MODULE 3

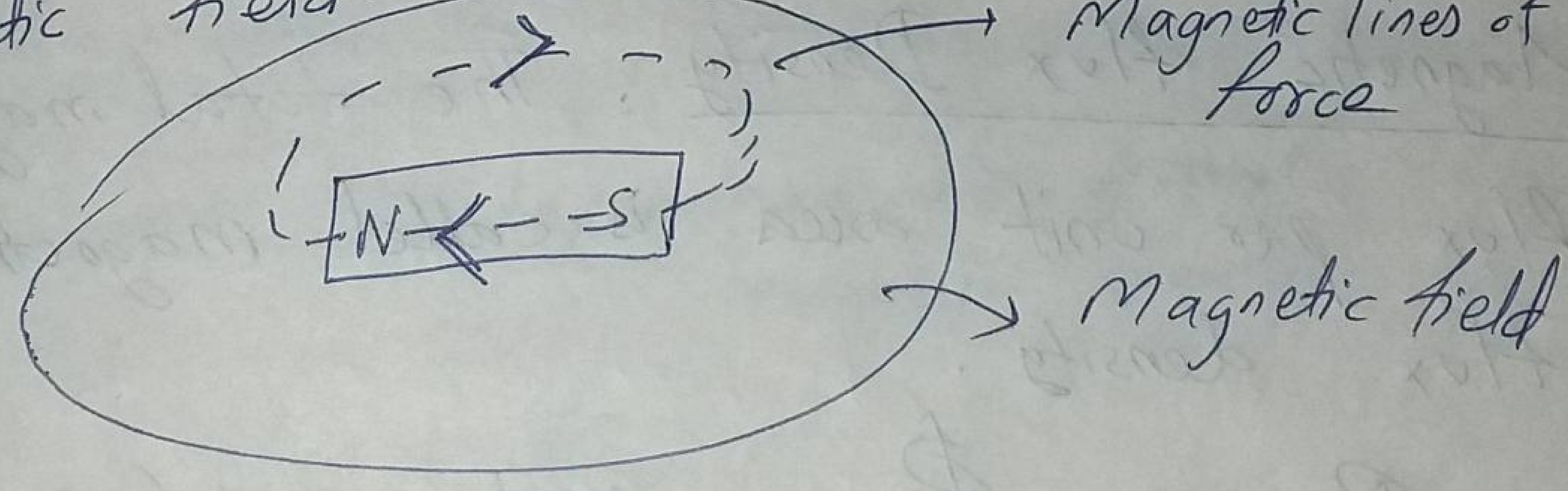
Magnetic Circuits :

MMF : The force that is created in a magnet that is responsible for flow of magnetic flux is called Magneto motive force mmf.

$MMF = NI$ $N \rightarrow$ No of turns
$I \rightarrow$ current

unit : Ampere Turns

Magnetic field : The space around a magnet upto which its force can be experienced is called Magnetic field.



Magnetic lines of force : These are imaginary closed paths drawn in a magnetic field to represent the magnetic field as shown in the figure

* Inside the magnet it is from S to N pole.
  Outside the magnet it is from N to S pole.

Magnetic flux: The total no of magnetic lines of force contained in a magnetic field is called magnetic flux.

Magnetic flux is the effective strength of the magnetic field around a magnet.

ϕ, unit Weber / Wb.

Magnetic field strength, H: The magneto motive force acting per unit length of a magnetic material is called Magnetic field strength.

$$H = \frac{mmf}{l}$$ Unit: AT/m.

Magnetic flux Density: The total magnetic flux per unit area is called magnetic flux density.

$$B = \frac{\phi}{A}$$ Unit Wb/m^2.

Reluctance: The total opposition to magnetic flux in a magnetic circuit is called Reluctance.

$$S = \frac{mmf}{\phi}$$

Also, $S = \frac{l}{\mu_0 \mu_r A} = \frac{l}{\mu A}$

$l \rightarrow$ length of the magnetic material

$\mu \rightarrow$ permeability of the magnetic material.
It is the property of the magnetic medium by which it will allow magnetic flux to pass through.

