CHAPTER 3

ELECTROMAGNETIC INDUCTION

3.1 Introduction

On August 29, 1831, a British scientist Michael Faraday (1771-1867) discovered the phenomenon of electromagnetic induction. After a variety of experiments he found that a moving magnetic field does give rise to an emf. Most commercial apparatus like motors, generators and transformers are based upon the principle of electromagnetic induction.

3.2 Faraday's Laws of electromagnetic induction

First law: This law states that whenever there is a change in magnetic flux linked with a coil, an emf is induced in it.

Second law: This law states that the magnitude of the induced emf is equal to the rate of change of magnetic flux linking with the circuit.

Consider a coil of 'N' turns. Let the flux linked with the coil change from ϕ_1 to ϕ_2 in 't' seconds.

$$\text{Initial flux linkages} = N\phi_1$$

$$\text{Final flux linkages} = N\phi_2$$

According to faraday's second law, The induced e.m.f,

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

Putting the above equation in its differential form,

$$|e| = N\frac{d\phi}{dt} \text{ volt}$$

3.3 Lenz's Law

The direction of the induced emf (or current) is given by Lenz's law. It states:

The direction of the induced current is such that it opposes the very cause, which produces it.

In the view of Lenz's law we can state Faraday's laws as,

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

Example 1

A coil of 1200 turns gives rise to a magnetic flux of 3mwb, when carrying a certain current. If the current is reversed in 0.2 seconds, what is the average value of emf induced in the coil.

Solution:

No. of turns of the coil, N = 1200

Change in flux linkages, $d\phi = 2 \times 3 = 6\text{mwb} = 6 \times 10^{-3}$ wb

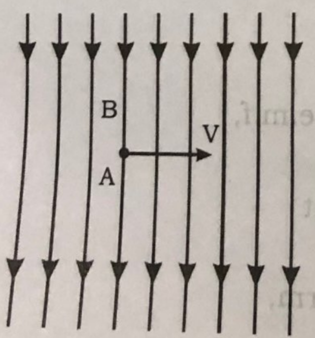
E.M.F induced in the coil, $e = N\left(\frac{d\phi}{dt}\right) = 1200\left(\frac{6 \times 10^{-3}}{0.2}\right)$ = **36 Volt**

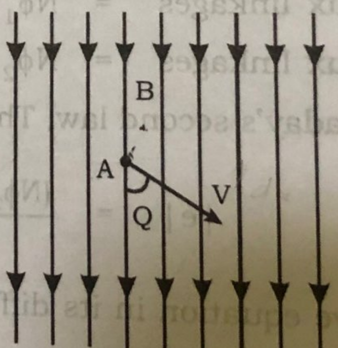
3.4 induced E.M.F

Induced e.m.f can either be (i) dynamically induced or (ii) statically induced. In the first case the field is stationary and the conductors cut across it. But in the second case the conductor remains stationary and the flux linked with it is changed.

3.5 Dynamically induced E.m.f

Consider a conductor of length 'l' meter lying within a uniform magnetic field of flux density B wb/m². Let it move through a distance dx in time dt.





Then the area swept by the conductor = $l \times dx$

Hence, flux cut by the conductor = flux density×area = $B \times l \times dx$ weber

According to Faraday's law, the induced emf in the conductor is given by

e = rate of change of flux linkages = $Bl(dx/dt) = BlV$ Volt

Where $V = (dx/dt)$ = velocity.

Thus dynamically induced e.m.f., e = $Bl V$ volt.

If the conductor moves at an angle θ to the direction of the flux, the induced emf is given by

$$e = Bl V \sin\theta \text{ Volt}$$

Example 2

A straight conductor of length 2 meters moves at right angle to a uniform magnetic field of flux density $2 wb/m^2$ with a uniform velocity of 40 meters/second. Calculate the induced emf in the conductor. Find the value of induced emf when the conductor moves at an angle of 45^0 with the direction of the field?

