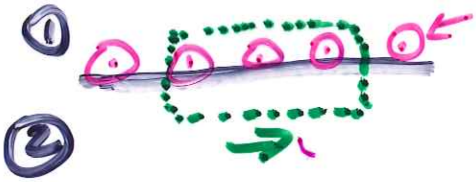
Boundary Conditions: $\Delta B_n = 0$

if no free surface current then $\Delta H_t = 0$

otherwise make amperian loop



$$(H_t^2 - H_t^1)\, l = K l$$

note: $\Delta H_t = 0$ in direction of K

If $J_f = 0$, then $\nabla \times H = 0$

$\nabla \cdot H = - \nabla \cdot M$, $M = \chi H$

$\frac{1}{\mu_0 K} B \to H$, $B \to \nabla \cdot B = 0$

Note: $\sigma_M = \vec{M} \cdot \hat{n}$ at boundary!

Uniform M sphere: inside $\vec{H} = -\frac{1}{3} \vec{M}$

$\vec{B} = \frac{2}{3} \mu_0 M$

outside: $\vec{m} = M \frac{4}{3} \pi R^3$

Magnetic sphere in uniform field

$B_{inside} = \frac{3K}{K+2} B_{outside}$ ← $\vec{B}$ wants in high K

Tech: A surround with $K_m \gg 1$ reduces magnetic field inside $\frac{B_{out}}{B_{in}} \approx \frac{K\left(1 - \frac{a^2}{b^2}\right)}{4}$

magnetic flux: $\phi_M = \int \vec{B} \cdot d\vec{A} \approx B A \cos\theta$

flux tube: $\vec{B}$ tangent to surface

flux constant inside flux tube: $\nabla \cdot B = 0$

Analogy: $J = g E$

$B = \mu H$

$\varepsilon_0 \rightarrow \varepsilon$

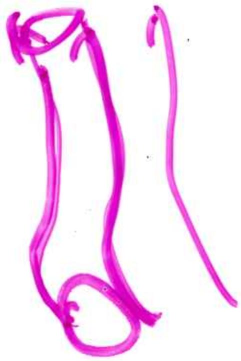
$$\oint \vec{E}\cdot d\vec{A} = \frac{Q}{\varepsilon}$$

$\rho_b \propto \rho_f$

$$\oint B\cdot dl = \mu I$$

$\nabla\cdot B = 0 \Rightarrow$

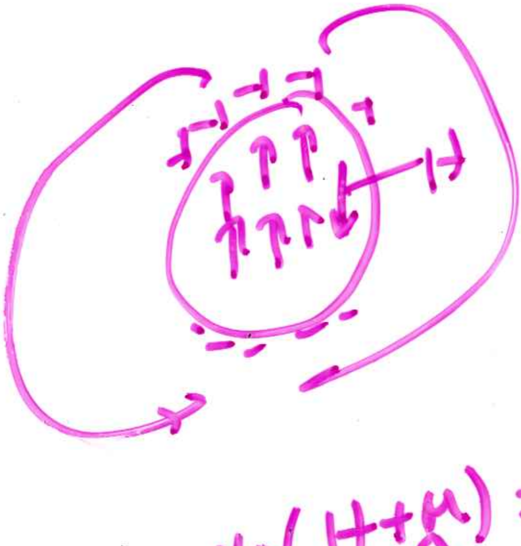
$\oint B\cdot dA = 0$

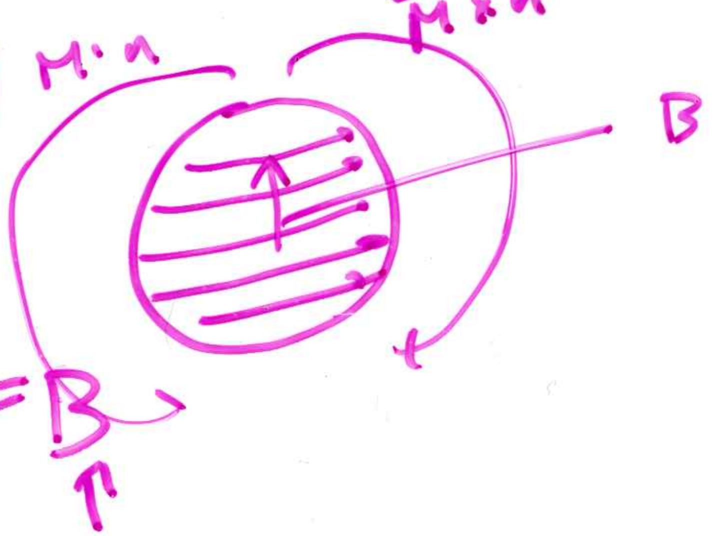


$$\oint H\cdot dl = I_f$$

$$J_M = \nabla\times M = \nabla\times\chi \underset{\uparrow\ \frac{B}{\mu}}{H} = \frac{\chi}{\mu}\nabla\times B$$

