Magnetic Circuit

Losses

Acknowledgement: *The materials presented in this lecture has been taken from open source, reference books etc. This can be used only for student welfare and academic purpose.*

Recap

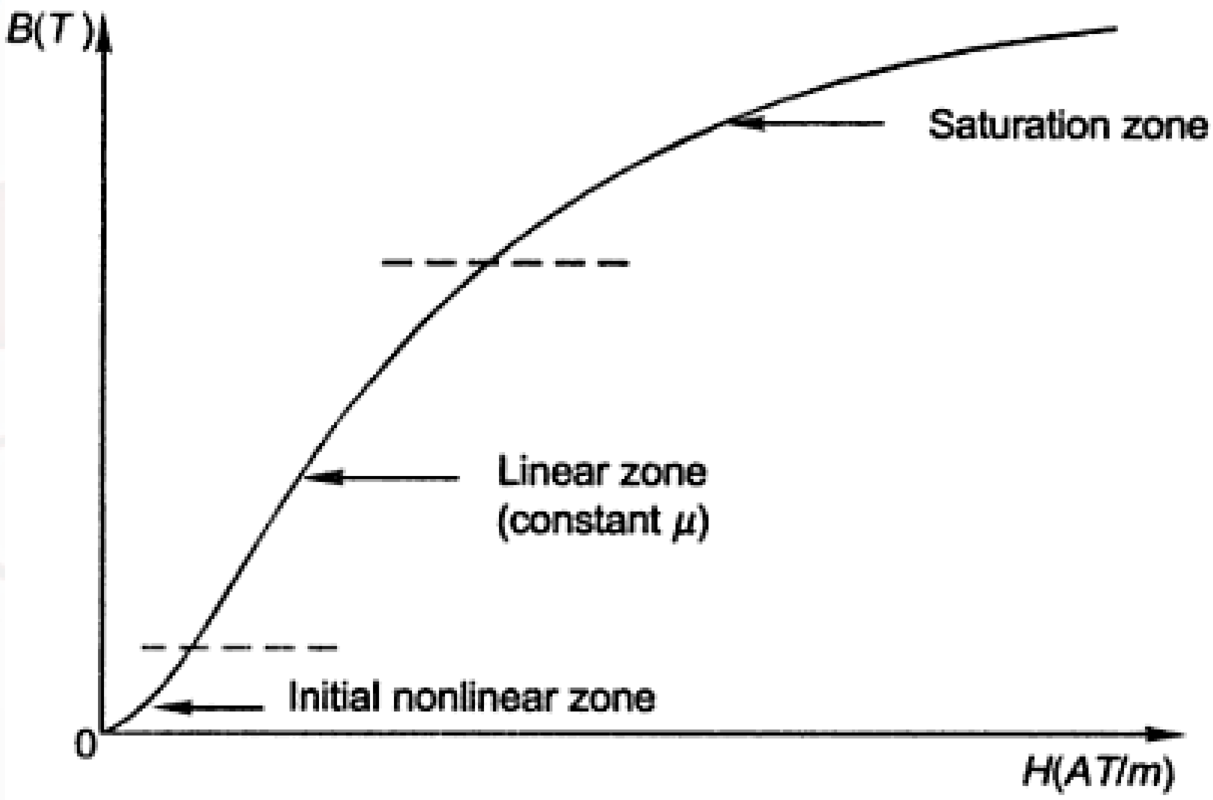
- Needs of magnetic coils
- Self inductance and Mutual inductances
- Dot convention in magnetic circuits
- Induced EMF and its types in Magnetic link circuits

Lecture-3 Objectives

- Magnetization curve
- Hysteresis Loop/ B-H Curve
- Magnetic Circuit losses and its types
- Fringing effect and stacking factor
- Properties of magnetic materials

