MAGNETOSTATIC MATERIALS & DEVICES

EE 3321 Electromagnetic Field Theory

Pioneering 21st Century Electromagnetics and Photonics

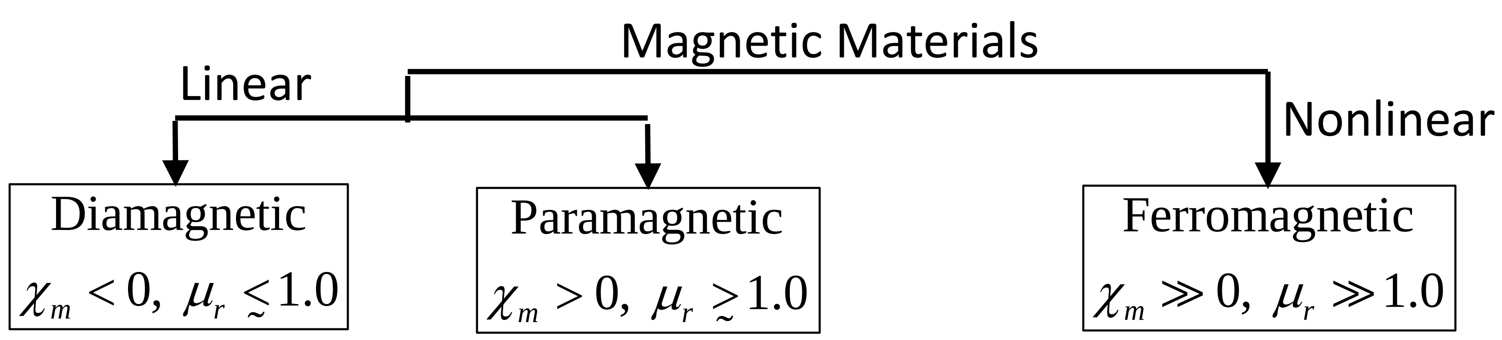
http://emlab.utep.edu

Classes of Materials

Diamagnetic – No permanent magnetic moment. Very weak response to a magnetic field where dipoles align to oppose applied field.

Paramagnetic – Weak magnetic response to applied field, but not permanent.

Ferromagnetic – Large permanent magnetic moments. Strongly magnetized by an applied field.



Total Magnetic Energy

General Case

$$W_m = \frac{1}{2}\iiint_V \left(\vec{B}\bullet\vec{H}\right)dv$$

LHI Media

$$W_m = \frac{1}{2}\iiint_V \mu\left|\vec{H}\right|^2 dv$$

Inductance, L

An inductor is a device that can store and discharge magnetic energy. It generates potential so as to oppose a change in current. They can generate very high voltages to do this!

$$L = \frac{\lambda}{I} = \frac{2W_m}{I^2}$$

Flux Linkage, λ

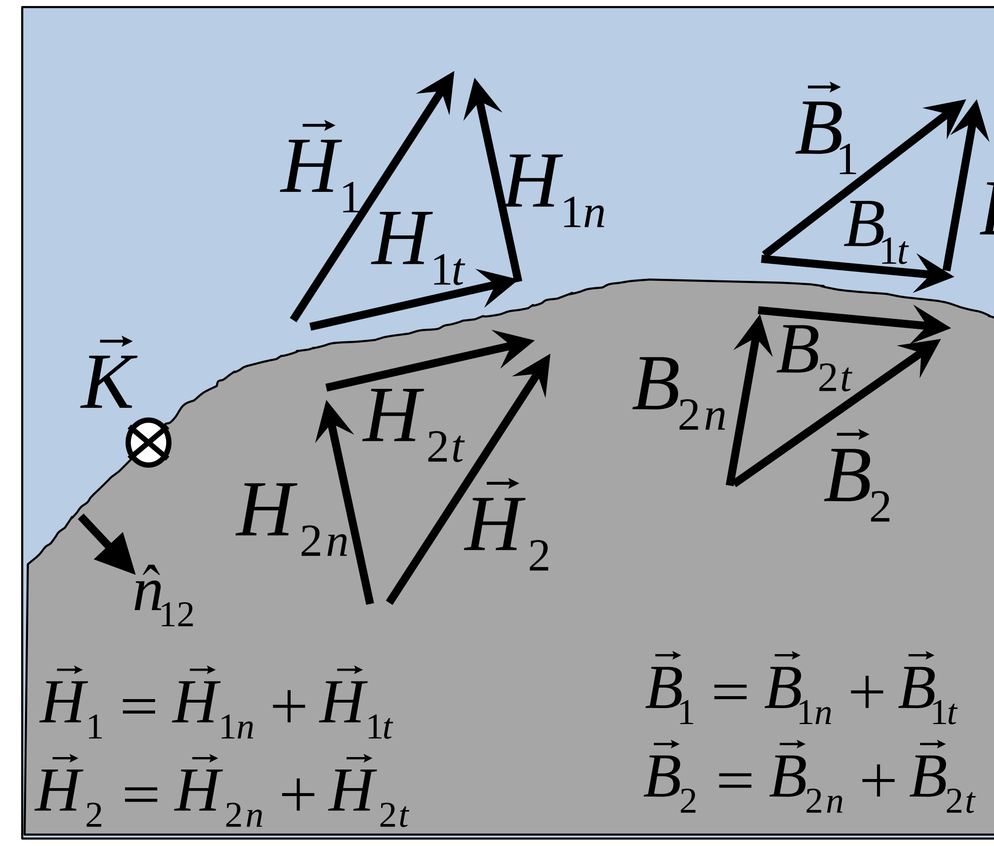
Flux linkage is like flux, but accounts for multiple loops.

