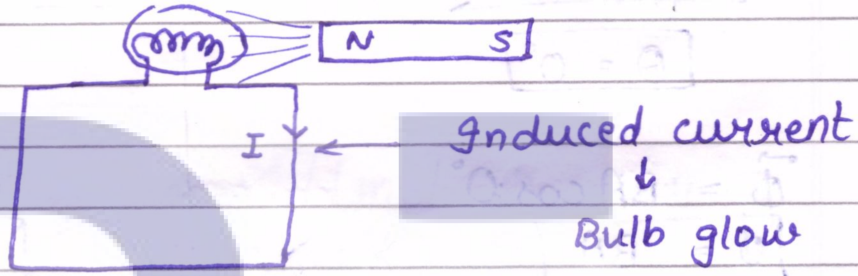
Chapter-6
(EMI)

★ EMI (Electromagnetic Induction)

Phenomenon of generating current / emf in a conducting circuit by change in strength position or orientation of an external Magnetic Field called "EMI".

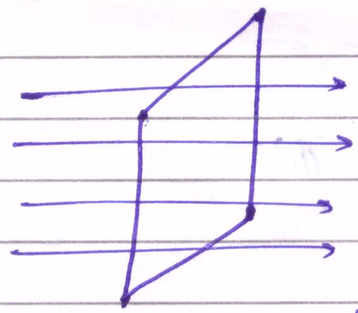


Induced current → Induced emf / voltage

★ Magnetic Flux (ϕ)

No. of magnetic lines passing through per unit Area.

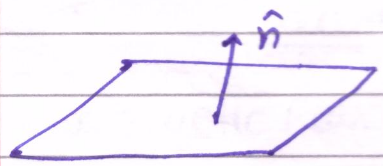
ϕ = Magnetic Flux



$$\boxed{\phi = \vec{B}\cdot\vec{S}}$$

$$\boxed{\phi = BS\cos\theta}$$

'θ' is angle between Area vector ($\hat{n}$) and Magnetic field (B).



Area vector – It is always perpendicular to surface.

→ $\boxed{\vec{S} = S\hat{n}}$

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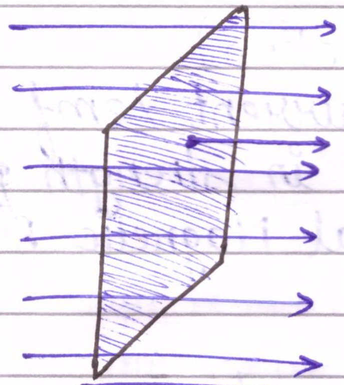
Two cases.

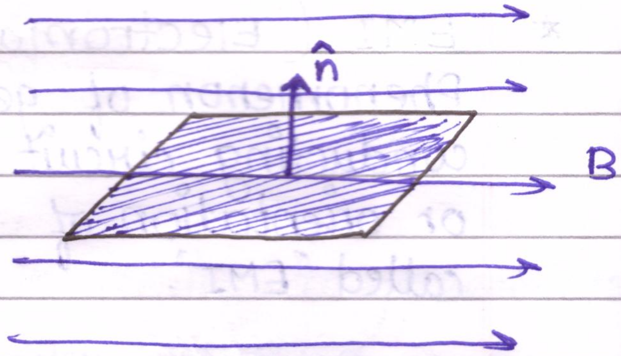


$\theta = 0°$

$\vec{\phi} = BA\cos 0°$

$\phi = BA$

Maximum Flux



$\theta = 90°$

$\phi = BA\cos 90°$

$\phi = 0$

Minimum flux

Note

Units

① $\phi = BA$

$B = \frac{\phi}{A} \rightarrow \frac{weber}{m^2}$

→ Unit of 'B' → $wb\,m^{-2}$

② Unit & dimension of 'ϕ'

$\phi = BA$

→ Unit of 'ϕ' = Tm^2

* $f = qvB$

$B = \frac{f}{qv} = \frac{N}{C\,ms^{-1}}$

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* $B = \frac{f}{qv} = \frac{N}{Cms^{-1}} \times \frac{m}{m} \Rightarrow \frac{J}{Cm^2sec^{-1}}$ ∵ $J = N \times m$

$$B = JC^{-1}m^{-2}s$$

* $B = \frac{f}{qv} = \frac{Nm}{Cm^2s^{-1}} = \frac{volt}{m^2s^{-1}}$ ∵ $volt = \frac{Nm}{C}$

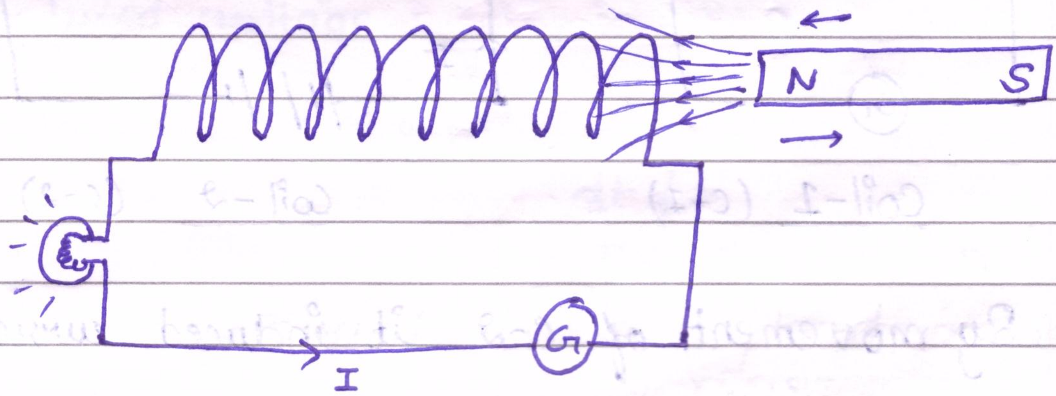
$$B = Volt\, sec\, m^{-2}$$

$\phi = BA \Rightarrow [Volt sec\, m^{-2}][m^2] \Rightarrow volt\, sec$

$\phi = volt\, sec$, $\phi = Tm^2$

Method of Charging of Magnetic Flux

① Current Induced by magnet



C-I Towards	C-II away
Magnetic Flux will Increase (↑)	Magnetic Flux will decrease (↓)

$\phi \rightarrow$ change in Magnetic Flux

↓

Induced current

↓

Induced EMF

At Result

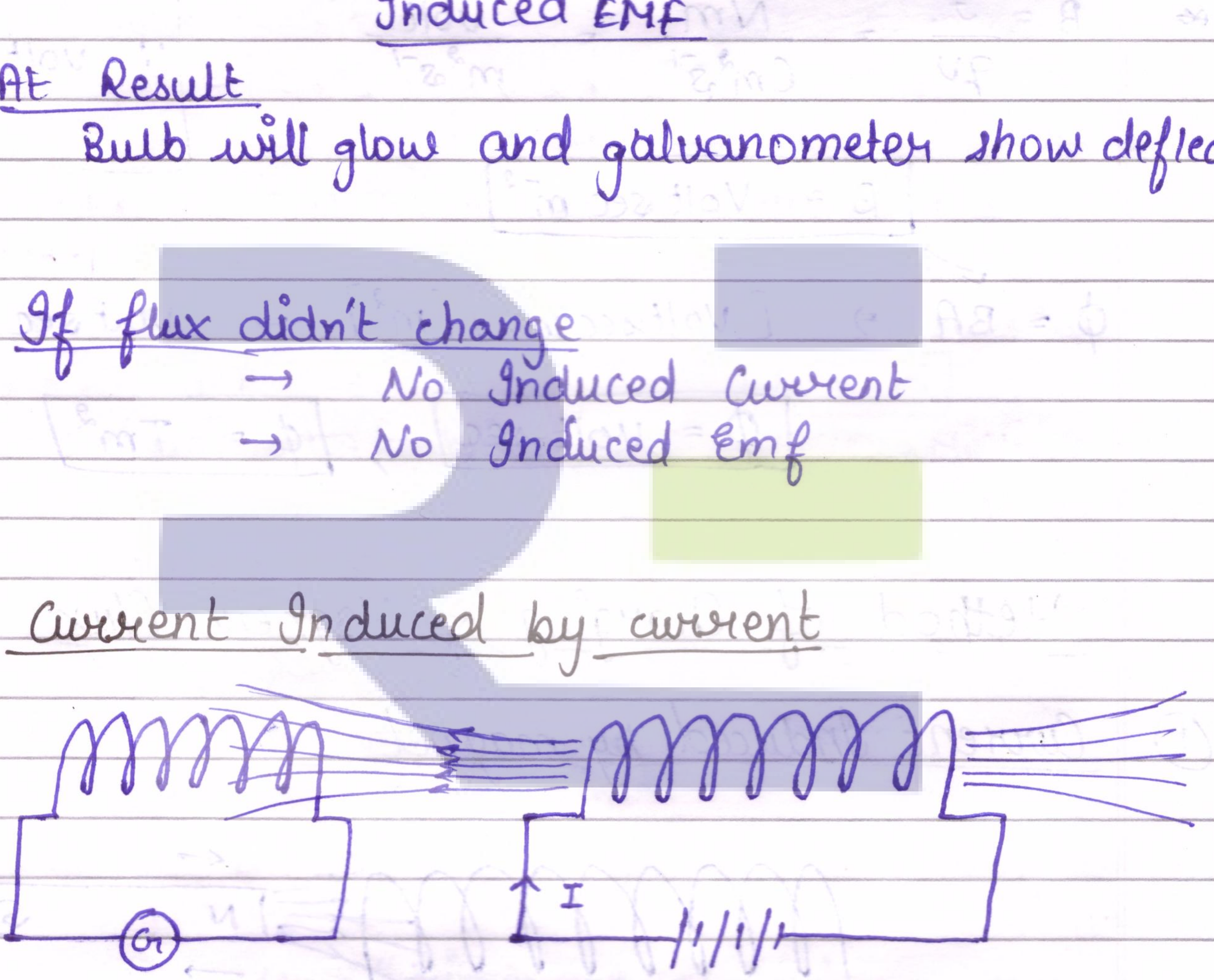
Bulb will glow and galvanometer show deflection.

