with dielectrics your knee-jerk reaction: $\varepsilon_0 \to \varepsilon$

(but don't go too far: Gauss is either

$$\oint \vec{E}\cdot d\vec{A} = \frac{Q_{total}}{\varepsilon_0} \quad \text{or} \quad \oint \vec{D}\cdot d\vec{A} = Q_f \quad \text{NOT} \quad \oint \vec{E}\cdot d\vec{A} = \frac{Q}{\varepsilon}\;)$$

similarly $\mu_0 \to \mu$ is <u>usual</u>

Note: for dielectrics we often had only σ_B

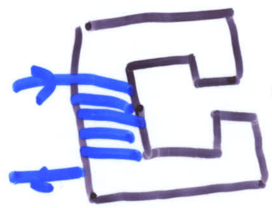
as: $\rho_B = -\nabla\cdot P = -\nabla\cdot\varepsilon_0\chi E = -\frac{\chi}{K}\nabla\cdot D = -\frac{\chi}{K}\rho_f$

and ρ_f was often zero inside dielectric

Similarly: $J_B = \nabla\times M = \chi\nabla\times H = \chi J_f$

and J_f is often zero inside magnetic material

Magnetic Circuits



← gap; δ

flux $\approx BA$

$$\oint \vec{H}\cdot d\vec{l} = \underbrace{NI}_{\text{"V"}} = \oint \frac{\vec{B}}{\mu}\cdot d\vec{l} = \underbrace{\phi}_{\text{"I"}} \int \frac{dl}{\mu A} = \phi\, \underbrace{R_{tot}}_{\substack{\text{reluctance} \\ \text{"R"}}}$$

$R_{tot} = \sum \frac{l_i}{\mu_i A_i}$; if dominated by gap $\hookrightarrow B = \mu_0 \frac{N}{\delta} I$

"flux return" → gap = ∞ solenoid

PM $\quad H_{pm} l_{pm} = -\phi R = -B_{pm} A_{pm} R$

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

"Keeper"

Note: Eqs not exact due to uncertainty l, μ, A

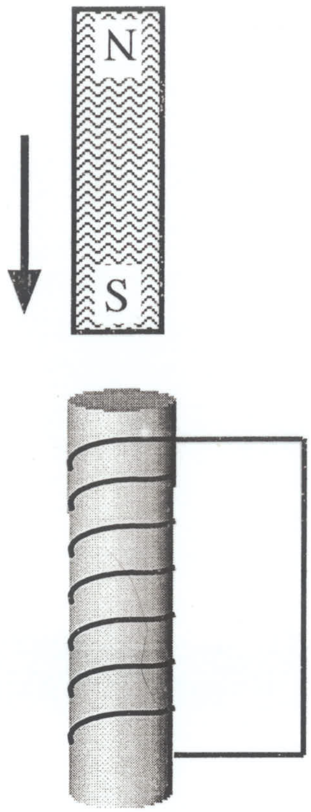
Induction: $-\frac{d}{dt}\phi = -\frac{d}{dt}\int \vec{B}\cdot d\vec{A} = \mathcal{E} = \oint E\cdot dl$

$= \int \nabla\times E\cdot dA$

$\therefore -\partial_t B = \nabla\times E$

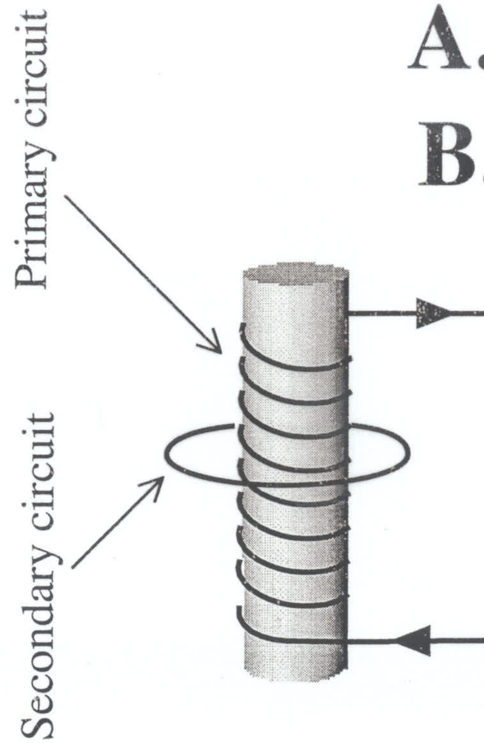
signs!

