PHYSICS INDUCTION

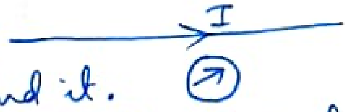
An institute of Science & Mathematics

Vinita Chawla
M.Sc. Physics (HRC, Delhi University)
M.Sc. Computer Science, B.Ed.,
CTET, HTET, PSTET, CSB Qualified
Contact: 91-8168258349
physicsinduction@gmail.com

CLASS XII : NOTES : CHAPTER-6 : ELECTROMAGNETIC INDUCTION : PHY

Varying $\vec{E}$ → produces $\vec{B}$ IIly, Varying $\vec{B}$ → produces $\vec{E}$

Hans Christian Oersted: when current is passed thro' a conductor, A magnetic field is developed around it.



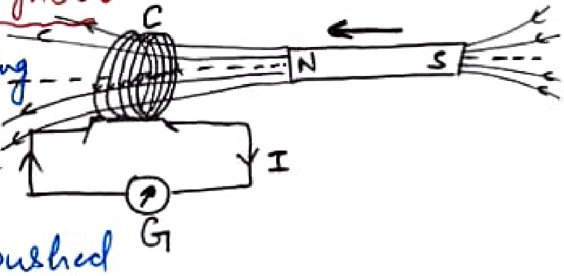
Michael Faraday (England) & Joseph Henry (USA): They demonstrated that varying magnetic fields induce electric currents in closed coils placed near it.

Faraday first made public his discovery that relative motion b/w a bar magnet & a wire loop produce a small current in the latter.

ELECTROMAGNETIC INDUCTION:- The phenomenon in which electric current is generated by varying magnetic fields is called EMI. The e.m.f. so developed is called **induced emf**. If the conductor is in the form of a closed circuit, a current flows in the circuit. This is called **induced current**.

THE EXPERIMENTS OF FARADAY AND HENRY:-

Experiment: 1 – Current induced by a magnet:



C: coil or a loop of few turns of a conducting material insulated from one another.

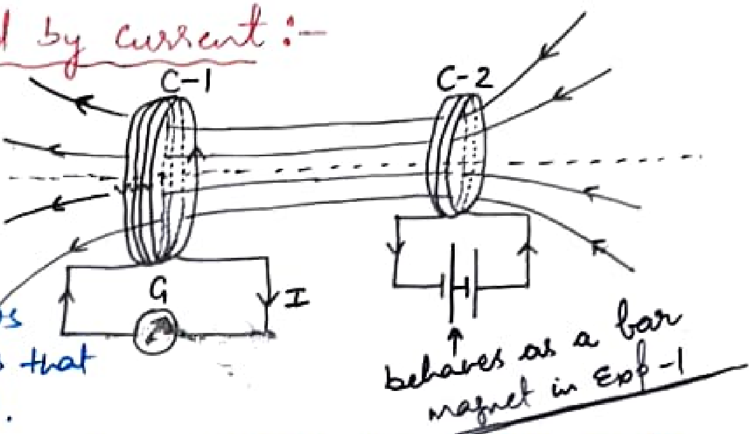
- There is no deflection in the galvanometer, when the bar magnet is held stationary.
- When the N-pole of the bar magnet is pushed towards the coil, the Ⓖ shows a sudden deflection, indicating that current is induced in the coil.
- When the magnet is moved away from the coil, the galvanometer Ⓖ shows deflection in the opposite direction, indicating reversal in the direct^n of induced current.
- When S-pole of a bar magnet is moved towards or away from the coil, the galvanometer, Ⓖ deflections are opposite to those observed with the N-pole for similar movements.

- The galvanometer, Ⓖ deflection (& hence induced current) is found to be larger, when magnet is pushed towards or pulled away from the coil faster.

⊛ When the bar magnet is held stationary & coil, C is moved towards or away from the magnet, the same effects are produced.

* Relative motion b/w the coil and the magnet is responsible for induction of electric current in the coil.

Experiment: 2- Current induced by current:-



A steady current through coil-2 produces a uniform $\vec{B}$ along its axis.

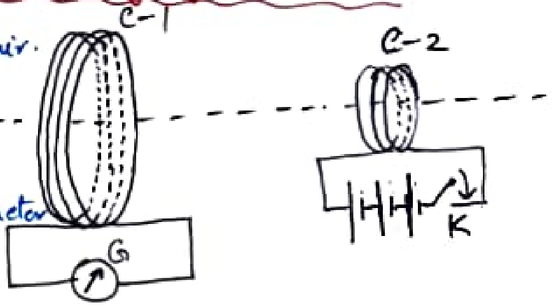
⊛ When C-2 is moved towards the coil C-1, the galvanometer shows a sudden deflection. This indicates that electric current is induced in C-1.

