4: ELECTROMAGNETISM

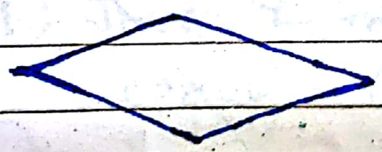
Magnet: The material having property of attracting iron pieces known as magnet.

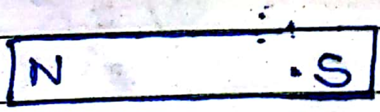
Types of magnet:

1. Permanent Magnet: It retain their magnetism over a long period of time

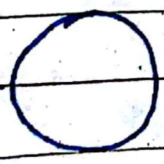
2. Temporary magnet: It retain their magnetism under certain conditions like in the presence of strong magnet or passing electric current around the magnetic material.

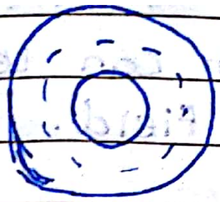
Types of magnets on basis of their shape

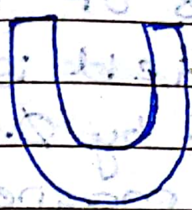
1.  Magnetic Needle

2. 

Bar Magnet

3.  Disc Magnet

4.  Ring Magnet

5.  Horse Shoe Magnet

* Properties of Magnet

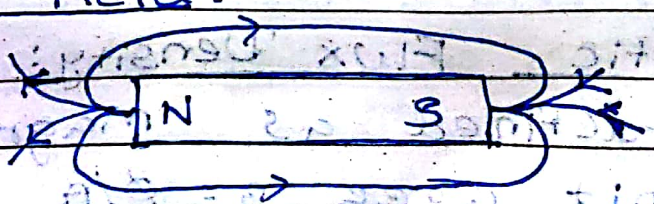
- For every magnet their are two ~~people~~ poles (North and South). So the magnet is known as dipole

- The magnet is always align in north south direction

- The line of force move from north to south outside the magnet and from south to north inside the magnet.

- Like pole repel each other and unlike pole attract each other.

Magnetic Field:



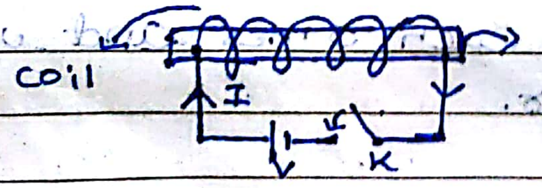
- The area around a magnet where the effect of magnetic force produce by magnet can be detected is known as magnetic field.

* **Magnetic Flux:** The total number of magnetic lines of force in magnetic field is known as magnetic flux. It is denoted by ϕ. unit of mf is weber (1 weber = 10^8 magnetic lines).

⇒ **Characteristic of Magnetic Flux lines:**

- They have no physical existence.
- They form close path
- They never touch/intersect each other
- Lines of magnetic flux closer to each other and having same direction repel each other
- Lines of magnetic flux closer to each other and having opp direction attract each other.

* **Electromagnet:** An electromagnet is a iron core around which coil is wound when current is passed through a coil the core is magnetize temperory.



coil is wound over iron core.

* **Magnetic Flux Density:**
It is defined as "Magnetic flux per unit area $B = \phi / A$ wb/m^2 or Tesla (T)

* Magneto Motive Force (mmf)

- It is defined as force which established flux through circuit.

$$mmf = N \times I$$

N → Number of turns, I → Current

- Magneto motive force is analogist to emf in electric circuit.

* Magnetic field intensity (H):

- It is defined as mmf per unit length of magnetic flux path and is denoted by H.

$$H = \frac{mmf}{l} = \frac{NI}{l} = \frac{AT}{m} \rightarrow \text{unit}$$

* Permiablity (μ)

- It is the ability of magnetic material to establish magnetic flux through it.

$$\mu = \mu_0 \mu_r$$

where $\mu_0 = 4\pi \times 10^{-7}$ H/m

* Relative permiability

It is defined as the ratio of flux density produce in the material to flux density in vaccum

* Reactance

It is defined as opposition offered by magnetic circuit to the establishment of magnetic flux and is denoted by S.

$$S = \frac{l}{\mu_0 \mu_r A} \frac{AT}{Wb}$$

* **Permeance**

- It is define as reciprocal of reluctance.

$$\text{Permeance} = \frac{1}{\text{reluctance}}$$

Permeance is ~~analogist~~ analogous to conductance in electric circuit.

* **Reluctivity**

- Reluctivity or specific ~~resistance~~ reluctance is defined as reluctance offered by magnetic circuit of $l = 1m$ & $A = 1m^2$.
- Reluctivity or specific ~~resist~~ reluctance

$$= \frac{l}{\mu \times A} \quad \text{if } l = 1m \text{ and } A = 1m^2$$

$$=$$

- Reluctivity is analogist to resistivity in electric circuit.