If flux didn't change

→ No Induced Current

→ No Induced Emf

(2) Current Induced by current



Coil-1 (C-1) Coil-2 (C-2)

By movement of C-2 it induced current in C-1

Current passing through from C-2 produced its magnetic field when these field come closed to C-1 it induced emf in C-1 and hence leads to induced current in C-1 due to change its Magnetic flux (ϕ).

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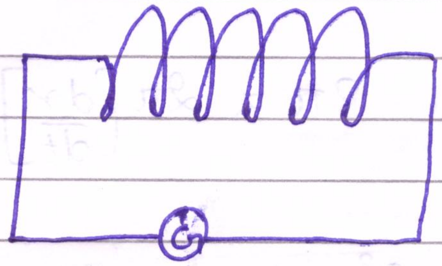
(3) Current Induced by Changing Current (Key)



Case I

Key → closed ⇒ current flow → Magnetic field formed

Magnetic Flux Increase ←

Case-II

Key - open ⇒ current is zero, Magnetic flux(↓)

After Case I + Case II

Magnetic flux change which induced current & induced voltage.

Note-

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

Ques A conducting circular loop is placed in uniform Transverse magnetic field of 0.02T. the radius of loop begin to shrink at a constant rate of

Ans $B = 0.02T$, $\frac{dr}{dt} = 0.1 m/sec$

$e = ?$, $r = 2cm = 2\times10^{-2} m$

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$$e = -\frac{d\phi}{dt} = \frac{d(BA)}{dt} = B\frac{d(A)}{dt} = B\frac{d(\pi r^2)}{dt}$$

$$e = B\pi \frac{d(r^2)}{dt} \Rightarrow B\pi \times 2\pi \left[\frac{dr}{dt}\right]$$

$$e = 0.02 \times \frac{22}{7} \times 2 \times 10^{-2} \times 0.1 \text{ volt}$$

Magnetic flux

$\phi = 3t^3 + 6t^2 + 8t + 2$

Qus Find the (a) Induced emf at 1 sec

(b) find the current if Resistance 2Ω?

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

$$e = -\frac{d}{dt}[3t^3 + 6t^2 + 8t + 2]$$

$$= (9t^2) + 12t + 8$$

at the $t = 1$ sec

$$= (9(1)^2 + 12(1) + 8)$$

$$= 9 + 12 + 8$$

$$e = 29 \text{ volt}$$

(b) $V = IR$

$29 = I \times 2$

$$I = \frac{29}{2} A$$

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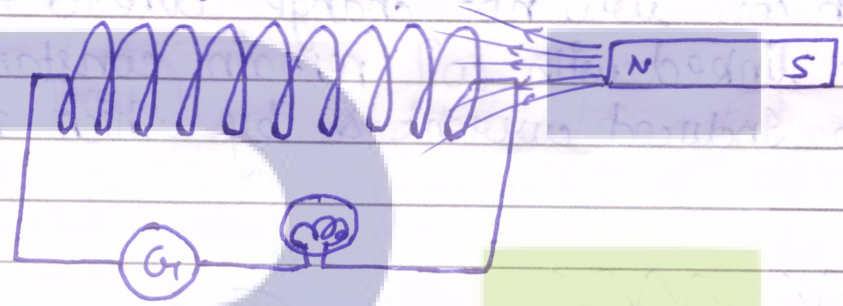
Note – $e = -\frac{d\phi}{dt} \Rightarrow -\left[\frac{\phi_2 - \phi_1}{t_2 - t_1}\right]$

$= -\left[\frac{B_2A_2 - B_1A_1}{t_2 - t_1}\right]$

$\Rightarrow -B\left[\frac{A_2 - A_1}{t}\right]$ $[B_1 = B_2]$

[∴ (-ve) sign show Induced emf always opposes any change in magnetic flux associated with circuit.]



Case 1 → When Magnet approach the coil
→ Magnetic lines linked with coil will be increased i.e., Magnetic flux will increased.
→ due to induced emf leads induced current
→ for oppose the magnet, coil will formed North pole
→ Repulsion [Same polarity]
→ anticlockwise current formed.

Case 2 → When magnet away from coil, magnetic field lines linked with coil will be decreased i.e magnetic flux derease
→ due to induced emf due to this Induced current it forms south pole & attract magnet
→ clockwise current formed.

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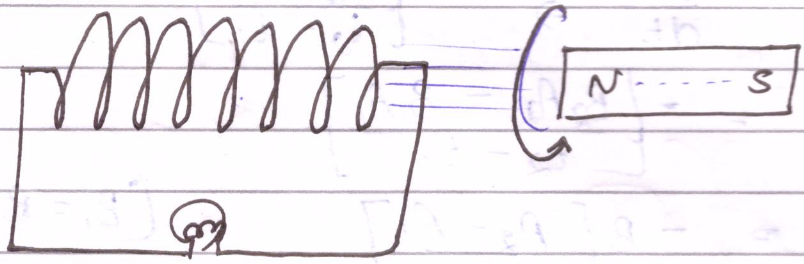
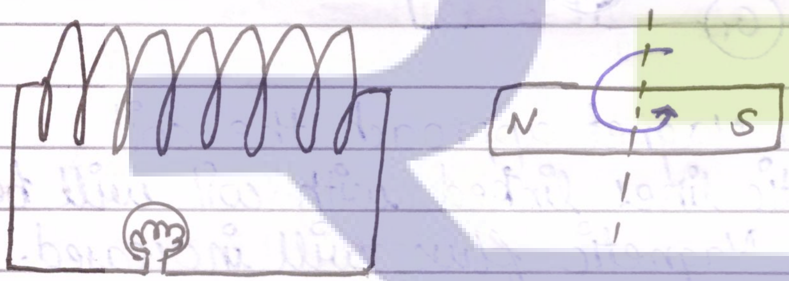
Ques 1



Magnet rotate along figure?

Ans By rotating the Magnet, Magnetic lines linked with coil will not change due to this magnetic flux linked with coil remain constant & so, No Induced current & by which bulb will not glow.

Ques 2

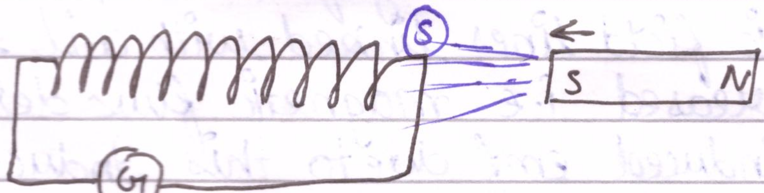


Will bulb glow in this case?

