MM4

(1) Ampere's law and Faraday's law

Ampere's law

magnetomotive force

$$mmf = F = \oint_C \bar{H}\cdot d\bar{l} = \int_S \bar{J}\cdot d\bar{a} = I_{TOT}\,[A]$$

Differential- or point- form

$$\nabla \times \bar{H} = \bar{J}$$

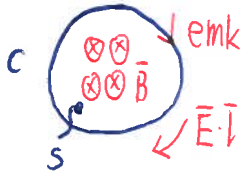
Faraday's law

electromotive force

$$emf = -V = \oint_C \bar{E}\cdot d\bar{l} = \int_S -\frac{\partial}{\partial t}\bar{B}\cdot d\bar{a} = -\frac{\partial}{\partial t}\phi\,[V]$$

Differential- or point- form

$$\nabla \times \bar{E} = -\frac{\partial}{\partial t}\bar{B}$$



Technical formula

A's law : $H\cdot l = N\cdot I$ [Av]

F's law : $V = -jwBAN$ [wbv]

Flux : $\phi = BA$ [wb]

Technical unit

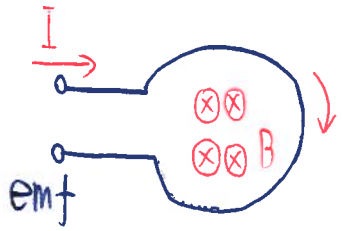
[Av] Ampere turns

[wbv] Web turns

[□Ω] square ohm

$\Lambda = BAN$ [wbv]

(2) Selfinduction



$$\phi = \int_S \bar{B} \cdot d\bar{a} \ [wb]$$

$$emf = -\frac{d}{dt}\phi N = -\frac{d\phi}{dI} N \cdot \frac{dI}{dt}$$

$$= -\frac{dI}{dt} \cdot L \ [V]$$

where

$$L \triangleq \frac{d\phi}{dI} \cdot N \ \left[\frac{Wb}{A} = H\right] \text{ is } \underline{\text{selfinduction}}$$

We see in KSN

$$V = jwIL \ (V)$$

$$\Rightarrow \frac{V}{I} = jwL$$

(3) Magnetic materials

Many materials are HiLS according to ε, μ, σ:

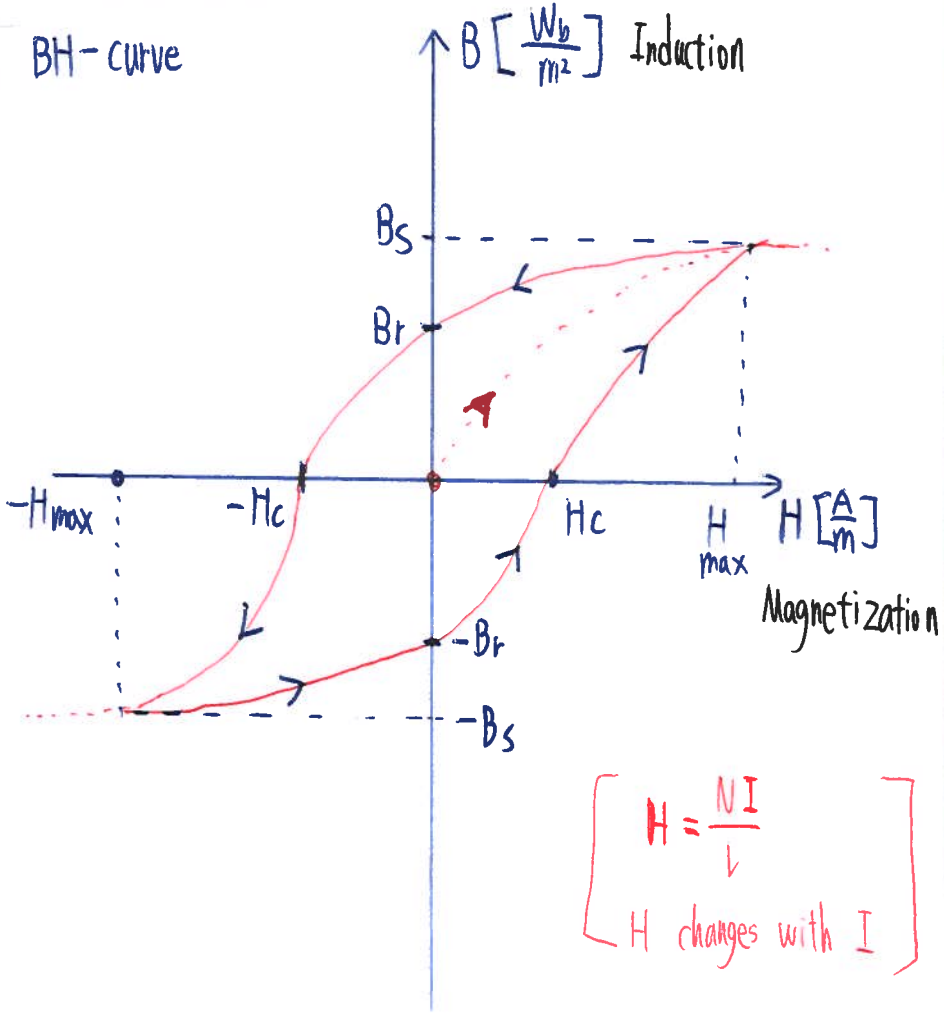
- Homogeneous
- Isotropic
- Linear
- Stationary (time invariant)

For HiLS materials, ε, μ, σ are constant

Magnetic materials

Diamagnetic	$\mu_r \leq 1$	linear	Cu, Ag
Paramagnetic	$\mu_r \geq 1$	linear	air, Al
Ferromagnetic	$\mu_r \gg 1$	nonlinear	Iron

(4) Hysteresis loop



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

H changes with I

Typical values

$B_s \left[\frac{Wb}{m^2}\right]$ Saturation flux

$H_{max} \left[\frac{A}{m}\right]$ Corresponding magnetization

$B_r \left[\frac{Wb}{m^2}\right]$ Residual magnetism

$H_c \left[\frac{A}{m}\right]$ Coercive force

Energy per loop (Energy loss)

$$U_M = \int B\,dH \quad \left[\frac{A}{m}\,\frac{Vs}{m^2} = \frac{J}{m^3}\right]$$

Permeability

$$\mu_{AVG} = \frac{B_s}{H_{max}}$$

$$\mu_{AC} = \frac{dB}{dH}$$