EddyCurrents & Self & Mutual Induction

1 Mark Questions

1.Why is the core of a transformer laminated? [Delhi 2013 c]

Ans.

The core of a transformer is laminated because of preventing eddy current being produced in the core. **(1)**

2.The motion of copper plate is damped, when it is allowed to oscillate between the two poles of a magnet. What is the cause this damping? [All India 2013]

AnsAs, the copper plates oscillate in the magnetic field between the two poles of the magnet, there is a continuous change of magnetic flux linked with the pendulum. Due to this eddy currents are set up in copper plate which try to oppose the motion of the plate (according to plate the Lenz's law) and finally bring it to rest.

3.A light metal disc on the top of an electromagnet is thrown up as the current is switched on. Why? Give reason. [All India 2013]

Ans.

When the current begins to grow through the electromagnet, the magnetic flux through the disc begins to increase. This sets up eddy current in the disc in the same direction as that of the electromagnetic current. **(1/2)**

Thus, if the upper surface of electromagnetic acquires *N*-polarity, the lower surface of the disc also acquires *N*-polarity. As, same magnetic poles repel each other, the light metallic disc is thrown up. **(1/2)**

4.How does the mutual inductance of a pair of coils change, when

(i)distance between the coils is increased and

(ii)number of turns in the coils is increased? [All India 2013]

Ans.

(*i*) A $\phi = MI$, with the increase in the distance between the coils the magnetic flux linked with the secondary coil decreases and hence, the mutual inductance of the two coils will decreases with the increase of separation between them. **(1/2)**

(*ii*) Mutual inductance of two coils can be found out by $M = \mu_0 n_1 n_2 Al$, i.e. $M \propto n_1 n_2$, so, with the increase in number of turns mutual inductance increases. **(1/2)**

5.How can the self-inductance of a given coil having N number of turns, area of cross-section A and lengths / be increased?[Forign 2009; Delhi 2012]

Ans. The self-inductance can be increased by the help of electric fields. It does not depend on the current through circuit but depends upon the permeability of material from which the core is made up off.

6.Define self-inductance of a coil. Write its SI unit. [All India 2010]

Ans.

Self-inductance of a coil is equal to the total magnetic flux linked with the coil, when unit current passes through it.

Also, self-inductance of a coil, is equal to the emf induced in coil, when rate of change of current in coil is 1 A/s .

SI unit of self inductance is 1 Henry (H)

$$1\text{H} = 1\text{V-s/A}$$ **(1)**

NOTE Any one definition is sufficient.

7.A plot of magnetic flux versus current (I) is shown in the figure for two inductions A and B Which of two has larger value of self-inductance? [Delhi 2010]

Ans.

Self-inductance of the inductor, $L = \phi / I$.

The slope of I - ϕ graph gives self-inductance of the coil.

Inductor *A* have got greater slope than inductor *B*, therefore self-inductance of *A* is greater than self-inductance of *B*. **(1)**

8.Define mutual inductance. Give its SI unit. [Foreign 2009]

Ans.

The mutual inductance of two inductor is equal to magnetic flux linked with one inductor when unit current flows through another conductor. **(1)**

or

The mutual inductance of two inductors is equal to emf induced in one coil, when rate of change of current in other coil is unity.

SI unit of mutual inductance = Henry (H)

$$1\,H = 1\,V\text{-}s/A$$ **(1)**

NOTE Any one definition is sufficient.

9.Mention any two useful applications of eddy currents.[Delhi 2009 C]

Ans.(i) Magnetic brake.

(ii) Magnetic furnace.

10The coils in certain galvanometers, have a fixed core made of a non-magnetic metallic material. Why does the oscillating coil come to rest so quickly in such a core?

Ans. Due to eddy currents produced in core whitih opposes the cause (deflection of coil), that produces it.

2 Marks Questions

11.What are eddy currents? Write their tWO applications. [All India 2012]

Ans. Eddy current Eddy currents are the currents induced in the bulk pieces of conductors when the amount of magnetic flux linked with the conductor changes.Eddy currents can be minimised by taking laminated core, consists of thin metallic sheet insulated from each other by varnish instead of a single solid mass. The plane of the sheets should be kept perpendicular to the direction of the currents. The insulation provides high resistance hence, eddy current gets minimised

Applications (i) Electromagnetic damping (ii) Induction furnace.

12.Define mutual inductance between two long coaxial solenoids. Find out the expression for the mutual inductance of inner solenoid of length / having the radius r_x and the number of turns per unit length due to the second outer solenoid of same length and n_2 number of turns per unit length. [Delhi 2012]

Ans.