Relation b/w B & H

- B is directly proportional to H

$B \propto H \Rightarrow B = \mu H$

* **Classification of Magnetic Materials**

Magnetic material are classified acc to their relative permeablity

i) Ferromagnetic: Their relative permeablity is greater than unity and depends on field strength. This materials can be easily magnetised.

eg:- Iron, Cobalt, nickel

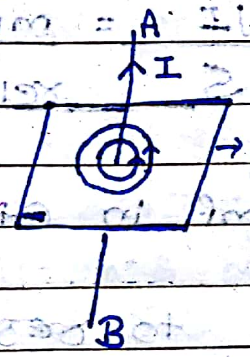
ii) Paramagnetic: Relative permiablity is greater than 1 and are sightly magnetised.
eg: Al, Platinum etc.

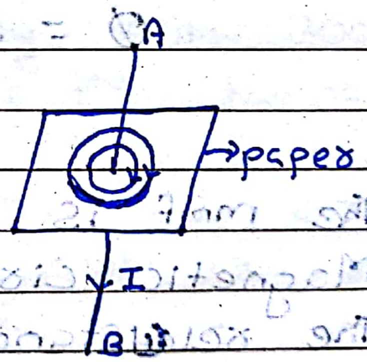
iii) Diamagnetic: Relative permiablity is slightly < 1 and have opposite effect of paramagnetic material.
eg:- Ag, Cu etc.

* Magnetic field due to current carrying conductor

- Direction of magnetic field produce by current carrying conductor can be found using right hand ~~rule~~ thumb rule.

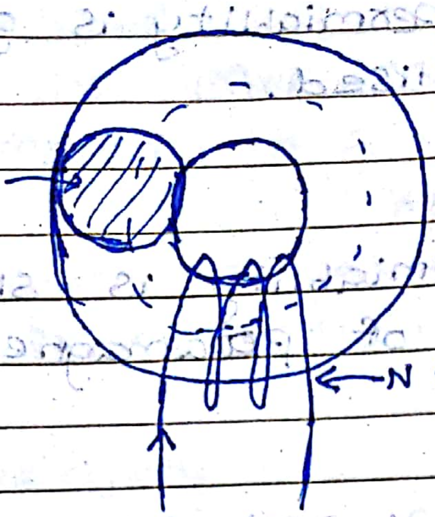
RHL → Hold the conductor in right hand in such a way that thumb indicates direction of flow of current, and bend fingers indicates direction of magnetic field.





* Analysis of Magnetic Circuit

- A simple magnetic circuit is made up of single magnetic material.



$$B = \frac{\phi}{A}$$

$$\Rightarrow \phi = B \cdot A$$

$$\phi = \mu H \cdot A$$

Also,

$$H = \mu_0 \mu_r \frac{NI}{l} \times A$$

Current $I = \frac{V}{R} = \frac{emf}{Resistance}$

$$\Rightarrow \phi = \frac{mmf}{reluctance}$$

$$\phi = \frac{NI}{l/\mu_0 \mu_r A} = \boxed{\frac{NI}{S} = \frac{mmf}{reluctance}}$$

The mmf is analogous to emf in ~~electrics~~ Magnetic circuit
The reluctance is analogous to resistance and flux is analogouls to current, so it is known as ohms law of magnetic circuit.

* **Leakage Flux:** Magnetic flux which doesnot follow the desire path in magnetic circuit is known as leakage flux. When a current is passed through a coil, magnetic flux ϕ is set, most of

the flux is set in desire path, but some of the flux is set around the coil. This flux is not utilised for any work. So it is known as leakage flux.

$$\phi = \phi_l + \phi_u$$

leakage flux — ϕ_l; Usefull flux — ϕ_u.

* Leakage coefficent (λ) / Hopkinson's leakage coeff.:

$$\lambda = \frac{\text{total flux}}{\text{Usefull flux}} = \frac{\phi_l + \phi_u}{\phi_u}$$

It's value lies between 1.1 - 1.25

Q- A coil is wound uniformly with 300 turns over a sealed ring of $\mu_r = 900$ having ring diameter, d = 20cm. The steel ring is made up of bar having cross-section of diameter 2 cm. If the coil has resistance of 50Ω and is connected to 250V DC supply, Calculate:

i) The magneto moving force
ii) Field intensity in ring.
iii) Reluctance of magnetic path
iv) Total flux
v) Permeance

i) ~~mmf = 300 × 5 × 900×~~

=

i) mmf = NI

$= 300 \times 5$

$= 1500$ A

ii) $H = \frac{NI}{l} = \frac{NI}{2\pi r} = \frac{1500}{2\pi r} = 2387.32$ AT/m

iii) $S = \frac{l}{\mu_0 \mu_r A} = \frac{2\pi r}{\mu_0 \mu_r \times A} = \frac{2 \times \pi \times 1 \times 10^{12} \times 10/\times 10}{4\pi \times 10^{-7} \times 900 \times 8.88 \times \pi \times 1 \times 1}$

$= 17.684 \times 10^5$ AT/wb

iv) $\phi = \frac{mmf}{S} = \frac{1500}{17.684 \times 10^5} = 0.848$ mwb

v) Permeance $= \frac{1}{S} = 5.655 \times 10^{-7}$ wb/AT

* Electromagnetic Induction

The process of generation of emf and production of current by changing the magnetic flux is known as electromagnetic induction

* Laws of electromagnetic induction

i) Faraday's law

ii) Fleming's right hand rule

iii) Lenz's law

i) Faraday's 1st Law: Whenever magnetic flux linked with the coil changes, an emf is induced in the coil.

ii) The Faraday's 2nd Law: The magn of induced emf in a coil is equal to rate of change of flux.