$\mu = \mu_0 \mu_r$

$\mu_0 \longrightarrow$ permeability of free space
$= 4\pi \times 10^{-7}$ Henry/meter

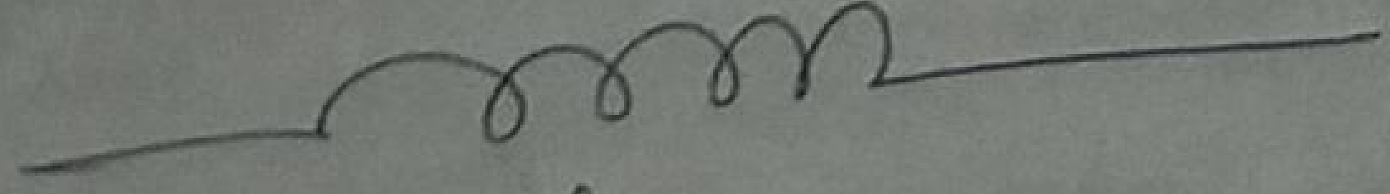
$\mu_r \rightarrow$ Relative permeability
$\rightarrow$ It depends on the type of magnetic medium.

Relation between B & H :

$B = \mu H$

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

Inductance :



L

$$L = \frac{N\phi}{I} \quad \text{Henry}$$

$$V_L = L\frac{di}{dt}$$

$$i_L = \int \frac{V_L}{L}\, dt \,.$$

Review of Ampere's & Biot Savart law

Ampere's law: It relates magnetic field strength to current in a magnetic medium. It states that the total magnetomotive force created is equal to the total current enclosed over the magnetic path which is closed in nature.

i.e mmf over a closed path $= I_{net}$.

Mathematically it is expressed as,

$$\oint H \cdot dl = I$$

$$\Rightarrow \oint \frac{B}{\mu} dl = I \Rightarrow \boxed{\oint B \cdot dl = \mu I}$$

Biot Savart Law :

It relates the value of a magnetic field at a specific point in space due to a short segment of current carrying conductor.

Thus, the value of flux density at any point inside a magnetic field is obtained by Biot savart law.

It is given as,

$$\vec{dB} = \frac{\mu_0 I}{4\pi} \frac{dl \times r}{r^2}$$

$$\Rightarrow \vec{dB} = \frac{\mu_0 I}{4\pi} \frac{dl \sin\theta}{r^2}$$

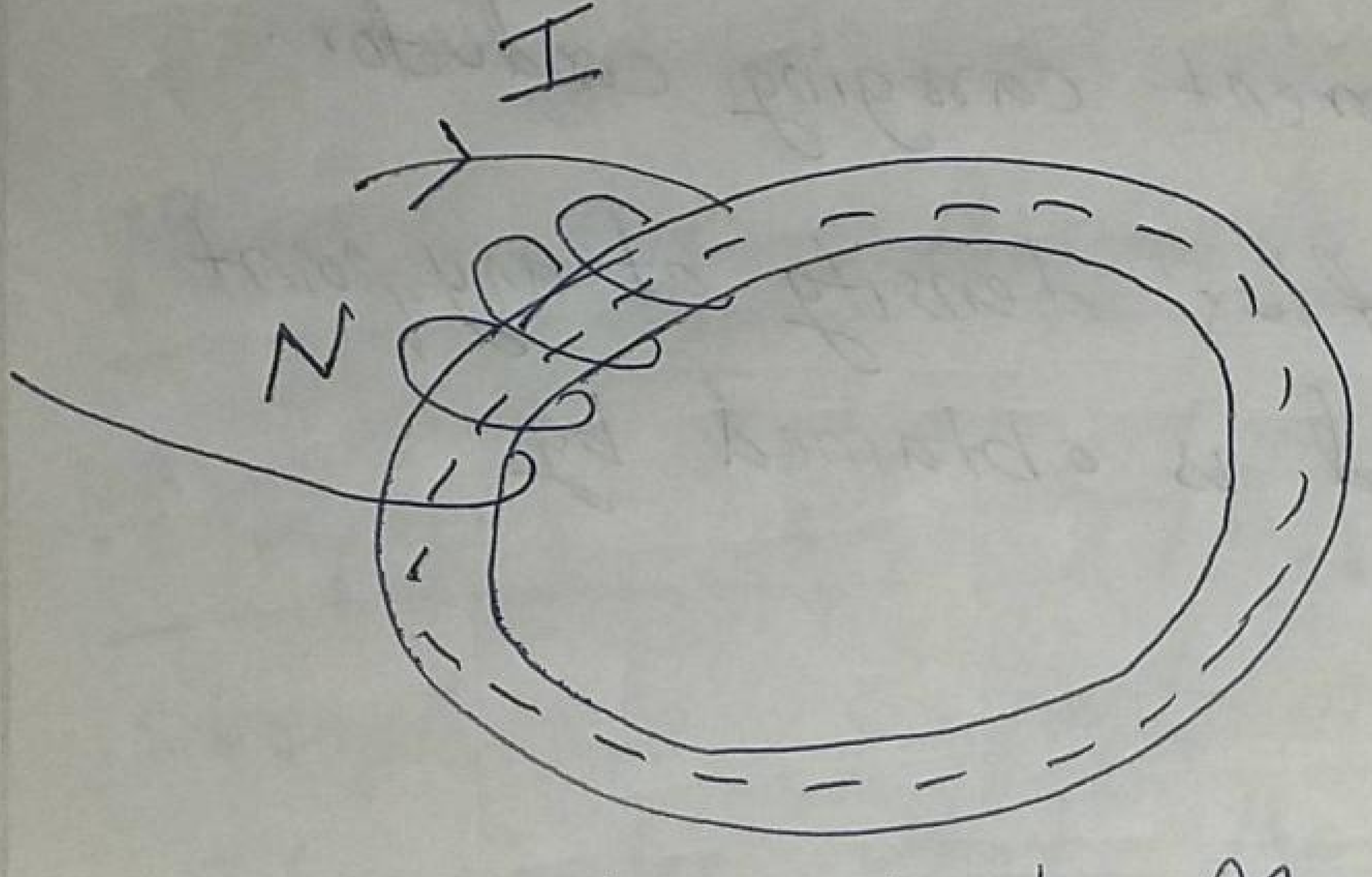
$$\Rightarrow B = \frac{\mu_0 I \, l \sin\theta}{4\pi \, r^2}$$

