Course Code: BEE01T1003 Course Name: BEEE

Magnetic Circuits

MMF, Flux and Reluctance

Prerequisite/Recapitulations

Prerequisite

- Physics (12^{th} class)

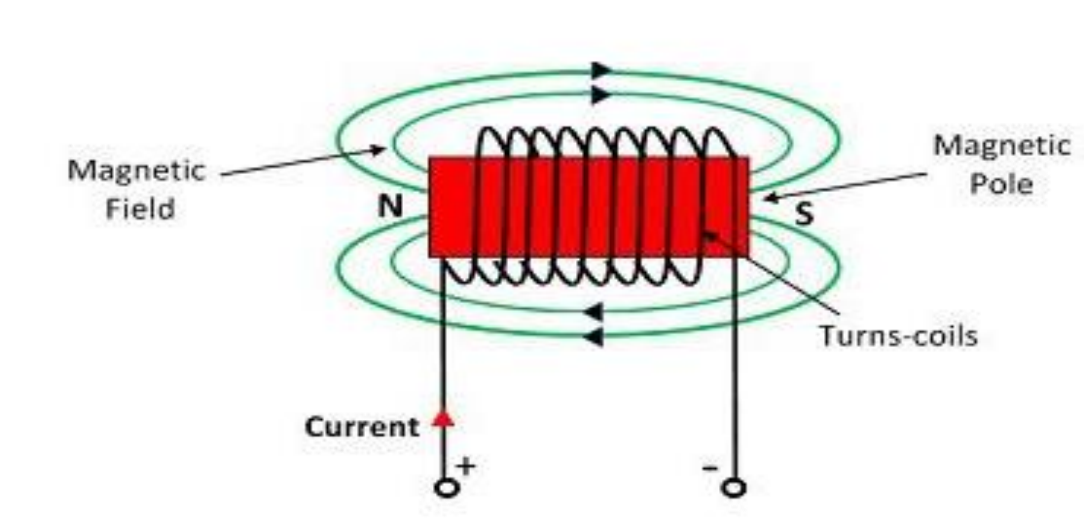
Recapitulations

- Ohm’s Law
- kirchhoff's current law
- kirchhoff's voltage law

Objectives

- **Electromagnetism** is a branch of physics that focuses on the interaction between electricity and magnetism.

- Electromagnetism is the interaction between conductors and fixed magnetic fields.



Introduction

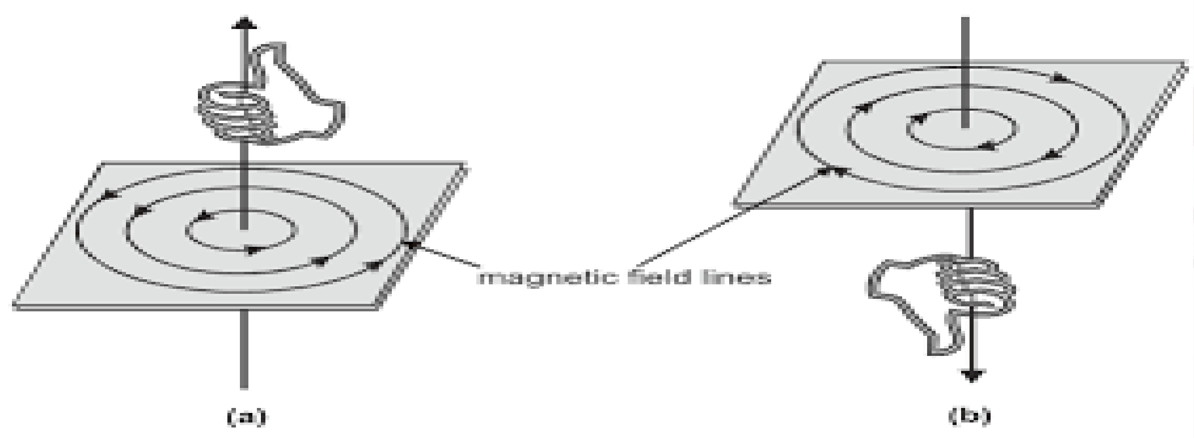
- **Electromagnets** are made of coils of wire with electricity passing through them.

