UNIT - III

MAGNETIC CIRCUITS

3.1 Introduction

In an electric circuit, electromotive force(emf) drives the current through the circuit.Similarly in a magnetic circuit,a magetomotive force(mmf) drives the flux through the circuit. The flow of current depends on the resistance while the flow of flux depends on the characteristics of the medium through which it is flowing. The flux can travel across an airgap also. Thus magnetic circuits may consist of an air gap along with the magnetic materials with which they are made up of.

- **Magnet**

A **magnet** is a material or object that produces a magnetic field. This magnetic field is invisible but is responsible for the most notable property of a magnet: a force that pulls on other ferromagnetic materials, such as iron, and attracts or repels other magnets.

- **Permanent Magnet**

A piece of magnetic material that retains its magnetism after it is removed from a magnetic field. Example- steel

- **Electromagnet**

An electromagnet is made from a coil of wire that acts as a magnet when an electric current passes through it but stops being a magnet when the current stops. Often, the coil is wrapped around a core of "soft" ferromagnetic material such as steel, which greatly enhances the magnetic field produced by the coil.

- **Magnet and its properties**

  - Like poles repel each other and unlike poles attract each other.
  - When a magnet is rolled into iron piece, maximum iron pieces accumulate at the two ends of the magnet while very few accumulate at the centre of magnet.

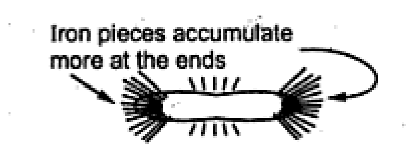

Fig. 3.1 Natural magnet

The points at which the iron pieces accumulate maximum are called poles of the magnet while imaginary line joining these poles is called axis of the magnet.

- When a magnet is placed near an iron piece, its property of attraction gets transferred to iron piece. Such property is called magnetic induction.

- **Magnetic Induction**

The phenomenon due to which a magnet can induce magnetism in a piece of magnetic material placed near it without actual physical contact is called magnetic induction.

- **Laws of Magnetism**
  - Like magnetic poles repel and unlike poles attract each other.
  - The force F exerted by one pole on other pole is

$$F \alpha M_1 M_2 / d^2$$
$$F = k\, M_1 M_2 / d^2$$

Where M_1 and M_2 are magnetic pole strengths , d is the distance between the poles and k is the nature of the surroundings.

- **Magnetic Field**

A field of force surrounding a permanent magnet or a moving charged particle, in which another permanent magnet or moving charge experiences a force

- **Magnetic Lines of Force**

The magnetic field of magnet is represented by imaginary lines around it which are called magnetic lines of force.

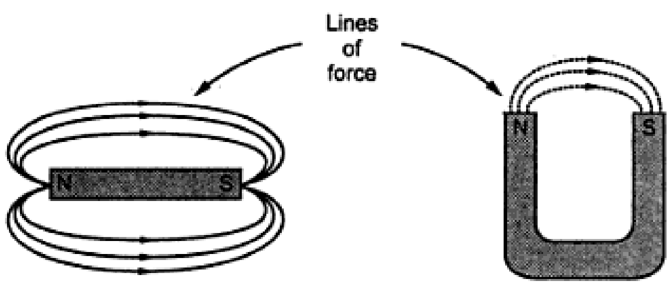

Fig. 3.2 Magnetic lines of force

- **Magnetic Flux(ϕ)**

The total number of lines existing in a particular magnetic field is called magnetic flux. Unit-Weber(Wb). Symbol for flux is ϕ.

1 weber=1×10^8 lines of force.

- **Pole Strength**

Every pole has a capacity to radiate or accept certain number of magnetic lines of force which is called pole strength.

- **Magnetic Flux Density(B)**

Magnetic flux Density is defined as the total number of **magnetic** lines of force passing through a specified area in a **magnetic** field. Symbol- B

B= Flux/ Area = ϕ/A (unit – Wb/m^2 or Tesla)

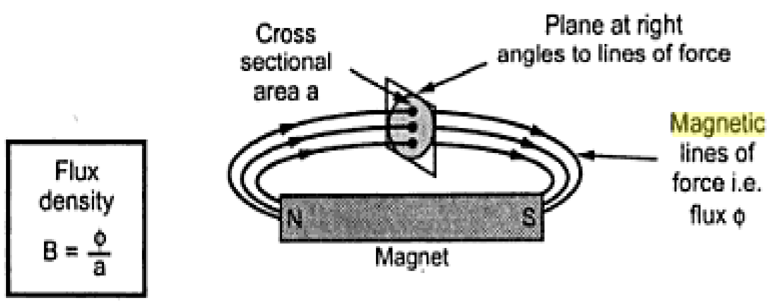

Fig. 3.3 Concept of Magnetic Flux Density

- **Magneto Motive Force(mmf)**

MMF is the cause for producing flux in a magnetic circuit. The amount of flux set up in the core depends upon current(I) and number of turns(N). The product of NI is called magneto-motive force and it determines the amount of flux set up in the magnetic circuit.

MMF= NI Unit- Ampere Turns(AT)

- **Reluctance**

The opposition that magnetic circuit offers to flux is called reluctance. It is defined as the ratio of magneto motive force to the flux.

$$S = MMF / Flux$$

S= NI / ϕ. Unit : AT/Wb

- **Permeance**

It is the reciprocal of reluctance.

$$Permeance = \frac{1}{Reluctance} = \frac{1}{S} \qquad \text{Unit : Wb/AT}$$

- **Magnetic Field Strength(H)**

This gives quantitative measure of strongness or weakness of the magnetic field. Field strength is defined as "the force experienced by a unit N-pole when placed at any point in a magnetic field ".It is denoted by H and its unit is newtons per weber(N/Wb) or ampere turns per meter(AT/m).It is defined as ampere turns per unit length.

$$H = \frac{Ampere\ \ turns}{lengt\ h} = \frac{NI}{l} \quad \text{(unit – AT/m)}$$

Where N- no. of turns of the coil, I- current through the coil, ℓ-length of the coil.

