Institut Megatech College of Technology

DEPARTMENT OF ENGINEERING & COMPUTING

# Unit 5:
# Electrical & Electronic Principles

Higher National Diploma in Electrical & Electronic Engineering

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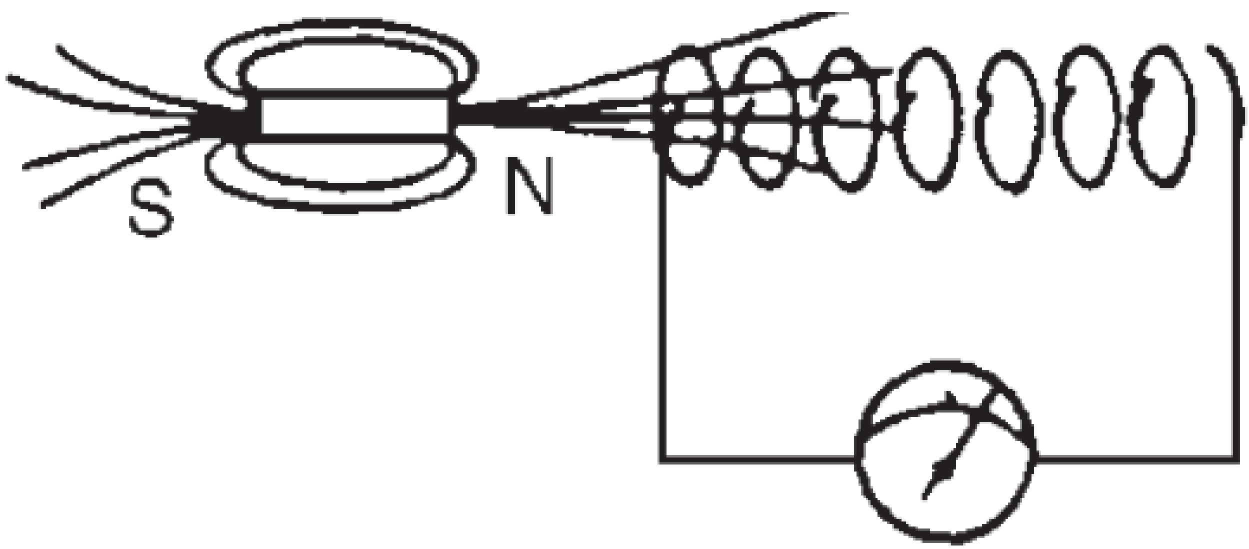
Outcome 1: Investigate Circuit Theory

# Criteria 1.3 :
# Analyse the Operation of Magnetically Coupled Circuits

# Electromagnetic Induction

• When a conductor is moved across a magnetic field so as to cut through the lines of force (or flux), an electromotive force (e.m.f.) is produced in the conductor.