$$\lambda = LI = \frac{2W_m}{I} \quad \text{(Webers)}$$

Stored Magnetic Energy

$$W_m = \tfrac{1}{2}LI^2 \quad \text{(Joules)}$$

Boundary Conditions



Normal Components:

$$\left(\vec{H}_1 - \vec{H}_2\right)\times\hat{n}_{12} = \vec{K}$$

$$\mu_1 H_{1n} = \mu_2 H_{2n} \qquad B_{1n} = B_{2n}$$

Tangential Components:

$$H_{1t} = H_{2t} \qquad \frac{B_{1t}}{\mu_1} = \frac{B_{2t}}{\mu_2}$$

Refraction:

$$\frac{\tan\theta_1}{\mu_1} = \frac{\tan\theta_2}{\mu_2}$$

Not Snell's Law

Analysis of Inductors

1. Choose suitable coordinate system.
2. Assume inductor carries current I_0.
3. Calculate H
   a. If symmetry exists, use Ampere's circuit law $I = \int_L \vec{H}\bullet d\vec{\ell}$ or $\nabla\times\vec{H} = \vec{J}$
   b. Otherwise, use Biot-Savart law
4. Calculate B from H
   $B = \mu H$
5. Calculate ψ from B
   $\psi = \iint_S \vec{B}\bullet d\vec{s}$
6. Calculate L
   $L = \dfrac{\lambda}{I} = \dfrac{N\psi}{I}$
   $\lambda = N\psi \equiv \text{flux linkage}$

Line Current

$$\vec{H} = \int_L \frac{Id\vec{\ell}\times\hat{a}_R}{4\pi R^2}$$

Surface Current

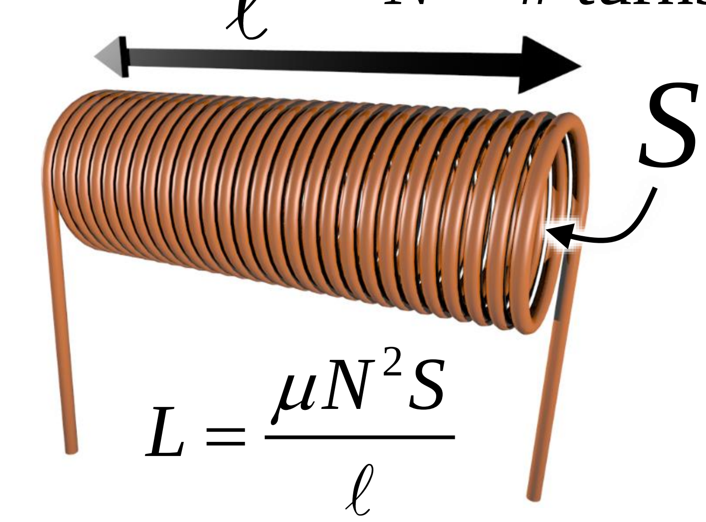
$$\vec{H} = \iint_S \frac{\vec{K}ds\times\hat{a}_R}{4\pi R^2}$$

Volume Current

$$\vec{H} = \iiint_V \frac{\vec{J}dV\times\hat{a}_R}{4\pi R^2}$$

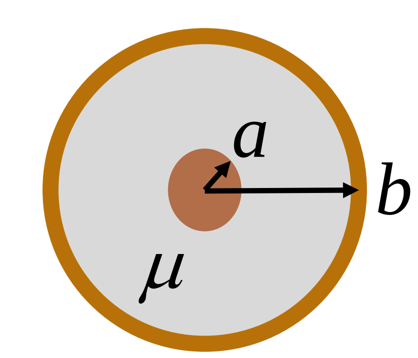
Solenoid

$N \equiv \#\ \text{turns}$



$$L = \frac{\mu N^2 S}{\ell}$$

Coaxial Cable



$$L = \frac{\mu\ell}{2\pi}\left[\frac{1}{4} + \ln\left(\frac{b}{a}\right)\right]$$