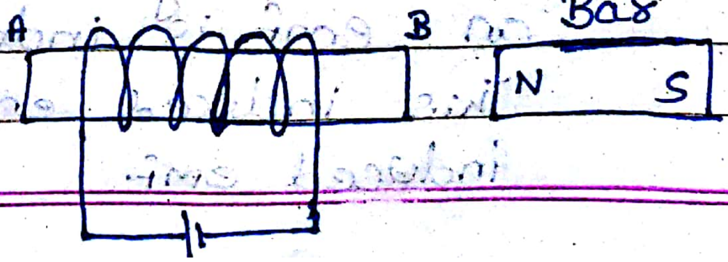
$$e = \frac{N(\phi_2 - \phi_1)}{t}$$

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

ii) Fleming right hand rule:
This rule can be applied when the conductor is moving across the field.
1st finger, 2nd finger and thumb of right hand are mutually perpendicular to each other. If 1st finger indicates direction of magnetic field, thumb indicates direction of motion of the conductor then the 2nd finger will indicate direction of induced emf in the conductor.

iii) Lenz's Law: This law is applied when the flux linked with the coil changes. The induced emf and current flows in the coil in such a direction that magnetic field opposes the cause which produces it.

Explaination:



When North pole of bar magnet is taken nearer to the coil, current is flowing in coil in such a way that side b of coil attains North polarity which opposes the movement of bar magnet.

When North pole of bar magnet is taken away from the coil, current is flowing in such a way that side b of the coil attains South polarity which again opposes the movement of bar magnet.

Types of Induced emf:

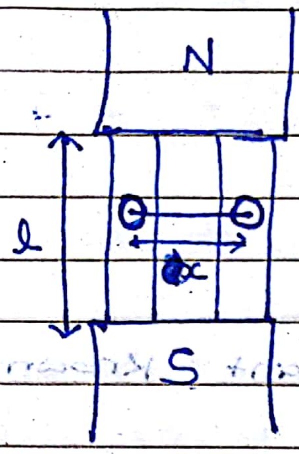
1. Dynamically Induced emf
2. Statically Induced emf
   i) Self induced emf
   ii) Mutually induced emf

1. Dynamically Induced emf: The conductor is moving in stationary magnetic field in such a way that there is change in flux. This type of emf is known as dynamically induced emf.
eg:- Generator.

2. Statically Induced emf:
   When the conductor is stationary and flux linking with the conductor change an emf is induced in conductor. This induced emf is known as statically induced emf.

It can be further classified into:
i) Self Induced emf
ii) Mutually Induced emf

1.



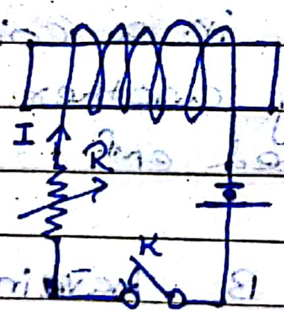
Area covered by conductor
$A = l \cdot dx$

$\therefore \phi = B \cdot A$
$= B \cdot l \cdot x$

$\Rightarrow e = \frac{d\phi}{dt} = B \cdot l \cdot \frac{dx}{dt}$

$\boxed{e = Blv}$

i) When conductor is stationary and magnetic field changes by changing the value of current.



The emf induced in a coil due to change of flux within the coil is known as self induced emf.

explanation: Consider a coil having n turns connected across supply voltage to

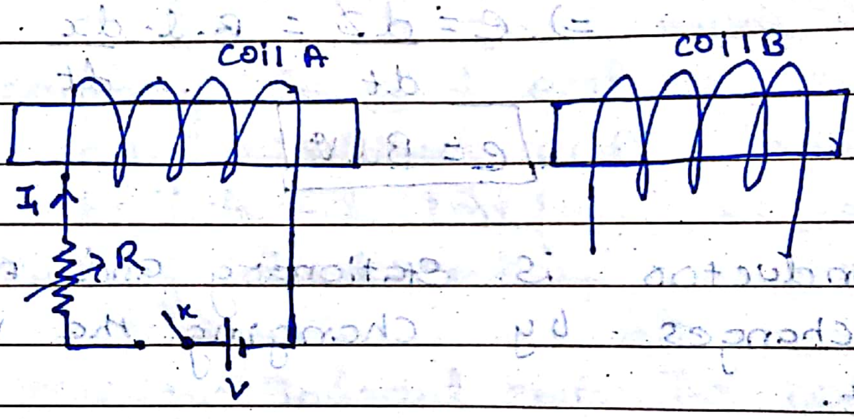
Switch. If the current through coil is changed by changing the value of R the flux linking with the coil also changes. This change in flux induces emf in coil which is known as Self induced emf.