Magnetic Circuit :

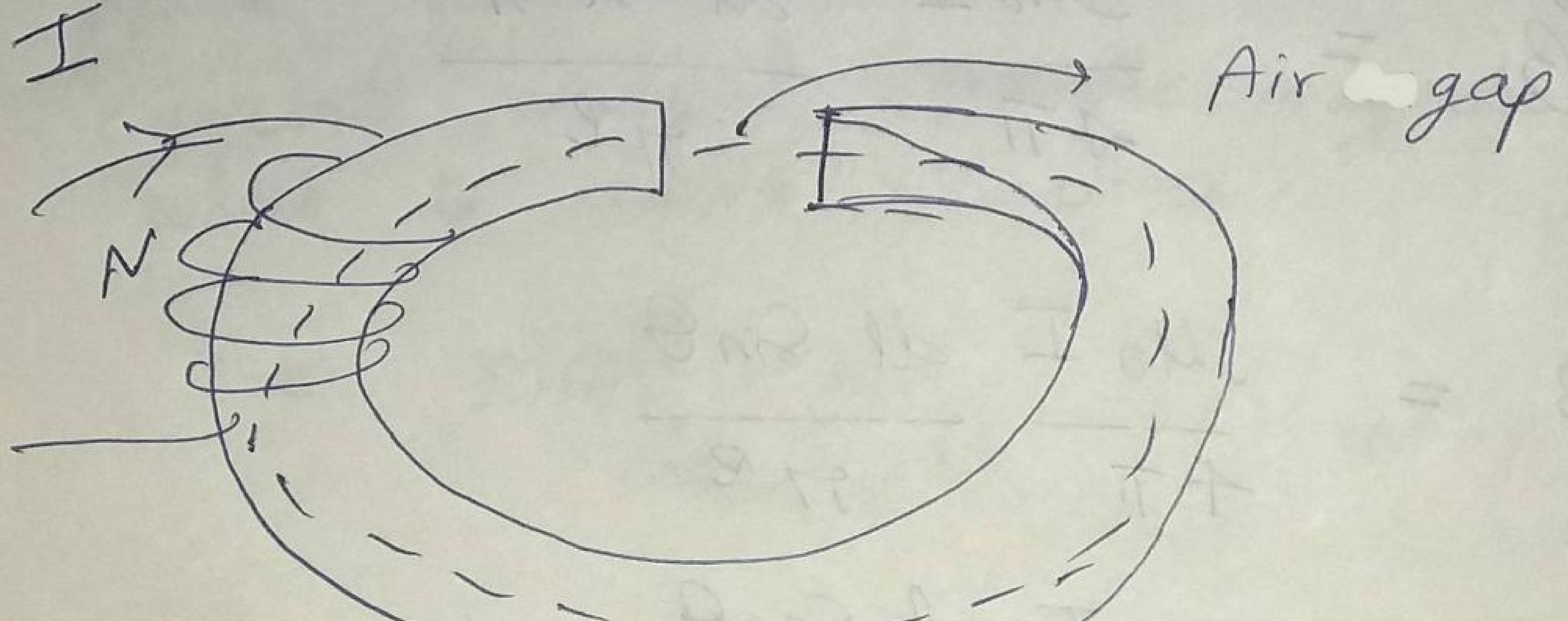
A magnetic circuit is the closed path through which magnetic flux will flow.