Solution:

$$B = 2wb/m^2 \quad l=2 \text{ meters}, v=40m/s$$

$$\text{Induced e.m.f } e = B \times l \times V \times \sin\theta = 2 \times 2 \times 40 \times 1 = 160 \text{ volt}$$

When $\theta = 45^0$

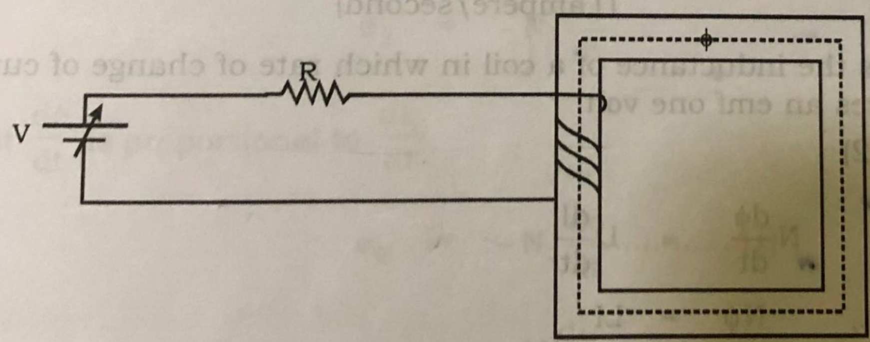
$$\text{Induced emf, } e = Bl V \sin\theta = 2 \times 2 \times 40 \sin 45^0 = \mathbf{113.13 \text{ volt}}$$

3.6 Statically induced EMF

Statically induced emf may be of two types. (a) self induced emf and (b) mutually induced emf.

(A)Self induced emf and self-inductance.

This is the emf induced in a coil due to the change of its own flux linked with it.



As the current in the coil changes due to the change in the applied voltage (V), flux linking with a coil also changes producing an emf. This emf is called self induced emf. As per Lenz's law, the direction of induced emf is such as to oppose any change in flux i.e., opposite to the flux producing it. Hence often it is referred to as the counter emf of self- induction. The property of the coil, which opposes any change of current or flux through it, is called its self-inductance and is denoted by letter L.

Expression of Self-inductance of a coil

Consider a coil of N turns carrying a current I amperes. When a current in the coil changes, the flux linking with the coil also changes. The emf induced in the coil is given by

$$e = -N\frac{d\phi}{dt} \quad \text{..................(1)}$$

$$= -\frac{d}{dt}(N\phi)$$

$$\alpha - \frac{d}{dt} \quad (\therefore N\phi \propto I)$$

$$e = -L\frac{dI}{dt} \quad \text{..................(2)}$$

Where 'L' is a constant called the self-inductance of the coil or coefficient of self-induction. Rewriting the equation (2) we get

$$L = -\frac{e}{(dI/dt)} \quad \text{..............(3)}$$

The unit of inductance is henry (H).

From equation (3)

$$I \text{ henry} = \frac{1 \text{ volt}}{(1 \text{ ampere/second})}$$

Thus one henry is the inductance of a coil in which rate of change of current of one ampere induces an emf one volt.

Comparing (1) & (2)

$$N\frac{d\phi}{dt} = L\frac{dI}{dt}$$

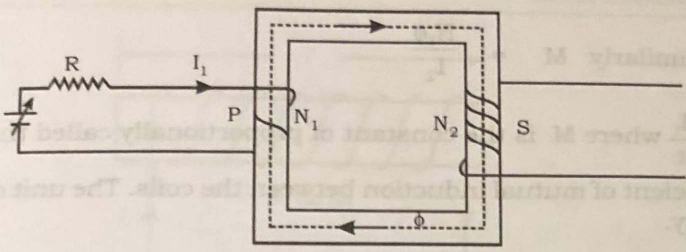
Integrating we get, $N\phi = LI$

$$\therefore \quad L = \frac{N\phi}{I}$$

Thus self-inductance of a coil is the flux linkages per ampere.

3.7 Mutually induced emf

The phenomenon of generation of induced emf in a circuit by changing the current in the neighbouring circuit is called mutual induction.



If there are 2 coils P & S close to each other, then any change of current in coil P results in mutually induced emf in coil S. Thus the 2 coils are mutually coupled. Any change in current I_1 of coil P causes changing flux to link with both the coils. The emf induced in coil P forms the self-induced emf while emf induced in coil S forms the mutually induced emf. Coil in which change in current takes place is usually called the primary while the other coil is called the secondary.