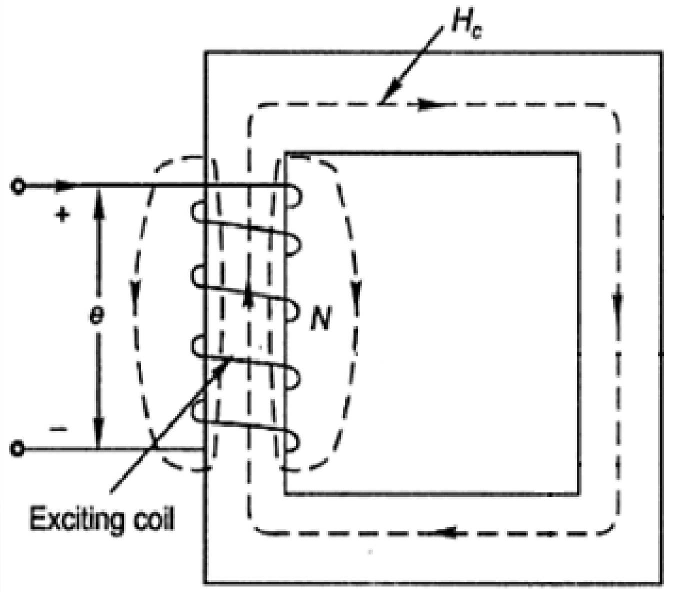
Magnetisation Curve

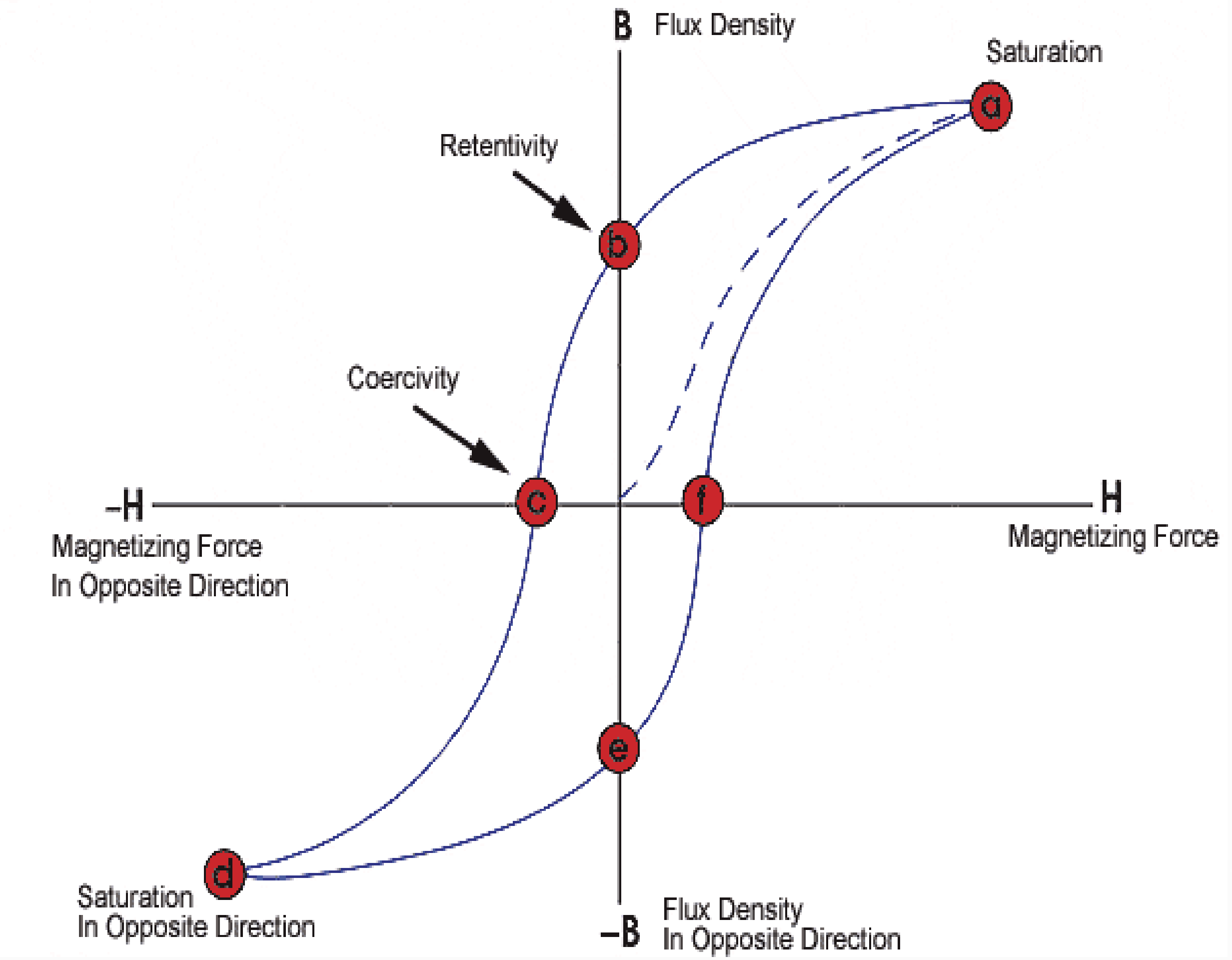
- The curve that shows the variation in magnetic flux density ***B*** with respect to the variation in magnetic field intensity ***H*** in a ferromagnetic material.



