Basic Electrical Technology

Introduction to Magnetism

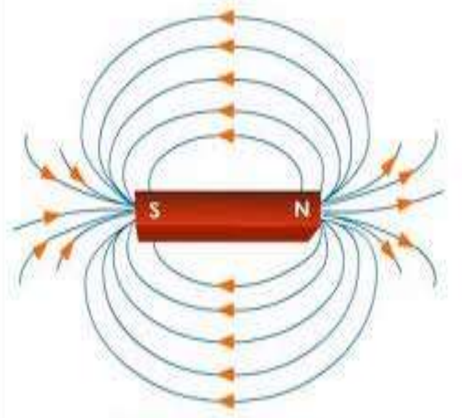
Magnetism

- A physical phenomena by which materials exert attractive or repulsive force on other materials.

- **Magnetic Materials**
  - Properties:
    - Points in the direction of geometric north and south pole when suspended freely and attracts iron fillings.
  - Classification:
    - Natural Magnets: Lodestone
    - Temporary magnets (exhibits these properties when subjected to external force)
    - Non-magnetic materials.

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.



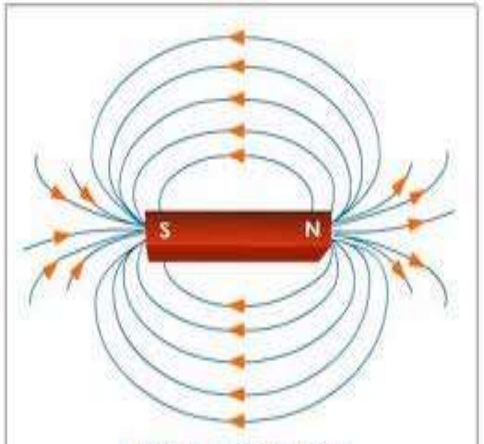
Field Lines Around a Bar Magnet

- **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
  - $\boldsymbol{B} = \boldsymbol{\Phi} / \boldsymbol{A}$
  - Unit : Wb/m^2 (Tesla)



Field Lines Around a Bar Magnet

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

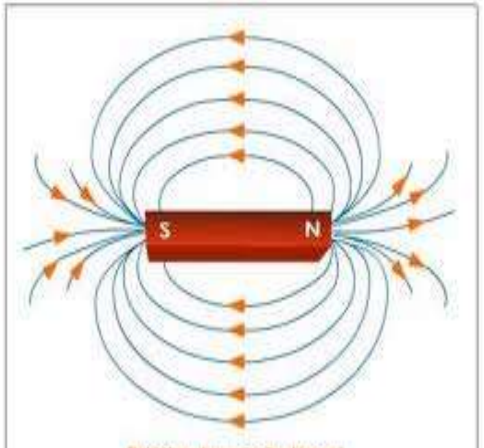
    Where, $\boldsymbol{\Phi}$ = Magnetic flux, $\boldsymbol{S}$ = Reluctance of the magnetic path,

    $\boldsymbol{N}$ = No. of turns of the coil, $\boldsymbol{I}$ = Current flowing through the coil
  - Unit: AT (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: AT/m



Field Lines Around a Bar Magnet

➢ **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

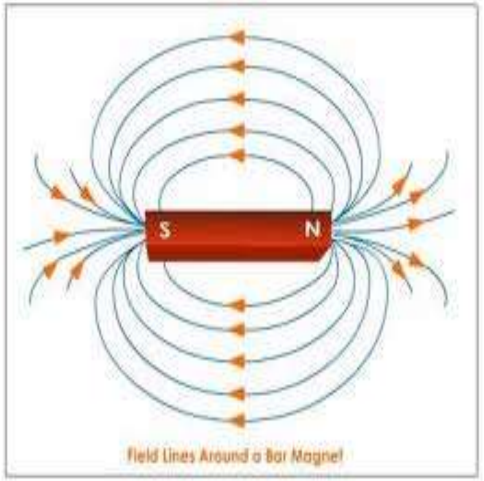
➢ **Relative Permeability (μ_r)**

- 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.
- Unit: AT/Wb



➢ Derivation of an expression for reluctance

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

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

$$B = \Phi/\, A$$

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

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

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

Illustration

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

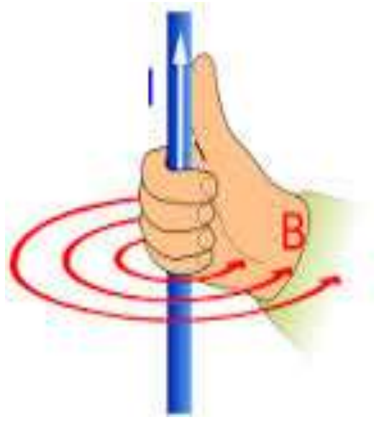
Ans:

a) 795774.72 AT/Wb

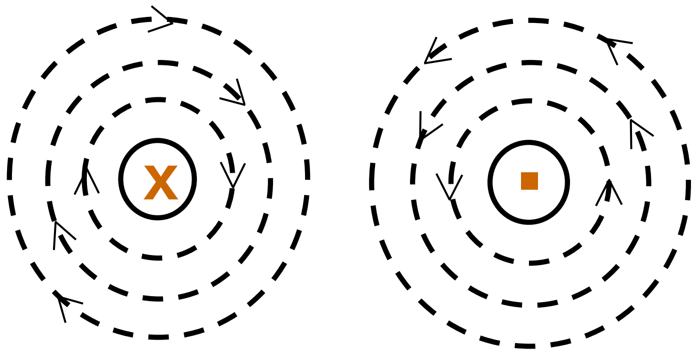
b) 1.06 A

Magnetic Field (in a Current-Carrying Conductor)

- An electric current flowing in a conductor creates a magnetic field around it.



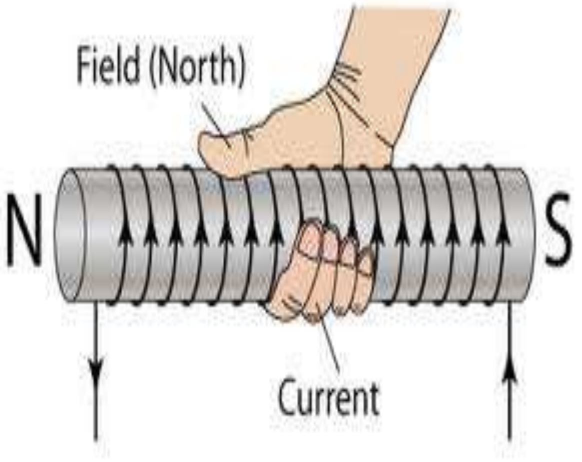
- **Direction of magnetic field**
  - **By Maxwell's Right Hand Grip Rule:**
  - Assume that the current carrying conductor is held in right hand so that the fingers wrap around the conductor and the thumb is stretched along the direction of current. Wrapped fingers will show the direction of circular magnetic field lines.

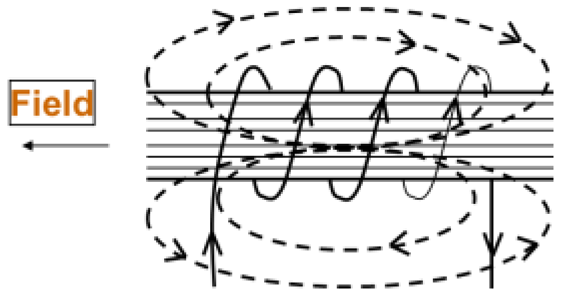


Current inwards Current outwards

Magnetic Field (in a Solenoid)

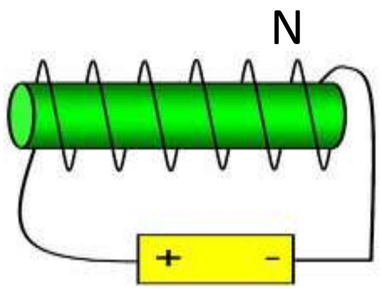
- **Direction of magnetic field**
  - **By Right Hand Grip Rule:**
  - If the coil is gripped with the right hand, with the fingers pointing in the direction of the current, then the thumb, outstretched parallel to the axis of the solenoid, points in the direction of the magnetic field inside the solenoid

