Review Last Class

Network Theorems:

Superposition Theorem

Thevenin Theorem

Norton Theorem

Maximum Power Transfer Theorem

Poly-Phase System

Definition, Connections, Phase Order

Phase voltage, Line voltage, phase current and Line Current

Relation between line voltage and phase voltage for Y load

Relation between line current and phase current for Δ load

Power Calculation

For Three-Phase System

For Y (or T)-connection	For Δ (or ∏)-connection
$I_L = I_P$ $\quad$ $V_L = \sqrt{3}V_P = 1.732V_P$	$V_L = V_P$ $\quad$ $I_L = \sqrt{3}I_P = 1.732I_P$

Power Calculation

Source Side

$$pf = \cos\theta \qquad rf = \sin\theta$$

$$S = 3E_P I_P = \sqrt{3}E_L I_L$$

$$P = 3E_P I_P \cos\theta = \sqrt{3}E_L I_L \cos\theta = S\cos\theta$$

$$Q = 3E_P I_P \sin\theta = \sqrt{3}E_L I_L \sin\theta = S\sin\theta$$

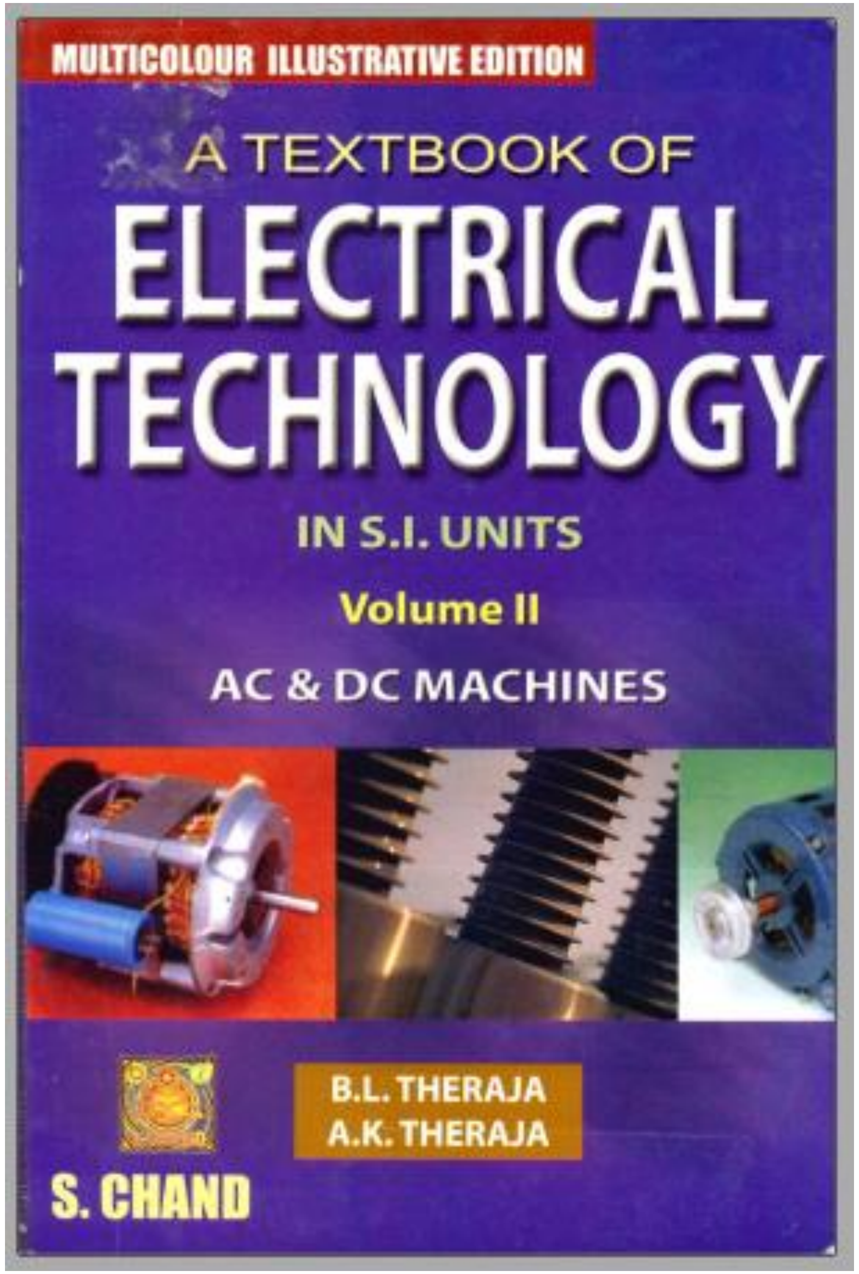
Load Side

$$S = 3I_P^2 Z \qquad P = 3I_P^2 R \qquad Q_L = 3I_P^2 X_L$$

$$Q_C = -3I_P^2 X_C \qquad Q = Q_L + Q_C$$

$$pf = \frac{P}{S} \qquad rf = \frac{Q}{S}$$

Electromagnetism and Fundamental Law's

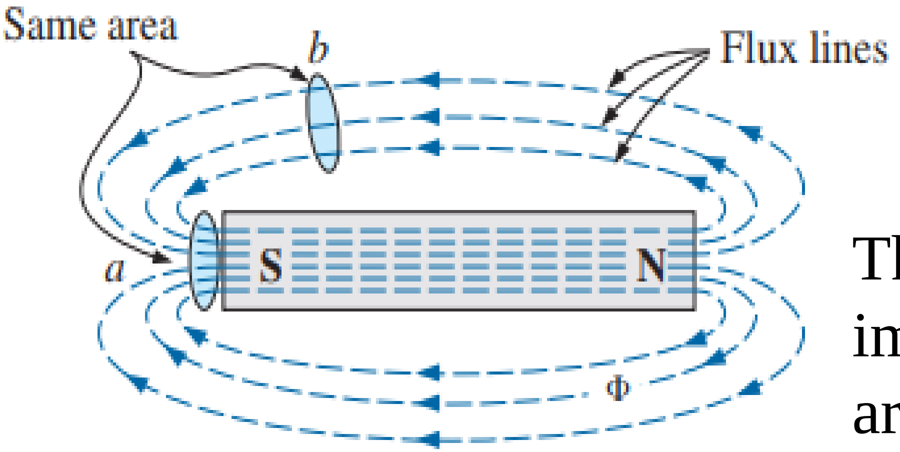


Electric Machine

1. Transformer
2. Generator
3. Motor

Magnets

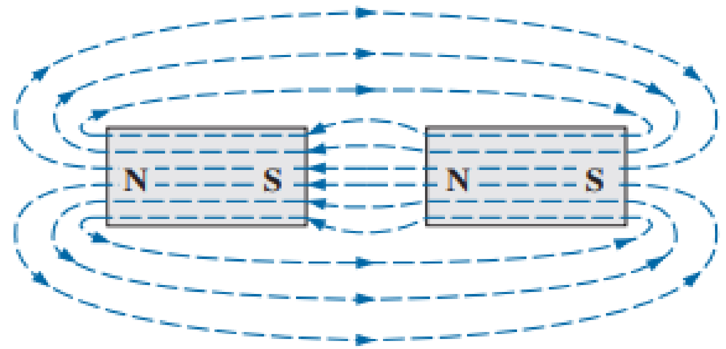
A magnet is a piece of metal that can **pull** certain types of metal toward itself.
The force (which pulls the material) of magnets, called **magnetic field** or **magnetism**, is a basic force of nature, like gravity.



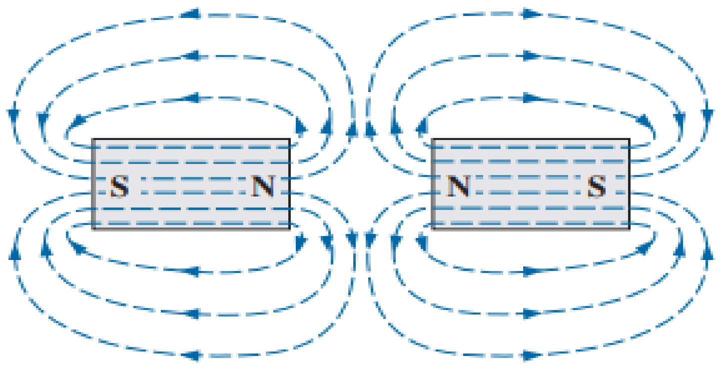
The magnetic field of magnet can be represented by imaginary lines (which is **invisible**) around magnet which are called **magnetic lines of force** or **lines of magnetic flux**.

The **magnetic lines of force** or **lines of magnetic flux** radiate from the north pole to the south pole, returning to the north pole through the metallic bar. That means, each flux line forms a **closed loop**.

If **unlike poles** of two magnets are brought together, the magnets **attract**.
If **like poles** of two magnets are brought together, the magnets **repel**.

