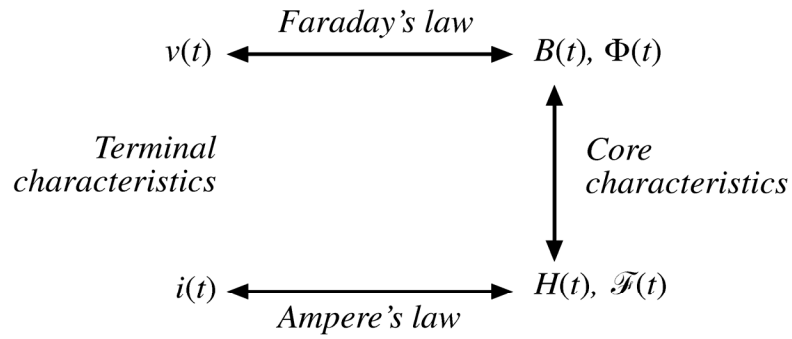


Basic Magnetics Relationships



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Chapter 13: Basic Magnetics Theory

Electric/Magnetic Duals

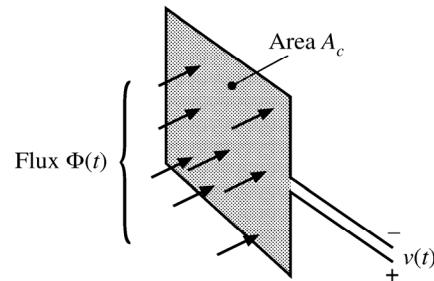
Faraday's Law

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

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

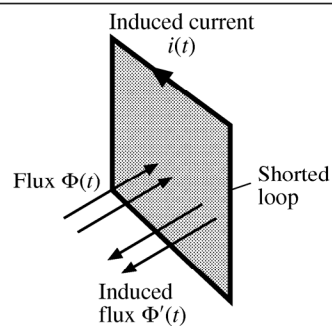


Lenz's Law

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

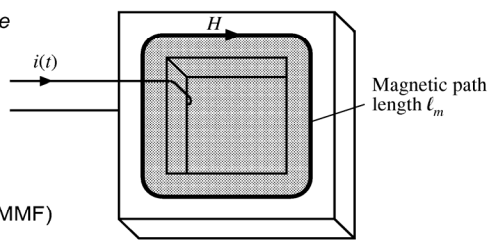
The net MMF around a closed path is equal to the total current passing through the interior of the path:

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

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

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

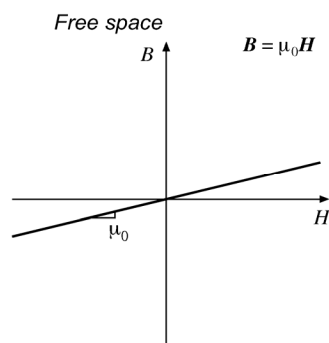


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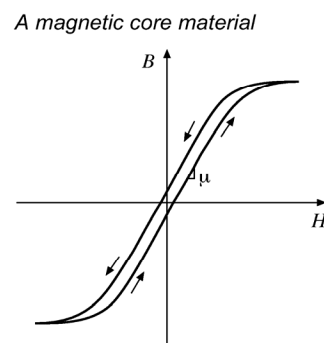
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Chapter 13: Basic Magnetism Theory

Core Material Characteristics



μ_0 = permeability of free space
= $4\pi \cdot 10^{-7}$ Henries per meter



Highly nonlinear, with hysteresis and saturation

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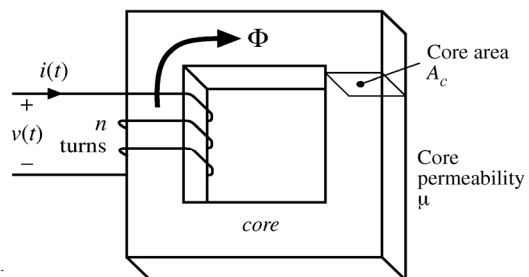
Chapter 13: Basic Magnetism Theory

Units

Table 12.1. Units for magnetic quantities

quantity	MKS	unrationalized cgs	conversions
core material equation	$B = \mu_0 \mu_r H$	$B = \mu_r H$	
B	Tesla	Gauss	$1\text{T} = 10^4\text{G}$
H	Ampere / meter	Oersted	$1\text{A/m} = 4\pi \cdot 10^{-3}\text{ Oe}$
Φ	Weber	Maxwell	$1\text{Wb} = 10^8\text{ Mx}$ $1\text{T} = 1\text{Wb} / \text{m}^2$

Inductor Example



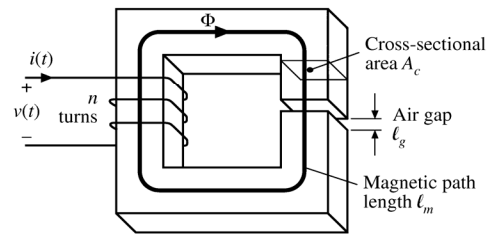
Magnetic Circuits



Inductor Magnetic Circuit Model



Example: Gapped Inductor



Gapped Inductor Magnetic Circuit

Effect of Air Gap

$$ni = \Phi (\mathcal{R}_c + \mathcal{R}_g)$$

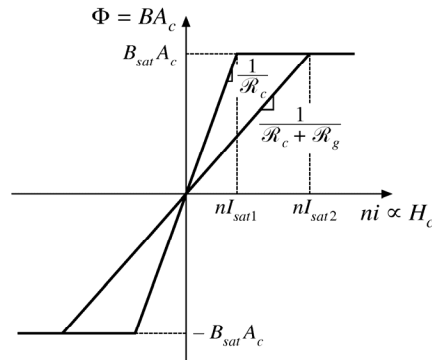
$$L = \frac{n^2}{\mathcal{R}_c + \mathcal{R}_g}$$

$$\Phi_{sat} = B_{sat} A_c$$

$$I_{sat} = \frac{B_{sat} A_c}{n} (\mathcal{R}_c + \mathcal{R}_g)$$

Effect of air gap:

- decrease inductance
- increase saturation current
- inductance is less dependent on core permeability



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Chapter 13: Basic Magnetics Theory

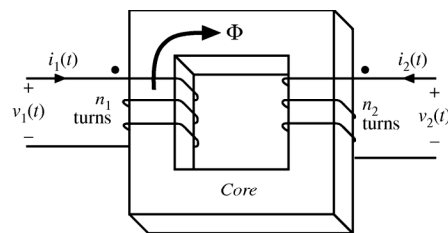
Transformer Example

Two windings, no air gap:

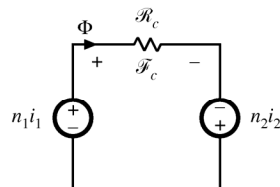
$$\mathcal{R} = \frac{\ell_m}{\mu A_c}$$

$$\mathcal{F}_c = n_1 i_1 + n_2 i_2$$

$$\Phi \mathcal{R} = n_1 i_1 + n_2 i_2$$



Magnetic circuit model:



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