- **Permeability**

Permeability is the ability with which the magnetic material forces the magnetic flux through a given medium.Permeability of a material means its conductivity for magnetic flux. Greater the permeability of a material, greater the conductivity for magnetic flux.

Flux density (B) is proportional to the magnetizing force (H).

$B \alpha H$

$B=\mu H$

$\mu=B/H$

- **Relative Permeability**

Relative Permeability of a material is equal to the ratio of flux density produced in that material to the flux density produced in air by same magnetizing force.

$$\mu_r = \frac{B}{B0} = \frac{\mu H}{\mu 0 H} = \frac{\mu}{\mu 0}$$

Therefore $\mu = \mu_0 \, \mu_r$

μ- absolute permeability

μ_0- absolute permeability of air or vaccum=$4\Pi x 10^{-7}$ H/m

μ_r -relative permeability of the material

Problem 3.1 A bar of iron $1cm^2$ in cross section has 10^{-4} Wb of magnetic flux in it. Find the flux density in the bar. If the relative permeability of iron is 2000, what is the magnetic field intensity in the bar?

Solution:

Area of iron bar(A)= 1cm2=$1x10^{-4}m^2$

Flux $\phi=10^{-4}$ Wb

$\mu_r=2000$

$B= Flux/ Area = \phi/A$ $=10^{-4} / 1x10^{-4} = 1 Wb/m^2$.

$H=B/\mu = B/\mu_0 \mu_r = 1/ (4\Pi x10^{-7} x 2000) = 397.88$ AT/m

Problem 3.2 A solenoid is wound with a coil of 200 turns. The coil is carrying a current of 1.5A. Find the value of magnetic field intensity when the length of the coil is 80cm.

Solution:

N=200

I=1.5A

ℓ=80cm=$80x10^{-2}$m=0.8m

$$H = \frac{NI}{l} = 200 * \frac{1.5}{0.8}$$

H=375AT/m.

Problem 3.3 A current of 2A passes through a coil of 350 turns wound on an iron ring of mean diameter 12cm. The flux density established in the ring is $1.4Wb/m^2$. Find the value of relative permeability of iron.

Solution:

I=2A

N=350

D=12cm=$12x10^{-2}$m=0.12m

B=$1.4Wb/m^2$

Length of the ring, l=2Πr = ΠD=Π*0.12

$$B = \mu H$$

$$B = \frac{\mu r \mu o NI}{l}$$

$$\mu r = \frac{Bl}{\mu o NI} = \frac{1.4 * \Pi * 0.12}{\mu o * \Pi * 350 * 2} = 600$$

Problem 3.4 A mild steel ring of mean circumference 50 cm and cross- sectional area of 5 cm^2 has a coil of 250 turns wound uniformly around it. Calculate.

(i) Reluctance
(ii) Current required to produce a flux of 700 µwb in the ring. Take μ_r of mild steel as380.

Area of steel ring A = $5cm^2 = 5\times10^{-4}m^2$ No of turns of the coil, N = 250

Length of the magnetic path=Circumference of the ring=l = 50 cm

$= 50\times10^{-2}$m

Flux, Φ = 700µwb

$= 700\times10^{-6}$ wb

Relative permeability of mild steel, $\mu_r = 380$, $\mu_o = 4\pi\times10^{-7}$H/m

$$S = \frac{l}{\mu o \mu r A}$$

$$= \frac{50 \times 10^{-2}}{4\pi \times 10^{-7} \times 380 \times 5 \times 10^{-4}}$$

=2094144AT/Wb

3.2 ELECTROMAGNETISM

The EMF may be produced either by batteries through chemical reaction or by thermocouples by heating the junction of two dissimilar metals. Michael faraday 1831 discovered that the EMF can also be produced by electromagnetic induction, used in commercial generation of power.

- **Electromagnetic Induction**

Whenever the magnetic flux linking with the coil changes, an EMF is induced in the coil. This phenomenon is called as electromagnetic induction.

Applications: microphones, telephones, transformers, generators motors etc.,

- **Production of induced EMF and current**

The change in flux linkage can be obtained by three methods

Method 1:

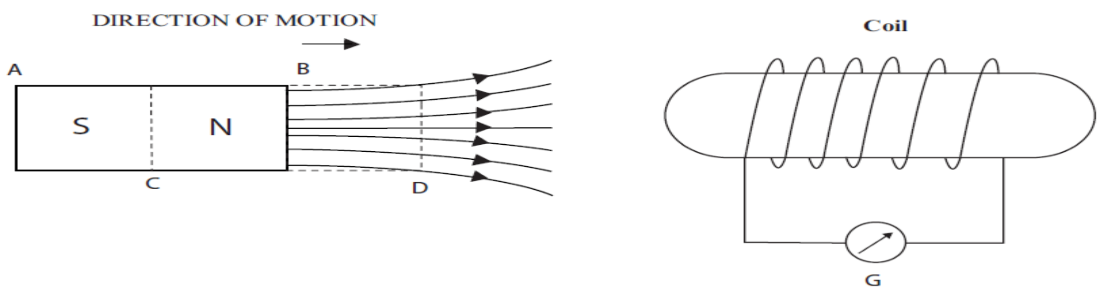

Fig.3.4

When a magnet is moved towards the coil there is deflection in the galvanometer connected across the coil thus indicating the flow of current. This current is due to the induced EMF in the coil.

- Change in flux results in production of EMF.
- Presence of EMF gives rise to flow of current.

If the magnet movement is stopped the pointer will show zero deflection. If the magnet moves with higher speed or if the number of turns of coil is increased or If we use the stronger magnet we can observe greater deflection of the pointer. As the magnet taken away from the coil, the flux linked with the coil is decreased the deflection of galvanometer is in the opposite direction.