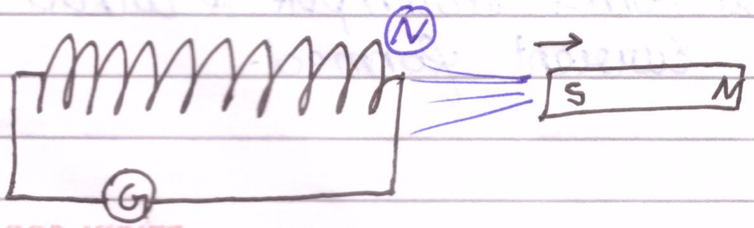
Ans By rotating magnet along y-axis, Magnetic field lines linked with the coil will be change due to this magnetic flux change. By which Induced current change so Bulb will glow.

---

①



②



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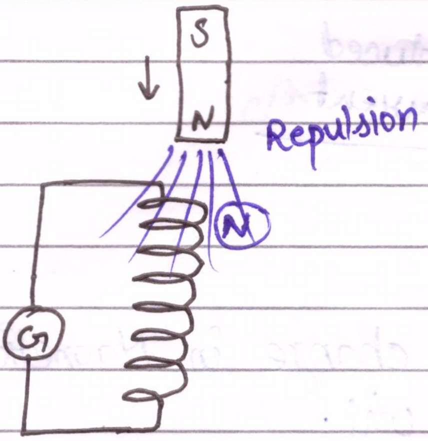
(3)



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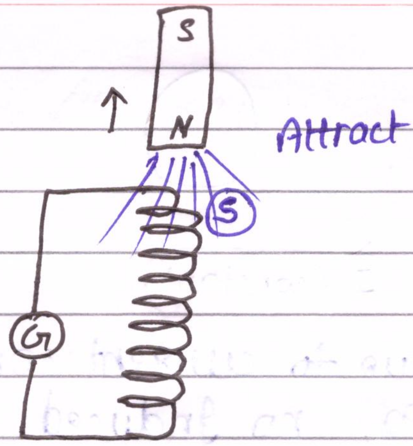

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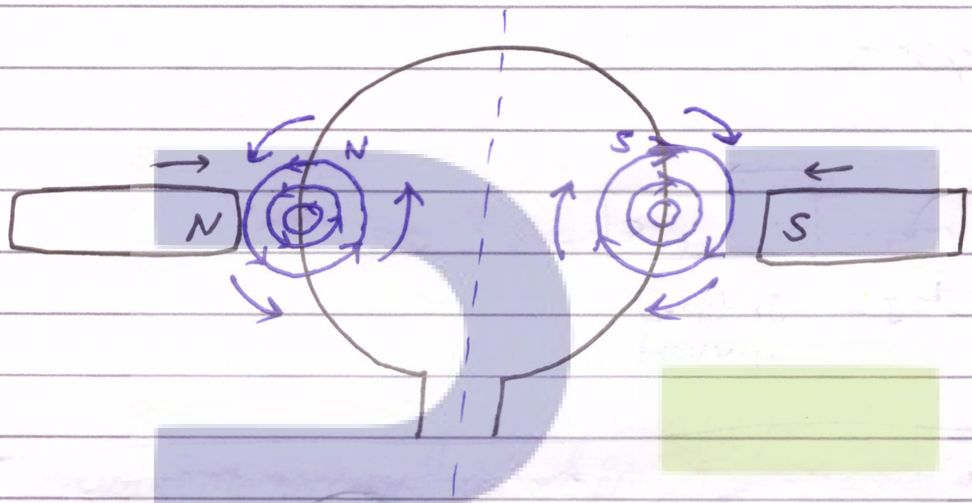
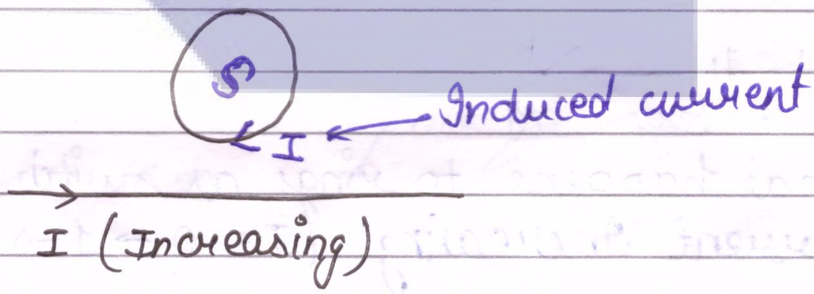
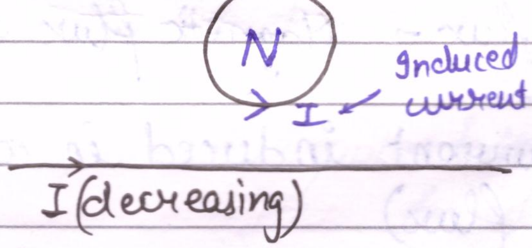


Qus Draw the direction of Induced current in figure

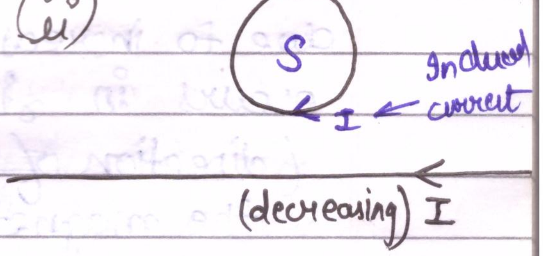


Qus Draw the direction of Induced current in figure

(i)



(ii)



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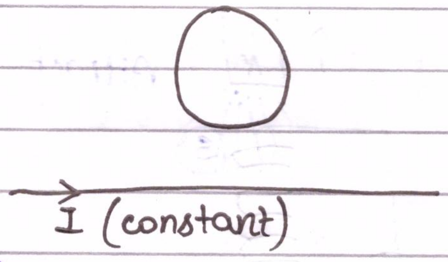
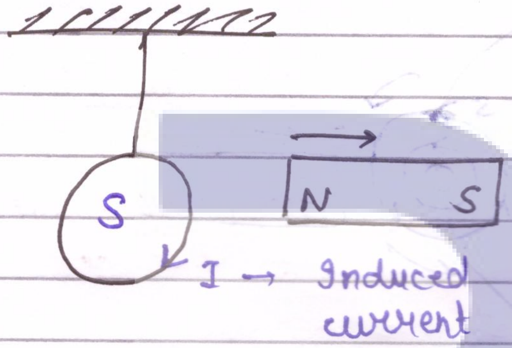
(iii)



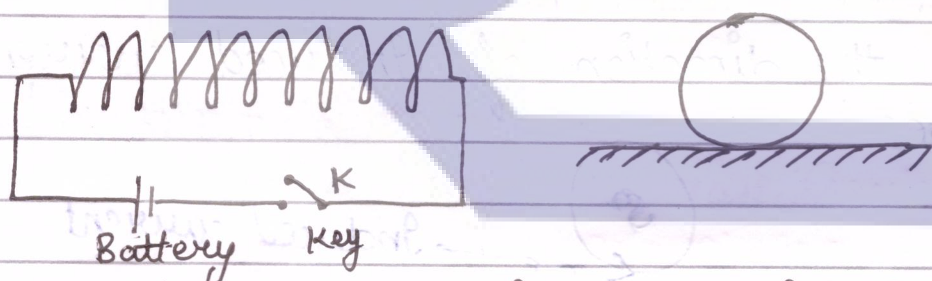
X no Induced current

Due to current constant, No change in Magnetic flux so, no Induced current in coil.

(iv)



Que



What happens to rings as switch is closed?

Ans Current Increasing ($I = 0 \rightarrow 1 \rightarrow 2 \rightarrow 3 - \cdots max$)

Due to increasing → Magnetic flux due to current also increased.

due to increase flux → Magnetic flux a induced current occurs in ring.

(direction of current induced in coil will oppose the magnetic flux)

Ring will repeat ⟶ move away from coil

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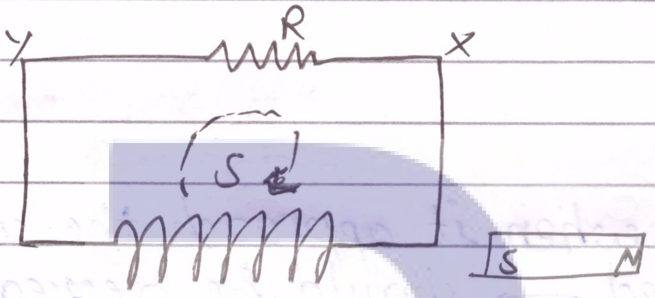
(1) Switch closed → Magnetic flux (↑)
↳ current increase

(2) Switch open → Magnetic flux (↓)
↳ current decrease

Qu.



If magnet move towards solenoid. what is direction of Induced current in (R)?

Ans

approach → Magnetic flux (↑) – due to this Induced current occur in coil.

