DSE 4A CLASS

Lecture-6

29/05/2021

Three phase system

The power supply system is mainly classified into two types, i.e., **single phase** and the three phase system.

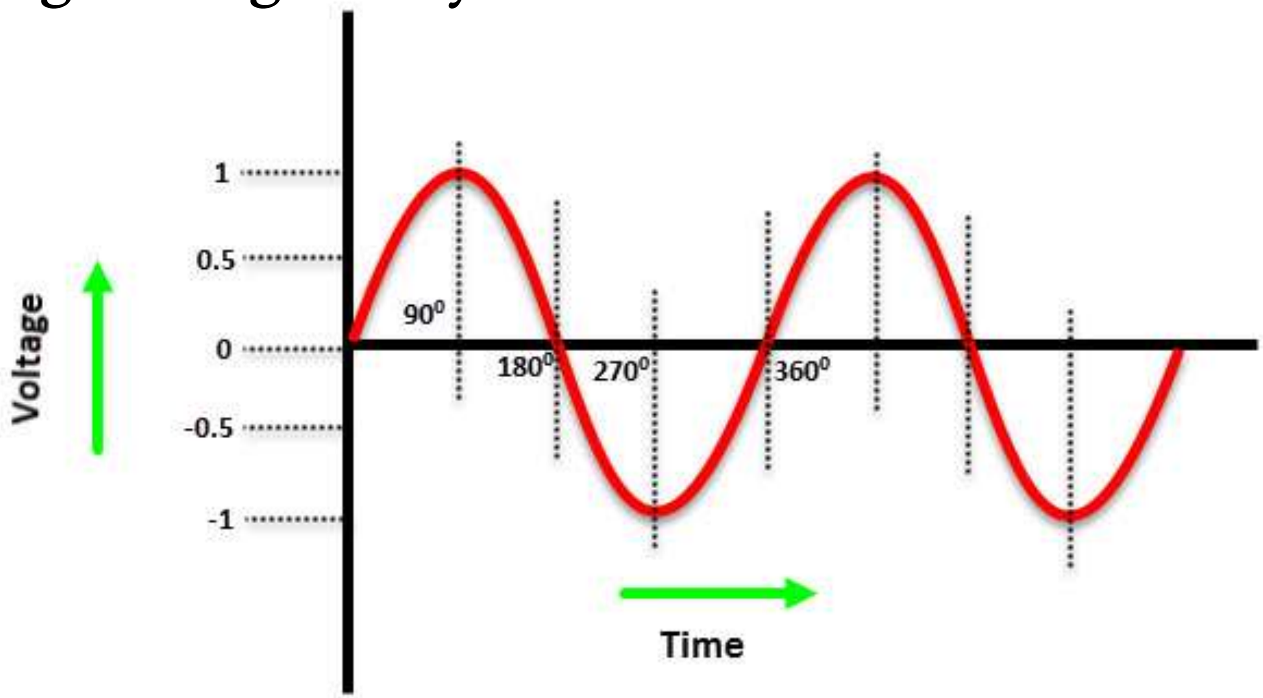
The **single phase** is used in a place where less power is required and for running the small loads.

The **three phases** are used in large industries, factories and in the manufacturing unit where a large

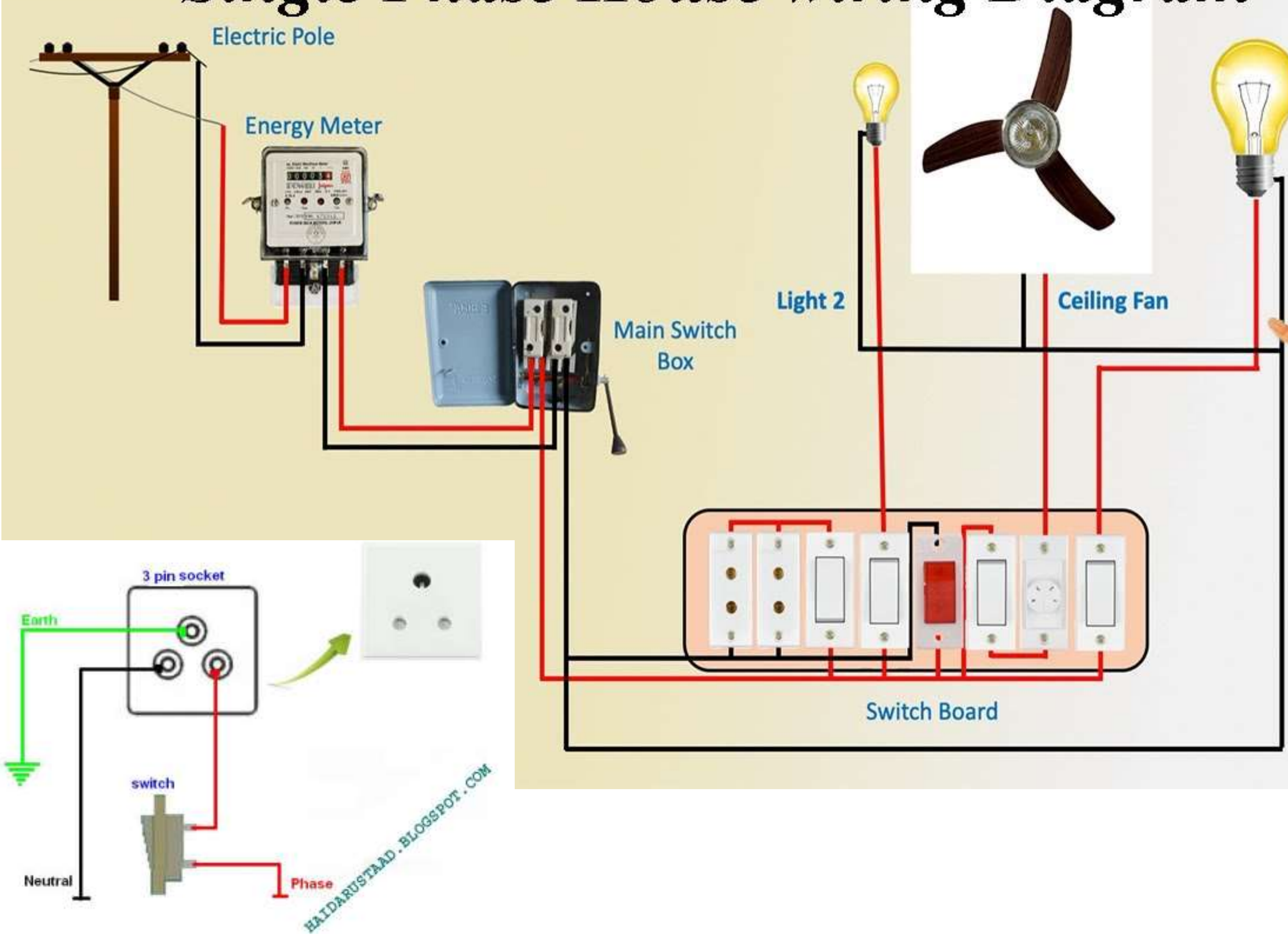
Single Phase System

- In single-phase system, the voltage rises to a peak in one direction of flow, subsides to zero, reverses, rises to a peak in the opposite direction, subsides to zero, and so on.
- The cycle repeats itself 60 times every second, which is where we get the term 60-cycle or 60-hertz alternating current.
- Single-phase connection requires the use of one transformer

In a Single Phase Power Supply, the power is distributed using only two wires called Phase and neutral. Since AC Power takes the shape of a sinusoidal wave, the voltage in a single phase supply peaks at 90^0 during the positive cycle and again at 270^0 during the negative cycle.



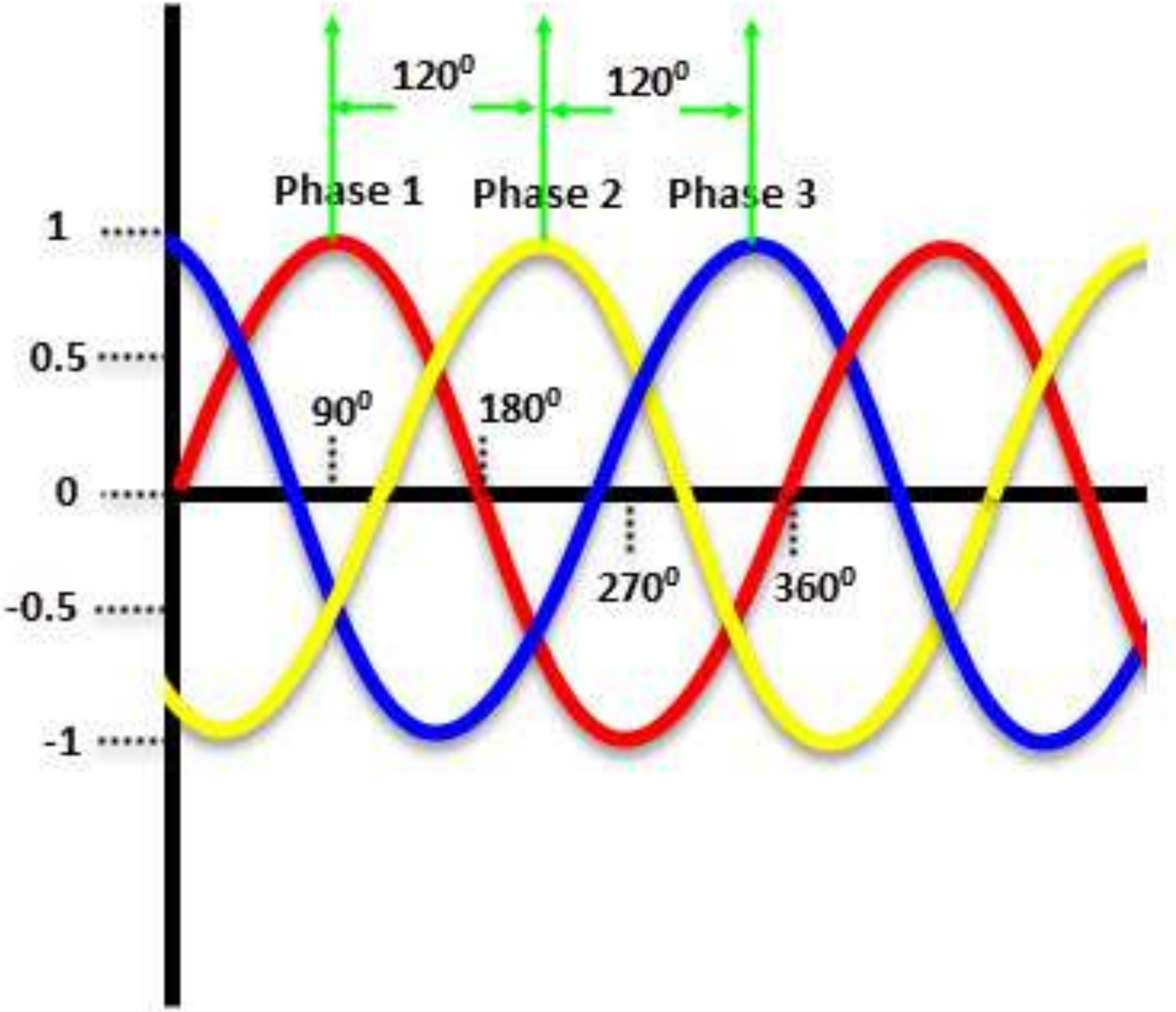
Single Phase House wiring Diagram

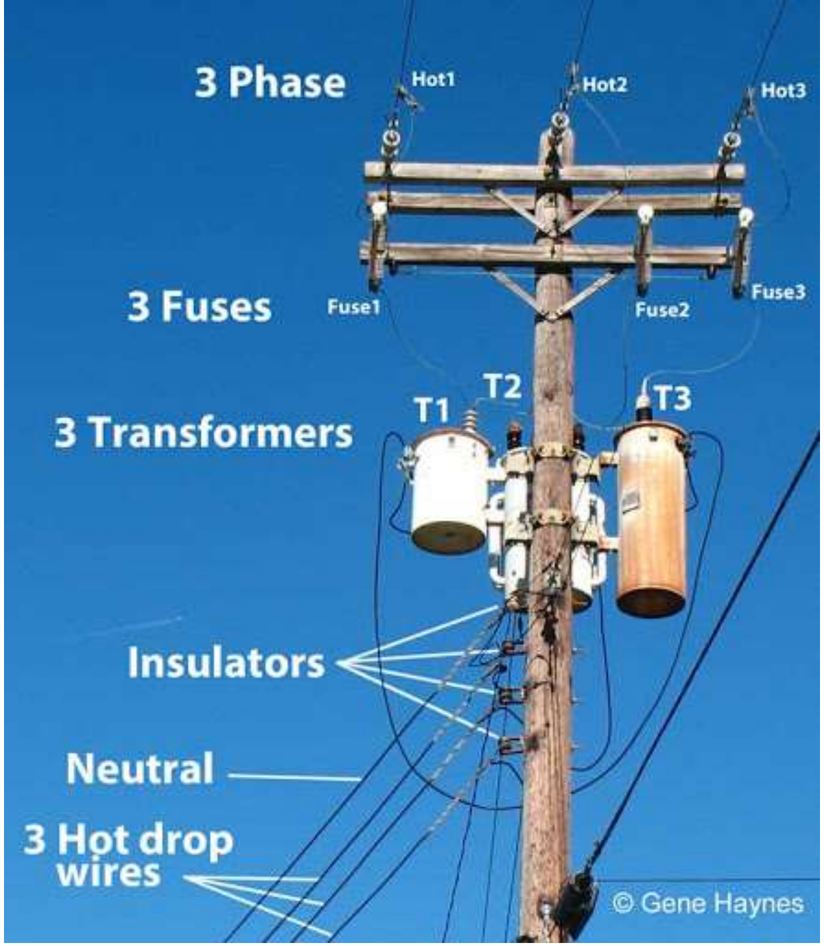


Three Phase System

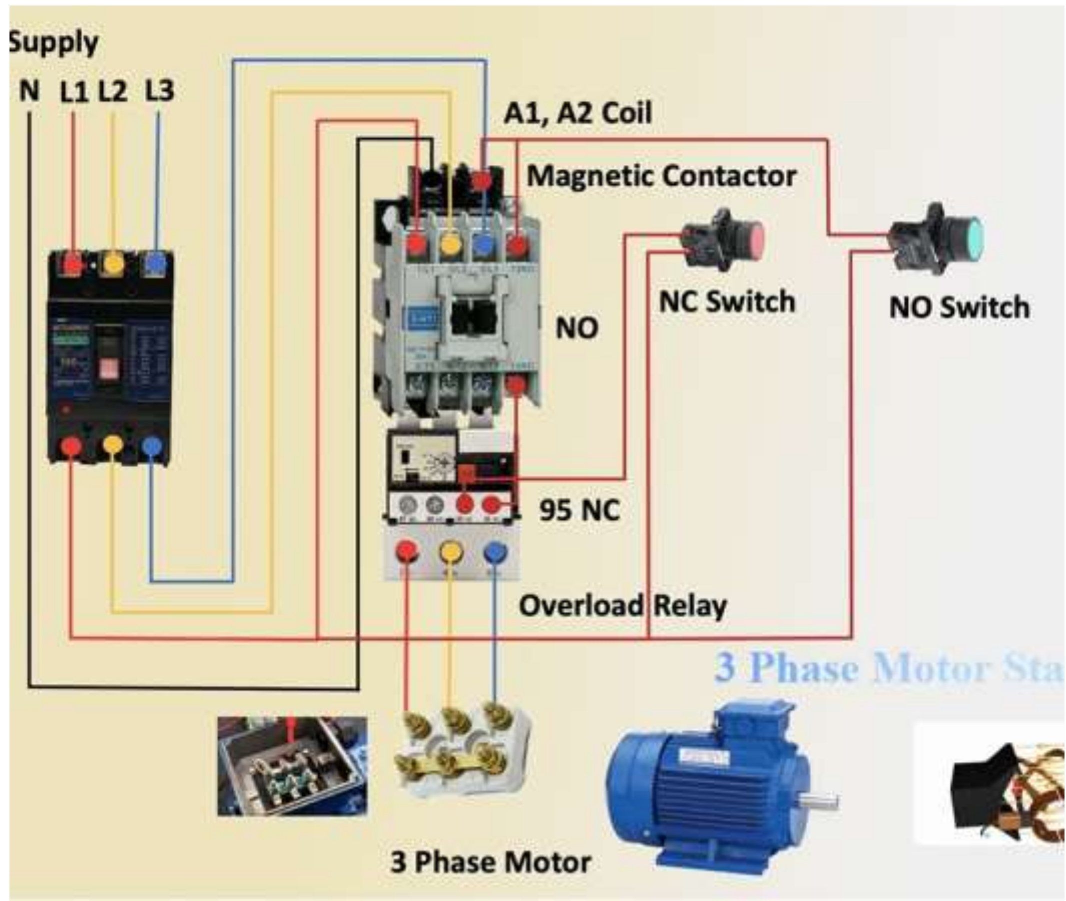
- In the case of three-phase system, there are three separate and distinct single-phase voltages.
- Each phase reaches its peak 120 degrees apart from the others.
- Three-phase connection requires two or three transformers.

