WEEK 7

SESSION 25

Magnetism and Magnetic circuits

- Define: Magnetic flux, magnetic field, flux density, Magnetic field strength(H), Absolute Permeability,
- Relative permeability, Mention their units
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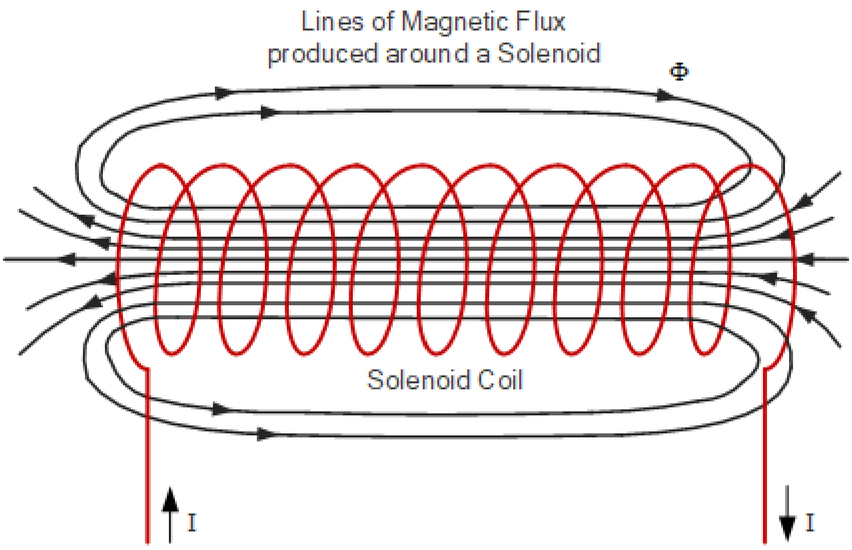
  https://youtu.be/Uop-zhEPo4M?si=5BbPVWWqK5SFy8Os



1. Magnetic Flux (Φ)

- Definition: The total number of magnetic field lines (or magnetic lines of force) passing through a given area.
- In the diagram, the curved red lines outside and inside the solenoid represent magnetic flux.
- It is the total number of magnetic field lines produced.
- Symbol: Φ
- Unit: Weber (Wb)

2. Magnetic Field (B-field)

- Definition: The region around a magnetic material or a moving electric charge within which magnetic force is experienced.
- Symbol: Usually represented by B
- Unit: Tesla (T) or Weber per square meter (Wb/m²)

3. Flux Density (B)

- Definition: The magnetic flux per unit area perpendicular to the direction of flux.
- $B = \frac{\Phi}{A}$
- Unit: Tesla (T) = Wb/m²

4. Magnetic Field Strength (H)

- Definition: Magnetizing force that produces magnetic flux in a material.

$$H = \frac{NI}{}$$

l

where N = number of turns, I = current, l = length of path.

- Unit: Ampere per meter (A/m)

5. Absolute Permeability (μ)

- **Definition**: Ability of a material to allow magnetic flux through it.

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

- Unit: Henry per meter (H/m)

6. Relative Permeability (μr)

- **Definition**: Ratio of permeability of a material to that of free space.

  $\mu_r = \frac{\mu}{\mu 0}\mu$

  where μ0=4π×10−7 H/m.

- Unit: Dimensionless (no unit)

SESSION 26

- Define magnetic circuit, MMF, Reluctance, laws of reluctance,
- Define flux density, magnetic leakage, leakage coefficient, permanence, and mention their units.

