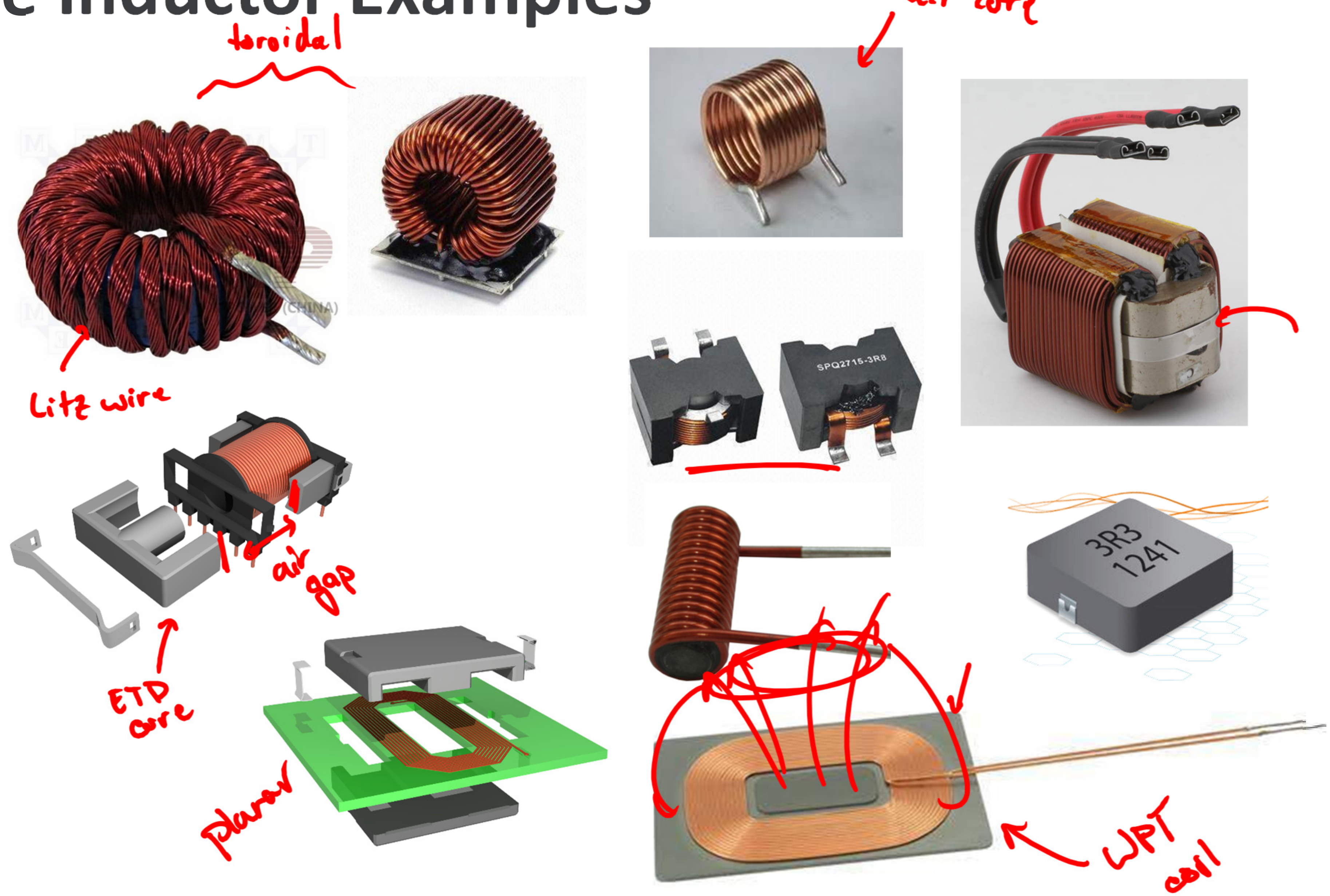
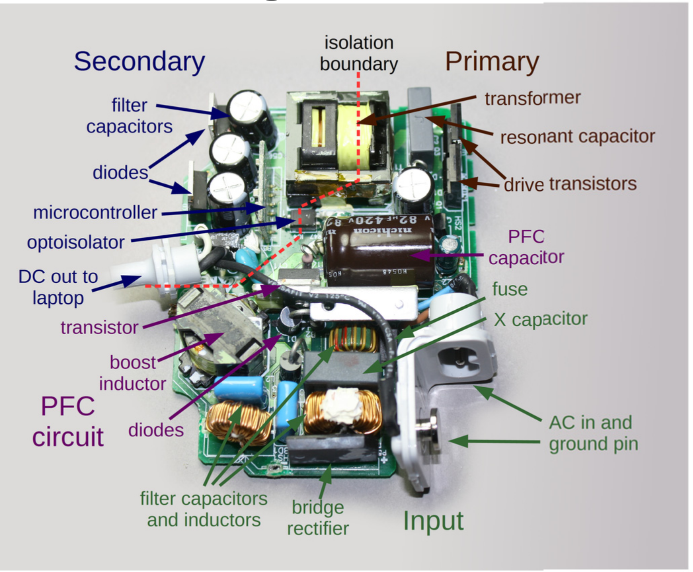
Part III: Magnetics

