Basic Electrical Technology

2. Magnetic Circuits & Electromagnetism

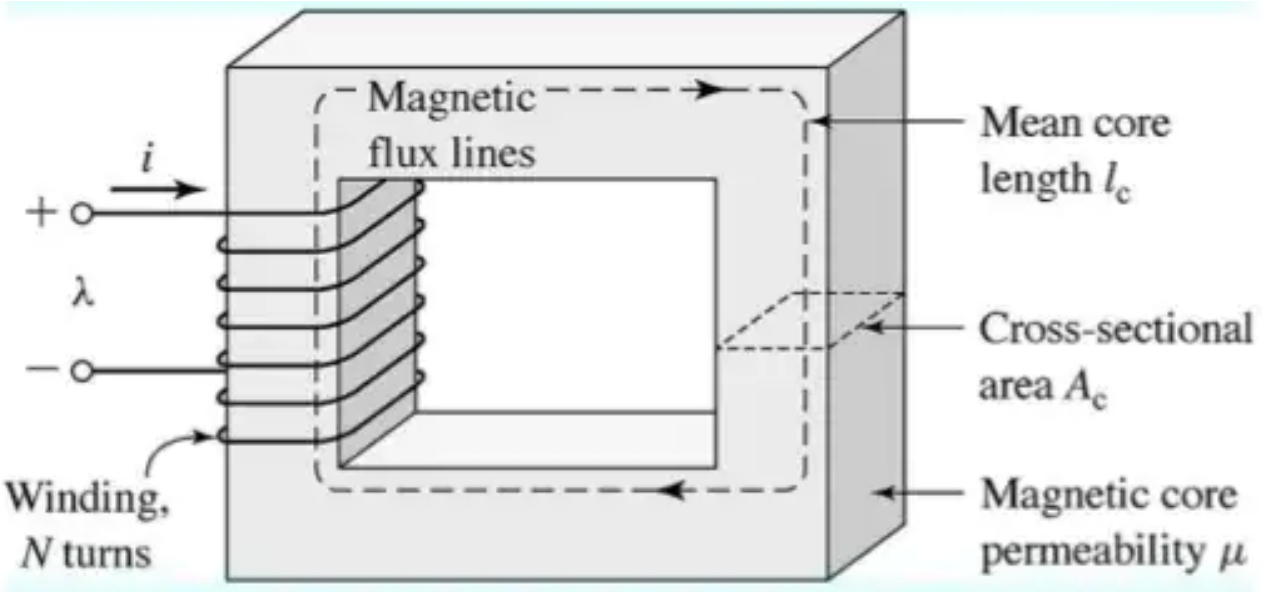
LECTURE 12 – 04 DEC 2021

Introduction to Magnetism

Magnetism

- A physical phenomena by which materials exert attractive or repulsive force on other materials
- **Magnetic Materials**
  - Properties:
    - Points in the direction of magnetic north and south pole when suspended freely and attracts iron filings
  - Classification:
    - Natural Magnets:
      - Occurs naturally in nature
      - All natural magnets are permanent magnet
      - Example: Lodestone (also called magnetite)
    - Temporary magnets (exhibits these properties when subjected to external force)
      - Example: Electromagnet – magnetic field is produced by an electric current
      - Electromagnets usually consists of wire wound into a coil.

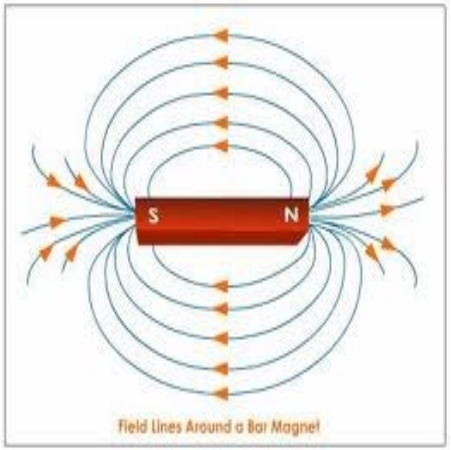
Simple Magnetic Circuit



Definitions

- **Magnetic Line of Force**
  - Closed path radiating from north pole, passes through the surrounding, terminates at south pole and is from south to north pole within the body of the magnet

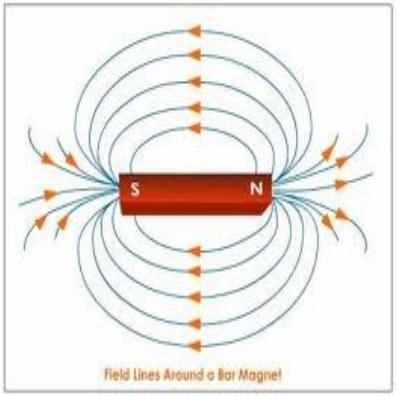
- **Magnetic Field**
  - The space around which magnetic lines of force act
  - Strong near the magnet and weakens at points away from the magnet



- **Magnetic Flux (ϕ)**
  - Analogous to Electric Current
  - Number of magnetic lines of force created in a magnetic circuit.
  - Unit : Weber (Wb)