Hysteresis Loop

- A hysteresis loop shows the variation of the magnetic flux density **(B)** with respect to the variation in magnetizing force **(H).**
- It is often referred to as the B-H loop.





Hysteresis Loop

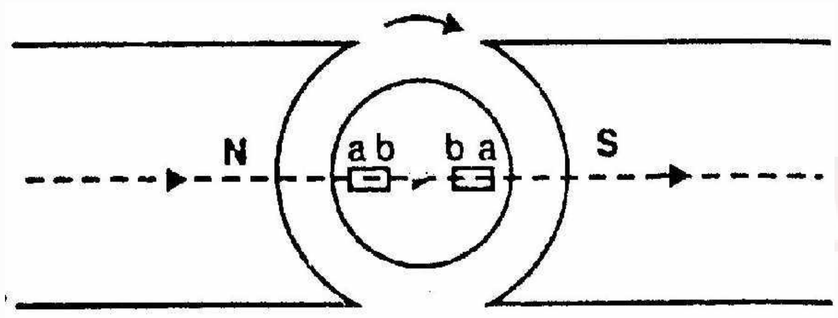
- **Retentivity** – It is the ability of a material to retain a certain amount of residual magnetic field when the magnetizing force is removed after achieving saturation.
- **Residual Magnetism** or **Residual Flux** – The magnetic flux density that remains in a material when the magnetizing force is zero.
- **Coercive Force** – The amount of reverse magnetic field which must be applied to a magnetic material to make the magnetic flux return to zero.

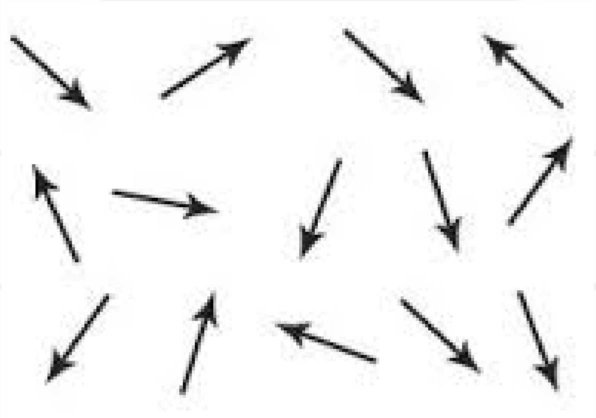
Hysteresis and Eddy Current Loss

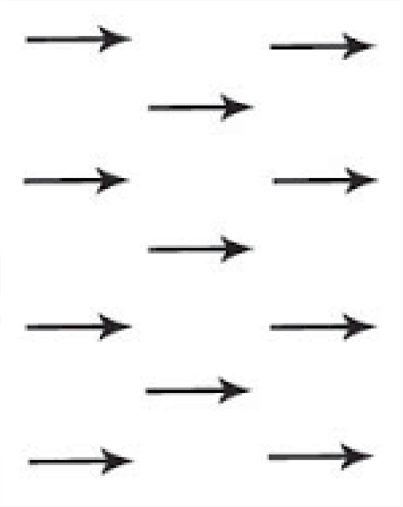
- When a magnetic material is subjected to cyclic magnetization, two kinds of power losses occur in it.
- Hysteresis loss and Eddy current loss together called core loss.

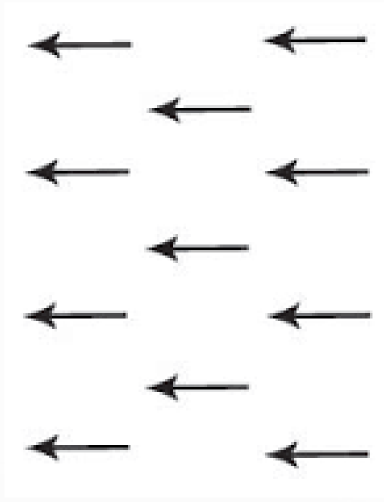
Hysteresis Loss

- Magnetic circuit is subjected to magnetic field reversals as it passes under successive poles.