Three-Phase Voltage



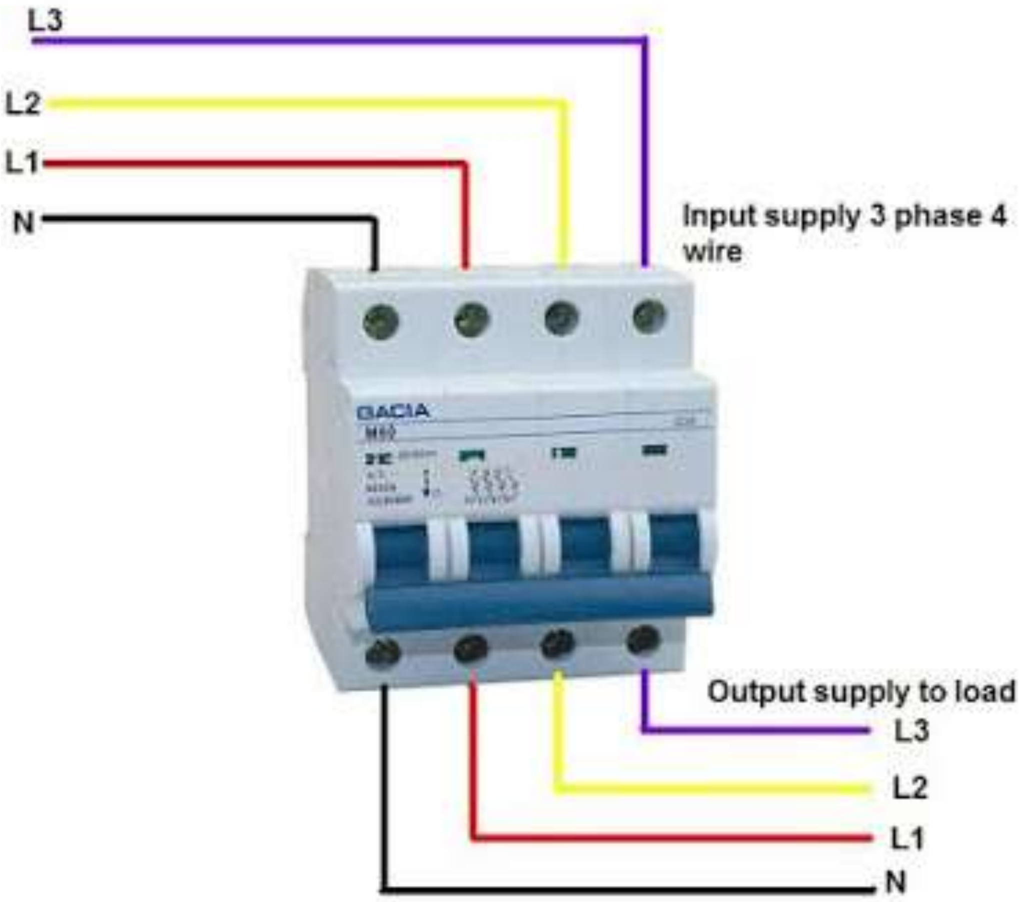

3 Phase
Hot1
Hot2
Hot3
3 Fuses
Fuse1
Fuse2
Fuse3
T1
T2
T3
3 Transformers
Insulators
Neutral
3 Hot drop wires
© Gene Haynes

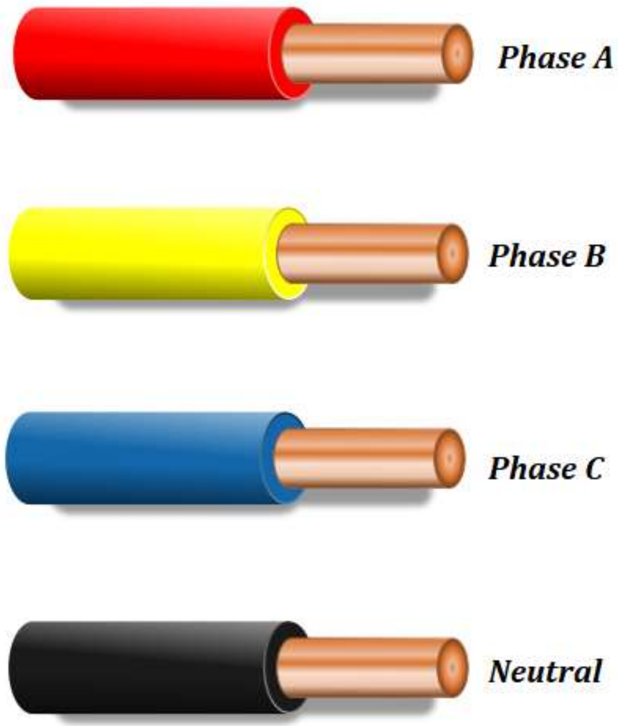

L3
L2
L1
N
PE


Supply
N L1 L2 L3
A1, A2 Coil
Magnetic Contactor
NC Switch
NO Switch
NO
95 NC
Overload Relay
3 Phase Motor Sta
3 Phase Motor

The three-phase system has four wire, i.e., the three current carrying conductors and the one neutral.

Standard practice is to colour code the three phases as Red, Yellow and Blue to identify each individual phase.

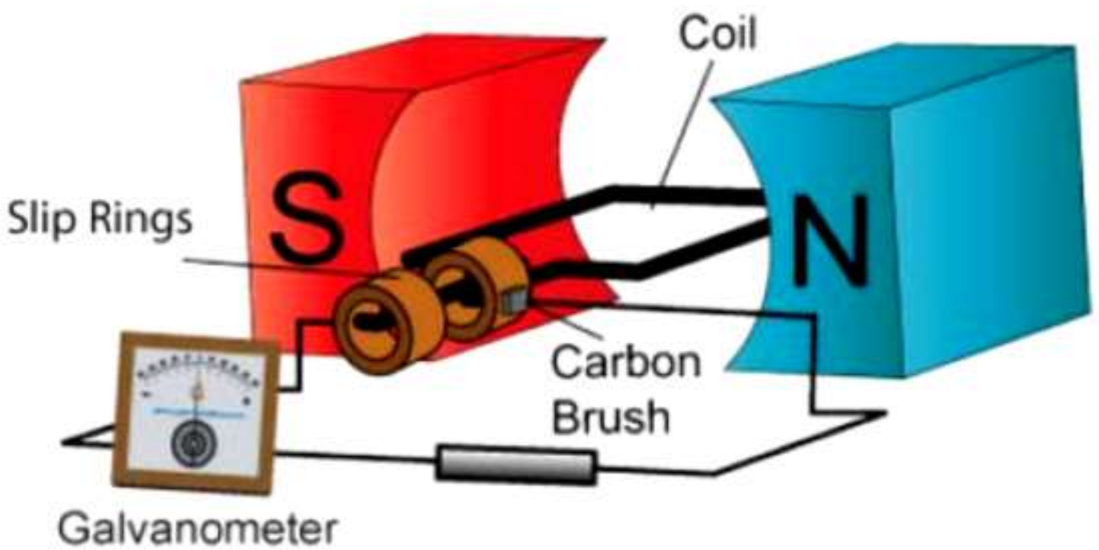




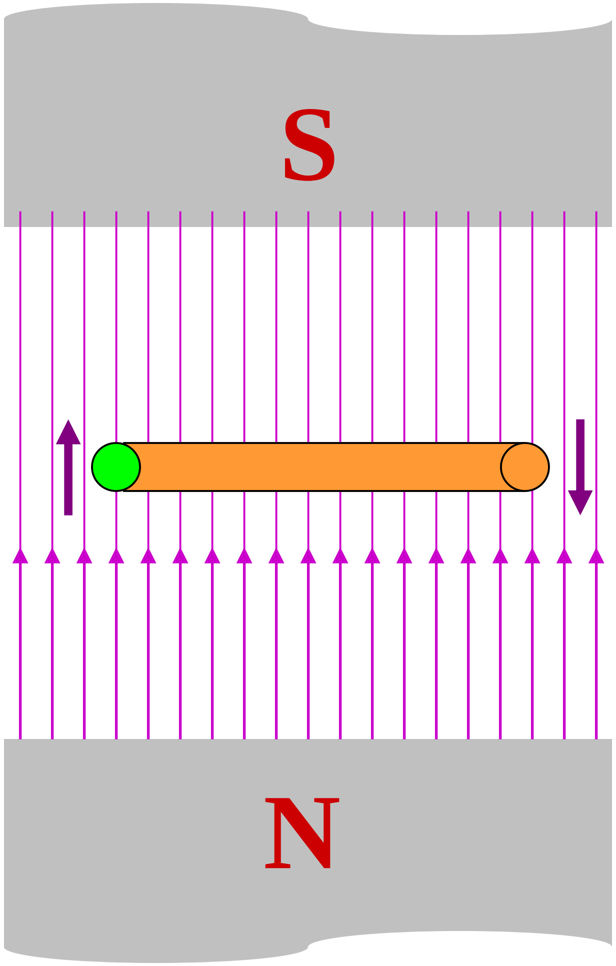
3-phase 4-wire system

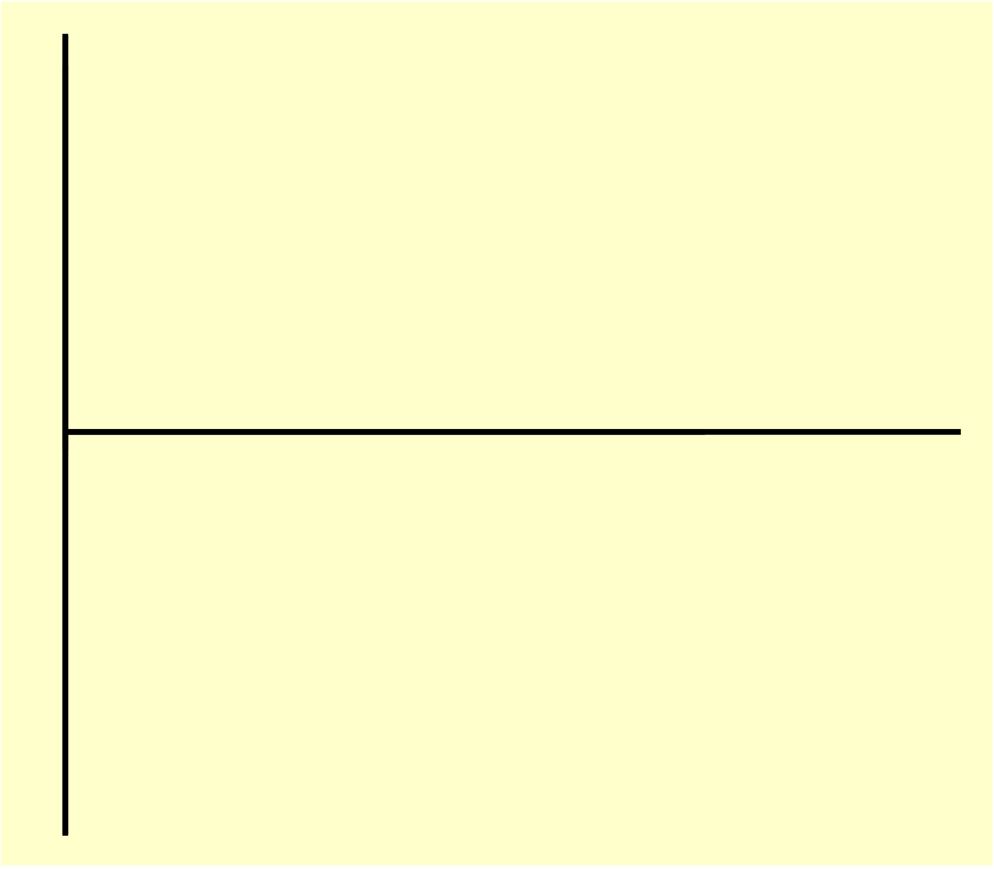
GENERATING A SINGLE PHASE

One-phase ac generator: static magnets, one rotating coil, single output voltage $v(t)=V_m\cos\omega t$.



GENERATING A SINGLE PHASE

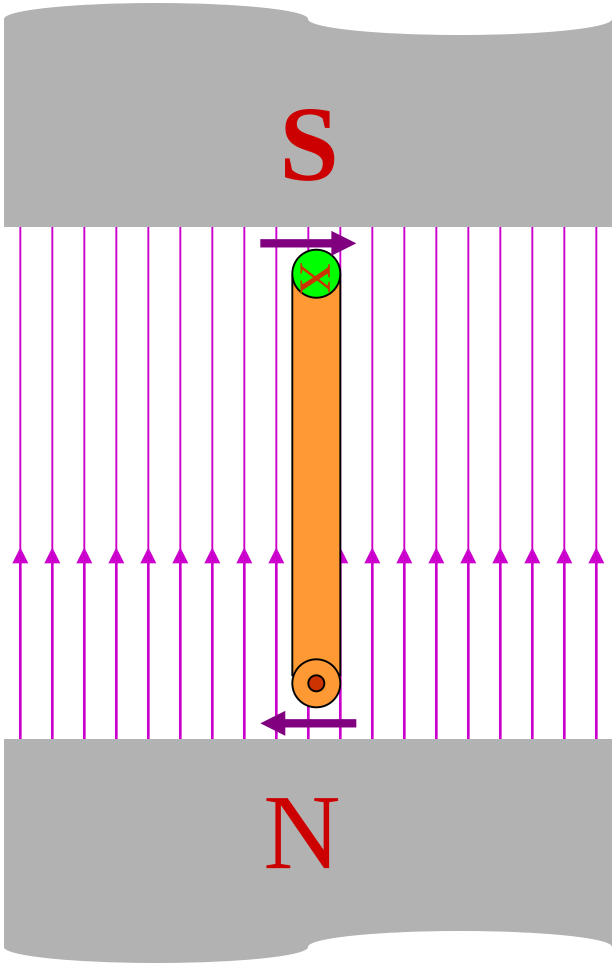


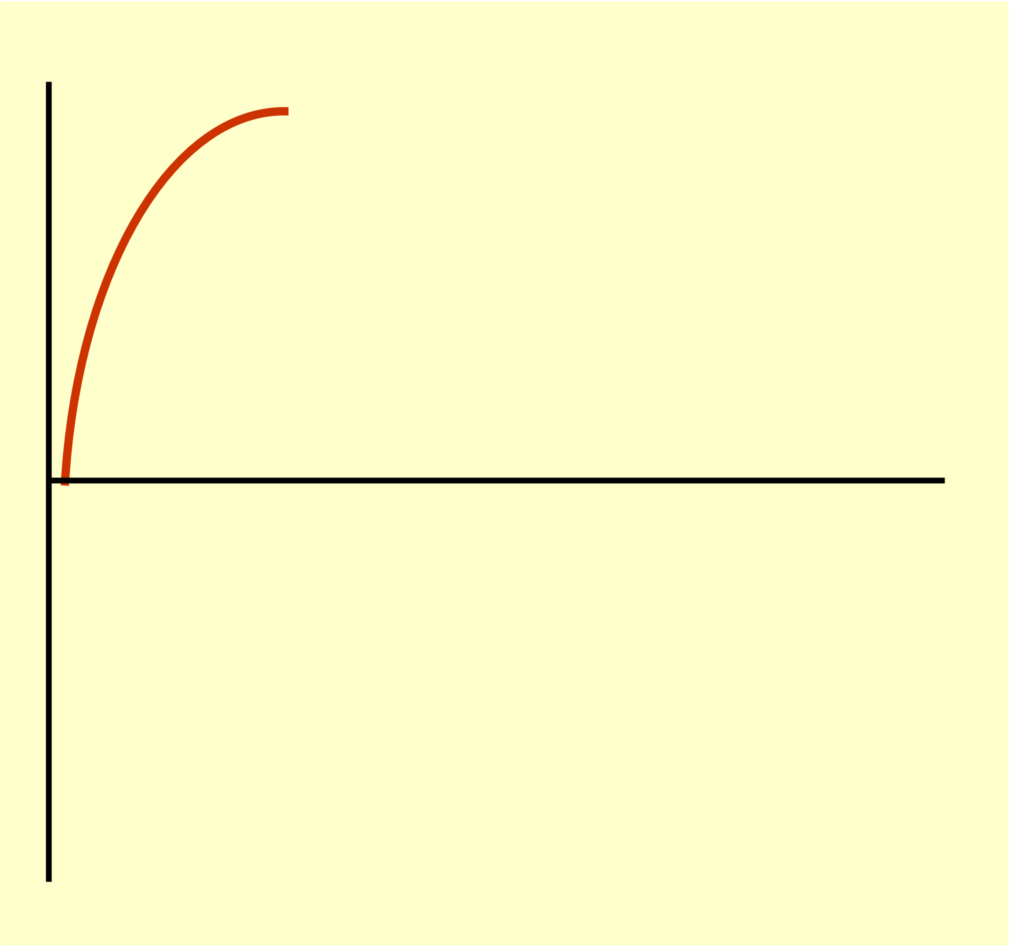


Motion is parallel to the flux.

No voltage is induced.

GENERATING A SINGLE PHASE

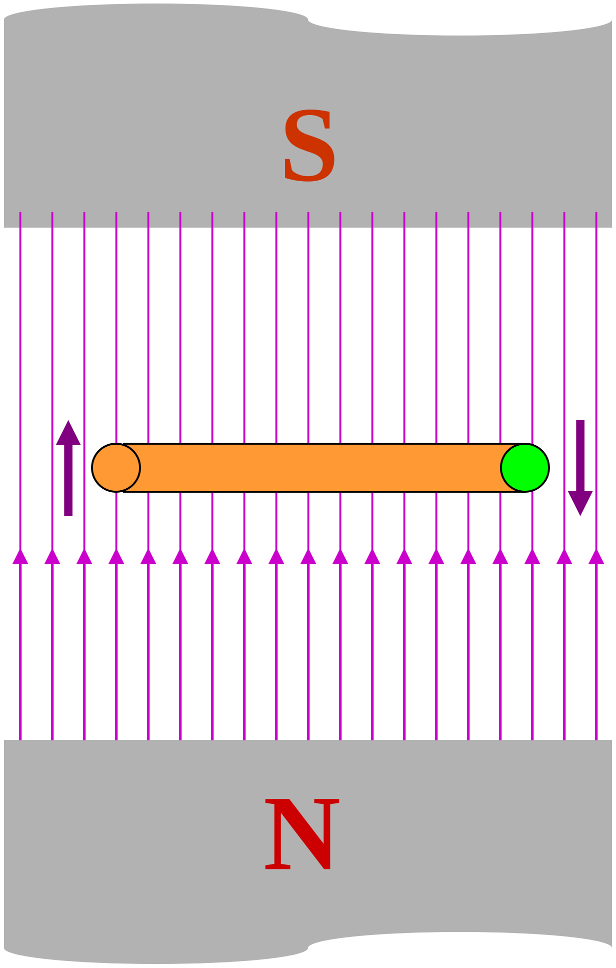


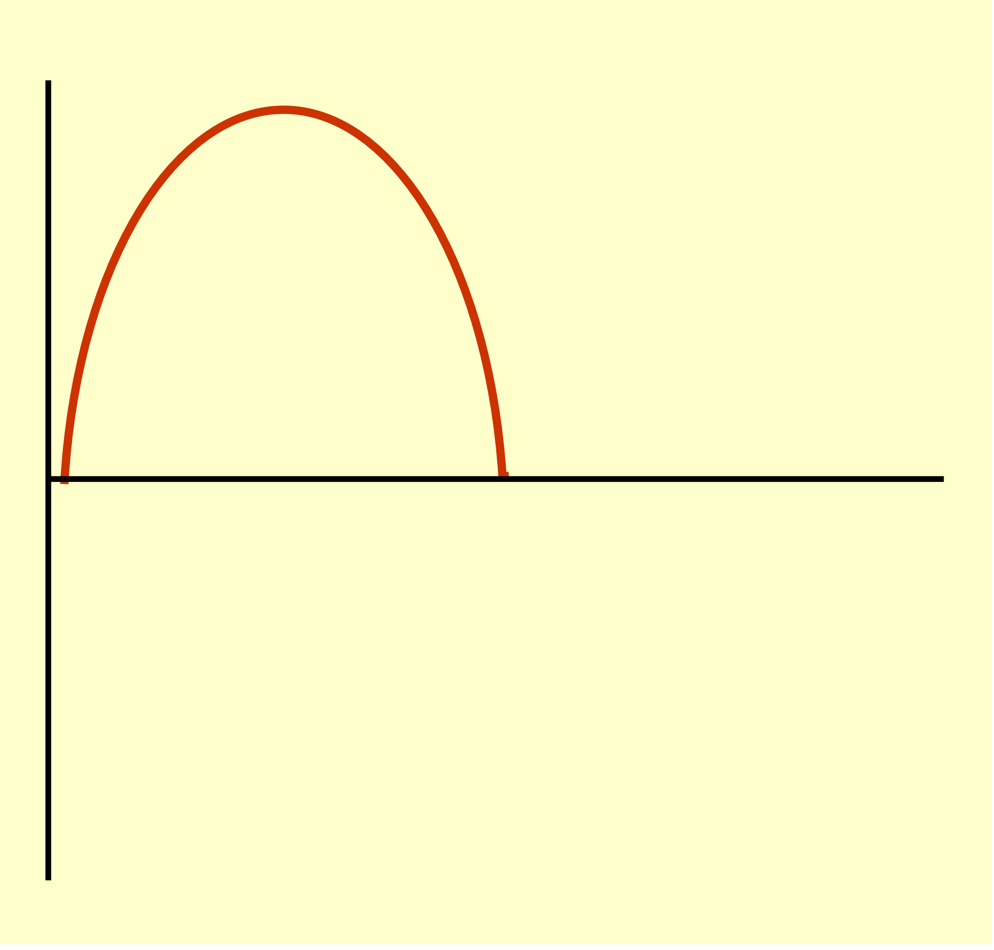


Motion is perpendicular to flux.

Induced voltage is maximum.