Due to change in the current in the one coil flux linked with the other coil is changing, we will calculate mutual inductance on this basis.

The phenomenon of generation of induced emf in a long solenoid due to a change of current in another neighbouring coaxial solenoid is known as mutual induction. **(1)**

13.Current in e circuit fails steadily bum AU A to 0.0 A in 10 ms. ii an average emf of 200 V is induced, then calculate the self-inductance of the Circuit. [Foreign 2011]

Ans.

The mutual induction for the pair of the solenoids is

$$M = \frac{\mu_0 n_1 n_2 A}{l} \quad \textbf{(1)}$$

$$\Delta I = -2\text{ A}$$

$$\Delta t = 10 \times 10^{-3}\text{ s}$$

$$V = 200\text{ V}$$

$$L = ?$$

$\because$ Induced emf, $e = -L\frac{\Delta I}{\Delta t}$ **(1)**

$$200 = -L\left(\frac{-2}{10 \times 10^{-3}}\right)$$

$$200 = L \times 2 \times 10^2$$

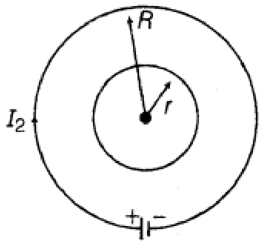
$\therefore$ Self-induction, $L = 1\text{H}$ **(1)**

14.Two concentric circular coils, one of small radius r and the other of large radius R, such that R >>r, are placed coaxially with centres coinciding. Obtain the mutual inductance of the a rran element.

Ans.

Let a current I_2 flows through the outer circular coil of radius R. Th magnetic field at the centre of the coil is

$$B_2 = \frac{\mu_0 I_2}{2R}$$



(1)

As $r << R$, hence field B_2 may be considered to be constant over the entire cross-sectional area of inner coil of radius r. Hence, magnetic flux linked with the smaller coil will be

$$\phi_1 = B_2 A_1 = \frac{\mu_0 I_2}{2R} \cdot \pi r^2$$

As, by definition $\phi_1 = M_{12} I_2$

Now mutual inductance, $M_{12} = \frac{\phi_1}{I_2}$

$$= \frac{\mu_0 \pi r^2}{R}$$

But $M_{12} = M_{21}$ = suppose, M

$$\therefore \quad M = \frac{\mu_0 \pi r^2}{R} \quad \textbf{(1)}$$

15.Two concentric circular coils C_1 and C_2, radius r_1 and r_2 ($r_1<<r_2$) respectively are kept coaxially. If current is passed through C_2, then find an expression for mutual inductance between the two coils.

[All India 2009,2011 C; Foreign 2011]

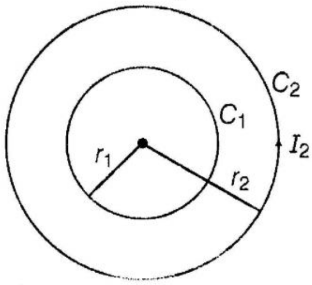
Ans.

In case of two concentric coil when current flows through one coil, the emf is induced in the other coil.

Let current I_2 passes through the coil C_2.

Magnetic field at centre due to current loop C_2

$$B_2 = \frac{\mu_0 N_2 I_2}{2r_2}$$



where, N_2 = number of turns in coil C_2 **(1/2)**

$\therefore$ Total magnetic flux linked with coil C_1

$$\phi_1 = N_1 B_2 A_1 \quad \textbf{(1/2)}$$

$$\phi_1 = N_1 \left(\frac{\mu_0 N_2 I_2}{2r_2} \right) (\pi r_1^2)$$

But, $\phi = \mu I_2$

$$\Rightarrow \quad MI_2 = \frac{\mu_0 N_1 N_2 I_2}{2r_2} \pi r_1^2$$

$$M = \frac{\mu_0 \pi N_1 N_2 r_1^2}{2 r_2} \quad \textbf{(1)}$$

16. A source of emf ε is used to establish a current I through a coil of self-inductance L. Show that the work done by the source of build up the current I is $\frac{1}{2} LI^2$. **[Delhi 2010C]**

Ans.

Here, we will use the concept of work energy-theorem i.e. here work against the emf induced will be stored in the form of magnetic energy.

The source of emf ε establishes current in coil in opposition of induced emf (Lenz's rule) and hence does the work for the same. This work done by source stores in the form of magnetic energy in the coil.

Let, I current flows through the coil of self-inductance L at any instant t when rate of change of current in coil is $\frac{dI}{dt}$.