Hysteresis Loss

- Some amount of power has to be spent to reverse the molecular magnets in the armature core continuously.
- It is considered as loss.
- The loss of power in the core due to hysteresis effect is called hysteresis loss.

Magnetic Circuit Losses

- It is given by Steinmetz formula.

$$Hysteresis\ loss, P_h = K_h\ B_{max}{}^{1.6} f\ v \quad watts$$

Where

$$B_{max} = maximum\ flux\ density\ in\ the\ core$$

$$f = frequency\ of\ magnetic\ reversals$$

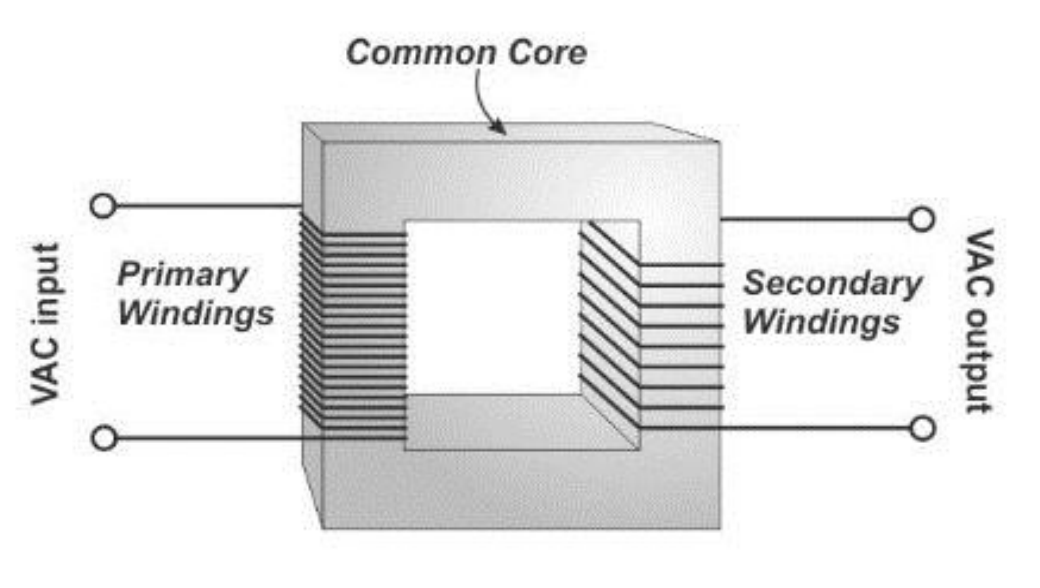
$$v = volume\ of\ armature\ in\ m^3$$

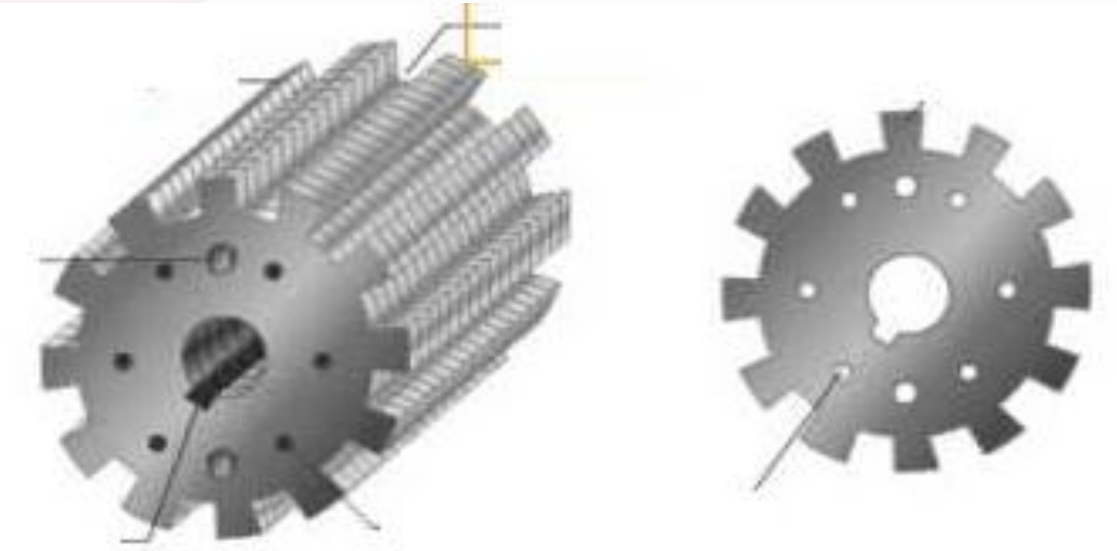
$$K_h = Steinmetz\ hysteresis\ co-efficient$$

- To reduce this loss, the magnetic core is made of such materials which have a low value of Steinmetz hysteresis co-efficient e.g., silicon steel.