$$e \propto \frac{di}{dt}$$

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

where L is constant known as self inductance.

ii)



The emf induced in a coil due to change of flux produced by another coil is known as mutually induced emf.

explanation:

Consider coil B having N_2 turns is placed near coil A having N_1 turns. When the switch K is closed, current i_1 flows through coil A which produces flux ϕ_1. Out of this flux ϕ_1, most of the flux say ϕ_{12} links with coil B. If the current through coil A is changed by changing the value of variable resistor R changes flux linking with coil B. This change in flux in coil B induces emf in coil B. This emf is known as mutually induced emf.

$$e \propto \frac{di}{dt}$$

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

where M = constant is known as mutual inductance

* Comparison of dynamically induced & Statically induced emf:

• ~~The magnetic field is stationary and conductor~~ is moving across the field.

Dynamically	Statically
• The magnetic field is stationary and conductor is moving across the field.	• conductor is stationary and magnetic field changes by changing the value of current
• The direction of induced emf is determined by Fleming's right hand rule.	• The direction of induced emf is determined by lenz law.
• The magn of emf is given by $\boxed{e = Blv\sin\theta}$	• The magn of emf is given by $\boxed{e = N\frac{d\phi}{dt}}$
• Generators works on principle of dynamically induced emf.	• Transformers works on principle of Statically induced emf.

Self Inductance: The property of a coil due to which it opposes the change of current flowing through the coil is known as self inductance.

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

$$= N \cdot \frac{d\phi}{di} \times \frac{di}{dt}$$

$$e = N \cdot \frac{\phi}{i} \times \frac{di}{dt} \quad -①$$

Also

$$e = L \cdot \frac{di}{dt} \quad -②$$

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

$$\phi = \frac{mmf}{S}$$

$$= \frac{NI}{S}$$

$$\Rightarrow \frac{\phi}{I} = \frac{N}{S}$$

$$\Rightarrow \boxed{L = \frac{N^2}{S}}$$

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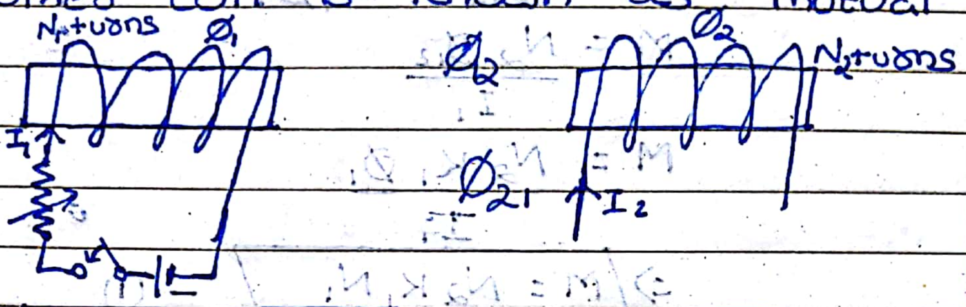
Mutual Inductance (M)

- The property of a coil due to which change of current in one coil induces emf in another coil is known as mutual inductance.



$$\boxed{M = \frac{N_2 \cdot \phi_{12}}{I_1}} \qquad \boxed{M = \frac{N_1 \phi_{21}}{I_2}}$$

- For 100% flux link

$$\phi_{12} = \phi_1$$

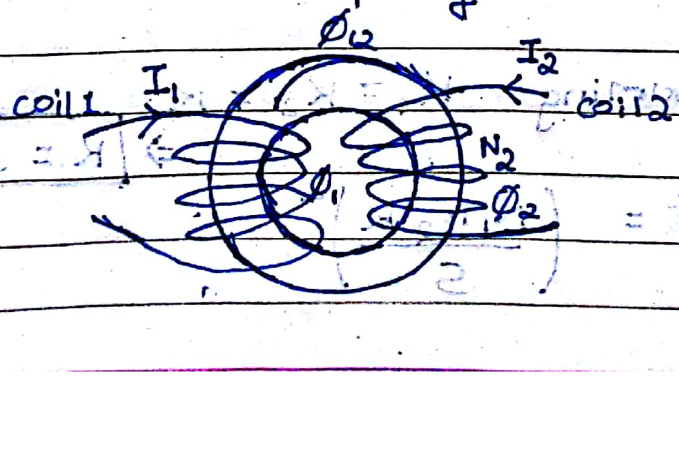
$$\Rightarrow M = \frac{N_2 \cdot \phi_1}{I_1}$$

