Lecture -16
Magnetic Effect of Electric Circuit

Topics

- Magnetic flux
- Flux density
- Reluctance
- Permeance
- Magnetic effect of electric circuit

Objectives

At the end of this lecture, student will be able to:

- Define magnetic flux, flux density and reluctance
- Explain Right hand thumb Rule and cork screw rule
- Analyze Series Magnetic Circuits
- Derive relation between the magnetic and electric circuits

Magnetic Flux

- Total number of lines of force existing in a magnetic field is called magnetic flux. The unit of flux is called weber and flux is denoted by (Ø).

1 weber = 10^8 lines of force

- Magnetic flux (Φm), is the amount of magnetic field (also called "magnetic flux density") passing through a surface (such as a conducting coil).

SI Unit - weber (Wb)

CGS unit - maxwell.

Parameters for Magnetic Circuits

Parameters	Symbols	Formulas	Units
Magnetic Flux Density	B	$B = \frac{\phi}{A}$	Wb/m^2 or tesla
Magnetic Field Strength	H	$H = \frac{NI}{l}$	AT/m
Absolute Permeability	µ	$\mu = \frac{B}{H}$	H/m
Permeability of Free Space	μ_0	-	$4\Pi \times 10^{-7}$
Relative Permeability	μ_r	$\mu = \mu_0 \mu_r$	H/m
Magnetomotive Force (M.M.F)	F	NI	Ampere-turns
Reluctance	S	$S = \frac{l}{\mu a}$ $S = \frac{NI}{\phi}$	AT/Wb or A/Wb
Permeance	P	P=1/S	Wb/AT or Wb/A

Magnetic Effect of an Electric Current (Electromagnets)

- When a coil or a conductor carries current, it produces the magnetic flux around it. Then it starts behaving as a magnet. Such a current carrying conductor is called an electromagnet

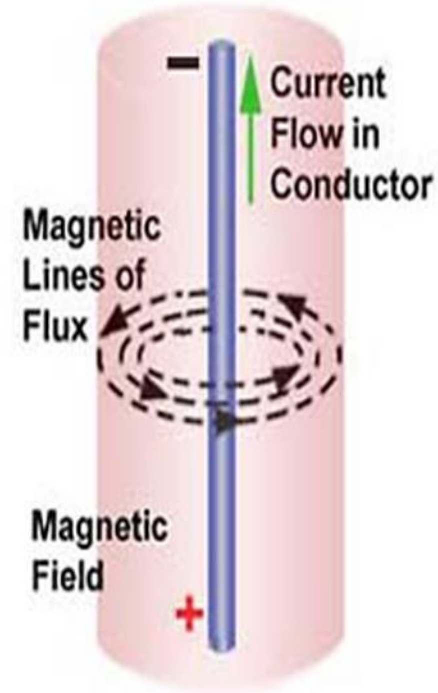
Electromagnets

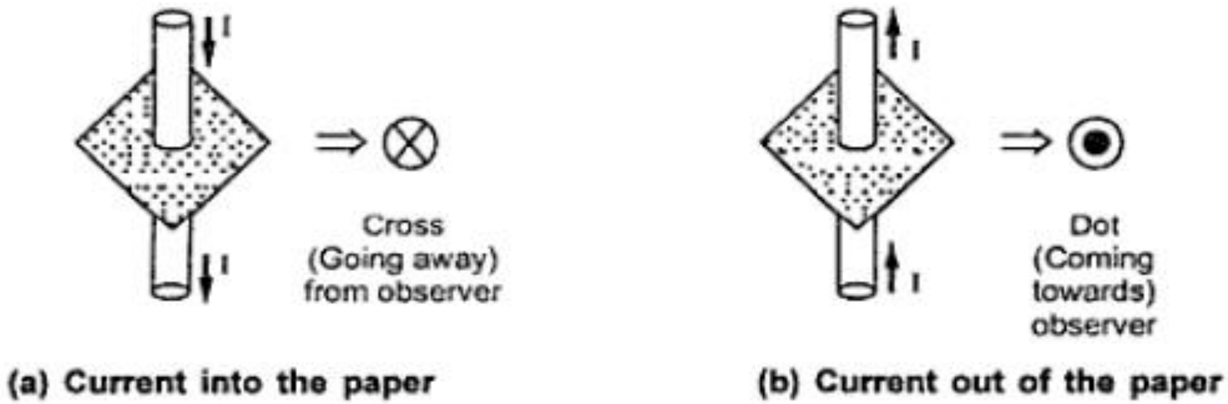
Electromagnet due to straight Current Carrying Conductor