Method2:

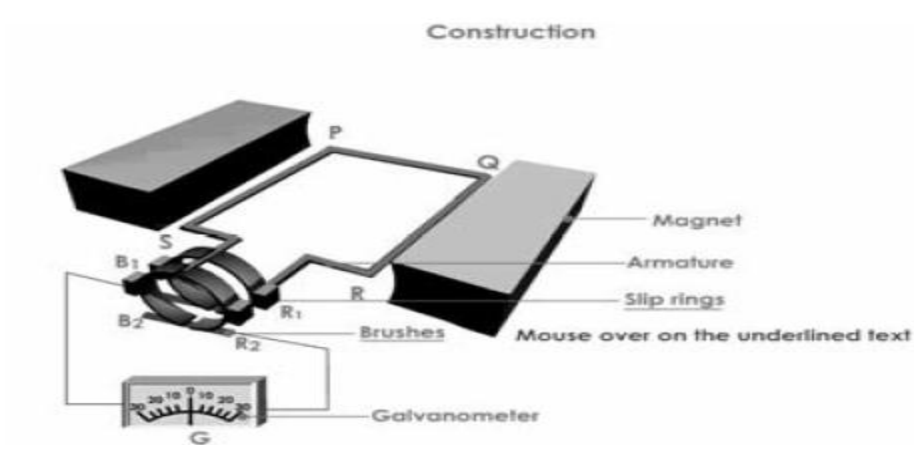

Fig.3.5

The EMF can also be induced in the coil by moving the coil and keeping the magnet stationary. These two methods of producing the emf are called the dynamic methods and the induced emf is called dynamically induced emf which is employed in generators (in ac and dc generators there is motion of conductors which results in the change in flux linkage).

Method 3:

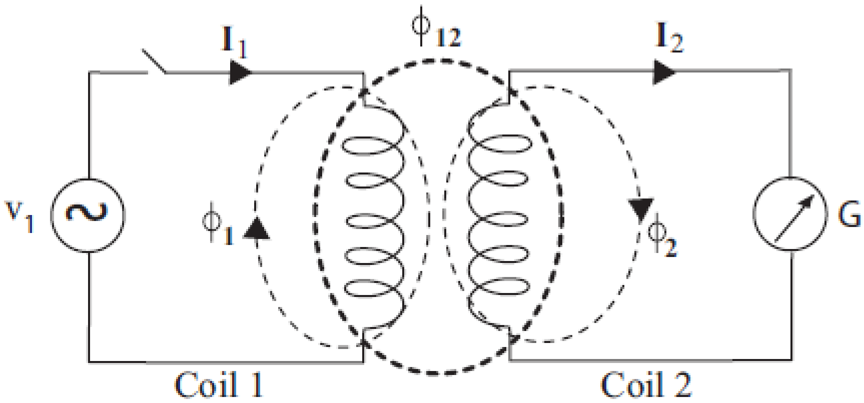

Fig.3.6

Both conductor and magnet are kept stationary and change in flux is obtained by changing the current this method of emf production is called statically induced emf which is employed in transformers.

- **Faradays law of electromagnetic induction**

First law: Whenever the conductor cut across the magnetic field,an emf is induced in the conductor or whenever the magnetic flux linking with any coil (circuit) changes an emf is induced in the coil

Second law: The magnitude of the induced emf is equal to the rate of change of flux linkage.

Suppose a coil has N turns, Let the flux through it change from Φ_1Weber to Φ_2 Weber in't' seconds product of N and Φ is called flux linkage.

The initial flux linkage = $N \Phi_1$

The final flux linkage = $N \Phi_2$

Change of flux linkage = $N\Phi_2 - N \Phi_1$

= $N(\Phi_2 - \Phi_1)$

Rate of change of flux linkage = $N(\Phi_2 - \Phi_1)/t$

Let e be the induced emf

According to faradays second law e=N$\frac{d\Phi}{dt}$ volts

Actually the direction of emf induced is so as to oppose the very cause producing it

$$e = - N\frac{d\Phi}{dt} \text{ volts}$$

Note:

i) To produce induced EMF in a conductor there must be a rotating magnetic field cutting the stationary conductor .EMF is also induced when a moving conductor is cut by a stationary magnetic flux.

ii) When there is no relative motion between the magnetic flux and the conductor no emf is induced in it.

iii) The direction of the induced emf in the coil depends upon the direction of the magnetic field and that of motion of the coil.

iv) If the conductor is moved parallel to the direction of flux,it does not cut the conductor. Hence no emf is induced in it.

- **Direction of induced emf:**

To determine the direction of induced EMF and current in a conductor the following rules are used

- **Fleming's right hand rule**

Statement: Stretch out the forefinger, middle finger and the thumb of the right hand such that they are mutually perpendicular to one another. If the forefinger points in the direction of magnetic field and the middle finger points in the direction of current then the thumb points in the direction of the motion of the conductor

Note: The direction of dynamically induced emf can be determined by Fleming's right hand rule This rule is in D.C. generators.

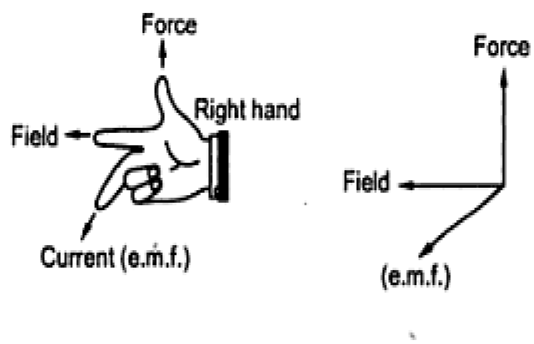

Fig. 3.7 Fleming's Right Hand Rule

- **Fleming's left hand rule**

Statement: Stretch out the forefinger middle finger and the thumb of the left hand mutually perpendicular to one another. If the forefinger points to the direction of the field and the middle finger points in the direction of the current, then, the thumb indicates the direction of the mechanical force exerted by the conductor.

