Gujarat Technological University

Diploma in Electrical Engineering

Semester-1

D C Circuits - 4310901

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Rajkot

Unit – 5
Magnetism
&
Electromagnetism

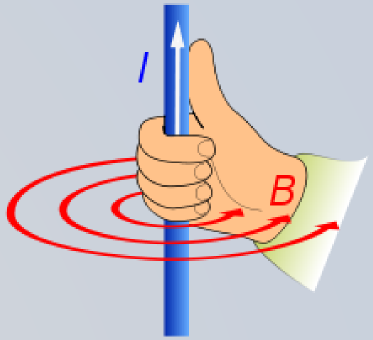
Topics

- Compare magnetic circuit with electric circuit
- Apply laws of electromagnetism to determine direction of flux, magnetic force, induced emf, flux density and field strength
- State Faraday's laws of electromagnetic induction, Flemings right- and left-hand rule and Lenz's law
- Compute equivalent inductance in various series-parallel combinations
- State applications of the given type of inductor
- Calculate the energy stored in the given inductor

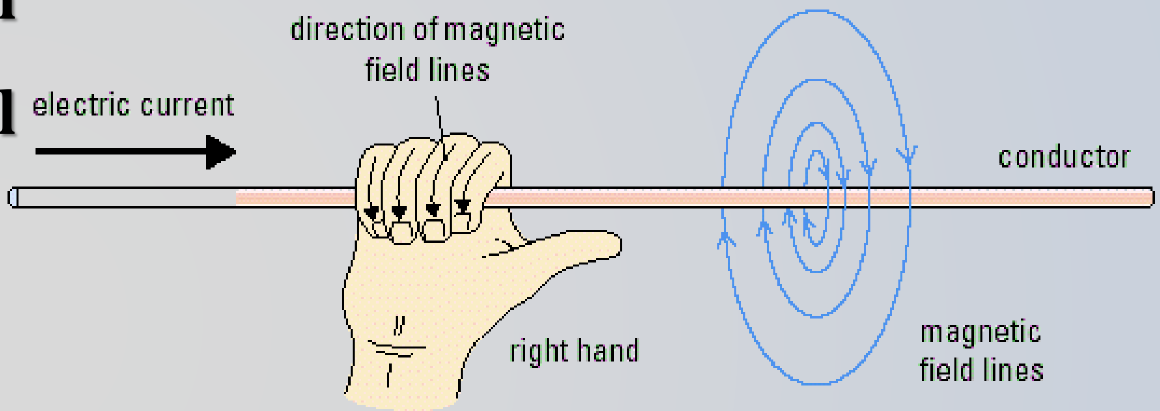
Electromagnetism

- Branch of physics that covers universal study of electricity & magnetism is known as Electromagnetics.
- Relation between electricity and magnetism was made by Hans Christian Oersted in 1819.
- H C Oersted discovered that magnetic field is produced by an electric current.
- Michael Faraday, Andre Ampere had produced electric current from magnetic field.

Magnetic Effect of Electric Current

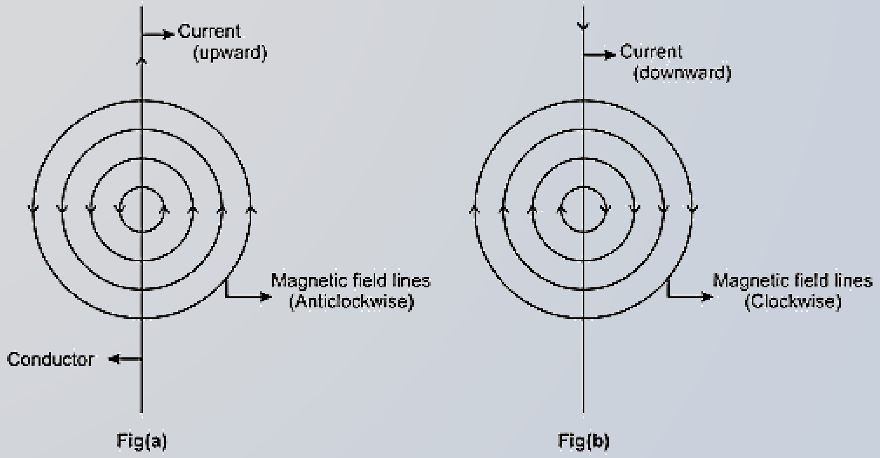


When an electric current flows through a conductor, magnetic field is set up all along the conductor.

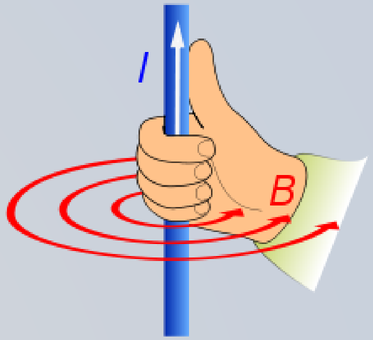


Right Hand Thumb Rule:

Hold the conductor in the right hand with the thumb pointing in the direction of current, then the fingers will point in the direction of magnetic field around the conductor.