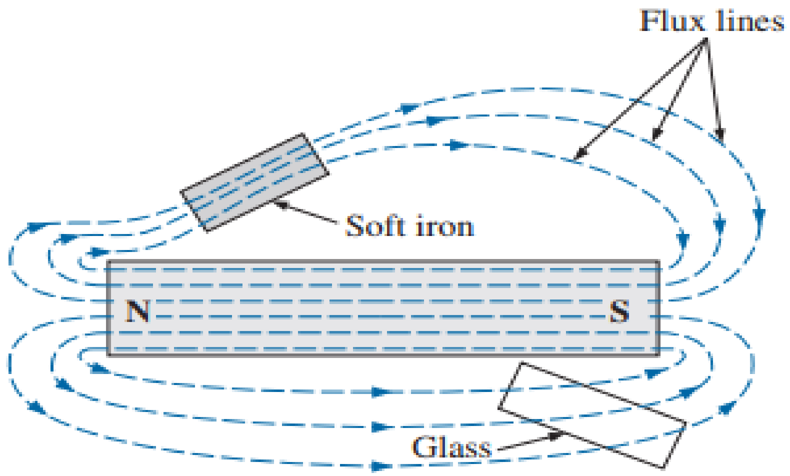


Flux distribution for two adjacent, opposite poles.



Flux distribution for two adjacent, like poles.

If a nonmagnetic material, such as glass or copper, is placed in the flux paths surrounding a magnet, an almost unnoticeable change occurs in the flux distribution.
If a magnetic material, such as soft iron, is placed in the flux path, the flux lines pass through the soft iron rather than the surrounding air because **magnetic flux lines pass with greater ease through magnetic materials than through air**.



Types or Classification of Magnets

Types of Magnet:

(*a*) **Permanent Magnet**:

(*i*) **Natural**: Obtained in a rock

(*ii*) **Artificial**: Made of a material that remains magnetized for long periods of time without the need for an external source of energy.

Diamagnetic: Materials that have permeabilities ($\mu = \mu_0\mu_r$ where $\mu_0 = 4\pi\times10^{-7}$ Wb/A-m) slightly less than that of free space are said to be diamagnetic [*Example*: *mercury, silver, carbon*, *copper etc.*].

Paramagnetic: Materials that have permeabilities slightly greater than that of free space are said to be paramagnetic [*Example*: *uranium, platinum, tungsten, aluminum, lithium etc.*].

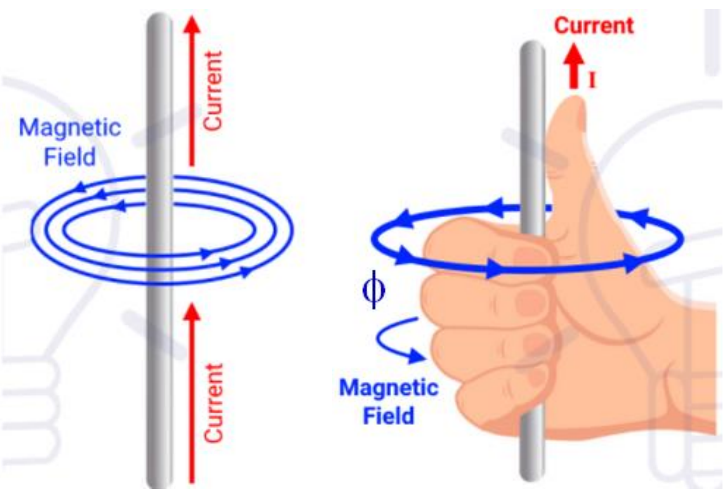
Ferromagnetic: Materials that have permeabilities is very high such as hundreds and even thousands of times that of free space are said to be ferromagnetic [*Example*: iron, nickel, steel, cobalt, and alloys of these metals].

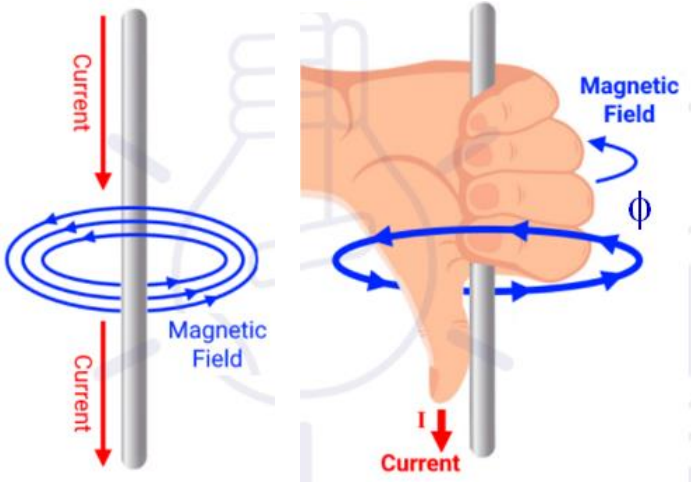
(*b*) **Electromagnet**: Perform same as magnet due to the flow of charge, or current in a conductor or coil or winding.

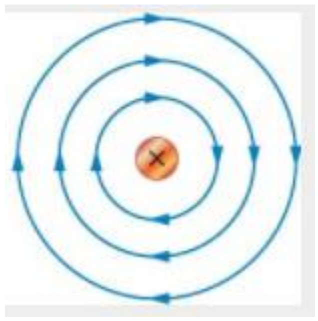
Electromagnetic Induction

Electromagnet due to Straight Current Carrying Conductor:

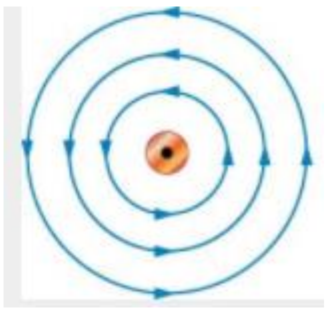
When a straight conductor carries a current, a magnetic flux is produced around the conductor all along its length. The magnetic flux lines will be in the form of concentric circles around the conductor. The direction of the magnetic flux lines is conveniently obtained by the ***Right–Hand Thumb/Grip Rule***.





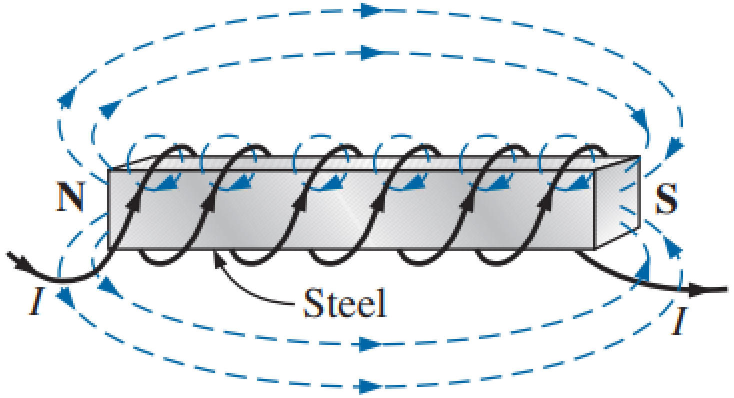


Current flowing away from viewer

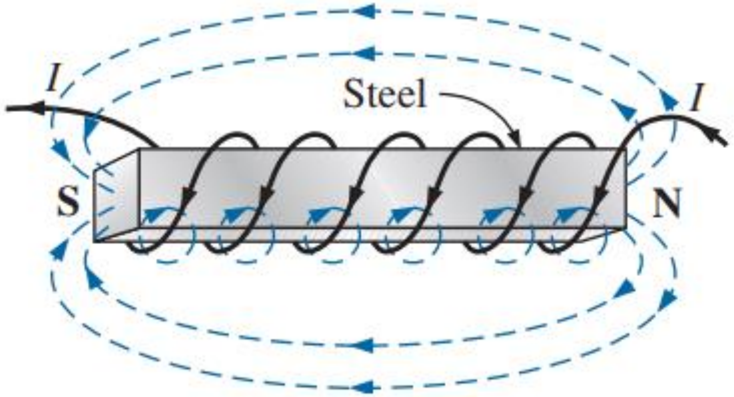


Current flowing towards viewer

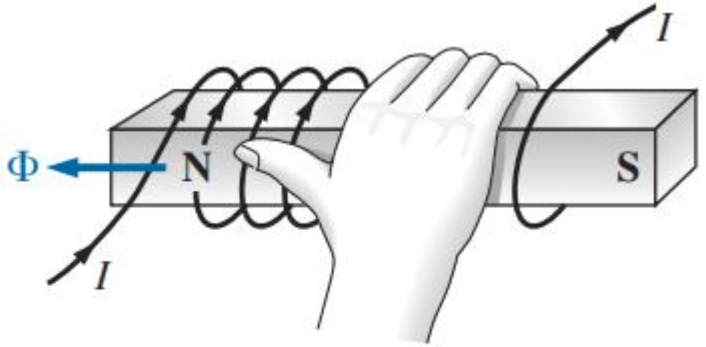
Right–Hand Thumb/Grip Rule: Suppose that a current carrying conductor is held in the right hand and the fingers are wrapped or curled around the conductor and the **thumb finger** is stretched in the **direction of current** flow. Then **wrapped or curled fingers** will give the **direction of circular magnetic flux line**.