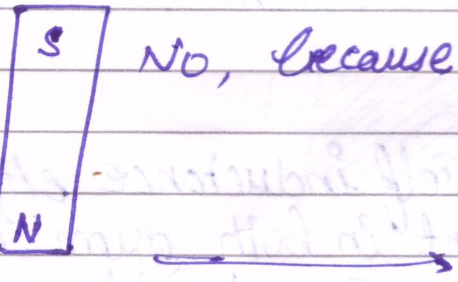
direction of Induced current will oppose the magnetic flux.

South pole formed.

Direction – y to x

Ques A vertical mettalic pole fall down through the plane of Magnetic meridian. Will any emf be induced b/w its end?

Ans



No, because pole interupts neither (H) & (V) component

Magnetic Meridian.

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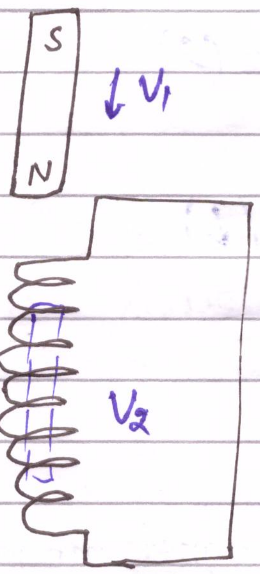
Ques



Find the relationship b/w (v_1) and (v_2) ?

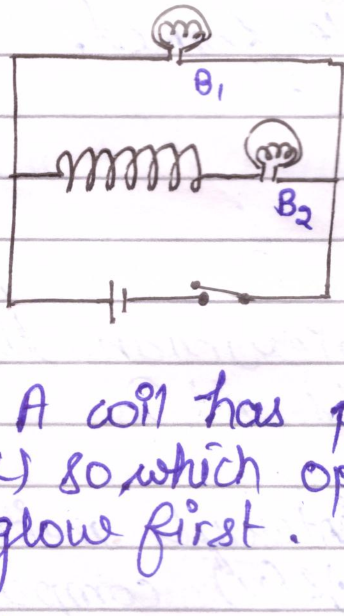
$v \rightarrow$ velocity

Ans Flux increased, when it approach the coil due to current Induced ⟶ should be decreased the flux North pole develop & repulsion occurs.

Under gravity also acts so velocity will decrease

$$V_1 > V_2$$

Ques



(a) when key is pressed which bulb will glow first?

(b) After sometime what will be the difference in their brightness

Ans (a) A coil has property called self inductance (L) so which opposes current so, (B_1) will glow first.

(b) After some time this self inductance effect neutrilization & current in both arm ready at their max value. So brightness of both

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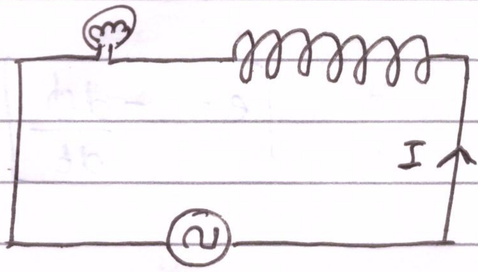
bulb will be same.

Que



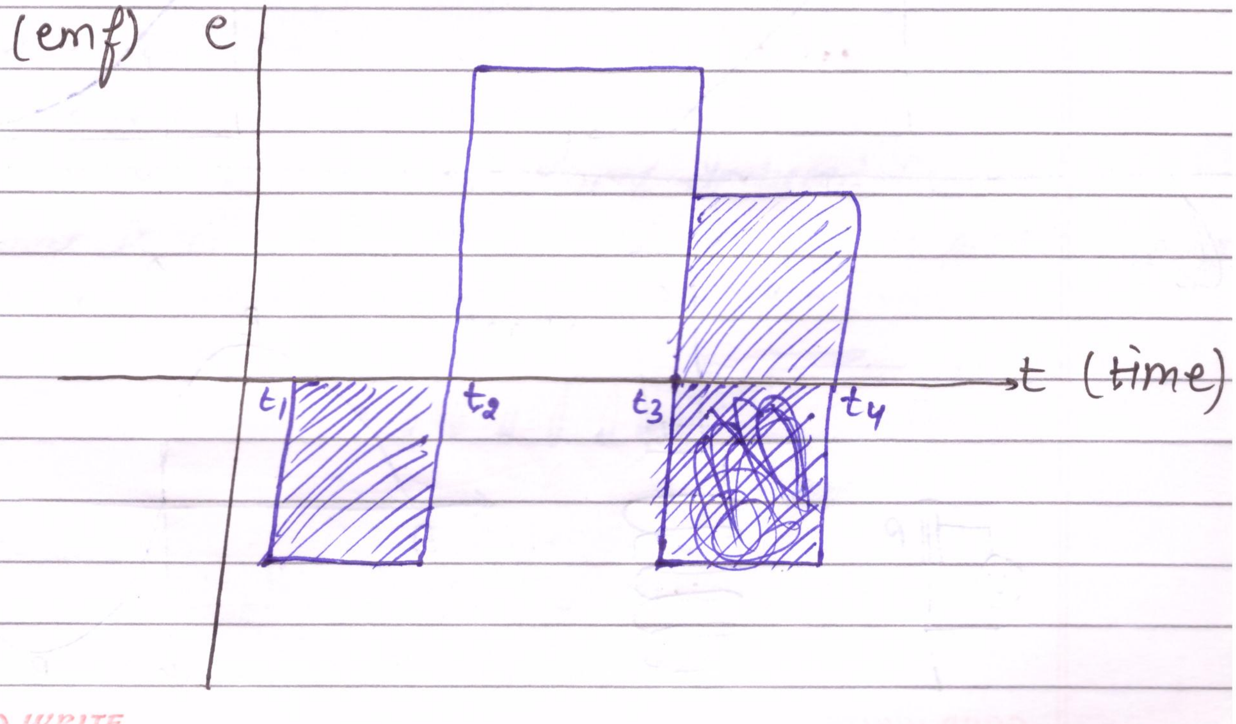
If soft iron core placed in solenoid then what will be effect on bulb?

Ans When we put soft iron core in solenoid the self inductance will be increased. So current (↓) bulb will be dimmer.

Que A rectangular coil P is moved from point A to another point B with uniform velocity (v) through a region of uniform magnetic field acting normal inwards as show in fig show graphically?

Ans

(a) Variation of a induced emf across point x & y of coil with time.?



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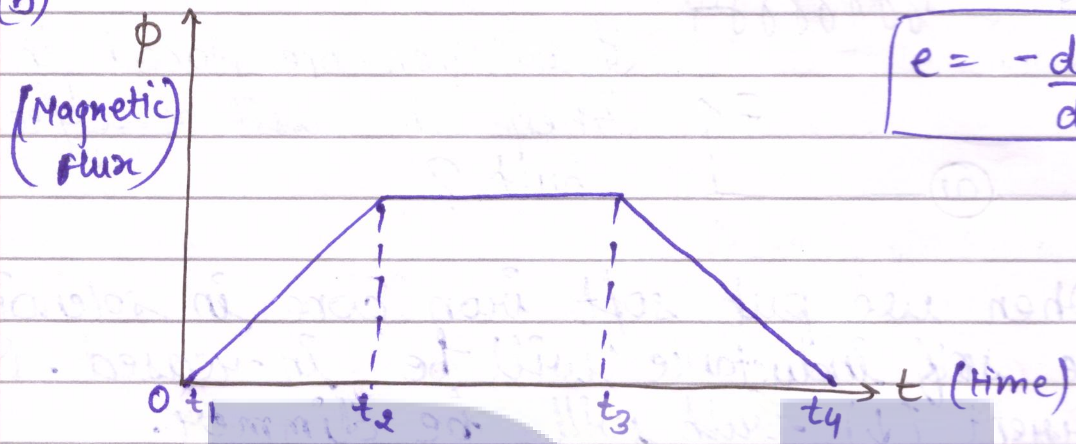
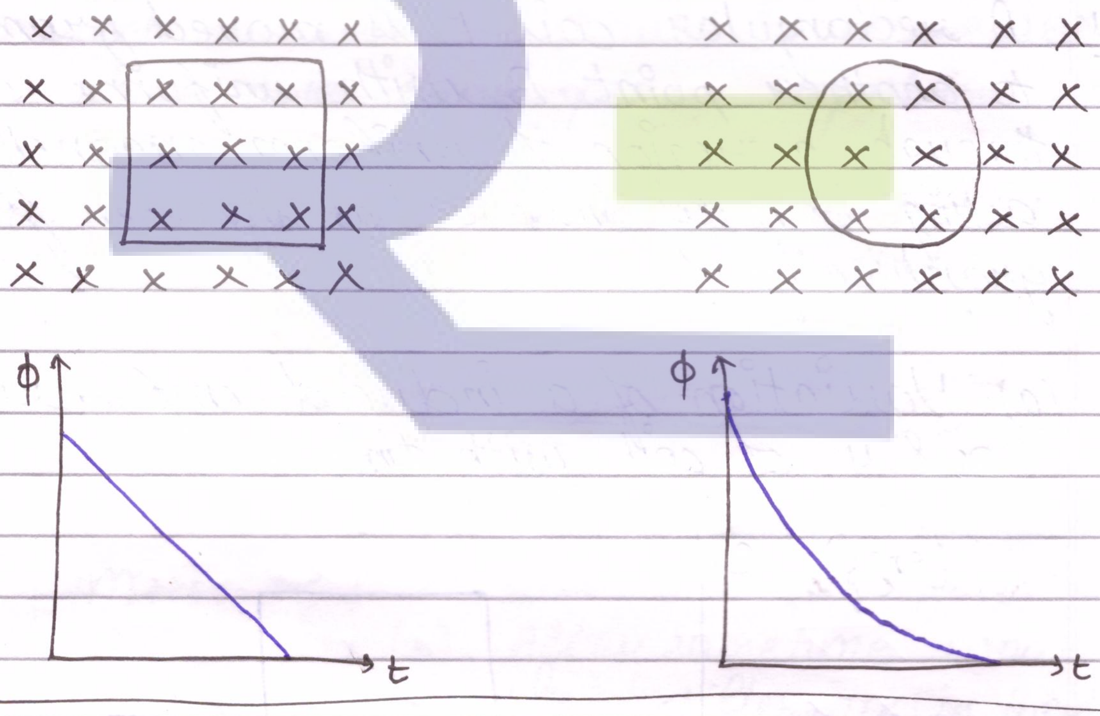
(b) Variation of magnetic flux associated with coils with time?