Mutual inductance between the two coils is the property by which change of current in one coil (primary) induces voltage in the other coil (secondary)

3.8 Expression for mutual inductance (M)

Consider two magnetically coupled coils P &S having turns N_1 & N_2 respectively as shown in figure. Let a current I_1 flowing in the coil P produces flux ϕ_1 webers in it. Let whole this flux links with the turns of the secondary coils S. Thus flux ϕ_2 linking with the coil S is equal to ϕ_1.

As per Lenz's law,

$$e_2 = -N_2 \frac{d\phi}{dt}$$

But $\frac{d\phi}{dt}$ is proportional to $\frac{dI_1}{dt}$

$$e_2 = -N_2 \frac{d\phi}{dt} \quad \text{..........(1)}$$

$$e_2 = -M \frac{dI_1}{dt} \quad \text{..........(2)}$$

Comparing eqn. (1) and (2) we get

$$N_2 \frac{d\phi}{dt} = M \frac{dI_1}{dt}$$

$$N_2 \phi = M I_1$$

$$\therefore M = \frac{N_2 \phi}{I_1}$$

Similarly $M = \frac{N_1\phi}{I_2}$

Hence $e = -M\frac{dI_1}{dt}$ where M is the constant of proportionally called the mutual inductance or coefficient of mutual induction between the coils. The unit of mutual inductance is henry.

3.9 Coefficient of coupling

Consider 2 coils P and S wound on the same core as shown in the figure. We have assumed earlier that the complete flux, ϕ_1 setup by the first coil P links with the second coil S. In practice it is not true. Let only a fraction k_1 $(k<1)$ of the flux ϕ_1 setup with the first coil P link with the second coil S. Then the flux linked with the second coil is $K_1\phi_1$.

$$M = \frac{N_2K_1\phi_1}{I_1}$$

Similarly complete flux ϕ_2 produced in the second coil S does not linked with the first coil P. Let only a fraction $K_2(K_2<l)$ of ϕ_2 link with coil P.

$$\text{Then } M = \frac{N_1K_2\phi_2}{I_2}$$

Multiplying equation 1&2 we get

$$M^2 = \frac{N_2K_1\phi_1}{I_1} \times \frac{N_1K_2\phi_2}{I_2} = \frac{K_1K_2N_1\phi_1}{I_1} \times \frac{N_2\phi_2}{I_2}$$

$$= K_1K_2L_1L_2 \qquad \left[\begin{array}{l} \frac{N_1\phi_1}{I_1} = L_1 \\ \frac{N_2\phi_2}{I_2} = L_2 \end{array}\right]$$

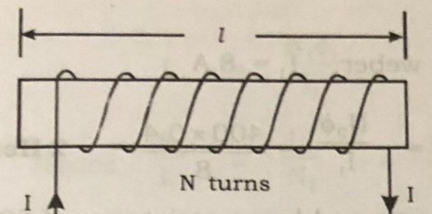
Where L_1& L_2 are the self-inductance of the first and second coil respectively. But both the coils P and S are wound on the same frame. Hence $K_1=K_2 = K$.

$$\text{Hence } M^2 = K^2L_1L_2$$

Or $K = \frac{M}{\sqrt{L_1L_2}}$ constant K is called the coefficient of coupling.

3.10 Self Inductance of a Solenoid

Consider an iron-cored solenoid of dimension as shown in figure.



l = Length of the solenoid

N = Number of turns

I = Current through the solenoid

A = Area of cross-section of the solenoid

L = Self inductance of the solenoid

$$\text{Flux } (\phi) = \frac{\text{MMF}}{\text{Reluctance}}$$

$$\phi = \frac{NI}{(l/A\mu_0\mu_r)} \quad \text{.........(1)}$$

$$\text{But } L = \frac{N\phi}{I}$$

$$\phi = \frac{LI}{N} \quad \text{........(2)}$$

Comparing equation (1) and (2)

$$\frac{LI}{N} = \frac{NI}{(l/A\mu_0\mu_r)}$$

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

$$\text{But Reluctance (S)} = l/A\mu_0\mu_r$$

$$\text{Hence } L = \frac{N^2}{S}$$

PROBLEMS

1. Two identical coils of 400 turns each lie in parallel plane and produced the flux of 0.04 weber. If current of 8 amp is flowing in one coil, find out the mutual inductance between coils?