$\therefore$ Induced emf, $E = -L\frac{dI}{dt}$ **(1)**

$\therefore$ Work done in establishing the current in small time interval dt is given by

$$dW = Pdt = -EIdt = -\left(-L\frac{dI}{dt}\right)Idt$$

$$dW = LIdI$$

$\therefore$ Total work done in increasing the current from zero to I.

$$\therefore \quad W = \int_0^I LI\,dI = L\int_0^I IdI$$

$$= L\left[\frac{I^2}{2}\right]_0^I = \frac{1}{2}L(I^2 - 0^2)$$

$$W = \frac{1}{2}LI^2$$

This work is stored as the energy in the inductor. **(1)**

17.Derive an expression for the self-inductance of a long air-cored solenoid of length / and number of turns N. [Delhi 2008]

Ans.

- Let the radius and length of air cored solenoid are r and l, respectively such that $r << l$ and having n turns per unit length.

$$\therefore \quad n = \frac{N}{l} \quad ...(i)$$

N = total number of turns

If, I current flows through the coil, then magnetic field is given by

$$B = \mu_0 nI \quad \textbf{(1)}$$

$\therefore$ Magnetic flux linked with each turn

$$\phi = BA = \mu_0 nIA$$

$\therefore$ Total magnetic flux linked with solenoid

$$N\phi = (\mu_0 nIA)N$$

But, $\quad N\phi = LI$

where, L is coefficient of self-induction.

$$(\mu_0 nIA)N = LI$$

$$L = \mu_0 nAN = \mu_0\left(\frac{N}{l}\right)AN$$

$$L = \frac{\mu_0 AN^2}{l} \quad \textbf{(1)}$$

This is required expression.

18.Define mutual inductance and write its SI unit. Write the expression for the mutual inductance between a pair of circular coil of radii r and R (.R > r). [Foreign 2008]

Ans.

The mutual inductance of two inductor is equal to magnetic flux linked with one inductor when unit current flows through another conductor. **(1)**

or

The mutual inductance of two inductors is equal to emf induced in one coil, when rate of change of current in other coil is unity.

SI unit of mutual inductance = Henry (H)

$$1\,H = 1\,V\text{-}s/A \quad \textbf{(1)}$$

NOTE Any one definition is sufficient.

Mutual inductance of pair of circular coils,

$$M = \frac{(\mu_0 \pi) N_1 N_2 r^2}{2R} \quad \textbf{(1)}$$

where, N_1 and N_2 are number of turns in inner and outer coil of radii r and R, respectively.

19.Derive an expression for the self-inductance of a long solenoid of N number of turns containing a medium of relative permeability u_r.[Foreign 2008]

Ans.

- Let the radius and length of air cored solenoid are r and l, respectively such that $r << l$ and having n turns per unit length.

$$\therefore \quad n = \frac{N}{l} \quad \text{...(i)}$$

N = total number of turns

If, I current flows through the coil, then magnetic field is given by

$$B = \mu_0 n I \quad \textbf{(1)}$$

$\therefore$ Magnetic flux linked with each turn

$$\phi = BA = \mu_0 n I A$$

$\therefore$ Total magnetic flux linked with solenoid

$$N\phi = (\mu_0 n I A) N$$

But, $N\phi = LI$

where, L is coefficient of self-induction.

$$(\mu_0 n I A) N = LI$$

$$L = \mu_0 n A N = \mu_0 \left(\frac{N}{l}\right) A N$$

$$L = \frac{\mu_0 A N^2}{l} \quad \textbf{(1)}$$

This is required expression.

For a core of medium of relative permeability μ_r.

$$\therefore \quad L = \frac{(\mu_0 \mu_r) N^2 A}{l} \quad (1/2)$$

20. The flux linked with a large circular coil of radius R is 0.5×10^{-3} Wb. When a current of 0.5 A flows through a small neighbouring coil of radius r, calculate the coefficient of mutual inductance for the given pair of coils.

If the current through the small coil suddenly falls to zero, what would be its effect in the larger coil? **[Delhi 2008C]**

Ans.

Flux linked with larger coil of radius,

$$R = 0.5 \times 10^{-3} \text{ Wb}$$

and $\quad I = 0.5 \text{ A}$

flows through neighbouring coil of radius r.