Also, –

$$\phi_1 = \frac{N_1 I_1}{S}$$

$$\Rightarrow \boxed{M = \frac{N_1 N_2}{S}}$$

* Coefficent of Coupling



$$\phi_1 = \frac{N_1 I_1}{S} \qquad K_1 \le 1$$

$$\cancel{M = \frac{N_2 N_1 K_1}{S}}$$

$$\phi_{12} = K_1 \phi_1$$

$$M = \frac{N_2 \phi_{12}}{I_1}$$

$$M = \frac{N_2 K_1 \phi_1}{I_1}$$

$$\Rightarrow \boxed{M = \frac{N_2 K_1 N_1}{S}} \quad — ①$$

$$\phi_{21} = K_2 \phi_2 \qquad K_2 \le 1$$

$$M = \frac{N_1 \phi_{21}}{I_2}$$

$$= \frac{N_1 K_2 \phi_2}{I_2}$$

$$\boxed{M = \frac{N_1 N_2 K_2}{S}} \quad — ②$$

Multiplying eqn ① and ②

$$M^2 = \frac{N_1^2 \cdot N_2^2 \cdot K_1 \cdot K_2}{S^2}$$

Assuming $K_1 = K_2 = K$

$$\Rightarrow \boxed{K = \sqrt{K_1 K_2}}$$

$$\Rightarrow M^2 = \left(\frac{N_1 N_2 K}{S}\right)^2$$

$$\Rightarrow \boxed{M = \frac{N_1 N_2 K}{S}}$$

Also,

$$M^2 = \frac{N_1^2}{S} \cdot \frac{N_2^2}{S} \cdot K^2$$

$$M^2 = L_1 \cdot L_2 \cdot K^2$$

$$\Rightarrow \boxed{K^2 = \frac{M^2}{L_1 \cdot L_2}}$$

Note: When $K = 1$ the coils are said to be tightly coupled.
And when $K = 0$ the coils are said to be magnetically isolated from each other.

Q- Flux of 10^{-3} Wb is produce by coil A when it carries current of 4A. Another coil B produces flux of 1.5×10^{-3} Wb having the same current. Coil A has 800 turn and coil B has 1200 turns. The coils are kept such that 80% of the flux, produce by coil A links with coil B. Calculate

i) Self-Inductance of each coil

ii) Mutual Inductance

iii) Coefficent of coupling

iv) % of flux, produce by coil B that links with coil A.

i) $L_1 = \cancel{800 \times 800} \frac{N_1 \times \phi_1}{I_1}$

$= \frac{800 \times 10^{-3}}{4} = 2 \times 10^{-1}$ H

$L_2 = \frac{\overset{300}{\cancel{1200}} \times 1.5 \times 10^{-3}}{\cancel{4}} = 4.5 \times 10^{-1}$ H

ii) $M = 1200 \times \frac{8}{10} \times \frac{10^{-3}}{4} = 24 \times 10^{-2}$ H

iii) $K = \frac{M}{\sqrt{L_1 \cdot L_2}} = \frac{24 \times 10^{-2}}{3 \times 10^{-1}} = 8 \times 10^{-1} = 0.8$

~~iv)~~ $\cancel{K = \sqrt{K_1 K_2}}$

$\cancel{\Rightarrow 0.8 = \sqrt{\quad}}$

$\cancel{K_2 = \frac{\overset{2}{24} \times 10^{-2} \times 4}{\frac{1200}{100} \times 800 \cdot 200} = 10^{6}}$

iv) $0.8 = \sqrt{0.8 \times K_2}$

$\Rightarrow K_2 = 0.8$

$\Rightarrow 80\ \%$

Q- Coil A and B with 50 and 500 turns resp are wound side by side on a close iron circuit of cross-section 50 cm^2 and mean length of 1.2 m. Estimate
i) L of each coil
ii) M between the coils.
iii) emf induced in coil A if the current in coil B increases steadily from 0-5 A in 0.01 sec. Assume $\mu_r = 1000$

i) $L_1 = \frac{N_1^2}{S}$

$$S = \frac{1.2}{10^3 \times \cancel{8.85 \times 10^{-12}} \times 50 \times 10^{-4} \times 4\pi \times 10^{-7}}$$

$$= \frac{1.2 \times 10^{7}}{\cancel{8.85} \times 5 \times 4\pi} = \cancel{2.71 \times 10^{10}} = 1.9 \times 10^5$$

$$L_1 = \frac{50 \times 50}{\cancel{2.71 \times 10^{10}} 1.9 \times 10^5} = \cancel{9.22 \times 10^{-8}} \quad 13.15 \times 10^{-3}\ H$$

$L_2 = \cancel{9.22 \times 10^{-6}} \quad 1.315\ H$

ii) $M = \frac{N_1 N_2}{S} = \frac{25000}{\cancel{2.71 \times 10^{10}} 1.9 \times 10^5} = \cancel{9.22 \times 10^{-7}} \quad 13.15 \times 10^{-2}\ H$

iii) $\frac{di}{dt} = \frac{5}{10^{-2}} = 5 \times 10^2 \Rightarrow E = 65.5$ ✓

$\cancel{\Rightarrow e = 9.22 \times 10^{-7} \times 5 \times 10^2 = 4.61 \times 10^{-5}}$