Electromagnet due to Circular Current Carrying Conductor

Magnetic Field due to Straight Conductor

- When a straight conductor carries a current, it produces a magnetic field all along its length. The lines of force are in the form of concentric circle in the planes right angles to the conductor.
- When current is going into the plane of the paper - **‘cross’**
- Current is coming out of the plane of the paper - **‘dot’**





Magnetic Circuits

$$\varphi = \frac{NI}{\dfrac{l}{\mu_0 \mu_r a}}$$

$$\boxed{\Phi = \frac{\boldsymbol{M.M.F}}{\boldsymbol{Relluctance}} = \frac{\boldsymbol{F}}{\boldsymbol{S}}}$$

where, NI = Magetomotive Force m.m.f in AT

S= $\frac{l}{\mu_0 \mu_r a}$ = Reluctance offered by the magnetic path

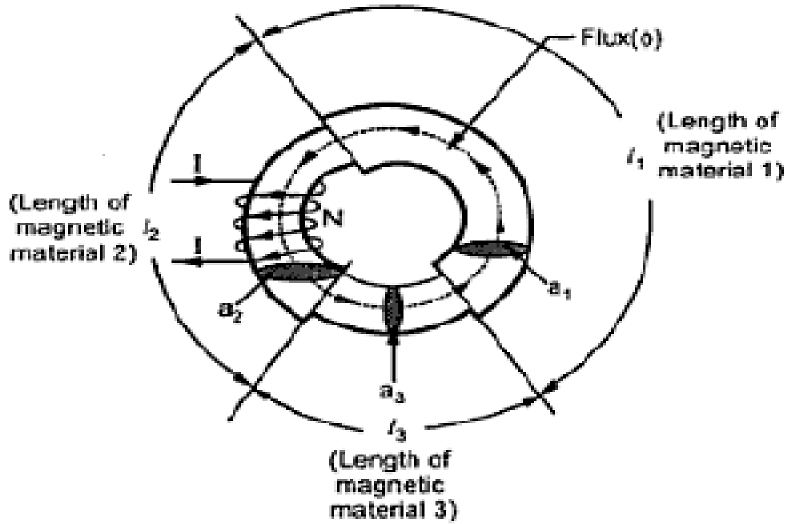
- The expression of the flux is very much similar to expression for current in electric circuit.

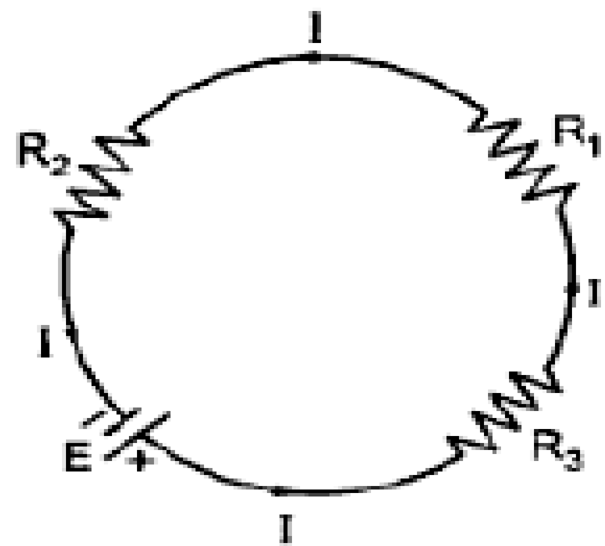
$$\boldsymbol{I} = \frac{\boldsymbol{E.M.F}}{\boldsymbol{Resistance}}$$

so that Current is analogous to Flux
E.M.F is analogous to M.M.F
Resistance is analogous to Reluctance