Total flux (ϕ) linked with one coil $= MI$

[I current flows in neighbour coil]

$$\therefore \quad 0.5 \times 10^{-3} = M \times 0.5$$

$$M = 10^{-3} \text{ H}$$ **(1)**

With the fall of current in small coil to zero, the magnetic flux linked with long coil decrease to zero quickly which in turn produces large induced emf in it. **(1)**

21.A large circular coil of radius R and a small circular coil of radius r are put in vicinity of each other. If the coefficient of mutual induction for this pair equals 1 mH, what would be the flux linked with the larger coil when a current of 0.5 A flows through the smaller coil?When the current in the smaller coil falls to zero, what would be its effect in the larger coil? [Delhi 2008 C]

Ans.

According to the question,

Mutual inductance for a given power of coil

$$M = 1\text{mH} = 1 \times 10^{-3} \text{ H}$$

$$I = 0.5 \text{ A}$$

$\therefore$ Total magnetic flux linked with larger coil,

$$\phi = MI$$

$$\phi = (1 \times 10^{-3}) \times 0.5$$

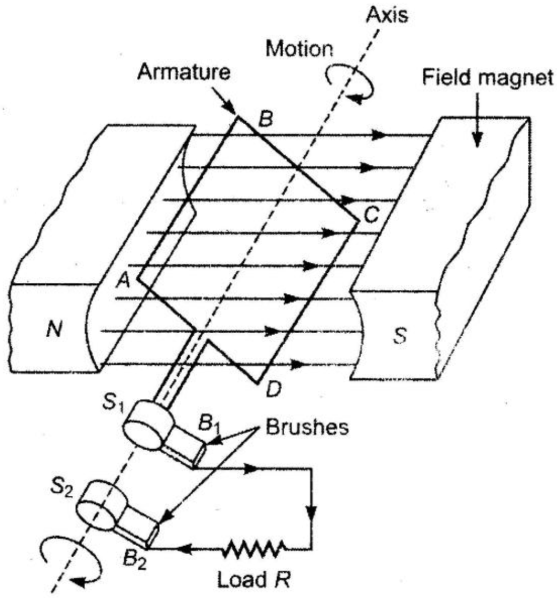
$$\phi = 5 \times 10^{-4} \text{ Wb}$$ **(1)**

3 Marks Questions

22.(i) Draw a schematic sketch of an AC generator describing its basic elements. State briefly its working principle. Show a plot of variation of (a) magnetic flux and (b) alternating emf versus time generated by a loop of wire rotating in a magnetic field, (ii) Why is choke coil needed in the use of fluorescent tubes with AC mains? [Delhi 2014]

Ans.

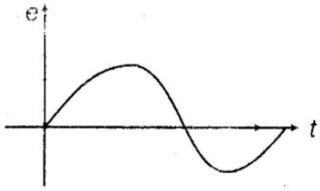
Whenever amount of magnetic flux linked with a coil changes, an emf induced in the coil. It lasts so long as the change in magnetic flux through the coil continues. **(1)**



Working When a closed armature coil rotates in a uniform magnetic field with its axis perpendicular to the magnetic field, the magnetic flux linked with the loop changes and emf induces in the coil. Let initially angle between area vector of coil and magnetic field B is 0°. Thereafter, AB comes downward and CD upward then by Fleming's right hand rule induced current flows from B to A.

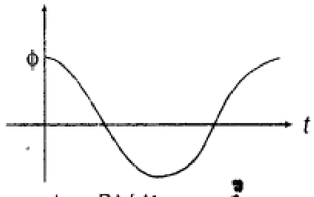
During the next half revolution, when CD comes downward end AB upward then current flows from C to D. During the first half rotation, current flows through $BAS_2B_2RB_1DC$ and during next half rotation along $CDB_1RB_2S_2AB$.

(*a*) **Variation of alternating emf with time**



$e = BNA\omega \cos \omega t$

(*b*) **Variation of magnetic flux with time**



$\phi = BNA \cos \omega t$

(*ii*) The choke coil is used to reduce the current. As its power factor is zero, it reduces the current without wasting the power. **(1)**

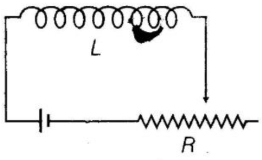
23.Define the term self-inductance of a solenoid. Obtain the expression for the magnetic energy stored in an inductor of self-inductance L to build up a current I through it.[All India 2014]

Ans.

(*i*) **Self-Inductance** Self-inductance is the property of a coil by virtue of which, the coil opposes any change in the strength of current flowing through it by inducing an emf in itself.

The induced emf is also called **back emf.** When the current in a coil is switched on, the self-induction opposes the growth of the current and when the current is switched off, the self-induction opposes the decay of the current.

