Module 3 : Magnetic Circuits 4 Hrs

Electromagnetic Induction: **Self and mutual; Magnetically coupled circuits;** Series and parallel magnetic circuits; Dot convention

Course Outcome (CO2)

Analyze the parameters of magnetically coupled circuits and compare various types of electrical machines

Concept of magnetic circuit

Magnetic Circuit Terminology:

- Magnetic flux (ϕ)
- Magnetic flux density (B)
- Magnetic field intensity (H)
- Magneto Motive Force (mmf)
- Reluctance S (or R_m)
- Permeability (P)
- Magnetization curve

Concept of magnetic circuit

- Reluctance = mmf/flux
- Flux density = flux/unit area
- Series magnetic circuit
- Parallel magnetic circuit
- B-H curve
- Magnetic leakage
- Leakage co-efficient = total flux/useful flux
- Relative permeability

Electric vs Magnetic circuit

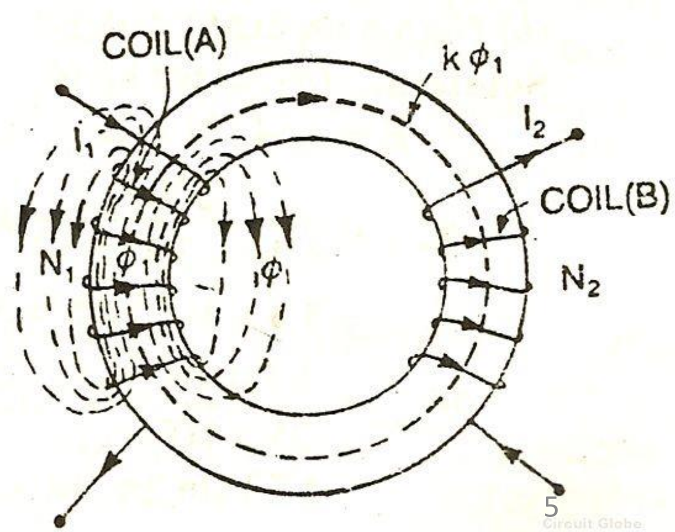
Electric Circuit	Magnetic Circuit
e.m.f. E (V)	m.m.f. F_m (AT)
current I (A)	flux Φ (Wb).
resistance R (Ω)	reluctance S (H^{-1})
$R = \rho l / A$	$S = l / \mu_0 \mu_r A$
$I = E / R$	$\Phi = mmf / S$

Leakage flux

- The magnetic flux which does not follow the intended path in a magnetic circuit.

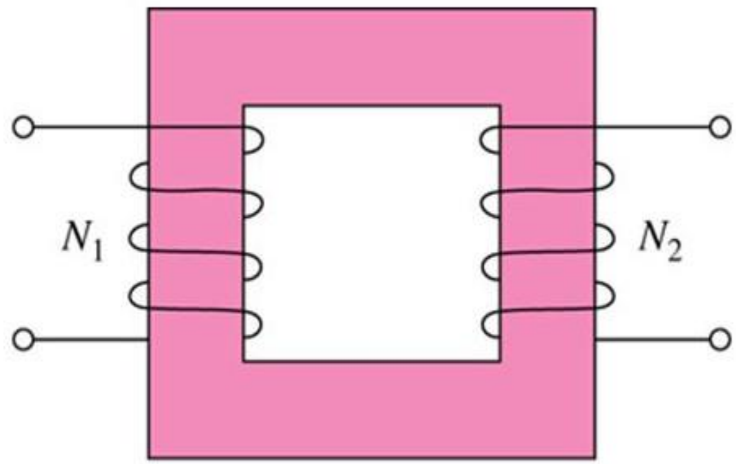
Leakage coefficient or leakage factor

- The ratio of the total flux produced to the useful flux set up in the air gap of the magnetic circuit
- Leakage coefficient =total flux/ useful flux



Magnetically coupled circuits

Magnetically coupled circuit is a combination of two individual circuits which are coupled by magnetic flux.

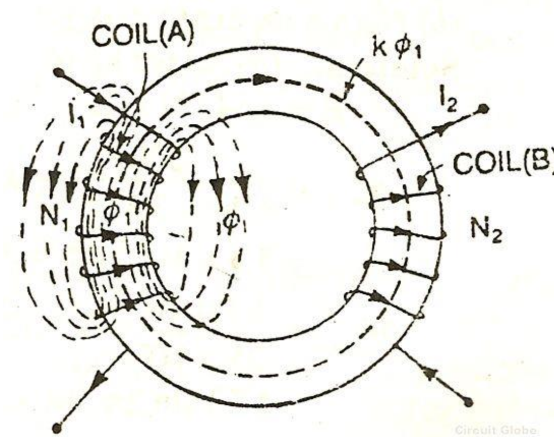


Ex: Transformer

Applications:

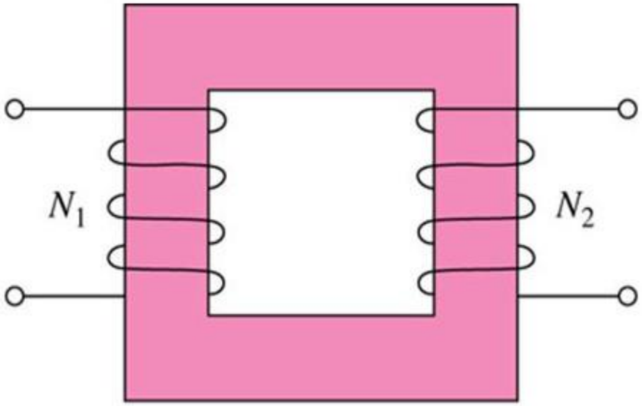
Power systems

Radio and television receivers

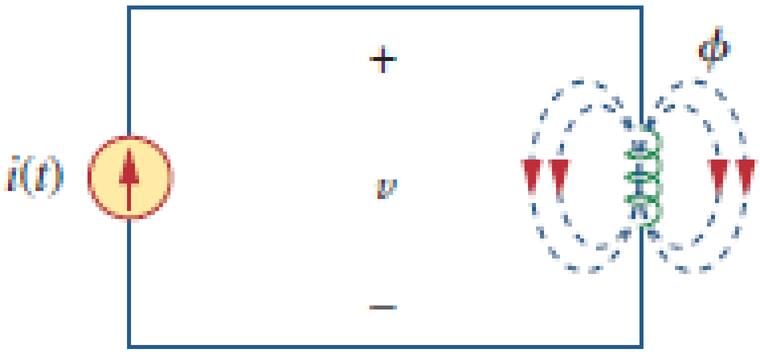


Self and mutual inductance

- **Self inductance** is the property of a coil, which causes a self-induced emf to be produced in the coil itself, when the current through it changes.
- **Mutual inductance** - ability of one coil to produce an emf in a nearby coil by induction when current in the first coil changes.



Self induced emf

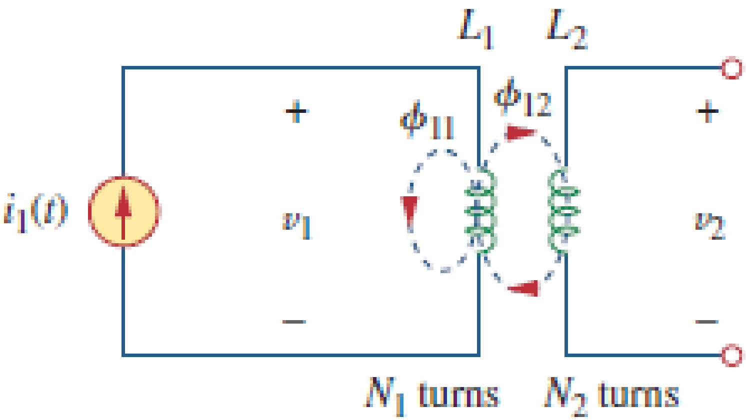


$No.of\ turns\ -N$
$Current\ -I$
$Flux\ -\emptyset$

$$v = N\frac{d\emptyset}{dt} \qquad v = L\frac{di}{dt} \qquad L = N\frac{d\emptyset}{di}$$

$(L\ is\ called\ the\ self\ Inductance)$

Mutually induced emf



- L_1 and L_2 are self Inductance of coil 1 and coil 2 respectively
- N_1 and N_2 are number of turns in coil 1 and coil 2 respectively

$$Voltage\ induced\ in\ coil\ 1\ is$$

$$v_1 = N_1 \frac{d\emptyset_1}{dt}$$

$$= N_1 \frac{d\emptyset_{11}}{di_1}\frac{di_1}{dt}$$

$$= L_1 \frac{di_1}{dt}$$

$$L_1 = N_1 \frac{d\emptyset_{11}}{di_1}$$

(self inductance of coil 1)

$$Voltage\ induced\ in\ coil\ 2\ is$$

$$v_2 = N_2 \frac{d\emptyset_{12}}{dt}$$

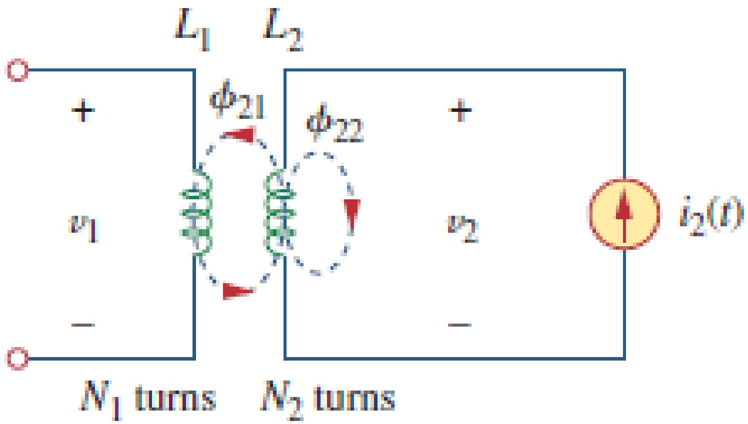
$$= N_2 \frac{d\emptyset_{12}}{di_1}\frac{di_1}{dt}$$

$$= M_{21} \frac{di_1}{dt}$$

$$M_{21} = N_2 \frac{d\emptyset_{12}}{di_1}$$

(mutual inductance of coil 2 w.r.t. coil 1)