(b)

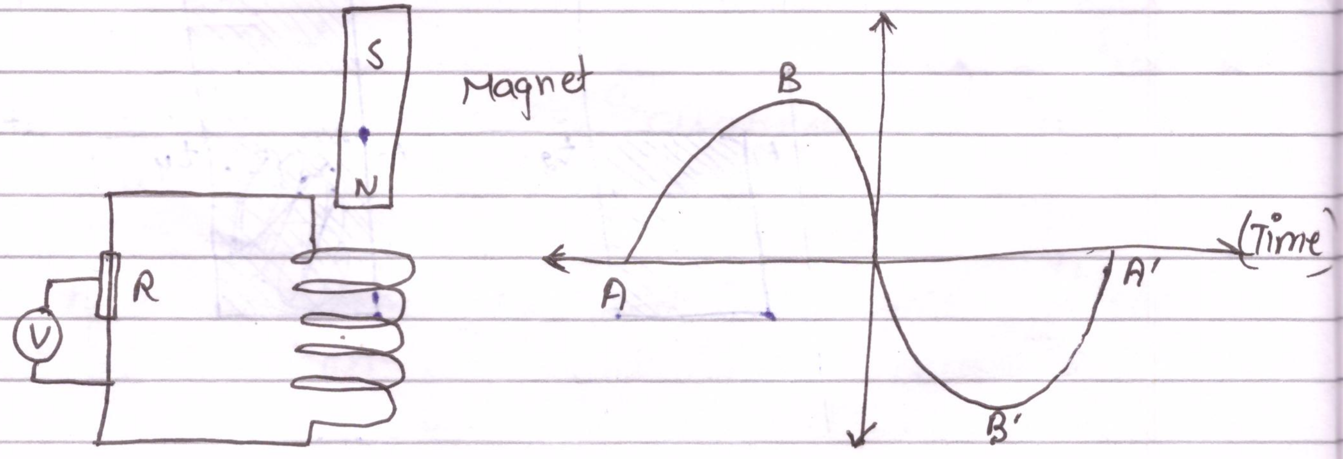


$$e = -\frac{d\phi}{dt}$$

(C)



Qu



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Explain the shape of graph ?

Ans: (i) As the magnet falls towards the coil flux linked with coil increased due to this emf induced.

The emf induced increases till magnet reach the top of coil at this point emf gets its maximum values.

(ii) Magnet starts moving through coil flux (↓) induced emf will also decreased.

When magnet moves completely inside the coil flux linked with coil starts increasing the induced current / emf also increases

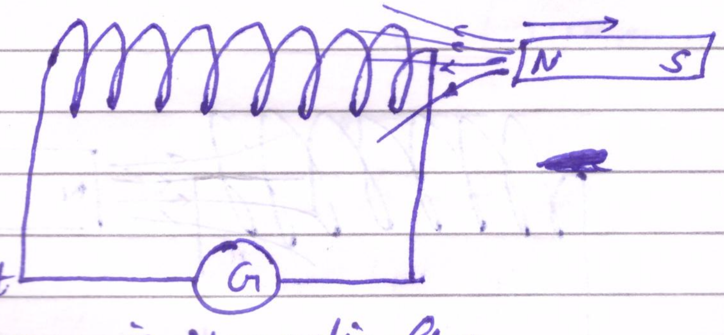
But in opposite direction. The Induced emf attain its maximum values when magnet first move out of coil.

As magnet move away from coil. Magnetic flux (↓) induced emf (↓).

Lenz's Law

According to this law direction of Induced Current is such that it opposes the Magnetic flux for its production charge

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



-ve sign shows that Induced current is oppose the charge in Maggnetic flux

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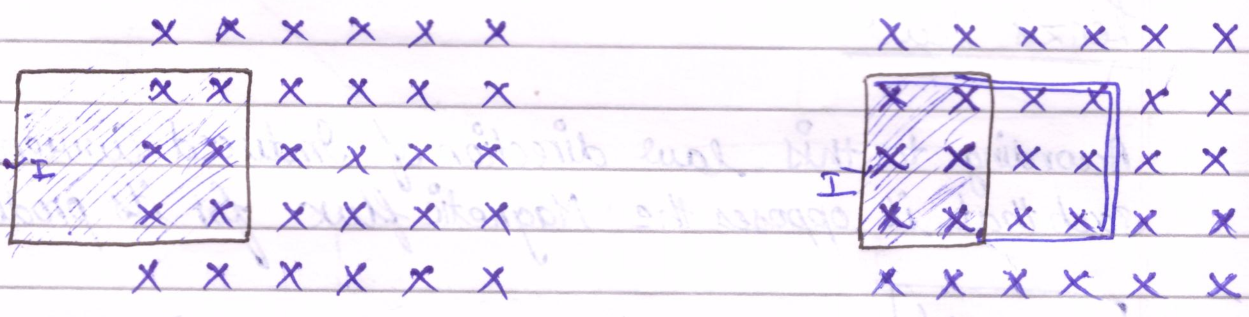
C-1 - When Magnet approach the coil, Magnetic flux increase due to Induced emf occur in coil, Induced current formed. So, (N) pole will form, (repulsion will occur) & anticlockwise current formed.

C-2 - When Magnet away from coil, Magnetic flux decreases. So, Induced current in such a way, due to oppose change in Magnetic flux So, (S) pole formed, (attraction will occur) and clockwise current formed.

Various Methods of producing EMF

1. By changing the magnitude of Magnetic Field (B).
2. By changing the Area.
3. By changing angles (θ) between direc^n of (B). & moving of surface Area (A). [orientation change].

