Magnetic materials

1) paramagnetic material
2) Diamagnetic material
3) Ferromagnetic material
   a) Soft Ferromagnetic material
   b) Hard Ferro-magnetic material
4) Ferrites
   a) Soft Ferrites
   b) Hard Ferrites

Based on μ_r

Diamagnetic	paramagnetic	Ferromagnetic
$\mu_r < 1$	$\mu > 1$	$\mu >> 1$
Gold, water, wood	platinum nickel	Iron, steel, cobalt

1) paramagnetic material – The materials which are not strongly attracted by a magnet, such as aluminium, tin, platinum, manganese etc are known as paramagnetic material. Their relative permeability is small but positive.

2) Diamagnetic materials – The materials which are repelled by a magnet such as zinc, mercury, lead, sulphur, copper, silver, wood etc are known as Diamagnetic materials. Their relative permeability is slightly less than unity.

3) Ferromagnetic material – The material which are strongly attracted by a magnet such as iron, steel, nickel, cobalt etc. are known as Ferromagnetic material. Their permeability is very high.

a) Soft Ferromagnetic material – They have high relative permeability, low coercive force easily magnetised and demagnetised and have extremely small hysteresis. Ferromagnetic materials are iron and its alloys with nickel, cobalt, aluminium etc.

b) <u>Hard Ferromagnetic material</u> – They have relatively low permeability and very high coercive force. These are difficult to magnetise and demagnetise. eg – Cobalt steel and various ferromagnetic alloys of nickel, aluminium and cobalt.

4) <u>Ferrites</u> – This is a special group of ferromagnetic materials that occupy an intermediate position between ferromagnetic and non-magnetic materials.

– high permeability

a) <u>Soft Ferrites</u> – Ceramic magnets also called ferromagnetic ceramic and ferrites are made of an iron oxide Fe_2O_3 with divalent dioxide as NiO, MnO or ZnO. These magnets have square hysteresis loop and high resistance to demagnetization.

b) <u>Hard Ferrites</u> – These are ceramic permanent magnetic material. The most important family of hard ferrites has basic composition $MO \cdot Fe_2O_3$.

→ called super paramagnetic [redacted] material

→ used for permanent magnet dc (PMDC) motor

B-H curve. (Hysteresis curve)

→ Graphical representation of magnetic flux density and magnetic flux intensity

$B \propto H$

B → magnetic flux density

H → magnetic flux intensity

B is dependent on H

$B = \phi/a$ Tesla (dense कति छ unit area मा कति magnetic lines travel भएको छ)

$H = \frac{NI}{l}$ AT/m (magnetic lines of force travel गर्दा कति magnetising force कुनै material or system मा लागेको छ त)

$B = \mu H$

$\mu = \mu_0 \mu_r$

$$\boxed{B = \mu_0 \mu_r H}$$

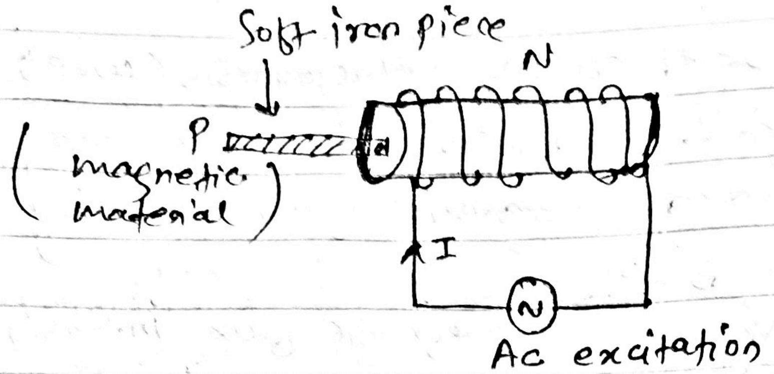
$\mu_0 = 4\pi \times 10^{-7}$

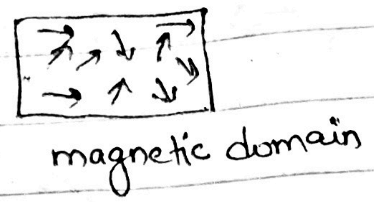
μ_r = Relative permeability of medium
= 1 (for air or vaccum)