A magnetic circuit can either be series or parallel.

A magnetic circuit is usually formed by taking a magnetic material and making it into a closed path and winding a coil on it to which a current is supplied.



A simple Magnetic circuit



A Magnetic circuit with material and air gap.

Associated Formulae :

$$mmf = NI$$

$$\text{flux}, \phi = \frac{mmf}{S}$$

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

For air gap with material :

$$S = S_{air\,gap} + S_{material}$$

$$= \frac{l_{air\,gap}}{\mu_0 \mu_{r_{airgap}} A_{airgap}} + \frac{l_{material}}{\mu_0 \mu_{r_{material}} A_{material}}$$

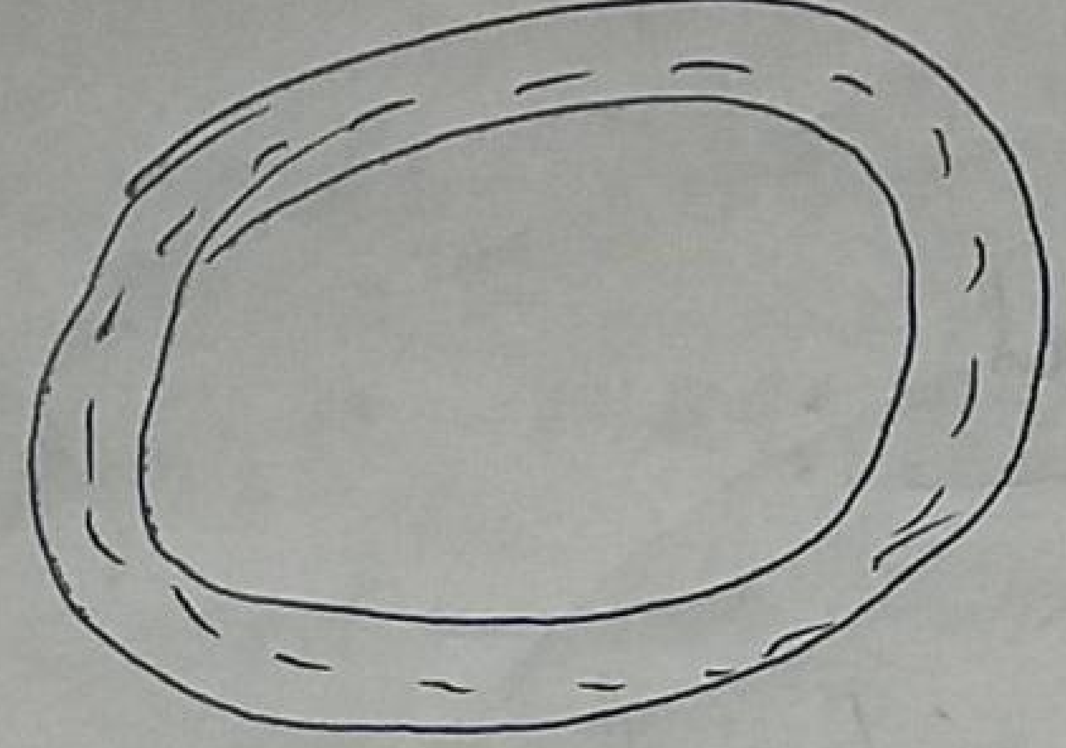
* Here area is cross section area.

