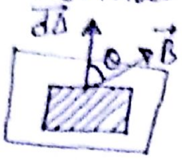
'ELECTROMAGNETIC INDUCTION [E.M.I]'

To produced induced current in the loop or, Induced emf, there should be Relative motion betn coil & the magnets, so that the magnetic flux change w.r.t time.

Magnetic flux (ϕ)

It is no. of lines of force passing through a surface placed normal to magnetic field.



Flux with small area element.

$$\boxed{d\phi = B(dA\cos\theta)}$$

$$\boxed{d\phi = \vec{B}\cdot d\vec{A}} \text{ (scalar quantity)}$$

unit → Wb, T×m² = MKS

Maxwell, Gs×cm² = CKS

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

Case-I → If field is uniform & surface is plane.

$$\phi_{net} = \int B\,dA\cos\theta$$

$$= B\cos\theta\int dA$$

$$* \boxed{\begin{array}{l}\phi_{net} = BA\cos\theta \\ \phi_{net} = \vec{B}\cdot\vec{A}\end{array}}$$

If no. of turn in the coil are 'N'

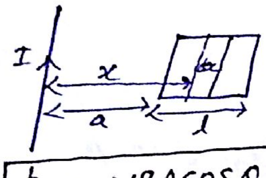
$$\boxed{\phi = NBA\cos\theta} *$$

Case-II → In case of non-uniform field.

$$* \boxed{\phi_{net} = \int \vec{B}\cdot d\vec{A}}$$

*** # A square of side 'l' is placed in same plane with a long wire as shown fig. then flux with loop.

$$\boxed{\phi_{net} = \frac{\mu_0 I l}{2\pi}\log_e\left[\frac{a+l}{a}\right]} *$$



***** #

$$\boxed{\begin{array}{l}\phi = NBA\cos\theta \\ \phi = f(B, A, \theta)\end{array}} *$$

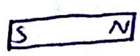
→ If $\phi \Rightarrow$ const $\Rightarrow$ NO EMI.

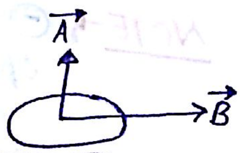
→ If $\phi \Rightarrow$ Non-const $\Rightarrow$ EMI. ✓

(i) → 

$A \perp B$

$\Rightarrow \phi = 0$

(ii) → 



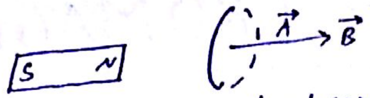
$$\boxed{\phi = 0}$$

|iii| →

$B_{wire} \perp A_{coil}$

$\Rightarrow \phi = 0$

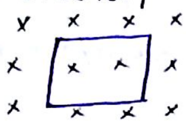
|iv| →



$\phi \neq 0$ but const

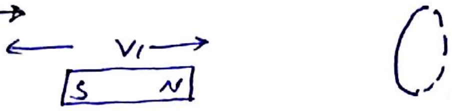
$\Rightarrow \frac{d\phi}{dt} = 0 \Rightarrow$ NO EMI

|v| → If a coil placed in uniform transverce magnetic field.



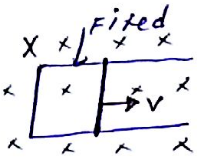
$\phi \neq 0$
but const.
NO EMI

|vi| →



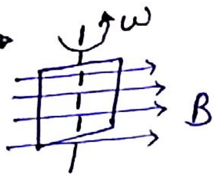
$\Rightarrow B \neq$ const
$\phi \neq$ const, EMI(✓)

|vii| →



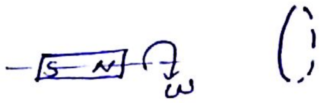
$A \neq$ const EMI(✓)
$\phi =$ const

|viii| →



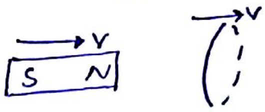
$\phi \neq$ const EMI(✓)
$\theta \neq$ const

|ix| →



$\phi \neq 0$ NO EMI
$\phi =$ const

|X| →



$\phi \neq 0$ NO EMI.
$\phi =$ const

Faraday's Law of EMI

On the basis of his observation, Faraday given, a Mathematical form of b/w the changing flux & Induced emf.
"Induced emf in a closed loop is always equal to Rate of change of flux w.r.t time"

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

If loop contains 'N' turns.

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

ϕ = Magnetic flux.
e = Induced emf in closed loop.

NOTE → * ⊖ve sign indecates that change in flux always opposes the ~~induced~~ induced emf generated in the loop.

* $\phi = BA\cos\theta$ It can be changed with the variation of B, A & θ.

* Induction takes place till the flux keep on changing.

$$\boxed{|e| \propto \frac{d\phi}{dt}}$$

|1|→ Variation w.r.t varying Magnetic field

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

$$e = -\frac{d\phi}{dt} = -\underbrace{\left\{\frac{dB}{dt}\right\}}_{\text{Rate of change of magnetic field.}} A\cos\theta$$

Uniform field

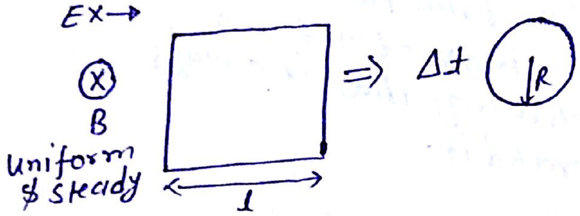
A uniform field is that which is same at all points in the space but its magnitude may change w.r.t time.

Steady field

Which is const. w.r.t time but it may be different at different points of the space.

|2|→ Variation w.r.t varying Area of coil

EX→



It becomes circular in time 'Δt' then Average Induced EMF.

$$2\pi R = 4l$$

$$R = \frac{2l}{\pi}$$

$$\Delta e = B\left(\frac{\Delta A}{\Delta t}\right)\cos\theta$$

$$A_i = l^2$$

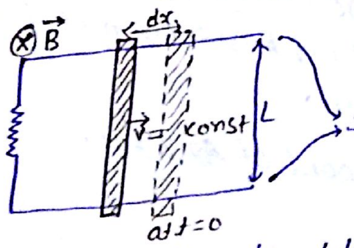
$$A_F = \pi R^2 = \pi \times \frac{4l^2}{\pi^2} = \frac{4l^2}{\pi}$$

$$\Delta A = l^2\left(\frac{4}{\pi} - 1\right)$$

$$\cos\theta = 1$$

✓ $\Delta e = Bl^2\left(\frac{4}{\pi} - 1\right)$

** NCERT EX→



Uniform & steady Find Induced EMF?