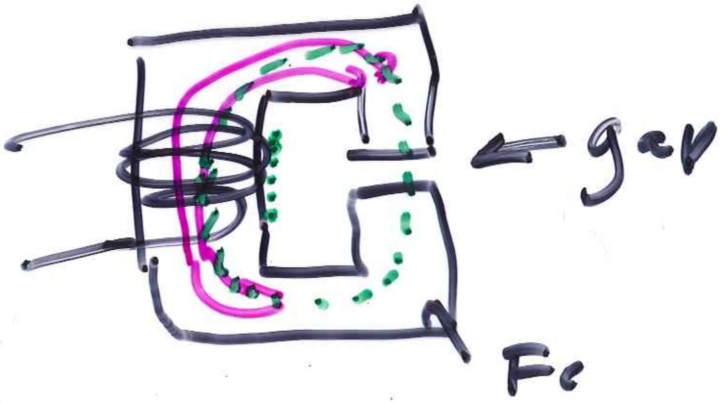
$$= \chi J_f$$

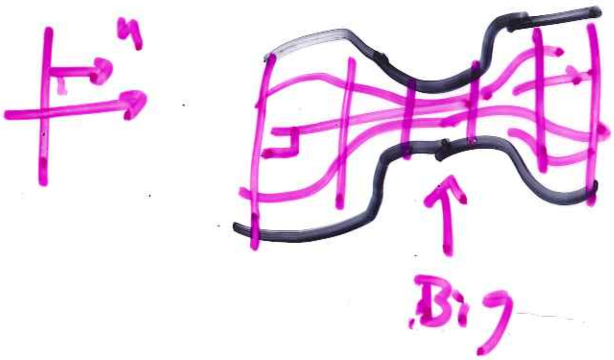




$$\mu_0(\underset{J}{H}+\underset{\uparrow}{M}) = \underset{\uparrow}{B}$$

Magnetic Circuits ⇔ V=IR





$$\phi = \oint \vec{B}\cdot d\bar{A}$$

$$\simeq BA\,\overbrace{\underbrace{\cos\overset{0}{\theta}}_{1}}^{1}$$

$$1 \quad \frac{\cos 90^\circ}{\overset{\shortparallel}{0}}$$

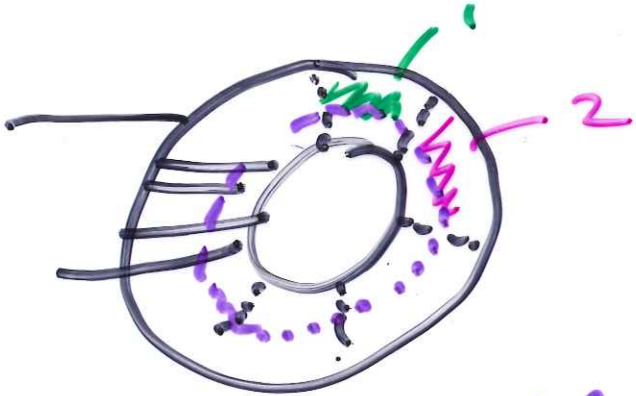
$$\simeq BA$$

$$B = \frac{\phi}{A}$$

$$\oint \underset{\underset{\frac{B}{\mu}}{\uparrow}}{H}\cdot dl = N\underset{\uparrow\,\text{free}}{I}$$