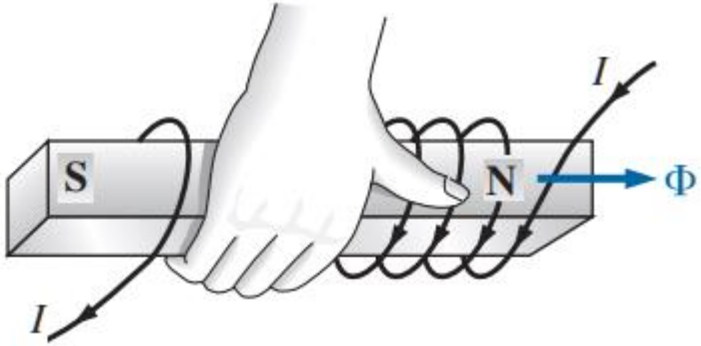
Electromagnet due to Circular Conductor (Coil) or Solenoid:

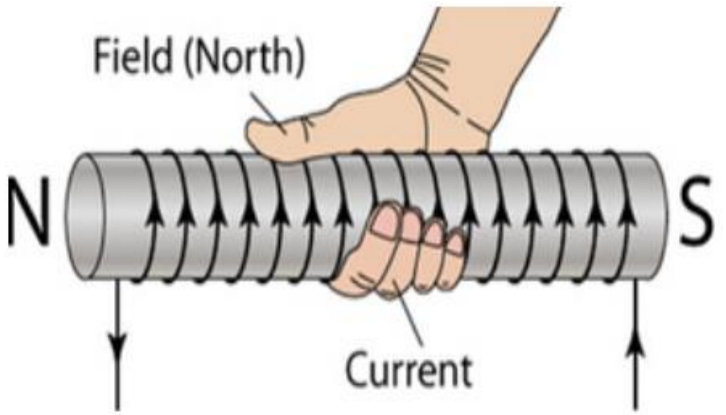


A **solenoid** is an arrangement in which long conductor is wound or wrapped with number of turns close together to form a coil.

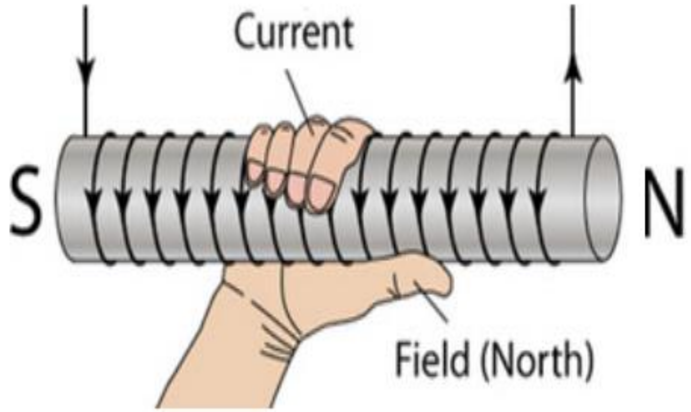


When a coil or solenoid is excited by the supply voltage so that it carries a current then it produces a magnetic field which acts through the coil along its axis and also around the solenoid. The direction of the magnetic flux lines is conveniently obtained by the ***Right–Hand Thumb/Grip Rule***.





Right–Hand Thumb/Grip Rule: Suppose that a current carrying coil or solenoid is griped such that the **curled fingers** in the **direction of current flow**. Then the **thumb finger** represents the **direction of flux** or the **North pole** of a magnet.



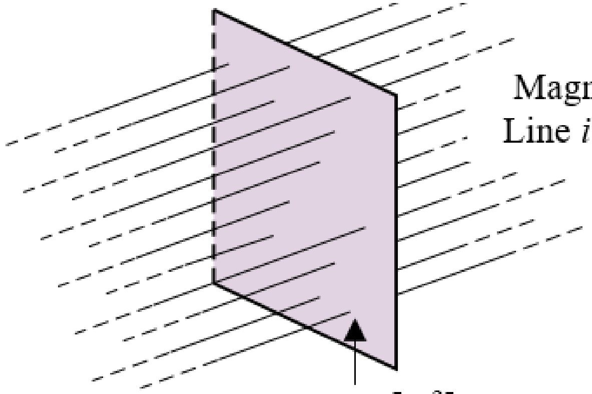
Some Definitions Related to Electromagnetic Induction

Magnetic Flux [Φ or ϕ]: The total number of magnetic lines of force existing in a particular magnetic field is called **magnetic flux**. The unit of magnetic flux is **weber** (Wb). It is denoted by Greek letter **Phi** (Φ for dc; ϕ for time varying case)

1 weber = 10^8 magnetic lines of force

Flux Density [B]: The magnetic flux [Φ or ϕ] per unit area (A) in a plane at right angles to the flux is known as **flux density**. The unit of magnetic flux is Wb/m^2 or Tesla [T]. It is denoted by B

Magnetic Flux density *i.e.* $B = \phi / A$ [Wb/m^2 or Tesla (T)]



Magnetic flux line crossing a surface or plane

Magnetomotive Force (MMF**) or Ampere-turns**: The product of number of turns of a coil and current is called **magnetomotive force** or **ampere-turns**.

$$\text{MMF} = NI \text{ [AT]}$$

Magnetic Field Strength or Magnetic Field Intensity or Magnetizing Force [H]: The magnetomotive force per unit length is called **magnetic field strength** or **magnetic field intensity** or **magnetizing force**.

$$H = \frac{\text{MMF}}{l} = \frac{NI}{l} \quad \text{[AT/m]}$$

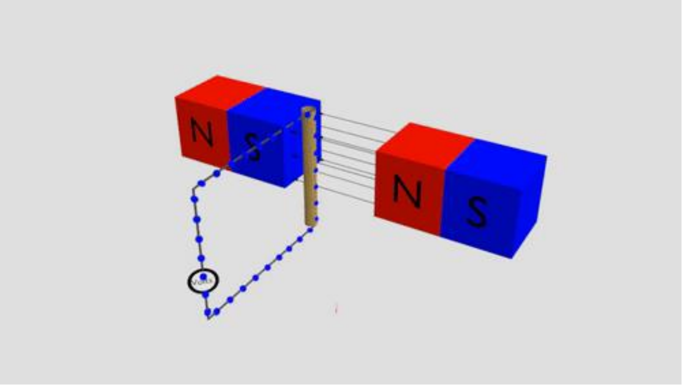
Absolute Permeability [μ]: The ratio of flux density (B) in a particular medium (other than vacuum or air) to the magnetic filed intensity (H) producing that flux is called **absolute permeability** of that medium.

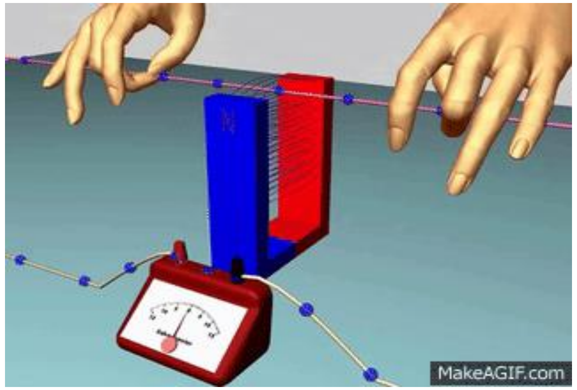
$$\mu = \frac{B}{H} \quad \text{[Henries/meter; H/m]}$$

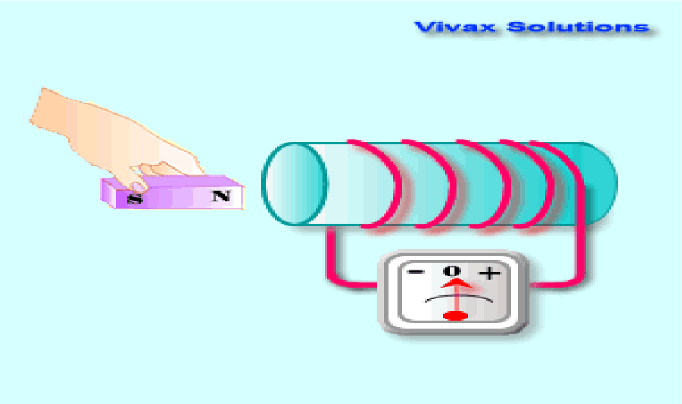
Faraday's Law of Electromagnetic Induction

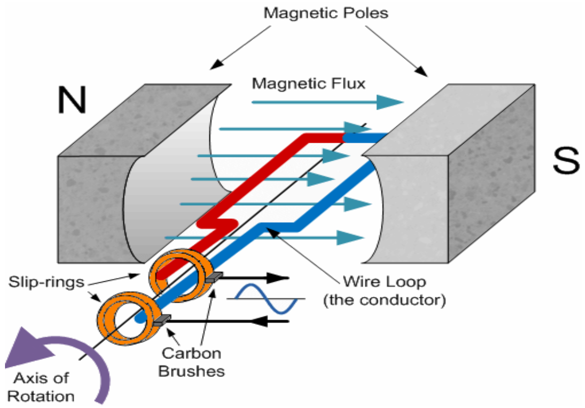
Statement of Faraday's Law 1: An induced emf is established in a conductor or circuit whenever the magnetic filed linking that conductor or circuit is changed.