⊛ When coil, C-2 is moved away from the coil C-1, the galvanometer shows a deflection in the opposite direction. This indicates that direc^n of current in coil, C-1 is reversed.

⊛ The deflection is temporary, It lasts so long as there is relative motion b/w the two coils.

⊛ The galvanometer deflection (& hence, induced current) is found to be larger, when coils are moved faster towards/away from each other.

Experiment: 3- Current induced by changing current:-



Relative motion isn't an absolute requir. Current can be induced even without relative motion.

⊛ When key, K is pressed, the galvanometer Ⓖ in coil, C-1 shows a momentary deflection, indicating that current is induced in coil, C-1

⊛ When the key, K is kept pressed continuously, there is no deflection in Ⓖ.

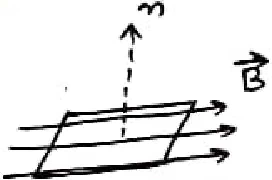
⊛ When the key, K is released, the galvanometer shows again a momentary deflection, but in the opposite direction. The pointer in Ⓖ returns to zero almost instant

⊛ The galvanometer deflection increases dramatically, when an iron rod is inserted into the coils along their axis, & the key K is pressed/released.

Cause of induced EMF:- An emf is induced in a coil, when amount of magnetic flux linked with the coil changes with time.

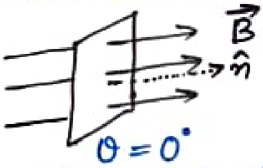
MAGNETIC FLUX: (ϕ_B): The magnetic flux, ϕ through any surface of area, $\vec{A}$ held in a magnetic field, $\vec{B}$ is measured by the total number of magnetic lines of force crossing the surface normally.

$$\phi_B = \vec{B} \cdot \vec{A} = BA\cos\theta$$



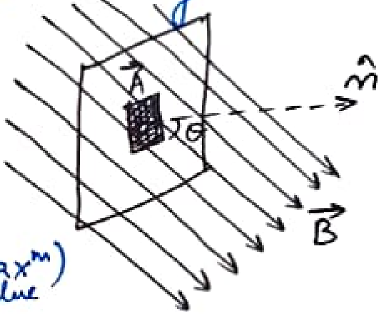
$\theta = 90°$

$\phi_B = BA\cos 90° = 0$



$\theta = 0°$

$\phi_B = BA\cos 0° = BA (= \text{max}^m \text{ Value})$



Unit of Magnetic Flux:- Weber, Wb.

1Wb: It's the amt of magnetic flux over an area of 1 sq-m held normal to a uniform magnetic field of one tesla.

Magnetic Flux is a scalar quantity

$$1\,Wb = 1T \times 1m^2$$

C.g.s. unit : maxwell (Mx) , $\boxed{1\,Wb = 10^8 \text{ maxwell}}$

FARADAY'S LAW OF INDUCTION: The magnitude of the induced emf in a circuit is equal to the time rate of change of magnetic flux thro' the circuit.

The induced emf is given by, $\varepsilon = -\frac{d\phi_B}{dt}$

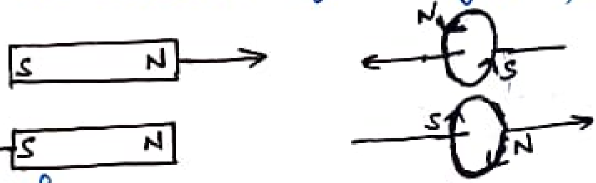
for a closed path, $\varepsilon = \oint \vec{E} \cdot d\vec{l}$

$\therefore \oint \vec{E} \cdot d\vec{l} = -\frac{d\phi_B}{dt}$ $\vec{E}$ - Nonconservative Time-varying

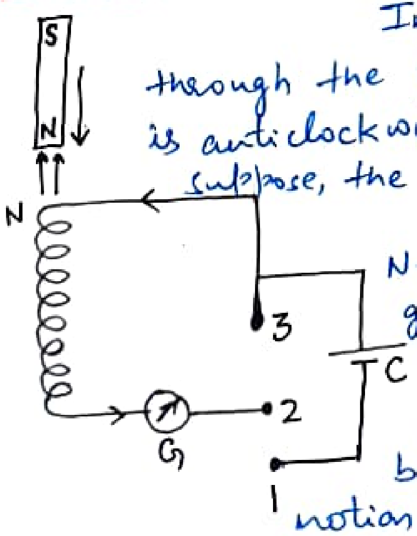
-ve sign is taken ∵ induced emf always opposes any change in magnetic flux.

LENZ'S LAW:- According to Lenz's law, the direction of induced emf/induced current is such that it opposes the cause (change in mag. flux) responsible for its production.

Direction of induced currents in the closed loop, when a magnet is moved towards or away from the loop.