Note: This rule is used in D.C. Motors.

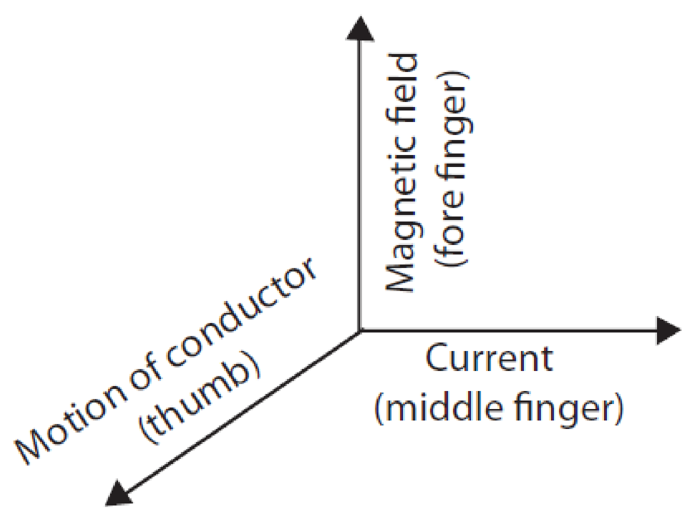

Fig. 3.8

Statement: In effect, electromagnetically induced emf and hence the current flows in a coil in such a direction that the magnetic field set up by it opposes the very cause producing it.

Note: The direction of statically induced emf lenz's law is used.

3.3 TYPES OF INDUCED EMF

When the flux linked with the coil or conductor changes an emf is induced in the coil. There are two ways to obtain the change in flux linkage. They are

3.3.1 Dynamically induced emf

When a conductor is moved in a stationary magnetic field or when the magnetic field is moved by keeping the conductor stationary an emf is induced provided the movement is done in such a way that the conductor is moved across the magnetic field. The emf thus induced is called as dynamically induced emf. An example of dynamically induced emf is the emf generated in D.C. and A.C. generators.

Consider the stationary magnetic field of flux density B wb/m^2 the direction of magnetic field is shown in the figure below and the conductor with circular cross section is placed
let the length of the conductor in field 'ℓ 'in meters .conductor is allowed to move at right angles to magnetic field, in a time of 'dt ' seconds the conductor is moved to a distance of 'dx' meters.

The area swept by the conductor = m^2

Magnetic flux cut by the conductor = flux density$*$area swept

= B ℓ dx Weber

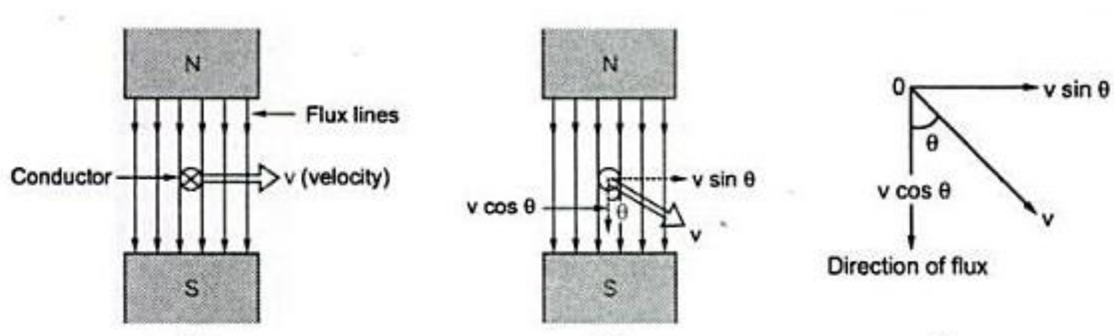

Fig.3.9. Conductor with Magnetic field

By faradays law of electromagnetic induction, the emf induced in the conductor is

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

If the number of turn in a conductor is one (N= 1)

$$e = \frac{d\Phi}{dt}$$

w.k.t

$$d\,\Phi = B\,\ell\,dx$$

$$e = B\,\ell\,dx/dt \qquad \text{since } dx/dt = v\text{(linear velocity)}$$

$$e = B\,\ell\,v \quad \text{volts}$$

If the conductor moves at an angle θ to the magnetic field then the velocity at which the conductor moves across the field is vsin θ,therefore

$$e = B \ell v \sin \theta \text{ volts}$$

The direction of the induced emf is determined by the Flemings right hand rule.

3.3.2 Statically induced emf

The flux is linked with the coil(conductor) without moving either the coil or field system but by changing the current in the field system. The emf induced in this way without motion of either conductor or flux is called statically induced emf.An example of statically induced emf is the emf induced in transformer winding.

It is further classified as i)self induced emf ii)mutually induced emf

- ***Self induced emf***

The emf induced in a coil due to change in the value of its own flux linking it is called self induced emf. Consider a coil shown in figure

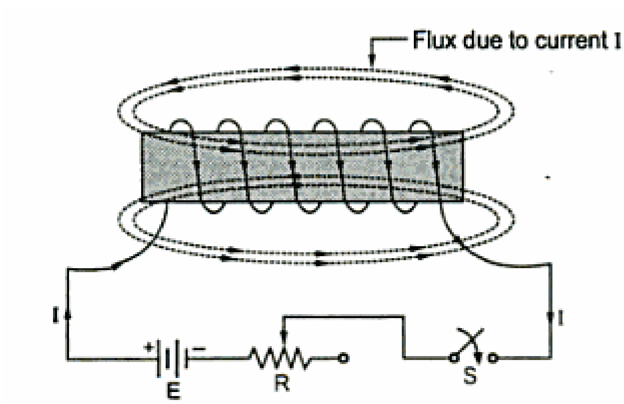

Fig. 3.10 Self Induced emf

If the current in the coil changes the flux linked with the coil also changes, which results in the production of emf, this is called self induced emf .The magnitude of this self induced emf

$$e = N\frac{d\Phi}{dt} \text{ volts}$$

The direction of the induced emf would be such as to oppose the very cause of production. Hence it is known as counter emf of self induction

- ***Self inductance (L)***

The property of a coil that opposes any change in the amount of current flowing through it is called its self inductance. It depends on the

i) Shape of the coil and number of turns

ii) Relative permeability of the magnetic material

iii) Speed in which the magnetic field changes.