Q- $N_1 = 250$

$I_1 = 2A$

Flux $= 0.3\ mWb = 3 \times 10^{-4}\ Wb$

$\frac{dI_1}{dt} = \frac{2A}{2msec} = 10^3\ A/S.$

Voltage induced $= 63.75V = e_{m_2}$

$K = 0.85$

Find i) Self inductance of two coils.

ii) mutual inductance

iii) no of turns in 2^{nd} coil

$L_1 = \cancel{\frac{250 \times 250}{}}\ \frac{250 \times 3 \times 10^{-4}}{10^3}$

$= 75 \times 10^{-6}$

$63.75 = L_2 \times 10^3$

$L_2 = 63.75 \times 10^{-3}$

$M = \frac{N_1 N_2 K}{S}$

$= 0.06375$

$63.75 \times 10^{-3} = N_2 \times$

$L_1 = \frac{250 \times 3 \times 10^{-4}}{2} = 37.5 \times 10^{-3}\ H$

$e_{M_2} = M \frac{di}{dt} \Rightarrow M \cdot \frac{63.75}{10^3} = 63.75 \times 10^{-3}$

$\frac{N_1 N_2 K}{S} = 63.75 \times 10^{-3} = K\sqrt{L_1 L_2}$

$\cancel{\Rightarrow N_2 = 63.75 \times 10^{-3} \times}$

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$$\Rightarrow \left(\frac{63.75\times10^{-3}}{0.85}\right)^2 \times \frac{1}{37.5\times10^{-3}} = L_2$$

$$L_2 = 150\times10^{-3}\,H$$

$\cancel{150\times10^{-3}} =$

$$M = \frac{N_2\times\phi_{12}}{I_1}$$

$$= \frac{N_2\times k\times\phi_1}{I_1}$$

$$\Rightarrow N_2 = \frac{63.75\times10^{-3}\times2}{0.85\times10^{3}}$$

$$= 500$$

Q- Coil has 480 turns, mean length of 30cm and crosssection area of 5 cm^2. Calculate i) the inductance of coil

ii) Avg EMF induced if current of 4A is reversed in 60msec

Soln:

$N=480$, $l = 30\times10^{-2}$ m, $A = 5\times10^{-4}$ m^2

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

$$= \frac{480\times480}{3\times10^{-1}}\times4\pi\times10^{-7}\times5\times10^{-4}$$

$$= 482.54\times10^{-6}$$

ii) $e = 482.54\times10^{-6}\times\frac{8}{60\times10^{-3}} = 643.38\times10^{-4}$

$4512 = 37.5$

Q- 2 identical coils A & B (consisting of 1500 turn each lies in parallel plane such that 70% of the flux produce by current in coil A links with coil B. Current of 4A flowing in coil A produces flux of 0.04 mWb in coil A. Calculate

i) L of each coil

ii) M

iii) If the current in coil A changes from 4A to -4A in 0.02 sec what will be the emf induced in coil B.

i) $L_A = \frac{1500 \times 0.04 \times 10^{-3}}{4}$

$= 15 \times 10^{-3}$

Also, $L_A = L_B = 15 \text{ mH} = L$

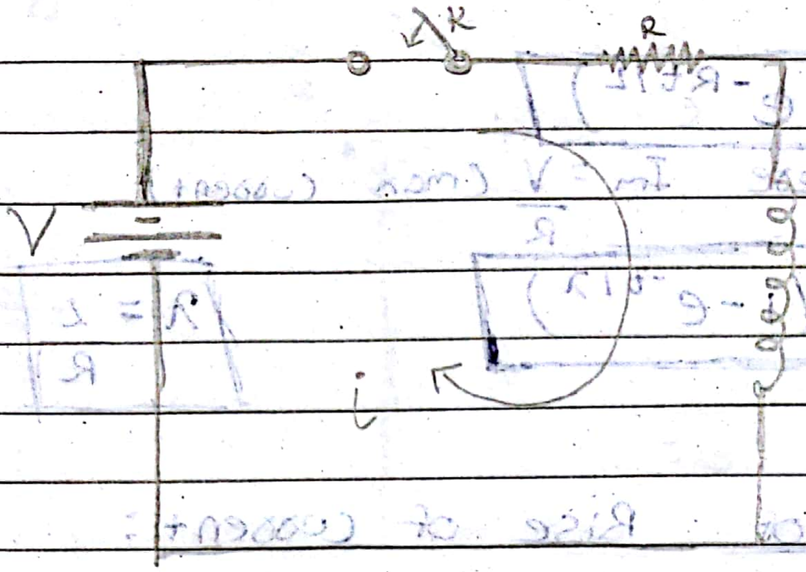
$\Rightarrow M = K\sqrt{L_1 L_2} = KL$

$= 0.7 \times 15 \times 10^{-3}$

$= 10.5 \times 10^{-3} \text{ H}$

$e = \frac{10.5 \times 10^{-3} \times 8}{2 \times 10^{-2}} = 4.2 \text{ V}$

Rise of current in an Inductive circuit



At $t=0$, $i=0$

By KVL

$$V - iR - L\frac{di}{dt} = 0$$

$$V = iR + L\frac{di}{dt}$$

$$V - iR = L\frac{di}{dt}$$

$$\frac{-R\,di}{V-iR} = \frac{-R\,dt}{L}$$

$\Rightarrow$ integrating both sides we get

$$\log(V - iR) = \frac{-Rt}{L} + C$$

At $t=0$, $i=0$

$$C = \log V$$

$$\Rightarrow 1 - \frac{iR}{V} = e^{-Rt/L}$$

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

$$\boxed{i = i_m\left(1 - e^{-Rt/L}\right)}$$

where $I_m = \frac{V}{R}$ (max current)

$$\boxed{i = i_m\left(1 - e^{-t/\lambda}\right)} \qquad \boxed{\lambda = \frac{L}{R}}$$

