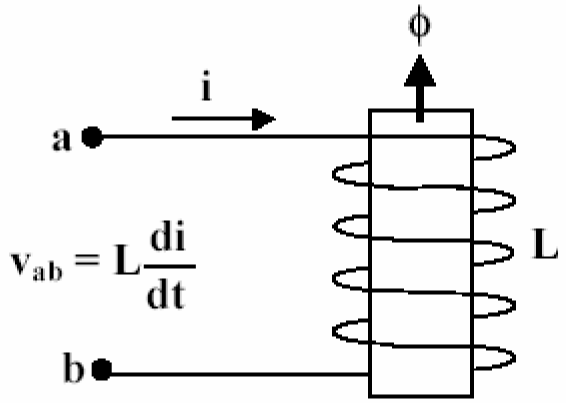
Coupled Circuits

Consider a coil around a magnetic core. If a current i flows through the coil, a flux ϕ is generated in the core.



$$\phi = \frac{1}{R_m} N\, i$$

where:
i = current through the coil
N = number of turns in the coil
R_m = constant known as reluctance
(depends on the magnetic path of the flux)

The direction of the flux can be determined by the Right-Hand Rule.

Fingers curled around coil – direction of current
Thumb – direction of flux

Reluctance, $R_m = \frac{l}{\mu . A}$ **AT/wb, where**

l = length of magnetic path
A = x-section area
μ **= permeability**

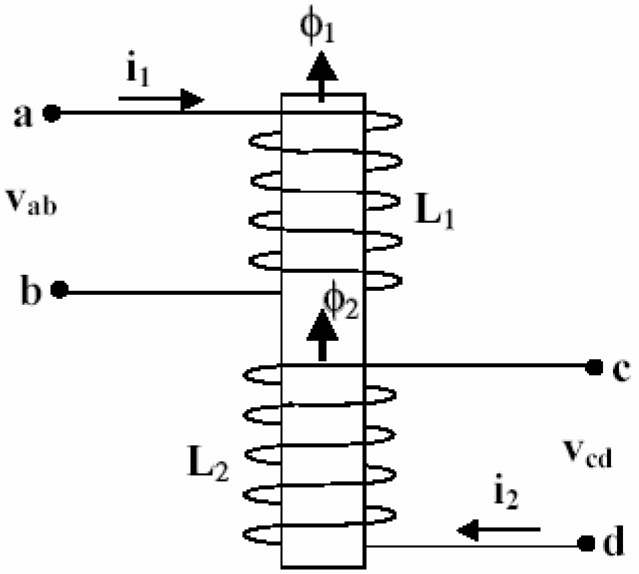
Flux Density, $B = \frac{\phi}{A}$ **wb/m²**

Magnetizing Force, $H = \frac{N.I}{l}$ **ampere turns/metre**

$B = \mu H$

Coupled Circuits - circuits that affect each other by mutual magnetic fields.

The flux ϕ_2 generated by current i_2 in Coil 2 induces a voltage in Coil 1, and vice-versa.



$$v_{ab} = L_1\frac{di_1}{dt} \pm L_{12}\frac{di_2}{dt}$$

$$v_{cd} = L_2\frac{di_2}{dt} \pm L_{21}\frac{di_1}{dt}$$

Self inductance L_1, L_2

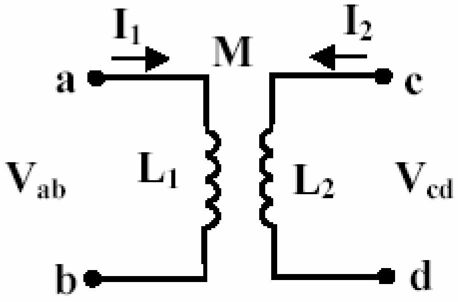
Mutual Inductance $M = L_{12} = L_{21}$

ratio of induced voltage in one circuit to the rate of change of current in another circuit

± depending on whether the fluxes add or oppose each other.

Coupled Circuit in Phasors

If input signals are sinusoidal waveforms,



$$V_{ab} = (j\omega L_1)\, I_1 \pm (j\omega M)\, I_2$$

$$V_{cd} = (j\omega L_2)\, I_2 \pm (j\omega M)\, I_1$$

± i.e. + or - depending on flux directions

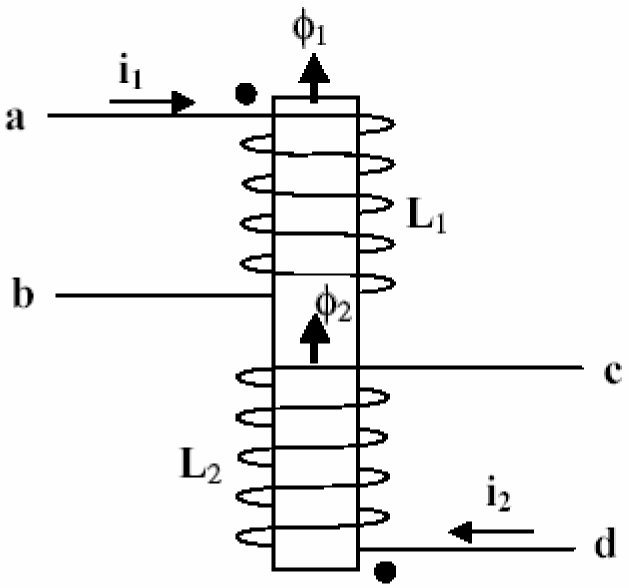
Determined by <u>Dot Convention</u>

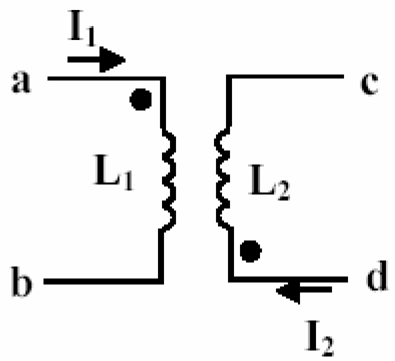
Dot Convention

➢ Place dots at one end of each coil, so that currents entering the dots produce fluxes that add each other.

➢ Use (+) sign in the equations if both currents enter the dotted terminals (or the undotted terminals).

➢ Use (-) sign in the equations if one current enters a dotted terminal and the other current enters an undotted terminal.





currents entering the dots produce upward fluxes

The dots provide information on how the coils are wound with respect to each other.

Rule:

A current i entering a dotted terminal in one coil induces a voltage $M\frac{di}{dt}$ with a positive polarity at the dotted terminal of the other coil.

M = mutual inductance

Coefficient of Coupling, k

$$k = \frac{M}{\sqrt{L_{11}L_{22}}} \qquad 0 \le k \le 1$$

k depends on the magnetic properties of the flux path.

When	**k = 0,**	**no coupling**
	k = 0.01 to 0.1,	**loose coupled**
	k ≈ 0.5,	**close coupled, e.g. air core**
	k ≈ 1.0,	**e.g. power transformer all the flux generated by one coil is linked to the other coil (i.e. no leakage flux)**