Lecture No. 14-16

“Magnetic Circuits”

Magnetic circuits :

It may be defined as the route or path which is followed by magnetic flux . The laws of magnetic circuits are quite similar to (but not the same as) these of the electric circuits .

Symbols used in magnetic circuits are :

H magnetic field strength .
B magnetic flux density .
Φ magnetic flux .
$\mu_\circ$ permeability of free space = $4\pi \times 10^{-7}$ H / m .
μ_r relative permeability of a medium (for air = 1) .

Consider an iron ring shown in fig. 1, having magnetic path of L m length , cross sectional area of A m^2 and a coil of N turns carrying current of I amper , the field strength inside the ring is :

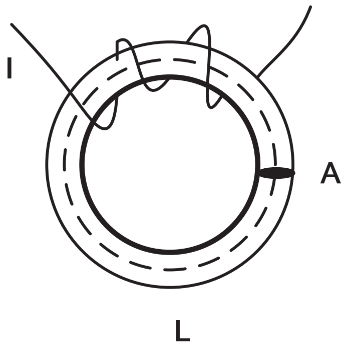

Fig 1

$$H = \frac{N I}{L} \quad AT / m$$

$$B = \mu_\circ \mu_r H \quad wb / m^2$$

$$B = \frac{\mu_\circ \mu_r N I}{L}$$

$$\Phi = B \times A$$

$$\Phi = \frac{N I}{L / \mu_\circ \mu_r A}$$

Where

N I is the amper turns , which produces magnetization in the magnetic circuit , it also called magneto motive force (m.m.f).

$L / \mu_\circ \mu_r A$ is called the reluctance of the circuit (S) which means the property of a material which oppose the creation of magnetic flux through a material .

<u>Composite magnetic circuits</u> :

A composite magnetic circuit shown in fig. 2 , consisting of three different magnetic materials of different permeability and lengths and one air gap . The reluctance of the circuit is the sum of individual reluctances as they are joined in series .

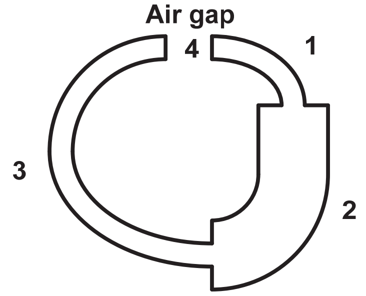

Fig. 2

$$\text{Total reluctance} = \sum \frac{L}{\mu_\circ \mu_r A}$$

$$= \frac{L_1}{\mu_\circ \mu_{r1} A_1} + \frac{L_2}{\mu_\circ \mu_{r2} A_2} + \frac{L_3}{\mu_\circ \mu_{r3} A_3} + \frac{L_a}{\mu_\circ A_a}$$

<u>Comparison between magnetic and electric circuit</u> :

Electric circuit	**Magnetic circuit**
$I = \frac{e.m.f}{R}$	$\Phi = \frac{m.m.f}{S}$
I (current)	Φ (magnetic flux)
e.m.f (voltage)	m.m.f (amper turns)
R (resistance)	S (reluctance)
$R = \rho \frac{L}{A}$	$S = \frac{L}{\mu_\circ \mu_r A}$

Example : An iron ring of mean length 50 cm and has an air gap of 1 mm and a winding of 200 turns . If the relative permeability of iron is 300 when a current of 1 A flows through the coil . Find the flux density , take $\mu_o = 4\pi \times 10^{-7}$ H / m . Assume that the flux density through the iron and air gap is the same .

Let AT_i is the amper turns of the iron :

$$AT_i = H_i \times L = \frac{B}{\mu_o \mu_r} \times L$$

$$= \frac{0.5\,B}{300\,\mu_o} = \frac{5\,B}{3\,\mu_o} \times 10^{-3}$$

Let AT_a is the amper turns of the air gap :

$$AT_a = H_a \times L = \frac{B}{\mu_o} \times L$$

$$= \frac{B}{\mu_o} \times 10^{-3}$$

Total amper turns = N I = 200 x 1 = 200

Total amper turns = $AT_i + AT_a$

$$200 = \frac{5\,B}{3\,\mu_o} \times 10^{-3} + \frac{B}{\mu_o} \times 10^{-3}$$

$$200 = \frac{8}{3} \times \frac{B}{4\pi \times 10^{-7}} \times 10^{-3}$$

$$B = 0.0942 \ wb / m^2$$

<u>Example</u> : A ring of a mean diameter 21 cm and cross sectional area of 10 cm^2 is made up of semi – circular sections of cast iron and cast steel . If each joint has an air gap of 0.2 mm . Find amper turns required to produce a flux of 5 x 10^{-4} weber in the magnetic circuit . The relative permeability of steel and iron are 852 and 165 respectively .

$$B = \frac{\Phi}{A} = \frac{5 \times 10^{-4}}{10 \times 10^{-4}} = 0.5 \ wb / m^2$$

1. <u>Air gap</u> :

$$H = \frac{B}{\mu_\circ} = \frac{0.5}{4\pi \times 10^{-7}} = 3.9 \times 10^{5} \ AT / m$$

Air gap length = 2 x 0.2 = 0.4 mm = 4 x 10^{-4} m

Amper turns = H x L = 3.9 x 10^{5} x 4 x 10^{-4} = 156

2. <u>Cast steel path</u> :

$$H = \frac{B}{\mu_\circ \mu_r} = \frac{0.5}{4\pi \times 10^{-7} \times 852} = 467 \ AT / m$$

Cast steel path length $= \dfrac{\pi D}{2} = \dfrac{21\,\pi}{2} = 33 \text{ cm} = 0.33 \text{ m}$

Amper turns $= H \times L = 467 \times 0.33 = 154$

3. <u>Cast iron path</u> :

$$H = \frac{B}{\mu_\circ\, \mu_r} = \frac{0.5}{4\pi \times 10^{-7} \times 165} = 2412 \ \text{AT / m}$$

Cast steel path length $= 0.33$ **m**

Amper turns $= H \times L = 2412 \times 0.33 = 795$

Amper turns required $= 156 + 154 + 795 = 1105$