Eddy Current Loss

- In addition to the voltages induced in the conductors, there are also voltages induced in the magnetic core.
- These voltages produce circulating currents in the core.





Eddy Current Loss

- It is given by

$$Eddy\ current\ loss, P_e = K_e\, B_{max}{}^2 f^2 t^2\, v \quad watts$$

Where

$$B_{max} = maximum\ flux\ density\ in\ the\ core$$

$$f = frequency\ of\ magnetic\ reversals$$

$$v = volume\ of\ armature\ in\ m^3$$

$$t = thickness\ of\ lamination\ in\ m$$

$$K_e = constant$$

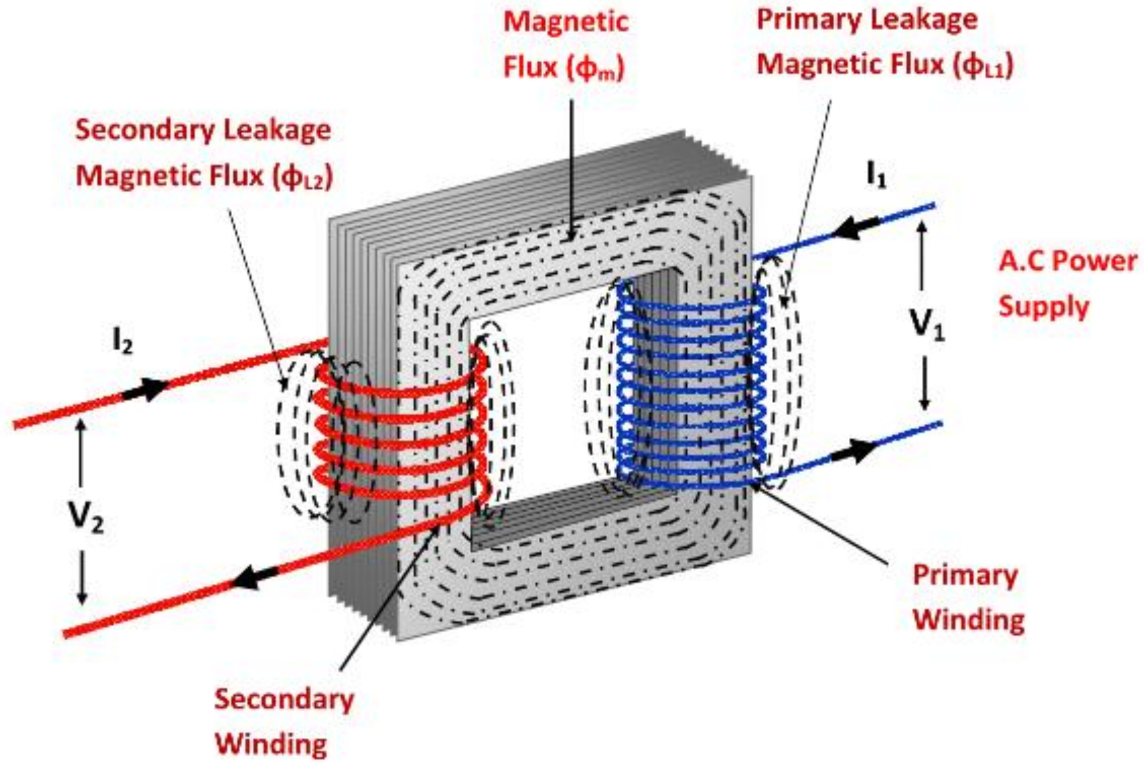
Magnetic Circuit Losses

Problem:

The core loss (hysteresis + eddy current loss) for a given specimen of magnetic material is found to be 2000 W at 50 Hz. Keeping the flux density constant, the frequency of the supply is raised to 75 Hz resulting in a core loss of 3200 W. Compute separately hysteresis and eddy current losses at both the frequencies.