Series Magnetic Circuit

- Magnetic circuit is composed of various magnetic materials of different permeability's of different lengths and of different cross sectional area. Such a circuit is called composite magnetic circuit
- When such parts are connected one after the other the circuit is called series magnetic circuit





Series Magnetic Circuit

Total ST= S1+S2+S3 = $\frac{l1}{\mu_1 a_1} + \frac{l_2}{\mu_2 a_2} + \frac{l_3}{\mu_3 a_3}$

Total ϕ = $\frac{Total\ m.m.f}{Total\ Reluctance} = \frac{NI}{S_T} = \frac{NI}{S_1+S_2+S_3}$

$$NI = S_T \emptyset = (S_1 + S_2 + S_3)\varphi$$

$$NI = S_1 \emptyset + S_2 \emptyset + S_3 \emptyset$$

(m.m.f)T= (m.m.f)1 + (m.m.f)2 + (m.m.f)3

The total m.m.f can be expressed as

$$(m.m.f)T = H_1 l_1 + H_2 l_2 + H_3 l_3$$

Where $H_1 = \frac{B_1}{\mu_1}, H_2 = \frac{B_2}{\mu_2}, H_3 = \frac{B_3}{\mu_3}$

Series Magnetic Circuit with Air Gap

- Total m.m.f = NI AT
- Total Reluctance ST = Si+Sg

Where Si = Reluctance of iron path

Sg= Reluctance of air gap

$$S_T = S_i + S_g$$

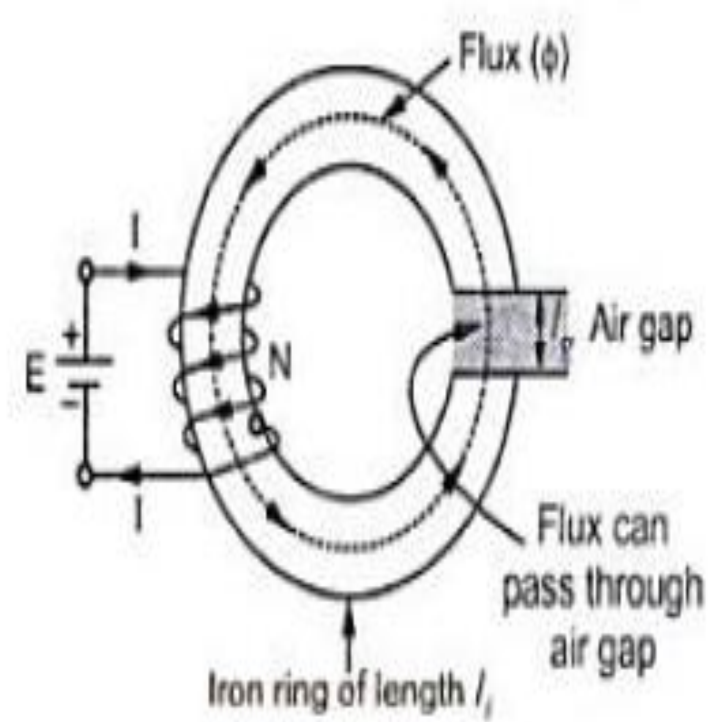
S_i = Reluctance of iron path

$$S_i = \frac{l_i}{\mu a_i}$$

$$S_g = \frac{l_g}{\mu_0 a_i}$$

Total m.m.f = m.m.f for iron + m.m.f for air gap

$$\boldsymbol{NI = S_i\emptyset + S_g\emptyset} \textbf{ AT for ring}$$



Summary

- The total number of lines of force existing in a magnetic field is called magnetic flux. The unit of flux is called weber and flux is denoted by (Ø)
- When a coil or a conductor carries current, it produces the magnetic flux around it. Then it starts behaving as a magnet. Such a current carrying conductor is called an electromagnet
- Current is going into the plane of the paper - **'cross'**
- Current is coming out of the plane of the paper - **'dot'**
- $\Phi = \frac{M.M.F}{Relluctance} = \frac{F}{S}$
- Composite magnetic circuits are connected one after the other is called series magnetic circuit