UNIT 3

MAGNETIC CIRCUIT

7.1 INTRODUCTION

The magnets are of two type.

Natural magnet: A material which is available as a magnet from the environment is called natural magnet.

Electromagnet: A material which is formed the magnet with the help of electricity is called electromagnet. If a magnetic material consist a coil of N turns and I current, this magnetic material consist the magnetic property, It is called electromagnet.

7.2 MAGNETIC CIRCUIT CONCEPT

Magnetic circuit: The closed path followed by flux is called the magnetic circuit.

Magnetic field: The region near a magnet where a force is experienced is called magnetic circuit.

Magnetic lines: The imaginary lines which represent the magnetic field is called magnetic lines.

Magnetic flux: The total number of magnetic lines in a magnetic field is called magnetic flux. It is represented by Ø.The unit of the flux is Weber.

$$1\ \text{Weber} = 10^{8}\ \text{magnetic lines}$$

Magneto Motive Force (MMF): The force behind the flow of flux in a magnetic circuit is called magneto motive force (MMF).The unit of the MMF is AT (Ampere Turns).

$$\text{MMF} = \text{NI (Ampere Turns)(AT)}$$

Where N = Number of turns of the coil I = Current in the coil

Reluctance: Opposition offered by the magnetic material to the flow of flux is called the reluctance. It is denoted by S. The unit of the reluctance is AT/Weber.

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

Where l = Length of the magnetic circuit. A = Cross sectional area of the magnetic circuit.

μ = Permeability μ_0= Absolute permeability μ_r = Relative permeability

Relation between MMF, Flux and Reluctance:

$$\text{MMF} = \emptyset S$$

If the compare this equation with ohms law then

MMF is similar to the EMF of the electric circuit.

Flux is similar to the current of electric circuit.

Reluctance is similar to the resistance of the electric circuit.

Permeance: Reciprocal of reluctance is called permeance. The unit of permeance is Weber/AT.

$$\text{Permeance} = \frac{1}{\text{S}}$$

Magnetic flux density: Flux per unit area is called the flux density.It is denoted by B and unit is Weber/m^2.

$$\text{B} = \frac{\text{Ø}}{\text{A}}\left(\frac{\text{Weber}}{\text{m}^2}\right) \text{ or Tesla}$$

Magnetic field intensity (Strength): The force experienced by a unit pole when placed at any point in the magnetic field is called Magnetic field intensity (strength) of that point. It is denoted by H and unit is AT/m.

$$\text{H} = \frac{\text{MMF}}{l} = \frac{\text{NI}}{l}\left(\frac{\text{AT}}{\text{m}}\right)$$

Permeability: It is defined as the ability of the material to carry the magnetic flux. It is denoted by μ.

$$\mu = \mu_0\mu_r = \frac{\text{B}}{\text{H}}$$

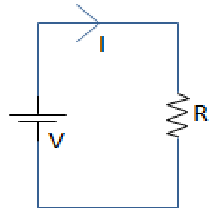
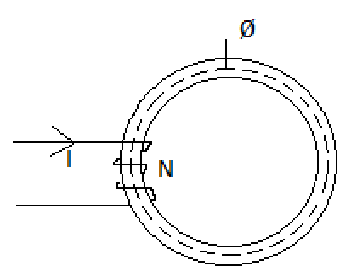
Where $\mu_0 = 4\pi \times 10^{-7}$is called absolute permeability.

μ_r is called relative permeability. Its value will depend on the material. $(\mu_r = 1 \text{ for air})$

7.3 ANALOGY BETWEEN ELECTRIC AND MAGNETIC CIRCUIT

Analogy consist the similarity and dissimilarity between electric and magnetic circuit.

Similarity

S. N.	ELECTRIC CIRCUIT	MAGNETIC CIRCUIT
1.		

2.	The closed path followed by current is called electric circuit.	The closed path followed by magnetic flux is called magnetic circuit.
3.	The force behind the flow of current is emf.	The force behind the flow of flux is mmf.
4.	Resistance opposes the flow of current.	Reluctance opposes the flow of flux.
5.	Current density $J = \frac{I}{A}$	Flux density $B = \frac{\emptyset}{A}$
6.	$EMF = IR$	$MMF = \emptyset S$
7.	$R = \frac{\rho l}{A}$	$S = \frac{l}{\mu A}$
8.	Kirchhoff voltage law and Kirchhoff current law is applicable to the electric circuit.	Kirchhoff mmf law and Kirchhoff flux law is applicable to the magnetic circuit.

Disimilarity

1.	Current actually flow in the electric circuit.	Flux does not flow in the magnetic circuit.
2.	Current cannot pass through the air.	Flux can pass through the air.
3.	If emf is removed then current is zero.	If mmf is removed the flux is not zero.

7.4 B-H CURVE

The graph plotted between the magnetic flux density (B) and magnetic field strength (H) is called the B-H curve.

For non-magnetic material: The relation between B and H is

$$B = \mu_0 H$$

Where $\mu_0 = 4\pi \times 10^{-7}$ is constant so

$$B \propto H$$

The graph between B and H is straight line as shown in fig. 7.1.