- **Moving charges** create magnetic fields, so when the coils of wire in an electromagnet have an electric current passing through them, the coils behave like a magnet.

- **Electromagnets** are widely used as components of other electrical devices, such as motors, generators, electromechanical solenoids, relays, loudspeakers, hard disks, MRI machines, scientific instruments, and magnetic separation equipment.

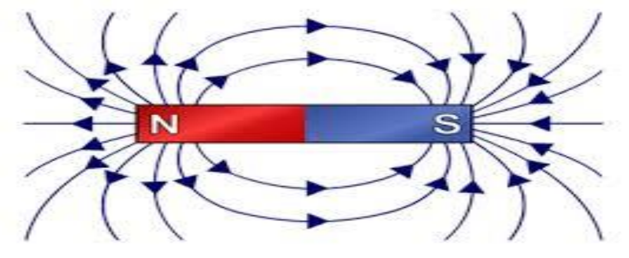
Magnetic Field

- **Magnetic field** encircle their current source.
- **Field** is perpendicular to the wire and that the field's direction depends on which direction the current is flowing in the wire.
- **A circular** magnetic field develops around the wire.



Properties of Magnetic Lines of Force

- Magnetic lines of force are directed from north to south outside a magnet.
- Magnetic lines of force are continuous.
- Magnetic lines of force in the same direction tend to repel each other.
- Magnetic lines of force tend to be as short as possible.
- Magnetic lines of force enter or leave a magnetic surface at right angles.
- Magnetic lines of force cannot cross each other.



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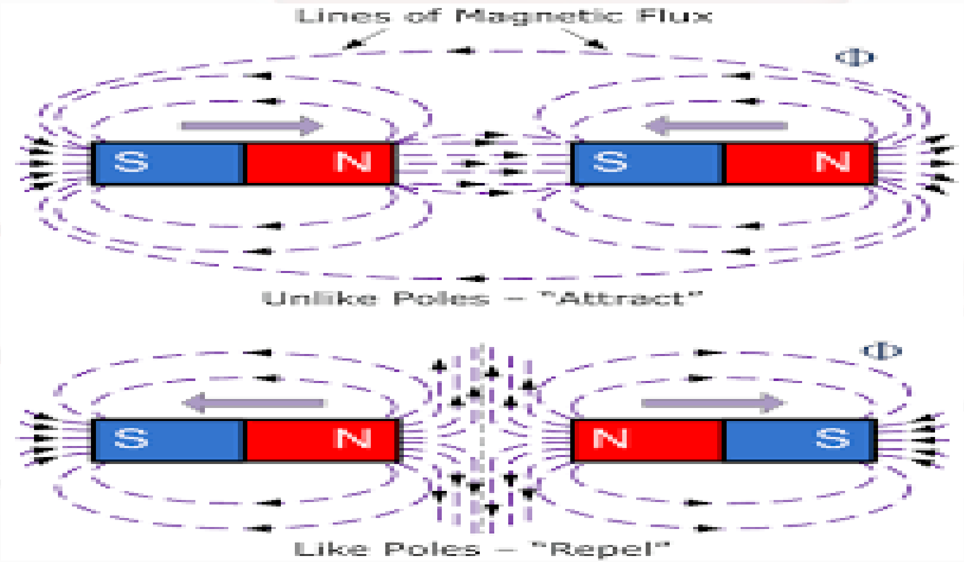
Four basic principles describe how magnetic fields are used in these devices:

1. A current-carrying wire produces a magnetic field in the area around it.
2. A time-changing magnetic field induces a voltage in a coil of wire if it passes through that coil.
3. A current-carrying wire in the presence of a magnetic field has a force induced on it.
4. A moving wire in the presence of a magnetic field has a voltage induced in it.



