Lecture # 19, 11/15/21

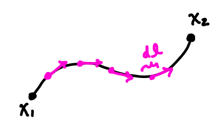
Today
- magnetics fundamentals (ch 10.1)
- Inductor design (11.1 – 11.2)

General Formulas / Laws

$$\underbrace{\overset{\text{total}}{\mathcal{F}}}_{\text{MMF}} = \int_{x_1}^{x_2} \vec{H} \cdot d\vec{l} \quad \Big\}\ \text{path length integral}$$

mag. field strength

density/length

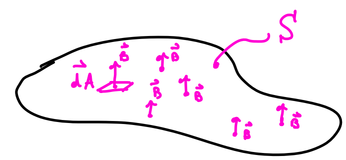


$$\underbrace{\overset{\text{total}}{\Phi}}_{\text{flux}} = \int_S \vec{B} \cdot d\vec{A} \quad \Big\}\ \text{surface integral}$$

flux density

per unit area

total flux across area S



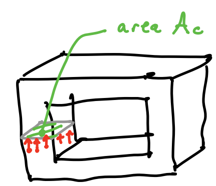
- Faraday's Law

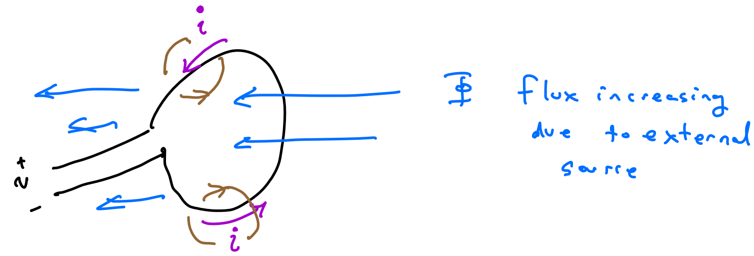
$$\underbrace{v(t)}_{\substack{\text{induced}\\ \text{voltage}}} = \underbrace{\frac{d\Phi(t)}{dt}}_{\substack{\text{flux rate}\\ \text{of change}}}$$

A_c = cross sectional area of core

* common approx: $\Phi \approx A_c B(t)$ — assumed same across surface A_c

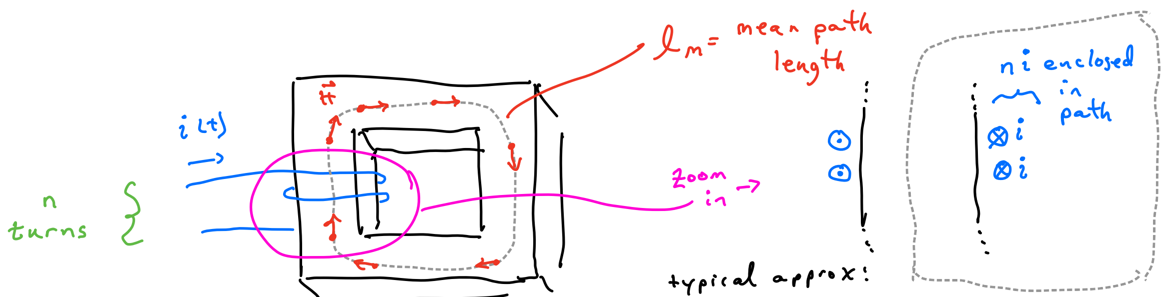
$$\approx A_c \frac{dB(t)}{dt}$$





i is induced & creates a field that opposes the change of flux in area

- Ampere's Law
  - Net MMF ($\mathcal{F}$) around closed loop equals the enclosed current passing through the loop.



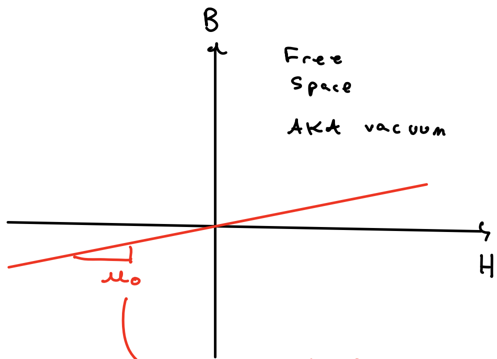
typical approx: $\vec{H}$ uniform around loop

$$\underbrace{\mathcal{F}(t)}_{n\,i(t)} = \underbrace{\oint \vec{H}\cdot d\vec{\ell}}_{H\ell_m} \implies \oint \vec{H}\cdot d\vec{\ell} \approx H\ell_m$$