Smooth metal Rails

$$V = dx/dt\ ,\ dA = Ldx$$

$$e = -B\frac{dA}{dt}\cos\theta = -B\times L\frac{dx}{dt}\,1 = -BLV$$

$$i_{induced} = \frac{e}{R} = \frac{BLV}{R}$$

Induced current & Total charge flown

$$e = -\frac{d\phi}{dt} = \left|\frac{d\phi}{dt}\right|$$

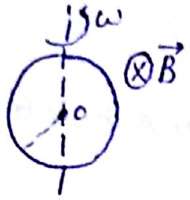
* $\boxed{i_{induced} = \frac{e}{R} = \frac{1}{R}\left|\frac{d\phi}{dt}\right|}$

* $\boxed{\text{Charge flown} = \Delta q = \frac{\Delta\phi}{R}}$

q→ charge flown due to Induced emf.

|3|→ Variation w.r.t varying angle b/w $\vec{B}$ & $\vec{A}$ i.e θ

A coil is kept such that it is ⊥ to magnetic field $\vec{B}$ as shown.



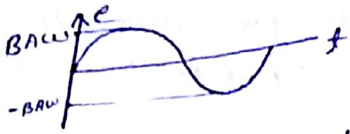
At $t = 0$
$\theta = 0$

$\boxed{\theta = \omega t}$

Let at $t = t$, the angle b/w $\vec{B}$ & $\vec{A}$ be θ

$\phi = BA\cos\theta$

$\frac{d\phi}{dt} = BA(-\sin\theta)\frac{d\theta}{dt}$



* $\boxed{e = -\frac{d\phi}{dt} = BA\omega \sin\omega t}$ ⇒ This is the principle of A.C generator.

Lenz's Law

Lenz explain the ⊖ve sign of Faraday's law in accordance with energy conservation principle.

Accordance to his law, induced emf in a close loop induced current in such a way that it always opposes the cause which has generated it.

Formala for EMI

(I) $\left\{ e = -\frac{d\phi}{dt} \right\}$

(II) $I_{induced} = \frac{e}{R} = -\frac{1}{R}\frac{d\phi}{R}$

(III) $Q_{Induced} = I_{ind}\, dt = \frac{-d\phi}{R}$

NOTE → * e & I depend on Rate of flux change but Q doesn't depend.

* Induced emf (e) doesn't depend on Resistant coil while $I_{induced}$ & $Q_{induced}$ on Resistant.

Ex → $\frac{d\phi}{dt} \neq 0$ & same for two identical coil of Ag & Au.

$\because R_{Ag} < R_{Cu}$

|i| → $\because e \not\propto R$ $\boxed{e_{Cu} = e_{Ag}}$

|ii| → $I_{induced} \propto \frac{1}{R}$ $\boxed{I_{Cu} < I_{Ag}}$

In Following coil $B \neq$ const.

$\Rightarrow \frac{d\phi}{dt} \neq 0$

$\Rightarrow$

	Metal	Plastic	Metal
EMI	✓	✓	✓
e	✓	✓	✓
Ind	✓	X	X

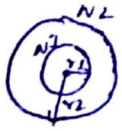
NOTE →

* Induced emf is independent of Resistance & nature of coil (metal, Plastic Wood etc).
* e & I depend on rate of flux change While $q_{induced}$ depend flux change only.

  Fast change of flux ⇒ High e & I
  Slow change of flux ⇒ Low e & I
  ⇒ $q_{induced}$ = same
  NO change of change ⇒ NO e & I

* $|e| \propto V_{relative}$

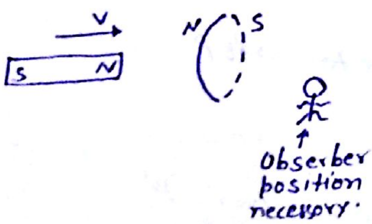
TWO circular coil are concentric & co-planer are N_1, r_1 & N_2, r_2 & $r_1 <<< r_2$. If current of coil two is changing at const Rate x amp/sec then calculated induced emf in coil one.



$$\boxed{e = -\frac{\mu_0 N_1 N_2 \pi r_1^2}{2 r_2} x}$$

*** Direction of Induced current using Lenz Law.

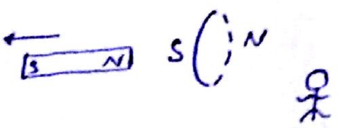
|1| →



$\phi = (\nu)$

$I_{induced}$ = clockwise (b/c it can see south pole)

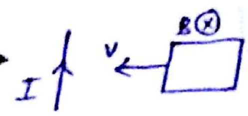
|2| →



$\phi = (\nu)$

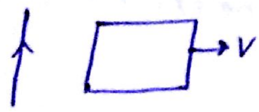
$I_{induced}$ = Anticlockwise [bcz it can see noth pole]

|3| → |i| →



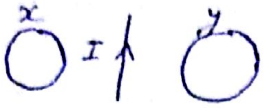
ϕ_{coil} ⊗ ↑ | $I_{induced}$ A.C.W
ϕ_{ind} ⊙

|ii| →



ϕ_{coil} ⊗ ↓ | $I_{induced}$ C.W
ϕ_{ind} ⊗

|3| →



$\because \phi_x = \odot = \text{const}$
$\phi_y = \otimes = \text{const}$] NO EMI

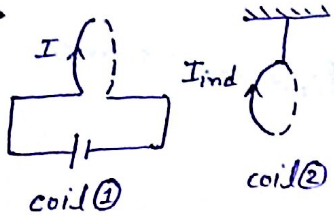
<u>case(i)</u> → I_{wire} (↑)ses.

	x	y
ϕ_{coil}	⊙ ↑	⊗ ↑
ϕ_{ind}	⊗	⊙
$I_{induced}$	C.W	A.C.W

<u>case(ii)</u> I_{ind} (↓)ses.

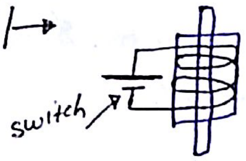
x	y
ϕ_{coil} = ⊙ ↓	ϕ_{coil} = ⊗ ↓
ϕ_{Ind} = ⊙	ϕ_{ind} = ⊗
I_{ind} = ACW	I_{ind} = CW

**
|4| →



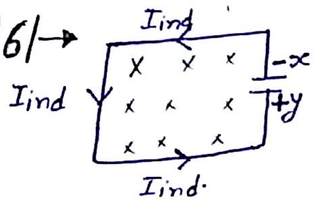
* If coil ① is heated
R(↑) ⇒ I(↓) ⇒ B1 (↓) ⇒ ϕ_2 (↓) Leftward.
So, Induced current in coil ② is same direction coil ①
so magnetic attraction b/w the coil b/c current
in same direction.

**
|5| →



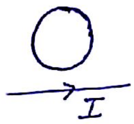
Flux with tiny loop is zero. If switch is made on suddenly some coil is associated with the loop & to oppose that opposite direction current is induced in tiny loop, so due to magnetic Repulsion in more away (धकेल दे).

|6| →



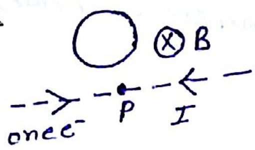
* If Field (↑), ϕ_{coil} ↑, ϕ_{ind} ⊙, I_{ind} = A.C.W
* using this induced current capacitor get charged so plate x become ⊖ x & y ⊕

|7| →



I = const.
ϕ_{coil} = 0 = const. | NO EMI

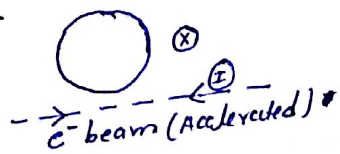
** AIIMS
|8| →



ϕ_{coil} = ↑⊗
ϕ_{ind} = ⊙
I_{ind} = ACW] When e⁻ is towards 'P'.