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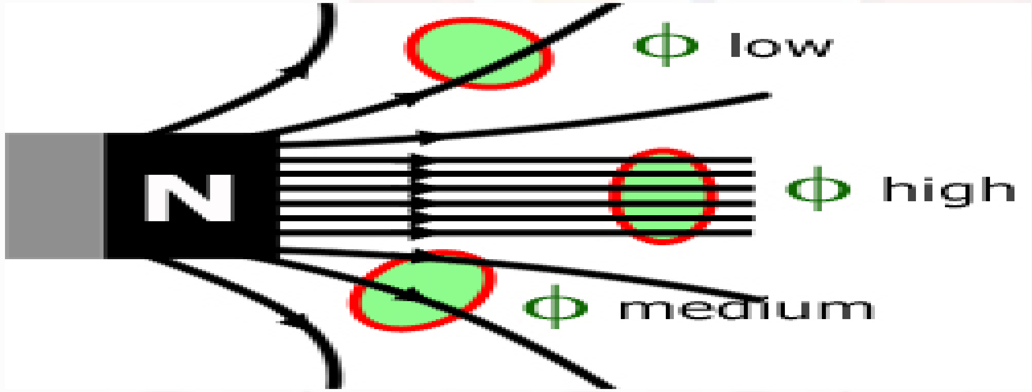
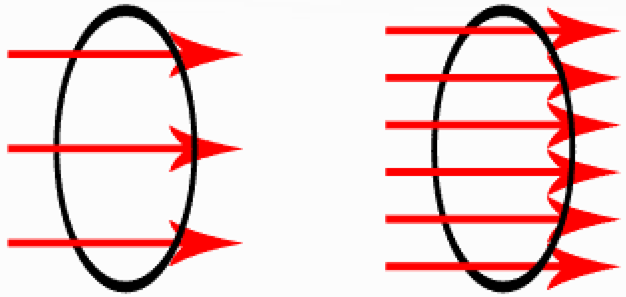
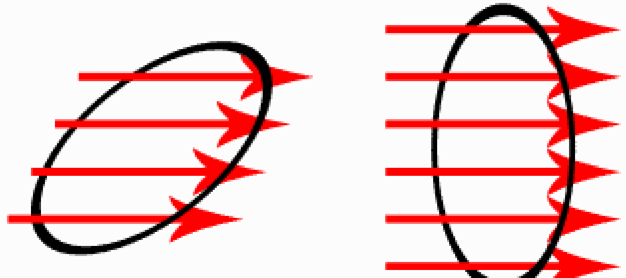
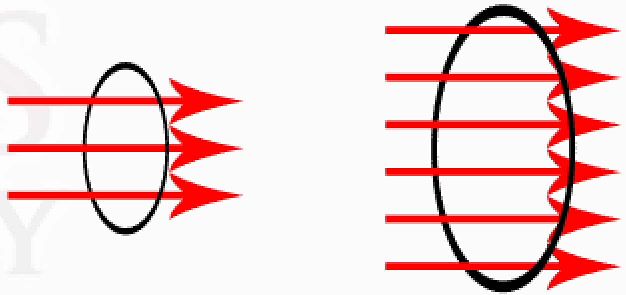
FLUX: Flux is defined as the number of field lines passing through a given closed surface. It gives the measurement of the total field that passes through a given surface area.
It is denoted by Φ. S.I unit is weber (Wb).
1 weber = 10^8 lines of force




Flux is proportional to the density of flow.


Flux varies by how the boundary faces the direction of flow.


Flux is proportional to the area within the boundary.

FLUX DENSITY: The flux density is the number of magnetic lines of flux that pass through a certain point on a surface. Flux density is the amount of flux per unit area perpendicular to the field. The SI unit is T (tesla), which is weber per square meter (Wb/m^2) and the unit in the CGS system is G (gauss).