Equation for self inductance

let

N= Number of turns in the coil

I=current in the coil.

If the current flowing through the coil changes the flux also changes which results in self induced emf

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

$$=\frac{d(N\Phi)}{dt}$$

Since the flux depends on the current so

$$N\Phi \quad \alpha \quad I$$

$$e \quad \alpha \quad \frac{dI}{dt}$$

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

Where L=self inductance of the coil in henry

- ***Other expression for self inductance***

Method 1

From the above equation $e= L\frac{dI}{dt}$

$$= \frac{d(\,LI)}{dt} \quad \ldots\ldots\ldots\ldots..(1)$$

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

$$= \frac{d(N\Phi)}{dt}\ldots\ldots\ldots\ldots..(2)$$

Since equation (1) and (2)

$$\frac{d(\,LI)}{dt} = \frac{d(N\Phi)}{dt}$$

$$LI = N\Phi$$

$$L = \frac{N\Phi}{I}\ldots\ldots\ldots\ldots\ldots..(3)$$

NΦ is also called as flux linkage.when N is in turns, Φ in Weber I in amperes, then L is in henrys.

Method 2

We know that magnetic field intensity $H = \frac{NI}{l}$..........(1)

Flux density $B = \mu_0 \mu_r H$ ....(2)

$$= \mu_0 \mu_r \frac{NI}{l}$$

We also know that $\Phi = B*a$

$$= \mu_0 \mu_r \frac{NI}{l} *a$$

We know that flux linkage = N Φ

$$= N^2 I \ \mu_0 \mu_r a/\ell$$

We know that $L = \frac{N\Phi}{I}$henry

$$= N^2 I \ \mu_0 \mu_r a/\ell$$

$$= N^2/l/\mu o \mu r a$$

$$L = N^2/S$$

- ***Mutually induced emf***

The emf induced in a circuit due to the charging current in the neighbouring circuit is called mutually induced emf.

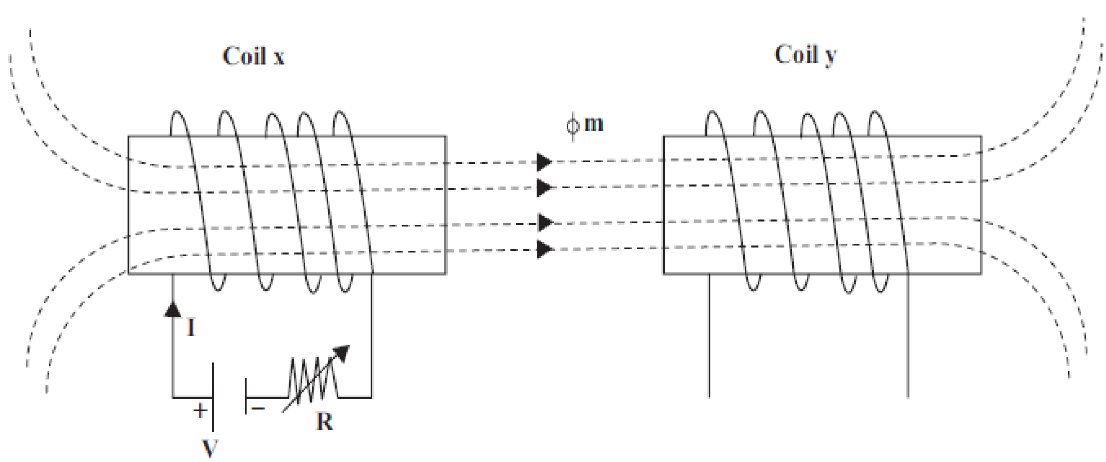

Fig. 3.11*Mutually induced emf.*

Here, coil x and coil y are close to each other, current flows through coil x due to this flux is produced in coil x part of the flux links the coil y which is called as mutual flux Φ_m. The flux common to both coil x and coil y is called mutual flux.

Note: If the current in coil x varies, emf in both the coil varies.

(i) The emf in coil x is called as self induced emf.
(ii) The emf in coil Y is called as mutually induced emf.

- ***Mutual inductance(M)***

Consider two coils X and Y placed close to each other, I_1 flows through coil X, a flux is set up and a part Φ12 of this flux links coil Y. This flux which is common to both the coils is called mutual flux (Φm). If current in coil X changes, the mutual flux alsochanges and hence emf is induced in coil Y. The emf induced in coil Y is called mutually induced emf.