So, self-induction is also called the **inertia of electricity.**



(*ii*) **Self-Inductance of long Solenoid** A long solenoid is one whose length is very large as compared to its area of cross-section. The magnetic field (*B*) at any point inside such a solenoid is practically constant and is given by

$$B = \frac{\mu_0 NI}{l} \quad \text{...(i)}$$

where, μ_0 = absolute magnetic permeability of free space, N = total number of turns in the solenoid

and I = length of the solenoid.

∴ Magnetic flux through each turn of the solenoid,

$$\phi = B \times \text{area of the each turn}$$

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

where, A = area of each turn of the solenoid.

Total magnetic flux linked with the solenoid = flux through each turn × total number of turns

$$N\phi = \mu_0 \frac{N}{l} IA \times N \quad \text{...(ii)}$$

If L is coefficient of self-inductance of the solenoid, then

$$\therefore \quad N\phi = LI \quad \text{...(iii)}$$

From Eqs. (ii) and (iii), we get

$$LI = \mu_0 \frac{N}{l} IA \times N$$

or $$L = \frac{\mu_0 N^2 A}{l}$$ **(1)**

If core is of any other magnetic material μ is placed, then

$$\mu = \mu_0 \mu_r$$

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

The magnitude of emf is given by

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

Multiplying (I) to both sides, we get

$$eI\,dt = LI\,dI \quad \text{...(iv)}$$

But $$I = \frac{dq}{dt}$$

or $Idt = dq$

Also, work done (dW) = Voltage (e) × Charge (dq)

or $dW = e \times dq = eIdt$

Substituting these values in Eq. (iv), we get

$$dW = LIdI \quad \text{...(v)}$$

Total work done in increasing the current from zero to I_0, we have

By integrating both sides of Eq. (v), we get

$$\int_0^w dW = \int_0^{I_0} LIdI$$

$$W = \frac{1}{2} LI_0^2$$

This work done in increasing the current flowing through the inductor is stored as the potential energy (U) in the magnetic field of inductor $U = \frac{1}{2} L I_0^2$c

24.The current flowing in the two coils of self-inductance =16 mH and L2 = 12 mH are increasing at the same rate. If the power supplied to the two coils are equal, find the ratio of

(i)induced voltages

(ii)the currents and

(iii)the energies stored in the coil at a given instant. [Foreign 2014]

Ans.

Given,

$$L_1 = 16 \text{ mH},$$
$$L_2 = 12 \text{ mH}$$

(i) Induced voltage is given by

$$v = L\frac{dI}{dt} \Rightarrow v \propto L$$

$$\frac{v_1}{v_2} = \frac{L_1}{L_2} \text{ (as } \frac{dI}{dt} \text{ is same)}$$

$$\Rightarrow \frac{v_1}{v_2} = \frac{16}{12} = \frac{4}{3} \quad \text{... (i)}$$

(ii) Power $(P) = Iv$

Now,

$$\frac{I_1}{I_2} = \frac{v_2}{v_1} \quad \text{(as } P \text{ is the same)}$$

$$\Rightarrow \frac{I_1}{I_2} = \frac{3}{4} \quad \text{... (ii)}$$

(iii) Energy stored is given by coil 1 and coil 2

$$E_1 = \frac{1}{2}L_1I_1^2 \quad \text{... (iii)}$$

$$E_2 = \frac{1}{2}L_2I_2^2 \quad \text{... (iv)}$$

On dividing Eqs. iii and (iv), we get

$$\frac{E_1}{E_2} = \frac{L_1I_1^2}{L_2I_2^2} = \frac{16}{12} \times \frac{9}{16} \text{ [from Eq. (ii)]}$$

$$\frac{E_1}{E_2} = \frac{3}{4}$$

25. Starting from the expression for the energy $W = \frac{1}{2}LI^2$, stored in a solenoid of self-inductance L to build up the current I, obtain the expression for the magnetic energy in terms of the magnetic field B, area A and length l of the solenoid having n number of turns per unit length. Hence, show that the energy density is given by $B^2 / 2\mu_0$.

[Delhi 2013C]

Ans.

Energy stored in the magnetic field

$$W = \frac{1}{2}LI^2$$

$$= \frac{1}{2}\frac{\mu_0 N^2 A}{L} \cdot \frac{B^2L^2}{\mu_0^2 N^2}$$

$$= \frac{\mu_0^2}{2\mu_0}(AL)^2 \quad \left[\because L = \frac{\mu_0 N^2 A}{L}, B = \frac{\mu_0 NL}{L}\right]$$

(2)

We know that, energy density,

$$u_B = \frac{\text{Energy}}{\text{Volume}}$$

$$= \frac{B^2}{2\mu_0} \quad [\therefore B = AL]$$

26.(i) Define self-inductance. Write its SI units.