GENERATING A SINGLE PHASE

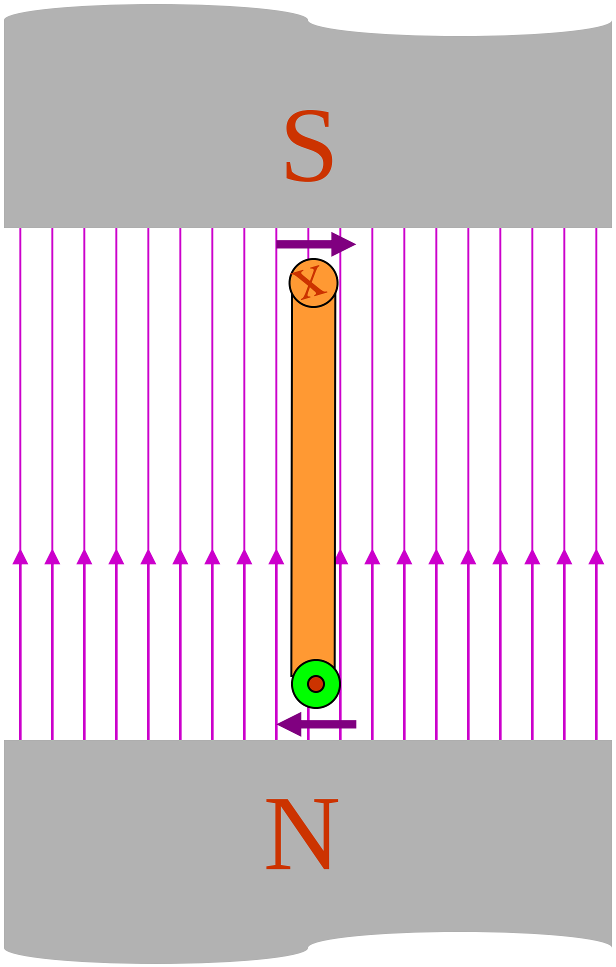


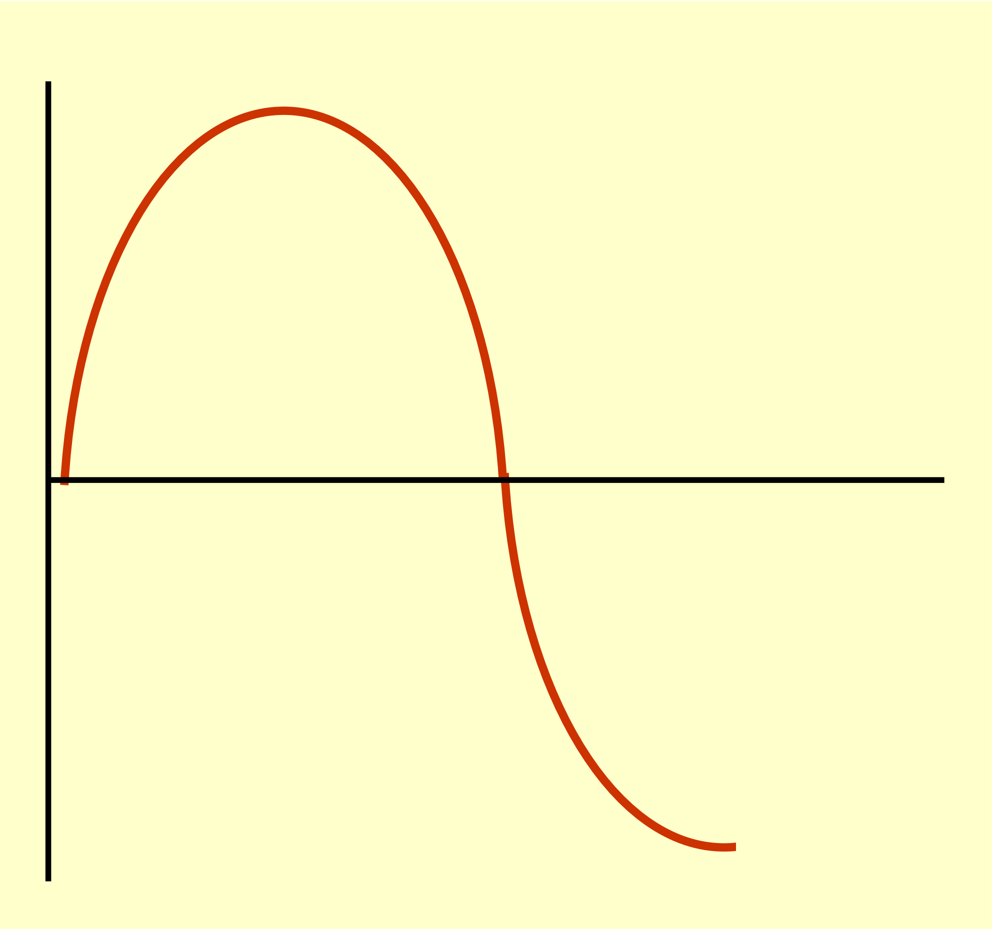


Motion is parallel to flux.

No voltage is induced.

GENERATING A SINGLE PHASE

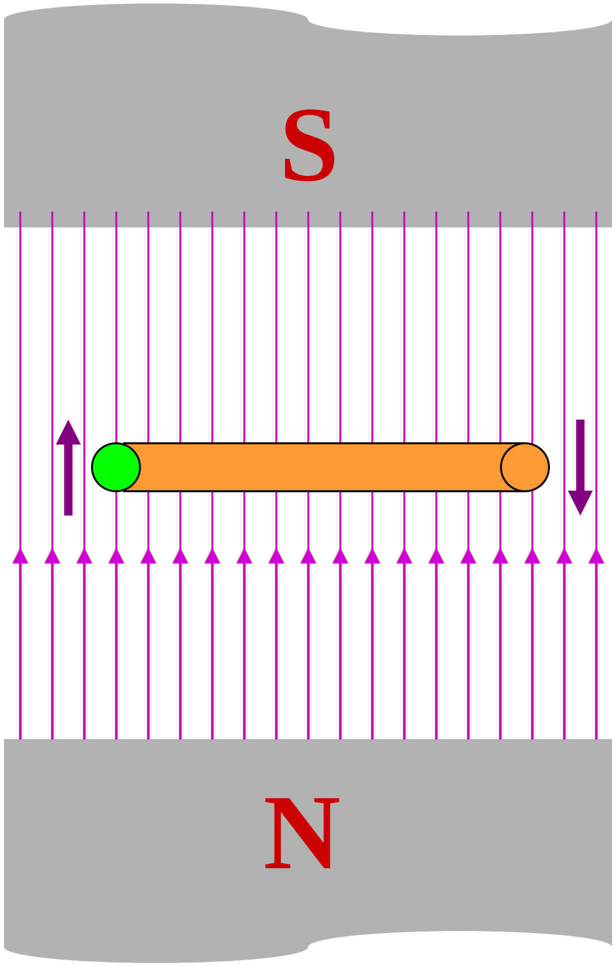


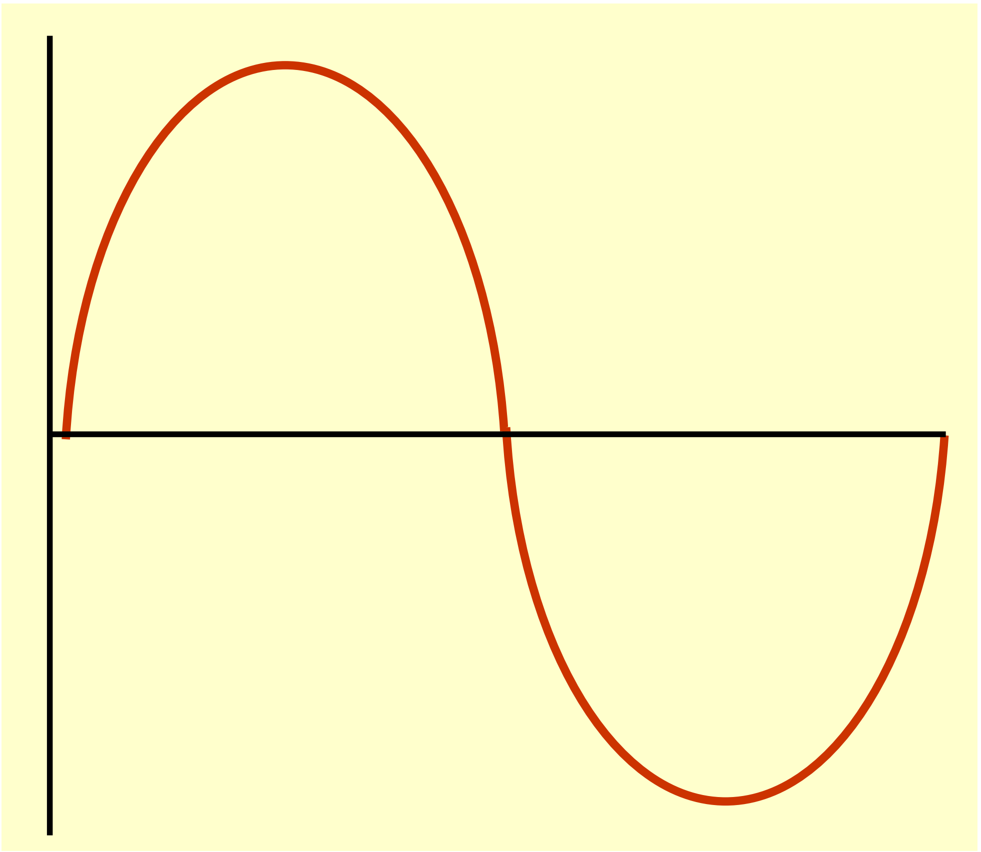


Motion is perpendicular to flux.

Induced voltage is maximum.

GENERATING A SINGLE PHASE





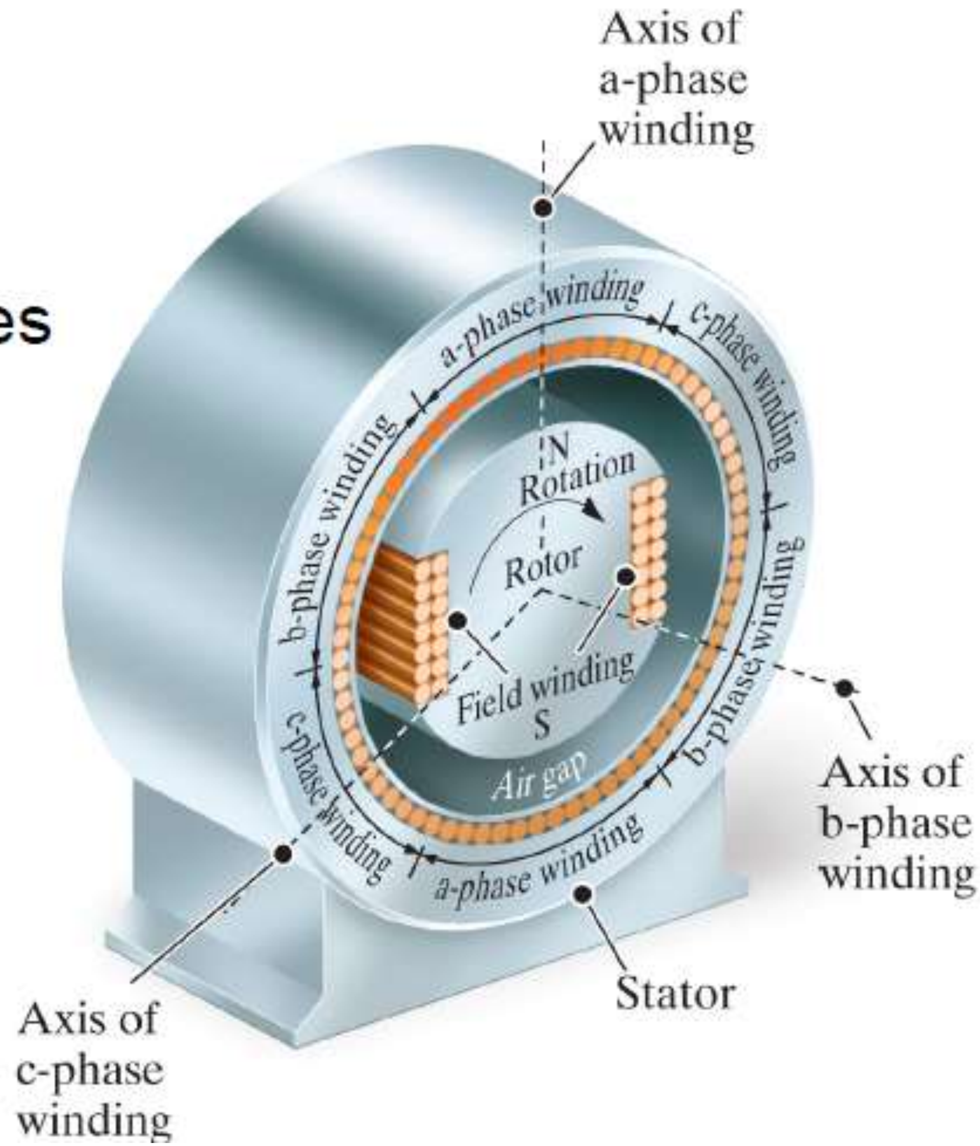
Motion is parallel to flux.

No voltage is induced.

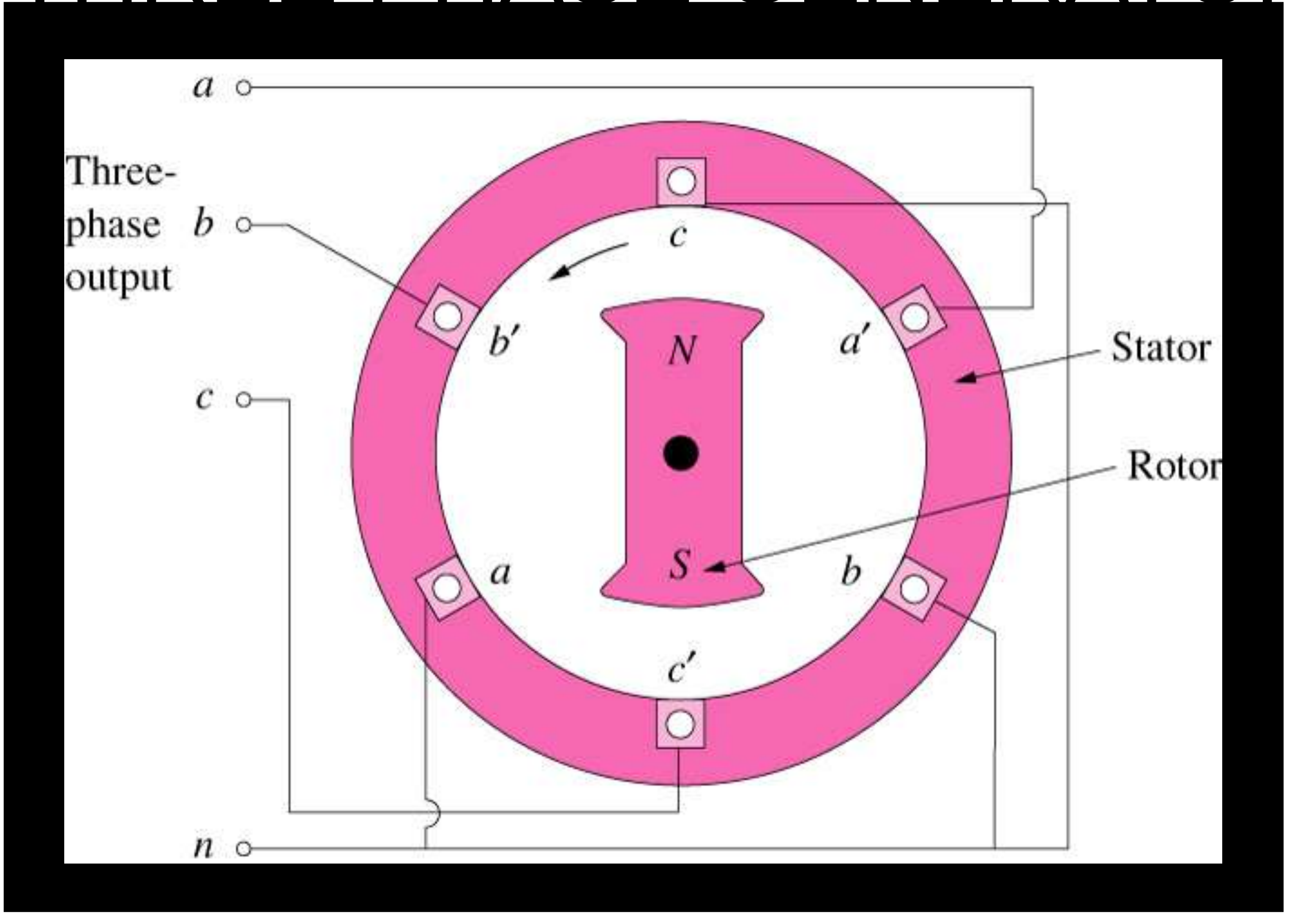
Ready to produce another cycle.

THREE PHASE GENERATOR

Three static coils,
rotating magnets,
three output voltages
$v_a(t)$, $v_b(t)$, $v_c(t)$.