Experimental Demonstration:-



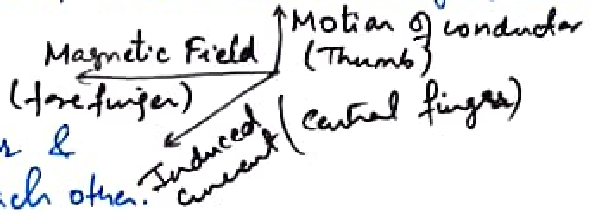
Insert the plug of key b/w 1 & 2. cell sends current through the coil. At the upper face of the coil, the current is anticlockwise, which would produce N-pole on this face. suppose, the galvanometer deflection is to the right

Insert the plug of key b/w 2 & 3. Now, move N-pole of a bar magnet towards the coil, The galvanometer shows sudden deflection to the right, indicating the current induced in the coil is anticlockwise & upper end of the coil behaves as North. It opposes the inward motion of N-pole of the bar magnet, which is the cause of induced current.

Lenz's Law & Energy Conservation:- It's this mechanical W.D. in moving the magnet w.r.t. the coil that changes into electrical energy producing induced current. Thus, Energy is being transformed only.

When we don't move the magnet, W.D. is zero. Therefore, induced Current is zero.

FLEMING'S RIGHT HAND RULE



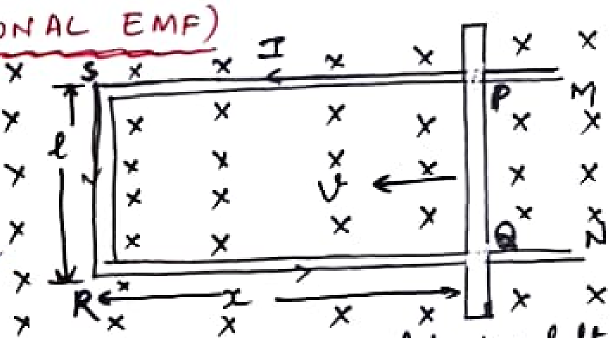
stretch the forefinger, central finger & thumb → mutually perpendicular to each other.

MOTION OF A STRAIGHT CONDUCTOR IN A MAGNETIC FIELD:-

(MOTIONAL EMF)

Assumption: ∄ no loss of energy due to friction.

Consider a rectangular conductor PQRS in which PQ is free to move. PQRS forms a closed circuit enclosing an area that changes as PQ moves.



The arm PQ is moved to the left side, thus decreasing the area of the rectangular loop. This movement induces current.

mag. flux, ϕ_B enclosed by the loop:

$$\phi_B = Blx \qquad (\vec{A} = lx)$$

∵ x is changing with time

$$\therefore\ \mathcal{E} = -\frac{d\phi_B}{dt} = \frac{-d}{dt}(Blx) = -Bl\frac{dx}{dt} = -Bl(-v) = \underline{Blv}$$

↑ motional emf

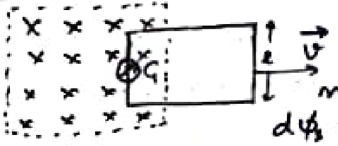
Now, consider any arbitrary charge, q in the conductor PQ, q is moving with the rod in the mag. field, B

∴ Lorentz mag. force, $F_B = qvB$

$\Rightarrow$ W.D. $= F_B \times l$

(moving q from P→Q) $= qvBl$

As, $\mathcal{E} = \dfrac{W}{q} \Rightarrow \underline{\mathcal{E} = Blv}$



$\rightarrow \Delta A = -l\Delta x$ decreased mag. flux.

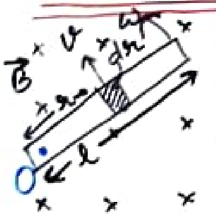
$d\phi_B = B \cdot \Delta$

$\Rightarrow d\phi_B = -Bl\Delta x$

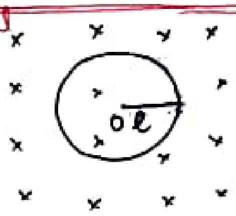
$$\mathcal{E} = -\frac{d\phi_B}{dt} = \frac{-d}{dt}(-Bl\Delta x)$$

$$= Bl\frac{\Delta x}{\Delta t} = Blv$$

EMF INDUCED IN A ROTATING BAR IN A MAGNETIC FIELD:-



Motional Emf



Consider a bar of length, l rotating with angular speed, ω about a pivot at one end, O.

consider a segment of the bar of length, dr, whose velocity is v.