(ii) Derive an expression for self-inductance of a long solenoid of length /, cross-sectional area A having N number of turns.[Delhi 2009]

Ans.(i)

Self-inductance of a coil is equal to the total magnetic flux linked with the coil, when unit current passes through it.
Also, self-inductance of a coil, is equal to the emf induced in coil, when rate of change of current in coil is 1 A/s .
SI unit of self inductance is 1 Henry (H)

$$1\text{H} = 1\text{V-s/A} \quad \textbf{(1)}$$

NOTE Any one definition is sufficient.

(ii)

- Let the radius and length of air cored solenoid are r and l, respectively such that $r << l$ and having n turns per unit length.

$$\therefore \quad n = \frac{N}{l} \quad \text{...(i)}$$

N = total number of turns

If, I current flows through the coil, then magnetic field is given by

$$B = \mu_0 nI \quad \textbf{(1)}$$

$\therefore$ Magnetic flux linked with each turn

$$\phi = BA = \mu_0 nIA$$

$\therefore$ Total magnetic flux linked with solenoid

$$N\phi = (\mu_0 nIA)N$$

But, $\quad N\phi = LI$

where, L is coefficient of self-induction.

$$(\mu_0 nIA)N = LI$$

$$L = \mu_0 nAN = \mu_0 \left(\frac{N}{l}\right) AN$$

$$L = \frac{\mu_0 AN^2}{l} \quad \textbf{(1)}$$

This is required expression.

27.Define the coefficient of mutual induction. A long solenoid of length / and radius is enclosed coaxially within another long solenoid of length I and radius r_2 ($r_2 > r_1$ and >> r_2). Deduce the expression for the mutual inductance of this pair of Solenoids. [Delhi 2009; Ail India 2008]

Ans.

The mutual inductance of two inductor is equal to magnetic flux linked with one inductor when unit current flows through another conductor. **(1)**

or

The mutual inductance of two inductors is equal to emf induced in one coil, when rate of change of current in other coil is unity.
SI unit of mutual inductance = Henry (H)

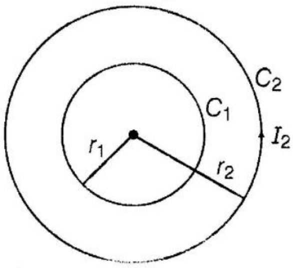
$$1\text{H} = 1\text{V-s/A} \quad \textbf{(1)}$$

NOTE Any one definition is sufficient.

> In case of two concentric coil when current flows through one coil, the emf is induced in the other coil.

Let current I_2 passes through the coil C_2.
Magnetic field at centre due to current loop C_2

$$B_2 = \frac{\mu_0 N_2 I_2}{2r_2}$$



where, N_2 = number of turns in coil C_2 **(1/2)**

$\therefore$ Total magnetic flux linked with coil C_1

$$\phi_1 = N_1 B_2 A_1 \quad \textbf{(1/2)}$$

$$\phi_1 = N_1 \left(\frac{\mu_0 N_2 I_2}{2r_2}\right)(\pi r_1^2)$$

But, $\phi = \mu I_2$

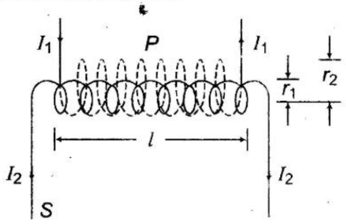
$$\Rightarrow \quad MI_2 = \frac{\mu_0 N_1 N_2 I_2}{2r_2} \pi r_1^2$$

$$M = \frac{\mu_0 \pi N_1 N_2 r_1^2}{2 r_2} \quad \textbf{(1)}$$

28.Deduce an expression for the mutual inductance of two long coaxial solenoids but having different radii and different number of turns. [All India 2009]

Ans.

Let coaxial solenoid P is wound over an another solenoid.



(1)

Let l = length of both solenoid.

r_1 and r_2 = radii of P and S

$A_2 = \pi r_2^2$ [area of secondary coil, S]

Magnetic induction in solenoid, P

$$B_1 = \mu_0 n_1 I_1$$ **(1)**

where, $n = \frac{N_1}{l}$ = number of turn per unit length.