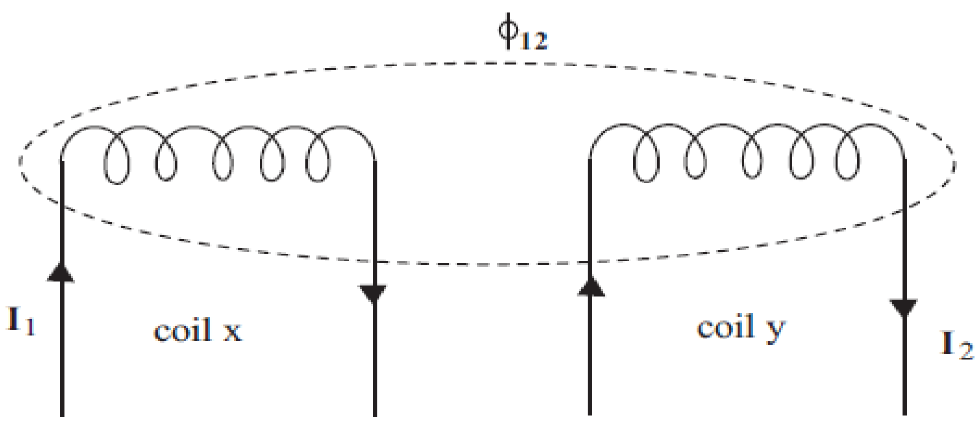

Fig.3.12

Expression for M:

Mutually induced emf in coil Y is directly propositional to the rate of changeof current in coil X.

$$e_m \, \alpha \frac{dI_1}{dt}$$

$$e_m = M\frac{dI_1}{dt}$$

M = Mutual inductance between the coils

Method 1:

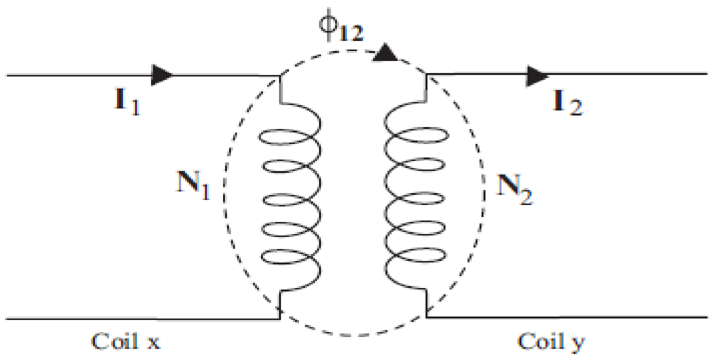

Fig.3.13

$$e_m = M\frac{dI_1}{dt}$$

$$= \frac{d}{dt}(MI_1)$$

3.4 Coefficicent Coupling

Co-efficient of coupling is defined as the fraction of magnetic flux produced by the current in one coil that links the other coil. If L1 and L2 are self inductances of two coils & M be the mutual inductance and K is the Co-efficient of coupling.

$$K = \frac{M}{\sqrt{L_1 L_2}}$$

Note:
When there in no mutual flux between two coils then K = 0, M = 0.

Proof:

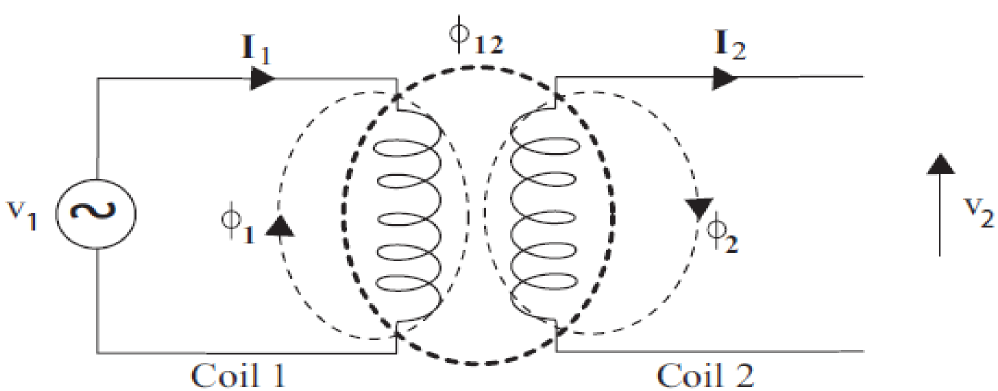

Fig.3.14

The ratio of the flux linked in the second coil to the total flux in the first coil due to current in the first coil is called co-efficient of coupling.

Let

Coil 1 and coil 2 be coupled magnetice and coil 1 is energized by a voltage of V1 Volts

- I1 produces a flux of Φ1 in coil 1
- Φ11 is the part of the flux linked only with coil1
- Φ12 is the part of the flux linking both the coil 1 and coil 2
- According to above definition

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

$$\phi_{12} = K\phi_1 \text{ ....(1)}$$

Due to reciprocal action i.e., when source connected to coil 2.

$$K = \frac{\phi_{21}}{\phi 2}$$

$$\phi_{21} = K\phi_2 \text{ ....(2)}$$

We know that

$$M = \frac{N_2\phi_{12}}{I_1}[coil\,1 \text{ with source voltage}] \text{ ....(3)}$$

$$M = \frac{N_1\phi_{21}}{I_2}[coil\,2 \text{ with source voltage}] \text{ ....(3)}$$

$$M^2 = M \times M$$

$$= \frac{N_2\phi_{12}}{I_1}\frac{N_1\phi_{21}}{I_2} \text{ ....(5)}$$

$$= \frac{N_2N_1\phi_{12}\phi_{21}}{I_1I_2} \qquad \because \phi_{12} = K\phi_1$$

$$\phi_{21} = K\phi_2$$

$$= \frac{N_2\,K\,\phi_1}{I_1} \times \frac{N_1\,K\,\phi_2}{I_2}$$

$$=K^2\left[\frac{N_2\ \phi_2}{I_2}\right]\left[\frac{N_1\ \phi_1}{I_1}\right]\ldots\ldots\ldots\ldots(6)$$