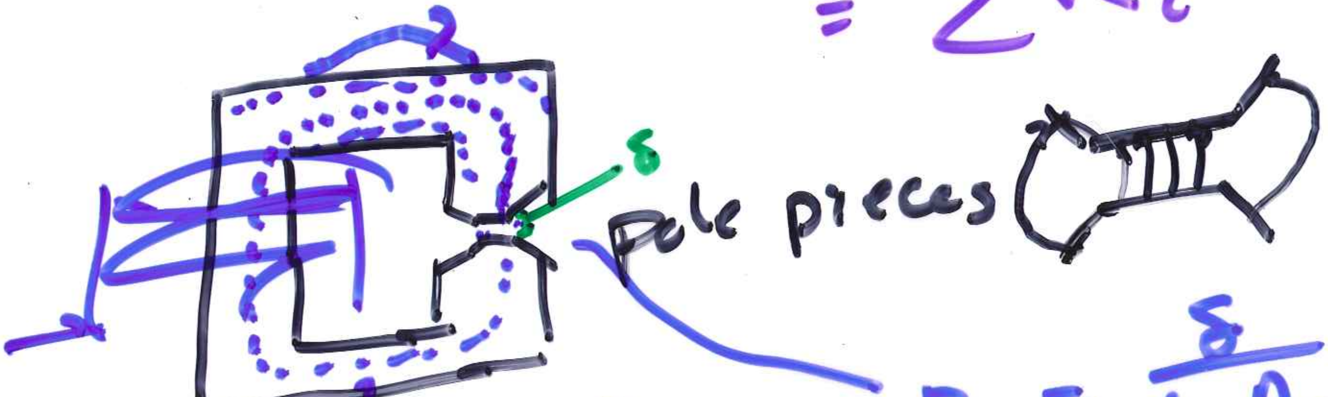
$$\underset{\underset{\text{"current"}}{\uparrow}}{\phi}\;\underbrace{\oint \frac{dl}{\mu A}}_{R} = N\underset{\underset{\text{"V"}}{\uparrow}}{I}$$

Reluctance



$$S \quad \oint \frac{dl}{\mu A} = \sum \frac{l_i}{\mu_i A_i}$$

$$= \sum R_i$$



$$R_i = \frac{l}{\mu_r A}$$

$$R_g = \frac{\delta}{\mu_0 A_g}$$

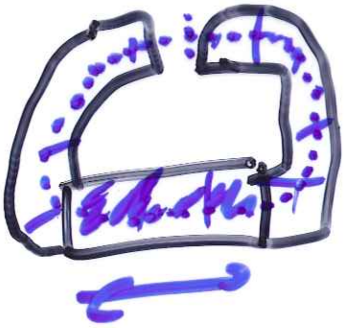
$$NI = (R_i + R_g)\phi$$

$$R_g >> R_i$$

$$NI = \frac{\delta}{\mu_0 \cancel{A}} B \cancel{A}$$

$$\mu_0 \frac{N}{\delta} I = B$$

$$B = \mu \frac{N}{l} I$$



$$\oint H \cdot dl = 0$$

$$\shortparallel$$

$$H_{pm} l_{pm} + \Phi R \leftarrow \frac{\overrightarrow{S}}{\mu A}$$

$$\uparrow$$

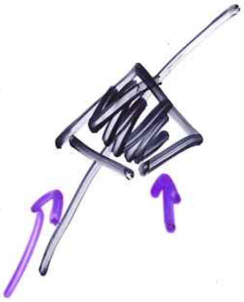
$$B A$$

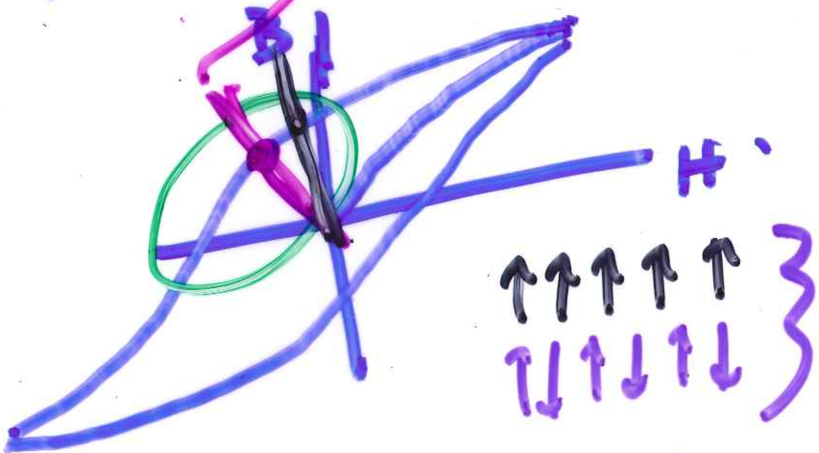
$$\shortparallel$$

$$B_{pm} A_{pm}$$

$$B_{pm} = -\frac{l_{pm}}{R A_{pm}} H_{pm}$$

$$\uparrow$$





- → Diamagnetic $\chi < 0$

- → Paramagnetic

$\chi > 0$

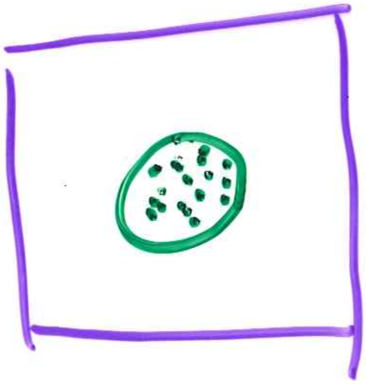
- → Ferromagnetic
  - → Antiferrous - Curie Temp
- → Ferrites ← χ