Solution:

$N_2 = 400$ turns, $\phi = 0.04$ weber, $I_1 = 8$ A

$$M = \frac{N_2\phi}{I_1} = \frac{400 \times 0.4}{8} = \textbf{2 Henry}$$

2. A coil is wound with 220 turns and has a resistance of 50 ohms. If exis voltage is 200 volts and magnetic flux is 0.08 weber, Calculate the inductance of the coil?

Solution:

$N_2 = 220$ turns, $\phi = 0.08$ Weber

$$I = \frac{V}{R} = \frac{200}{50} = 4A$$

$$L = N\phi/I = \frac{220 \times 0.08}{4} = \textbf{4.4 Henry}$$

3. A coil of 200 turns carries a current of 4A. The magnetic flux linkage w the coil is 0.02 Wb. Calculate the inductance of the coil. If the curren uniformity reserved in 0.02 seconds, calculate the self induced emf in coil?

Solution:

N = 200 turns, $\phi = 0.02$ wb, I = 4A

Inductance of the coil,

$$L = \frac{N\phi}{I} = \frac{200 \times 0.02}{4} = 1H$$

As the current is reversed, change in current

$$dI = 4 - (-4) = 8A$$

$$\text{Induced emf } |e| = L\frac{dI}{dt} = \frac{1 \times 8}{0.02} = \textbf{400 Volts}$$

4. Two identical coils P and S each having 500 turns lie in parallel pla Current in coil P changing at the rate of 500 A/ second induces emf of Volts in coil S. Calculate the mutual inductance between the two coil the self inductance of each coil is 50mH. Calculate the flux produced in P per ampere of current and coefficient of coupling between the two co

$$e_1 = \frac{MdI_1}{dt}$$

Hence

$$M = \frac{e_2}{dI_1/dt} = \frac{12}{500} = 0.024 \text{ H}$$

$$L_1 = \frac{N_1\phi_1}{I_1}$$

$$\text{Hence} \quad \frac{\phi_1}{I_1} = \frac{L_1}{N_1} = \frac{50\times10^{-3}}{500} = 10^{-4} \text{ wb/A}$$

$$K = \frac{M}{\sqrt{L_1L_2}} = \frac{0.024}{\sqrt{50\times10^{-3}\times50\times10^{-3}}} = \textbf{0.48 or 48\%}$$

5. An air solenoid has 300 turns, its length is 25 cm and cross-sectional area 3 cm². Calculate its self inductance. If the coil current of 10A is completely interrupted in 0.04 second, calculate the induced emf in the coil.

Solution

$N = 300$, $l = 25\text{cm} = 0.25\text{m}$, $A = 3\text{cm}^2 = 3\times10^{-4}\text{m}^2$

$$\mu_r = 1 \text{ (Air core)}$$

$$L = \frac{N^2A\mu_0\mu_r}{l} = \frac{300^2\times3\times10^{-4}\times4\pi\times10^{-7}\times1}{0.25}$$

$$L = 1.357\times10^{-4}\text{ H}$$

$$\text{Induced emf (e)} = \frac{Ldi}{dt} = \frac{1.357\times10^{-4}\times10}{0.04} = \textbf{0.034 volt}$$

6. An air-cored toroidal coil has 450 turns and a mean diameter of 30cm and a cross-sectional area of 3cm². Calculate (i) the inductance of the coil (ii) the average emf induced if a current of 2A is reversed in 0.04 Second.

Solution.

$$N = 450, d=30\text{cm}=0.3\text{ m}$$

$$l = \pi d = \pi\times0.3\text{m}$$

$$A = 3\text{cm}^2 = 3\times10^{-4}\text{cm}^2$$

$$\mu_r = 1 \text{ (Air core)}$$

(i) $$L = \frac{N^2A\mu_0\mu_r}{l} = \frac{450^2\times3\times10^{-4}\times4\pi\times10^{-7}\times1}{\pi\times0.3}$$

$$L = \mathbf{8.1\times10^{-5}\text{ H}}$$

(ii) $$e = \frac{LdI}{dt} = \frac{8.1\times10^{-5}\times4}{0.04} = \mathbf{8.1\times10^{-3}\text{ volt}}$$

7. An inductive circuit is carrying a current of 4 Amps. If its inductance is 0.15 Hen Find the value of the self induced e.m.f. when the current is reduced to zero in ms?