ϕ_{coil} = ⊗↓
ϕ_{ind} = ⊗
I_{ind} = C.W] When e⁻ away from 'P'

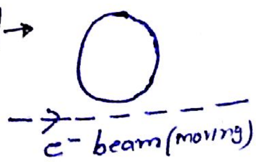
**
|9| →



ϕ_{coil} = ⊗ ↑
ϕ_{ind} = ⊙
I_{ind} = A.C.W

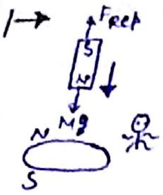
| Accln. ≠ 0
$\boxed{V(↑), I(↑)}$

AIIMS *
|10| →



I = const & no. of e⁻ approaching = no. of e⁻ moving.
ϕ_{coil} = 0 = const.
NO EMI

|11| → |i| →

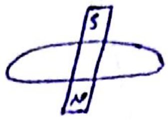


$I_{ind} = A \cdot C \cdot W = N$ = seen by observer

$F_{net} = mg - F_{Rep}$

$\boxed{F_{net} < Mg \quad a < g}$

|iii| →



$I_{ind} = 0$

At this instant Induced change the direction so

$\boxed{I_{ind} = 0}$

$\boxed{a = g}$

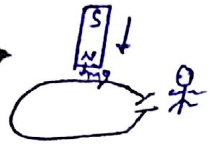
|ii| →

$C \cdot W = I_{ind}$

$F_{net} = Mg - F_{att}$

$\boxed{F_{net} < Mg \quad a < g}$

|12| |i| →



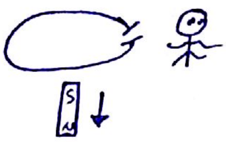
$\phi = v$

$I = \times$ (No cross loop)

EMF $= v$

$\boxed{I_{ind} = 0 \quad a = g}$

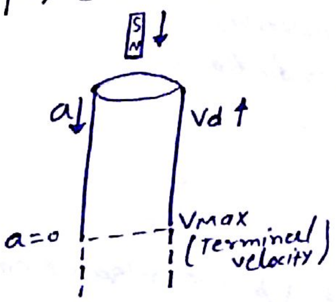
|ii| →



$e \neq 0$

$\boxed{I_{ind} = 0 \quad a = g}$

** |13| → Bar magnet falling in long metal pipe.



$\boxed{a < g}$

$V(\uparrow) = e(\uparrow) \Rightarrow I_{ind}(\uparrow)$

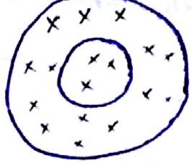
opposition $(\uparrow) = a(\downarrow)$

at last $a = 0$ $(V = V_{max})$ (Terminal velocity).

NOTE →

* If pipe is heated then its Resistance(↑) so for balancing the Rate of $\boxed{e \propto V_{rel}}$, So final terminal velocity is more than previous case It is obtain at lower position in pipe than above case.

|14| → $I_{induced} = ?$



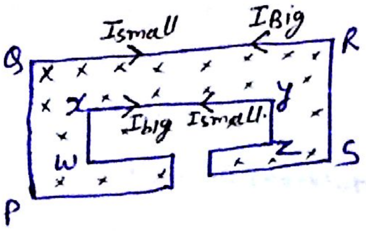
If $B(\uparrow)$, then for each coil

ϕ_{coil} ⊗ ↑

$\phi_{induced}$ ⊙

$I_{ind} = A \cdot C \cdot W$.

** |15| →

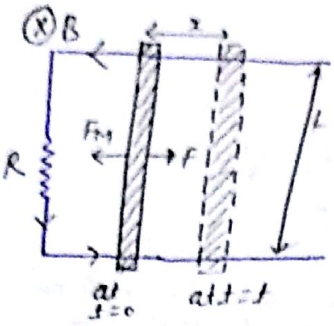


$\boxed{(Area)_{big} > (Area)_{small} \quad (I_{ind})_{big} > (I_{ind})_{small}}$

By superposition of current as shown in diagram.

$\boxed{I_{QR} \neq 0 \ (R \text{ to } Q) \quad I_{xy} \neq 0 \ (x \text{ to } y)}$

Rod is moved with const. force (F) as shown. Find its velocity as function of time.



$F = Ma = a = F/M$

Induced emf $\Rightarrow \boxed{e = BVL}$ (at $t=t$)

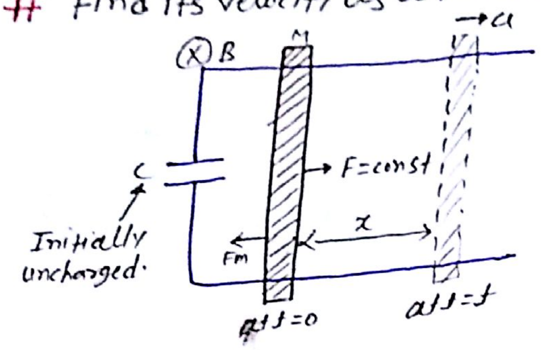
$\boxed{\text{Induced} = \frac{BVL}{R}}$

$F_m = IBL = \frac{B^2VL^2}{R}$

At $t \to \infty$

$\boxed{V = \frac{FB}{B^2L^2}}$ → Terminal velocity

Find its velocity as a function of time.



induced emf at $t=t$

$V = e = BVL$

$q = CV = CBVL$

$i = \frac{dq}{dt} = CBL\frac{dv}{dt}$

$\boxed{F_m = iBL = B^2L^2C\frac{dv}{dt}}$

$\boxed{a = \text{const.}}$

$\phi = f(B, A, \theta)$

If $\frac{d\phi}{dt} \neq 0 \Rightarrow$ EMI

- Static EMI (If $B \neq$ const) → Self Induction, mutual Induction.
- Motional/dynamic (If $A \neq$ const).
- Periodic EMI (If $\theta \neq$ const).

Self Induction

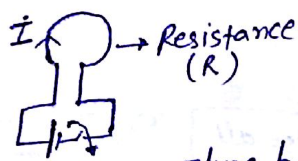
* When current in a coil changes & Induction takes place in same coil.
* Due to self Induction coil opposes the change in current.

Self Inductance (L)

It is a property due to which coil opposes the change of current

So, it is called "Inertia of Elasticity"

current in the coil faces two opposition.



(i) → Resistance of coil.

(ii) → Induced emf in the coil.

Flux passing through the coil

$\phi_{self} \propto I$

$\boxed{\phi_{self} = LI}$

self induction of coil.

NOTE → (i) → Weber / Ampere Henery.

(ii) → Induced emf in the coil $(e) = -\frac{d\phi}{dt} = -L\left(\frac{dI}{dt}\right)$

* During charging of current through a coil, their is an additional battery in the ckt whose emf can be written as–

$$\boxed{\text{emf of Induced battery} = L\left(\frac{dI}{dt}\right)}$$

* $\boxed{R = \frac{V}{I}}$ — It is property wich oppose the charge flow.