THREE PHASE GENERATOR

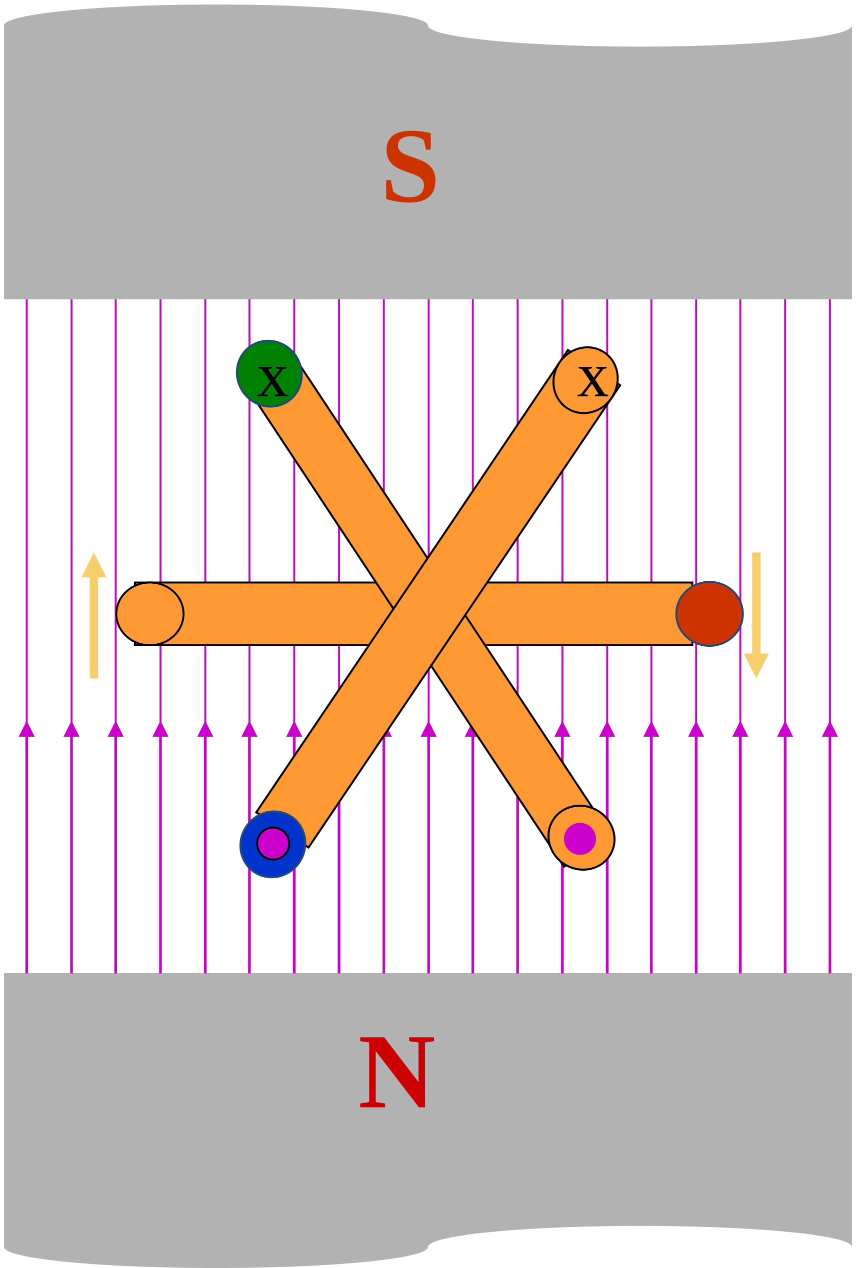


The generator consists of a rotating magnet (rotor) surrounded by a stationary winding (stator)

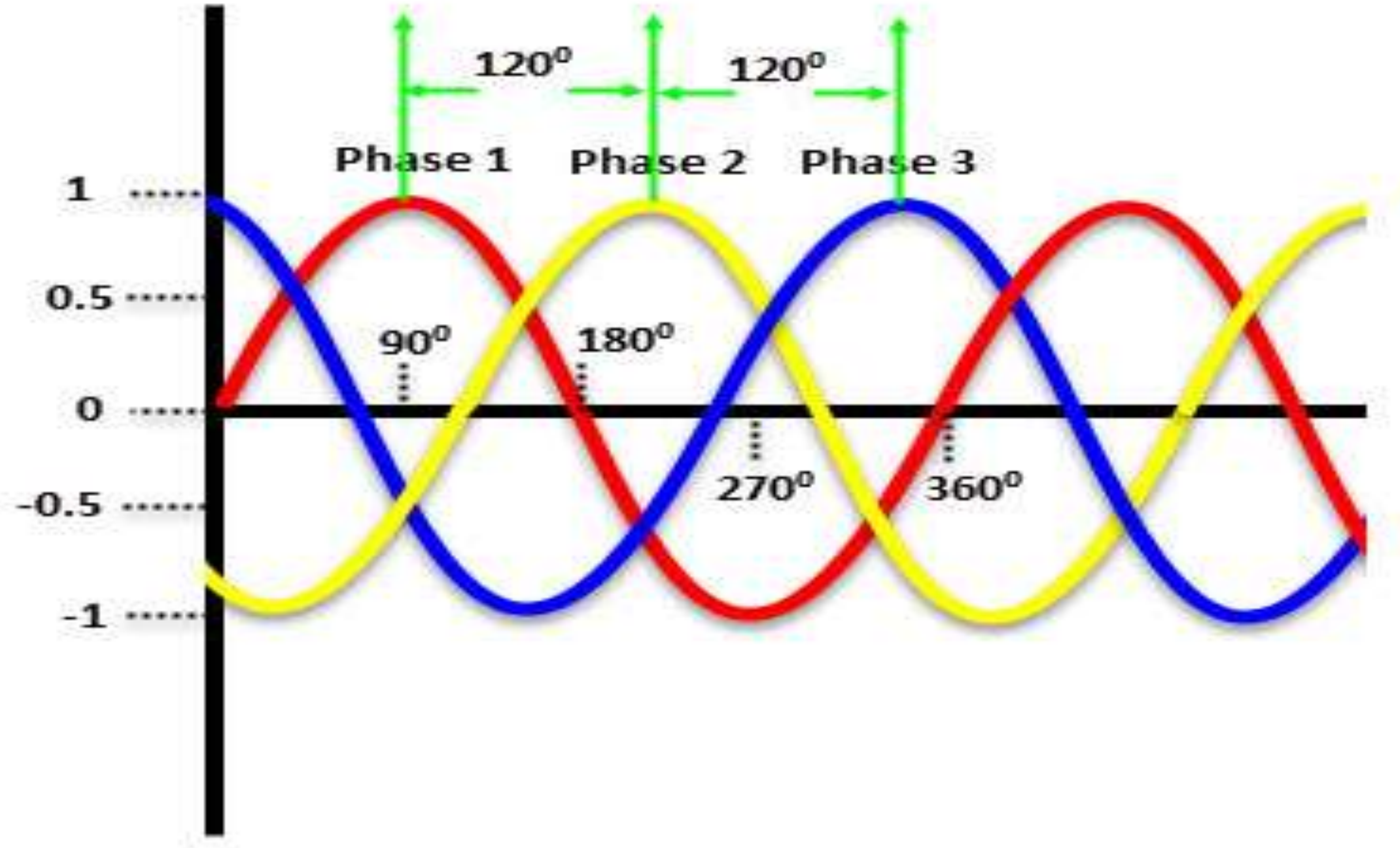
GENERATOR WORK

- Three separate windings or coils with terminals a-a', b-b', and c-c' are physically placed 120° apart around the stator.
- As the rotor rotates, its magnetic field cuts the flux from the three coils and induces voltages in the coils.
- The induced voltage have equal magnitude but out of phase by 120°.

GENERATION OF THREE-PHASE AC



THREE-PHASE WAVEFORM



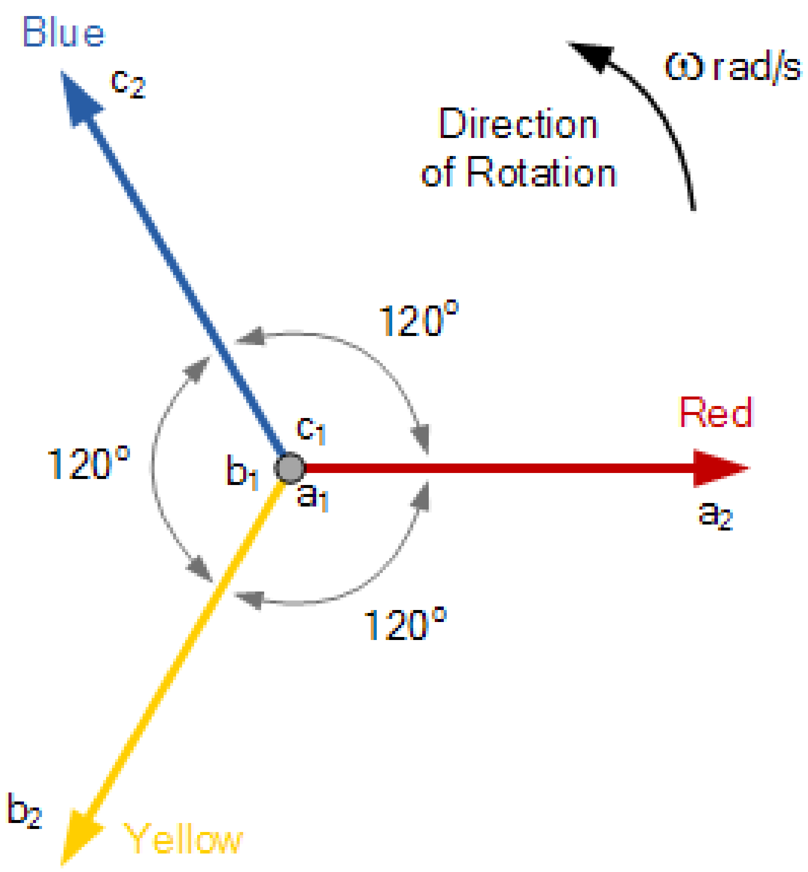
Phase 2 lags phase 1 by 120°.

Phase 3 lags phase 1 by 240°.

Phase 2 leads phase 3 by 120°.

Phase 1 lags phase 3 by 120°.

Three-phase Phasor Diagram



The phase voltages are all equal in magnitude but only differ in their phase angle.

Red Phase: $V_{RN} = V_m \sin\theta$ V_{RN} is taken as the reference voltage

Yellow Phase: $V_{YN} = V_m \sin(\theta - 120^o)$

Blue Phase: $V_{BN} = V_m \sin(\theta - 240^o)$

or

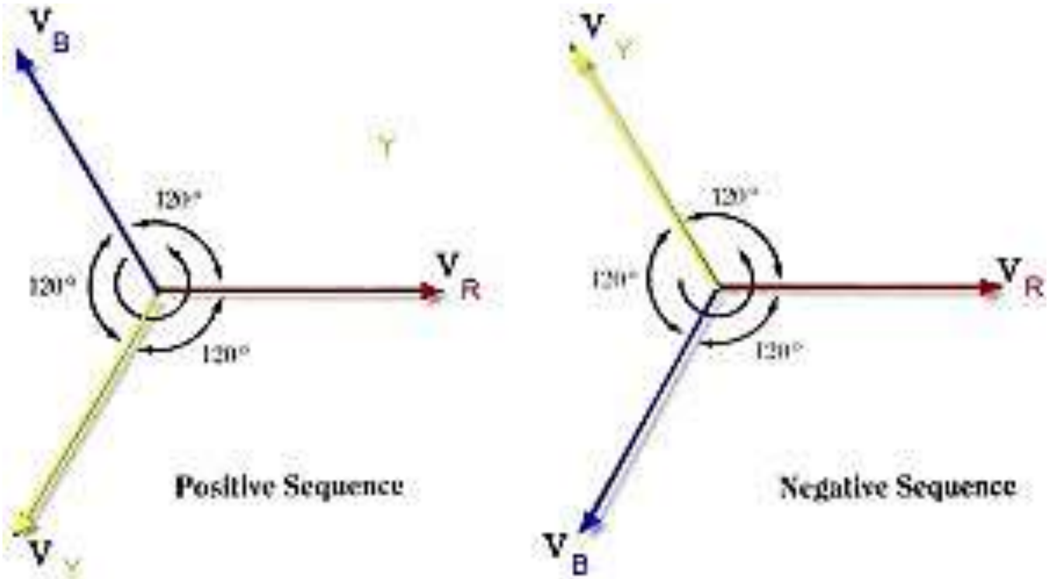
$V_{BN} = V_m \sin(\theta + 120^o)$

As the three individual sinusoidal voltages have a fixed relationship between each other of 120° they are said to be "**balanced**"

In a set of balanced three phase voltages their phasor sum will always be zero as: $V_a + V_b + V_c = 0$

Phase Sequence

The ***phase sequence*** is the time order in which the voltages pass through their respective maximum values.



The phase sequence **RYB** : R attains its maximum value first in anti-clockwise direction followed by Y phase 120° later, and B phase 240° later than the R phase. RYB is considered as a positive sequence

The phase sequence **RBY**: R followed by B phase is at 120° later and Y phase is at 240° later than the R

PHASE VOLTAGES and LINE VOLTAGES

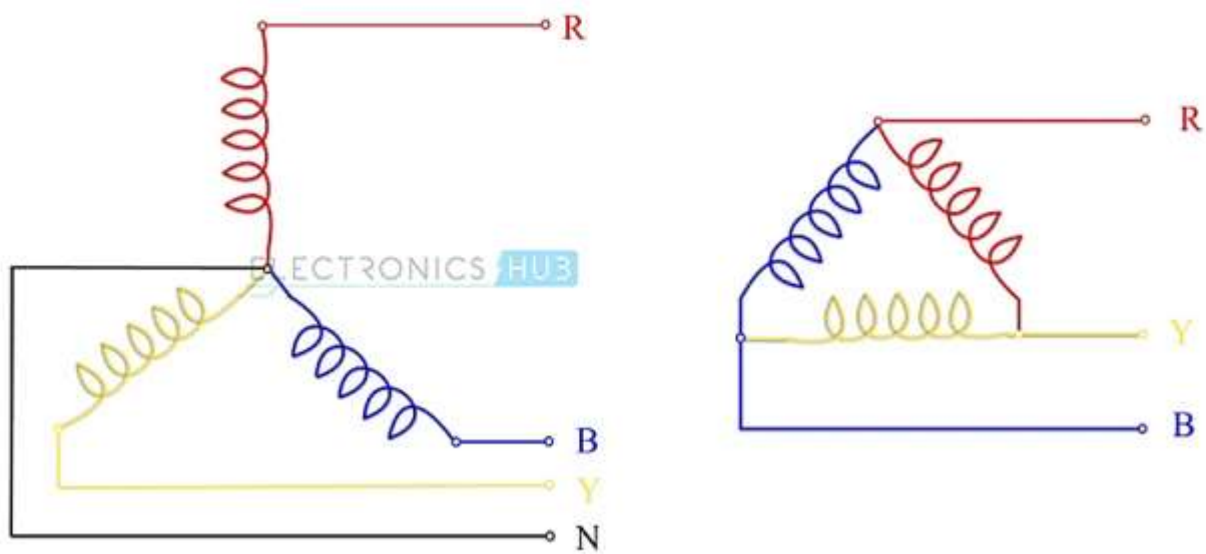
- Phase voltage is measured between the neutral and any line: line to neutral voltage
- Line voltage is measured between any two of the three lines: line to line voltage.

Types of Connections in Three-Phase System

Three-phase transformers consist of three separate sets of coils, each of which is connected to an individual phase. They are connected in two ways:

Star connection

Delta connection

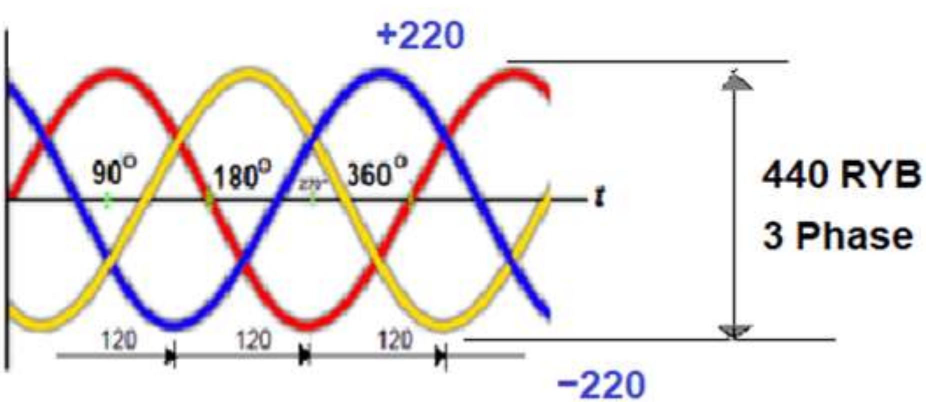


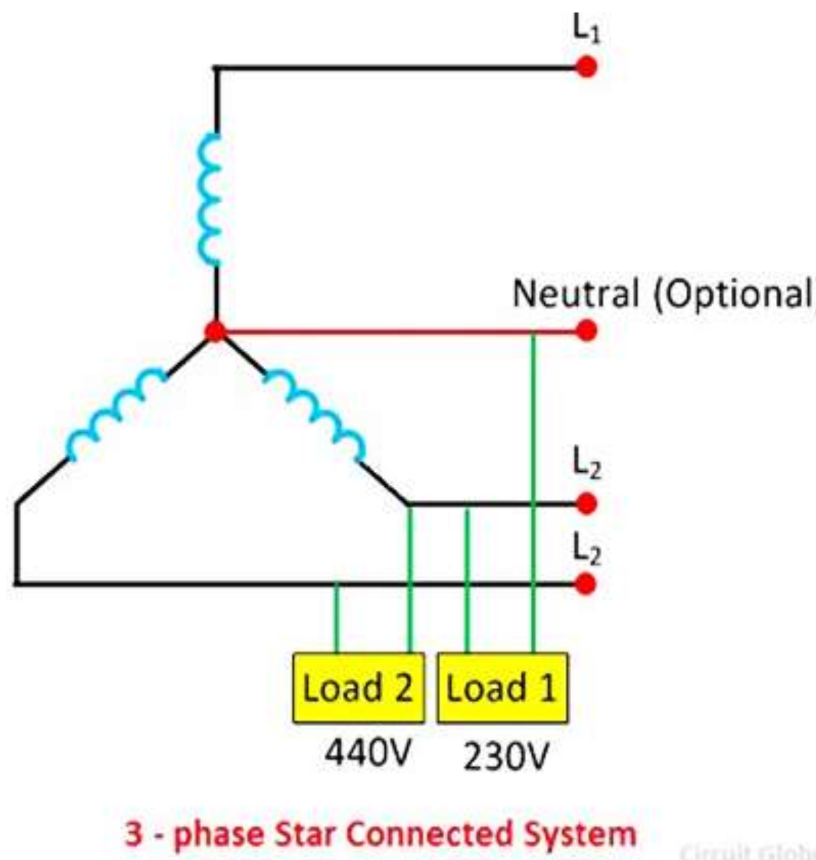
Star Connection (Y or WYE) Delta Connection (Δ)

Star Connection

The star connection requires four wires in which there are three phase conductors and one neutral conductor. Such type of connection is mainly used for long distance transmission because it has a neutral point. The neutral point passes the unbalanced current to the earth and hence makes the system balance.

The phase voltage is 220V, and the line voltage is

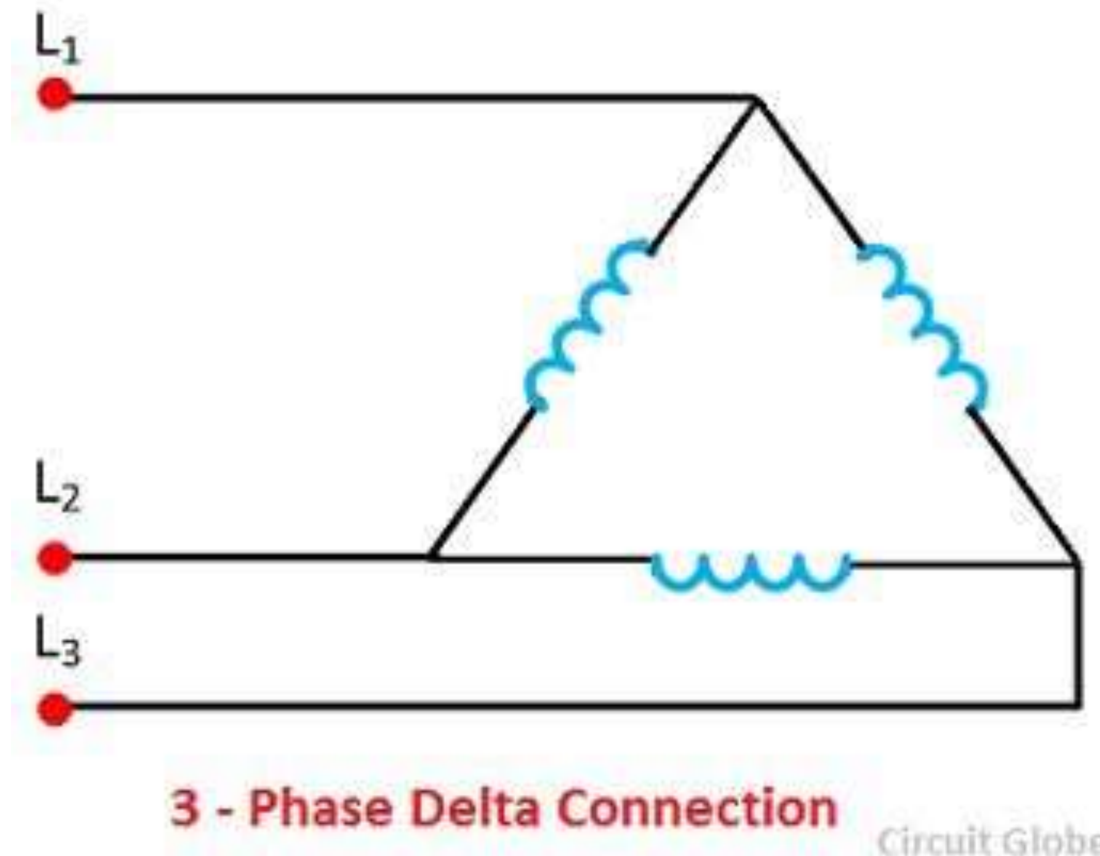




Delta Connection

The delta connection has three wires, and there is a no neutral point. The line voltage of the delta connection is equal to the phase voltage.