∴ induced emf in the segment moving ⊥r to B: $d\mathcal{E} = Bv\,dr = B(r\omega)dr$

Thus, $\underline{\mathcal{E}} = B\omega\int_0^l r\,dr = B\omega\left|\frac{r^2}{2}\right|_0^l = \underline{\frac{1}{2}B\omega l^2}$

ν = freq. of rotation : $\omega = 2\pi\nu$ ∴ $\underline{\mathcal{E}} = \frac{1}{2}B(2\pi\nu)l^2 = \underline{\pi B\nu l^2}$

Area swept by the bar per rotation $= \pi l^2$

Change in flux per rot (T) in

$d\phi_B = B(\pi l^2)$

$$\mathcal{E} = \frac{d\phi_B}{dt} = \frac{B\pi l^2}{T} = \pi B\nu l^2$$

INDUCED EMF BY CHANGING THE RELATIVE ORIENTATION OF COIL AND MAGNETIC FIELD :-

$\phi_B = \vec{B}\cdot\vec{A} = BA\cos\theta$

& $\theta = \omega t$ (ω: Angular velocity)

Induced emf in the coil, $\varepsilon = -\frac{d\phi_B}{dt} = -\frac{d}{dt}(BA\cos\omega t) = BA\omega\sin\omega t$

Induced current in the coil, $i = \frac{|\varepsilon|}{R} = \frac{BA\omega}{R}\sin\omega t$

POWER DISSIPATED IN A CONDUCTOR MOVED IN A MAGNETIC FIELD :-

Motional e.m.f produced in the conductor, $\varepsilon = Blv$

Let R be the resist of movable arm PQ (Assuming that the Rs of remaining arms QR, RS & SP is negligible)

∴ Induced current in the loop, $I = \frac{\varepsilon}{R} = \frac{Blv}{R}$

The magnitude of force on the conductor PQ moving in the mag. field

$$F = BIl = B\left(\frac{Blv}{R}\right)l = \frac{B^2l^2v}{R} \quad (F - \text{opp. to velocity}, v)$$

Power required to push the conductor with velocity, v

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

As, the conductor is pushed mechanically, the mechanical energy dissipated per second is given by

$$P = I^2R = \left(\frac{Blv}{R}\right)^2 \cdot R = \frac{B^2l^2v^2}{R}$$

which is same as the power required to push the conductor.

∴ Mechanical Energy reqd to move the conductor PQ is converted into electrical energy first (i.e., the induced e.m.f) & then to thermal energy.

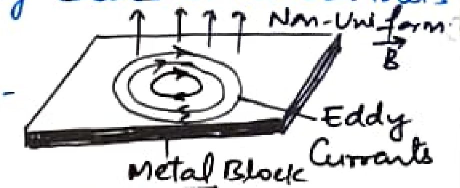
∴ Heat energy produced/sec $= \frac{B^2l^2v^2}{R}$

EDDY CURRENT :- If flux is changed in a closed circuit, a current is induced in it. If instead of a closed circuit, a metal plate or a disc is either made to vibrate in a magnetic field or placed in a variable magnetic field, induced currents are set up in it & acc. to Joule's law, this plate or disc gets heated. These induced currents are called eddy currents or Foucault's Currents as Foucault was the first to study these currents in 1895.

Eddy Currents are the currents induced in the bulk piece of Conductors when the amount of magnetic flux linked with the conductor changes.

However, their flow patterns resemble swirling eddies in water. That's why they are called eddy currents.

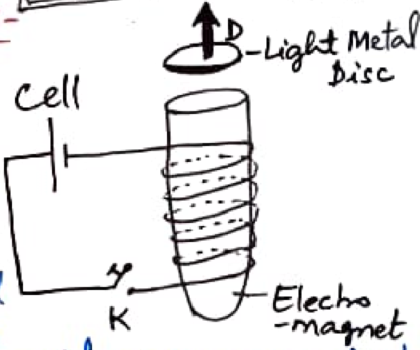
e.g. when a Metallic block is placed in a non-uniform $\vec{B}$, eddy currents are produced in the block.



$$i = \frac{\text{induced e.m.f.}}{\text{resistance}} = \frac{\varepsilon}{R} = \frac{-d\phi_B/dt}{R}$$

Experimental demonstration of Eddy Currents:-

Exp-1: Jumping Disc Experiment:-

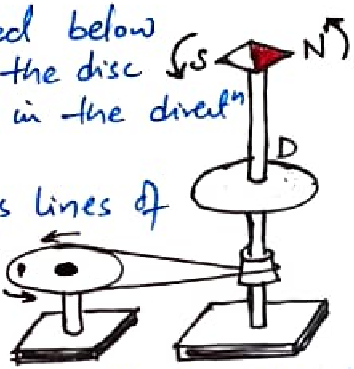


⊙ When K is pressed, disc is thrown up into the air due to eddy currents developed in the disc.

⊙ As current thro' the solenoid increases, ϕ_B along its axis increases ∴ magnetic flux linked with the disc increases. If upper end of the solenoid acquires N-polarity the lower face of D will also acquire N-polarity in accordance with the Lenz's law. The force of repulsion b/w the two throws the disc up in the air. Later, the disc falls down due to gravity.