Ans.

$$L = 0.15\text{ H}, I = 4\text{A}$$

$$\text{Induced emf} = L\frac{dI}{dt} = 0.15 \times \frac{(4-0)}{10 \times 10^{-3}} = \mathbf{60\ V}$$

8. A conductor of 2 m long moves at right angles to a magnetic field of flux densi Tesla with a velocity of 12.5 m/sec. What will be the induced e.m.f. in the conduc

Ans. Induced e.m.f. $= BlV = 1 \times 2 \times 12.5 = 25$ Volt

9. Two coils having 150 and 200 turns respectively are wound side by side on closed magnetic circuit of cross section. $1.5 \times 10^{-2}\ m^2$ and mean length 3 m. T relative permeability of the magnetic circuit is 2000. Calculate (i) the mutu inductance between the coils (ii) the voltage induced in the second coil if t current changes from 0 to 10 A in the first coil in 20 m sec?

Ans.

$$N_1 = 150,\ N_2 = 200,\ A = 1.5 \times 10^{-2}\ m^2$$

$$l = 3\text{ m},\ \mu_r = 2000$$

$$\text{Mutual inductance between the coils (M)} = \frac{\mu_0 \mu_r N_1 N_2 A}{l}$$

$$= \frac{4\pi \times 10^{-7} \times 2000 \times 150 \times 200 \times 1.5 \times 10^{-2}}{3} = 0.3768\text{ H}$$

$$\frac{dI}{dt} = \frac{10-0}{20 \times 10^{-3}}$$

Voltage induced in the second coil,

$$e = M \cdot \frac{dI}{dt} = \frac{0.3768 \times 10}{20 \times 10^{-3}} = \mathbf{188.4\ volt}$$

10. An emf of 16 volts is induced in a coil of inductance 4H. What must be the rate change of current?

Ans.

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

$$\frac{dI}{dt} = \frac{16}{4} = 4\text{A/S}$$

Rate of change of current = 4 A/S

11. A coil induces 350 mV when the current changes at the rate of 1 A/sec. What the value of inductance?

Ans.

$$\text{Induced voltage (e)} = 350 \times 10^{-3}\text{ V}$$

$$\text{Rate of change of current} = \frac{di}{dt} = 1\text{A / Sec}$$

$$\text{Equation for induced voltage e} = L\frac{di}{dt}$$

Then, inductance $L = \frac{350 \times 10^{-3}}{1} = 350\ H$ 350 mH

12. Two coils having 150 and 200 turns respectively are wound side by side on a closed magnetic circuit of cross section $1.5 \times 10^{-2}\ m^2$ and mean length 3 m. The relative permeability of the magnetic circuit is 2000. Calculate

(i) the mutual inductance between the coils.

(ii) the voltage induced in the second coil if the current changes from 0 to 10 A in the first coil in 20 ms.

Ans. $N_1 = 150,\ N_2 = 200,\ A = 1.5 \times 10^{-2}\ m^2,\ l = 3\ m$

$$\mu_r = 2000$$

$$\text{Mutual inductance, } M = \frac{\mu_0 \mu_r N_1 N_2 A}{l}$$

$$= \frac{4\pi \times 10^{-7} \times 2000 \times 150 \times 200 \times 1.5 \times 10^{-2}}{3}$$

$$= 0.376\ H$$

$$\frac{dI}{dt} = \frac{10-0}{20 \times 10^{-3}}$$

Voltage induced in the second coil

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

$$= 0.376 \times \frac{10}{20 \times 10^{-3}}$$

$$= 188.4\ V$$

*13. A coil consists of 750 turns and a current of 10A on the coil gives rise to a flux of 1.2m Wb. Calculate the inductance of the coil. If the current is reversed in 0.01 second, find the voltage induced in the coil.

Ans. No. of turns = 750

$I = 10\ A,\ \phi = 1.2 \times 10^{-3}\ Wb$

$$\text{Inductance } L = \frac{N\phi}{I} = \frac{750 \times 1.2 \times 10^{-3}}{10} = 90\ mH$$

$$\frac{di}{dt} = 0.01 \text{ second}$$

$$e = L \times \frac{di}{dt} = 90 \times 10^{-3} \times 0.01 = 0.9\ mV$$

*14. A square coil of 10 cm, side and with 100 turns is rotated at a uniform speed of 500 r.p.m about an axis at right angles to a uniform field of 0.5 Wb/m^2. Calculate the instantaneous value of induced e.m.f when the plane of the coil is (i) at right angle to the plane of the field and (ii) at 45^0 with the field direction

Ans.