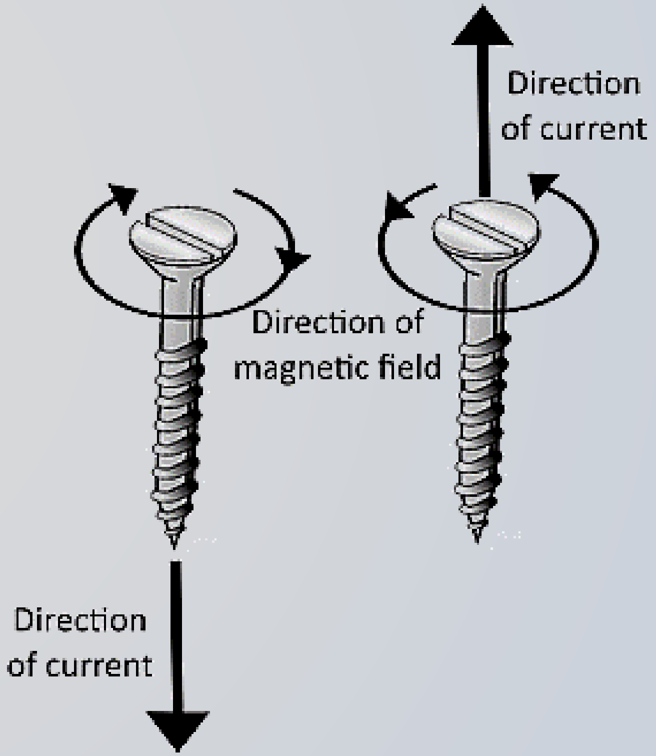


Magnetic Effect of Electric Current

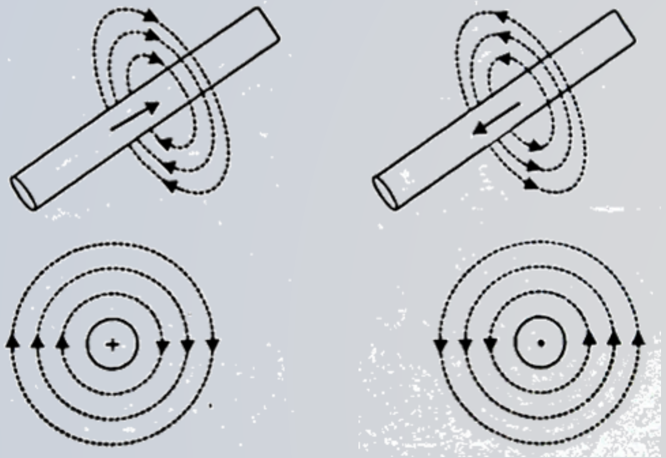


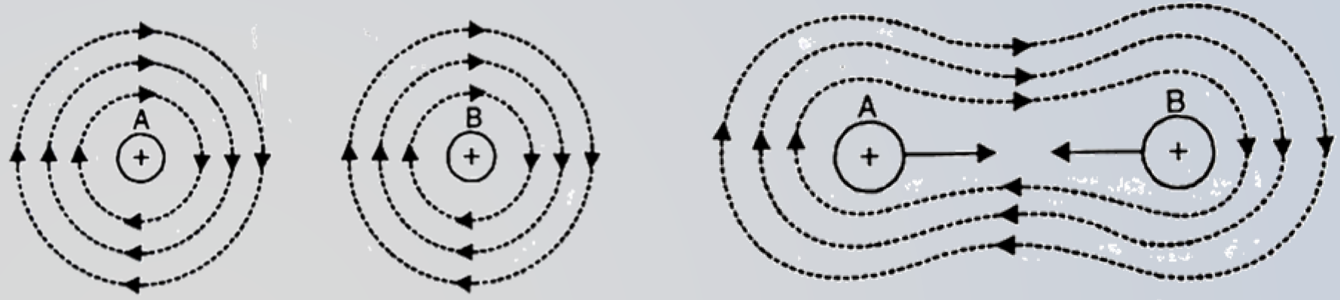
Cork Screw Rule:

If a corkscrew is turned so that it moves in the direction of conventional current flow, then the direction of rotation of the corkscrew corresponds to the direction of the magnetic field.

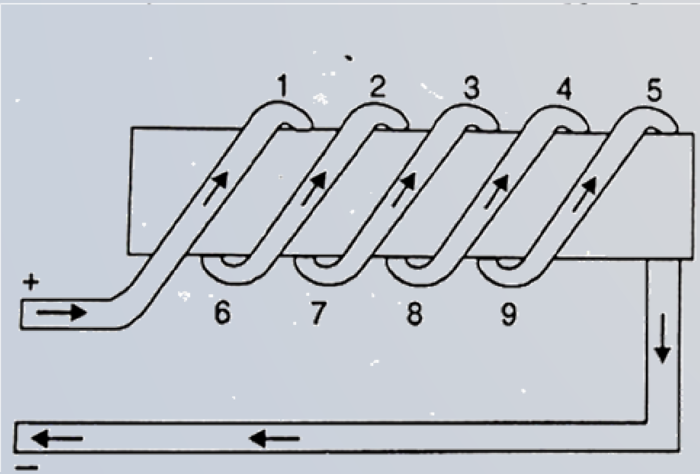


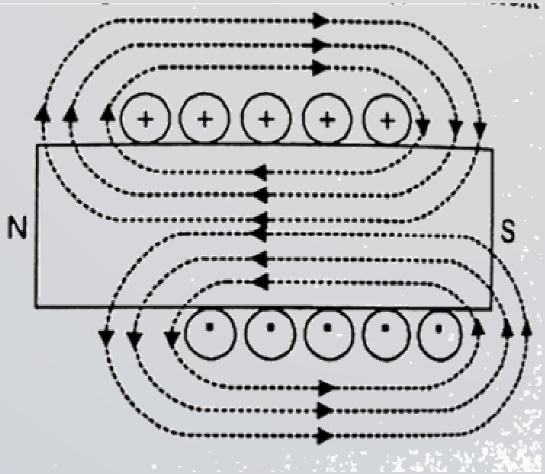
Magnetic Effect of Electric Current

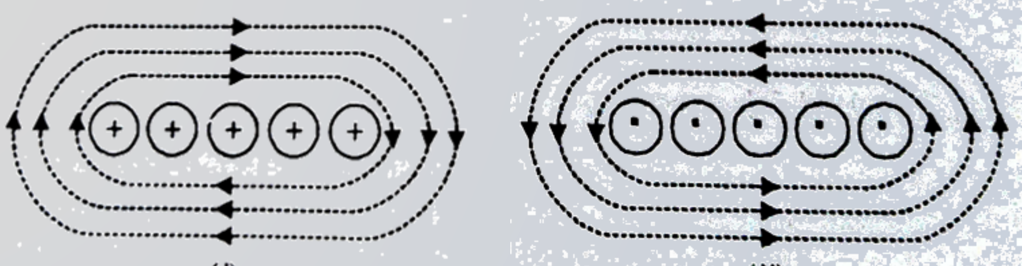




(i) (ii)



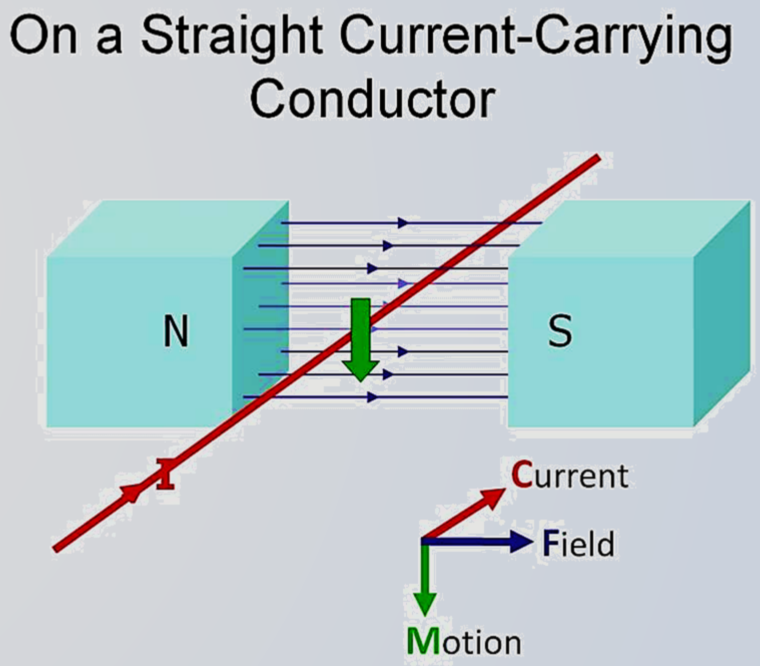




(i) (ii)

Current Carrying Conductor in a Magnetic Field

When a current carrying conductor is placed at right angle to a magnetic field, conductor experience a force which acts in a direction perpendicular to both the field and the current.