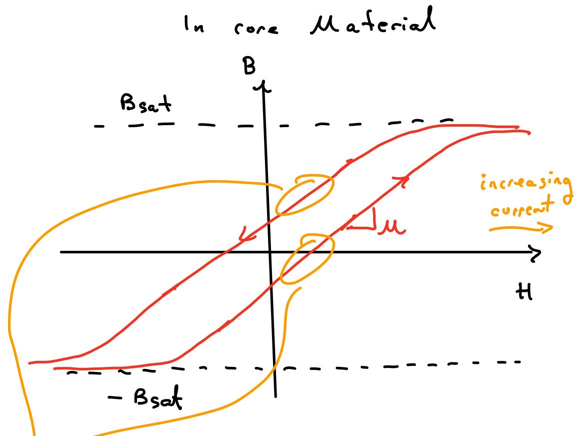
$n\,i(t) = H\ell_m$

enclosed current

Core Characteristics (Link Faraday & Ampere)



→ permeability of free space $= 4\pi \times 10^{-7}$ H/m



due to hysteresis, "material memory"

- μ = material permeability

  $= \mu_r \mu_o$

  ↑ relative permeability

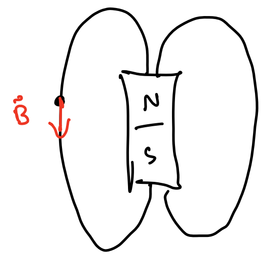
  where $\mu_r \approx 10^3$ to 10^5

  ↑ like a field "amplification factor"

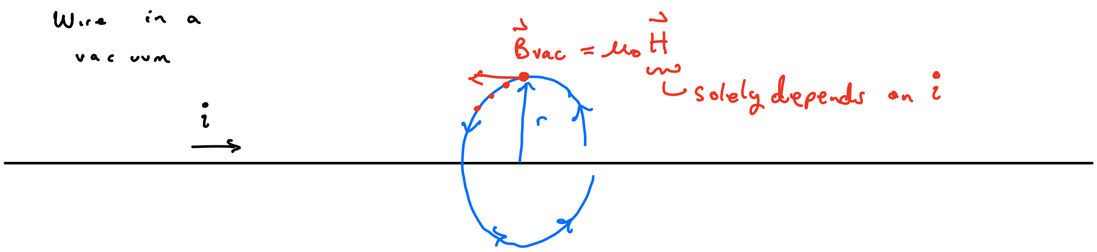
- Bsat typical
  - → 0.3 to 0.5 T, ferrites (in lab)
  - → 0.5 to 1 T, powdered iron
  - → 1 T to 2 T, iron laminates

Q: What is H "Field intensity"

A: It is not the actual flux "Field density" B that is often visualized



It is a quantity solely due to i flows & is independent of material/medium



$$\mathcal{F} = \oint \vec{H} \cdot d\vec{l} =$$

$$= H \underbrace{(2\pi r)}_{l}$$

$$i = Hl$$

for fixed i

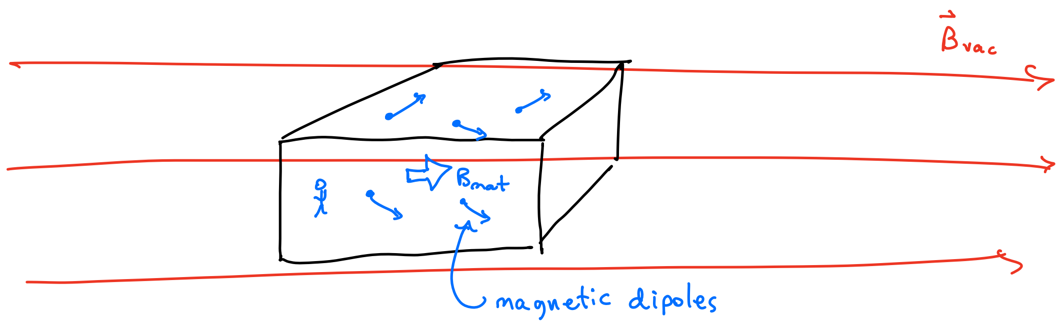
Hr & Hl is constant

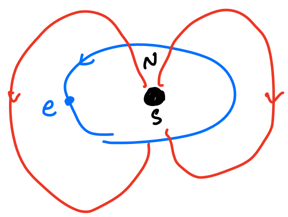
$\Rightarrow$ as r or $l \uparrow$, then $H \downarrow$

$\vec{H}$ & $\vec{B}$ are related by constant scaling

$$\vec{B}_{vac} = \mu_0 \vec{H}$$

- Now introduce a core material





B field sum vectorially

$$\vec{B}_{net} = \vec{B}_{vac} + \vec{B}_{mat}$$

magnetic susceptibility

$$\hookrightarrow \vec{B}_{mat} = \chi B_{vac}$$

$$= \vec{B}_{vac} + \chi \vec{B}_{vac}$$

$$= (1 + \chi)\vec{B}_{vac}$$

$*$ recall $\vec{B}_{vac} = \mu_0 H$

$$= \mu_0 \underbrace{(1 + \chi)}_{\mu_r} \vec{H}$$