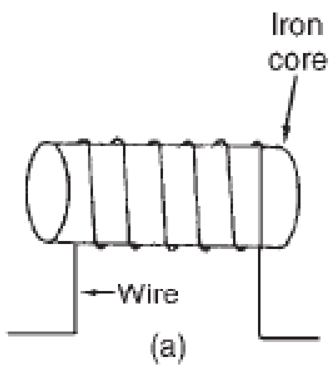


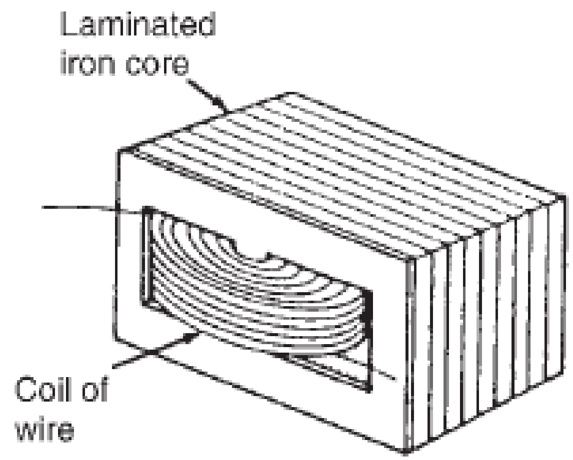
# Rules

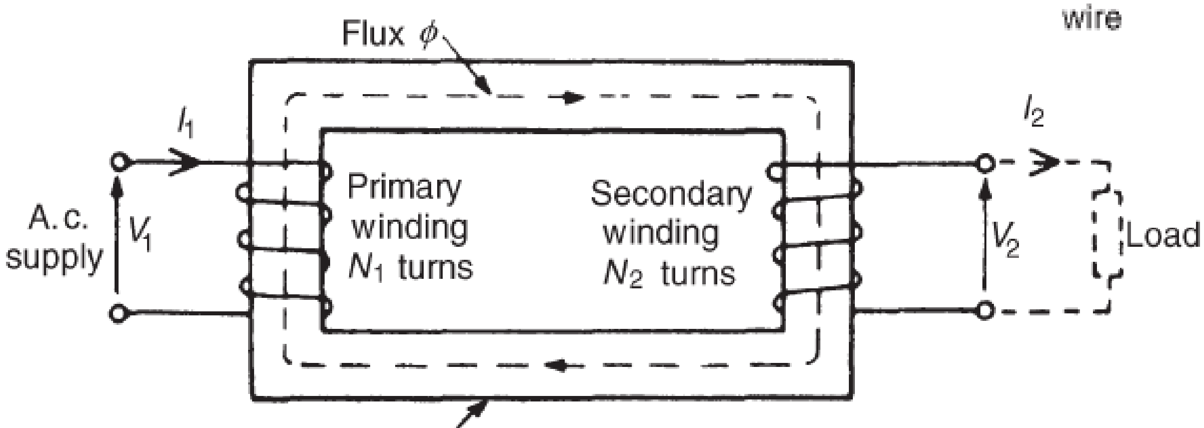
**Faraday's laws of electromagnetic induction state:**
*(i) 'An induced e.m.f. is set up whenever the magnetic field linking that circuit changes.'*
*(ii) 'The magnitude of the induced e.m.f. in any circuit is proportional to the rate of change of the magnetic flux linking the circuit.'*

**Lenz's law states:**
'*The direction of an induced e.m.f. is always such that it tends to set up a current opposing the motion or the change of flux responsible for inducing that e.m.f.'.*