$$F = B\,I\,l\,\sin\theta,\ Newtons$$

$B = Flux\ Density, Wb/m^2$

$I = Current, A$

$l = Effective\ Length, m$

$\theta = Angle\ between\ conductor\ \&\ magnetic\ field$

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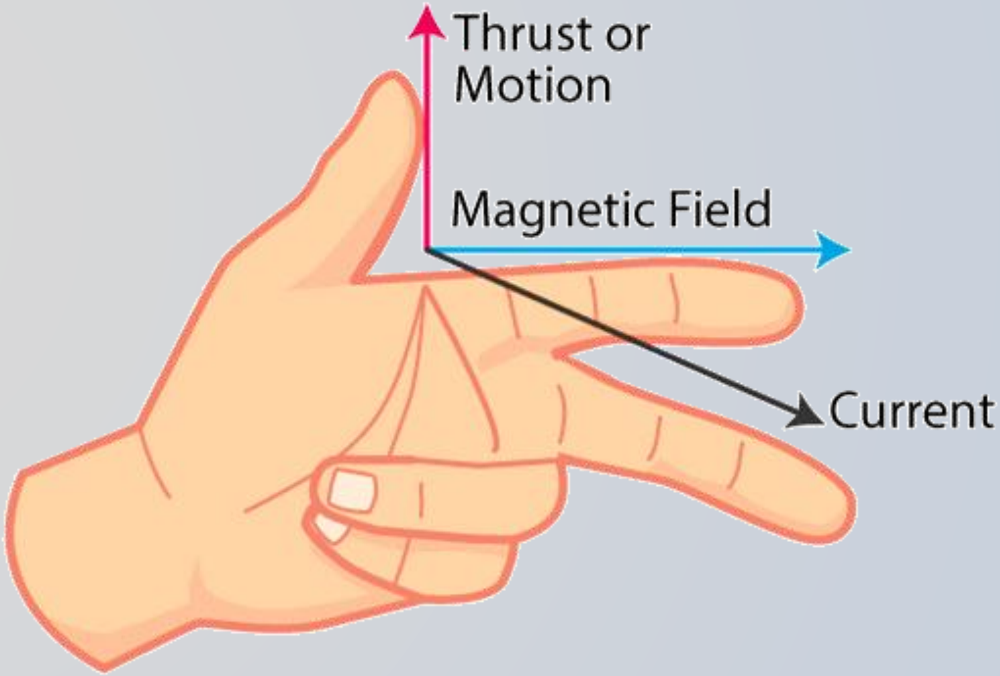
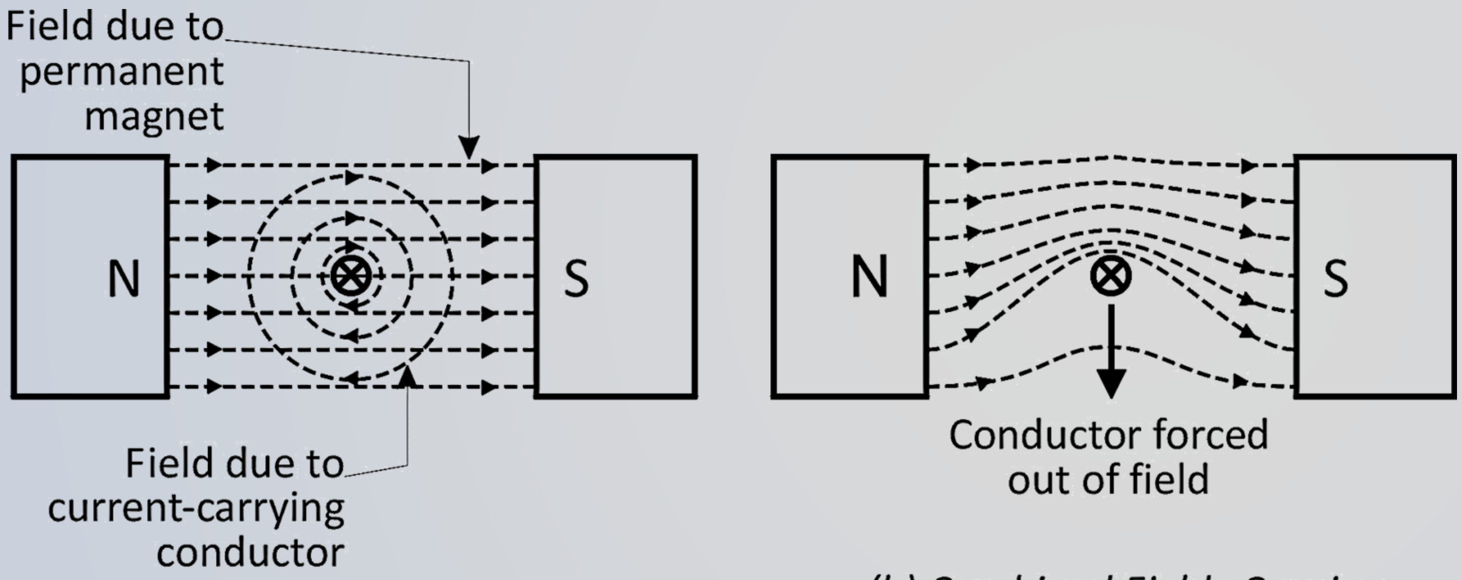
Current Carrying Conductor in a Magnetic Field

Fleming's Left-Hand Rule :

Stretch out the First finger, seCond finger and thuMb of your left hand so that they are at right angles to one another, if the First finger points in the direction of magnetic Field and seCond finger points towards the direction of Current, then thuMb will point in the direction of Motion of the conductor.