* $\boxed{C = \frac{Q}{V}}$ — It is capacitance to hold the charge.

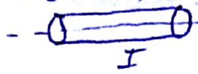
* $\boxed{L = \frac{\phi}{I}}$ — Self Inductance of coil. (oppose the change in current)

'L' circular coil →

N, R, I

$$\boxed{L_{circular} = \frac{\mu_0 \mu_r N^2 \pi R}{2}}$$

'L' solenoid

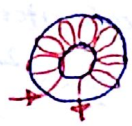


(N, R, I)

I

$$\boxed{L_{solenoid} = \mu_0 \mu_r n^2 \, vol}$$

'L' Toroid



$$\boxed{L_{Toroid} = \frac{\mu_0 \mu_r N^2 r^2_{frame}}{2 R_M}}$$

* L → does not depend on → ϕ, I
* L → depend on dimension parameter & number of turns & medium b/w the coil.

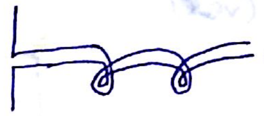
* Which of the following are possible.

(i) → L = 0 & R = 0 (×)

(ii) → L ≠ 0 & R ≠ (✓) In practical choke coil.

(iii) → L ≠ 0 & R = 0 (✓) In ideal choke coil condn. only

(iv) → L = 0 & R ≠ 0



[Non – Inductive wiring of coil]

→ In this arrangement is used in Resistance box to cancel the 'L' of inside coil.

Two circular coil L_1/L_2 = ? If →

(i) → Same no. of Turns Radius R_1 & R_2 → $\boxed{\frac{L_1}{L_2} \propto \frac{R_1}{R_2}}$

(ii) → Same Radius & Turn N_1 & N_2 → $\boxed{\frac{L_1}{L_2} = \left(\frac{N_1}{N_2}\right)^2}$

(iii) → If circular coil of N_1 turn converted into N_2 turns.

$$\boxed{\frac{L_1}{L_2} = \frac{N_1}{N_2}}$$

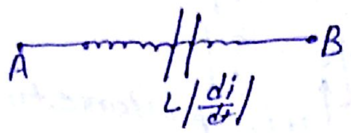
(iv) → coil of Radius R_1 converted R_2 Radius

$$\boxed{\frac{L_1}{L_2} = \frac{R_2}{R_1}}$$

Scanned by CamScanner

Inductor

It is a long solenoid wich behave like source of emf when current through it changes.



* If current is ↑ through Inductor

$$\boxed{V_A - V_B = L\left|\frac{Li}{dt}\right|}$$

* If current is ↓ through Inductor

$$\boxed{V_A - V_B = -L\left|\frac{di}{dt}\right|}$$

Potential Energy (U)

For stablising current in conductor external work is done b/c opposes change of current this work done is stored in the form of P.E

In Inductor

$$\boxed{U = \frac{1}{2}LI^2}$$

In capacitor

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

* This Energy is stored in the form of magnetic Field.
* Energy spend by battery is LI^2 so Remaning half part wasted in form of Heat.

Energy density (u)

Energy stored per unit volume

$$u = \frac{\text{Energy}}{\text{volume}} = \frac{\frac{1}{2}LI^2}{(\text{vol})}$$

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

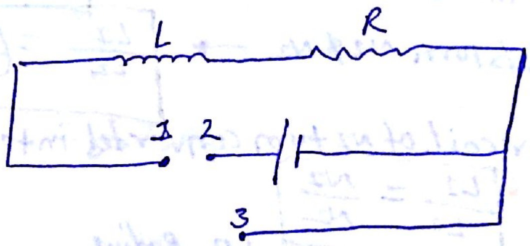
solenoid

$B = \mu_0 n i$

$L = \mu_0 n^2 A$

'u' per unit Length $= \frac{1}{2}(\mu_0 n^2 A) i^2$

Charging & Discharging of Inductor



Case I → ** Charging or, Growth of current (1-2)

$t = 0$	$t(\uparrow)$	$t = \infty$ (fullcharge)
$e = \max$	$e(\downarrow)$	$e = 0$
$I_{ckt} = 0$	$I_{ckt}(\uparrow)$	$I_{ckt} = \frac{V_0}{R} = \max$
$U_L = 0$	$U_L(\uparrow)$	$U_L = \max$

$$I(\uparrow) \rightleftarrows e(\downarrow)$$

→ By KVL

$$\boxed{\begin{aligned} I_{ckt} &= I_{max}\left(1 - e^{-\frac{R}{L}t}\right) \\ I_{ckt} &= \frac{V_0}{R}\left(1 - e^{-\frac{R}{L}t}\right) \end{aligned}}$$

→ Time const
Time in which current become approx 63% of Imax.

$$\boxed{\tau = \frac{L}{R}} \qquad \boxed{\begin{aligned} t &= \tau = 63\% \\ t &= 5\tau = 99.3\% \end{aligned}}$$

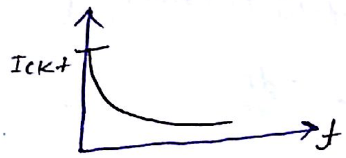
case-II → ** Discharging or, Decay of current (1-3)

$t = 0$	$t(\uparrow)$	$t = \infty$ (Full discharge)
$U_L = \max$	$U_L(\downarrow)$	$U_L = 0$
$I_{ckt} = \max$	$I_{ckt}(\downarrow)$	$I_{ckt} = 0$

* During discharging Induced current is in same direction as charging current

→ By KVL

$$\boxed{I_{ckt} = I_{max} = e^{-\frac{R}{L}t}}$$



→ Time const

$$\boxed{\tau = \frac{L}{R}} \qquad \boxed{\begin{aligned} t &= \tau = 63\% \text{ discharge} \\ t &= 5\tau = 99.3\% \text{ discharge.} \end{aligned}}$$

**

In Inductor		In capacitor	
* At $T = 0$	L = open ckt	* At $T = 0$	C = short ckt
* At $T = \infty$	L = Short ckt	* At $T = \infty$	C = open ckt.

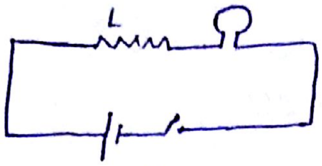
NOTE → * If Inductor (L) are in series

$$\boxed{L_{eff} = L_1 + L_2 + L_3 + L_4 + \cdots + L_N}$$

* If Inductor (L) are in parallel.

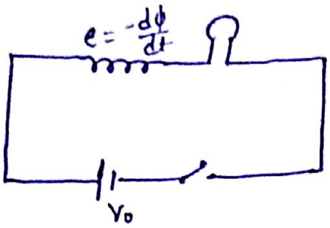
$$\boxed{\frac{1}{L_{eff}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \frac{1}{L_4} + \cdots \frac{1}{L_N}}$$

NCERT
#



When switch is made on current (↑)se exponentially so bulb brightness(↑)ses Gradually & acure max brightness After some time.