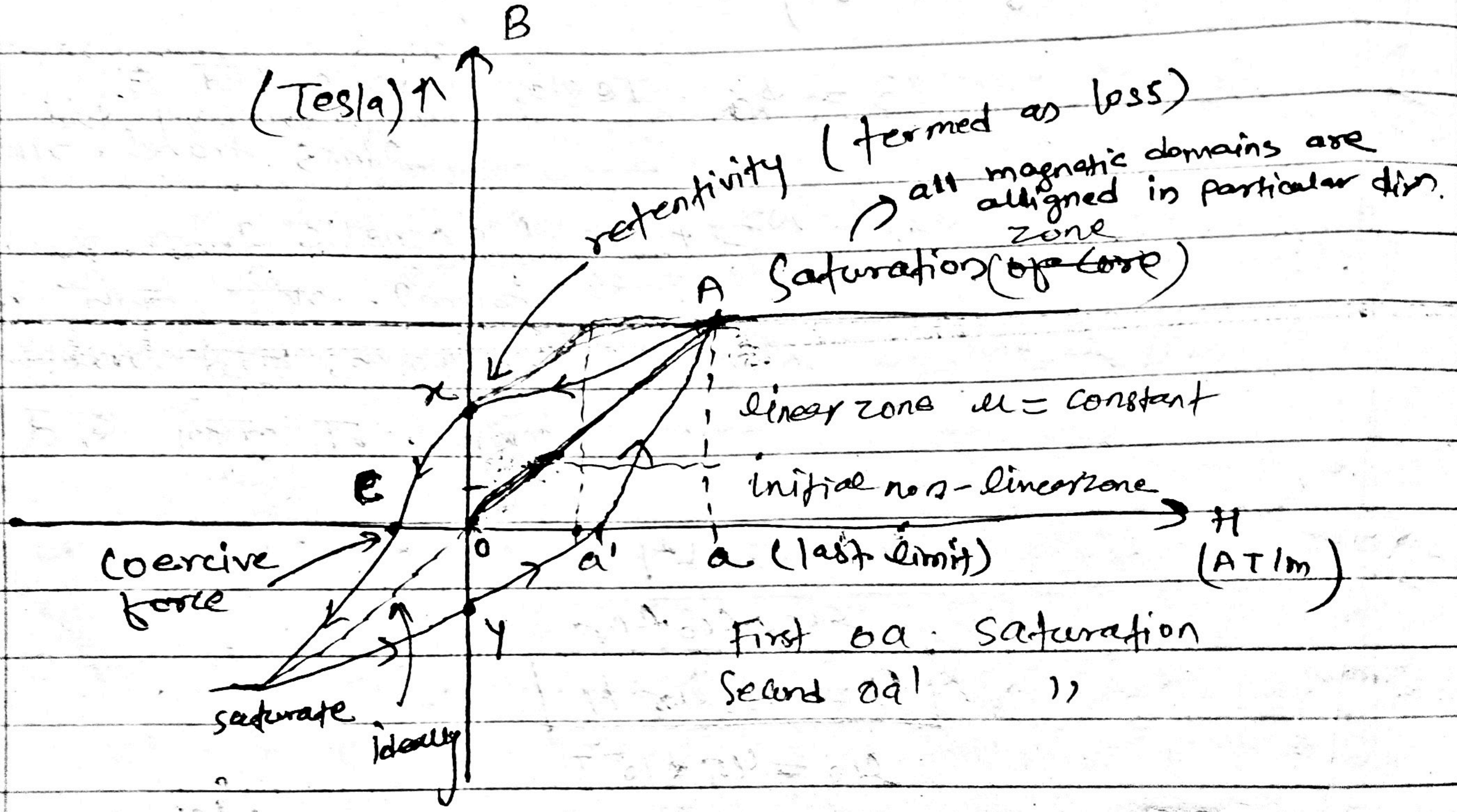
$\uparrow B \propto H \uparrow$

$\uparrow H \propto I \uparrow$

current ↑ then H ↑







→ Firstly increasing current then H will increase which will cause increase in B but it will increase proportionally (linearly) upto saturation.

→ Now, decreasing current, B-H will reduce through Ax (not through Ao) and x is the point called retentivity (store magnetic flux)

↳ property to store residual magnetism inside it is known as retentivity

Hysteresis loss

Hysterein (greek)
that stands for lagging behind

H is 0 but $B \neq 0$ so B is lagging behind H.

coercive force → c point ($B = 0$, $H \neq 0$)
(oc)

→ Force required to eliminate or to reduced residual magnetism is called coercive force

Retentivity → store residual magnetism due to which if we start the system next time then it will start from higher value (i.e from x) not from zero. and magnetic material will saturate in lesser time as before (oa').
and if we start again for next time the same system then may be the system will not start as it will be saturated when we start so we need to eliminate residual flux (residual magnetism)

→ To eliminate residual magnetism, we apply H in negative direction.

Magnetically Induced Emfs (or voltages)

→ Magnetic field has effect on electric circuit and is when the flux linking the circuit changes, an emf is induced. Electromagnetic induction of emf (or voltage) is basic to the operation of transformers, generators (ac or dc) and motors (ac or dc).

→ This effect is described by Faradays law of electromagnetic induction, which states that the magnitude of emf (or voltage) is directly proportional to the rate of change of flux linkage or to the product of number of turns and rate of charge of flux linking the coil,

$$\boxed{\text{Induced emf}(e) = -N\frac{d\phi}{dt} \text{ volts.}}$$

→ The direction of induced emf is given by lenz law and it states that the direction of induced emf is such that the current produced by it set up a magnetic field opposing the cause that produces it.

$$\boxed{e = -N\frac{d\phi}{dt} \quad \text{volts}}$$

Emf can be induced by changing the flux linking in two ways –

i) By increasing or decreasing the magnitude of the current producing the linking flux. In this case there is no motion of the conductor or coil relative to the field, and an emf induced in this way is known as statically induced emf.

ii) By moving a conductor in a uniform magnetic field and emf produced in this way is known as dynamically induced emf.