Line Voltage and Phase Voltage are same



PHASE CURRENTS and LINE CURRENTS

- Line current (I_L) is the current in each line of the source or load.

- Phase current (I_ϕ) is the current in each phase of the source or load.

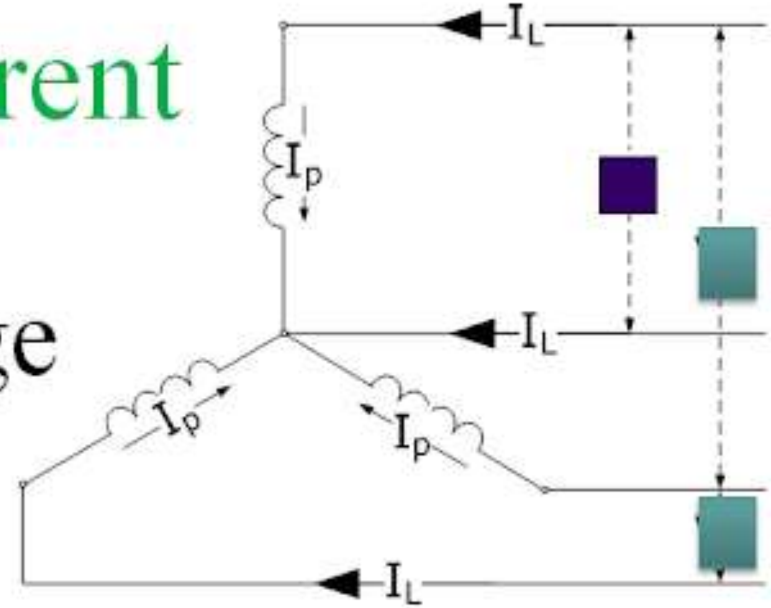
Star Connection

I_L = Line Current

Ip= Phase Current

Vp= Phase Voltage

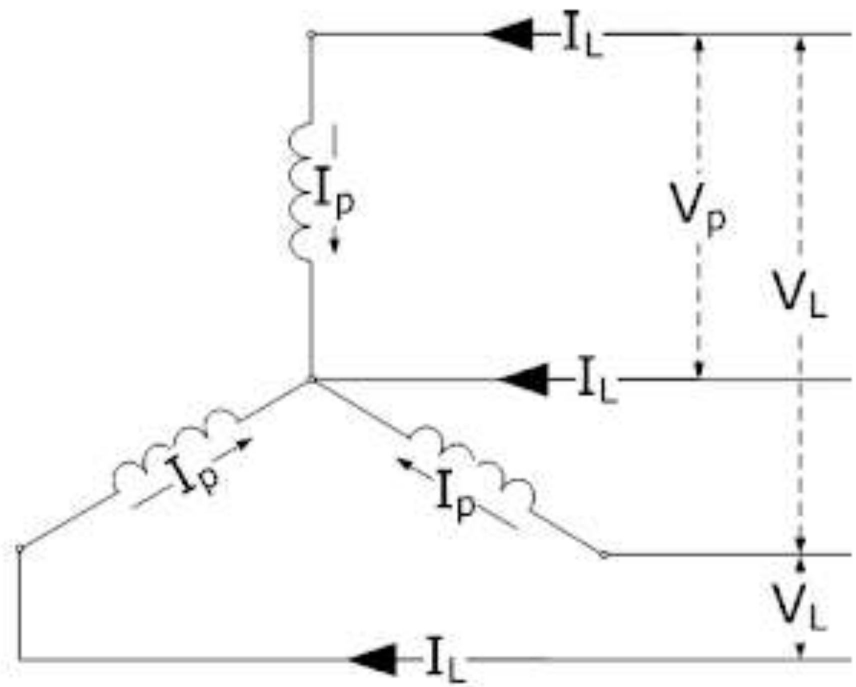
VL= Line Voltage



Star Connection

$$I_L = I_p$$

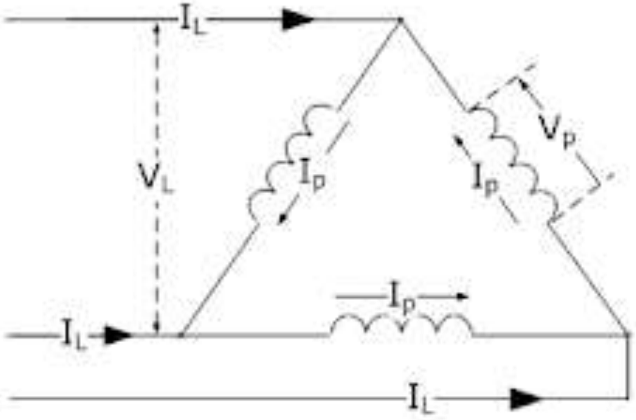
$$V_L = \sqrt{3} \times V_p$$

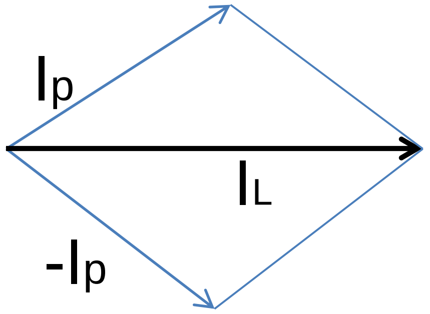


Delta Connection

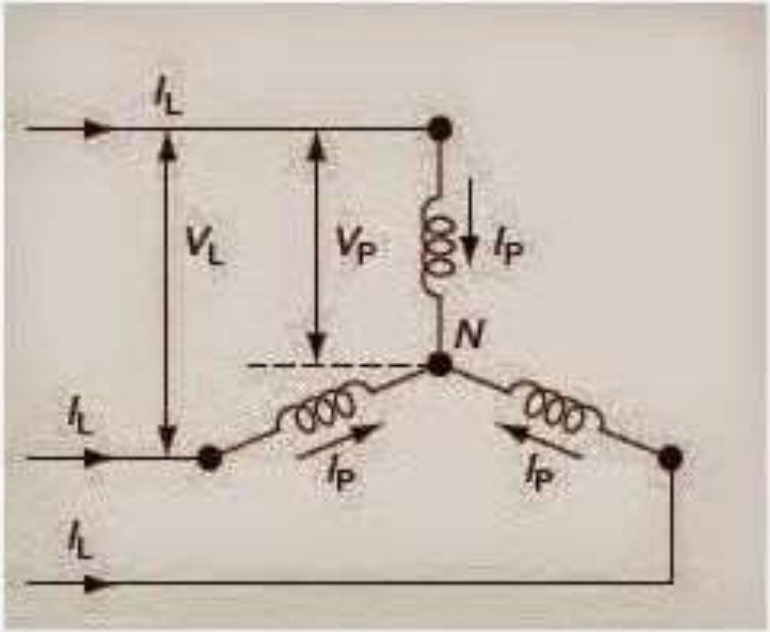
$$V_L = V_P$$

$$I_L = \sqrt{3} \times I_P$$

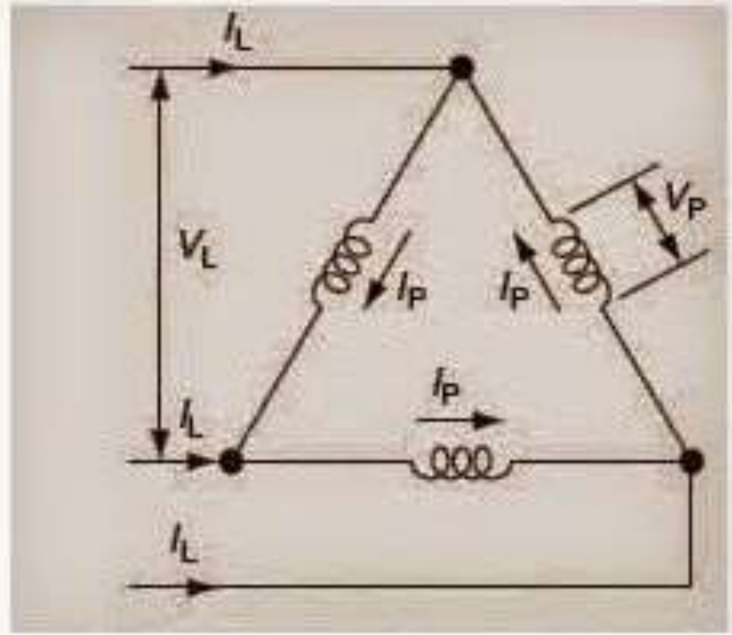




Star Connection



Delta Connection

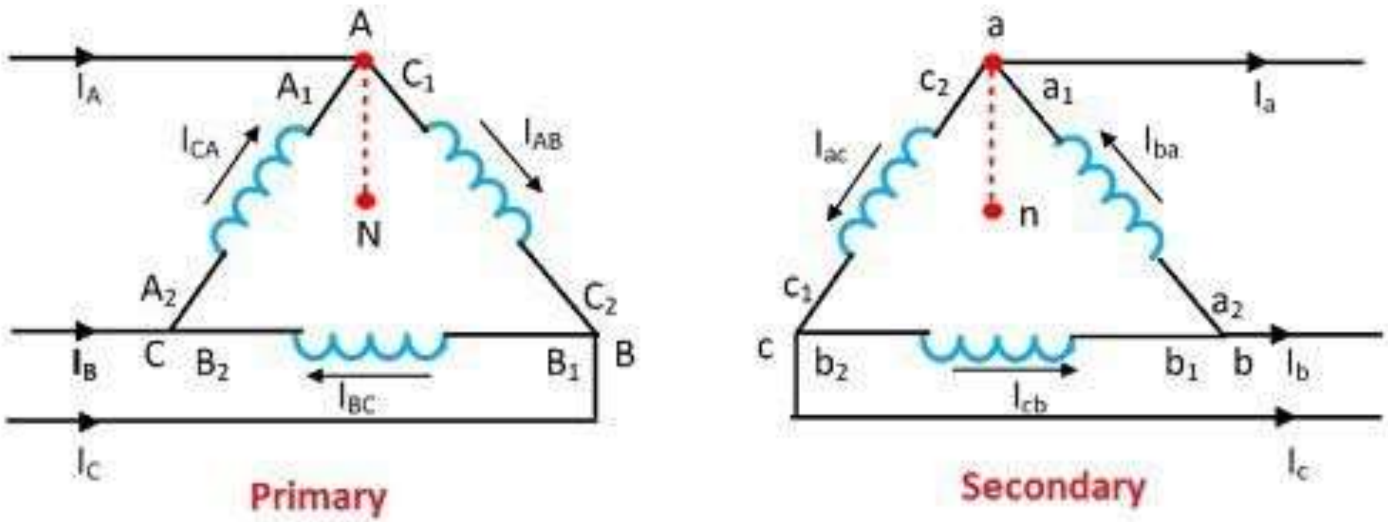


Connection	Phase Voltage	Line Voltage	Phase Current	Line Current
Star	$V_P = V_L \div \sqrt{3}$	$V_L = \sqrt{3} \times V_P$	$I_P = I_L$	$I_L = I_P$
Delta	$V_P = V_L$	$V_L = V_P$	$I_P = I_L \div \sqrt{3}$	$I_L = \sqrt{3} \times I_P$

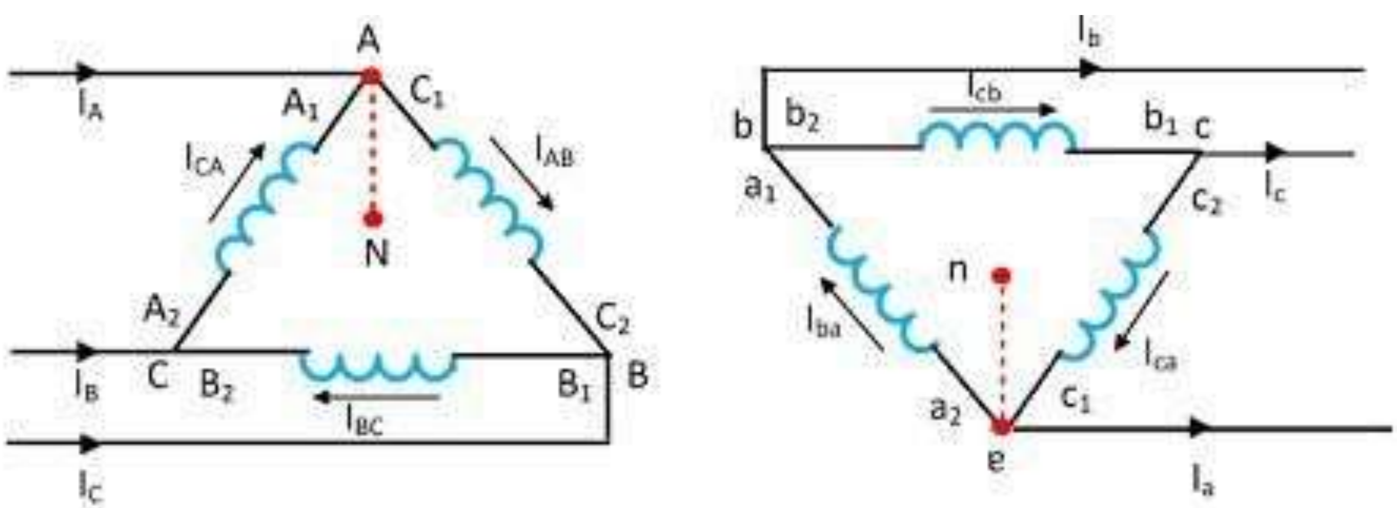
The primary and secondary of the transformer can be independently connected either in star or delta.

There are four possible connections for a 3-phase transformer bank.

- Δ – Δ (Delta – Delta) Connection
- Y – Y (Star – Star) Connection
- Δ – Y (Delta – Star) Connection
- Y – Δ (Star – Delta) Connection



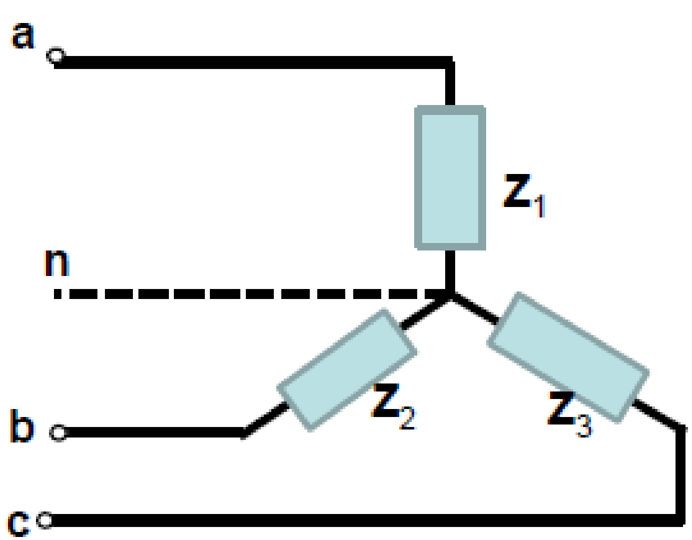
Delta-Delta Connection of Transformer



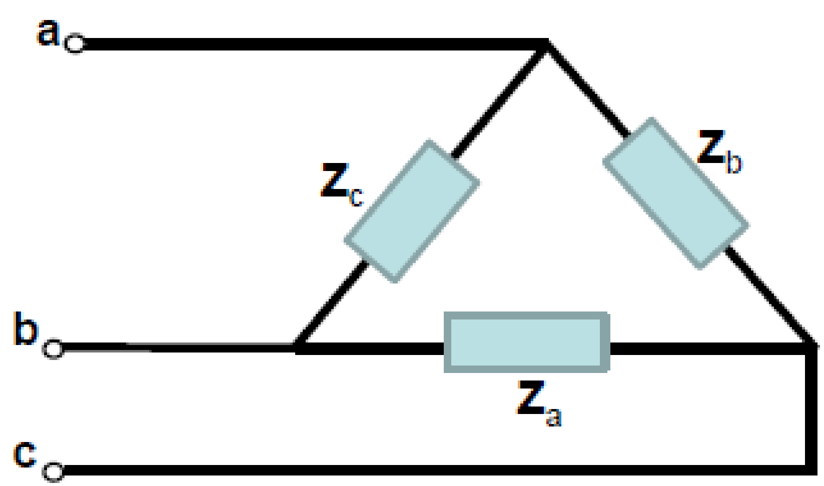
180° Phase Shift of Delta-Delta Connection of Transformer

Balanced 3-phase systems   LOAD CONNECTIONS

Y connection



Δ connection

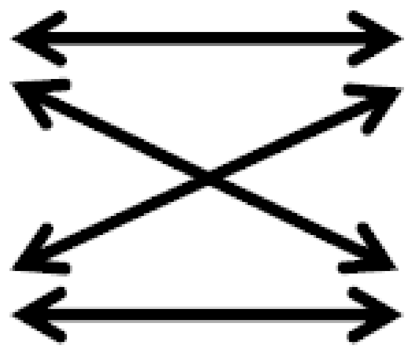


Balanced load:

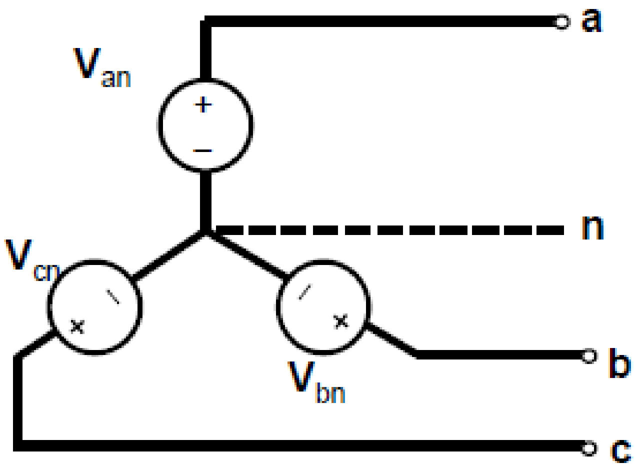
$Z_1 = Z_2 = Z_3 = Z_Y$ $Z_a = Z_b = Z_c = Z_\Delta$ $Z_Y = \frac{Z_\Delta}{3}$