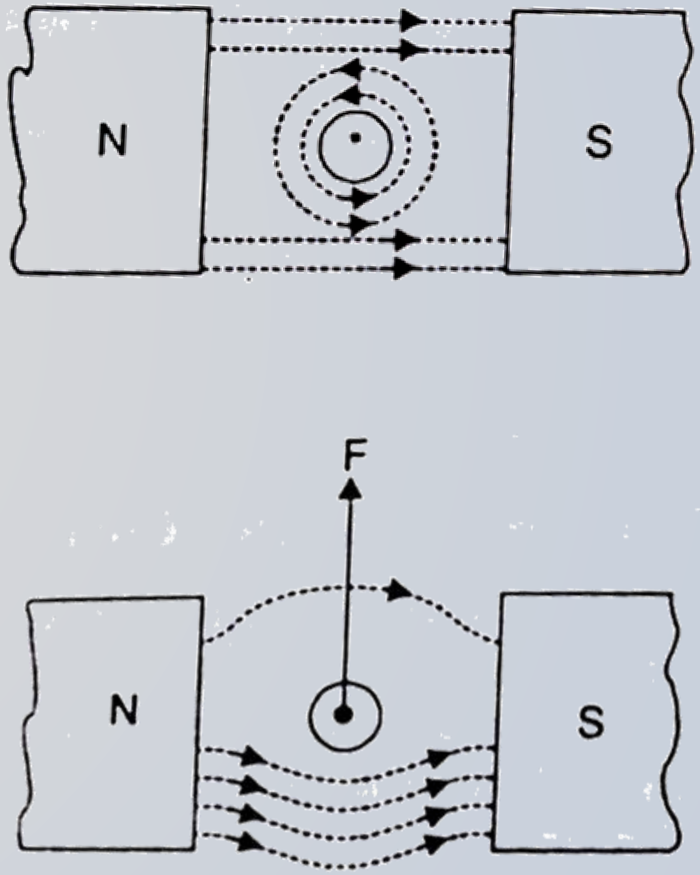


Mechanism of Force Production

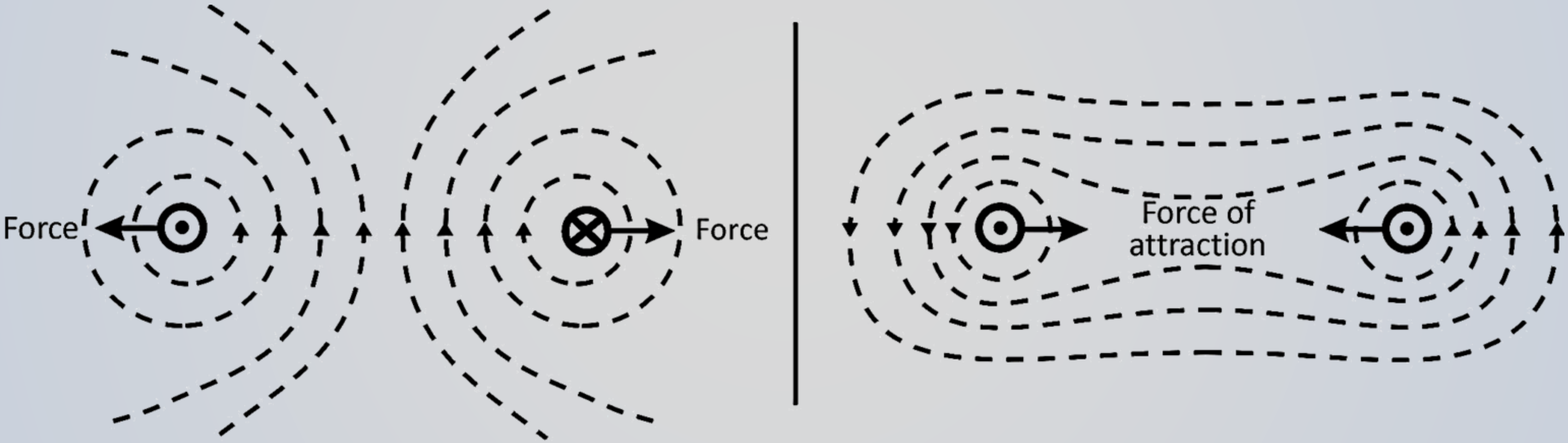


(a) Individual Fields

(b) Combined Fields Causing Force on Conductor



Magnetic Force between Two Parallel Conductors



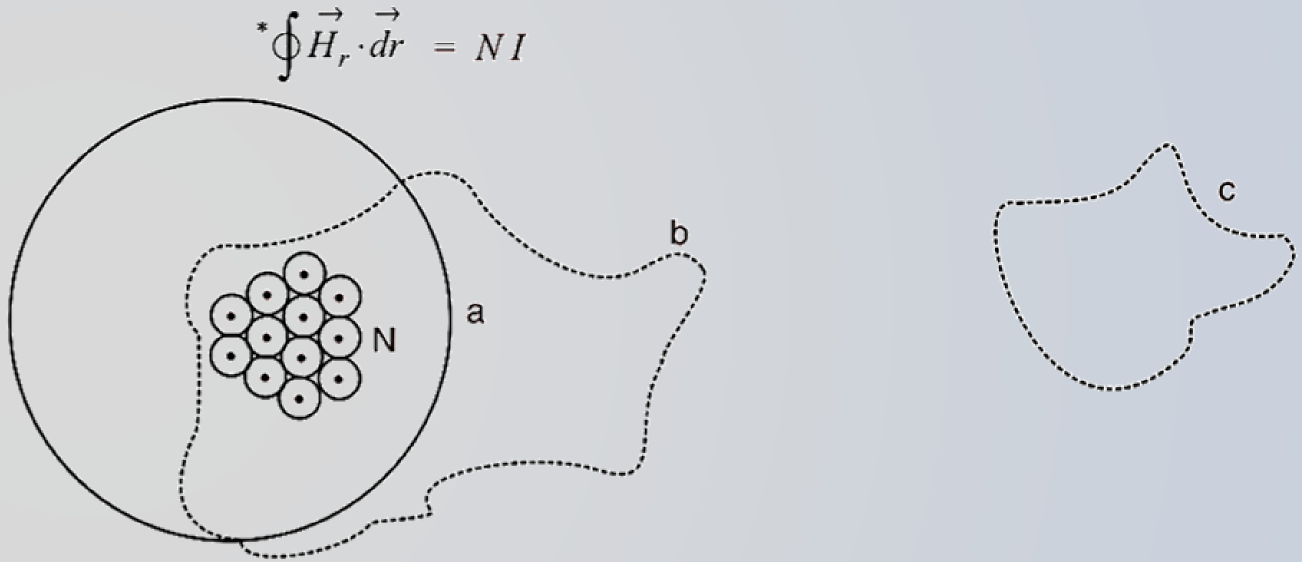
(a): Fields and forces - currents in opposite directions

(b): Fields and forces - currents in same direction

Ampere's Circuital Law

The work done on or by a unit N-pole in moving once round any complete path is equal to the product of current and number of turns enclosed by that path.

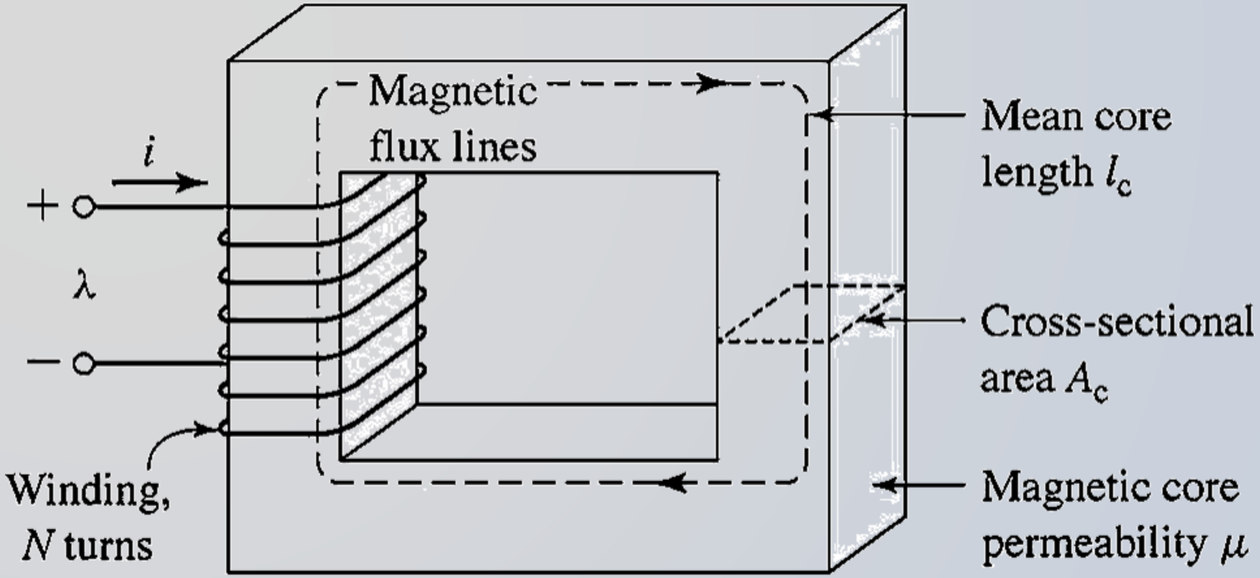
$$H \times l = N\,I$$



Magnetic Circuit

Definition

- *The closed path followed by magnetic flux is called Magnetic Circuit*
- *The magnetic circuit consist of :*
  - *Magnetic Material to pass flux*
  - *Coil to pass current for excitation*



Terms related to Magnetic Circuit

- **Magneto Motive Force(m.m.f)**

The work done in moving a unit magnetic pole, once round the magnetic circuit is known as Magneto Motive Force.

$$m.m.f = N\,I, \qquad ampere - turns(AT)$$

- **Reluctance (S)**

The opposition that the magnetic circuit offers to flux is called Reluctance.