$\therefore$ Total flux linked with solenoid S

$$\phi_2 = B_1 A_2 N_2$$

$$\Rightarrow \quad \phi_2 = B_1 (\pi r_2^2) N_2$$

$$= (\mu_0 n_1 I_1) \pi r_2^2 N_2$$

$$\phi_2 = \left(\mu_0 \frac{N_1}{l} \cdot I_1\right) \pi r_2^2 N_2$$

$$\Rightarrow \quad \phi_2 = \frac{\mu_0 \pi I_1 N_1 N_2 r_2^2}{l} \quad \text{...(i)}$$

But $\phi_2 = MI_1$

where, M = coefficient of mutual induction

$$\Rightarrow \quad MI_1 = \frac{\mu_0 \pi N_1 N_2 r_2^2}{l} I_1$$

$$M = \frac{\mu_0 \pi N_1 N_2 r_2^2}{l}$$ **(1)**

This is required expression for coefficient of mutual induction.

5 Marks Questions

29.(i) Draw a labelled diagram of AC generator and state its working principle

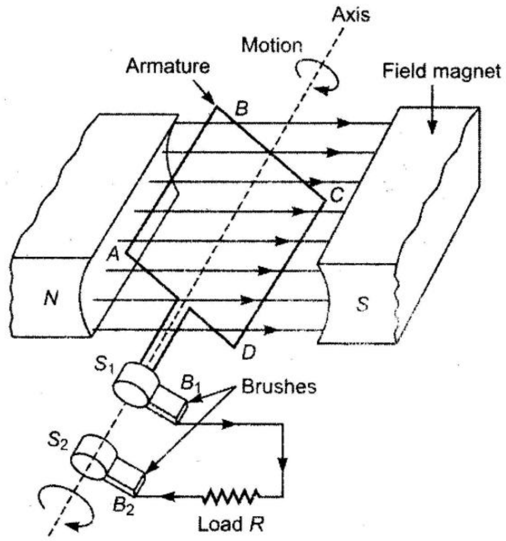
(ii)How is magnetic flux linked with the armature coil changed in a generator ?

(iii)Derive the expression for maximum value of the induced emf and state the rule that gives the direction of the induced emf.

(iv)Show the variation of the emf generated versus time as the armature is rotated with respect to the direction of the magnetic fields. [Delhi 2014 C]

Ans.

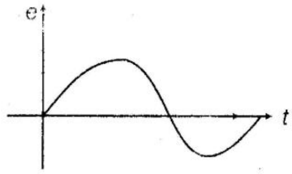
Whenever amount of magnetic flux linked with a coil changes, an emf induced in the coil. It lasts so long as the change in magnetic flux through the coil continues. **(1)**



Working When a closed armature coil rotates in a uniform magnetic field with its axis perpendicular to the magnetic field, the magnetic flux linked with the loop changes and emf induces in the coil. Let initially angle between area vector of coil and magnetic field B is 0°. Thereafter, AB comes downward and CD upward then by Fleming's right hand rule induced current flows from B to A.

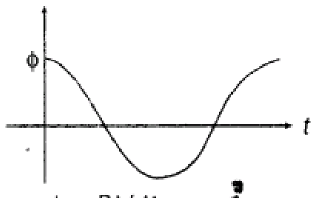
During the next half revolution, when CD comes downward end AB upward then current flows from C to D. During the first half rotation, current flows through $BAS_2B_2RB_1DC$ and during next half rotation along $CDB_1RB_2S_2AB$.

(a) **Variation of alternating emf with time**



$e = BNA\omega \cos \omega t$

(b) **Variation of magnetic flux with time**



$\phi = BNA \cos \omega t$

(ii) The choke coil is used to reduce the current. As, its power factor is zero, it reduces the current without wasting the power. **(1)**

Thus, the direction of flow of current in resistance R get changed alternatively after every half cycle.

Thus, AC is produced in coil. **(1)**

Let at any instant total magnetic flux linked with the armature coil is given G.