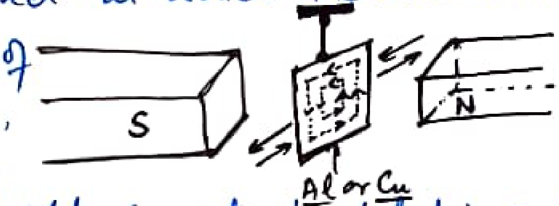
Exp-2: Argo's Experiment:- (1824)

A Cu disc, D is situated below a magnetic needle NS. When the disc is rotated fast, the magnetic needle also rotates in the direcⁿ of rotation of the disc but with lesser speed.

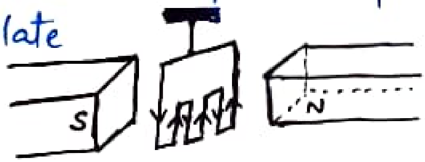


When the disc D is rotated, it cuts lines of force coming from the magnetic needle & as a result of it, eddy currents are produced in the disc, which oppose the motion of the disc. (As a result of it, a couple acts on the disc which retard its motion) An equal & opp. couple will act on the magnetic needle (Newton's IIIrd law) Needle will start rotating in the same direcⁿ in which the disc is rotating.

Exp-3: Stenzl's Experiment:-



In the absence of $\vec{B}$, plate oscillates for a longer time. But in the $\vec{B}$, Oscillations are damped & the plate stops oscillating sooner, because of eddy currents developed in the plate.



to minimize eddy currents: When the metallic plate with slots cut in it, is made to oscillate, damping effect is much smaller. Eddy currents are reduced. This is because, mag. moments of the induced currents (which oppose the motion) depend upon the area enclosed by the currents. $(\vec{M} = I\vec{A})$.

Applications of Eddy Currents:

(i) **Magnetic Brakes** :- A strong 'B' is applied to a metallic drum rotating with axle connecting the wheels, large eddy currents set up in the rotating drum oppose the motion of the train.

(ii) **Electromagnetic Damping - Dead beat Galvanometer** :- Certain galvanometers have a fixed core made of non-magnetic metallic material. When the coil oscillates, the eddy currents generated in the core oppose the motion & bring the coil to rest quickly.

(iii) **Induction Furnace** :- It's used to produce high temperatures which are utilised in preparing alloys by melting the constituent metals. The large eddy currents generated produce high temp.

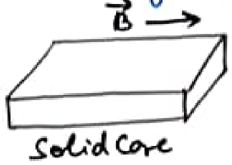
(iv) **Electric Power meters** :- A rotating shiny disc in the power meter of our house rotates due to eddy currents developed by magnetic fields produced by alternating current.

(v) **Induction Motor** :- A Rotating $\vec{B}$ produces → a.c. motor strong eddy currents in a rotor, which starts rotating in the direct^n of $\vec{B}$.

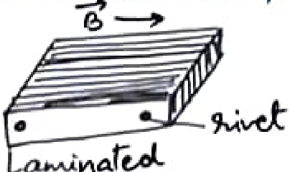
(vi) **Diathermy** :- in deep heat treatment of the human body.

(vii) **Speedometers** :- based on eddy currents and Energy meters.

Undesirable effects of Eddy Currents :- • Oppose the relative motion • involve loss of energy in the form of heat • Excessive heating may reduce the life of appliances.



Solid Core



Laminated Core

To Minimise the eddy Currents: Metal core used in the appliances is taken in the form of thin sheets. Each sheet is electrically insulated from the other. The planes of these sheets are arranged parallel to $\vec{B}$, so that they cut across the eddy current paths. Large Resistance b/w the thin sheets confines the eddy currents to the individual sheets.

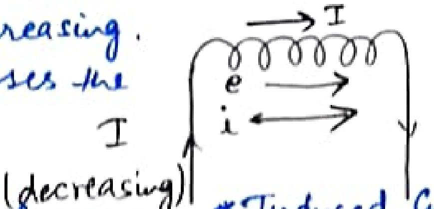
INDUCTANCE :-

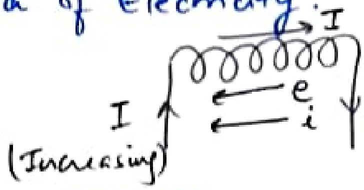
Self Induction: Self-Induction is the property of the coil by virtue of which, the coil opposes any change in the strength of current flowing through it by inducing an e.m.f in itself.

* Self-Induction is also called Inertia of Electricity.

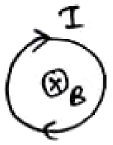
* when current, I is increasing. Self induced e.m.f opposes the increase.

* when current, I is decreasing, self induced e.m.f opposes the decrease.





* Induced Current, i opposes growing Current & supports dying current.



Consider a coil carrying current, I placed in a mag. field.