Statement of Faraday's Law 2: The magnitude of induced emf is equal to the rate of change of flux linkages ($d\phi/dt$) with the coil.









Lenz's Law

To determine the polarity of induced emf, Lenz's law is applied.

Statement of Lenz's law: The direction of an induced emf produced by the electromagnetic induction is such that it sets up a current which always opposes the cause that is responsible for inducing the emf.

According Faraday's law 2 and to Lenz's law, an induced emf is mathematically expressed as follows:

$$e = -N\frac{d\phi}{dt} \quad [\mathrm{V}]$$

Nature of Induced EMF

EMF gets induced in a conductor, whenever there exists change in flux with that conductor, according to Faraday's law. Such change in flux can be brought about by the following methods:

(***a***) **Statically Induced EMF**:

By using a stationary conductor, a stationary electromagnet and varying the magnetic flux by supplying ac current to the electromagnet. This principle is used in **transformer**.

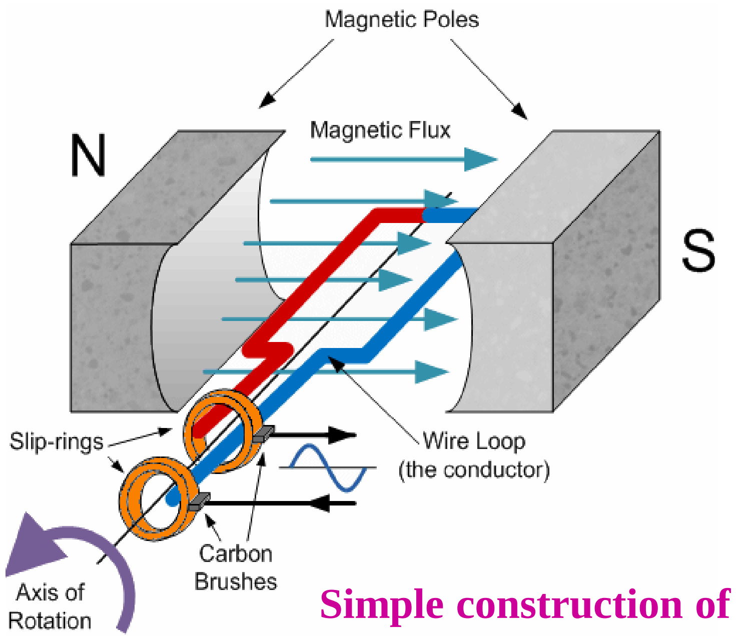
(***b***) **Dynamically Induced EMF**:

(***i***) By using a stationary permanent magnet (or an electromagnet fed by dc current) and a moving conductor. This principle is used in all **dc generators and motors**.

(***ii***) By using a stationary conductor, a rotating or moving permanent magnet (or an electromagnet). This principle is used in large **synchronous generators and motors**.

(***iii***) By using a stationary conductor which produced rotating or moving flux, a rotating or moving conductor with a relative speed between rotating flux and rotating conductor. This principle is used in an **induction generators and motors**.

Magnitude of Dynamic Induced EMF



Simple construction of a generator

Magnitude of Induced voltage or emf affected by **flux density** (*B*), the **effective length of conductor** (*l*), the **conductor velocity** (*v*) and sine of angle (α) between **flux line and the direction of motion of conductor**.

$$E = Blv\sin\theta \quad [\text{Volt, V}]$$

Fleming's Right-Hand Rule

Although the direction of induced emf could be determined by Lenz's law, it is found more convenient to use ***Fleming's Right-Hand Rule***.

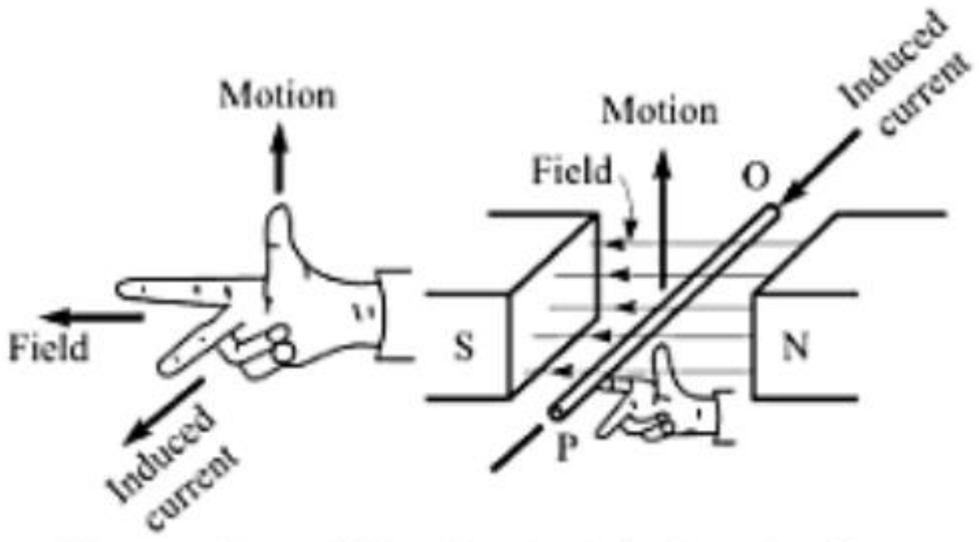


Illustration of Fleming's right-hand rule.

Statement of Fleming's Right-Hand Rule: Stretch the first (fore) finger, the second (middle) finger and the thumb finger of right hand in mutually perpendicular direction to each other. Arrange the right hand so that **first finger point in the direction of flux line** (North pole to south pole) and **thumb in the direction of motion of conductor** then the **middle finger will point in the direction of current (or emf)**.

Problem A conductor moves with a velocity of 15 m/s at an angle of (a) 90°, (b) 60° and (c) 30° to a magnetic field produced between two square-faced poles of side length 2 cm. If the flux leaving a pole face is 5 μWb, find the magnitude of the induced e.m.f. in each case.

Solution:

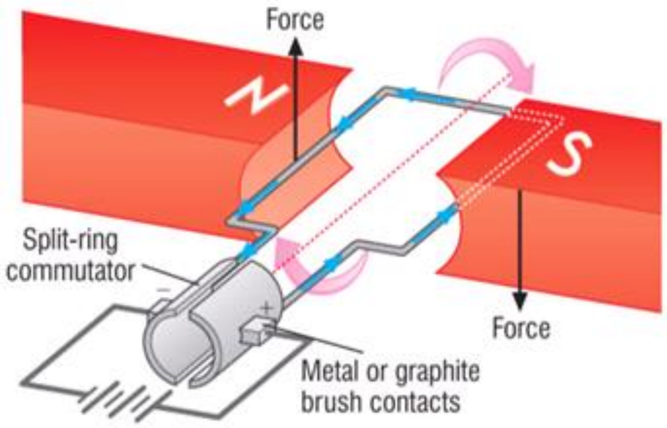
$v = 15$ m/s; length of conductor in magnetic field, $l = 2\,\text{cm} = 0.02\,\text{m}$; $A = 2 \times 2\,\text{cm}^2 = 4 \times 10^{-4}\,\text{m}^2$, $\Phi = 5 \times 10^{-6}\,\text{Wb}$

(a) $$E_{90} = Blv \sin 90^\circ = \left(\frac{\Phi}{A}\right) lv \sin 90^\circ$$
$$= \frac{(5 \times 10^{-6})}{(4 \times 10^{-4})}(0.02)(15)(1)$$
$$= \mathbf{3.75\,mV}$$

(b) $$E_{60} = Blv \sin 60^\circ = E_{90} \sin 60^\circ = 3.75 \sin 60^\circ$$
$$= \mathbf{3.25\,mV}$$

(c) $$E_{30} = Blv \sin 30^\circ = E_{90} \sin 30^\circ = 3.75 \sin 30^\circ$$
$$= \mathbf{1.875\,mV}$$

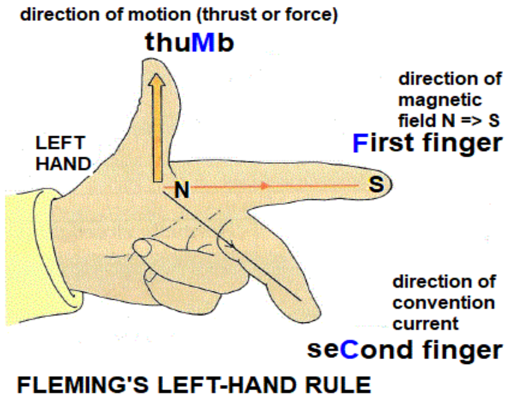
Force on a Current Carrying Conductor in A Magnetic Field



Lorentz or Electromagnetic Force: When a current-carrying conductor is placed in a magnetic field, a force is developed or produced or established on the conductor which is called *electromagnetic force*, or Lorentz force.