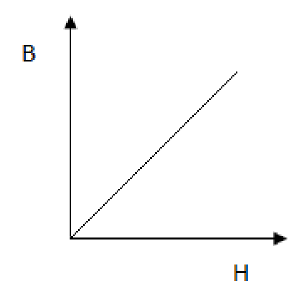


Fig. 7.1

For magnetic material: The relation between B and H is

$$B = \mu_0 \mu_r H$$

Where μ_0 is constant but μ_r is not constant but varies with increase the flux density.

With the increase in H first increase B linearly but after some time B is constant as shown in fig. 7.2.

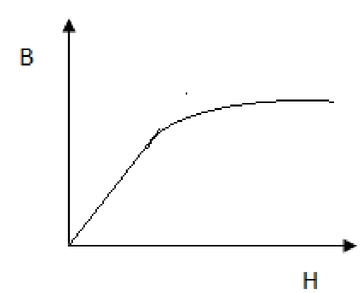


Fig. 7.2

7.5 HYSTERESIS LOOP

The lagging of flux density (B) behind the field intensity (H) is called hysteresis.

When an unmagnetised iron rod shown in fig. 7.3 (a) is wound with a coil having N turns is supplied by a varying current(I) then a closed loop(ACDEFGA) as shown in fig. 7.3 (b) is formed between the B and H is called hysteresis loop.

Step to draw Hysteresis loop

At the origin (O): In the starting when current is zero H=0 then B=0.

Path (OA): When current is increase H is increased, so B will also increase until the point A. After that point if you will increase H, B will not increase. It is the point of maximum flux density B_m.

Path (AC): Now current is decreased to zero, H is decreases to zero. According to hysteresis B will also decrease but not to zero. B will follow the path AC. The OC is called the residual magnetism. The power of retaining the residual magnetism is called the retentivity of the material. It is the property of the material by which it is made magnet.

Path (CD): Now the current is increased in opposite direction, so H is also increased in opposite direction, until B becomes zero at the point. At this point B is zero but H=OD, OD is called the coercive force which is required to demagnetize the magnet.

Path (DE): Now if the current in continue to increase, result in further increase in H, so B will increases upto the point E. Now the material is again magnet but with opposite polarity.

Path (EFGA): Now further decrease and further increase in H result in the path of B is EFGA.

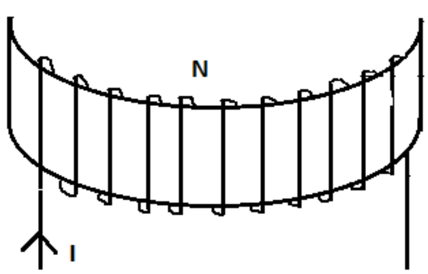


Fig. 7.3 (a)

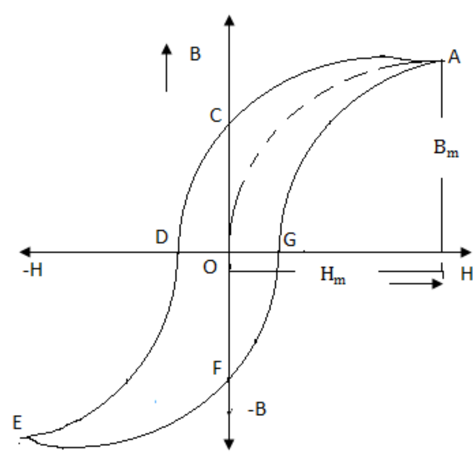


Fig. 7.3 (b)

7.6 MAGNETIC MATERIAL

Material can be broadly classified into the following.

(1) Ferromagnetic Material (Magnetic material)
(2) Non Ferromagnetic Material (Non Magnetic material)
(3) Ferrites

Ferromagnetic material: The materials which are strongly attracted by a magnet are known as ferromagnetic material. Their relative permeability is very high from several hundred to many thousand. Example: Iron, steel, nickel, cobalt and their alloy. They are of two types

(i) Soft ferromagnetic material
(ii) Hard ferromagnetic material

Soft ferromagnetic material: Those materials which easily magnetized called ferromagnetic material. They have high permeability, low coercive force, easily magnetized and demagnetized and have extremely small hysteresis. Ease of magnetization and demagnetization make them suitable for application in electromagnet, motor, generator, transformer, inductor, relay etc. Example: iron and its alloy with nickel, cobalt, aluminum.

Hard ferromagnetic material: Those retaining their magnetism with great tenacity called hard magnetic material. They have low relative permeability, high coercive force. They are difficult to magnetized and demagnetized. They are suitable for use as permanent magnet in loud speaker etc. Example: Cobalt, steel and alloy of nickel, aluminum.

Non Ferromagnetic Material: The materials which are not strongly attracted by magnet called non ferromagnetic material. Their permeability is very less around unity. Example: Platinum, Copper, silver, Zinc, Mercury. They are of two types.

(i) Paramagnetic material
(ii) Diamagnetic material

Paramagnetic material: The materials which are not strongly attracted by magnet are called paramagnetic material. Their relative permeability is small and slightly greater then unity. Example: aluminum, air, platinum

Diamagnetic material: The materials which are repelled by a magnet are called diamagnetic material. Their relative permeability is small and slightly less than unity. Example: Zinc, mercury, copper, silver

Ferrites: This is a special group of ferromagnetic material that occupies an intermediate position between ferromagnetic material and non ferromagnetic material. Example: Iron oxides, nickel oxides, zinc oxides.