Length of the coil 'l' = 10×10^{-2} m

No. of turns 'N' = 100

Speed in rpm = 500

Flux density 'B' = 0.5 Wb/m^2

Emf induced in one side of coil having 'N' turns

$$e = N \times Blv \sin\theta$$

Total emf induced in both sides of coil is

$$e = 2BlNv \sin\theta \text{ volt}$$

where v is peripheral velocity in m/sec

and $v = \pi \times f \times b$

where 'b' is the width of coil in meters and 'f' is the frequency of rotation of coil in Hz.

(i) Coil is right angled to the plane of the field.

So, here $\theta = 90^0$ $\sin 90 = 1$

$$e = 2\pi \times \frac{500}{60} \times 0.5 \times 0.1^2 \times 100 = 26.17 \text{ V}$$

(ii) Here $\theta = 45^0$ $\sin 45 = 0.7071$

$$e = 2\pi \times \frac{500}{60} \times 0.5 \times 0.1^2 \times 100 \times 0.7071 = 18.51 \text{ V}$$

15. A conductor of length 1 metre moves at right angles to a uniform magnetic field of flux density of 1.5 Wb/m^2 with a velocity of 50 metre/second. Calculate e.m.f induced in it.

Ans. $l = 1$m $B = 1.5\ Wb/m^2$ $v = 50$ m/s

Emf induced $e = Blv \sin\theta$ volts

Here $\sin\theta = 1$ $\therefore \theta = 90^0$

So $e = 1.5 \times 1 \times 50 \times 1 = 75$ V

16. Two coupled coils connected in series have an equivalent inductance of 0.725 when connected in aiding and 0.425 when connected in opposing. Find self and mutual inductance, if coefficient of coupling is 0.42.

Ans.

$L' = 0.725$ (additive)

$L'' = 0.425$ (substractive)

Coefficient of coupling $K = 0.42$

$L' = L_1 + L_2 + 2M$

$L'' = L_1 + L_2 - 2M$

$0.725 = L_1 + L_2 + 2M$ ....(1)

$0.425 = L_1 + L_2 - 2M$ ....(2)

Substracting eqn (2) from eqn(1)

We get,

$0.3 = 4M$

Mutual inductance $M = \frac{0.3}{4} = 0.075$

Put value of M on Eqn.(1)

$$0.725 = L_1 + L_2 + 0.15$$
$$L_1 + L_2 = 0.575 \text{ H} \qquad \ldots\ldots(3)$$

In general

$$M = K\sqrt{L_1 L_2}$$
$$0.075 = 0.42\sqrt{L_1 L_2}$$
$$L_1 L_2 = 0.0318 \qquad \ldots\ldots(4)$$
$$L_1 = \frac{0.0318}{L_2} \qquad \ldots\ldots(4a)$$

Put this value of L_1 on eqn. (3)

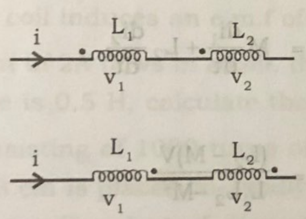
$$\frac{0.0318}{L_2} + L_2 = 0.575$$

Then, get an equation

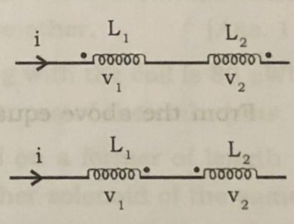
$$L_2^2 - 0.575\, I_2 + 0.0318 = 0$$
$$L_L = 0.513 \text{ H}$$
$$\& \; L_2 = 0.575 - 0.513 = 0.0625 \text{ H}$$

17. Derive the expression for effective inductance when two coils are connected (i) in series and (ii) in parallel.

Ans. Two coils can be connected in series so that their fluxes at any instant are in the same direction or in opposite direction. These two connections are known as series aiding and series opposing.