~~Rise~~ Rate of Rise of current :

$$\frac{di}{dt} = + i_m \times + \frac{R}{L} e^{-t/\lambda}$$

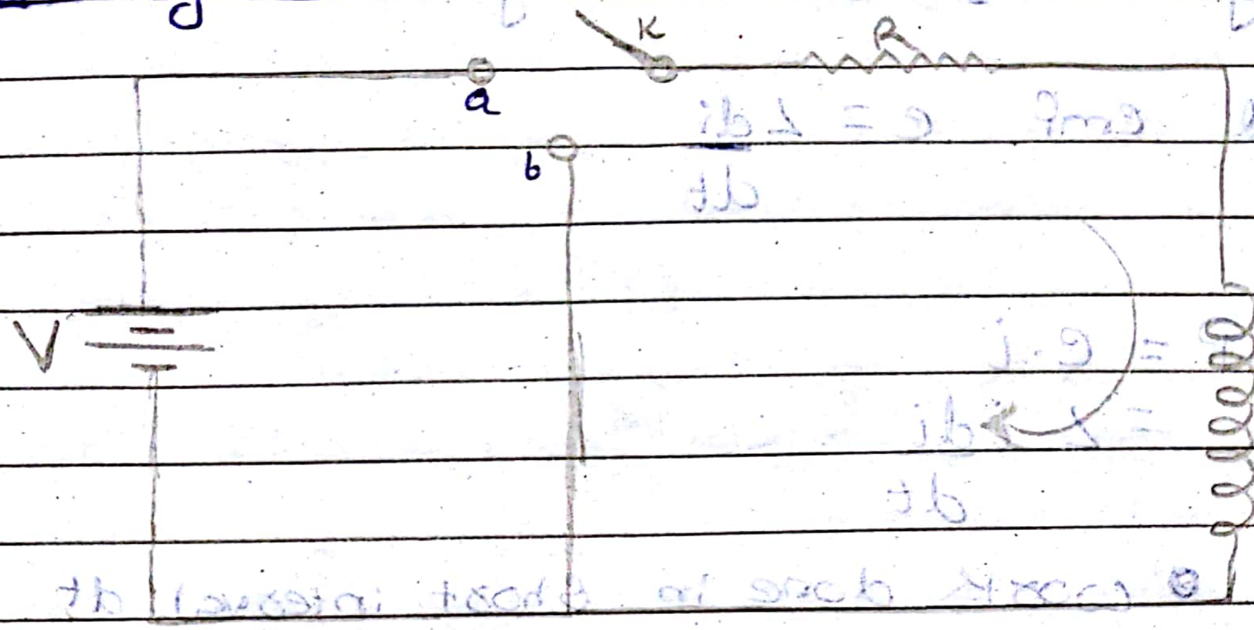
$$= \frac{R \cdot i_m}{L} \times e^{-t/\lambda}$$

At $t = 0$

$$\left.\frac{di}{dt}\right|_{t=0} = \frac{i_m \cdot R}{L}$$

$$= \boxed{\frac{V}{L}}$$

Decay in current in inductive circuit



At $t=0$, $i = i_m = \frac{V}{R}$

By KVL,

$$0 = iR + L\frac{di}{dt}$$

$$\Rightarrow \frac{di}{i} = -\frac{R}{L}dt$$

$$\Rightarrow \log i = -\frac{Rt}{L} + C$$

At $t=0$

$$C = \log i_m$$

$$\Rightarrow i = i_m \cdot e^{-Rt/L}$$

$$\boxed{i = i_m \cdot e^{-t/\lambda}}$$

* Energy Stored in magnetic field

induced emf $e = L\frac{di}{dt}$

$P = e \cdot i$

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

• work done in short interval dt

$dw = L\, i \frac{di}{\cancel{dt}} \cdot \cancel{dt}$

$\Rightarrow dw = L\, i\, di$

$\Rightarrow \boxed{W = \frac{1}{2} L I^2}$

Rise of current :

Q- Coil having resistance of 20Ω and inductance of 12 H is connected to supply voltage of 100V. Find

i) Rate of change of current at the instant of closing the switch

ii) Final steady value of current.