Mutually induced emf



- L_1 and L_2 are self Inductance of coil 1 and coil 2 respectively
- N_1 and N_2 are number of turns in coil 1 and coil 2 respectively

$$Voltage\ induced\ in\ coil\ 1\ is$$

$$v_1 = N_1 \frac{d\emptyset_{21}}{dt}$$

$$= N_1 \frac{d\emptyset_{21}}{di_2} \frac{di_2}{dt}$$

$$= M_{12} \frac{di_2}{dt}$$

$$Voltage\ induced\ in\ coil\ 2\ is$$

$$v_2 = N_2 \frac{d\emptyset_2}{dt}$$

$$= N_2 \frac{d\emptyset_{22}}{di_2} \frac{di_2}{dt}$$

$$= L_2 \frac{di_2}{dt}$$

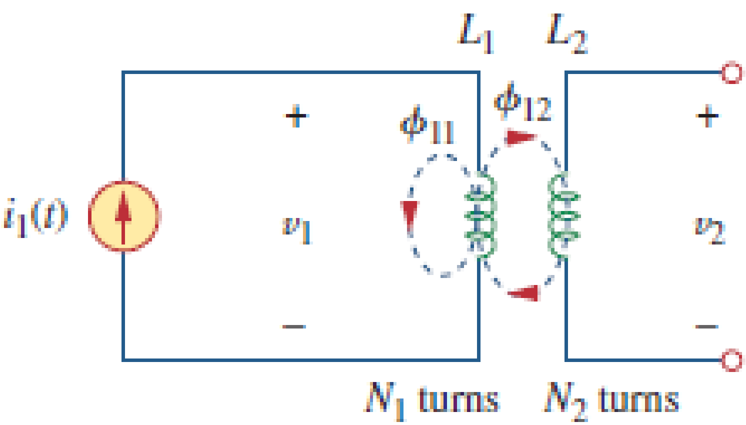
$L_2 = N_2 \frac{d\emptyset_{22}}{d2}$

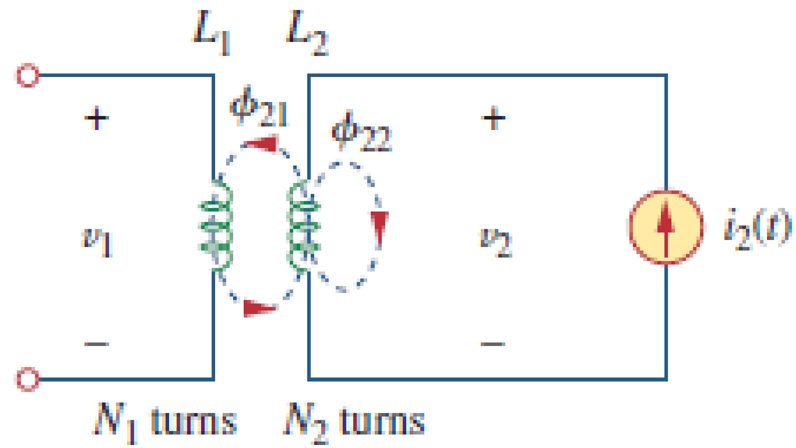
(self inductance of coil 2)

$M_{12} = N_1 \frac{d\emptyset_{21}}{di_2}$

(mutual inductance of coil 1 w.r.t. coil 2)

Coefficient of coupling (k)





$$L_1 = N_1 \frac{d\emptyset_{11}}{di_1}$$

(self inductance of coil 1)

$$L_2 = N_2 \frac{d\emptyset_{22}}{d2}$$

(self inductance of coil 2)

$$M_{12} = N_1 \frac{d\emptyset_{21}}{di_2}$$

(mutual inductance of coil 1 w.r.t. coil 2)

$$M_{21} = N_2 \frac{d\emptyset_{12}}{di_1}$$

(mutual inductance of coil 2 w.r.t. coil 1)

$$M = N_1 \frac{\emptyset_{21}}{i_2} = N_1 \frac{k\emptyset_{22}}{i_2}$$

$$M = N_2 \frac{\emptyset_{12}}{i_1} = N_2 \frac{k\emptyset_{11}}{i_1}$$

$$M^2 = N_2 \frac{k\emptyset_{11}}{i_1} N_1 \frac{k\emptyset_{22}}{i_2}$$

Dot convention