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

- **Permeance**

It is a measure of the ease with which flux can pass through the material.

$$Permeance = \frac{1}{S} = \frac{a\mu_0\mu_r}{l}$$

Analysis of Magnetic Circuit

$$B = \frac{\emptyset}{a}\ \mathrm{Wb}/m^2$$

$$B = \mu\mathrm{H}\ \mathrm{Wb}/m^2$$

$$H = \frac{B}{\mu_0\mu_r}\ AT/m$$

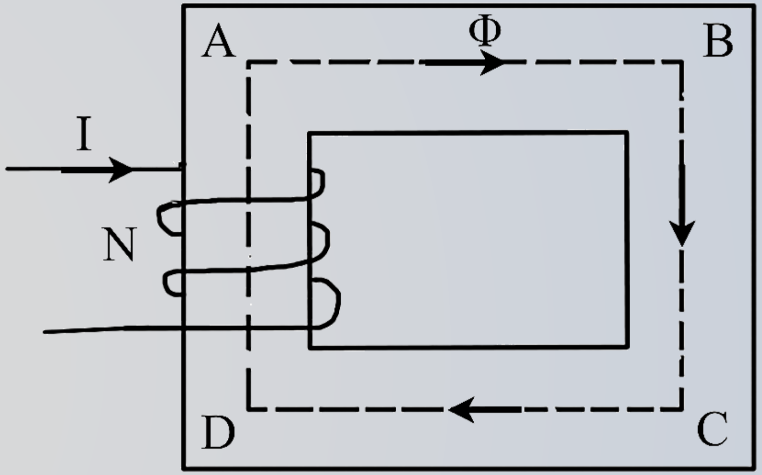
$$H = \frac{\emptyset}{a\mu_0\mu_r}\ AT/m$$

$$H \times l = N\,I$$

$$\frac{\emptyset}{a\mu_0\mu_r} \times l = N\,I$$

$$\emptyset = \frac{N\,I}{(l/a\mu_0\mu_r)}$$

$$Flux = \frac{m.m.f}{Reluctance}$$



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Comparison between Magnetic & Electric Circuit

Similarities

1. The closed path for magnetic flux is called a magnetic circuit.	1. The closed path for electric current is called an electric circuit.
2. Flux, $\phi = \dfrac{\text{m.m.f.}}{\text{reluctance}}$	2. Current, $I = \dfrac{\text{e.m.f.}}{\text{resistance}}$
3. m.m.f. (ampere-turns)	3. e.m.f. (volts)
4. Reluctance, $S = \dfrac{l}{a\mu_0\mu_r}$	4. Resistance, $R = \rho \dfrac{l}{a}$
5. Flux density, $B = \dfrac{\phi}{a} \text{Wb/m}^2$	5. Current density, $J = \dfrac{I}{a} \text{A/m}^2$
6. m.m.f. drop $= \phi S$	6. Voltage drop $= I R$
7. Magnetic intensity, $H = N I / l$	7. Electric intensity, $E = V/d$
8. Permeance	8. Conductance.
9. Permeability	9. Conductivity

Comparison between Magnetic & Electric Circuit

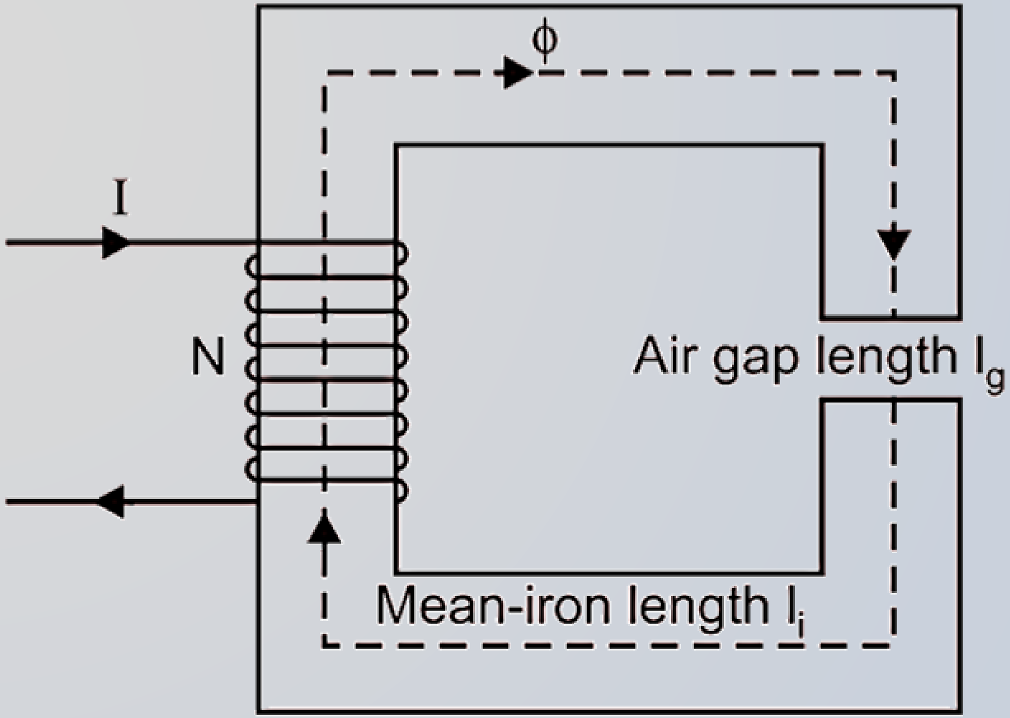
Magnetic Circuit	Electric Circuit
Magnetic flux does not flow	Electric current flows
There is no magnetic insulator.	There are a number of electric insulators.
Value of relative permeability varies with flux density, so reluctance is not constant	Value of resistivity is slightly with change in temperature
No energy is expended to maintain flux	Energy is expended is dissipated in terms of heat

Airgap in Magnetic Circuit

- The magnitude of AT required for air gap is much greater than that required for iron part of the magnetic circuit.

- Reluctance of air gap = $\frac{l_g}{a\mu_0}$

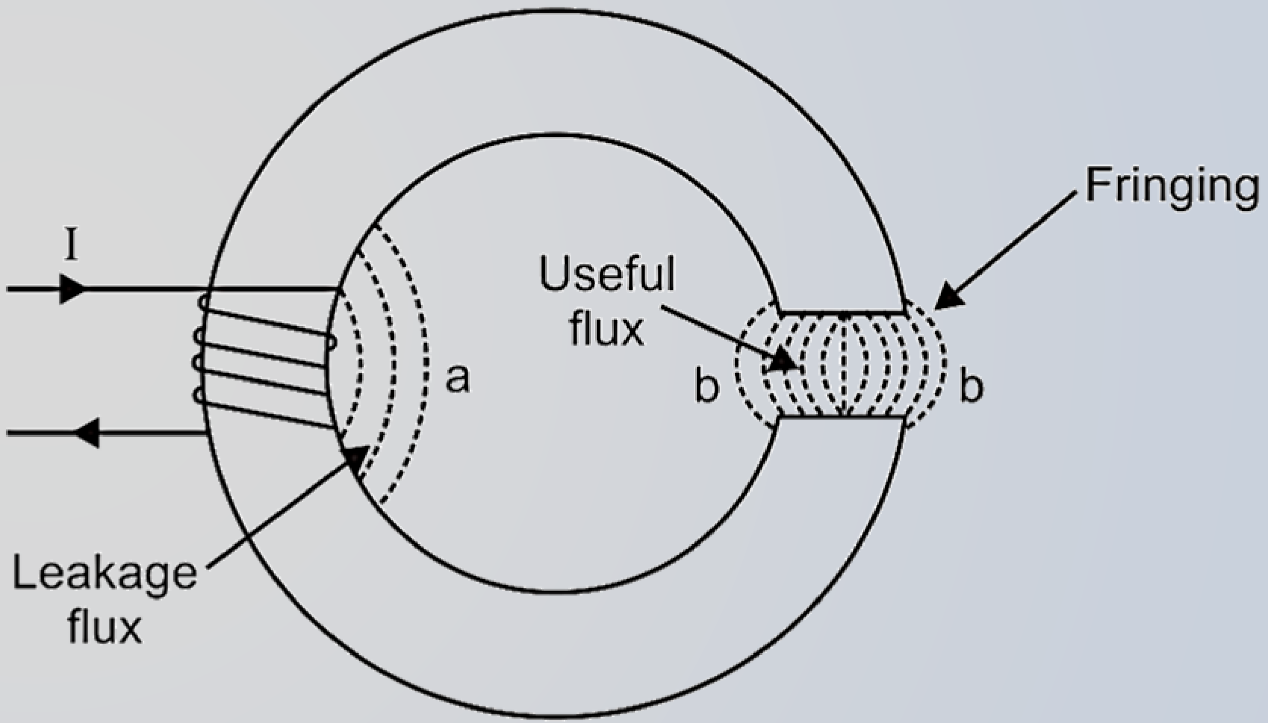
- Reluctance of iron part= $\frac{l_i}{a\mu_0\mu_r}$