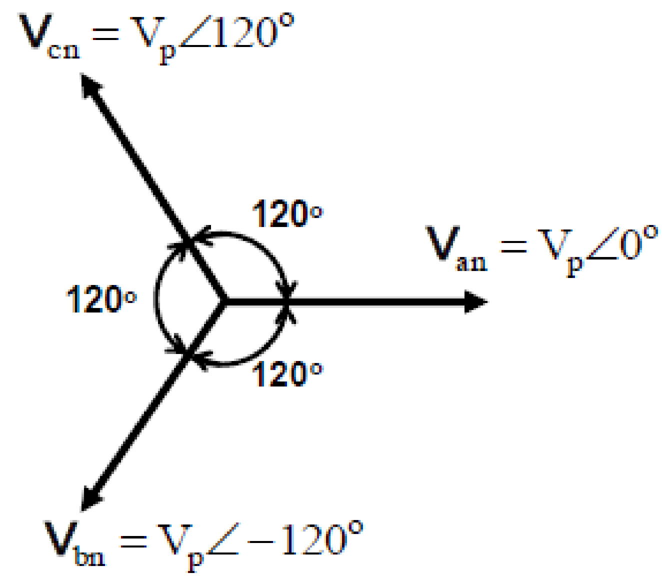
SOURCE-LOAD CONNECTION

SOURCE CONNECTIONS	**LOAD CONNECTIONS**
Y connected source	**Y connected load**
Δ connected source	**Δ connected load**



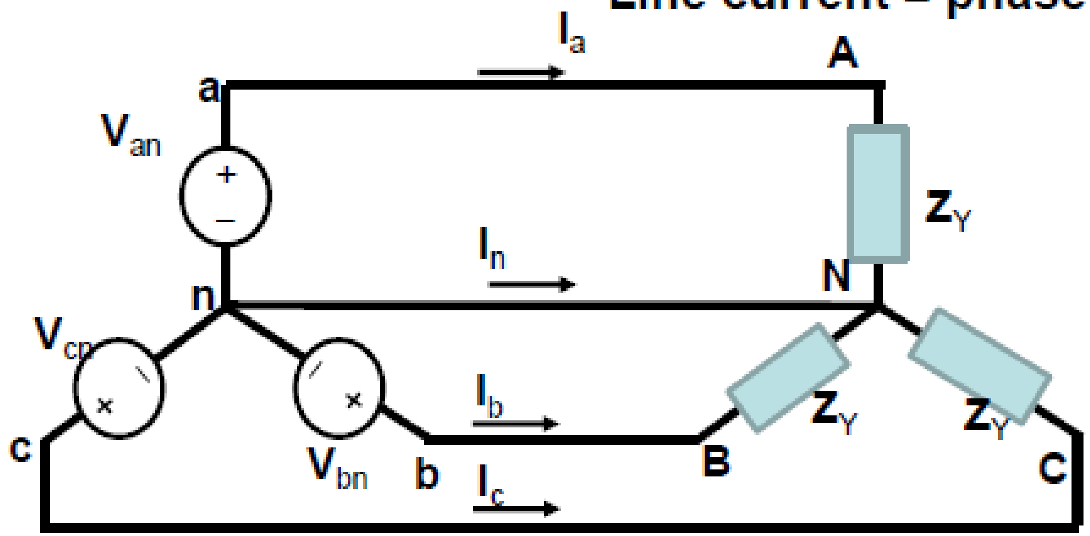
Y-Y **Y-Δ** **Δ-Y** **Δ-Δ**


a
V_an
+
–
n
V_cn
V_bn
b
c


$V_{cn} = V_p\angle 120^\circ$
120°
$V_{an} = V_p\angle 0^\circ$
120°
120°
$V_{bn} = V_p\angle -120^\circ$

Balanced 3-phase Y-Y

Line current = phase current



$$V_{an} = V_p\angle 0^o$$
$$V_{bn} = V_p\angle -120^o$$
$$V_{cn} = V_p\angle 120^o$$

Phase voltages

measured between the <u>neutral</u> and any line
(line to neutral voltage)

$$I_a = \frac{V_p\angle 0^o}{Z_Y}$$
$$I_b = \frac{V_p\angle -120^o}{Z_Y}$$
$$I_c = \frac{V_p\angle 120^o}{Z_Y}$$

line currents

$$\therefore I_a + I_b + I_c = I_n = 0$$

The wire connecting n and N can be removed !

$$\mathbf{V}_{ab} = V_a - V_b = V_a - V_b + V_n - V_n =$$
$$= V_{an} + V_{nb} = V_p\angle 0^o + V_p\angle 60^o$$
$$= \sqrt{3}V_p\angle 30^o$$

$$V_{bc} = V_{bn} + V_{nc}$$
$$= \sqrt{3}V_p\angle -90^o$$

$$V_{ca} = V_{cn} + V_{na}$$
$$= \sqrt{3}V_p\angle 150^o$$

line-line voltages
OR
Line voltages

Balanced 3-phase systems

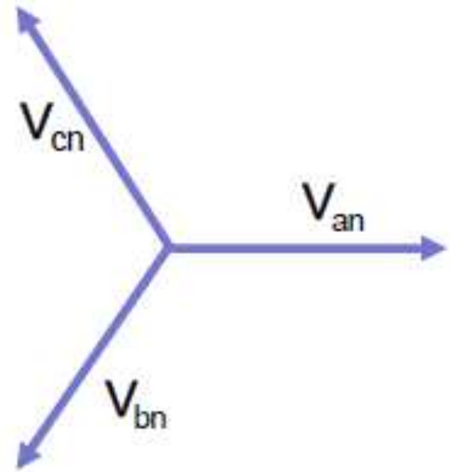
Balanced Y-Y Connection

$$
\begin{aligned}
\mathbf{V}_{ab} &= V_{an} + V_{nb} \\
&= V_p \angle 0^o + V_p \angle 60^o \\
&= \sqrt{3} V_p \angle 30^o
\end{aligned}
$$

Balanced 3-phase systems

Balanced Y-Y Connection

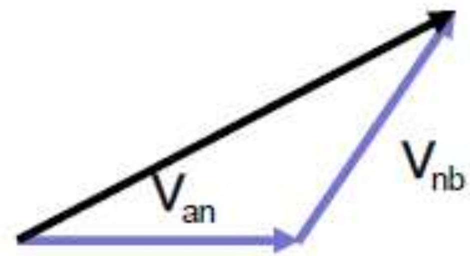
$$\mathbf{V}_{ab} = V_{an} + V_{nb}$$
$$= V_p\angle 0^o + V_p\angle 60^o$$
$$= \sqrt{3}V_p\angle 30^o$$



Balanced 3-phase systems

Balanced Y-Y Connection

$$\mathbf{V}_{ab} = V_{an} + V_{nb}$$
$$= V_p\angle 0^o + V_p\angle 60^o$$
$$= \sqrt{3}V_p\angle 30^o$$

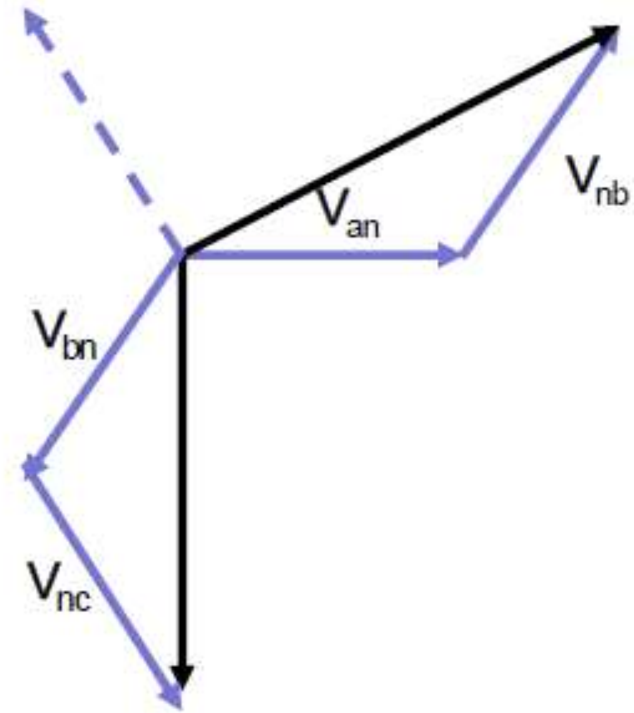


Balanced 3-phase systems

Balanced Y-Y Connection

$$\mathbf{V}_{ab} = V_{an} + V_{nb}$$
$$= V_p\angle 0^o + V_p\angle 60^o$$
$$= \sqrt{3}V_p\angle 30^o$$

$$\mathbf{V}_{bc} = V_{bn} + V_{nc}$$
$$= \sqrt{3}V_p\angle -90^o$$



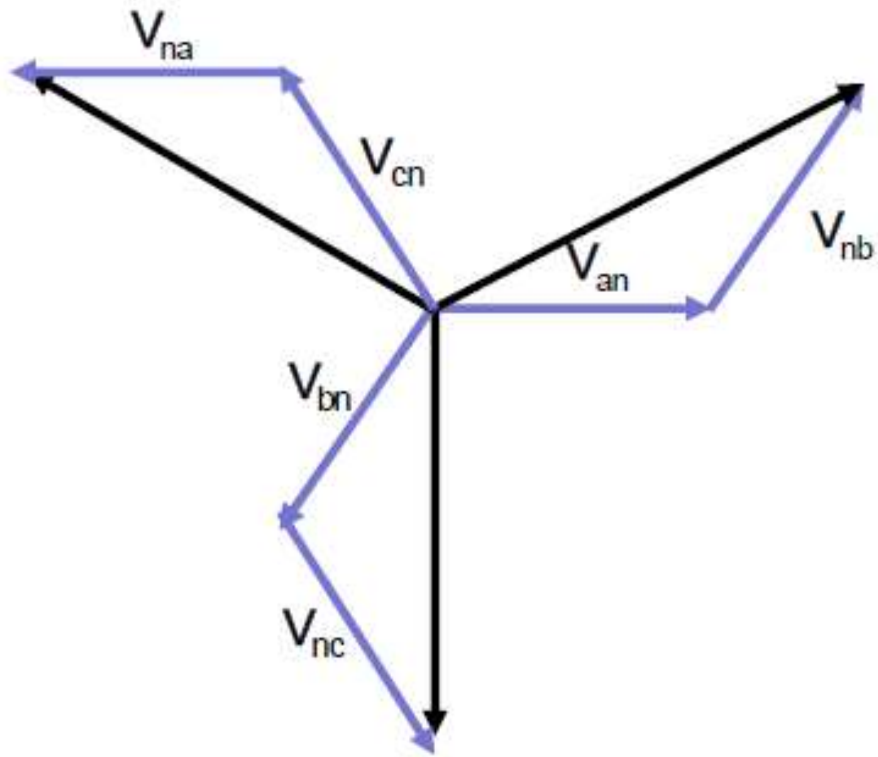
Balanced 3-phase systems

Balanced Y-Y Connection

$$\mathbf{V}_{ab} = V_{an} + V_{nb}$$
$$= V_p\angle 0^o + V_p\angle 60^o$$
$$= \sqrt{3}V_p\angle 30^o$$

$$\mathbf{V}_{bc} = V_{bn} + V_{nc}$$
$$= \sqrt{3}V_p\angle -90^o$$

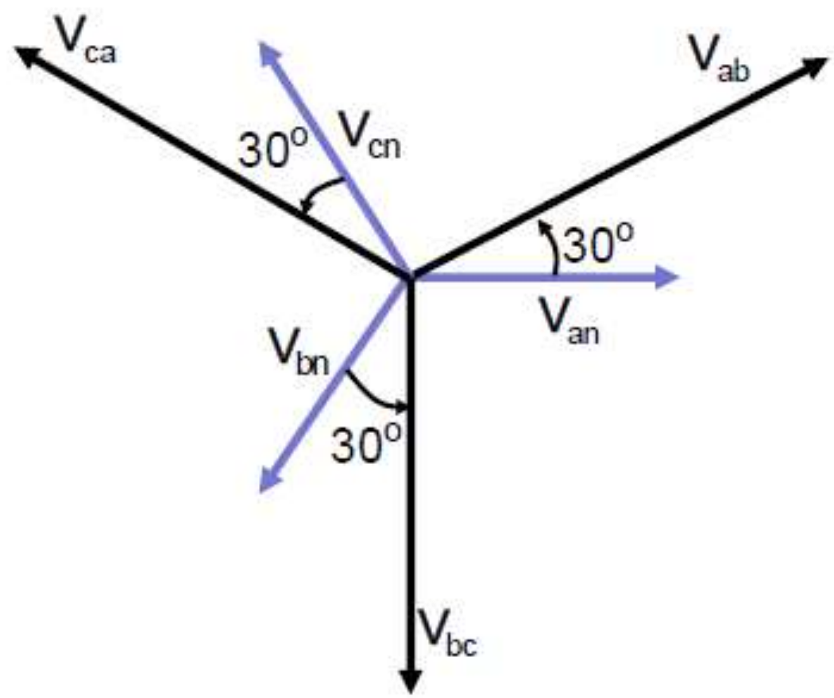
$$\mathbf{V}_{ca} = V_{cn} + V_{na}$$
$$= \sqrt{3}V_p\angle 150^o$$



Balanced 3-phase systems

Balanced Y-Y Connection

$$\mathbf{V}_{ab} = V_{an} + V_{nb}$$
$$= V_p\angle 0^\circ + V_p\angle 60^\circ$$
$$= \sqrt{3}V_p\angle 30^\circ$$



$$\mathbf{V}_{bc} = V_{bn} + V_{nc}$$
$$= \sqrt{3}V_p\angle -90^\circ$$

$$\mathbf{V}_{ca} = V_{cn} + V_{na}$$
$$= \sqrt{3}V_p\angle 150^\circ$$

$$V_L = \sqrt{3}V_p$$

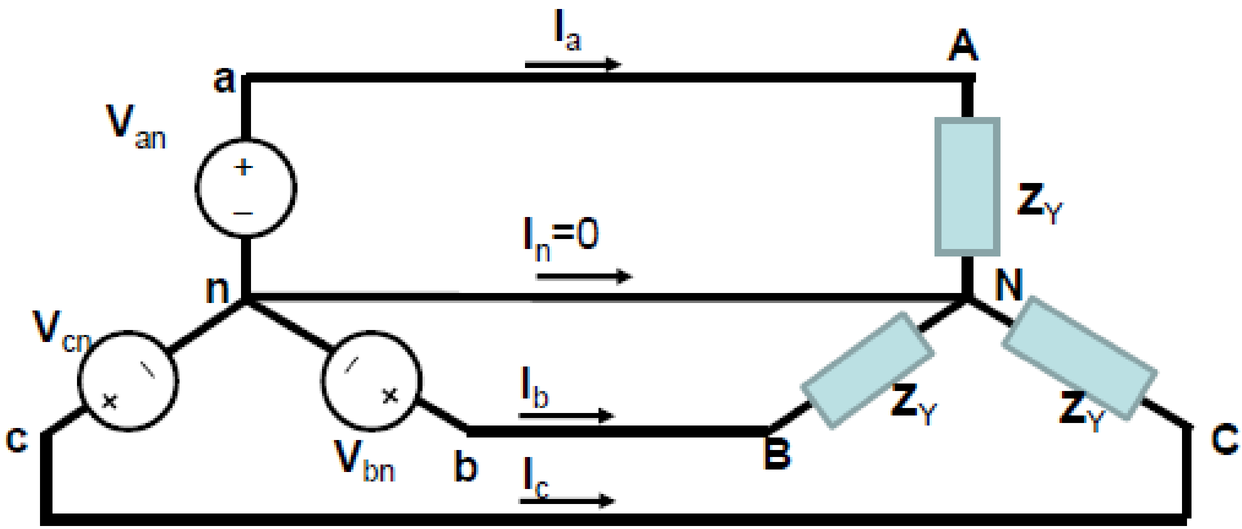
where $V_L = |\mathbf{V}_{ab}| = |\mathbf{V}_{bc}| = |\mathbf{V}_{ca}|$ and $V_p = |\mathbf{V}_{an}| = |\mathbf{V}_{bn}| = |\mathbf{V}_{cn}|$

Line voltage LEADS phase voltage by 30°

Balanced 3-phase systems

Balanced Y-Y Connection

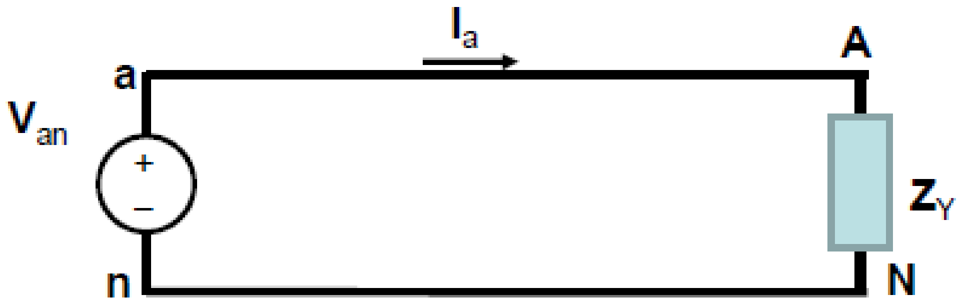
For a **balanced Y-Y** connection, analysis can be performed using an equivalent per-phase circuit: e.g. for phase A:



Balanced 3-phase systems

Balanced Y-Y Connection

For a **balanced Y-Y** connection, analysis can be performed using an equivalent per-phase circuit: e.g. for phase A:



$$I_a = \frac{V_{an}}{Z_Y}$$

Based on the sequence, the other line currents can be obtained from:

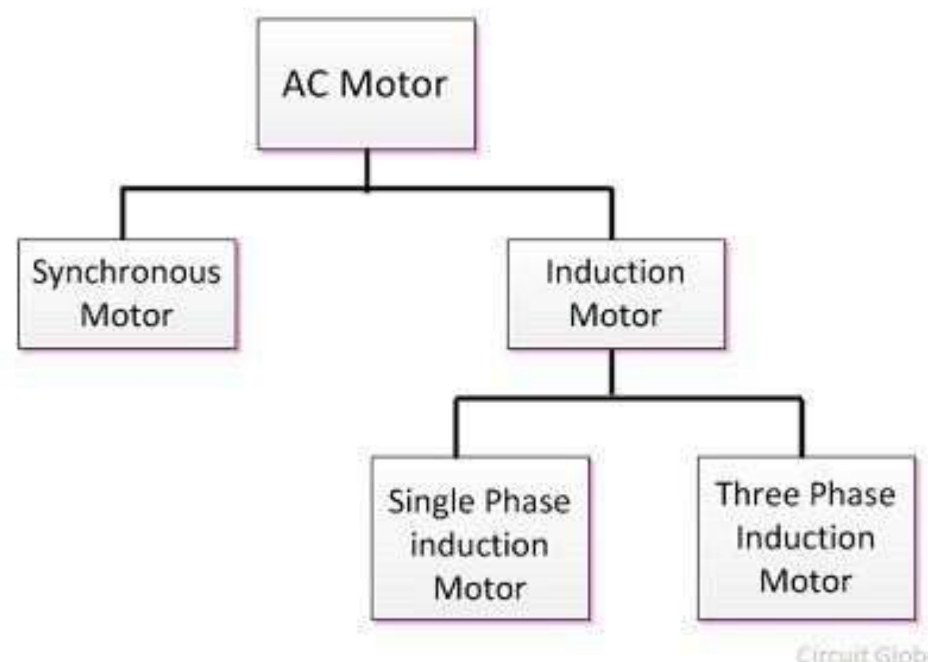
$$I_b = I_a \angle -120^o \qquad I_c = I_a \angle 120^o$$

Induction Motor

An **induction motor** is a commonly used AC electrical machine that converts electrical energy into mechanical energy.