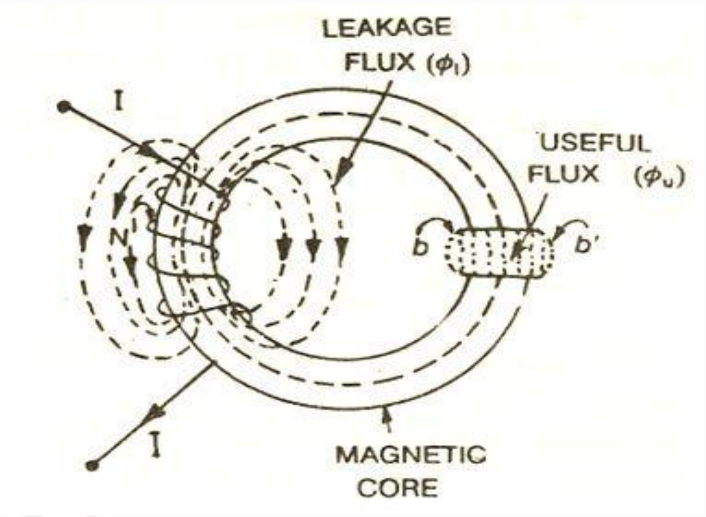
Leakage Flux

- The stray flux, which does not take part in the energy conversion process, is called ***leakage flux***.
- This leakage flux can never be eliminated.
- The effect of leakage flux is incorporated in machine models through the concept of the leakage inductance.



Fringing

- The flux in a magnetic circuit bulges (or fringes) outwards while passing through an air-gap.
- This results in **non-uniform flux density** in the air-gap, **enlargement of air-gap area** and **reduction in flux density** in air-gap.
- This phenomenon is called ***fringing***. The effect of fringing increases with the increase in air-gap length.



Stacking Factor

- Magnetic cores are made up of thin, lightly insulated (coated with varnish) laminations to reduce eddy current loss.
- As a result, the net cross sectional area of the core occupied by the magnetic material is less than its gross cross section.
- Hence the ratio of net cross sectional area to the gross cross sectional area of the core is called ***Stacking factor***.

Magnetic Circuit Losses

- The field winding of DC electromagnet is wound with 800 turns and has a resistance of 40Ω when exciting voltage is 230 V and the magnetic flux around the coil is 0.004 Wb. Calculate self-inductance and energy stored in magnetic field.

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

$$i = \frac{V}{R} = \frac{230}{40} = 5.75\ A$$

$$\therefore L = \frac{800 \times 0.004}{5.75}$$

$$L = 0.556\ H$$

$$Energy\ Stored\ in\ magnetic\ field, e = \frac{1}{2} Li^2$$

$$e = \frac{1}{2} 0.556 \times 5.75^2$$

$$e = 9.19\ Joules$$

Magnetic Circuit Losses

- Two coils ***A*** and ***B*** are wound on same iron core. There are 600 turns on ***A*** and 3600 turns on ***B***. 4 amps of current through the coil ***A*** produces a flux of 500 X 10^{-6} Wb in the core. If this current is reversed in 0.02 seconds, calculate average emf induced in coils ***A*** and ***B***.
  - Current reversal means that the current changing from +4A to -4A.
  - Actual change in current is 8A. Hence change in flux is 1000 X 10^{-6} wb

$$EMF\ in\ coil\ A = N_1.\frac{d\phi}{dt}$$

$$EMF\ in\ coil\ A = 600.\frac{0.001}{0.02}$$

$$E = 30\ V$$

$$EMF\ in\ coil\ B = N_2.\frac{d\phi}{dt}$$

$$EMF\ in\ coil\ B = 3600.\frac{0.001}{0.02}$$

$$E = 180\ V$$

Properties of Magnetic Materials

- All materials are classified according to their relative permeability.

Paramagnetic	• μ_r slightly greater than 1
Diamagnetic	• μ_r slightly lesser than 1
Ferro & Ferrimagnetic	• μ_r much higher than that of free space

Properties of Magnetic Materials

- Ferromagnetic materials are further subdivided into ***hard*** and ***soft***.

Hard (Per. Magnet)	Soft
• Alnico • Chromium steel • Copper nickel alloys • Metal alloys	• Iron and its alloys with nickel, cobalt, tungsten and aluminium

Magnetic Circuit Losses

Summary

- Magnetization curve
- Hysteresis Loop/ B-H Curve
- Magnetic Circuit losses and its types
- Fringing effect and stacking factor
- Properties of magnetic materials