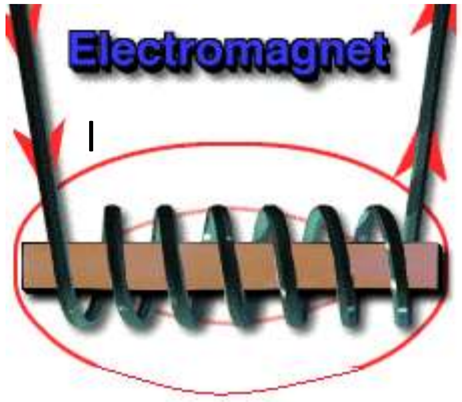




Electromagnets

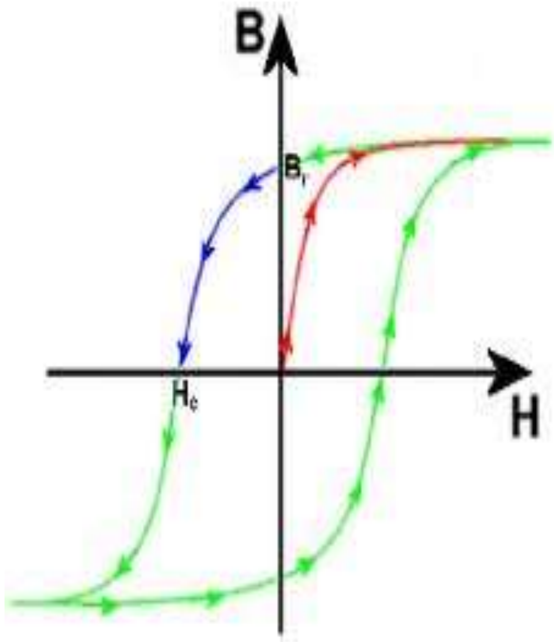
- **Principle:** An electric current flowing in a conductor creates a magnetic field around it
- Strength of the field is proportional to the amount of current in the coil.
- The field disappears when the current is turned off.
- A simple electromagnet consists of a coil of insulated wire wrapped around an iron core.
- Widely used as components of motors, generators, relays etc.





Losses in Magnetic Circuit

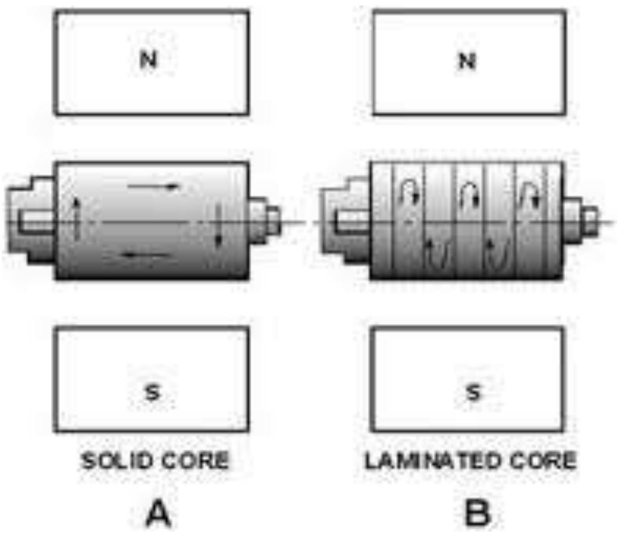
- **Hysteresis Loss**
  - Lagging of magnetization or flux density behind the magnetizing force is called **Magnetic Hysteresis**
  - The energy dissipated as heat in the process of magnetization and demagnetization which is proportional to the area of hysteresis loop is the **Hysteresis Loss**



Hysteresis loop

Losses in Magnetic Circuit

- **Eddy Current Loss**
  - The varying flux in the magnetic core induces emf and hence eddy current within the material.
  - Flow in closed loops in planes perpendicular to the magnetic field
  - Results in loss of power and heating of the material.
  - Cores of electric machines are laminated to reduce eddy current loss



Comparison of Electric and Magnetic Circuits

Analogy:

Electric Circuits	Magnetic Circuits
Current	Flux
Current Density	Flux Density
EMF	MMF
Conductivity	Permeability
Resistance	Reluctance

Differences:

Electric Circuits	Magnetic Circuits
Current actually flows	Flux does not flow
Current can not flow in air / vacuum	Flux can be created in air / vacuum