Definitions

- **Magnetic Flux Density (B)**
  - Analogous to Current Density
  - No. of magnetic lines of force created in a magnetic circuit per unit area normal to the direction of flux lines
  - $\boldsymbol{B = \Phi / A}$
  - Unit : Wb/m^2 (Tesla)



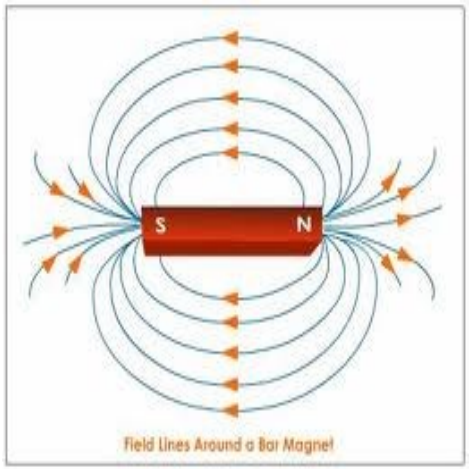
- **Magneto Motive Force (F)**
  - Analogous to EMF
  - Force which drives the magnetic lines of force through a magnetic circuit
  - $\boldsymbol{F = \Phi \times S = N \times I}$

    Where, $\boldsymbol{\Phi}$ = Magnetic flux, $\boldsymbol{S}$ = Reluctance of the magnetic path

    $\boldsymbol{N}$ = No. of turns of the coil, $\boldsymbol{I}$ = Current flowing through the coil
  - Unit: A-T (Ampere-Turns)

Definitions

- **Magnetic Field Strength (H)**
  - Analogous to Electric Field Strength
  - The magneto motive force per meter length of the magnetic circuit
  - $\boldsymbol{H = (N \times I)/l}$
  - Unit: A-T/m



- **Permeability (μ)**
  - Analogous to Conductivity
  - A property of a magnetic material which indicates the ability of magnetic circuit to carry magnetic flux.
  - $\boldsymbol{\mu = B \,/\, H}$
  - $\mu_0 = 4\pi \times 10^{-7} \Longrightarrow$ Permeability of free space or air or non magnetic material
  - Unit: H/m

- **Relative Permeability (μ_r)**
  - Permeability of the material with reference to air / vacuum
  - $\boldsymbol{\mu_r = \mu/\mu_0}$

Definitions

- **Reluctance (S)**
  - Analogous to Resistance
  - Opposition of a magnetic circuit to the setting up of magnetic flux in it,
  - Depends upon: **length** of the magnetic circuit, **area of cross-section** of the circuit and **nature of material** that makes up the magnetic circuit.
  - Unit: AT/Wb

- **Derivation of an expression for reluctance**

$$H = (N \times I)/l$$

$$\mu = B \,/\, H$$

$$B = \Phi / A$$

$$F = N \times I = H \times l = (B/\mu) \times l = ((\Phi/A)/\mu) \times l = \frac{\Phi}{\mu A} \times l$$

$$F = \frac{\Phi}{\mu_0 \mu_r A} \times l = \Phi \times S$$

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

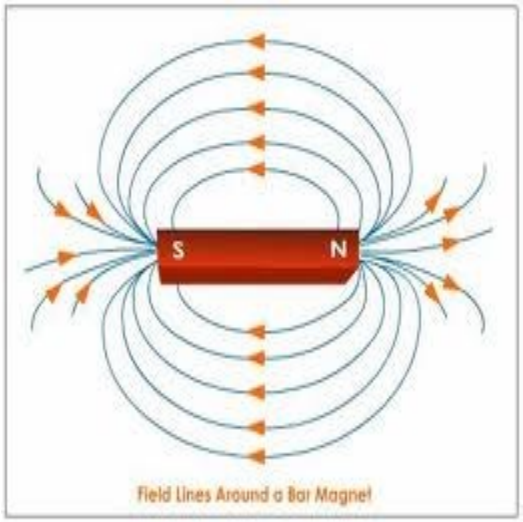


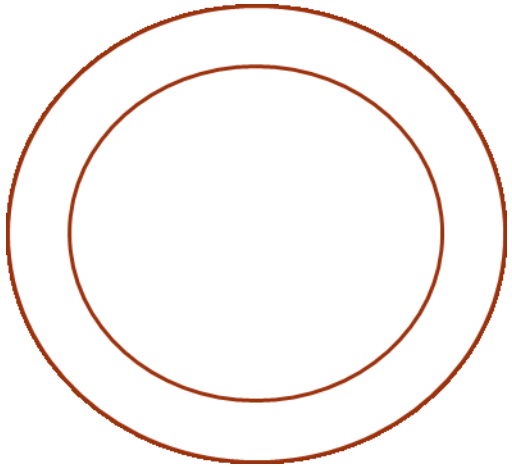
Illustration 01

A ring made of ferromagnetic material has 500 mm^2 as cross-sectional area and 400 mm as mean circumference. A coil of 600 turns is wound uniformly around it. Calculate:

a) The reluctance of the ring

b) The current required to produce a flux density of 1.6 T in the ring

Take μ_r of the ferromagnetic material as 800 for flux density of 1.6 T



Ans:

a) 795774.72 A-T/Wb

b) 1.06 A