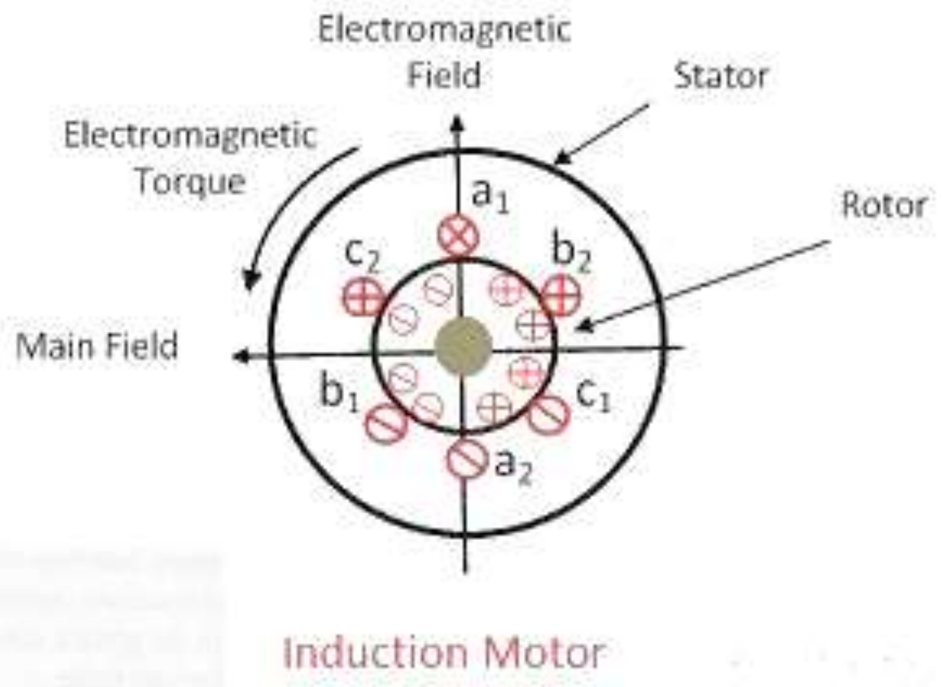
The motor which works on the **principle of electromagnetic indu**

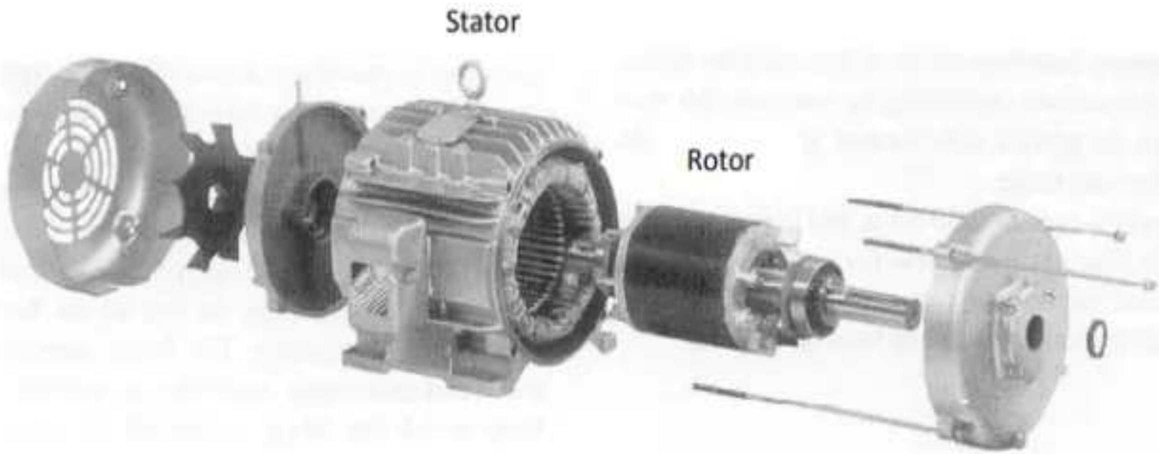
g esl



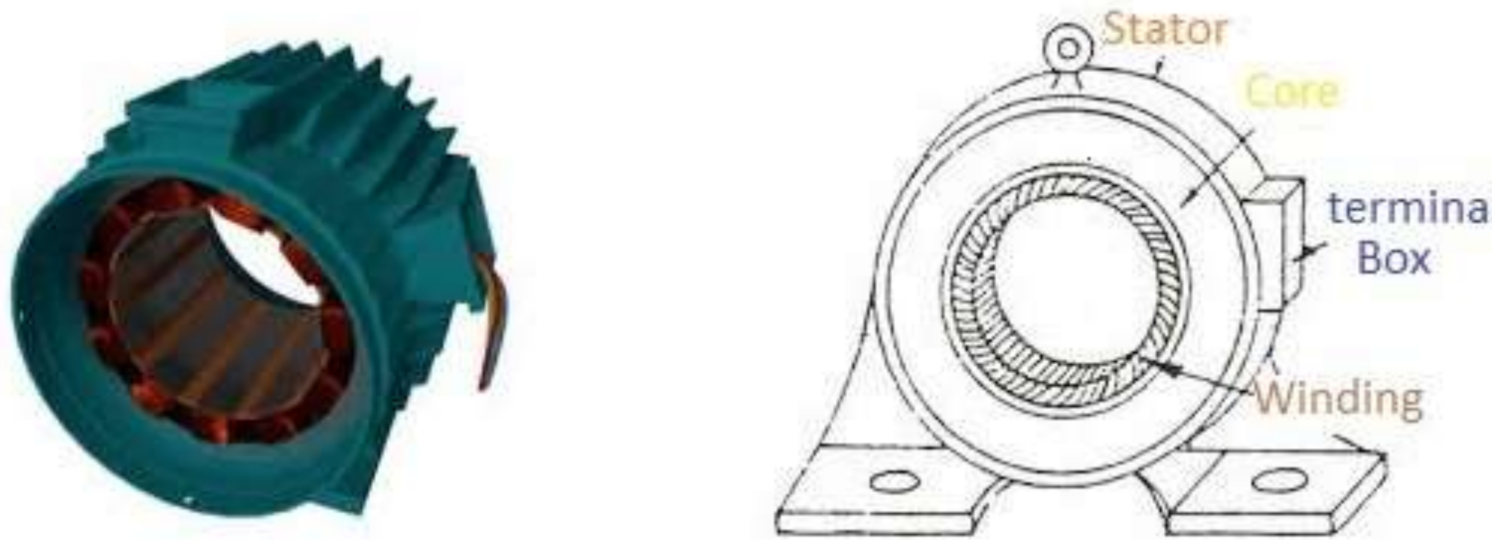
The **stator** and **rotor** are two essential parts of the motor. The stator is the stationary part, and it carries the overlapping windings wh

the main or field winding

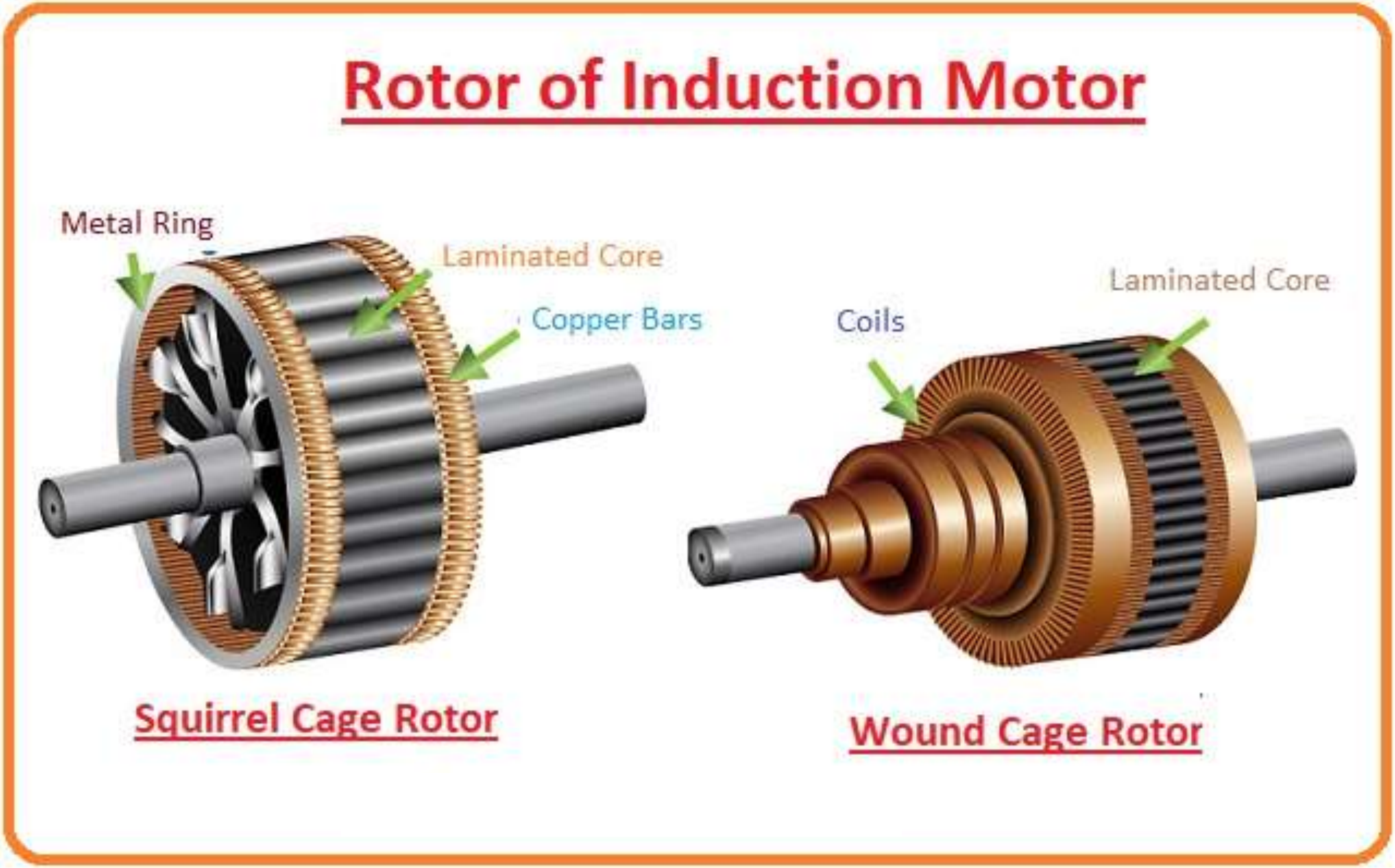




Stator of Induction Motor



It is the static part of induction motor. In this portion stator winding is wound and input supply terminals are connected.



The rotor of the induction motor is its rotating part which rotates in the magnetic field.

Types of Induction Motors

The types of induction motors can be classified depending on whether they are a single phase or three phase induction motor.

Single Phase Induction Motor

The types of single phase induction motors include:

1. Split Phase Induction Motor
2. Capacitor Start Induction Motor
3. Capacitor Start and Capacitor Run Induction Motor
4. Shaded Pole Induction Motor

Three Phase Induction Motor

The types of three phase induction motors include:

1. Squirrel Cage Induction Motor
2. Slip Ring Induction Motor

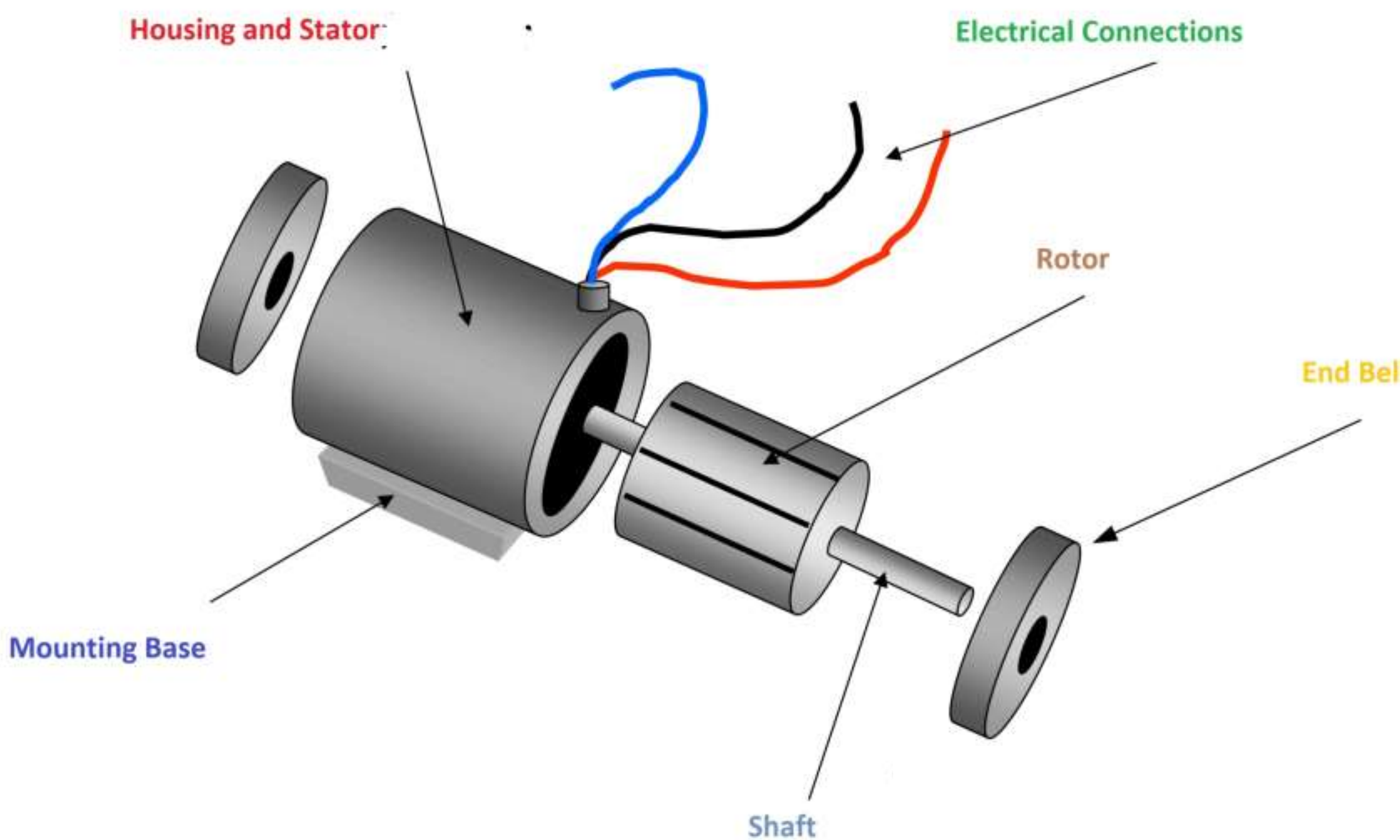
Single Phase Induction Motor

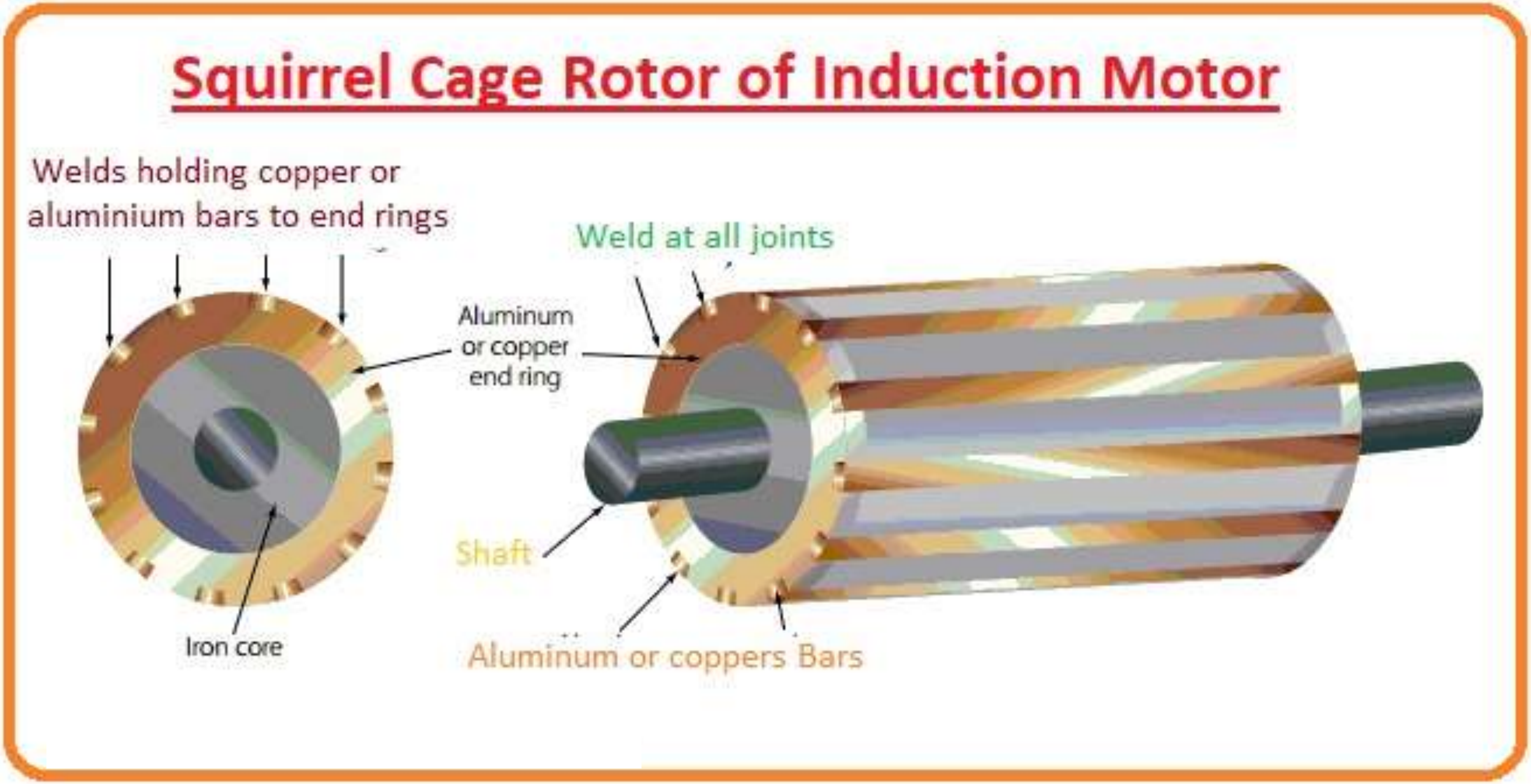
The Induction motor which works on single-phase AC power is called **Single Phase Induction Motor.**

The power line available for us at homes is 240V/50Hz AC single-phase power line and the Inductions motors which we use in our day to day life in our homes are called Single Phase Induction Motors.