I) <u>Dynamically induced emf</u> – By moving conductor in a uniform magnetic field and emf induced in this way is known as dynamically induced emf.

Let conductor moving with velocity v m/s in the direction of field as shown in fig (a). In this case no flux is cut by conductor, so no emf is induced in it.

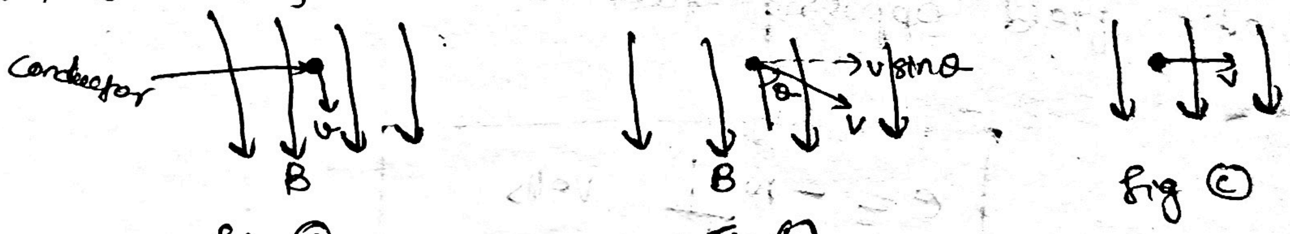


fig (a) Fig (b) fig (c)

Now when conductor moving with velocity v m/s in the direction perpendicular to the direction of magnetic field as shown in fig (c), the flux is cut by conductor, therefore an emf is induced in the conductor

$$\boxed{e = Blv}$$

when conductor is moved at angle θ as shown in fig (b) then induced emf is proportional to the component of velocity perpendicular to the direction of magnetic field.

$$\boxed{e = Blv \sin\theta}$$

→ The direction of induced emf is given by Flemming right hand rule.

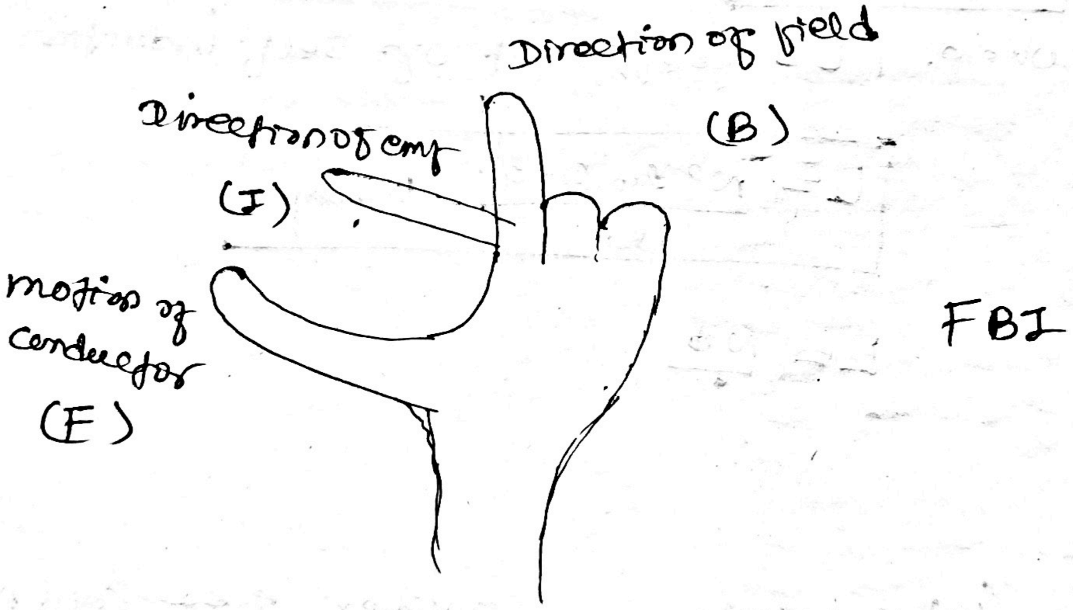


fig. Flemming Right hand rule

2) <u>Statically Induced emf</u> - Statically induced emf may be a) self induced or b) mutually induced emf

a) <u>Self induced emf</u> - when the current flowing through the coil is changed, the flux linking with its own winding changes and due to the change in linking flux with the coil, an emf known as self induced emf is induced.

$$\boxed{e = -L \frac{di}{dt}}$$

where, L = coefficient of self induction

$$\boxed{L = \frac{N^2 \mu_0 \mu_r a}{l} \text{ henry}}$$

$$L = \frac{N\phi}{i}$$

b) <u>mutually induced emf</u> - Consider two coils A and B placed together so that flux created by one coil completely links with other coil. when current in coil A increases, the flux linkage in coil B also increases, an emf induced in coil B is known as mutually induced emf.

$$\boxed{e_m = -M \frac{di_1}{dt}}$$ where, $$\boxed{M = \frac{N_1 N_2 \mu_0 \mu_r a}{l}}$$

coefficient of mutual induction