If : I(increase) → B(increase) ⇒ ϕ_B (increase) ⇒ induced e.m.f

⇓

i will dec the primary current I ⇐ induced i current, (Lenz's law)

Coefficient of Self Induction:-

Self Inductance of a coil:-

As, Flux thro' a coil is prop. to current : $\phi_B \propto I$

 for a closely wound coil of N turns : $N\phi_B \propto I$

↑ flux linkage

$\Rightarrow N\phi_B = LI$

where L: coeff of self induction/inductance

$\Rightarrow L = \frac{N\phi_B}{I}$

L depends on : No. of turns, Area of cross section & nature of material (core) on which the coil is wound.

As, $e = -\frac{d\phi_B}{dt} = -\frac{d}{dt}\left(\frac{LI}{N}\right) = -\frac{L}{N}\cdot\frac{dI}{dt}$ (for N turns)

$= -L\frac{dI}{dt}$ (for 1 turn)

For a coil

$L = \frac{\phi_B}{I} = \frac{-e}{dI/dt}$ $(e = W/q)$

Unit of L : Henry, H

1 H = 1 volt-sec/ampere = 1 Wb/A

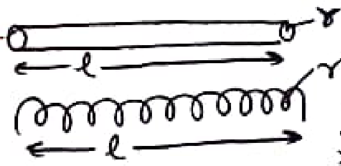
Dim. of L : $[M^1 L^2 T^{-2} A^{-2}]$

* coeff. of self induction is equal to

→ the amt of mag. flux linked with the coil when unit current flows thro' the coil. i.e., $I = 1 \Rightarrow \phi_B = L$

→ e.m.f induced in the coil when rate of change of current thro' the coil is unity. i.e., if $\frac{dI}{dt} = 1\,A/s \Rightarrow L = -e$

Self Inductance of a long solenoid:-



(l >> r)

∴ B-inside is practically constant

As, $B = \frac{\mu_0 N I}{l}$ (N-Total no. of turns)

∴ mag. flux thro' each turn = B × Area of each turn

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

⇒ Total mag. flux linked with the solenoid = N × Flux thro' each turn

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

Also, $\phi = LI$

$\therefore LI = \frac{\mu_0 N^2 A}{l} I \Rightarrow \boxed{L = \frac{\mu_0 N^2 A}{l}}$

If core is of any other mag. material, $\mu = \mu_0 \mu_r \therefore L = \frac{\mu N^2 A}{l}$

L of solenoid depends upon : $L \propto \frac{1}{l}$, $L \propto A$, $L \propto N^2$ & L ↑ if air core of solenoid is replaced by core of some other mag material

Grouping of coils :

(i) **Coils in series :** consider no. of coils $L_1, L_2 ---, L_n$ connected in series & coeff of coupling $K=0$. As, I - same, e - different

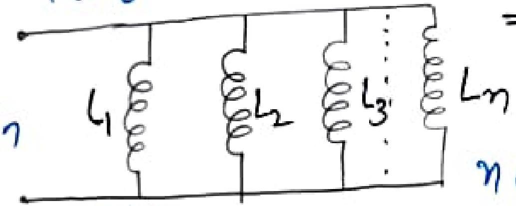
$$\therefore e = e_1 + e_2 + ----- e_n$$

$$\Rightarrow L_s \frac{dI}{dt} = L_1 \frac{dI}{dt} + L_2 \frac{dI}{dt} + ---- + L_n \frac{dI}{dt} \Rightarrow \boxed{L_s = L_1 + L_2 + -- + L_n = \sum_{i=1}^{n} L_i}$$

(ii) **Coils in parallel :-** $K=0$

I - different, e - same

$$\therefore I = I_1 + I_2 + -- + I_n$$



n coils : $L_1, L_2 -- L_n$

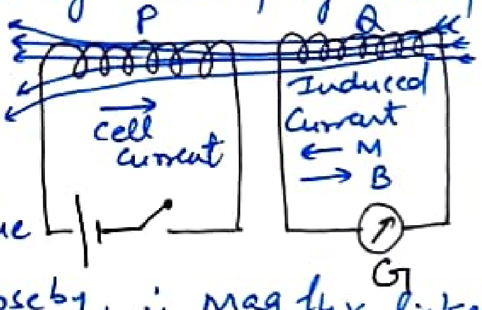
$$\Rightarrow \frac{dI}{dt} = \frac{dI_1}{dt} + \frac{dI_2}{dt} + --- + \frac{dI_n}{dt}$$

$$\Rightarrow \frac{e}{L_p} = \frac{e}{L_1} + \frac{e}{L_2} + ---- + \frac{e}{L_n} \qquad \left[\because \frac{dI}{dt} = \frac{e}{L}\right]$$

$$\Rightarrow \boxed{\frac{1}{L_p} = \frac{1}{L_1} + \frac{1}{L_2} + ----- + \frac{1}{L_n} \Rightarrow \frac{1}{L_p} = \sum_{i=1}^{n} \frac{1}{L_i}}$$

MUTUAL INDUCTION :- It's the property of two coils by virtue of which each opposes any change in the strength of current flowing through the other by developing an opposing emf.