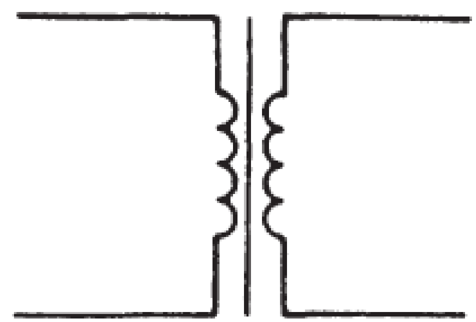
# Magnetically Coupled Circuits




Transformer



Symbol

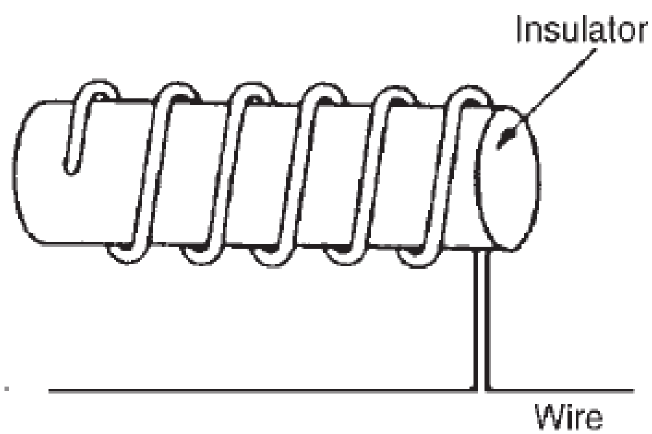
# Self-Inductance

$$E = -L\frac{di}{dt} \text{ volts}$$

$\frac{di}{dt}$ *is the rate of change of curent*

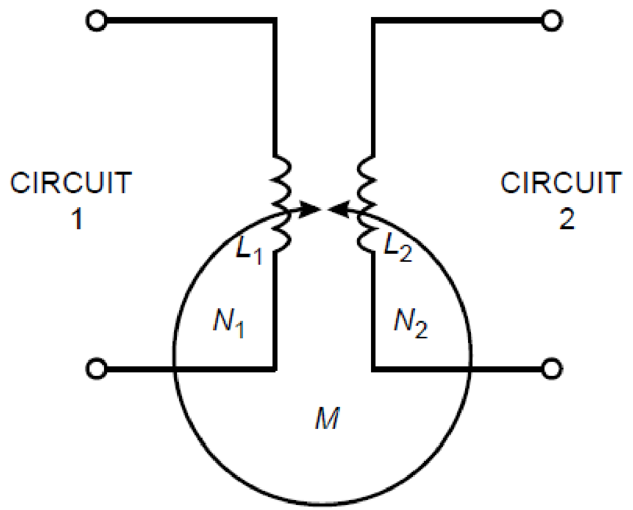
$$E = -N\frac{d\Phi}{dt} \text{ volts}$$

$\frac{d\phi}{dt}$ *is the rate of change of flux*




$$L = \frac{N\Phi}{I} \text{ henrys}$$

# Mutual-Inductance




$$E_2 = -M\frac{dI_1}{dt} \quad \text{or} \quad E_1 = -M\frac{dI_2}{dt}$$

***$E_1$ – EMF induced at Circuit 1***
***$E_2$ – EMF induced at Circuit 2***
***M - Mutual Inductance between two circuits***

$$M = N_2\frac{d\Phi_2}{dI_1} \;\; \textit{and} \;\; M = N_1\frac{d\Phi_1}{dI_2}$$

# Coupling Coefficient

• The coupling coefficient k is the degree or fraction of magnetic coupling that occurs between circuits.

$$k = \frac{\text{flux linking two circuits}}{\text{total flux produced}} \qquad \textbf{coefficient of coupling, } k = \frac{M}{\sqrt{(L_1 L_2)}}$$

• If there is no magnetic coupling, $k = 0$.

• If the magnetic coupling is perfect (all the flux produced in the primary links with the secondary, $k = 1$

• **tightly coupled -** most of the flux produced by current in one coil passes through the other

• **loosely-coupled - If the coils are spaced** apart, only a part of the flux links with the second, and the coils are termed

# Exercise 1

Two coils have self inductances of 250 mH and 400 mH respectively. Determine the magnetic coupling coefficient of the pair of coils if their mutual inductance is 80 mH.

From coupling coefficient equation,

$$k = \frac{M}{\sqrt{(L_1 L_2)}} = \frac{80 \times 10^{-3}}{\sqrt{[(250 \times 10^{-3})(400 \times 10^{-3})]}} = \frac{80 \times 10^{-3}}{\sqrt{(0.1)}} = \mathbf{0.253}$$

# Exercise 2

Two coils, X and Y, having self inductances of 80 mH and 60 mH respectively, are magnetically coupled. Coil X has 200 turns and coil Y has 100 turns. When a current o in coil X the change of flux in coil Y is 5 mWb. Determine (a) the mutual inductance between the coils, and (b) the coefficient of coupling.

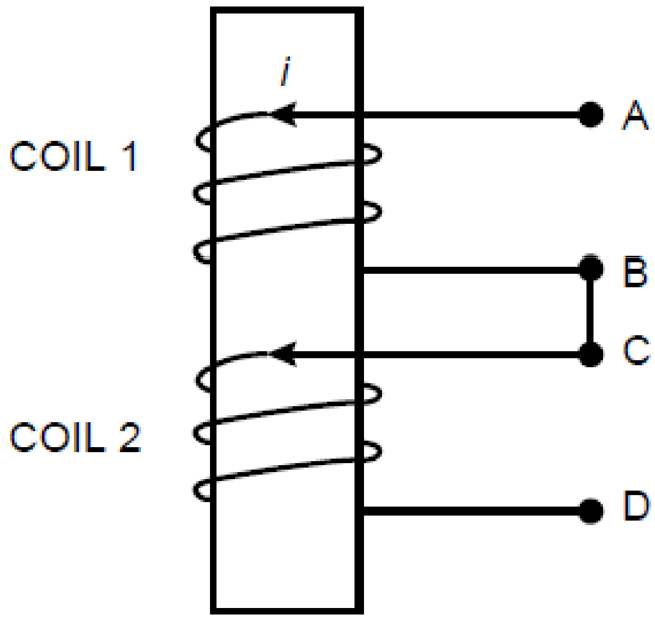
$$\boldsymbol{M} = N_Y \frac{d\Phi_Y}{dI_X} = \frac{(100)(5 \times 10^{-3})}{(4 - -4)}$$

$$= \mathbf{0.0625\ H} \text{ or } \mathbf{62.5\ mH}$$

$$\boldsymbol{k} = \frac{M}{\sqrt{(L_X L_Y)}}$$

$$= \frac{0.0625}{\sqrt{[(80 \times 10^{-3})(60 \times 10^{-3})]}} = \mathbf{0.902}$$