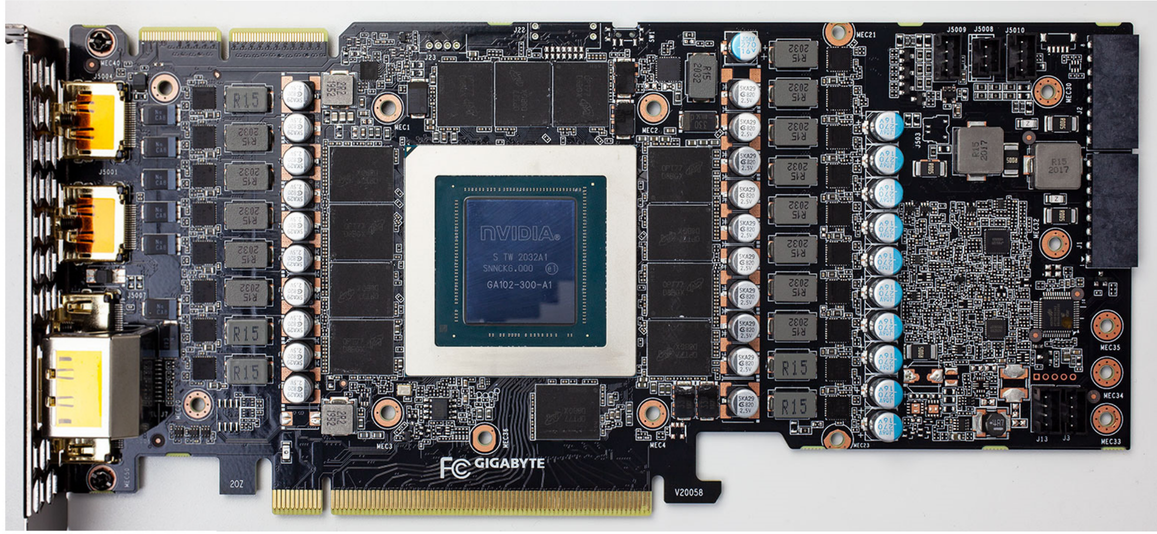
- Ch 10 Basic Magnetics Theory
- Ch 11 Inductor Design
- Ch 12 Transformer Design
  - Ch. 13-15 in 2nd edition