This force constitutes the basis of operation of motors.

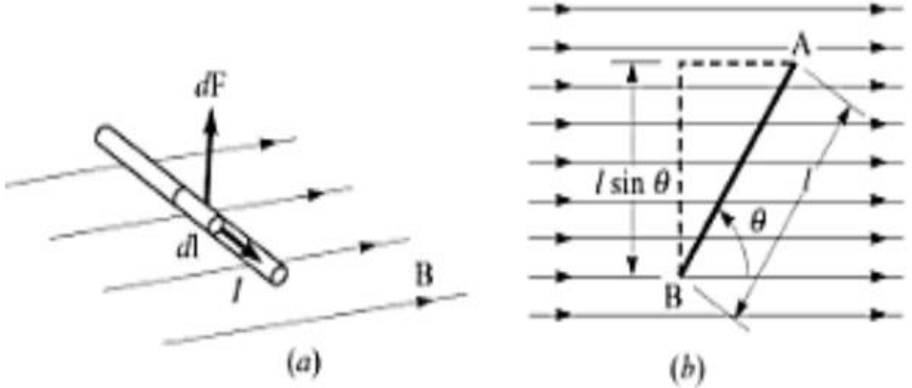
The direction of the magnetic flux lines is conveniently obtained by the **Fleming's Left-Hand Rule**.



Statement of Fleming's Right-Hand Rule: Stretch the first (fore) finger, the second (middle) finger and the thumb finger of right hand in mutually perpendicular direction to each other. Arrange the right hand so that **first finger point in the direction of flux line** (North pole to south pole) and the **middle finger to the direction of current** then **thumb will point in the direction of force of conductor**.

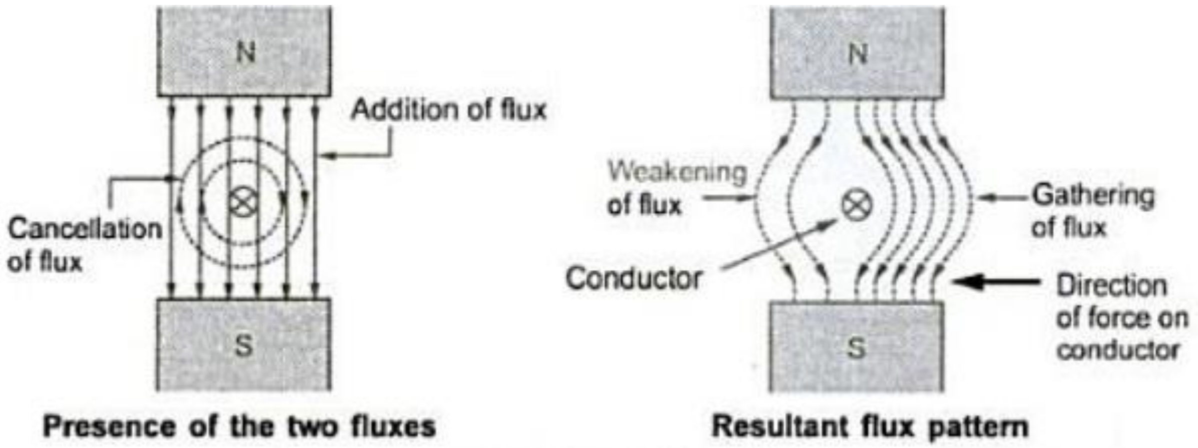
Magnitude of Force: Force on a current carrying conductor affected by **flux density** (B), the **effective length of conductor** (l), the **current** (v) and sine of angle (α) between **flux line and the direction of motion of conductor**.

$$\boxed{F = BlI\sin\theta \quad [\text{Newton, N}]}$$



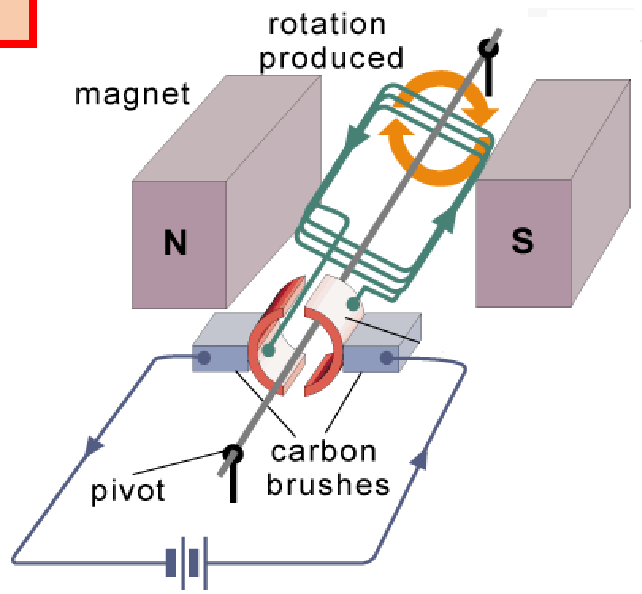
How a Force and Torque are Produce on the Conductor?

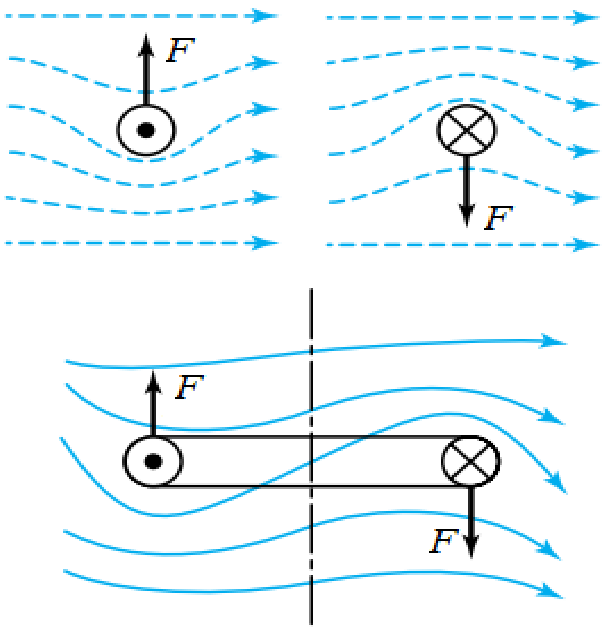
There is presence of two magnetic field. The force is created due to the interaction with each other.
Left side of conductor, conductor flux opposes the permanent magnet flux. Due to the interaction, the resultant left flux is **weakening**.
Right side of conductor, conductor flux assists with the permanent magnet flux. Due to the interaction, the resultant right flux is **strengthening/accumulating**.
Conductor experiences a force from high flux lines area towards low flux lines area i.e. from right to left.



Interaction of the two flux lines

In an electrical machine, the direction of two conductor sides are different.
The developed forces in two sides are opposite direction.
The opposite direction of two sides forces are developed torque/rotation on shaft of electrical machine.





Example 3.5 : *Calculate the force experienced by the conductor of 20 cm long, carrying 50 amperes, placed at right angles to the lines of force of flux density 10×10^{-3} Wb/m².*

Solution : The force experienced is given by,

$F = B I l \sin\theta$ where $\sin(\theta) = 1$ as $\theta = 90$ degrees

B = Flux density = 10×10^{-3} Wb/m²

l = Active length = 20 cm = 0.2 m

I = Current = 50 A

$F = 10 \times 10^{-3} \times 50 \times 0.2 = \mathbf{0.1\ N}$

Problem A conductor 350 mm long carries a current of 10 A and is at right-angles to a magnetic field lying between two circular pole faces each of radius 60 mm. If the total flux between the pole faces is 0.5 mWb, calculate the magnitude of the force exerted on the conductor.

