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EE1101: Circuits and Network Analysis

Lecture 40: Magnetic Circuit Analysis

and 41 November 10, 2025 / Nov 11, 2025

Topics :

1. Introduction to Magnetic Circuits
2. Magnetic Circuits with One Winding

$V \longrightarrow \mathcal{F}$ (MMF)

$R \longrightarrow \mathcal{R}$ (Reluctance)

$i \longrightarrow \phi$ (flux

Introduction to Magnetic Circuits

2 fundamental laws associated with magnetic domain

$\vec{B} \rightarrow$ mag flux density ($\vec{B} = \mu \vec{H}$)

($\vec{H} \rightarrow$ mag field intensity)

① ACL: $\oint_C \vec{H} \cdot \vec{dl} = I_{enc} + \underbrace{\quad}_{\text{displacement current } (\propto \vec{D})}$

① for ckts in this course displacement current is Negligible.

② Faraday's law: $\underbrace{\oint \vec{E} \cdot \vec{dl}}_{v} = -\frac{d\lambda}{dt} = -\frac{d}{dt}\int_S \vec{B} \cdot \vec{ds}$

Typical framework:

$$\text{Current } (i) \xrightarrow[\text{(ACL) } (\checkmark)]{\text{Biot-Savart's law } (\times)} \text{Magnetic field intensity } (\vec{H})$$

$$\downarrow \; \vec{B} = \mu \vec{H}$$

$$\text{Voltage } (v) \text{ (induced)} \xleftarrow[\text{(Lenz Law)}]{\text{Faraday's Law}} \text{Magnetic flux density } (\vec{B})$$

when there are multiple paths

↓

Conservation Principle.

$\underbrace{\oint B \, \vec{ds} = 0}$

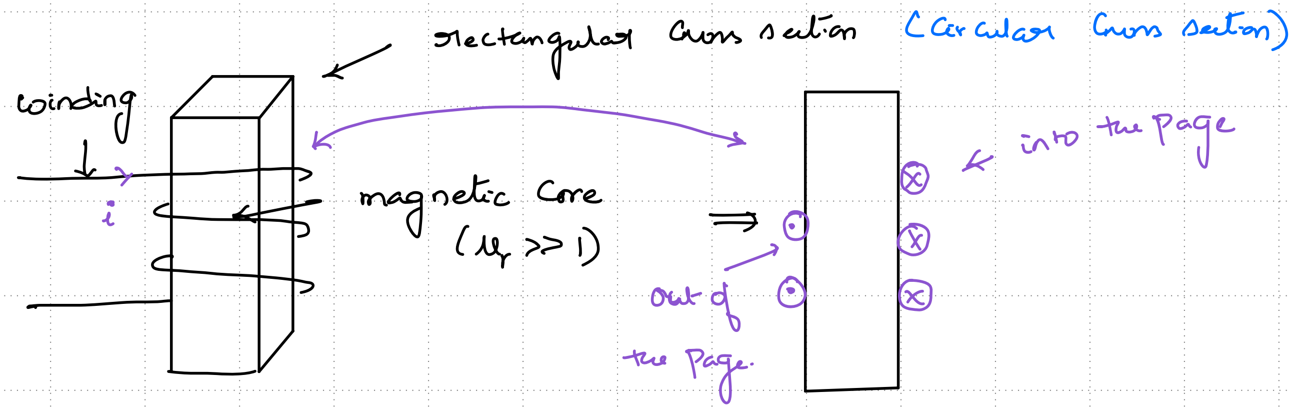
(MMF $\longrightarrow \mathcal{F}$

Reluctance $\longrightarrow \mathcal{R}$

inductance, flux, flux linkage)

Introduction to Magnetic Circuits

For the ckts to be dealt in this course :

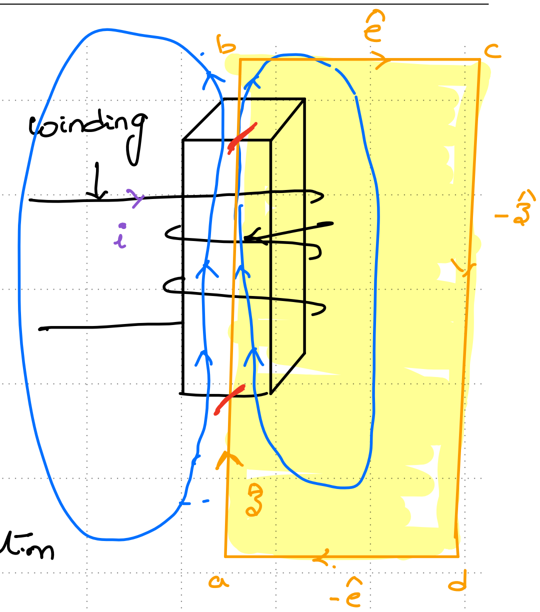


① Magnetic Core ($\mu_r >> 1$) $\Rightarrow$ a) Magnetic field intensity in the core $\gg$ magnetic field intensity in air. (Neglected)

b) field lines → along the core
→ field intensity within the sec of the core → uniform.

c) Typically in a direction that is normal to the cross section of core.