(where, $\theta = \omega t$ is the angle made by area vector of coil with magnetic field.)

$$\phi = NBA\cos\theta = NBA\cos\omega t$$

$$\therefore \quad \frac{d\phi}{dt} = -NBA\omega\sin\omega t$$

$$-\frac{d\phi}{dt} = NBA\omega\sin\omega t$$

By Faraday's law of EMI, $e = \frac{-d\phi}{dt}$

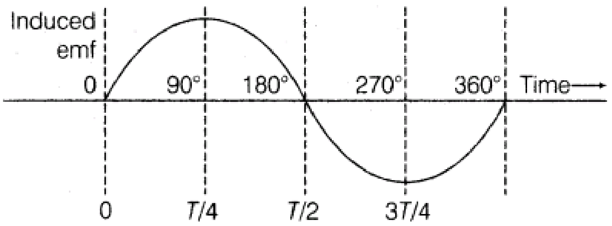
Induced emf in coil is given by,

$$e = NBA\omega\sin\omega t$$

$$e = e_0\sin\omega t$$

where, $e_0 = NBA\omega$

= peak value of induced emf



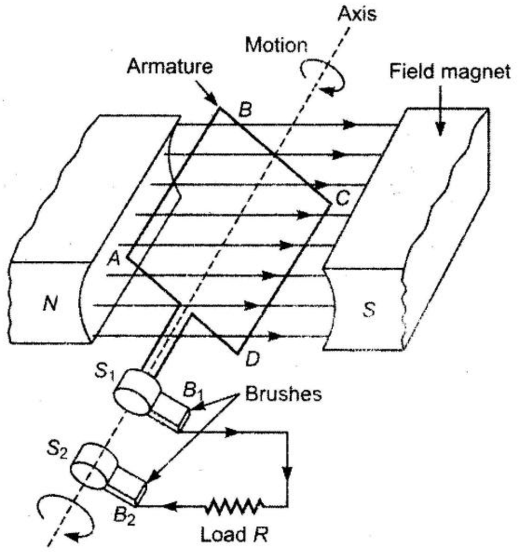
The mechanical energy spent in rotating the coil in magnetic field appears in the form of electrical energy. **(1)**

30.State the working of AC generator with the help of a labelled diagram. The coil of an AC generator having N turns, each of area A, is rotated with a constant angular velocity to. Deduce the expression for the alternating emf generated in the coil.What is the source of energy generation in this device?

[Delhi 2010, All India 2008]

Ans.

Whenever amount of magnetic flux linked with a coil changes, an emf induced in the coil. It lasts so long as the change in magnetic flux through the coil continues. **(1)**



Working When a closed armature coil rotates in a uniform magnetic field with its axis perpendicular to the magnetic field, the magnetic flux linked with the loop changes and emf induces in the coil. Let initially angle between area vector of coil and magnetic field B is 0°. Thereafter, AB comes downward and CD upward then by Fleming's right hand rule induced current flows from B to A.

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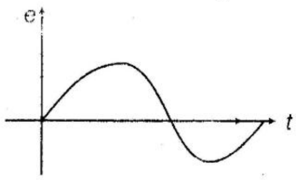
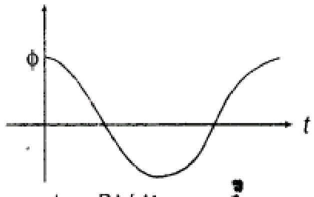
(a) **Variation of alternating emf with time**



$e = BNA\omega \cos \omega t$

(b) **Variation of magnetic flux with time**



$\phi = BNA \cos \omega t$

(ii) The choke coil is used to reduce the current. As its power factor is zero, it reduces the current without wasting the power. **(1)**

Thus, the direction of flow of current in resistance R get changed alternatively after every half cycle.

Thus, AC is produced in coil. **(1)**

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(where, $\theta = \omega t$ is the angle made by area vector of coil with magnetic field.)

$$\phi = NBA\cos\theta = NBA\cos\omega t$$

$$\therefore \quad \frac{d\phi}{dt} = -NBA\omega \sin\omega t$$

$$-\frac{d\phi}{dt} = NBA\omega \sin\omega t$$

By Faraday's law of EMI, $e = \frac{-d\phi}{dt}$

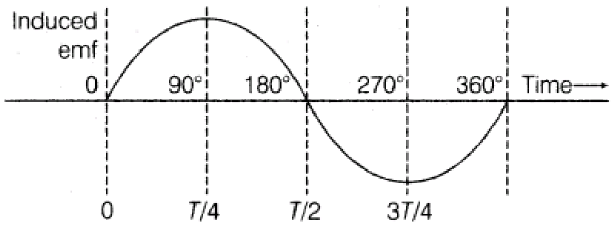
Induced emf in coil is given by,

$$e = NBA\omega \sin\omega t$$

$$e = e_0 \sin \omega t$$

where, $e_0 = NBA\omega$

= peak value of induced emf



The mechanical energy spent in rotating the coil in magnetic field appears in the form of electrical energy. **(1)**

(d) Direction of induced emf can be determined using Fleming's right hand rule. **(1)**