$E = -\nabla\phi - \partial_t A$



The sorth pole of a bar magnet is approaching the solenoid

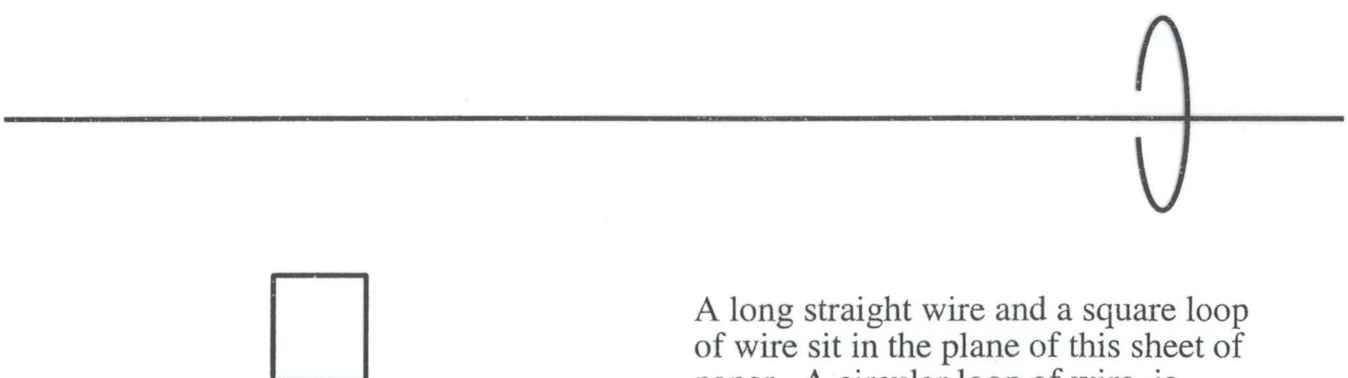
A. Up **B.** Down



A. Left

B. Right

The current shown flowing through the primary circuit is increasing



A. Clockwise

B. CCW

A long straight wire and a square loop of wire sit in the plane of this sheet of paper. A circular loop of wire is centered on the long wire, but sits in a plane perpendicular to this sheet of paper. For several minutes there has been no current flowing in any wire. A battery (not shown) is connected and a current starts to flow to the right through the long straight wire.

$$\bar B = \sum \bar B_i \propto \sum \underline{\underline{I}}_i$$

$$\phi = \int B \cdot dA$$

inductance

$$\phi_i = \sum M_{ij} I_j$$

$$M_{ii} = L_i$$

self inductance

mutual inductance

$$B(\bar r_2) = \frac{\mu_0 I_1}{4\pi} \int d\bar r_1 \times \frac{(\overline{r_2 - r_1})}{|\overline{r_2 - r_1}|^3}$$

$$= \nabla_2 \times A_2 \quad \frac{\mu_0 I}{4\pi} \int \frac{d\bar r_1}{|r_2 - r_1|}$$

$$\phi_2 = \int_{S_2} B(r_2) \cdot dA_2$$

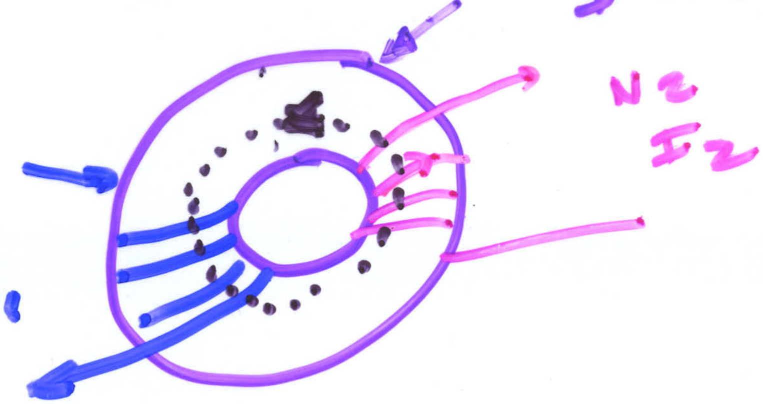
$$M_{21} = \frac{\phi_2}{I_1} = \frac{\mu_0}{4\pi} \int B(\bar r_2) \cdot dA_2$$

$$= \frac{\mu_0}{4\pi} \int \nabla_2 \times \oint_1 \frac{d\bar r_1}{|\overline{r_2 - r_1}|} \cdot dA_2$$

$$= \frac{\mu_0}{4\pi} \oint_2 \oint_1 \frac{d\bar{r}_1}{|r_2 - r_1|} \cdot d\bar{r}_2$$

$$= M_{12}$$

$$L_1 = M_{11}$$



$$\oint \bar{H} \cdot d\bar{l} = N_1 I_1 + N_2 I_2$$

" " average "