Magnetic Circuits with One Winding



① given the information related to mag. core & winding.

essential to apply ACL.

a) figure out the field lines (orientation)

(i) is there a closed path through the mag. medium / core?

(ii) apply Right hand rule to figure out orientation

b) Approx. related to $\mu_r \gg 1$

(i) field intensity in air ≈ 0.

(ii) " " " core = const.

c) ACL : $\oint_C \vec{H} \cdot \vec{dl} = I_{enc}$

(i) choice of closed path? → & its orientation → in line with Right hand rule.

→ based on ⓑ

↳ pick a path where $|\vec{H}|$ is either 0 or constant?

(ii) How to compute I_{enc}?

$\oint_S \vec{J} \cdot \vec{ds}$

a) often any open surface to the chosen loop

b) Net current through the surface

$= Ni$ ($\pm$, RH rule)

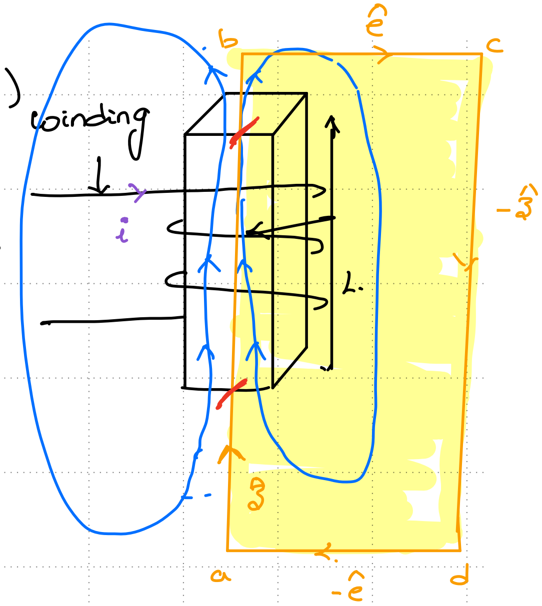
Magnetic Circuits with One Winding

$$\oint \vec{H}\cdot\vec{dl} = I_{enc} = Ni \Rightarrow \int_a^b \underbrace{\vec{H}}\cdot dz\,\hat{z} + \int_b^c \cancel{\vec{H}}^{\,0}\cdot dl\,\hat{e} + \int_c^d \cancel{\vec{H}}^{\,0}\,dz(-\hat{z})$$

$$+ \int_d^a \cancel{\vec{H}}^{\,0}\,dl(-\hat{e}) = Ni$$

$$= \int H\hat{z}\cdot dz\,\hat{z} = Hl = Ni$$

$$\Rightarrow H = \frac{Ni}{l}$$



① MMF: $\underbrace{\int \vec{H}\cdot\vec{dl}}_{\text{(for a sec)}} = Ni = (\mathcal{F})$

② Mag. flux density $\vec{B} = \mu\vec{H} = \frac{\mu N i}{l}\hat{z}$.

③ flux: $\int \vec{B}\cdot\vec{ds}$ = flux associated with the surface across which winding is wound.

$\vec{ds} = dx\,dy\,\hat{z}$.

Since B is uniform & along $\vec{ds}$ $\Rightarrow \int \vec{B}\cdot\vec{ds} = B A_c = \frac{\mu N i}{l} A_c$.

$$\mathcal{R} = \frac{\mathcal{F}}{\phi} = \frac{l}{\mu A}$$

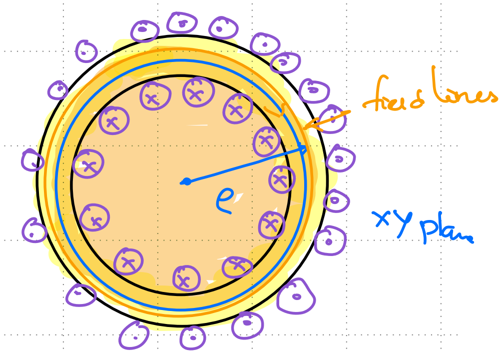
④ flux linkage (λ) = Total flux linking winding $(N\phi) = N^2\frac{\mu i}{L}A_c$.

$$\frac{\lambda}{i} = L = \frac{N^2\mu A_c}{L}$$

⑤ $v = \frac{d\lambda}{dt} = L\frac{di}{dt}$ ($\lambda = Li$)

Magnetic Circuits with One Winding

Lec-41 [11/11/25]



a) figure out the field lines (orientation)

(i) is there a closed path through the mag. medium / core?