1)



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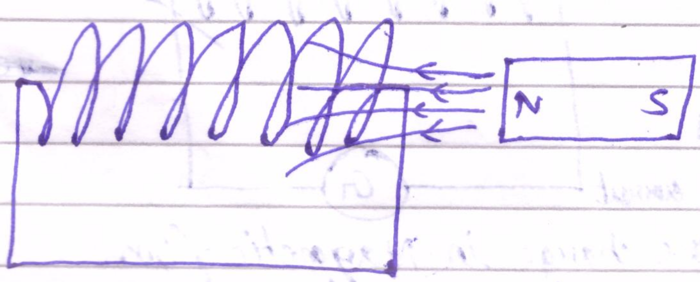

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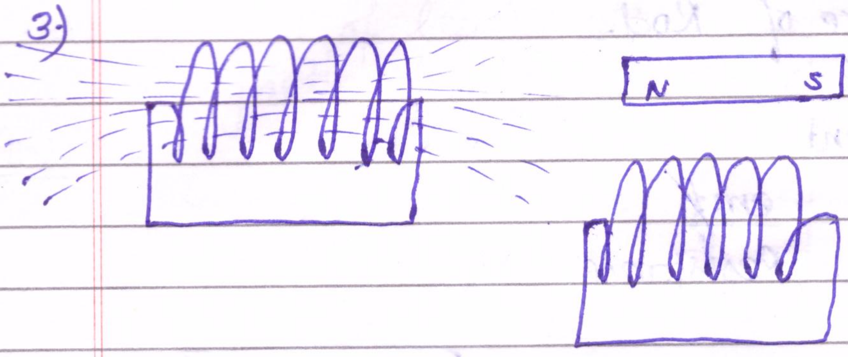
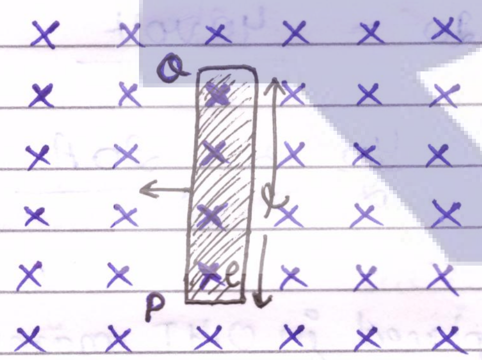


★ Motional Electromotive force [Motional EMF]

when a conducting rod is moved through a constant Magnetic field, an emf is Induced in rod, this is called "Motional Electromotive force"



Let PQ is rod of length (l) move with velocity (v) in magnetic field (B)

When charge move through P to Q.

work → $w = f \cdot d$

$\because [\theta = 90^\circ]$ $w = [qvB\sin\theta] d$

$w = [qvB\sin 90^\circ] l$

$\boxed{w = qvBl}$

Induced emf $= \frac{w}{q}$

$= \frac{qvBl}{q} \Rightarrow \boxed{e = Blv}$

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If 'R' is Resistance of Rod.

$$R = \frac{emf}{current}$$

$$Current = \frac{emf}{Resistance}$$

$$I = \frac{e}{R} = \frac{Blv}{R} \Rightarrow \boxed{I = \frac{Blv}{R}}$$

Ques A rod of length 5m move with 20m sec^{-1} in 0.4T . how much emf Induced & reduced current . If resistance of rod is 2Ω ?

Ans $l = 5m$, $v = 20m/sec$, $B = 0.4T$

(a) $e = Blv = 5 \times \frac{0.4}{10} \times 20 = 40 \text{ volt}$

(b) current , $I = \frac{Blv}{R} = \frac{40}{2} = 20A$

Ques A rod of length 5m , placed in 0.4T magnetic field. having 4A current how much force it act.

Ans

As we know that,

$$F = BIl\sin\theta$$
$$= BIl\sin 90 \quad [\theta = 90]$$
$$= BIl$$

$$= 0.4 \times 5 \times 4$$

$$\boxed{F = 8N}$$

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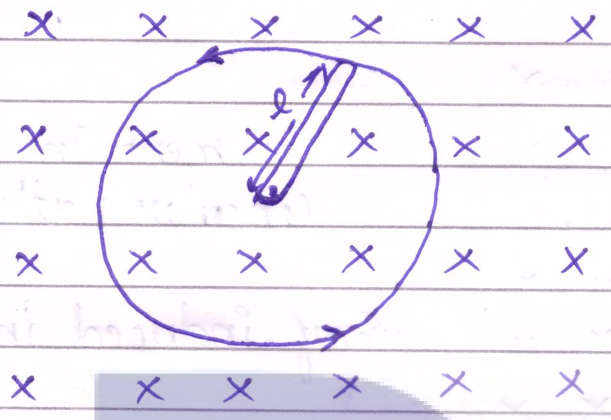
Ques: A Rod of length (l) moving in circular path in magnetic field & find the induced emf?

Ans:



(i) $e = Blv$

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

As we know,

$v = r\omega$

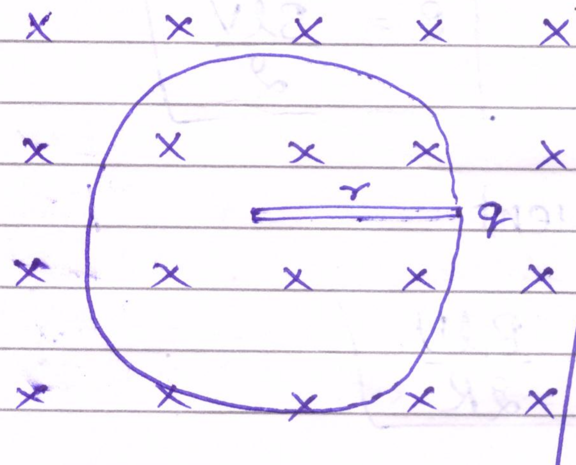
$v = r \times \frac{2\pi}{T}$

$e = Blv$

$$e = Bl\left[r \times \frac{2\pi}{T}\right]$$

Ques A charge particle is moving in Magnetic Field (B) with velocity (v) and radius (r), find the Magnetic moment?

Ans



$M = NIA$ $[N = 1]$

$M = IA$

$I = \frac{q}{t}$

$t = \frac{d}{v} = \frac{2\pi r}{v}$

$I = \frac{qv}{2\pi r}$

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$$m = \left[\frac{qv}{2\pi r}\right]\pi r^2$$

Ques:

Movement in circular Path ?

emf induced in rod ?

Sol:

$$e = \frac{\phi}{t} = \frac{BA}{t}$$

$$v = r\omega$$

$$v = r \times 2\pi\nu$$

$$v = r \times 2\pi \frac{1}{T}$$

$$T = \frac{2\pi r}{v}$$

$$e = \frac{BA}{r \times \frac{2\pi}{v}}$$

$$e = \frac{BAv}{2\pi r}$$

[r = l]

$$e = \frac{B\pi l^2 v}{l \times 2\pi}$$

$$e = \frac{Blv}{2}$$

Induced Current

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

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[Energy conduction in Motional Emf]

Let PQ is length of rod (l) having resistance (r)

Current Induced in loop → $I = \frac{e}{r} = \frac{Blv}{r}$

Magnitude of force on conductor (PQ) moving in Magnetic field:

$$F = BIl$$

$$F = B\left[\frac{Blv}{r}\right]l$$

$$\boxed{F = \frac{B^2l^2v}{r}}$$

Power required to Push conductor with velocity (v)

$$P = F \times v$$

$$P = \left[\frac{B^2l^2v}{r}\right] \times v = \frac{B^2l^2v^2}{r}$$

$$\boxed{P = \frac{B^2l^2v^2}{r}}$$

(1) $= e = Blv$

(2) $= I = \frac{e}{R} = \frac{Blv}{R}$

(3) $f =$ ~~Bil~~ $BIl = B\left[\frac{Blv}{R}\right]l = \frac{B^2l^2v}{R}$

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

(4) $P = fv \Rightarrow \boxed{P = \left[\frac{B^2l^2v}{R}\right]v = \left[\frac{B^2l^2v^2}{R}\right]}$

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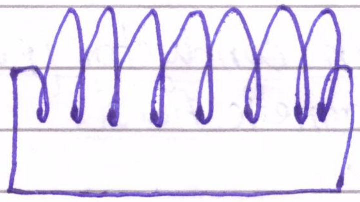
Self Inductor (L)

It is a property of coil by virtue of which the coil opposes any change in the strength of current flowing through it by inducing emf in itself.



Let I is current in coil
Let ϕ is magnetic flux linked with coil.

$$\phi \propto I$$

$$\boxed{\phi = LI}$$

$L \longrightarrow$ Self Inductance

$$e = -\frac{d\phi}{dt} \Rightarrow -\frac{d(LI)}{dt} \Rightarrow \boxed{e = -L\frac{dI}{dt}}$$

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

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

Unit: $L = \frac{\text{volt} \times \text{sec}}{\text{Ampere}} \Rightarrow [\text{volt sec } A^{-1}]$

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Henry (H) $\Rightarrow$ $H = \text{volt sec } A^{-1}$

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

$$L = -e \times \frac{1}{q}, \quad q = \frac{I}{t}$$

$$H = \text{volt } C^{-1}$$

Dimension of (L)

$$H = \text{volt} \times C^{-1}$$

$$V = Ed = \frac{f}{q} \times d$$

$$V = \frac{MLT^{-2}}{AT} \times L \Rightarrow [ML^2T^{-3}A^{-1}]$$

$$H = ML^2T^{-3}A^{-1} \times [AT]^{-1}$$
$$= ML^2T^{-3}A^{-1} \cdot A^{-1}T^{-2} \Rightarrow ML^2T^{-4}A^{-2}$$

$$H = [MA^{-2}L^2T^{-4}]$$

Ques: What is the emf will be increased in 10H inductance in which current change from 10A to 7A in 9×10^{-2} sec?