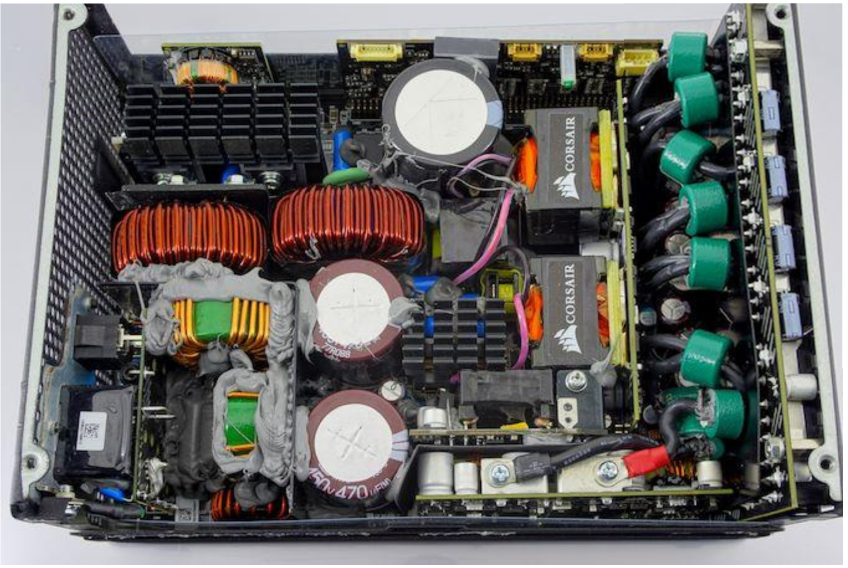
Some Inductor Examples

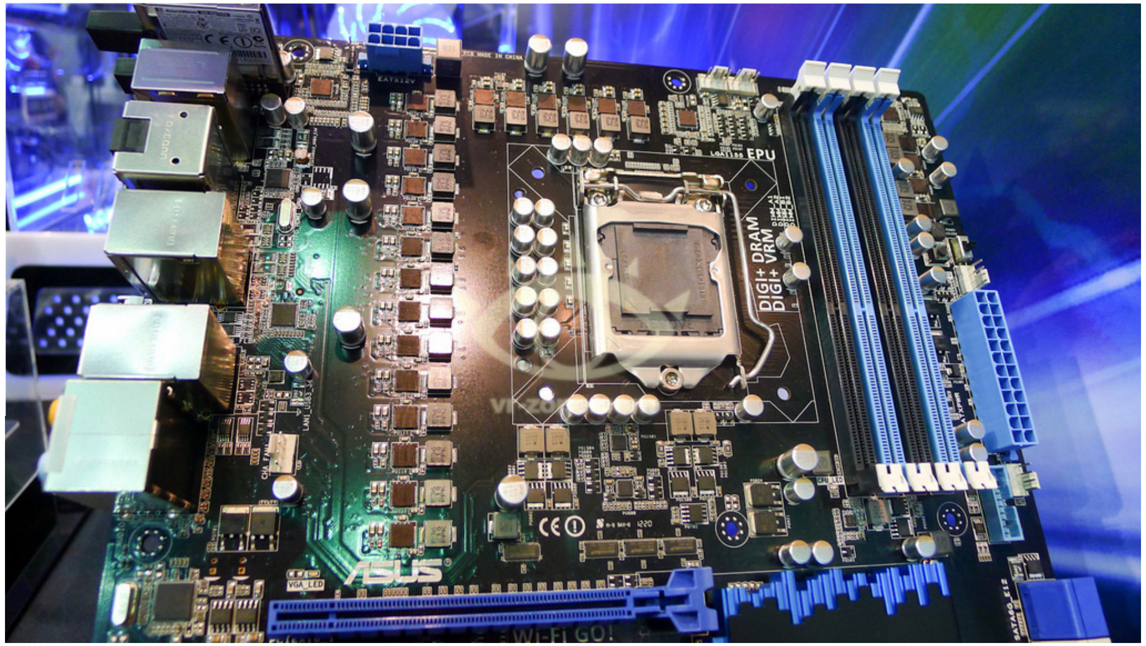


Example Power Converters

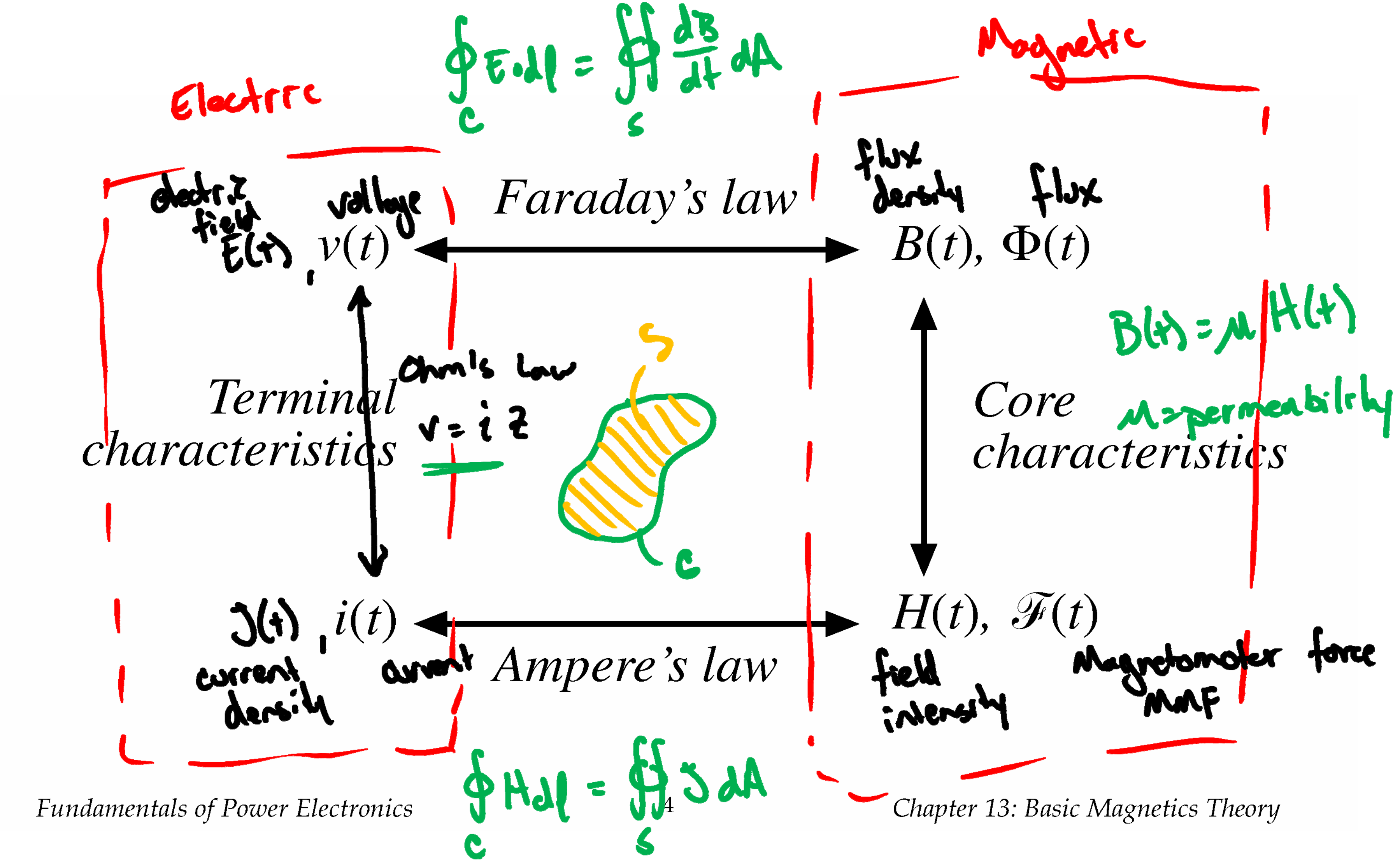






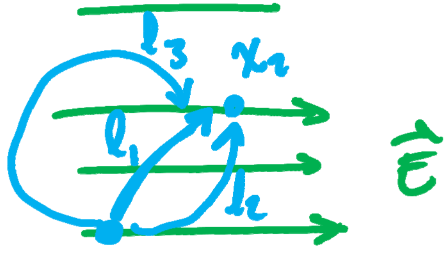


Basic Magnetics Relationships



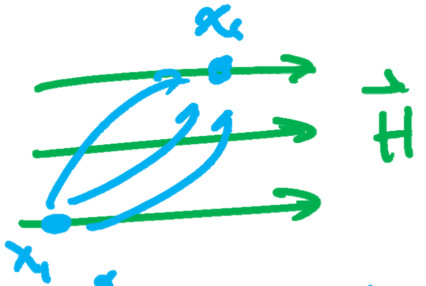
Electric/Magnetic Duals

Electric



$$\int_{x_1}^{x_2} \vec{E}\, dl = V_{x_2,x_1}$$