$H \, 2\pi r \quad l \rightarrow \frac{Bl}{\mu}$

$\frac{B}{\mu}$

$$B = \frac{\mu}{l} (N_1 I_1 + N_2 I_2)$$

flux 1 loop = $\underline{BA} = \int B \, dA$

$$\phi_1 = N_1 B A = \frac{\mu A}{l} (N_1^2 I_1 + N_1 N_2 I_2)$$

$$L_1 = \frac{A\mu}{l} N_1^2 \qquad M_{12} = \frac{\mu A}{l} N_1 N_2$$

$$\phi_2 \Rightarrow L_2 = \frac{A\mu}{l} N_2^2 \qquad M_{21} =$$

$$M_{21} = k\sqrt{L_1 L_2}$$

$$-1 \leftarrow 0 \rightarrow 1$$

$$\mathcal{E}_2 = -\frac{d\Phi_2}{dt} = -L_2\frac{dI_2}{dt} - M_{21}\frac{dI_1}{dt}$$

emf = V

$$\mathcal{E}_1 = -L_1\frac{dI_1}{dt} - M_{12}\frac{dI_2}{dt}$$

$$I_2 = 0$$

$$\frac{\mathcal{E}_2}{\mathcal{E}_1} = \frac{-M_{12}\frac{dI_1}{dt}}{-L_1\frac{dI_1}{dt}} = \frac{N_1 N_2}{N_1^2} = \frac{N_2}{N_1}$$

Tranformer

non-linear.

$\mathcal{E}_2 \gg \mathcal{E}_1$

$N_2 \gg N_1$

$\frac{1}{2}B\cdot D$

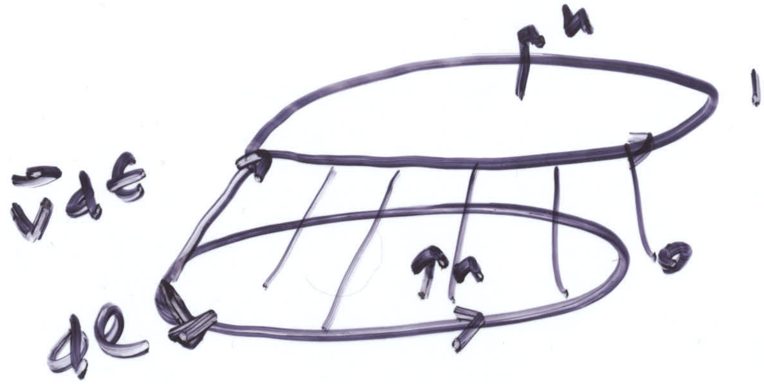
I

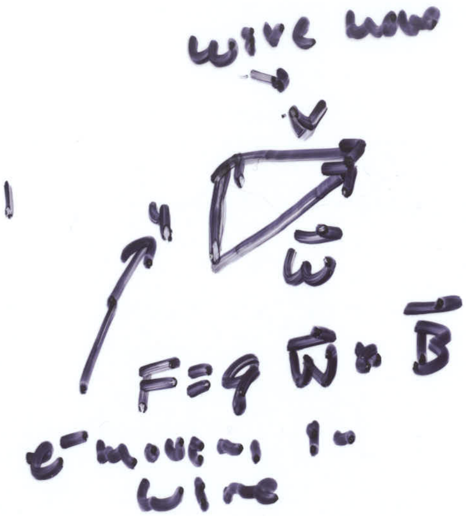
$\frac{1}{2}B\cdot ct$

Ferrites

Eddy Currents

Motional Emf.





$\Delta\phi$

$$\phi_1 = \phi_0 + \text{ribbon} \underbrace{\overline{dA}}_{\vec{v} \times \vec{dl}\, dt}$$

$$d\phi = \int B \cdot \underset{\substack{\uparrow \\ \vec{w} \\ ?}}{\vec{v}} \times \vec{dl}\, dt$$

$$v = w - u$$

$$u \times dl = 0$$

$$= \int B \cdot \vec{w} \times d\vec{l}\, dt$$

$$= \int (B \times \vec{w}) \cdot dl$$

$$= -\int (w \times B) \cdot d\vec{l}$$

$$-\frac{d\phi}{dt} = \int \underset{\uparrow\ \text{force/charge}}{f} \cdot dl = \mathcal{E}$$