# Coils Connected in Series



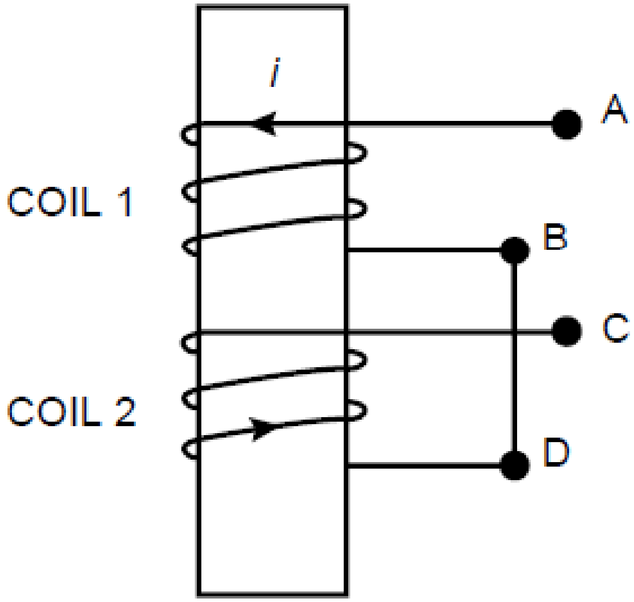

If the winding between terminals A and D are considered as a single circuit having a self inductance $L_A$ henrys then if the same increase in $dt$ *seconds is* $di$ *amperes then the e.m.f. induced in the* complete circuit is

$$L_A \frac{di}{dt} = (L_1 + L_2 + 2M)\frac{di}{dt}$$

$$\mathbf{L_A = L_1 + L_2 + 2M}$$

$$L_1 \frac{di}{dt} + L_2 \frac{di}{dt} + 2\left(M \frac{di}{dt}\right) \text{ volts} = (L_1 + L_2 + 2M)\frac{di}{dt} \text{ volts}$$

# Coils Connected in Series



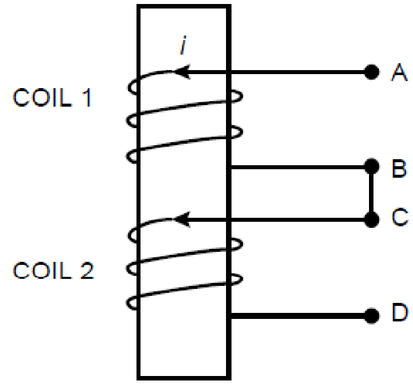

$$L_1\frac{di}{dt} + L_2\frac{di}{dt} - 2M\frac{di}{dt}$$

If the winding between terminals A and D are considered as a single circuit having a self inductance $L_B$ henrys then if the same increase in $dt$ *seconds is* $di$ *amperes then the e.m.f. induced in the* complete circuit is

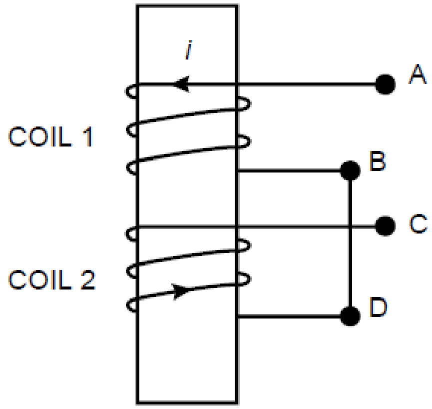
$$L_B\frac{di}{dt} = L_1\frac{di}{dt} + L_2\frac{di}{dt} - 2M\frac{di}{dt}$$

$$\mathbf{L_B = L_1 + L_2 - 2M}$$

# Coils Connected in Series




$$L_A = L_1 + L_2 + 2M$$




$$L_B = L_1 + L_2 - 2M$$

The total inductance *L* of inductively coupled circuits

$$L = L_1 + L_2 \pm 2M$$