P & Q : 2 coils



* On pressing key, K in coil P : Current increases from zero to maximum value ϕ_B linked with P increases. As S is closeby, ∴ mag flux linked with S will also change (increase). According to Lenz's law, induced current in S, would oppose the increase in current in P by flowing in a direction opposite to the cell current in P.

* On releasing key, K, I(in P) dec. from max to zero. ϕ_B linked with P decreases. ϕ_B linked (associated) with S also decreases. ∴ An emf will be induced in S. Induced current in S opposes the decrease in current in P i.e., it prolongs the decay of current.

Coefficient of Mutual Induction :- (Mutual Inductance of two coils)

Let I be the strength of current in coil-1. & ϕ be the total amount of magnetic flux linked with all the turns of the neighbouring coil. then, $\phi \propto I \Rightarrow \boxed{\phi = MI}$ M: coeff. of Mutual Inductance

If $I = 1$, $\phi = M \Rightarrow$ M is the amt of mag flux linked with 1 coil when unit current flows thro' the neighbouring coil.

As, emf, $e = -\frac{d\phi}{dt}$ $\therefore e = -\frac{d}{dt}(MI) = \boxed{-M\frac{dI}{dt}}$

If $\frac{dI}{dt} = 1 \Rightarrow e = -M$ or $M = -e \rightarrow$ M is equal to the e.m.f induced in one coil when rate of change of current thro' the other coil is unity.

Dim of M: $[M^1L^2T^{-2}A^{-2}]$

Unit of M:- Henry, H , $1H = 1 Wb/A = 1 V\text{-}s/A$

M depends on geometry of 2 coils (size, shape, no. of turns, nature of mat $\rightarrow$ permeability) Dist. b/w 2 coils & relative placement of two coils (i.e., Orientation of 2 coils) common A

Reciprocity thm It doesn't matter which one of them fn as primary or the secondary coil.

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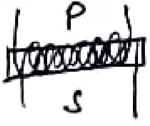
Coeff of coupling: It's a measure of the strength of coupling b/w the 2 coils.

$K = \frac{M}{\sqrt{L_1L_2}}$

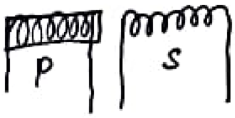
M: coeff of M.I. of 2 coils

L_1 & L_2: " " S.I. " " "

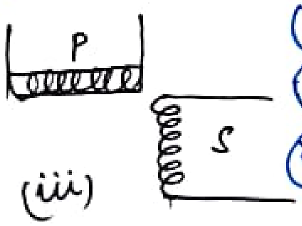
$0 \leq K \leq 1$



(i)



(ii)



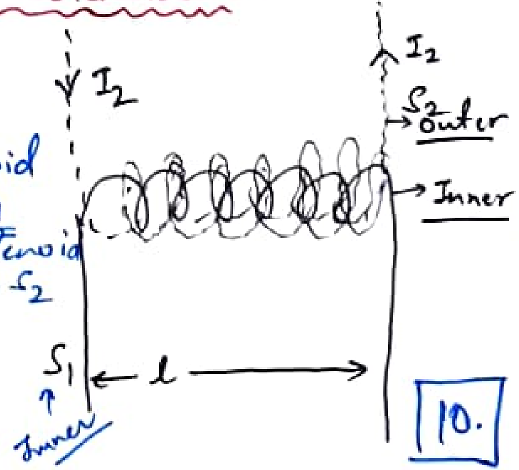
(iii)

(i) → K : maximum

(ii) → K - less than (i)

(iii) → K : minimum

Mutual Inductance of two long co-axial solenoids :-



l : length of the 2 coils

n_1 : no. of turns per unit length of inner solenoid S_1

n_2 : " " " " " " " outer solenoid S_2

r_1 : radius of Inner solenoid S_1

r_2 : " " Outer " S_2

Assumptions :- No edge effects ($l >> r_2$), Uniform B throughout the length & width of the solenoid.

I_2 : time varying current thro' S_2

b'coz of this $I_2 \to B_2 \to \phi_2$: time varying mag. flux. & it sets up a time varying mag. flux ϕ_1 thro' S_1