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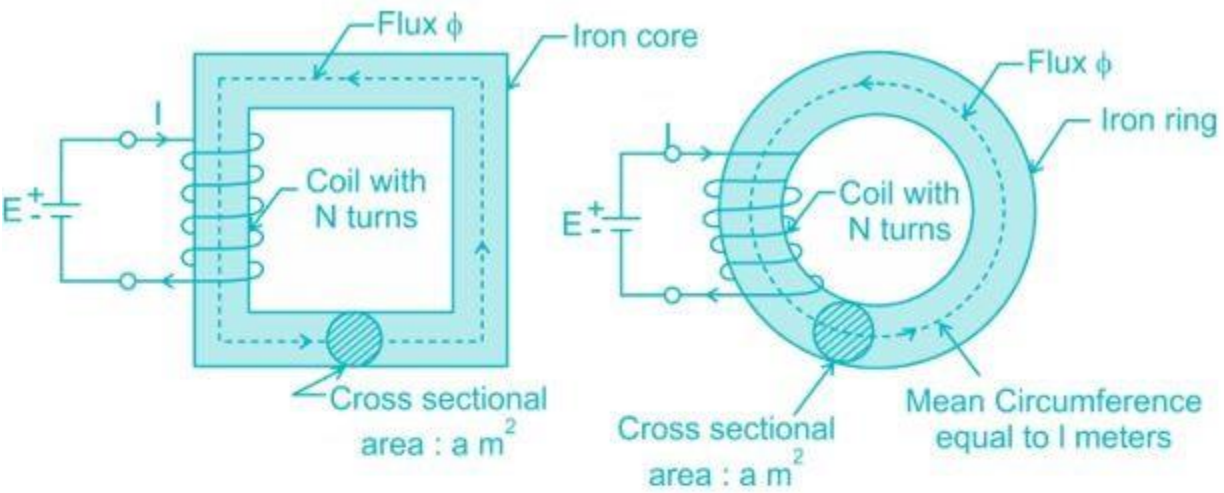
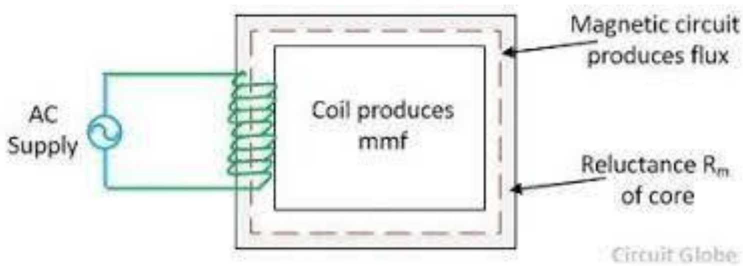


1. Magnetic Circuit

- **Definitio n:**

A magnetic circuit is a closed path followed by magnetic flux (Φ), usually made of ferromagnetic material such as iron or steel, which provides a low reluctance path for the flux.

2. Magnetomotive Force (MMF)



Definition: 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 Magnetomotive Force.

- In the figure:
  - Electric current in the coil produces magnetomotive force (MMF = NI).
  - This MMF drives magnetic flux around the closed iron ring, similar to how an electric circuit carries current.

3. Reluctance (ℜ)

Definition: The opposition offered by a magnetic circuit to the flow of magnetic flux (similar to resistance in an electric circuit).

- Formula: $R = \frac{l}{\mu A}$

where

- l = length of the magnetic path (m)
- A = cross-sectional area (m^2)

- μ = permeability of material (H/m)
- Unit: Ampere-turns per Weber (AT/Wb)

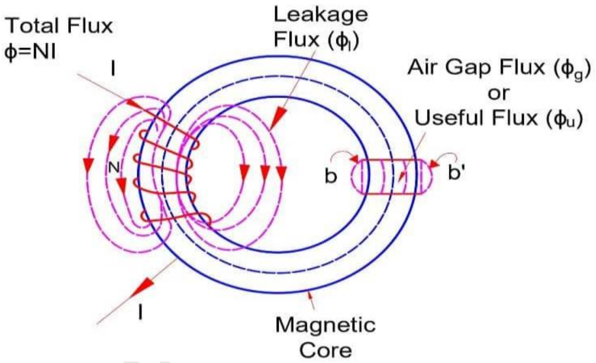
4. Laws of Reluctance

- Just like resistances in electricity:
  - Series law: Total reluctance is the sum of reluctances in series.
  - $$\mathcal{R}_{total} = \mathcal{R}_1 + \mathcal{R}_2 + \dots$$
  - Parallel law: In parallel paths, the reciprocal of total reluctance equals the sum of reciprocals.
  - $$\frac{1}{\mathcal{R}_{total}} = \frac{1}{\mathcal{R}_1} + \frac{1}{\mathcal{R}_2} + \dots$$

5. Flux Density (B)

- Flux density (B) is a measure of a magnetic field's strength,
- Definition:the amount of magnetic flux passing through a unit area perpendicular to the flux
- $B=\Phi/A$
- Unit: Tesla (T) = Wb/m²

6. Magnetic Leakage



Definition

- Leakage flux is the portion of the total magnetic flux that does not follow the intended path of the magnetic circuit.

Causes

- It's caused by factors like the material of the magnetic core becoming saturated (unable to hold more flux), the presence of air gaps between components, and the alignment or positioning of magnets.