Solution:

$l = 350\,\text{mm} = 0.35\,\text{m}$; $I = 10\,\text{A}$;

Area of pole face $A = \pi r^2 = \pi (0.06)^2\,\text{m}^2$;

$\Phi = 0.5\,\text{mWb} = 0.5 \times 10^{-3}\,\text{Wb}$

Force $F = BIl$, and $B = \dfrac{\Phi}{A}$

hence force $F = \left(\dfrac{\Phi}{A}\right) Il$

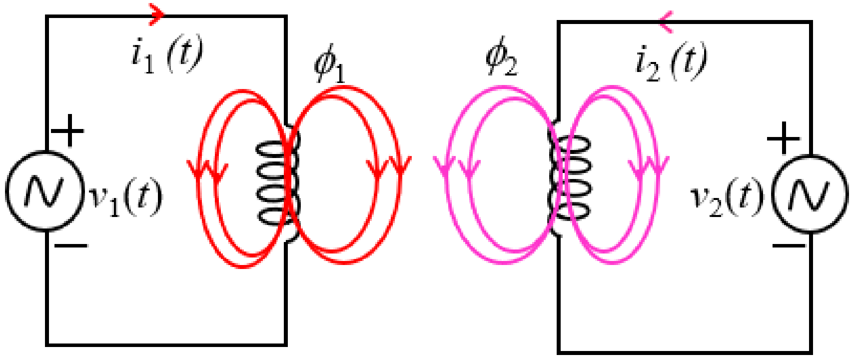
$$= \frac{(0.5 \times 10^{-3})}{\pi (0.06)^2}(10)(0.35)\ \text{newtons}$$

i.e. force = 0.155 N

Self Inductance
Leakage Inductance
Mutual Inductance

Self Flux, Leakage Flux and Mutual Flux

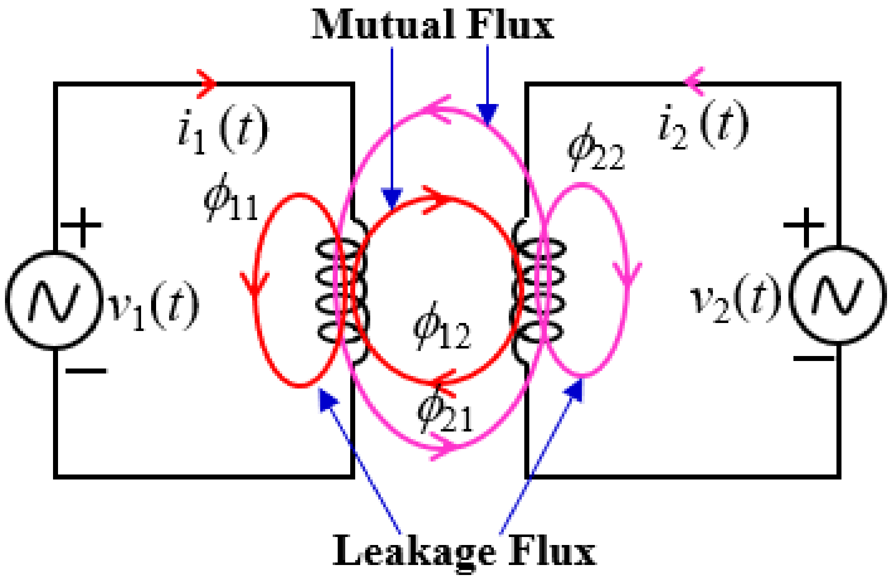
Self Flux: The total flux which is generated by a supplying current through a coil in an electromagnetic system is called self flux.



ϕ_1 **is self-flux** which is produced by the current i_1.
ϕ_2 **is self-flux** which is produced by the current i_2.

Leakage Flux: The portion of self-flux does not link with other coils is called leakage flux. (due to current i_1)
$\boldsymbol{\phi_{11}}$ (due to current i_1) and $\boldsymbol{\phi_{22}}$ (due to current i_2) are leakage flux.

Mutual Flux: The portion of self-flux links with other coils is called leakage flux.
$\boldsymbol{\phi_{12}}$ (due to current i_1 and link to coil 2) and $\boldsymbol{\phi_{21}}$ (due to current i_2 and link to coil 1) are mutual flux.



$$\phi_1 = \phi_{11} + \phi_{12} \qquad \phi_2 = \phi_{22} + \phi_{21}$$

Self Inductance, and Mutual Inductance

If a time-changing source [$v_1(t)$] as shown in ***Figure*** (***a***) is applied to a coil 1, the produced self–flux [$\phi_1(t)$] also will be time-changing. According to **Faraday's law of Electromagnetic Induction** an emf $e_1(t)$ [due to self–flux $\phi_1(t)$ since $\phi_1(t)$ links in coil 1] and an emf $e_{12}(t)$ [due to mutual flux $\phi_{12}(t)$ since $\phi_{12}(t)$ links in coil 2] are induced.

The induced emfs can be given by:

$$e_1(t) = N_1 \frac{d\phi_1(t)}{dt} = \left(N_1 \frac{d\phi_1(t)}{di_1(t)} \right) \frac{di_1(t)}{dt} = (L_1) \frac{di_1(t)}{dt}$$

$$e_{12}(t) = N_2 \frac{d\phi_{12}(t)}{dt} = \left(N_2 \frac{d\phi_{12}(t)}{di_1(t)} \right) \frac{di_1(t)}{dt}$$

$$= (M_{12}) \frac{di_1(t)}{dt}$$

N_1 and N_2: Number of turns of coil 1 and coil 2

L_1 and M_{12}: Self inductance of coil 1 and Mutual inductance due to current 1 in coil 2

Similarly, for **Figure** (***b***) we have:

$$e_2(t) = N_2 \frac{d\phi_2(t)}{dt} = \left(N_2 \frac{d\phi_2(t)}{di_2(t)} \right) \frac{di_2(t)}{dt} = (L_2) \frac{di_2(t)}{dt}$$

$$e_{21}(t) = -N_1 \frac{d\phi_{21}(t)}{dt} = -\left(N_1 \frac{d\phi_{21}(t)}{di_2(t)} \right) \frac{di_2(t)}{dt}$$

$$= -(M_{21}) \frac{di_2(t)}{dt}$$

L_2 and M_{21}: Self inductance of coil 2 and Mutual inductance due to current 2 in coil 1

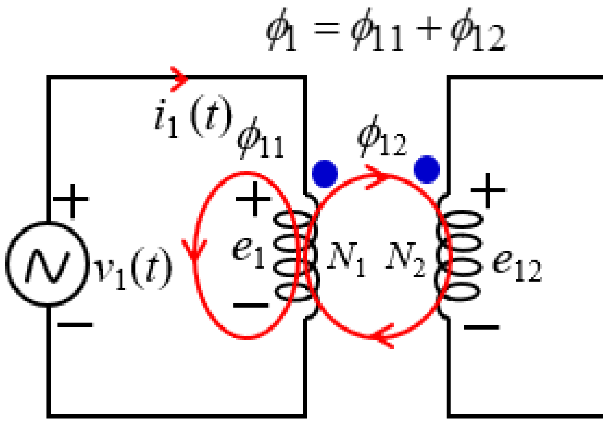


Figure (***a***)

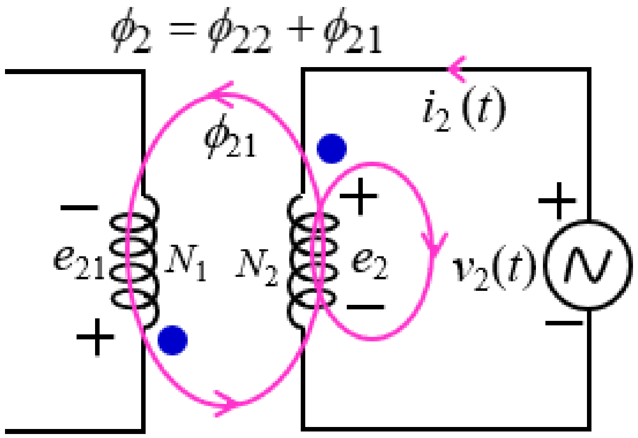


Figure (***b***)

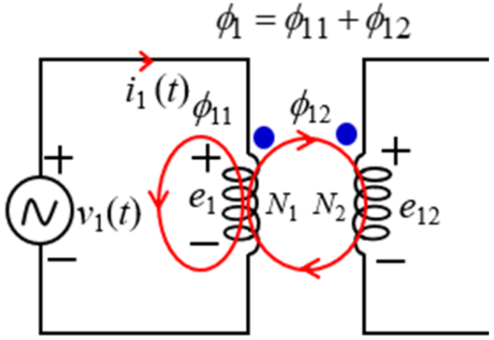


Figure (*a*)

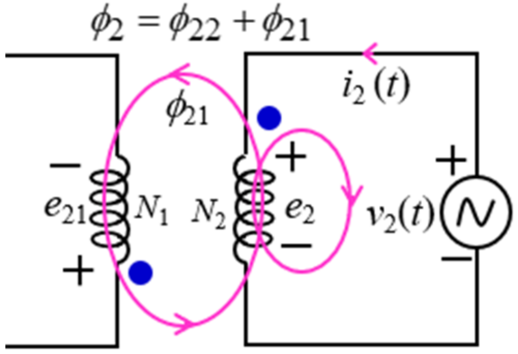


Figure (*b*)

M_{12} and M_{21} are equal if the medium of mutual fluxes of $\phi_{12}(t)$ and $\phi_{11}(t)$ are same, thus we have:

$$M_{12} = M_{21} = M$$

Polarity of induced emf due to mutual flux: The **dots** shown in the two figures indicate the polarity of the induced emf between the coils.