∴ $\phi_1 = M_{12} I_2$ M_{12} : coeff of M.I. of S_1 w.r.t. S_2

& Mag. field due to I_2 in $S_2 = B_2 = \mu_0 n_2 I_2$

$$\text{Therefore, } \underset{\overset{\uparrow}{M_{12} I_2}}{\phi_1} = B_2 A_1 N_1$$

$$= (\mu_0 n_2 I_2)(\pi r_1^2)(n_1 l)$$

$$= (\mu_0 n_1 n_2)(\pi r_1^2)(l I_2)$$

$$\therefore \underline{M_{12} = \mu_0 n_1 n_2 \pi r_1^2 l} = \mu_0 n_1 n_2 A_1 l = \mu_0 \left(\frac{N_1}{l}\right)\left(\frac{N_2}{l}\right) A_1 l$$

$$\Rightarrow \boxed{M_{12} = \frac{\mu_0 N_1 N_2 A_1}{l}}$$

A_1 : Area of inner solenoid

|||ly for the reverse case

I_1 : time varying current thro' S_1

ϕ_2 : " " mag. flux (due to I_1) in S_2

∴ $\phi_2 = M_{21} I_1$, M_{21} : Coeff of M.I. of S_2 w.r.t. S_1

$$\text{Also, } \underset{\overset{\downarrow}{M_{21} I_1}}{\phi_2} = B_1 A_1 N_2$$

$$= (\mu_0 n_1 I_1)(\pi r_1^2)(n_2 l)$$

$$= (\mu_0 n_1 n_2)(\pi r_1^2) I_1 l$$

$$\Rightarrow \underline{M_{21} = \mu_0 n_1 n_2 \pi r_1^2 l} \Rightarrow \boxed{M_{12} = \frac{\mu_0 N_1 N_2 A_1}{l}}$$

A_1 : Area of inner solenoid

$$\therefore \textbf{M.I.} : \boxed{M = \frac{\mu_0 N_1 N_2 A}{l} = \mu_0 n_1 n_2 A l}$$

$l \to$ length of LONGER Solenoid (when S_1 & S_2 are of diff lengths)

$A \to$ Area of INNER solenoid (∵ ∃ no B in the region b/w the 2 solenoids.)

AC Generator OR AC Dynamo

Mechanical Energy → Electrical Energy
(Application of EMI)

Principle : based on EMI, i.e., whenever the amt of mag flux linked with a coil changes, an e.m.f. is induced in the coil.

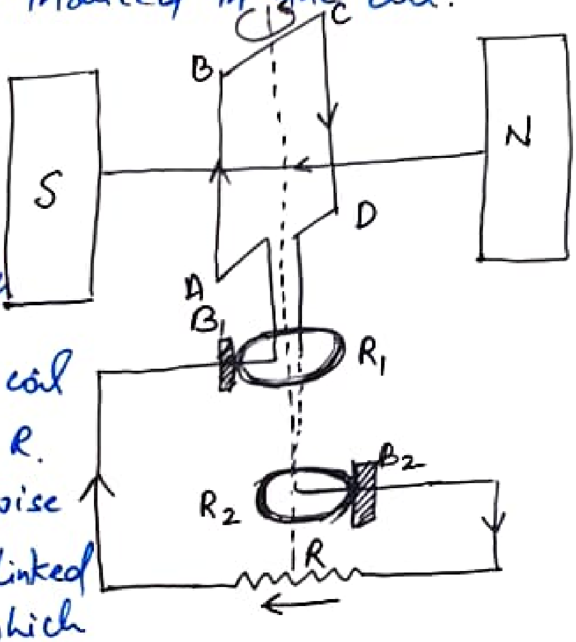
Construction :-

(i) Armature : ABCD (with large no. of turns)

(ii) Field Magnets : N & S.

(iii) Slip Rings : R_1 & R_2 : Rotate with the coil

(iv) Brushes : B_1 & B_2 : pass I from coil to the ext load Resistance, R.



Working :- coil is rotated clockwise (or anti clockwise), the amt of ϕ_B linked with the coil changes b'coz of which current is induced in the coil.

Induced current in the external circuit changes direction after every half rotation of the coil. Hence, the current induced is alternating current.

To calculate : e

N → no. of turns in the coil

A → Area enclosed by each turn of the coil

$\vec{B}$ → strength of mag field.

θ → Angle which normal to the coil makes with $\vec{B}$ at any instant, t.

As $\phi = N(\vec{B}\cdot\vec{A})$

$\Rightarrow \phi = NBA\cos\theta = NAB\cos\omega t \quad (\because \theta = \overset{\text{Angular velocity}}{\omega} t)$

$\underline{\underline{\omega = 2\pi\nu}}$

φ varies with the rot of the coil

$$\therefore e = -\frac{d\phi}{dt} = -\frac{d}{dt}(NAB\cos\omega t) = -NAB\frac{d}{dt}(\cos\omega t)$$

$$= -NAB(-\sin\omega t).\omega$$

$$\Rightarrow \boxed{e = NAB\omega\sin\omega t}$$

e will be max : $\sin\omega t = 1 \Rightarrow e_{max} = NAB\omega = e_0$ (say)

$$\therefore \underline{e = e_0\sin\omega t} \quad \& \quad i = \frac{e}{R} = \frac{e_0}{R}\sin\omega t = i_0\sin\omega t$$