iii) Time constant

iv) Time taken for the current to reach value of 4A

i) $\frac{di}{dt} = \frac{V}{L} = \frac{100}{12} = \frac{50}{6} = \frac{25}{3} = 8.33$ Å/sec

ii) $\cancel{e^{-t/\lambda} = 1}$

$\cancel{\Rightarrow \frac{-t}{\lambda} = 0 \Rightarrow \lambda}$

$i_m = \frac{100}{20} = 5$ Å

iii) $\lambda = \frac{L}{R} = \frac{12}{20} = 0.6$ sec

iv) $4 = 5(1 - e^{-t/\lambda}) \Rightarrow e^{-t/\lambda} = 0.2$

$\frac{t}{\lambda} = 1.609$

$t = 0.965$ sec

Q- D.C Voltage of 120V is applied to a coil having $R = 8\Omega$ and $L = 12H$. Calculate:

i) Value of current 0.3 sec after switching on the supply.

ii) With the current having reached the final value how much time it would take for the current to reach value of 6 Å after switching of the supply.

i) $I = \frac{120}{8}\left(1 - e^{-0.3/1.5}\right) = 2.71$ Å

ii) $6\text{Å} = \frac{120}{8} \times e^{-t/1.5} \Rightarrow t = 1.374$ sec.

Q- Circuit of resistance r and inductance L has direct voltage of 230 V, after switching on the current in the circuit, it was found 5 A when t = 0.3 sec. After the current had reached its final value, the circuit was suddenly short circuited. The current was again found to be 5A at point t = 0.3 sec after short circuiting the coil. Find the values of R and L.

$V = 230\,V$

$$5 = \frac{230}{R}\left[1 - e^{-0.3/\lambda}\right] \qquad 5 = \frac{230}{R} \cdot e^{-0.3/\lambda}$$

$$1 - e^{-0.3/\lambda} = e^{-3/\lambda}$$

$$1 - e^{-3/10\lambda} = e^{-3/\lambda}$$

$$\log\left(1 - e^{-3/10\lambda}\right) = -\frac{3}{\lambda}$$

$$-\log\left[\frac{e^{+3/10\lambda} - 1}{e^{-3/10\lambda}}\right] = -\frac{3}{\lambda}$$

$$1 - \frac{5R}{230} = e^{-0.3/\lambda}$$

$$\log\left(\frac{230 - 5R}{230}\right) = \frac{-0.3}{\lambda}$$

$1 - e^{-0.3/\lambda} = e^{-0.3/\lambda}$

$\Rightarrow e^{-0.3/\lambda} = \frac{1}{2}$

$\frac{+3}{10\lambda} = 0.693$

$\Rightarrow \lambda = 0.4328 = \frac{L}{R}$

$5 = \frac{230}{R}\left[1 - e^{-0.3/0.432}\right]$

$5 = \frac{230}{R \times 2} \Rightarrow R = 23\ \Omega$ ~~$\Rightarrow 0.04348\ \Omega$~~

~~$\Rightarrow \lambda = 0.01887$~~

$L = 9.9544\ H$

Q- Relay has $R = 300\,\Omega$ and it is switched on to 100 V DC supply. If the current reaches 63.2% of its final steady value in 2 msec. Determine

i) $\lambda =$

ii) Inductance of circuit

iii) Final steady value of current

iv) Initial rate of rise of current

iii) $I_m = \frac{V}{R} = \frac{1}{3}$

i) $0.632 = 1 - e^{-t/\lambda}$

$e^{-t/\lambda} = \cancel{0.368}\ 0.368$

$\Rightarrow \frac{+t}{\lambda} = 0.9996$

$\Rightarrow \lambda = \frac{2 \times 10^{-3}}{0.999672}$

$\lambda = 2\ \text{m sec}$

ii) $L = 0.6\ H$

iv) $\frac{di}{dt} = \frac{V}{L} = \frac{100 \times 10}{6} = 166.66$

Coil having $L = 6.4\,H$ and $R = 8\Omega$ is connected to constant 200V supply. How long ~~will~~ does it take the voltage across resistor to reach 100V.

$$i = \frac{V}{R} = \frac{100}{8}$$ $i = \frac{V}{R}$

$$\frac{100}{8} = \frac{200}{8}\left(1 - e^{-t/\lambda}\right) \Rightarrow 1 - e^{-t/\lambda} = \frac{1}{2}$$

$$e^{-t/\lambda} = \frac{1}{2} \Rightarrow +\frac{t}{\lambda} = +0.6931$$

$$\Rightarrow t = 0.6931 \times \frac{6.4}{8} = 0.554\,sec$$

The armature of relay working on 200V D.C supply is not actuated until the current reaches 0.35A which occurs 4 msec after the relay circuit is closed. This time being the time const of circuit. Calc. L and R of relay and di/dt.

$$0.35 = \frac{200}{R}\left(1 - e^{-t/\tau}\right)$$

$$R = 361.211\,\Omega$$

$$\frac{L}{R} = 4\times10^{-3} \Rightarrow L = 0.38 \quad L = 1.444\,H$$

$$\frac{di}{dt} = \frac{V}{L} = \frac{200}{1.444} = 138.504\ A/sec$$

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