$$M^2=K^2\ \frac{N_2\ \phi_2}{I_2}\ \frac{N_1\ \phi_1}{I_1}$$

$$L_1=\frac{N_1\ \phi_1}{I_1},\quad L_2=\frac{N_2\ \phi_2}{I_2}$$

$$M^2=K^2\left[L_1\ L_2\right]$$

$$K^2=\frac{M^2}{L_1L_2}\ldots\ldots\ldots\ldots(7)$$

$$K^2=\frac{M}{L_1}\ \frac{M}{L_2}\ldots\ldots\ldots\ldots(8)\,(\text{or})$$

$$\text{K}=\frac{M}{\sqrt{L_1L_2}}\ldots\ldots\ldots\ldots(9)$$

3.5 Analogy of magnetic and electric circuits

S.No	Magnetic Circuits	Electric Circuits
1	The closed path for magnetic flux is called magnetic circuit	The closed path for electric current is called electric circuit
2	Magnetic flux Φ in webers	Electric current $'I'$ in amperes
3	Magneto motive force 'NI' in ampere turns	Electromotive force in volts
4	Magnetic flux $\Phi = \frac{\text{mmf}}{\text{reluctance}}$	Electric current $I = \frac{\text{emf}}{\text{resistance}}$
5	Reluctance S $= \frac{l}{\mu_o\mu_r A}$ in AT/wb	Resistance R $= \frac{\rho l}{A}$ in ohms
6	Permeance $= \frac{1}{\text{reluctance}}$	Conductance $= \frac{1}{\text{resistance}}$
7	Reluctivity	Resistivity

8	Permeability	Conductivity
9	Flux density B $=\frac{\Phi}{A}$ in wb/m^2	Current density J $=\frac{I}{A}$ in A/m^2
10	Magnetic intensity H $=\frac{NI}{l}$ in AT/m	Electric intensity E $=\frac{V}{d}$ in volts/metre
11	Magnetic flux does not actually flow in a magnetic circuit.	The electric current actually flows in an electric circuit.
12	The reluctance of a magnetic circuit is not constant and it depends up on flux density in the material.	The resistance of an electric circuit is practically constant, even though it varies slightly with temperature.
13	In a magnetic circuit, energy is required to create the flux and not to maintain it.	In an electric circuit, energy is required so long as the current has to flow through it.
14	For magnetic flux, there is no perfect insulator.	There are many electrical insulators like glass, air, rubber etc.

Problem 3.5 Calculate the emf induced in a coil of 200 turns, when the flux linking with it changes from 1 milliweber to 3 milliweber in 0.1 sec

Given data:

i) No of turns (N) = 200
ii) Initial value of flux (Φ1) = 1 mwb
= 1 × 10-3 wb
iii) Final value of flux (Φ2) = 3 mwb
= 3 × 10-3 wb

Solution:

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

change in flux $d\Phi = \Phi_2 - \Phi_1 = 3 \times 10^{-3} - 1\times10^{-3}$
= 2 × 10-3 wb

$$e = -200 \times \frac{2\times10^{-3}}{0.1} = 4 \text{ volts (in magnitude)}$$

Problem 3.6 A coil of 50 turns is linked by a flux of 20 mWb. If this flux is reversed in a time of 2 ms, Calculate the average emf induced in the coil.

Given:

i) No of turns (N) = 50
ii) Flux linked in coil (Φ) = 20 mwb
= 20X10-3 wb.
iii) Time required for flux reversal (t) = 2 ms

Solution
Emf induced in the coil (e)??

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

change in flux dΦ= 20-(-20) = 40 mWb

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

$$=\frac{50\times40\times10^{-3}}{2\times10^{-3}}$$

=1000V

emf induced e= 1000V

Problem 3.7 A coil of 100 turns of wire is wound on a magnetic circuit of reluctance 2000 AT/Wb. If a current of 1 A flowing in the coil is reversed in 10 ms, find the average emf induced in the coil.

Given:

i) No. of turns (N) = 100
ii) Reluctance (S) = 2000 ATwb
iii) Current in coil (I) = 1A
iv) Time required to reversal current t= 10 ms

Solution:

$$\text{Emf induced in coil } e = N\frac{d\Phi}{dt}$$

$$Flux = MMF / S$$
$$=NI / S$$
$$= \frac{100\times1}{2000}$$
$$=0.05 \text{ Wb}$$

When a current of 1A is reversed in coil change in flux,

$$(d\varphi)=0.05-(0.05)=0.1mWb$$

$$e = N\frac{d\Phi}{dt}$$
$$= \frac{100\times0.1\times10^{-3}}{10\times10^{-3}}=1V$$

emf = 1V

Problem 3.8 A coil of 2000 turns surrounds a flux of 5mWb produced by a permanent magnet. The magnet is suddenly drawn away causing the flux inside the coil to drop to 2mWb in 0.1 sec. What is the average emf induced?

Given:

i) No of turns is coil (N) = 2000 turns

ii) Initial value of flux ($\Phi 1$) = 5 mwb
= 5×10^{-3}WB
iii) Final value of flux Φ = 2mWb = 2 $\times10^{-3}$ WB
iv) Time required for change in flux (dt) = 0.1 sec
v) change is flux $d\Phi$ = 5 - 2 = 3 mwb.

Solution:

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

$$= \frac{\mathbf{2000\times3\times10^{-3}}}{\mathbf{0.1}}$$

$$=60V$$

emf induced = 60 V.

Problem 3.9 A current of 5 Amperes when flowing through a coil of 1000 turns establishes a flux of 0.3 mwb. Determine the inductance of the coil.

Given:

I=5A
N=1000 turns
Φ=0.3mWb
=$0.3\text{x}10^{-3}$Wb

Solution:

$$L = \frac{N\emptyset}{I}$$

$$= \frac{1000 \times 0.3 \times 10^{-3}}{5}$$

=0.06H

Problem 3.10 A coil of 1500 turns carries a current of 10 A establishes a flux of 0.5 mWb. Find the inductance of the coil.

Given:

I =50 A
N =1500 turns
Φ =5×10^{-3} WB

Solution:

$$L = \frac{N\emptyset}{I}$$

$$= \frac{1500\times5\times10^{-3}}{50}$$

=0.075H

Problem 3.11 A coil has self inductance of 10H. If a current of 200 mA is reduced to zero in a time of 1 ms. Find the average value of induced emf across the terminals of the coil.

