Day 14

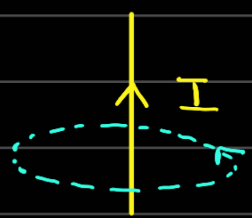
→ machines
- Asynchronous (induction machine)
  - Slipring
  - Squirrel cage
- Synchronous
  - Permanent magnet
  - Brushless DC
- AC
- DC ✗ (commutation issues – limited use)

→ To be discussed :

- magnetic circuits (3 hrs)
- Transformer (5 hrs)
- Induction machine (6 hrs)
- Synchronous machine (6 hrs)

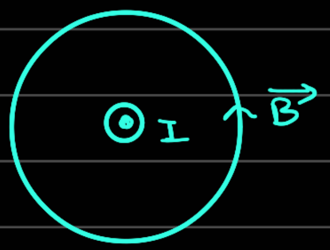
→ Quiz (20%) – Last week of October
→ Assignment – 10%
→ Attendance – if ≥80% ; 30% marks (additional) on assignment
→ Endsem – 40%

☆ Magnetic Circuits :–

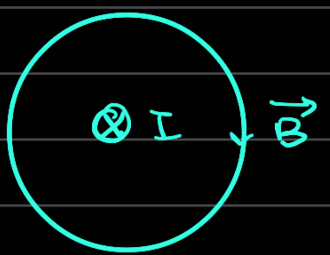


→ **Dot and Cross convention:**

⊙ – Arrow towards me



⊗ – Arrow away from me



→ **Ampere's circuital law:**

$$\oint_C \vec{H}\cdot d\vec{l} = \int_S \vec{J}\cdot d\vec{s}$$

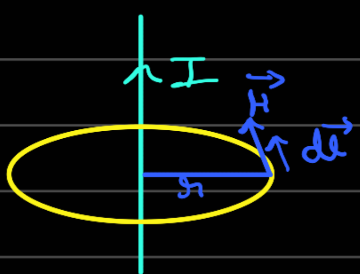
$\oint_C$ → line integral along closed contour C

$\oint_S$ → surface integral on surface S that encloses C

H: magnetic field intensity (AT/m) → Turn

J: current density (A/m²)

→ **Application:**



$$H\oint_C dl = H\times 2\pi r$$

$$\int_S \vec{J}\cdot d\vec{s} = I$$

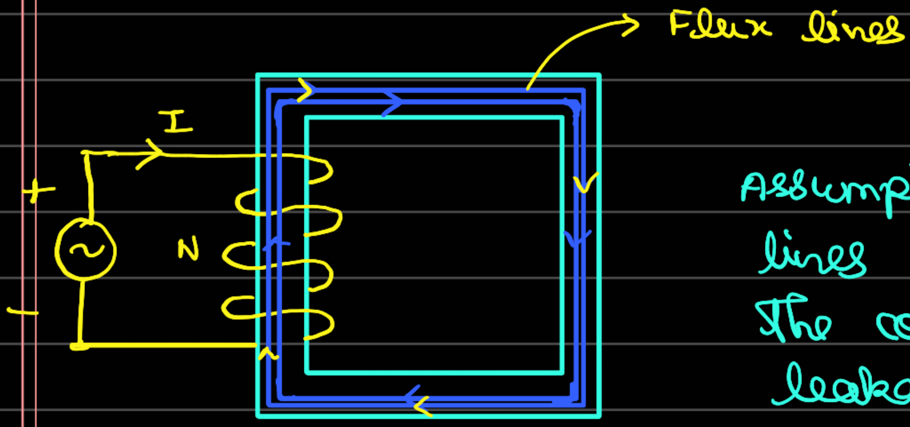
so $H = \dfrac{I}{2\pi r}$

magnetic flux density, $B = \mu_0 \mu_r H$

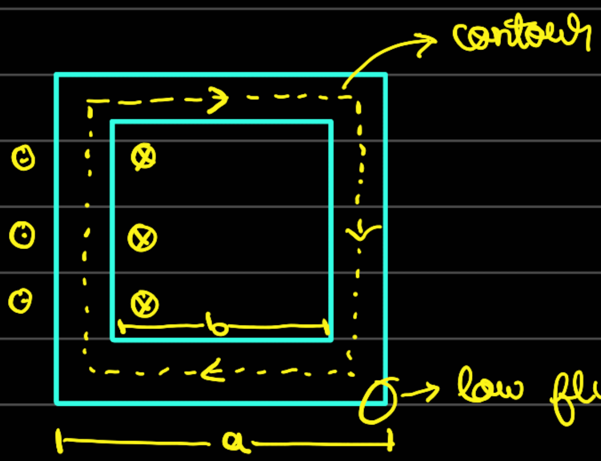
$\mu_r = 1$ for air.