For more than one Material :

$$S = S_1 + S_2 + S_3 + \cdots$$

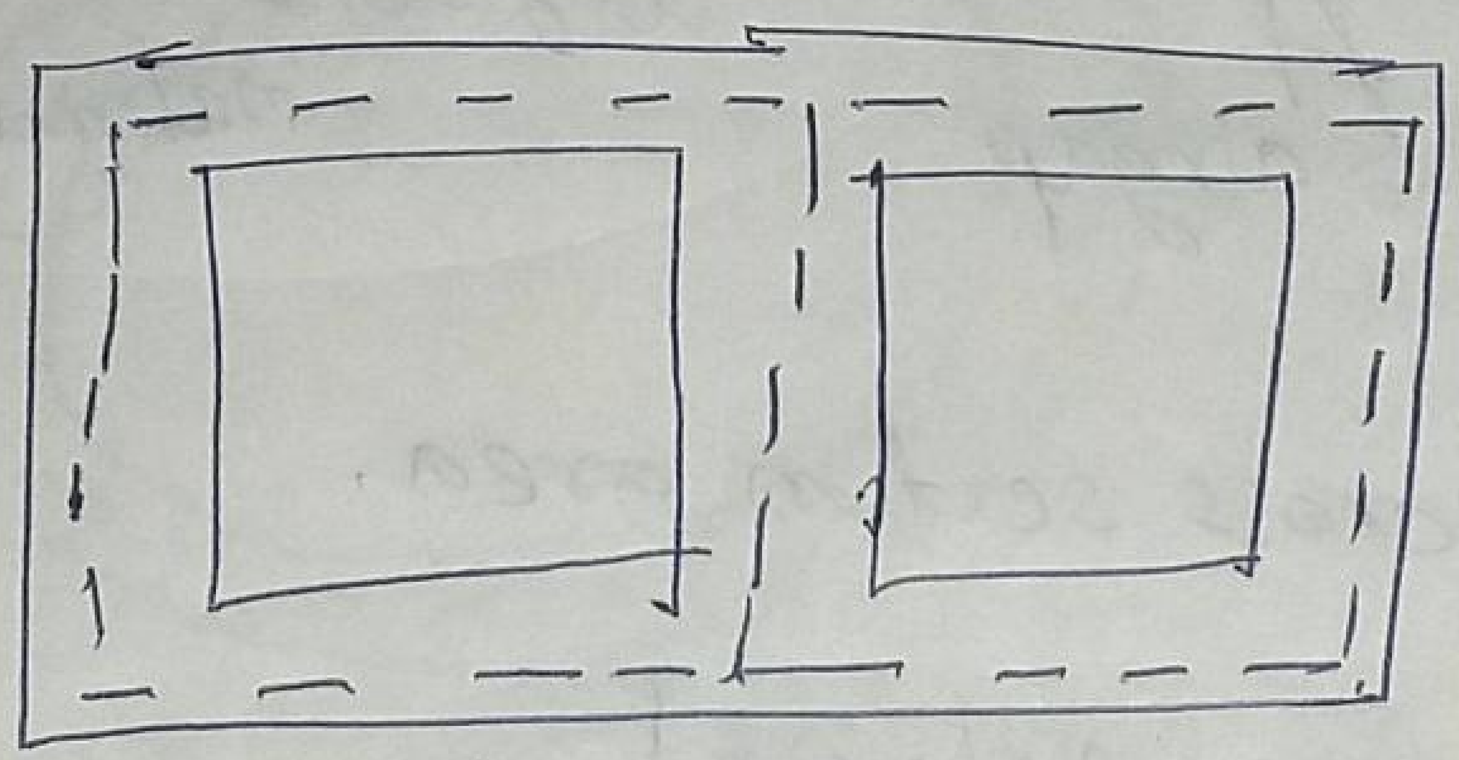
Series and Parallel Magnetic Circuits

If magnetic flux forms a single closed path in a magnetic medium then it is a series magnetic circuit.



→ Series Magnetic circuit

If magnetic flux divides through a magnetic material, then it is a parallel magnetic circuit



parallel Magnetic circuit.

Hysteresis and Hysteresis Loss :

When a magnetic material is continuously magnetized and demagnetized with the passing of a current and cutting off the current, then after continuous encounters, some of the molecules of the magnet becomes permanently magnetized. Even if the supply is cut off, some magnetic property is retained by the magnet. This process is called Magnetic Hysteresis and is usually referred as the lagging of flux density B behind H.