Series aiding connection



Series opposing connection

In series aiding connection, the total voltage induced in each of the two coils is partly due to its self inductance and partly due to mutual inductance. Therefore,

$$V_1 = L_1\frac{di}{dt} + M\frac{di}{dt} = (L + M)\frac{di}{dt}$$

$$V_2 = (L_2 + M)\frac{di}{dt}$$

$$V = V_1 + V_2 = \frac{di}{dt}(L_1 + L_2 + 2M)$$

But $\frac{V}{di/dt}$ is the total inductance L_a.

Therefore $L_a = L_1 + L_2 + 2M$

In the series opposing connection, the mutually induced voltage opposes the self induced voltage.

Therefore, $$V_1 = L_1 \frac{di}{dt} - M\frac{di}{dt} = (L_1 - M)\frac{di}{dt}$$

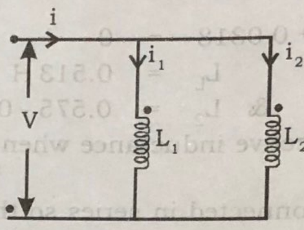
$$V_2 = (L_2 - M)\frac{di}{dt}$$

$$V = V_1 + V_2 = (L_1 + L_2 - 2M)\frac{di}{dt}$$

Therefore, the total inductance L_b of the series opposing connection is

$$L_b = L_1 + L_2 - 2M$$

Coils are connected in parallel



$$V = L_1\frac{di_1}{dt} + M\frac{di_2}{dt}$$

$$V = M\frac{di_1}{dt} + L_2\frac{di_2}{dt}$$

From the above equations

$$\frac{di_1}{dt} = \frac{(L_2 - M)V}{L_1L_2 - M^2}$$

$$\frac{di_2}{dt} = \frac{(L_1 - M)V}{L_1L_2 - M^2}$$

$$i = i_1 + i_2$$

$$\frac{di}{dt} = \frac{di_1}{dt} + \frac{di_2}{dt} = \frac{(L_1 + L_2 - 2M)V}{L_1L_2 - M^2}$$

If L_p is the equivalent inductance of parallel arrangement.

$$\frac{di}{dt} = \frac{1}{L_P}V$$

Therefore, $$L_P = \frac{L_1L_2 - M^2}{L_1 + L_2 - 2M}$$

PRACTICE PROBLEMS

1. A conductor of length 15 cm is moved at 750 mm/s at right angles to a uniform flux density of 1.2 T. Determine the e.m.f induced in the conductor.[*Ans.*0.135 V]

2. Find the speed that a conductor of length 120 mm must be moved at right angles to a magnetic field of flux density 0.6 to induce in it an e.m.f of 1.8 V.
[*Ans.* 25 m/s]

3. A 25 cm long conductor moves at a uniform speed of 8 m/s through a uniform magnetic field of flux density 1.2 T. Determine the current flowing in the conductor when (a) its ends are open circuited (b) its ends are connected to a load of 15 ohms resistance. [*Ans.* (a) 0 (b) 0.16 A]

4. Determine the e.m.f induced in a coil of 200 turns when there is a change of flux of 25 mWb linking with it in 50 ms. [*Ans.* 100 V]

5. An e.m.f of 1.5 kV is induced in a coil when a current of 4A collapses uniformly to zero in 8 ms. Determine the inductance of the coil. [*Ans.* 3H]

6. A coil is wound with 600 turns and has a self inductance of 2.5 H. What current must flow to set up a flux of 20 mWb. [*Ans.*4.8A]

7. The mutual inductance between two coils is 150 mH. Find the magnitude of the e.m.f induced in one coil when the current in the other is increasing at a rate of 30 A/s. [*Ans.* 4.5 V]

8. Determine the mutual inductance between two coils when a current changing at 50 A/s in one coil induces an e.m.f of 80 mV in the other. [*Ans.* 1.6 mH]

9. When a current of 2A flows in a coil, the flux linking with the coil is 80 μWb. If the coil inductance is 0.5 H, calculate the number of turns of the coil. [*Ans.* 12500]

10. A solenoid consisting of 1000 turns of wire wound on a former of length 100 cm and diameter 3 cm is placed co-axially within another solenoid of the same length and number of turns, but of diameter 6 cm. Find approximately the mutual inductance and the coupling coefficient of the arrangement.[*Ans.* 0.887 mH, 0.5]