Given:

L = 10 H

dI = 200 mA = 200×10^{-3} A

dt = 1 ms = 1×10^{-3} sec

Solution:

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

$$= \frac{10 \times 200 \times 10^{-3}}{1 \times 10^{-3}}$$

=2000V

Problem 3.12 A air cored solenoid has 400 turns, its length is 30 cm and cross sectional area of 5 cm^2 . Calculate self inductance.

Given:

N = 400

l = 30 cm = 30×10^{-2} m

a = 5 cm2 = 5×10^{-4} m

Solution:

$$L = \frac{N^2}{S} = \frac{400^2}{S}$$

$$S = \frac{l}{\mu o \mu r A}$$

$$= \frac{30\times10^{-2}}{4\pi\times10^{-7}\times1\times5\times10^{-4}}$$

$$= 4.77 \times 10^{8} AT/m$$

$$L = \frac{400^2}{4.77\times10^{8}}$$

$$= 3.354 \times 10^{-4} H$$

Problem 3.13 The number of turns in a coil is 250. When a current of 2 A flows in this coil, the flux in the coil is 0.3 mwb. When this current is reduce to zero in 2 ms. The voltage induced in a coil lying in the vicinity of coil in 63.75 volts. If the co-efficient of coupling between the coil is 0.75, find self inductances of the two coils, mutual inductance and number of turns in the second coil.

Given data:

N_1 = 250 turns

I_1 = 2 A

Φ_1 = 0.3 mwb =0.3×10^{-3} WB

di_1 = 2 A

dt = 2 ms = 2×10^{-3} s

e_m = 63.75v k = 0.75

Solution:

a) $L_1 = \frac{N_1 \emptyset_1}{I_1} = \frac{250 \times 0.3 \times 10^{-3}}{2}$

=0.0375H

b) $M = K\sqrt{L_1 L_2}$

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

$$e_m = M\frac{di_1}{dt} = 63.75V$$

$$M = \frac{63.75}{2/2 \times 10^{-3}}$$

$= 63.75mH$

Substituting these values of M, L_1 and K

$$L_2 = \frac{(63.75 \times 10^{-3})^2}{0.75^2 \times 37.5 \times 10^{-3}}$$

=0.193H

=193mH

c) $em_2 = N_2 \frac{d\emptyset_2}{dt}$

$$\emptyset_2 = K\emptyset_1$$

$$= N_2 \frac{d(k\emptyset_1)}{dt}$$

$$= N_2 \frac{k(d\emptyset_1)}{dt}$$

$$em_2 = N_2 \times 0.75 \times \frac{0.3 \times 10^{-3}}{2 \times 10^{-3}}$$

$$63.75 = 0.1125 N_2$$

$$N_2 = \frac{63.75}{0.1125}$$

$$N_2 = 567\ turns$$

PART A- Questions

1. What is electromagnet?
2. Define flux. Give its unit.
3. Define magnetic flux density. Give its unit.
4. Define magnetic field intensity. Give its unit.
5. Define mmf. Give its unit.
6. What is reluctance? Give its unit.
7. Define retentivity.
8. What is permeance. Give its unit.
9. State Ohm's law of magnetism.
10. A bar of iron 1cm^2 in cross section has 10^{-4} wb of flux in it. Find the flux density in the bar. If the relative permeability of iron is 2000. what is the magnetic field intensity in the bar?
11. A solenoid is wound with a coil of 200 turns. The coil is carrying a current of 1.5A. Find the magnetic field intensity when the length of the coil is 80cm.
12. A current of 2A passes through a coil of 350 turns wound on an iron ring of mean diameter 12cm.The flux density established in the ring is 1.4wb/m^2. find the value of relative permeability of iron.
13. State Faraday's law of electromagnetic induction.
14. Define Lenz's law.
15. Define self inductance and give its unit.
16. Define mutual inductance and give its unit
17. Define leakage flux and leakage factor.
18. What is fringing?
19. State Fleming's right hand rule.
20. State Fleming's left hand rule.
21. Define coefficient of coupling.

PART- B- Questions

1. State Faraday's law of electromagnetic induction. Derive the expression for dynamically induced emf .
2. Explain about statically induced emf with a neat sketch and Give the expression for self and mutual inductance.
3. An iron ring of mean length 50cm has an air gap of 1mm and a winding of 200 turns. If the permeability of the iron ring is 400 when a current of 1.25A flows through the coil, find the flux density.

4. An iron ring 8cm mean diameter is made up of round iron of diameter 1cm and permeability of 900, has an airgap of 2mm wide. It consists of winding with 400 turns carrying a current of 3.5A. Determine, i) mmf ii)total reluctance iii) flux iv)flux density.
5. Find the AT required to produce a flux of 0.4mwb in the airgap of a circular magnetic circuit which has an airgap of 0.5mm. The iron ring has 4cm^2 cross section and 63cm mean length. The relative permeability of iron is 1800 and leakage coefficient is 1.15.
6. Compare electric and magnetic circuit.
7. A coil of 50 turns is linked by a flux of 20mwb. If this flux is reversed in a time of 2ms. Calculate the average emf induced in the coil.
8. A coil of 100 turns of wire is wound on a magnetic circuit of reluctance 2000AT/wb. If a current of 1A flowing in the coil is reversed in 10ms, find the average emf induced in the coil.
9. Two 100 turns air cored solenoids have length 20cm and cross sectional area of 3cm^2 each. If the mutual inductance between them is 5μH. Find the coefficient of coupling.
10. Two magnetically coupled coils have self inductances L_1=100mH & L_2=400mH. If the coefficient of coupling is 0.8. Find the value of mutual inductance between the coils. What would be the max possible mutual inductance.
11. A coil of 800 turns is wound on a wooden former and a current of A produces flux of 200x10^{-6} wb. Calculate the inductance of a coil and induced emf when current is reversed in 0.2 sec.