7. Leakage Coefficient (λ)

- Definition: The ratio of total flux produced (Φt) to useful flux (Φu) in the magnetic circuit. (ratio of the total magnetic flux produced in a magnetic circuit to the useful flux that passes through the air gap.)

$$\lambda=\frac{\Phi t}{\Phi u}$$

Unit: Dimensionless (no unit)

8. Permeance (P)

- Definition: The ease with which a magnetic circuit allows magnetic flux. It is the reciprocal of reluctance
- Unit: Wb/AT

$$P = \frac{1}{\mathcal{R}} = \frac{\mu A}{l}$$

SESSION 27

- State the relationship between Flux, flux density, MMF and Reluctance
- Compare Electric circuit with magnetic circuit

Relationship between Flux, Flux Density, MMF and Reluctance

https://youtu.be/Epzddjp4Qt8?si=rFINW7hvrOFjmve7

Quantity	Formula	Unit	Relation
Flux (Φ)	$\Phi = \frac{MMF}{\Re}$	Weber (Wb)	Flux is proportional to MMF and inversely proportional to Reluctance
Flux Density (B)	$B = \frac{\Phi}{A}$	Tesla (T) or Wb/m²	Flux per unit area
MMF	$MMF = N \cdot I$	Ampere-turn (AT)	Driving force producing flux
Reluctance (ℜ)	$\Re = \frac{l}{\mu A}$	AT/Wb	Opposition to flux

Comparison: Electric Circuit vs Magnetic Circuit

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Aspect	Electric Circuit	Magnetic Circuit
Driving Force	EMF (E, Volts)	MMF (N·I, Ampere-turns)
Flowing Quantity	Current (I, Amps)	Flux (Φ, Webers)
Opposition	Resistance (R, Ohms)	Reluctance (ℜ, AT/Wb)
Fundamental Law	$I = \frac{E}{R}$	$\Phi = \frac{MMF}{\Re}$
Material Property	Resistivity (ρ)	Permeability (μ)
Density	Current Density (A/m²)	Flux Density (Tesla, Wb/m²)

SESSION 28

Useful constants & formulas

- $\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H/m}$
- $\mu = \mu_0 \mu_r$
- Reluctance: $\mathcal{R} = \dfrac{l}{\mu A}$ (AT/Wb)
- MMF: $\mathrm{MMF} = NI$ (AT)
- Flux: $\Phi = \dfrac{\mathrm{MMF}}{\mathcal{R}}$ (Wb)
- Flux density: $B = \dfrac{\Phi}{A}$ (T)

Problem 1:

A magnetic core has:

- Mean length of magnetic path $l = 0.30\ \mathrm{m}$,
- Cross-sectional area $A = 4 \times 10^{-4}\ \mathrm{m}^2$,
- Relative permeability $\mu_r = 1200$,
- Coil of $N = 400$ turns carrying current $I = 0.5\ \mathrm{A}$.

Find:

(a) Reluctance of the core

(b) MMF

(c) Flux

(d) Flux density

Solution

1. $\mu = \mu_0 \mu_r = 4\pi \times 10^{-7} \times 1200 = 4\pi \times 10^{-7} \times 1200\ \mathrm{H/m}.$
2. $\mathcal{R} = \dfrac{l}{\mu A} = \dfrac{0.30}{(\mu_0 \cdot 1200) \cdot 4.0 \times 10^{-4}} = 4.9736 \times 10^5\ \mathrm{AT/Wb}.$
3. $\mathrm{MMF} = NI = 400 \times 0.5 = 200\ \mathrm{AT}.$
4. $\Phi = \dfrac{\mathrm{MMF}}{\mathcal{R}} = \dfrac{200}{4.9736 \times 10^5} = 4.021 \times 10^{-4}\ \mathrm{Wb}.$
5. $B = \dfrac{\Phi}{A} = \dfrac{4.021 \times 10^{-4}}{4.0 \times 10^{-4}} = 1.005\ \mathrm{T}.$

Problem 2:

A magnetic core has:

- Mean length $l = 0.20 \text{ m}$
- Cross-sectional area $A = 2.0 \times 10^{-4} \text{ m}^2$
- Relative permeability $\mu_r = 1000$

A coil of $N = 200$ turns carries current $I = 0.5 \text{ A}$.

Find:

(a) Reluctance $\mathcal{R}$ (AT/Wb)

(b) MMF (AT)

(c) Flux Φ (Wb)

(d) Flux density B (T)

Solution

Useful constant: $\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$.

$\mu = \mu_0\mu_r = 4\pi \times 10^{-7} \times 1000 = 1.25663706 \times 10^{-3} \text{ H/m}$.

(a) Reluctance

$$\mathcal{R} = \frac{l}{\mu A} = \frac{0.20}{(1.25663706 \times 10^{-3})(2.0 \times 10^{-4})} = 7.957747 \times 10^{5} \text{ AT/Wb}$$

(b) MMF

$$\text{MMF} = NI = 200 \times 0.5 = 100 \text{ AT}$$

(c) Flux

$$\Phi = \frac{\text{MMF}}{\mathcal{R}} = \frac{100}{7.957747 \times 10^{5}} = 1.256637 \times 10^{-4} \text{ Wb}$$

(d) Flux density

$$B = \frac{\Phi}{A} = \frac{1.256637 \times 10^{-4}}{2.0 \times 10^{-4}} = 0.6283185 \text{ T}$$

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