The loss in form of heat due to magnetic hysteresis is called Hysteresis loss. It is given as,

$$W_h = \eta B_{max}^{1.6} f V \text{ watts.}$$

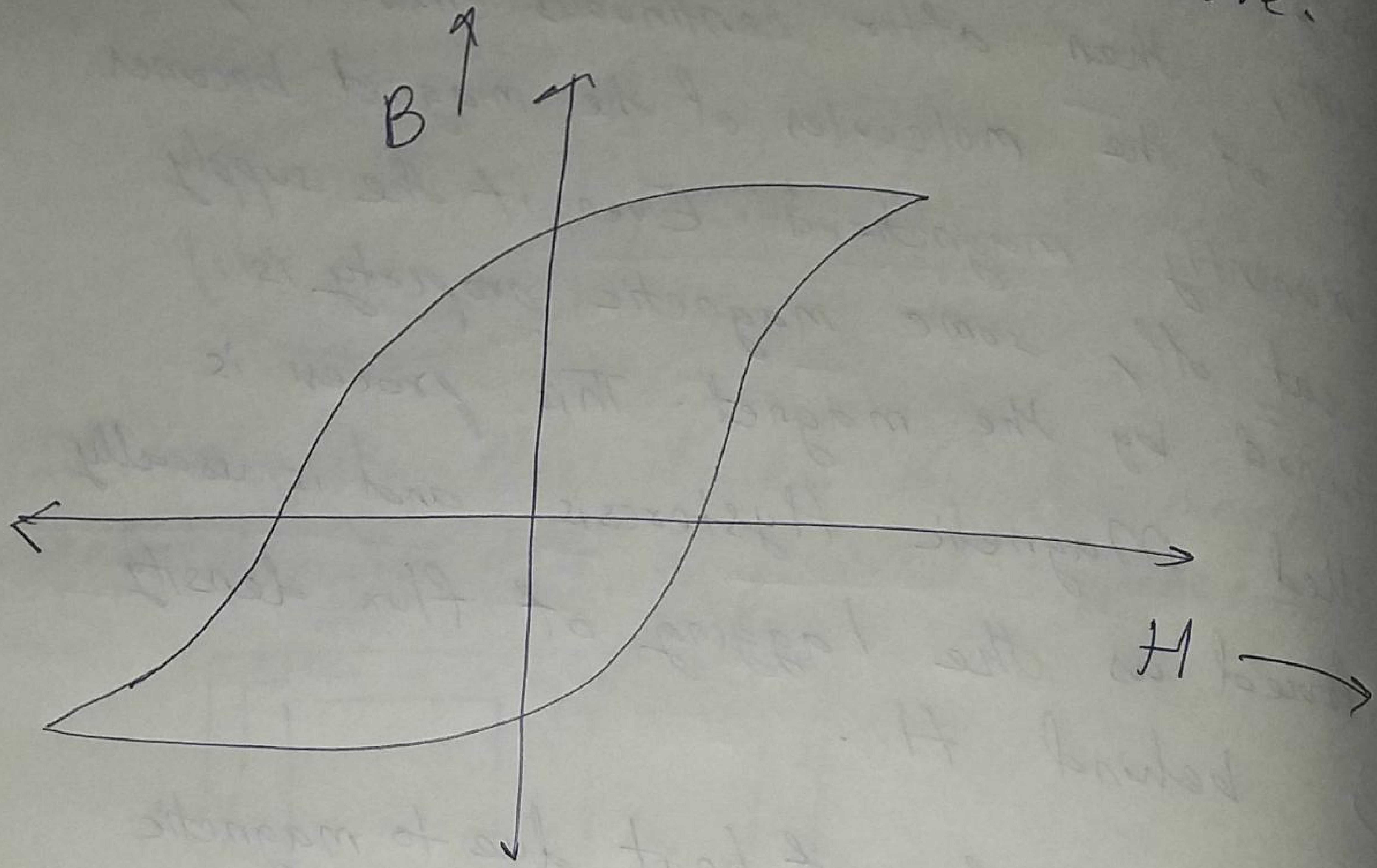
$\eta \rightarrow$ steinmetz's or hysteresis constant

$B_{max} \rightarrow$ Maximum value of flux density

$f \rightarrow$ frequency $V \rightarrow$ Volume of magnetic material

BH curve :

The graphical representation of the relation between flux density B and magnetic field strength H is called BH curve.



This curve is also called Hysteresis curve. It makes evident the lasting induced magnetization of certain materials.

The closed loop that is formed in the figure is called BH loop.