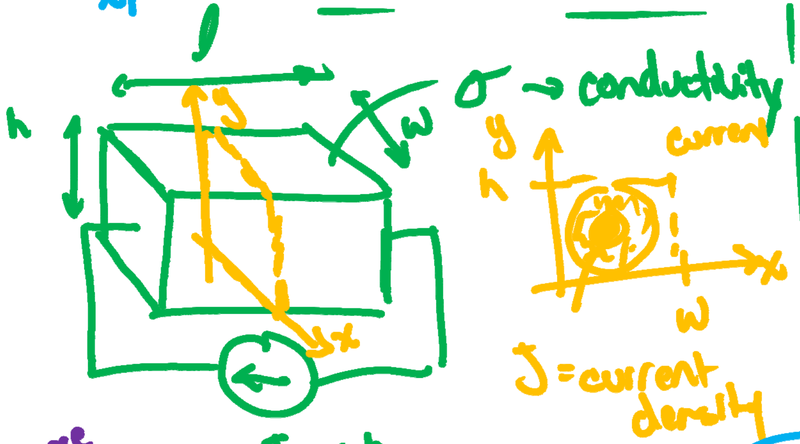
Magnetic



$$\int_{x_1}^{x_2} H\, dl = \mathcal{F}_{x_2,x_1}$$

$E \leftrightarrow H$

$V \leftrightarrow \mathcal{F}$



I

$$\int_0^w\int_0^h J\, dy\, dx = I$$

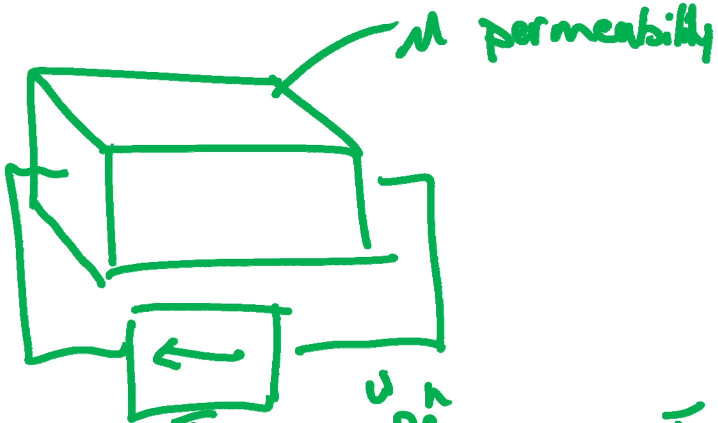
resistance

$$R = \frac{1}{\sigma}\frac{l}{hw}$$

$J \leftrightarrow B$

$I \leftrightarrow \Phi$

$R \leftrightarrow \mathcal{R}$



Φ

$$\int_0^w\int_0^h B\, dy\, dx = \Phi$$

reluctance

$$\mathcal{R} = \frac{1}{\mu}\frac{l}{hw}$$

Faraday's Law

$$V_{turn} = \oint_C E \cdot dl = \iint_S \frac{dB}{dt} dA = \frac{d\Phi(t)}{dt} = \frac{dB(t)}{dt} A_c$$

Voltage $v(t)$ is induced in a loop of wire by change in the total flux $\Phi(t)$ passing through the interior of the loop, according to