Magnetic Leakage and Fringing

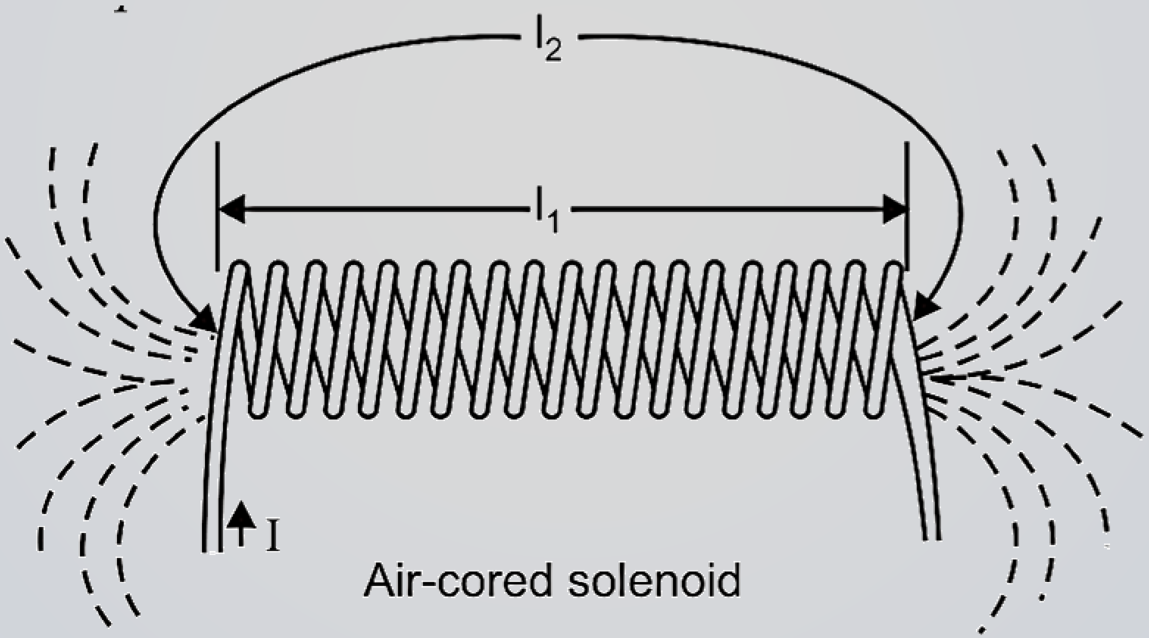
- **The flux that does not follow the desired path in a magnetic circuit is called a *leakage flux.***

- **when passing through non-magnetic material such as air, magnetic lines of force repel each other and tend to bulge out. This effect is known as *fringing.***



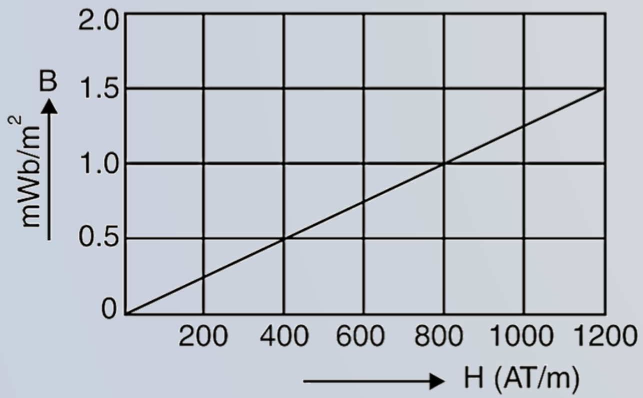
Solenoid

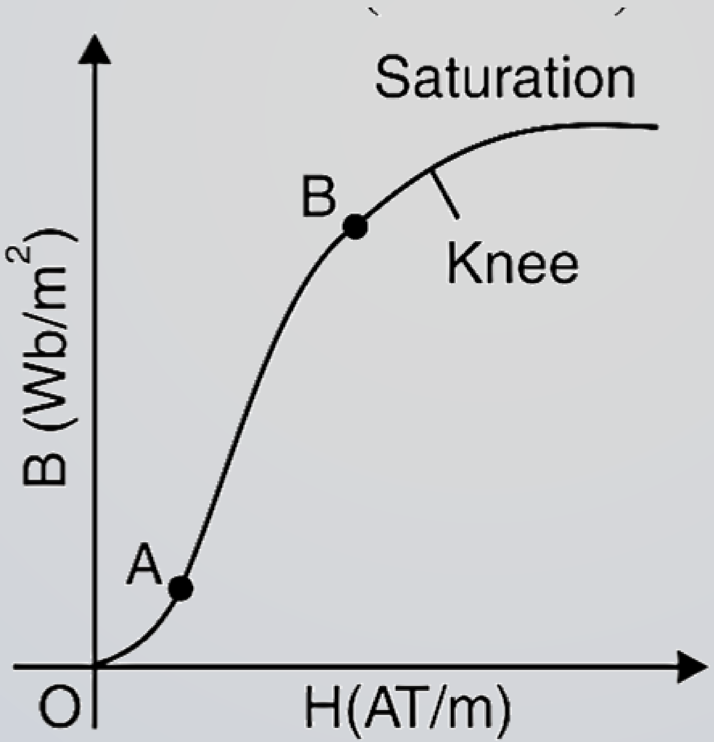
- A long coil of wire consisting of closely packed loops is called a solenoid.