Ans

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

$$e = -L\left(\frac{I_2 - I_1}{t}\right) \Rightarrow -10 \times \left(\frac{10-7}{9 \times 10^{-2}}\right)$$

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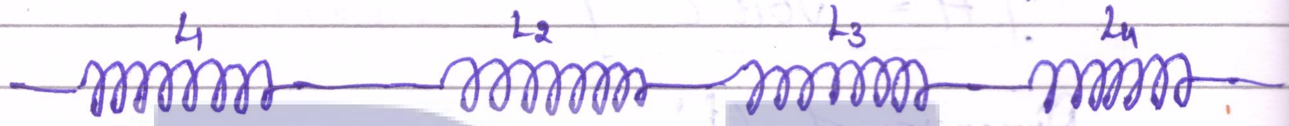
$$e = \frac{10 \times \cancel{3} \times 10^{2}}{\cancel{9}\,3} = \frac{10^3}{3}$$

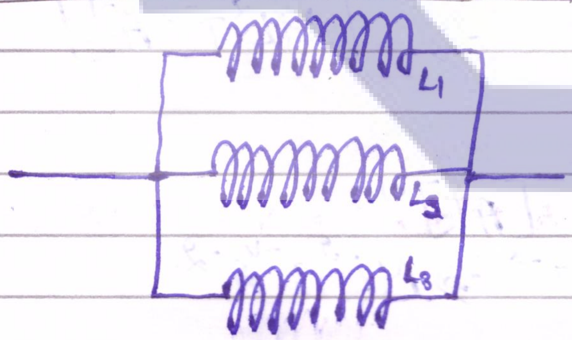
$$\boxed{e = 333.33\ V}$$

① Inductance in Series



$$\boxed{L = L_1 + L_2 + L_3 + L_4}$$

② Inductance in Parallel



$$\boxed{\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{Z_3} + \cdots + \frac{1}{L_n}}$$

Note

Series = $\boxed{L = L_1 + L_2 + L_3 \cdots\cdots L_n}$

Parrallel = $\boxed{\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \cdots + \frac{1}{L_n}}$

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Eddy Current: It is current induced in Bulk piece of conductor when amount of Magnetic flux linked with conductor charges.

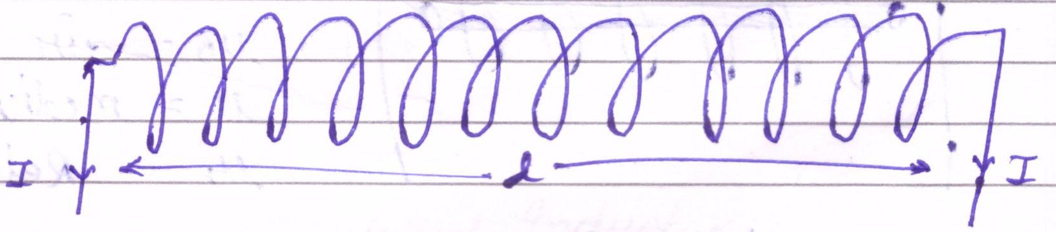
$$I = \frac{e}{R}, \quad \phi = BA, \quad e = -\frac{d\phi}{dt}$$

$$I = -\frac{d\phi}{dt} \times \frac{1}{R}$$

★ Application of Eddy current

1. Electromagnetic damping
2. Induction ~~brake~~ furnance
3. Magnetic Brake
4. Electromagnet meter
5. Induction Motor
6. Speedometer of Automobile
7. Also used in dia-Theory ie deep heat threatnes of human body.

Self Inductance of Long Solenoid



Magnetic field of Solenoid at a point (P)

$$B = \mu_0 n I$$

$$B = \mu_0 \times \frac{N}{l} \times I$$

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$\left[\because n = \frac{N}{l} = \text{No. of turn per unit length}\right]$

Total Magnetic through Solenoid

ϕ = (flux through each turn) x total no of turns

$$\phi = (BA) \times N$$

$$\phi = \left(\frac{\mu_0 N I}{l}\right) \times A \times N$$

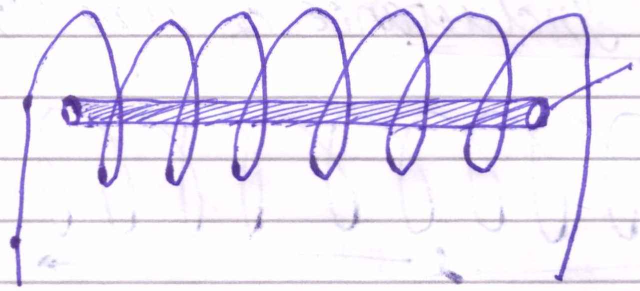
$$\phi = \frac{\mu_0 N^2 I A}{l} \quad \text{------} (1)$$

$$\boxed{\phi = LI}$$

So, $LI = \frac{\mu_0 N^2 I A}{l}$

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

Note



μ_0 = air
μ = medium
μ_r = Relative

$$L' = \frac{\mu N^2 A}{l} \quad [\mu = \mu_0 \times \mu_r]$$

$$L' = \frac{\mu_0 \times \mu_r \times N^2 A}{l} \Rightarrow \boxed{L' = \mu_r \times L}$$

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Ques What is Self Inductance of Solenoid length 40 cm Area is 20 cm² & If total no. of turn 8000?

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

$= \left[\frac{4\pi \times 10^{-7} \times (8000)^2 \times 20 \times 10^{-4}}{40 \times 10^{-2}}\right]$ ----- Δ

Note:

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

$L \propto N^2$

$$\frac{L_1}{L_2} = \frac{N_1^2}{N_2^2}$$

Ques One solenoid have self Inductor is 100H when No. of turn 20. what will be

$\frac{L_2}{L_1} = \left(\frac{N_2}{N_1}\right)^2$ $L_1 = 100H$, $N_1 = 20$
$L_2 = ?$, $N_2 = 50$

$$L_2 = \left(\frac{50}{20}\right)^2 \times 100$$

Mutual Inductance

It is property of coils by virtue of which each opposes any charge in strength of current flowing through the other by developing an opposing emf.

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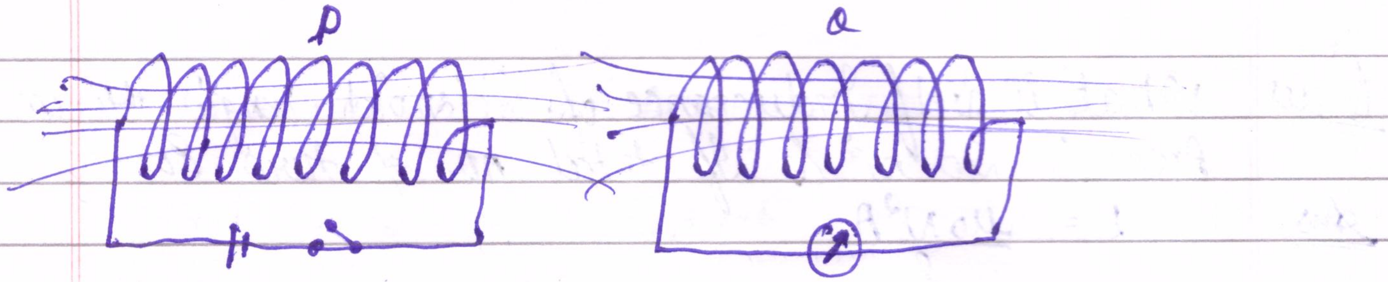

Mutual Inductance

It is property of two coils by virtue of which each opposes any charge in strength of current flowing through the other by developing an opposing emf.

$\phi \Rightarrow$ Magnetic flux.