$B = \phi / A \quad Wb/m^2$

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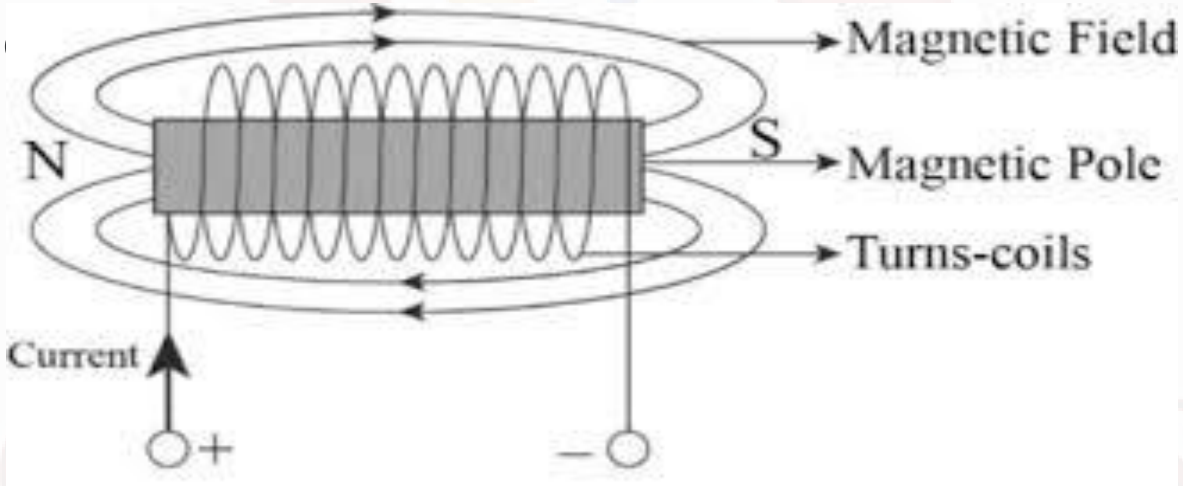
MMF: It stands for Magnetomotive force (mmf).The current flowing in an electric circuit is due to the existence of electromotive force similarly magnetomotive force (MMF) is required to drive the magnetic flux in the magnetic circuit. The magnetic pressure, which sets up the magnetic flux in a magnetic circuit is called Magn



It is denoted by F_m.
F_m = NI ampere-turns (At),
where N = number of turns and I = current in amperes. Since 'turns' has no units, the SI unit of mmf is the ampere(A), but to avoid any possible confusion 'ampere-turns', (A t)

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Magnetic field Intensity(H):-

- The magnetic field intensity is the mmf per unit length along the path of the flux.
- It is also known as magnetic flux intensity and is represented by the letter H.
- Its unit is ampere turns per meter. H= mmf / Length. H = NI/l AT/m Where H is magnetic field intensity N is the number of turns l is average path length of the magnetic flux

Magnetic Flux Linkage(λ):-

The product of magnetic coupling to a conductor, or the flux through a single turn times the number of turns in coils.

$$\lambda = n\emptyset$$

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RELUCTANCE:- It is defined as the ratio of magnetomotive force to magnetic flux. **It represents the opposition to magnetic flux**, and depends on the geometry and composition of an object.

$$\mathcal{R} = \frac{\mathcal{F}}{\Phi}$$

- R is the reluctance in ampere-turns per weber (a unit that is equivalent to turns per henry). Turns refers to the winding number of an electrical conductor comprising an inductor.
- F is the magnetomotive force (MMF) in ampere-turns
- Φ is the magnetic flux in webers.

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$$\mathcal{R} = \frac{l}{\mu_0 \mu_r A} = \frac{l}{\mu A}$$

l is the length of the circuit in meters.

μ_0 is the permeability of vacuum,

μ_r is the relative magnetic permeability of the material (dimensionless)

μ is the permeability of the material

A is the cross-sectional area of the circuit in m^2

Permeance:- The reciprocal of the magnetic reluctance is known as the magnetic permeance

$$Permeance\ (P) = \frac{1}{Reluctance} = \frac{1}{R}$$

PERMEABILITY:- The magnetic permeability is defined as the property of the material to allow the magnetic line of force to pass through it. The magnetic permeability of the material is directly proportional to the number of lines passing through it. It is denoted by μ. SI unit is Henry per meter (H/M or Hm^2) or newton per ampere square ($N\text{-}A^2$). The permeability of the air or vacuum is represented by μ_0 which is equal to $4\pi\times17^{-7}$ H/m.

It is expressed by the formula shown below.

$$\mu = \frac{B}{H}$$

Where,
B – magnetic flux density
H – magnetic field intensity
SI unit is Henry per meter (H/M or Hm^2) or newton per ampere square ($N\text{-}A^2$).

The Iceberg Illusion
Success is an iceberg
WHAT PEOPLE SEE
SUCCESS!
WHAT PEOPLE DON'T SEE
Persistence
GOAL
Dedication
Failure
FAIL
Hard work
Sacrifice
THINGS I HAVE TO GIVE UP
1.
2.
3.
Discipline
Disappointment