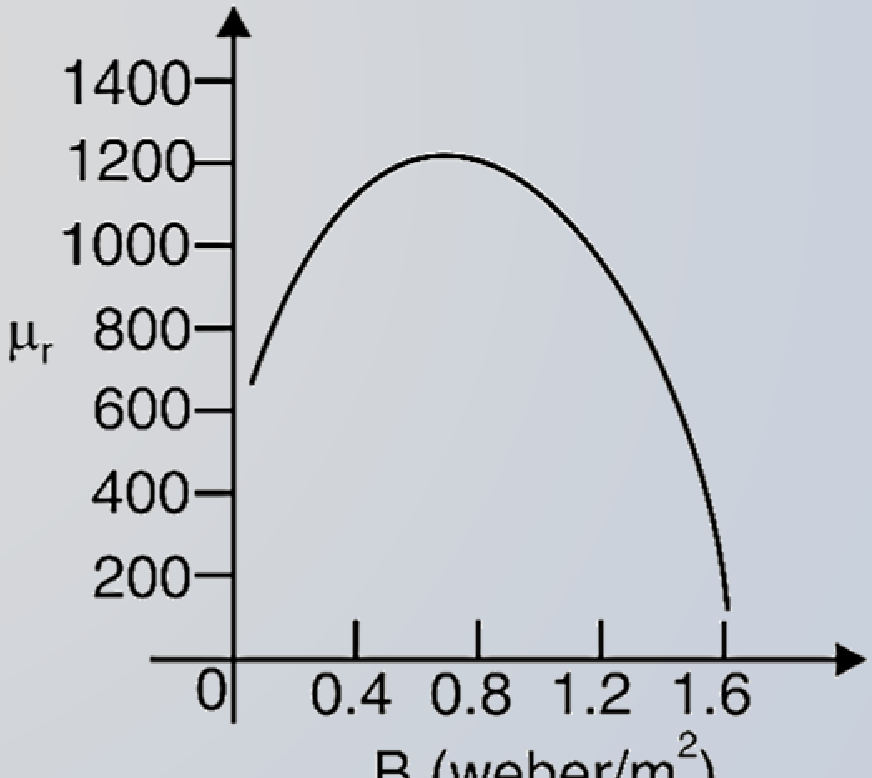


B-H Curve

- The B-H curve (or magnetisation curve) indicates the manner in which the flux density (B) varies with the magnetising force (H).