NCERT
#



(i) → When switch is ON.

$\phi(\uparrow) \Rightarrow \frac{d\phi}{dt} = -ve \Rightarrow e = -ve$

$\Rightarrow V_{bulb} = \boxed{V_0 - e}$

(ii) → After some time

$I = const$

$\phi \leftrightarrow$

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

$e = 0$

$\boxed{V_{bulb} = V_0}$ (proper bright)

(iii) → After switch made of

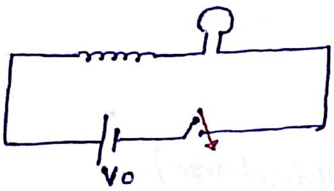
$\phi(\downarrow) \Rightarrow \frac{d\phi}{dt} = \ominus ve$

$\boxed{e = \oplus ve}$

$\Rightarrow V_{bulb} = \boxed{V_0 + e}$

So bulb may not get fused or sparking takes place near the switch.

** NCERT AIIMS
#



* During insertion of IRON Rod in coil

$\phi(\uparrow) \Rightarrow \frac{d\phi}{dt} = \oplus ve$

$\boxed{e = \ominus ve}$

$\boxed{V_{bulb} = V_0 - e} \Rightarrow \boxed{brightness \downarrow}$

* After full Insertion flux become max but const so no EMI.

$\boxed{V_{bulb} = V_0 \text{ (bulb Acuire its Initial max brightness)}}$

NOTE → Battery equivalent model

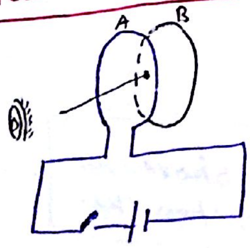
(i) → If current is (↑) then

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

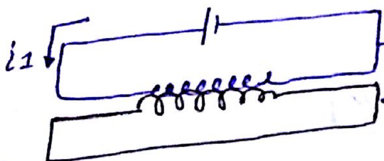
(ii) → If current is (↓) then

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

Mutual Induction (M)



Ability to Resist change in flux due to change in current in the other coil is defined by mutual Inductance of the system.



Flux passing through coil ① due to curren i_1 in it

$\phi_1 \propto i_1$

Some part of ϕ_1 will also linked with coil ② say ϕ_{21}

$\phi_{21} \propto i_1$

* $\boxed{\phi_{21} = M_{21} i_1}$

M depend on →

* Shape & size of coil.
* Dist. b/w coils.
* Medium b/w coil.
* orientation b/w coil.

M_{21} = Mutual inductance of coil ② w.r.t coil ①

Similarly, If coil ② is connected with battery instead of coil ①

$\phi_2 \propto i_2$

$\phi_2 \propto i_2$

$\boxed{\phi_2 = M_{12} i_2}$

M_{12} = Mutual Inductance of coil ① w.r.t coil ②

* For all type of Geometry * $\boxed{M_{21} = M_{12}}$

* scalar
* unit → $\frac{Wb}{A}$, Henery.

*→ Induction emf due to Mutual Induction

$$e_2 = -\frac{d\phi_2}{dt} = -\frac{d}{dt}(MI_1)$$

*
$$\boxed{\begin{aligned} e_2 &= -M\frac{dI_1}{dt} \\ e_1 &= -M\frac{dI_2}{dt}\end{aligned}}$$

* M b/w two coil

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

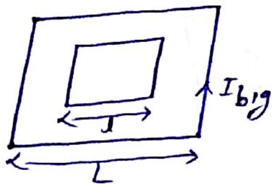
L_1 & L_2 ⇒ self Induction of coil

K ⇒ coupling cofficient.

$\boxed{0 \le K \le 1}$

* Ideal or, perfect coupling (K=1).
* M is defined for a particular arrangement of two coil.

Two square coil of side 'L' & 'l' are concentric & coplaner shown. If (L>>l). Then mutual induction?



* $\boxed{B_{big} = 2\sqrt{2}\frac{\mu_0 I_{big}}{\pi L}}$

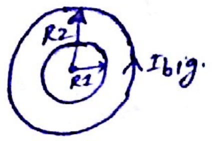
Flux with small coil

$\phi_{small} = B_{big} A_{small} \cos 0°$

* $\boxed{\phi_{small} = \left(\frac{2\sqrt{2}\mu_0 I_{big}}{\pi L}\right) l^2}$

* $\boxed{M = \frac{\phi_{small}}{I_{big}} = \frac{2\sqrt{2}\mu_0 l^2}{\pi L}}$

Two concentric coplaner circular loop as shown ($R_1 << R_2$) Find M=?



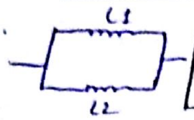
* $\boxed{I_{big} = \frac{\mu_0 I_{big}}{2R_2}}$

* $\boxed{\phi_{small} = \frac{\mu_0 I_{big}}{2R_2}(\pi R_1^2)}$

* $\boxed{M = \frac{\phi_{small}}{I_{big}} = \frac{\mu_0 \pi R_1^2}{2R_2}}$

Grouping of Inductor

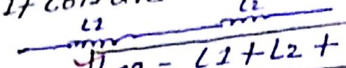
(i) → Parallel



$$\boxed{L_{eq} = \frac{L_1 L_2}{L_1 + L_2}}$$

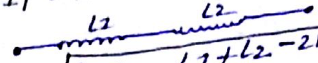
(ii) → Series

(a) → If coil are in same sence.



$$\boxed{L_{eq} = L_1 + L_2 + 2M}$$

(b) → If coil are in opposite sense.



$$\boxed{L_{eq} = L_1 + L_2 - 2M}$$

Motional / Dynamic EMI

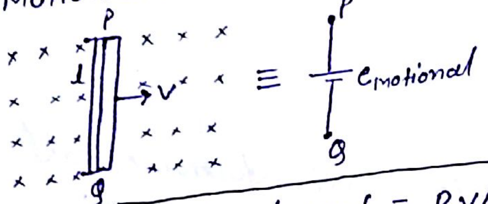
When a conducting Rod moves in ⊥ magnetic field cutting the field line then due to magnetic force its free e- are shifted at one end of Rod. this is called so potential difference is produced b/w the end of Rod. this is called Motional EMI

∴ In steady state

$e E_{induced} = e(\vec{v} \times \vec{B})$

$E_{induced} = BV$

* $\boxed{V_P - V_Q = BVL}$



$\boxed{\text{Motional emf} = BVL}$ *

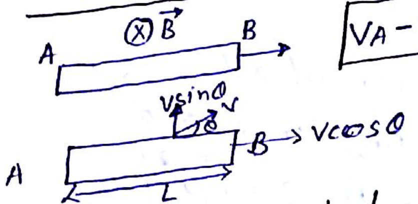
NOTE → * Where, all the three vectors i.e $\vec{B}$, $\vec{v}$ & $\vec{l}$ are mutually ⊥.

* If all Three vector are coplaner or, any two vector are parallel or, anti-parallel. then, no flux cutting.

so, $e_{motional} = 0$.