$\phi \propto I$

$\phi = MI$ [$\because$ M $\to$ Mutual Inductance]

$e = -\frac{d\phi}{dt} \Rightarrow \frac{-d(MI)}{dt} = \frac{-MdI}{dt}$

$$\boxed{e = -\frac{MdI}{dt}}$$

Unit : $M = \frac{e\,dt}{dI}$ M = unit = henry (H)

$M = \left[\frac{volt \times sec}{Amp}\right]$

$$\boxed{H = volt \times sec \times Amp^{-1}}$$

$$\boxed{H = weber\ Amp^{-1}}$$

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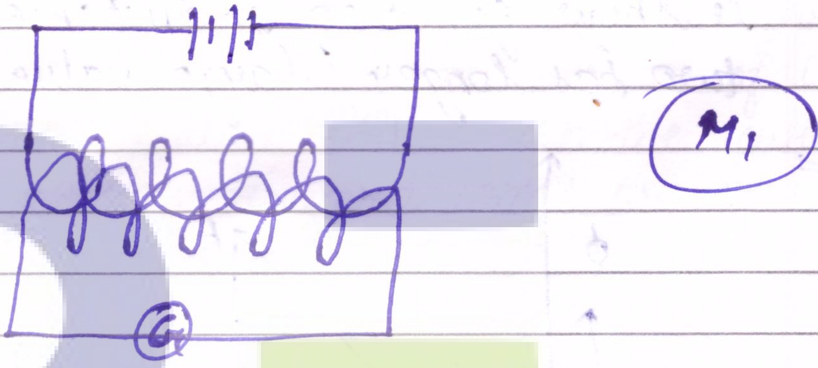
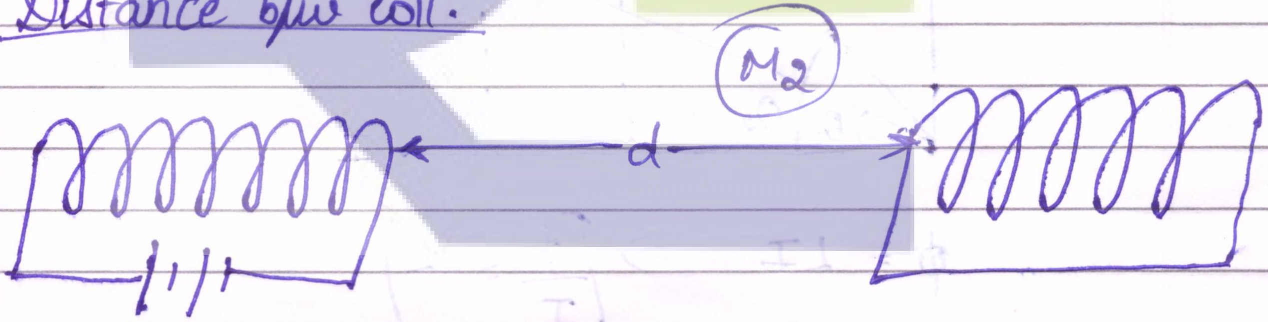
Coefficient of Mutual Inductance of two Coil depend on

① **Geometry of coil :**

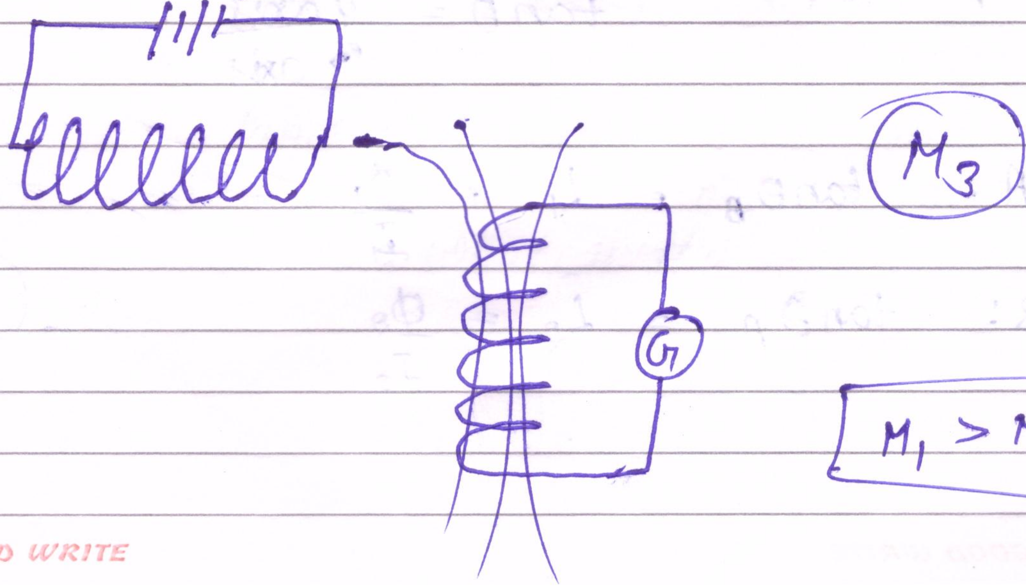
→ Size of Coil
→ No. of turns
→ Nature of Material



② **Distance b/w coil.**



③ **Orientation of coil**



$M_1 > M_2 > M_3$

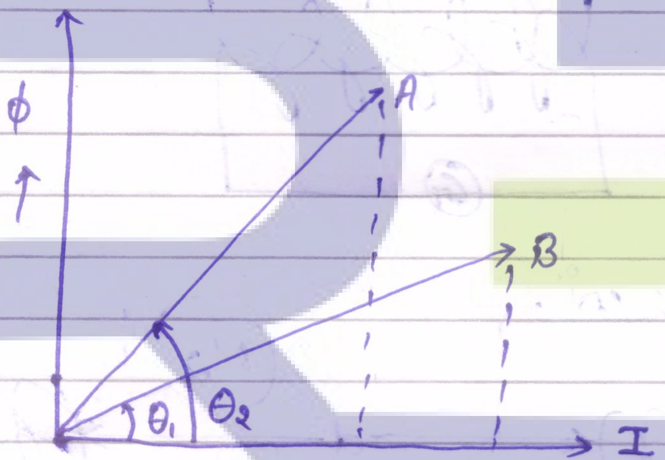
Coefficient of Coupling (K)

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

$$K < 1$$

Ques A plot of Magnetic flux (ϕ) induced current (I) is show for two Inductance (A) & (B) which of two has longer / large value of Self Inductance?

Ans



$$\phi = LI \Rightarrow \frac{\phi}{I} = L$$

Shape of Graph

$$\tan\theta = \frac{y \text{ axis}}{x \text{ axis}}$$

A : $\tan\theta_B = L_1 = \frac{\phi_1}{I_1}$ ——— (1)

B : $\tan\theta_A = L_2 = \frac{\phi_2}{I_2}$ - - - (2)

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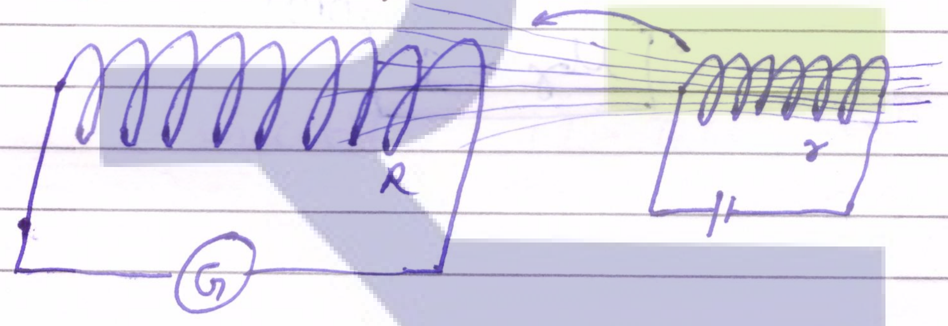
$Q_B > Q_A$

$$L_B > L_A$$

Qus A Large circular coil of radius R & a small circular coil of radius (r) are put in vicinity of each other. If coefficient of Mutual Inductance of this pair equals 1mh. What would be flux linked with longer coil when a current of 0.5 A flows through the smaller coil. When the current in smaller coil falls to zero. what would be its effect the longer coil.

Ans



$M = 1mh = 10^{-3} H$

$\phi = ?$ $\qquad \phi = MI$

$$\phi = 10^{-3} \times 0.5 \text{ weber}$$

Ques Self Inductance of an air core Inductor increases from 0.01H to 10 mH. When an Iron core is introduced in it. What is the relative pervitivity of Core?

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Ans $0.01\,H \longrightarrow 10\,mH$

$\mu_r = ?$

$L_0 = \frac{\mu_0 N^2 A}{l}$

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

$$\boxed{L' = \mu_r \times L_0}$$

$10 \times 10^{-3} = \mu_r \times 0.01$

$\mu_r = \frac{10 \times 10^{-3}}{0.01} \times 10^2$

$$\boxed{\mu_r = 1}$$

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