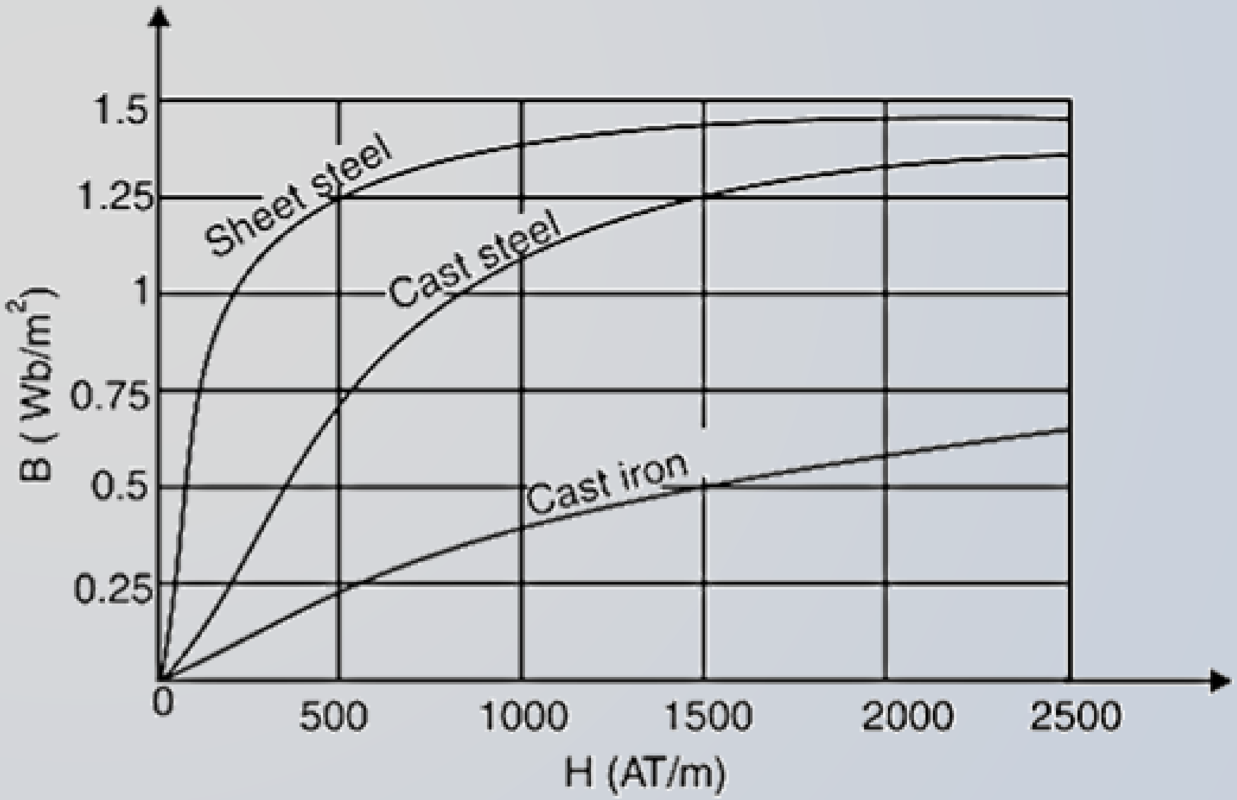




B-H Curve

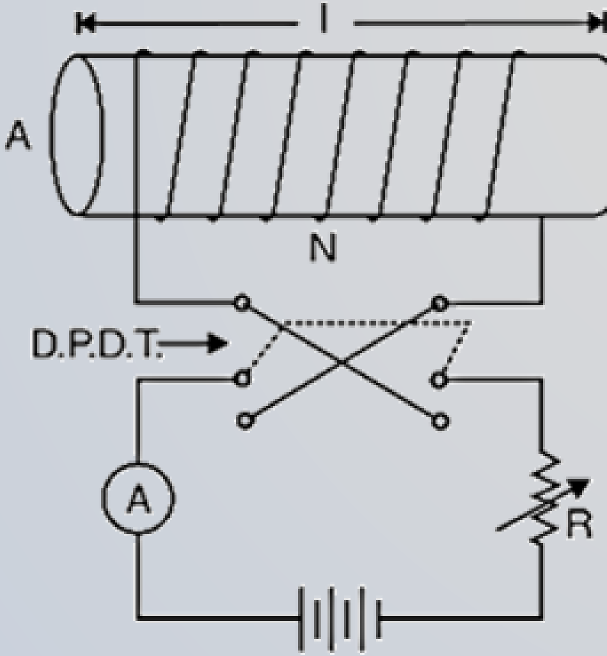
- **Calculation of required m.m.f**

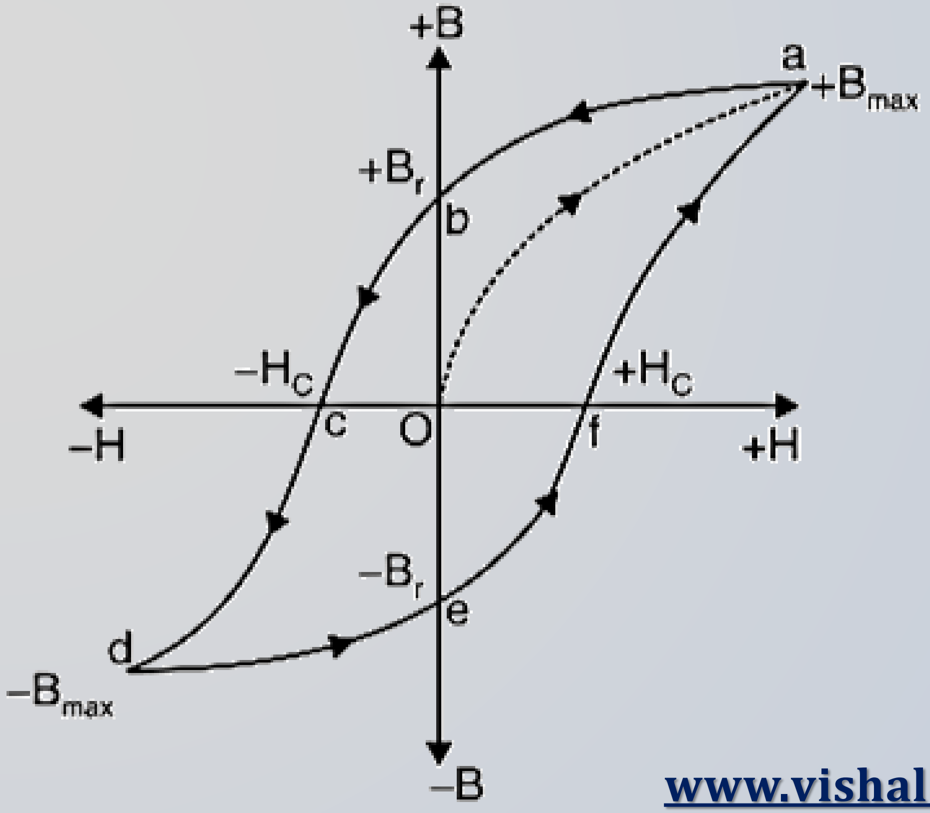
$$mmf\ required, NI = H \times l$$



Magnetic Hysteresis

- The phenomenon of lagging of flux density (B) behind the magnetising force (H) in a magnetic material subjected to cycles of magnetisation is known as magnetic hysteresis.





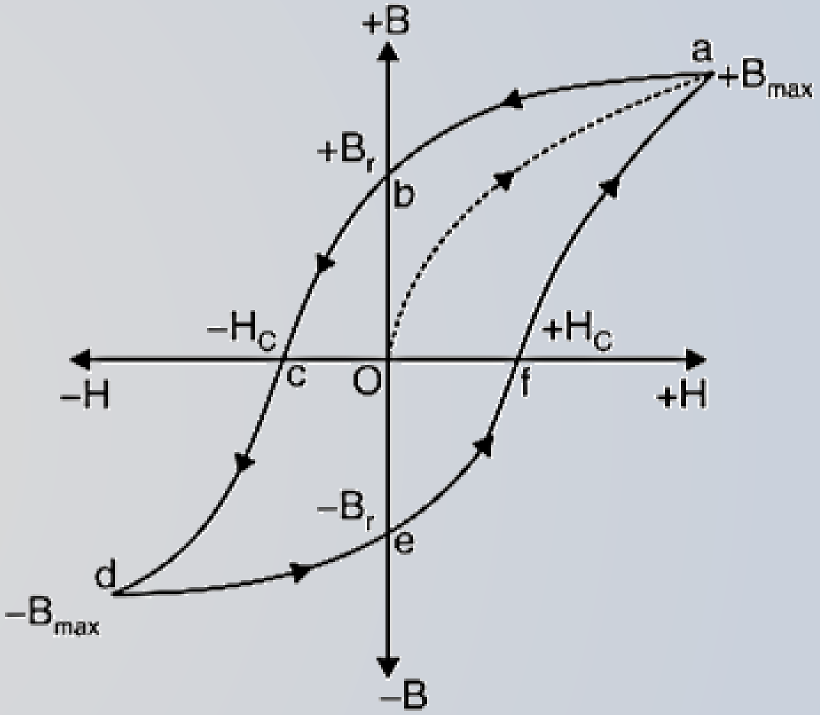
Magnetic Hysteresis

Retentivity

The power of retaining residual magnetism is called retentivity of the material.

Coercive Force

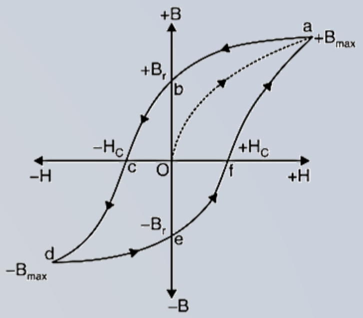
The value of H required to wipe out residual magnetism is known as coercive force.



$$B_r = Residual\ Flux\ Density$$

$$H_C = Coercive\ Force$$

Magnetic Hysteresis



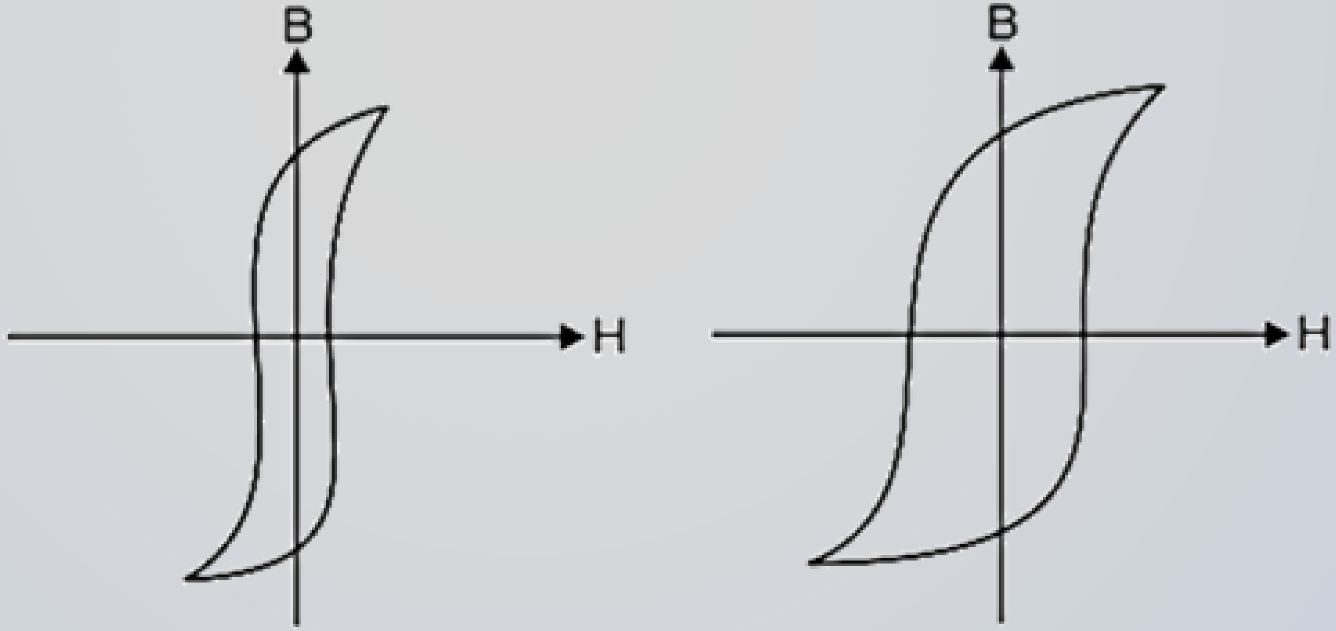
The phenomenon of lagging of flux density (B) behind the magnetising force (H) in a magnetic material, subjected to cycles of magnetisation is known as magnetic hysteresis.

Hysteresis Loop

When a magnetic material is subjected to one cycle of magnetisation, B always lags behind H so that the resultant B-H curve forms a closed loop, called hysteresis loop.

Hysteresis Loss

When a magnetic material is subjected to a cycle of magnetisation (i.e. it is magnetised first in one direction and then in the other), an energy loss takes place due to the molecular friction in the material this is known as Hysteresis Loss.



Silicon steel Hard steel

References

Basic Electrical Engineering
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Thank You

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