* If $\vec{v} \parallel \vec{B}$, $\vec{B} \parallel \vec{l}$, $\vec{l} \parallel \vec{v}$ or, all are coplaner then emf will be zero.

Case-I → When $\vec{B}$, $\vec{v}$ & $\vec{l}$ are in different direction.



$\boxed{V_A - V_B = 0}$

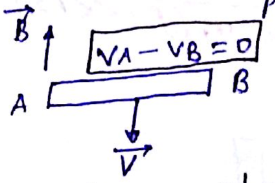
$\boxed{V_A - V_B = B(v\sin\theta)L}$

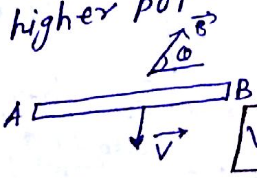
Right hand palm Rule

Finger → magnetic field.

Thumb → velocity.

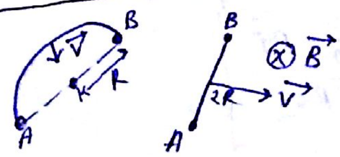
palm → higher pot.





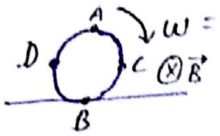
$\boxed{V_A - V_B = 0}$

Case-II → Arbitrary shaped conductor



$\boxed{V_A - V_B = BV(2R)}$

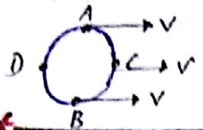
A Ring is pure Rolling in magnetic field $\vec{B}$.



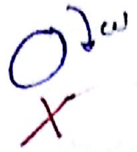
$V_A - V_B = ?$

$V_A - V_C = ?$

* pure translation

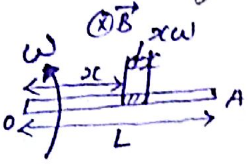


* pure Rotation



$$\boxed{V_A - V_B = 2BVR}$$
$$\boxed{V_A - V_C = BVR}$$

Case III → Rod Rotating about an end in $\vec{B}$



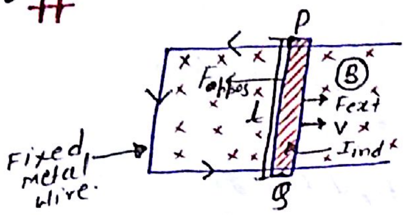
$$\boxed{V_0 - V_A = \frac{1}{2} B\omega L^2}$$

P.D b/w two points:

$e = \int_{x_i}^{x_f} B\omega x \, dx$

$e = \frac{1}{2} B\omega (x_f^2 - x_i^2)$

#



(i) → If Resistance of loop is 'R'

$$\boxed{I_{ind} = \frac{e}{R} = \frac{Bvl}{R}}$$

(ii) → opposing Force on Rod

$$F_{opps} = \left(\frac{Bvl}{R}\right) lB\sin 90^\circ$$
$$F_{opp} = \frac{B^2 l^2 v}{R}$$

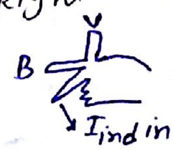
(iii) → Required Accl^n force to maintain const velocity on Rod

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

(iv) → Required ext. power to maintain const. velocity on Rod.

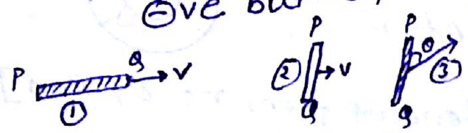
$$\boxed{P_{ext} = \vec{F}_{ext} \cdot \vec{v}} \qquad \boxed{P_{ext} = \frac{B^2 l^2 v^2}{R}}$$

Fleming Right hand Rule for direction of Induced in Moving Rod



* This Rod is equivalent to cell so, current is not from ⊕ve to ⊖ve but is from ⊖ve to ⊕ve.

Ex →



(i) → $l \parallel v \Rightarrow e = 0$ (∵ $l \parallel v$, so no flux cutting)

(ii) → Flux cutting is so $e_{motional} = Bvl$

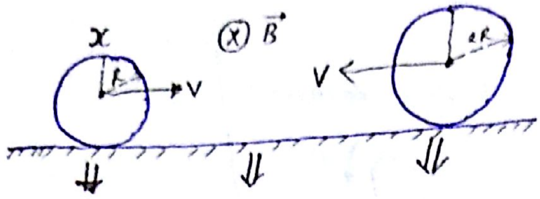
Induced = P to Q [Q = ⊖ve, P = ⊕ve]

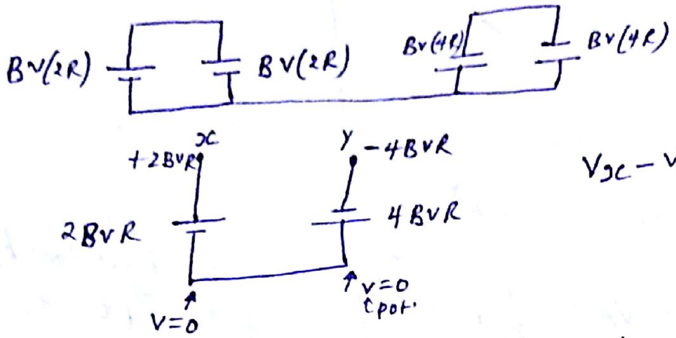
(iii) → Flux cutting is there so $e_{motional} = B(v\sin\theta)l$

$e = Bvl\sin\theta$

Q = ⊖ve / P = ⊕ve.

Two conducting Ring are moving linearlly on a conducting surface as shown. Find potential difference b/w their Heighest points!





$V_x - V_y = 2BVR - (-4BVR)$

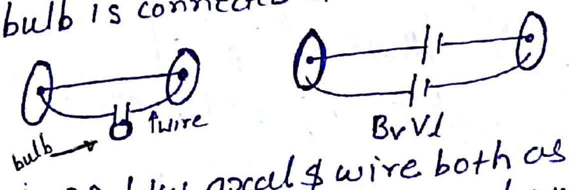
$\boxed{V_x - V_y = 6BVR}$

Free Falling Metal Rod (North-south).
* Doesn't cut B_H & B_V line so ($e_{motional} = 0$)

Free Falling Metal Rod (East-West)
* Doesn't cut B_V line so ($e = 0$)
* It cut B_H line so ($e_{motional} = B_H v l$)

An Aeroplane Moving in Horizontal plane at a Fix height from the surface.
Across the length of Aeroplane ($e=0$)
* V // l of aeroplane, so Across the length of Aeroplane ($e=0$)
* Wings cut the B_V lines, so P.D across the wing $e = B_V V l_{wings}$.
Imp * If ~~plane~~ plane is on equator $B_V = 0$, so PD acros wings ($e=0$)

For moving train.
|i| → velocity of train // length of train, so PD across initial & Final End of train = 0.
|ii| → Axial of train cuts B_V lines so, PD acros axal $e = B_V l_{axal}$.
Imp |iii| → If a bulb is connected b/w Ends of axal then,



There is P.D b/w axal & wire both as shown but as a loop net emf = 0 so, bulb does not glow.