If the **dots** are at the same end of the coils, the voltage induced in coil 2 by a current in coil 1 has the same polarity as the voltage induced by the same current in coil 1; otherwise, the voltages are in opposition, as shown in **Figure** (***b***). Thus, the presence of such dots indicates that magnetic coupling is present between two coils.

It should also be pointed out that if a current (and therefore a magnetic field) were present in the second coil as shown in **Figure** (***c***), an additional voltage would be induced across coil 1. The voltage induced across a coil is, in general, equal to the sum of the voltages induced by self-inductance and mutual inductance. Thus, we have:

$$v_1(t) = e_1(t) + e_{21}(t) = L_1 \frac{di_1(t)}{dt} + M \frac{di_2(t)}{dt}$$

$$v_2(t) = e_2(t) + e_{12}(t) = L_2 \frac{di_2(t)}{dt} + M \frac{di_1(t)}{dt}$$

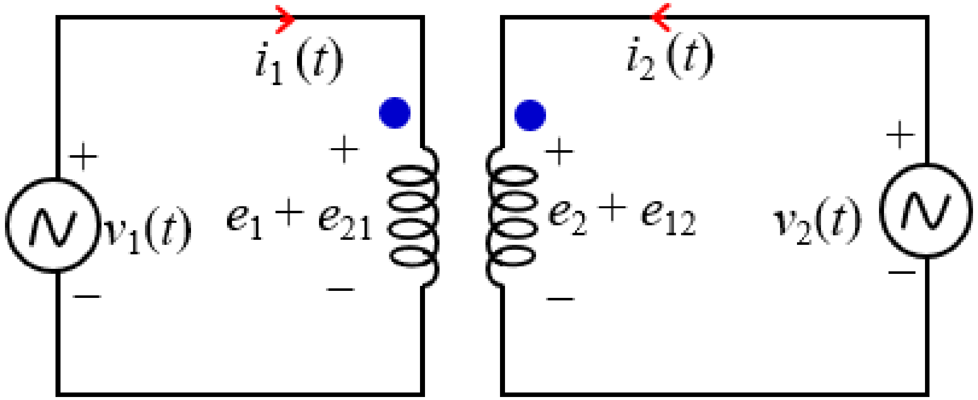
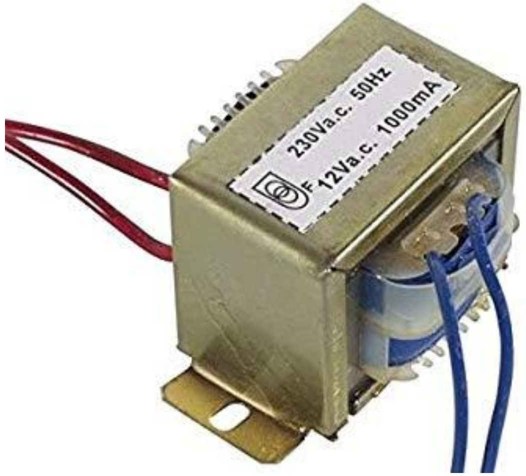


Figure (*c*)

Transformer

Chapter 21 [Text Book 1]
Chapter 32 [Text Book 2]

Transformer



Definition of Transformer

Transformer is a static device which transfers the electrical energy from one circuit to another circuit by raising or lowering the voltage without changing frequency.

Transformers are used in both communication and power circuits.

Construction of Transformer

There are two basic parts of a transformer:

(*a*) Windings, and (*b*) Magnetic cores

Windings: In a conventional transformer there have high voltage (**HV**) and low-voltage (**LV**) windings.

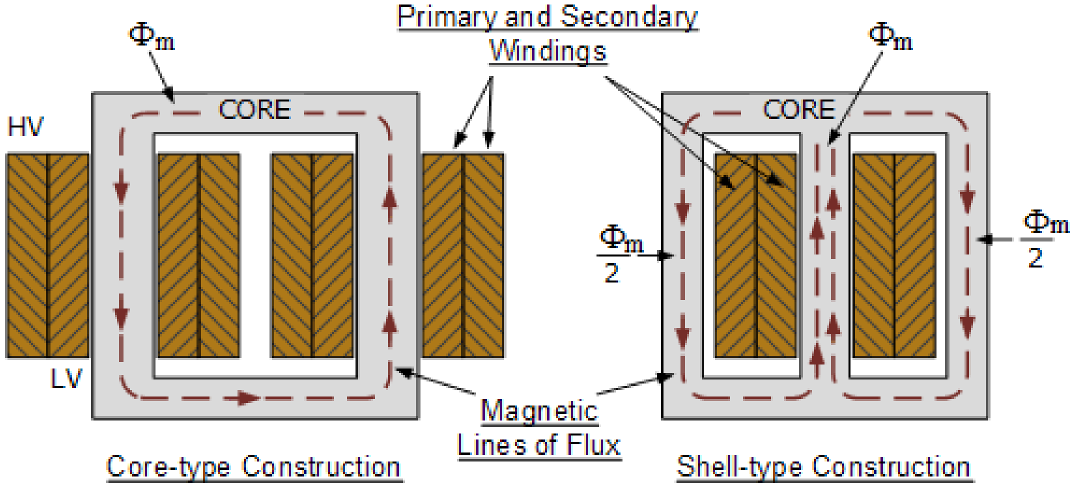
Primary (or ***driving***) winding/coil/side [either HV or LV]: The winding at which source is connected is called primary winding.

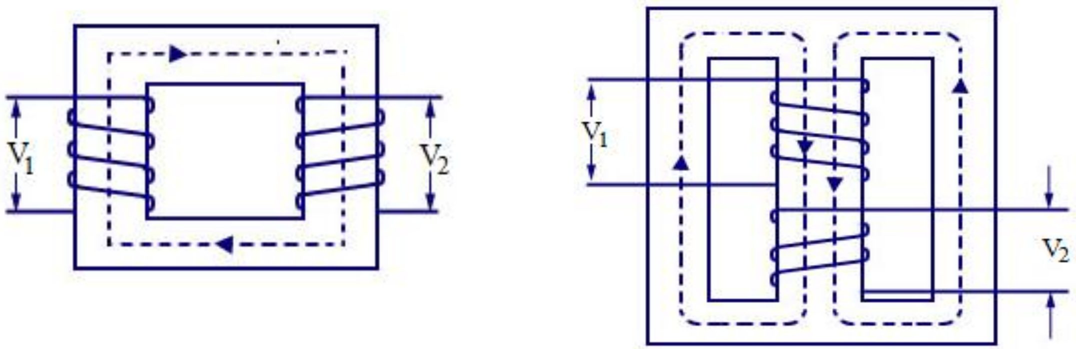
Secondary (or ***Receiving***) winding/coil/side [either HV or LV]: The winding at which load is connected is called primary winding.

Cores: There are two basic types of Magnetic cores:

(***a***) **Core Type**: the windings surround a considerable part of the core

(***b***) **Shell Type**: the core surrounds the considerable portion of the windings