(ii) apply Right hand rule to figure out orientation $(-\hat{\phi})$

essential to apply ACL.

b) Approx. related to $\mu_r >> 1$

(i) field intensity in air $\simeq 0$.

(ii) " " " core = const.

c) ACL: $\oint_C \vec{H} \cdot \vec{dl} = I_{enc}$

(i) Choice of closed paths? → & its orientation

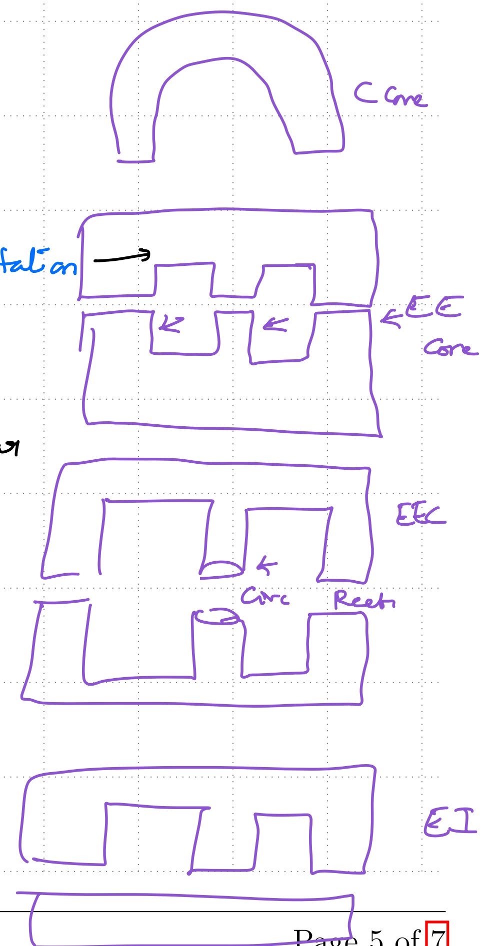
↓

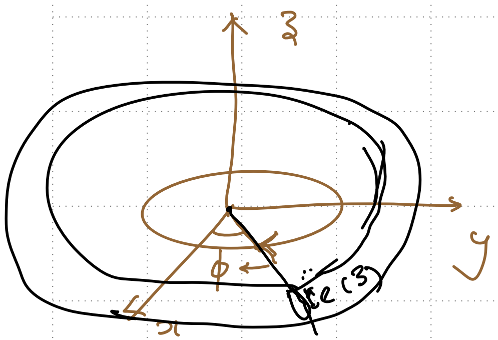
along the field lines (circular in nature & radius 'e' : $-\hat{\phi}$)

(ii) How to compute I_{enc}?

↓

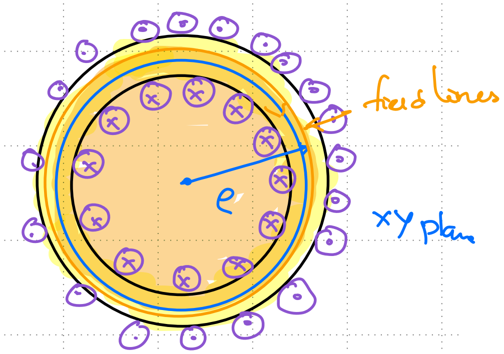
Ni





Magnetic Circuits with One Winding

Lec - 41 [11/11/25]



$$\oint \vec{H}\cdot\vec{dl} = Ni$$

$$H\,(-\hat{\phi})\cdot(\rho\, d\phi\,(-\hat{\phi})) = Ni$$

$$\int_0^{2\pi} H \rho\, d\phi = Ni \Rightarrow H = \frac{Ni}{2\pi\rho} \qquad \vec{H} = \frac{Ni}{2\pi\rho}(-\hat{\phi})$$

② Mag. flux density $\vec{B} = \mu\vec{H} = \frac{\mu N i}{2\pi\rho}(-\hat{\phi})$

③ flux: $\int \vec{B}\cdot\vec{ds}$ = flux associated with the surface along which winding is wound.

$$\vec{ds} = d\rho\, dz\, (-\hat{\phi})$$

since B is uniform & along $\vec{ds}$ $\Rightarrow \int \vec{B}\cdot\vec{ds} = B A_c = \frac{\mu N i}{2\pi\rho} A_c.$

④ flux linkage $= N\phi = N^2 \frac{\mu i}{2\pi\rho} A_c$