IF 'n' identical Rod is Rotates as shown.
* Each Rod is equivalent to shell of $\frac{1}{2}B\omega L^2$
* If there Free end are connected by conducting wire as shown it is // Groupping of 'n' identical cell.

|i| → P.D b/w periferi & centre [Independent from no. of Rod]
$= \boxed{\frac{1}{2}B\omega l^2}$

|ii| → P.D b/w two points of perifery = 0
EX → Bicycle wheel.

Scanned by CamScanner

If no. of Rods become infinite then it is equivalent to Rotating disc ⊥ Magnetic Field.

So, PD b/w Periferi & centre.

* $\boxed{PD = \frac{1}{2} B\omega R^2}$ (R = Radius of DISK)

NOTE → * Faraday copper disc generation based on this concept.

Angular disc

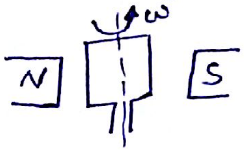
OF Rotating is Rotating is far field.

* $\boxed{P.D = \frac{1}{2} B\omega (R^2 - r^2)}$

* Rotating disc, If metalic Rod rotating ⊥ as disc as shown then non induction takes place. so $\boxed{PD = 0}$

Periodic EMI

When a coil placed in magnetic field Ratate an about axis shown. then its orientation w.r.t field changing continuosly. so flux with coil changes continuosly & Induction takes place this is called periodic EMI.



Flux with coil $(\phi) = NBA\cos\omega t$

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

$e = -NBA\frac{d}{dt}(\cos\omega t)$

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

Induced Electric Field

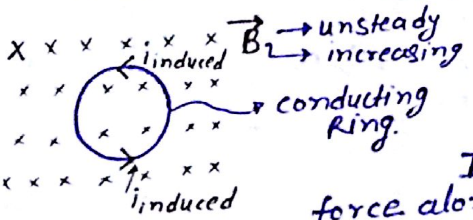
A time varying magnetic field produces an induced electric field Wich have Following properties.

|a| → They always exist in the form of closed loop may be circular or Non-circular. (Work done in close loop is zero)

|b| → They are non-conservative in nature.
i.e $\boxed{\oint \vec{E}\cdot d\vec{l} \neq 0}$

|c| → Their approximate direction can be found a/c to Lenz's Law.

consider a time varying magnetic field & a circular Ring is kept inside the field.



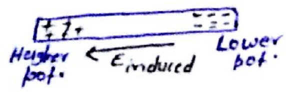
$\boxed{\oint \vec{E}\cdot d\vec{l} \neq 0}$

Initially all the e's were at Rest & magnetic force alone can't circulate them in the loop. so an Induced electric field Wich is produced as a Result of Insteady magnetic field develops the Induced current in the loop.

→ In Electrostates,

$q \oplus \xrightarrow{E} \ominus q$

But, Induced Electric field.



Faraday has measured the same $\oint \vec{E}\cdot d\vec{l}$ Wich comes equal to $-\frac{d\phi}{dt}$

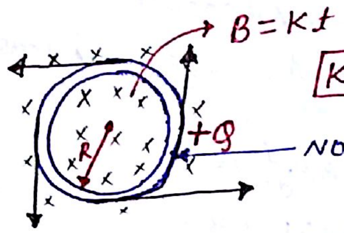
$$\boxed{e_{\substack{induced \\ closeloop}} = \oint \vec{E}\cdot d\vec{l} = -\frac{d\phi}{dt}}$$

Special case

$B = F(t)$

consider a case when magnetic field is confined in a cylindrical Region as shown, If magnetic field is varying with time induced Electric field in the form of close circular loop will be developed around the Region.

Find
|a| → Torque Acting on the Ring.
|b| → Initial Angular Accl$\underset{..}{n}$.



$$\int d\tau = \int \{(dq)\,E\}R$$

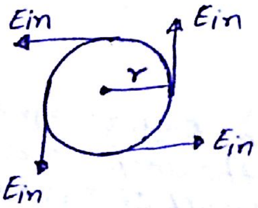
$$\tau = QER = Q\left[\frac{R}{2}K\right]R$$

$$\boxed{\tau = \frac{QKR^2}{2}}$$

$$I\alpha = \frac{KQR^2}{2}$$

$$\boxed{\alpha = \frac{KQ^2}{2M}}$$

E_{in}



$$\boxed{E_{in} = \begin{cases} -\frac{r}{2}\left(\frac{dB}{dt}\right), & r<R \\ -\frac{R^2}{2r}\left(\frac{dB}{dt}\right), & r\geq R \end{cases}}$$

A uniform $\vec{B}$ is in cylindrical Region of Radius 'R' whose crosssection is as shown If field is changing at const. rate $d\phi/dt$. Find Induced EMF field at position 'P' where,

(i) → $r > R$ (ii) → $r < R$.

(i) →

Induction $\oint \vec{B}$ in same coil $(A = \pi R^2)$

$$E / dl = A\frac{dB}{dt}$$

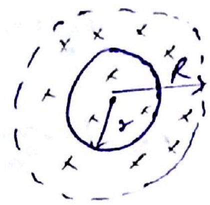
$$\boxed{E(2\pi r) = (\pi R^2)\left(\frac{dB}{dt}\right)}$$

$$\boxed{E \propto \frac{1}{r}}$$

(ii) → $\oint \vec{E} \cdot dl = A\frac{dB}{dt}$

$$\boxed{E(2\pi r) = (\pi r^2)\frac{dB}{dt}}$$

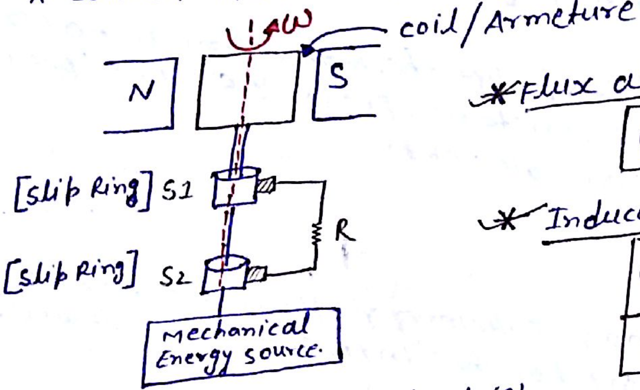
$$\boxed{E \propto r}$$



**

AC Generator

* Based on EMI (periodic Induction)
* convert Mechanical energy into electric Energy.



* Flux at any instant 't'

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

* Induced emf

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

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

* If Resistance of loop 'R'

$$I_{ind} = \frac{e}{R} \qquad \boxed{I_{ind} = \frac{NAB\omega\sin\omega t}{R}}$$

$\frac{e_{max}}{\phi_{max}} = ?$ $\quad \frac{NAB\omega}{NAB} = \omega$

[cos leading 90° than sin]

* Flux is leading Emf by 90°, so when flux is max. then emf is zero.
* Frequency of produced AC

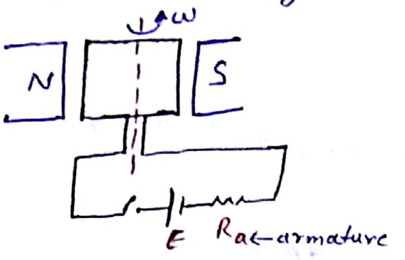
$$\boxed{F = \frac{N \times P}{2}}$$

P = pole
N = No. of Revolution per sec.