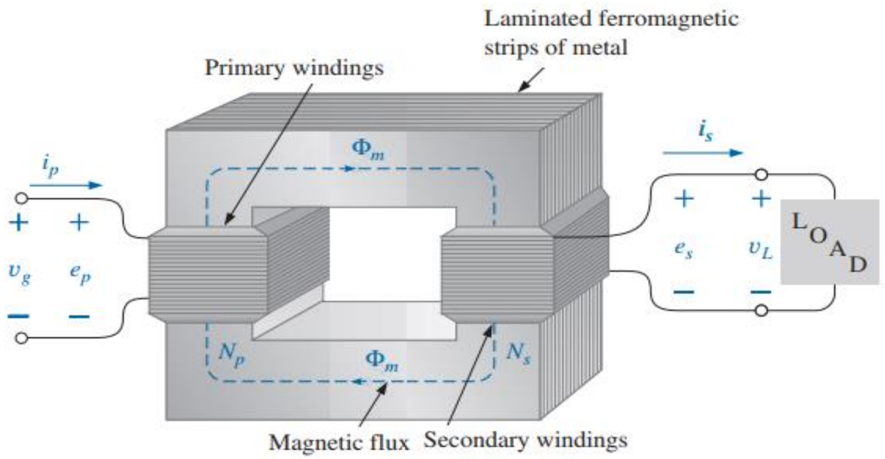


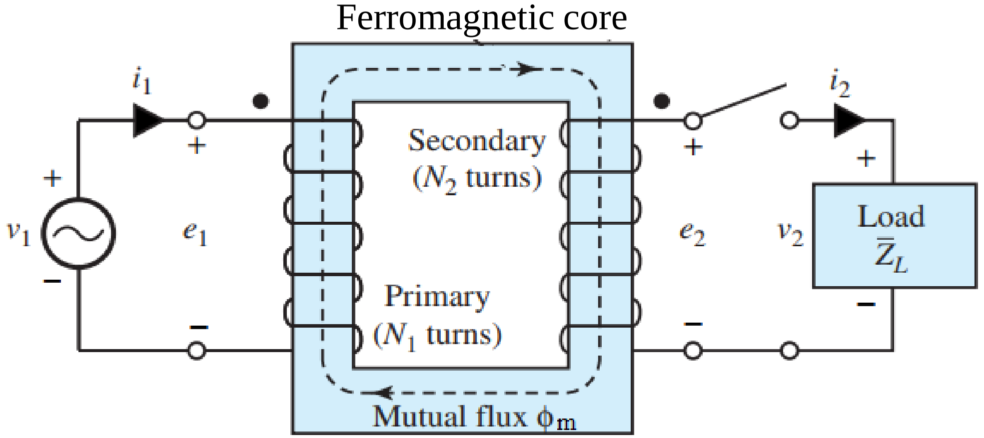


https://www.youtube.com/watch?v=XrIXioEn3yQ

Working Principle of Transformer

- When the primary winding is excited by an alternating voltage (v_g or v_1), an alternating current (i_p or i_1) starts to flow in primary side.
- The alternating current sets up an alternating flux
  [$\phi(t) = \Phi_m \sin(2\pi f)t = \Phi_m \sin\omega t$ Wb] in the core.
- The secondary winding is linked by most of this flux. According to ***Farady's Law of Electromagnetic Induction*** emfs in primary side (e_p or e_1) and secondary side(e_s or e_2)] are induced.
- According to ***Lenz's Law*** primary side emf (e_p or e_1) opposes the supply voltage (v_g or v_1). The primary side emf (e_p or e_1) is called back emf since it limits the flow of primary side current (i_p or i_1).
- If the secondary side circuit is closed, the secondary current (i_s or i_2) flows through the load. This is way energy is transferred from primary circuit to the secondary circuit through the medium of the magnetic field.
- When secondary current flows, it sets up a flux which is reduced the mutual flux. Then primary emf is reduced therefore primary current increases as well as primary fluxes is increased. Finally, the mutual flux will be back to its the previous values. So, the load current cannot change the mutual flux in the core.





Schematic of two-winding transformer.

Here,
v_L or v_2: Load voltage
N_p or N_1: Number of turns of primary side
N_s or N_2: Number of turns of secondary side
$\boldsymbol{Z}_L$: Load impedance

32.6 EMF Equation of a Transformer

Let, the expression of developed flux in core due the supply ac voltage (v_g or v_1) is:

$$\phi(t) = \Phi_m \sin \omega t$$

Based on the Faraday's Law, the expression induced voltage in primary side and secondary side can be obtained as follows:

$$e_1(t) = -N_1 \frac{d\phi(t)}{dt} = (2\pi f)N_1\Phi_m \sin(\omega t - 90°) \text{ V}$$

$$e_2(t) = -N_2 \frac{d\phi(t)}{dt} = (2\pi f)N_2\Phi_m \sin(\omega t - 90°) \text{ V}$$

The RMS Value of $e_1(t)$ and $e_2(t)$ are as follows:

$$E_1 = \frac{(2\pi f)N_1\Phi_m}{\sqrt{2}} = 4.44\, fN_1\Phi_m \qquad \text{(i)}$$

$$E_2 = \frac{(2\pi f)N_2\Phi_m}{\sqrt{2}} = 4.44\, fN_2\Phi_m \qquad \text{(ii)}$$

32.7 Voltage Transformation Ratio (K)

From the Eqs. (i) and (ii), we have:

$$\frac{V_2}{V_1} = \frac{E_2}{E_1} = \frac{N_2}{N_1} = K$$

This constant K is called ***voltage transformation ratio*** or ***transformation ratio*** or ***turns ratio***.

If the losses of a transformer are neglected, then

$V_1 = E_1$; $V_2 = E_2$ and

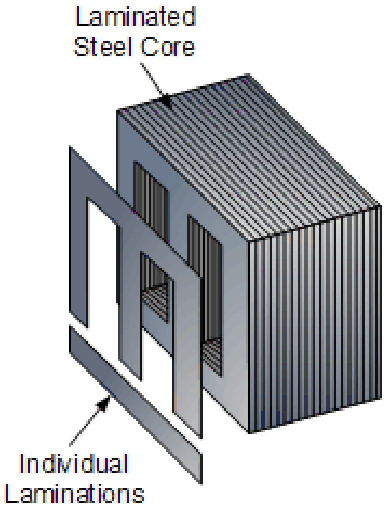
input VA = output VA,

that means:

$$S_2 = S_1$$

$$V_2 I_2 = V_1 I_1$$

$$\frac{I_2}{I_1} = \frac{V_1}{V_2} = \frac{E_1}{E_2} = \frac{1}{K}$$



Hence, currents are the ***inverse ratio*** of the (voltage) transformation ratio.

Problem An ideal transformer has a turns ratio of 8:1 and the primary current is 3 A when it is supplied at 240 V. Calculate the secondary voltage and current.

Solution:

A turns ratio of 8:1 means $\frac{N_1}{N_2} = \frac{8}{1}$, i.e. a step-down transformer.

$\frac{N_1}{N_2} = \frac{V_1}{V_2}$ or secondary voltage

$$V_2 = V_1\left(\frac{N_2}{N_1}\right) = 240\left(\frac{1}{8}\right) = \mathbf{30\ volts}$$

Also, $\frac{N_1}{N_2} = \frac{I_2}{I_1}$; hence secondary current

$$I_2 = I_1\left(\frac{N_1}{N_2}\right) = 3\left(\frac{8}{1}\right) = \mathbf{24\ A}$$

Problem An ideal transformer, connected to a 240 V mains, supplies a 12 V, 150 W lamp. Calculate the transformer turns ratio and the current taken from the supply.

Solution:

$V_1 = 240$ V, $V_2 = 12$ V, $\qquad I_2 = \frac{P}{V_2} = \frac{150}{12} = 12.5$ A

$$\text{Turns ratio} = \frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{240}{12} = \mathbf{20}$$

$\frac{V_1}{V_2} = \frac{I_2}{I_1}$, from which, $I_1 = I_2\left(\frac{V_2}{V_1}\right) = 12.5\left(\frac{12}{240}\right)$

Hence current taken from the supply, $I_1 = \frac{12.5}{20}$

$$= \mathbf{0.625\ A}$$

Problem A 5 kVA single-phase transformer has a turns ratio of 10:1 and is fed from a 2.5 kV supply. Neglecting losses, determine (a) the full load secondary current, (b) the minimum load resistance which can be connected across the secondary winding to give full load kVA and (c) the primary current at full load kVA.

Solution:

(a) $\dfrac{N_1}{N_2} = \dfrac{10}{1}$ and $V_1 = 2.5\,\text{kV} = 2500\,\text{V}$

Since $\dfrac{N_1}{N_2} = \dfrac{V_1}{V_2}$, secondary voltage

$$V_2 = V_1\left(\frac{N_2}{N_1}\right) = 2500\left(\frac{1}{10}\right) = 250\,\text{V}$$

The transformer rating in volt-amperes $= V_2 I_2$ (at full load), i.e. $5000 = 250 I_2$

Hence full load secondary current

$$I_2 = \frac{5000}{250} = \mathbf{20A}$$

(b) Minimum value of load resistance,

$$R_L = \frac{V_2}{I_2} = \frac{250}{20} = \mathbf{12.5\,\Omega}$$

(c) $\dfrac{N_1}{N_2} = \dfrac{I_2}{I_1}$, from which primary current,

$$I_1 = I_2\left(\frac{N_2}{N_1}\right) = 20\left(\frac{1}{10}\right) = \mathbf{2\,A}$$

Problem A 100 kVA, 4000 V/200 V, 50 Hz single-phase transformer has 100 secondary turns. Determine (a) the primary and secondary current, (b) the number of primary turns and (c) the maximum value of the flux.

Solution:

$V_1 = 4000\text{ V},\ V_2 = 200\text{ V},\ f = 50\text{ Hz},\ N_2 = 100\text{ turns}$

(a) Transformer rating $= V_1 I_1 = V_2 I_2 = 100\,000$ VA

Hence primary current, $I_1 = \dfrac{100\,000}{V_1} = \dfrac{100\,000}{4000}$ $= \mathbf{25\ A}$

and secondary current, $I_2 = \dfrac{100\,000}{V_2} = \dfrac{100\,000}{200}$ $= \mathbf{500\ A}$

(b) From equation (3), $\dfrac{V_1}{V_2} = \dfrac{N_1}{N_2}$

from which, primary turns,

$$N_1 = \left(\frac{V_1}{V_2}\right)(N_2) = \left(\frac{4000}{200}\right)(100)$$

i.e. $\mathbf{N_1 = 2000\ turns}$

(c) From equation , $E_2 = 4.44 f \Phi_m N_2$

from which, maximum flux Φ_m

$$= \frac{E_2}{4.44 f N_2} = \frac{200}{4.44(50)(100)}$$

(assuming $E_2 = V_2$)

$= \mathbf{9.01 \times 10^{-3}\ Wb}$ or $\mathbf{9.01\ mWb}$