so $B = \dfrac{\mu_0 I}{2\pi r}$

→ magnetic circuit :



Assumptions: All flux lines are confined to the core (No magnetic leakages)



$$\oint_C \vec{H}\cdot d\vec{l} =$$

A_c $\phi = \int \vec{B}\cdot d\vec{s}$ (Assume $\vec{B}$ is uniform) ↓ throughout core

$= BA_c$

so $\vec{H}$ – uniform.

so $\oint_c \vec{H}\cdot d\vec{l} = H \oint_c d\vec{l}$

$= H\, l_c$ → mean length of core

(middle one chosen for less errors)

$= 2H(a+b)$

$\oint \vec{J}\cdot d\vec{S} = NI$

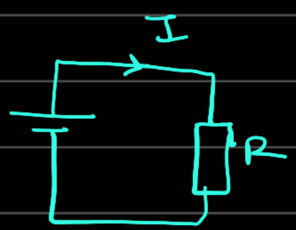
So $H\, l_c = NI$

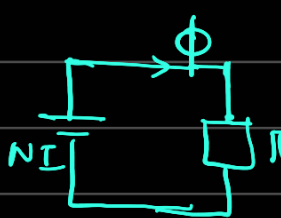
$\therefore\; B = \mu_0 \mu_r \dfrac{NI}{l_c}$

Flux, $\phi = B A_c$

$= \mu_0 \mu_r \dfrac{N I A_c}{l_c}$

$$\Rightarrow \underbrace{\phi}_{I} \; \underbrace{\frac{l_c}{\mu_0 \mu_r A_c}}_{R} = \underbrace{NI}_{V}$$





$R = \dfrac{l_c}{\mu_0 \mu_r A_c}$

$$\underbrace{NI}_{\text{mmf}} = \underbrace{\phi}_{\text{Flux}}\, R \rightarrow \text{Reluctance}$$

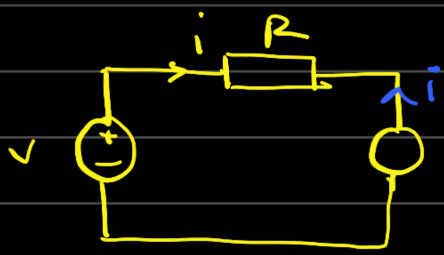
$$\underbrace{V}_{\text{EMF}} = \underbrace{I}_{\text{current}}\, R \rightarrow \text{Resistance}$$

Electrical		Magnetic	
Current	I	Flux	ϕ
EMF	V	mmF	NI
Resistance	R	Reluctance	$\mathcal{R} \rightarrow \dfrac{l_c}{\mu_0 \mu_r A_c}$
Current density	J	Flux density	B
Electric Field intensity	E	magnetic field intensity	H

$$V = E d$$
$$\updownarrow \qquad \updownarrow \;\; \updownarrow$$
$$NI = H l_c$$

$$\sigma \equiv \mu_0 \mu_r$$

$$J = \sigma . E$$
$$\updownarrow \qquad \updownarrow \quad \updownarrow$$
$$B = \mu \; H$$



$$\mathcal{E} = \frac{d\psi}{dt}$$

$(\psi = N\phi)$
↓
Flux linkage

$$v(t) = i(t) R + \frac{d\psi(t)}{dt}$$

- Ref. Books —
  (i) Electric machinery by A.E. Fitzerald
  (ii) Theory of A.C. machinery by M.G. Say
  (iii) Principles of machines and Power electronics by P.C. Sen

- NPTEL – Basic elec. engg. (Prof Umanand (IISc)

Analysis of elec. machines : Prof. Krishna Vasudevan (IITM)

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