NOTE → In DC ~~motor~~ Generator commutor is used in place of slip Ring which makes the load current unidirectional.

DC MOTER

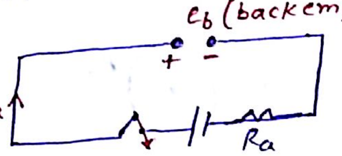
* It convert Electric Energy into Heat Energy. So, its Just opposite to Generator.



* Due to current in coil torque is excerted on coil by external magnetic field so, coil rotate hence mechanical energy is produced.
* Due to flux change, back emf is produced in coil which oppose the applied valtage so equivalent ckt. of moter.

$e = NAB\omega \sin \omega t$

$\boxed{e \propto \omega}$



$$\boxed{\begin{aligned} I &= \frac{E - e_b}{R_a} \\ E &= e_b + I_a R_a \end{aligned}}$$ * ⇒ Moter equation.

When moter is started!

(i) → $t = 0 \Rightarrow \omega = 0 \Rightarrow e_b = 0 \Rightarrow I_a = \frac{E}{R_a}$, I_a = max & unsafe.

(ii) → $t \Rightarrow (\uparrow) \Rightarrow \omega \Rightarrow \uparrow \Rightarrow e_b \Rightarrow (\uparrow) \Rightarrow I_a(\downarrow) \Rightarrow$ Moving towards safe current.

(iii) → After some moment, ω = const $\Rightarrow e_b$ const $\Rightarrow I_a \Rightarrow$ const. (min & safe)

Starter

It is variable Resistance used to protect the moter from Initial excess current as moter get speed its resistance get (↓) & at net speed It resist a zero resistance in moter ckt.

power

* $\boxed{P_{input} = EI_a}$ *
* $\boxed{P_{loss} = I_a^2 R_a}$ *
* $P_{output} = P_{input} - P_{loss}$

$= EI_a - I_a^2 R_a$

$= I_a[E - I_a R_a]$

*$\boxed{P_{output} = I_a R_b}$

Imp * 100% Efficiency not possible bcoz $e_b = E$ not possible in this case current will be zero.

* For max output power. *$\boxed{\frac{Ee_b - e_b^2}{R_a}}$

$\frac{dP_{out}}{de_b} = \frac{E - Re_b}{R_a} = \boxed{0}$*

(i) → $\boxed{e_b = \frac{E}{2}}$*

(ii) → $\% \eta = \frac{e_b}{E} \times 100\% = \boxed{50\%}$*

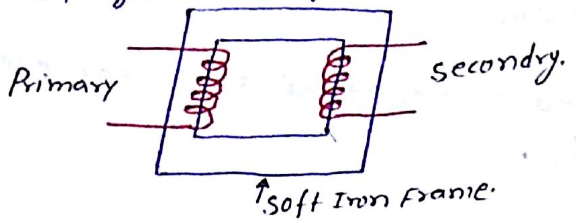
(iii) → $I_a = \frac{E - e_b}{R_a} = \boxed{\frac{E}{2R_a}}$*

(iv) → $(P_{out})_{max} = I_a e_b$

$= \left(\frac{E}{2R_a}\right)\left(\frac{E}{2}\right) = \boxed{\frac{E^2}{4R_a}}$*

'Tranformer'

* Based on Mutual Induction.
* Works for AC only not for DC.
* If (↑) or (↓) AC voltage & makes opposite change in current.
* Input frequency = output frequency.
* phase difference of (π) b/w Input & output voltage.
* convert high Alternating voltage to Low Alternating voltage & vice-versa.



* For Ideal transformer power = const = VI = const., $V \propto \frac{1}{I}$

$$\boxed{K = \frac{N_S}{N_P} = \frac{V_S}{V_P} = \frac{I_P}{I_S} = \frac{\sqrt{Z_S}}{\sqrt{Z_P}}}$$

Z_S → secondry. Z_P → Primary.

Step up	Step down
$V_S > V_P$	$V_S < V_P$
$N_S > N_P$	$N_S < N_P$
$I_S < I_P$	$I_S > I_P$
$Z_S > Z_P$	$Z_S < Z_P$
$K > 1$	$K < 1$
↑ Turn Ratio more than one so, step up.	↑ Turn Ratio less than one so step down.

$\because R = \frac{\rho l}{A} \propto \frac{1}{A}$

* secondry wire will be thicker than primary wire.

* Turn Ratio equal to 100. If 5V battery or, cell connected at primary then secondry battery is source of DC so output = 0.

$$\boxed{\% \eta = \frac{P_{out}}{P_{input}} \times 100}$$

There is no moving part in this machine so, its efficiency more than Generator.

Loss in transformer

|i| → Flux Loss → To minimise this soft Iron frame is used.

* |ii| → Hysteresis Loss → To minimise this Area of Hysterisis Loop should be Induce so Soft Iron is used.

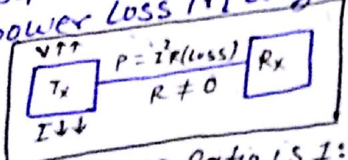
* |iii| → Eddy current Loss (Iron Loss) → To minimise this laminated core of soft Iron is used.

|iv| → copper Loss (I^2R Loss) → Heat Loss in copper binding.

|v| → Humming Loss → It is noise produced due to 'Magnato Striction Effect.'

Application of Transformer

* For Electrical sepration b/w two ckt.
* use to Reduce power loss in Long distance power transmision.



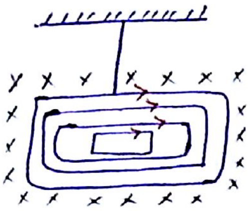
T.C

In a setup transformer, the turn Ratio is 1:2. A lechanche cell (emf = 1.5 V) is conneted across the primary. Then voltage develop in the secondry coil will be ⟶ zero

*[Transformer doesn't work on dc]

Scanned by CamScanner

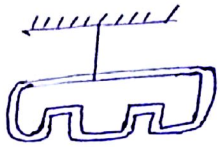
Eddy current



When flux with a metallic str. (plate, cylinder, sphere) changes with time, then induced current are in the form of large no. of concentric loop. Wich is similar to eddies in water so called Eddy current / Facault current.

(i) → Eddy current produce large amount of Heat.

(ii) → To reduce eddies current Resistance of metallic str. is (↑) using laminated or, slooted str.



By making slooted e^- is elongated. so Resistance (↑) so eddy current (↓).

Application of Eddy current

Dead beat ⓖ

In Moving Coil ⓖ vibrate for sometime at deflected position & dumping takes some time. In dead beat ⓖ Inside a coil a metallic plate is Inserted in Wich eddy current are produced due to vibration so it is produce Fast damping.

Ex → * Speed meter in vechile
* Electric break in train

learn in NCERT →
* Induction cooker (Furness)
* Induction coil in T.V