↑↓↑↓↑↓↑↓

g shell

→ E_m

$$E - E_p + \overset{0}{\sum} \frac{1}{r^3}$$



B_M

↑

$\frac{2}{3} \mu_0 \underline{M}$

$B ; B_m$

$\underline{\chi \sim 10^{-4}}$

Colomb

$\underline{1820}$ — Biot-Savart

$$B = \mu_0 \oint \frac{I\, d\vec{l} \times (r-r')}{|r-r'|^3}$$

Ch 11 Induction. → Faraday ; Henry

Lenz

1860 ← Maxwell

Scott

↕

1890 → Herz

→ 1900

Higgs

1967 Weinberg

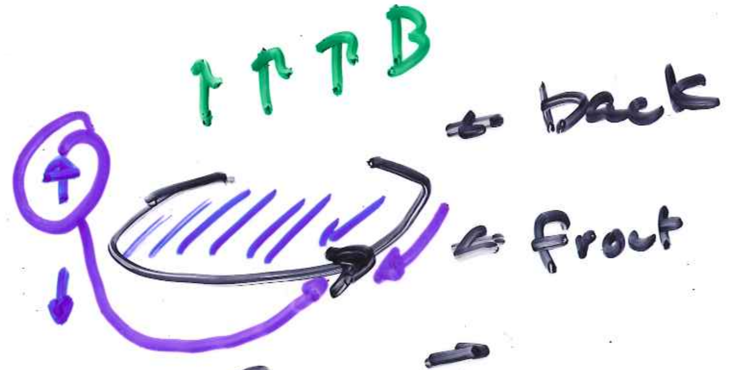
1976 Charm quark

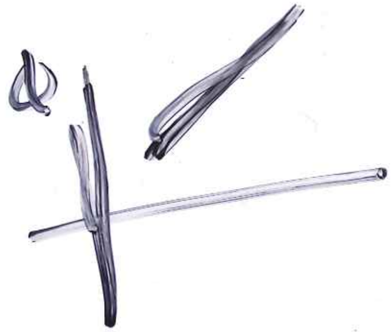
Induction

$E \to V \to I \to B$ (with a return arrow from B to E)

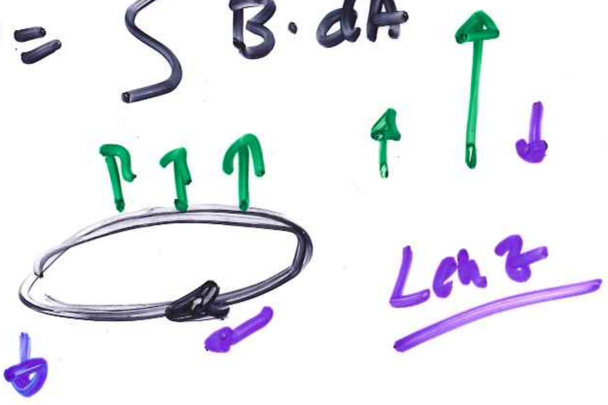
$$-\frac{d}{dt}\Phi_M = \mathcal{E}$$

$$= \oint \vec{E}\cdot d\vec{l}$$





$$\phi = \int B\cdot d\vec{A}$$



$$-\frac{d}{dt}\int B\cdot d\underset{\uparrow}{A} = \oint E\cdot d\vec{l}$$

$$= \int \overline{\nabla\times E}\cdot d\underset{\uparrow}{A}$$

$\nabla\times A$

$$-\nabla\phi \quad -\frac{d}{dt}B = \nabla\times E \underset{\uparrow}{=} 0$$

Static

$$\nabla\times(\overbrace{E+\partial_t A}) = 0$$

$$E \neq -\nabla\phi$$

$$E = -\nabla\phi - \overbrace{\partial_t A}^{B_{\text{chan}}}$$