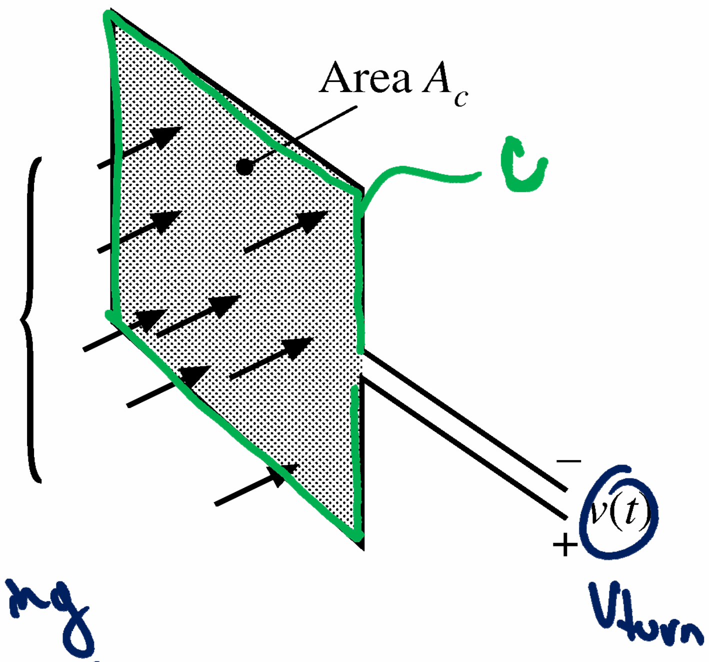
$$v(t) = \frac{d\Phi(t)}{dt}$$

For uniform flux distribution, $\Phi(t) = B(t)A_c$ and hence

$$\boxed{v(t) = A_c \frac{dB(t)}{dt}}$$

Vturn

simplifying assumption



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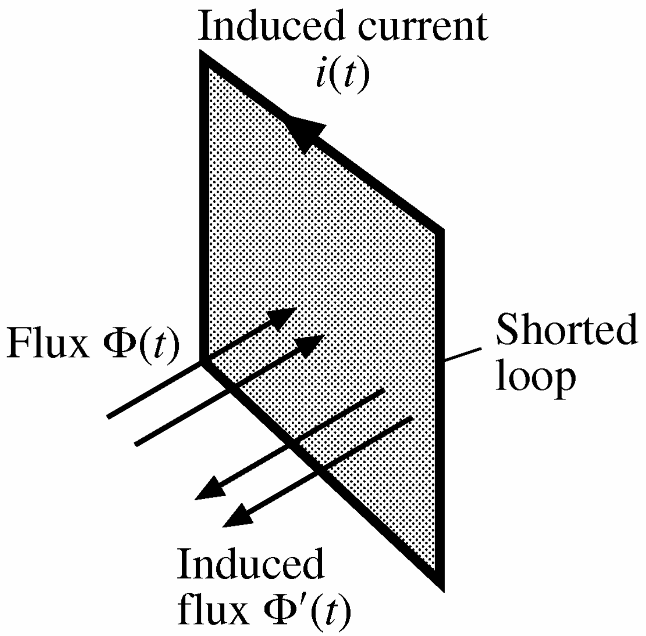
Lenz's Law

Right hand rule

The voltage $v(t)$ induced by the changing flux $\Phi(t)$ is of the polarity that tends to drive a current through the loop to counteract the flux change.

Example: a shorted loop of wire

- Changing flux $\Phi(t)$ induces a voltage $v(t)$ around the loop
- This voltage, divided by the impedance of the loop conductor, leads to current $i(t)$
- This current induces a flux $\Phi'(t)$, which tends to oppose changes in $\Phi(t)$



Ampere's Law

$$\mathcal{F} = H l_m = \oint_c H \cdot dl = \oiint_s J\, dA = I_{enclosed} = i(t)$$

The net MMF around a closed path is equal to the total current passing through the interior of the path:

$$\oint_{\text{closed path}} \boldsymbol{H} \cdot d\boldsymbol{\ell} = \text{total current passing through interior of path}$$

Example: magnetic core. Wire carrying current $i(t)$ passes through core window.

- Illustrated path follows magnetic flux lines around interior of core
- For uniform magnetic field strength $H(t)$, the integral (MMF) is $H(t)\ell_m$. So

$$\boxed{\mathcal{F}(t) = H(t)\ell_m = i(t)}$$

simplifying assumption