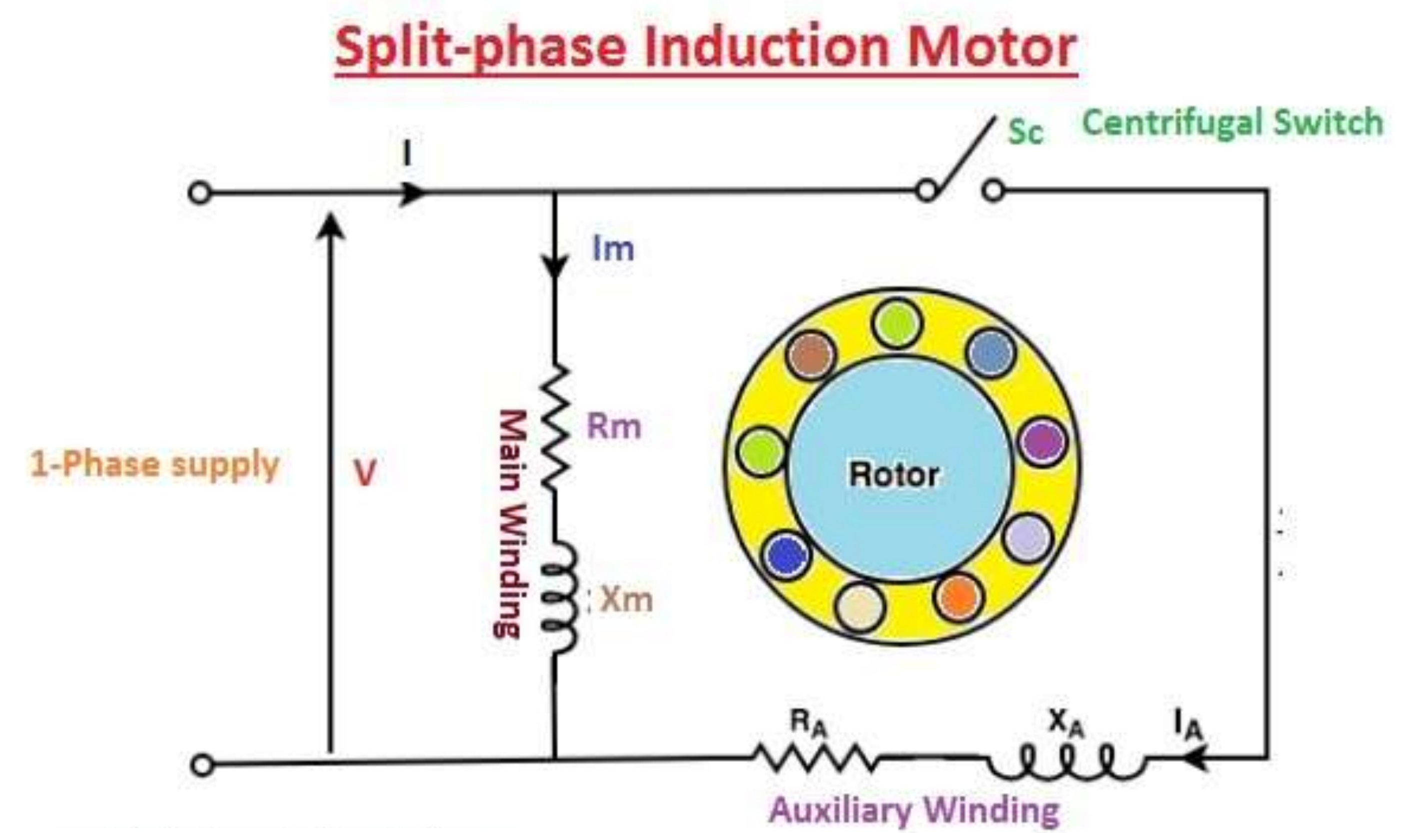
The single-phase induction motor is frequently used motor for refrigerators, washing machines, clocks, drills

Parts of Single phase Induction Motor





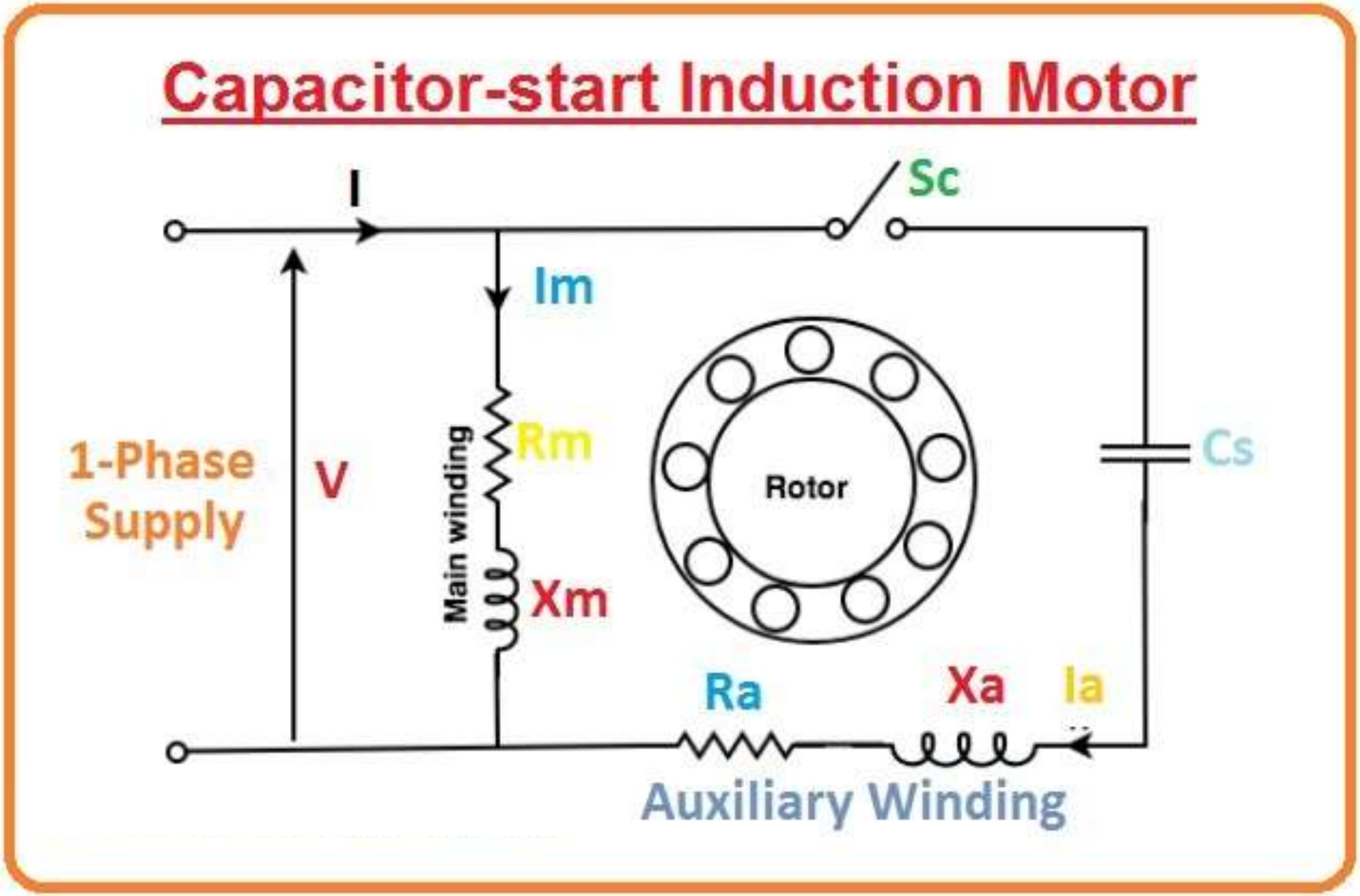
This type of rotor comprises of a sequence of conductor bars which are arranged in a cylindrical shape structure in the different slots. All these are connected with the slip ring on both sides.



It is also named as a resistor start motor

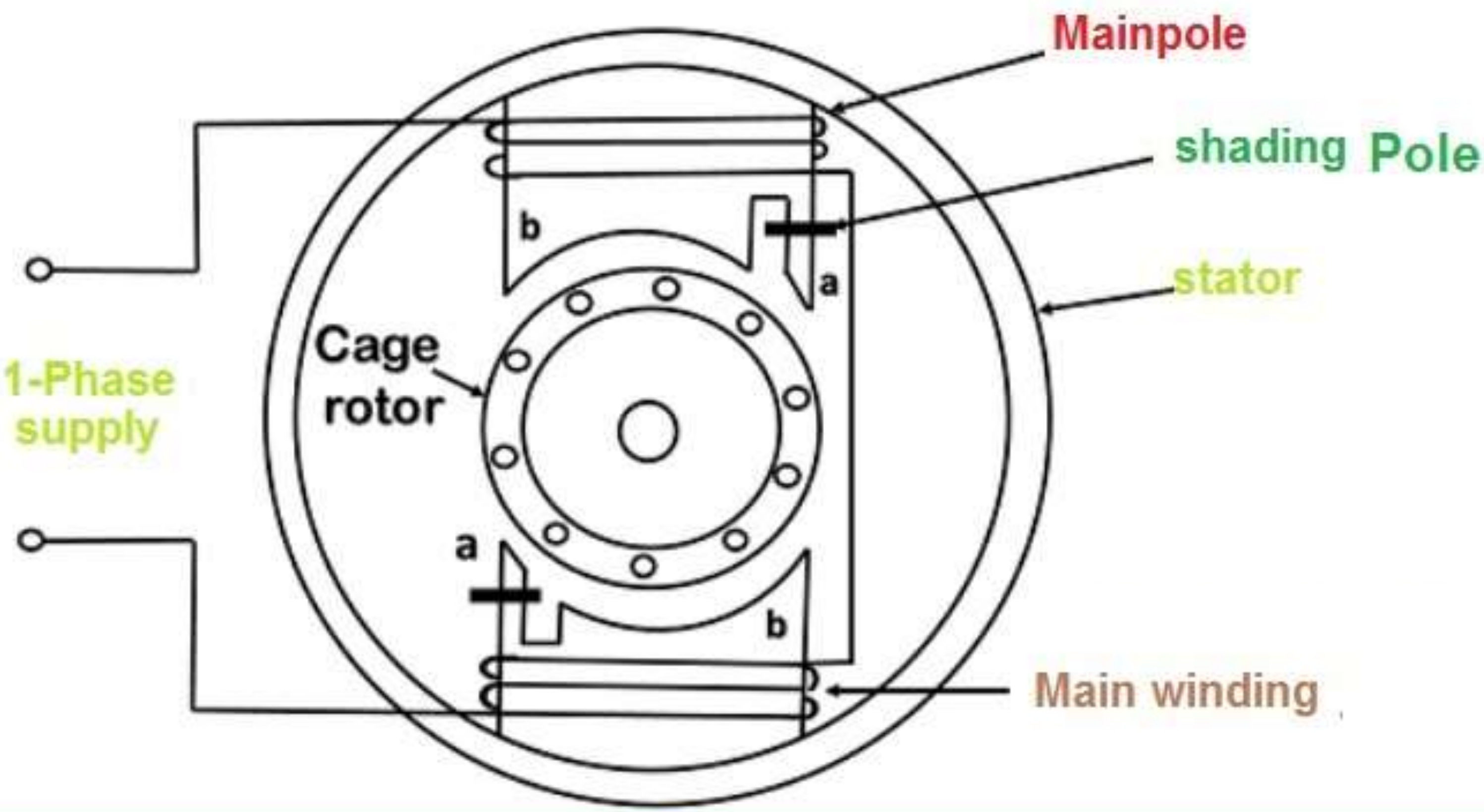
It comprises a cage rotor and its static part consists of two windings. The first one is known as **main winding** and the other is **starting winding** which is also named as **auxiliary winding**. They are connected at

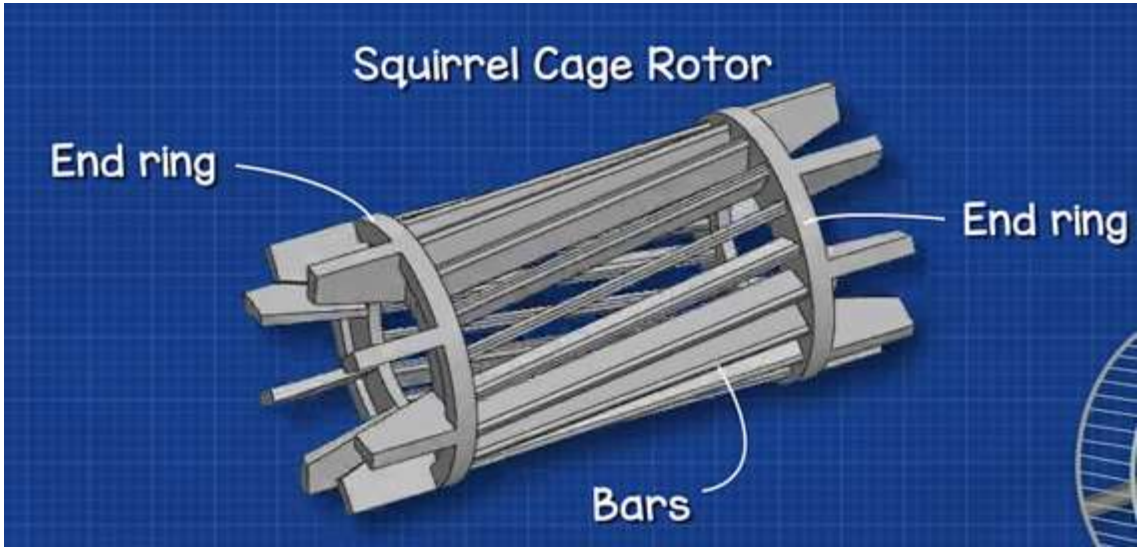
These motors provide less starting torque.

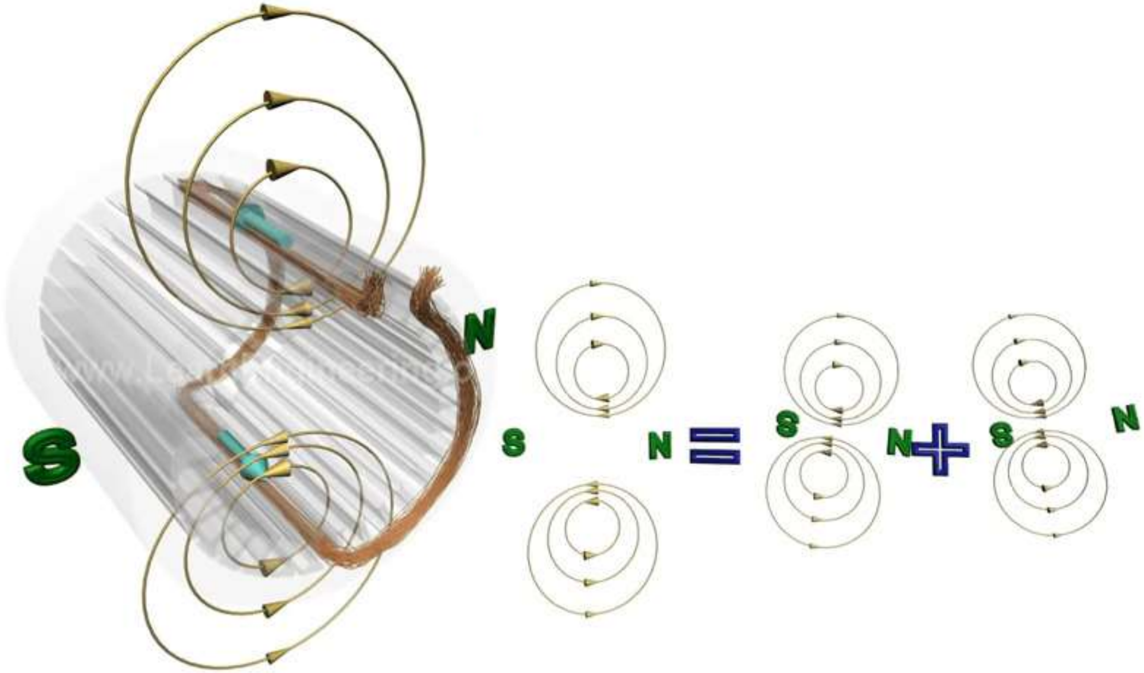


This type of induction motor produces a higher starting torque about three to four-time than the full load torque.
For higher starting torque the capacitor values

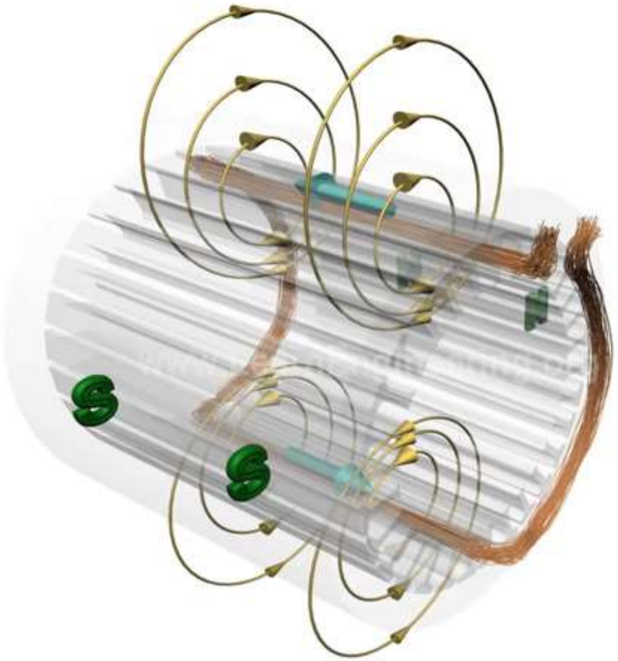
Shaded Pole Induction Motor

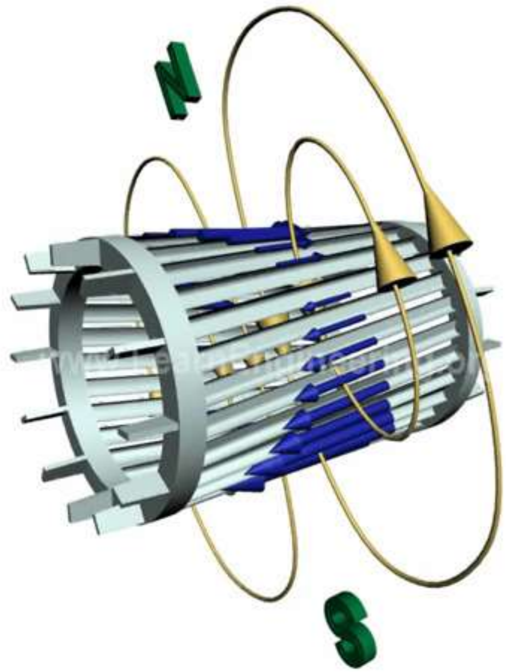






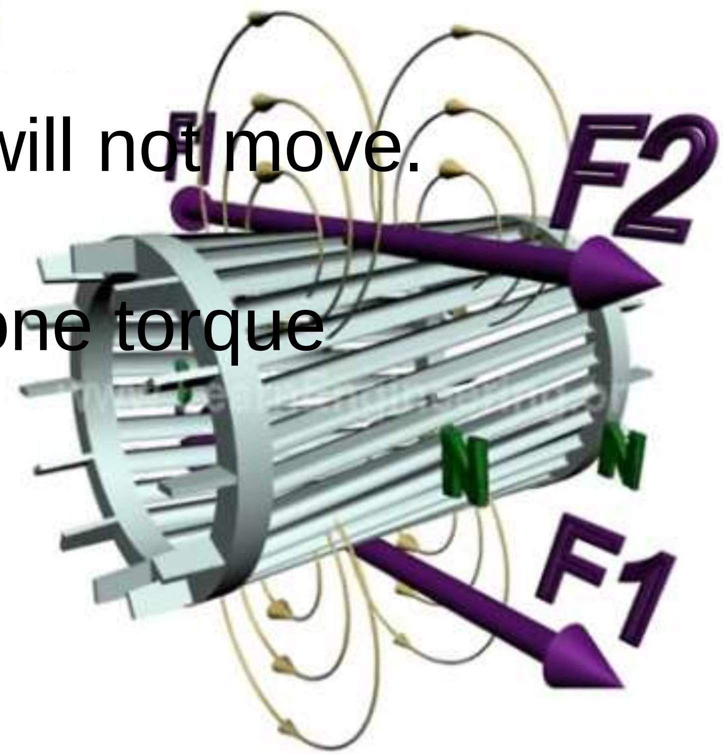
A fluctuating field is sum of two oppositely rotating ma





If two torque is equal the motor will not move.

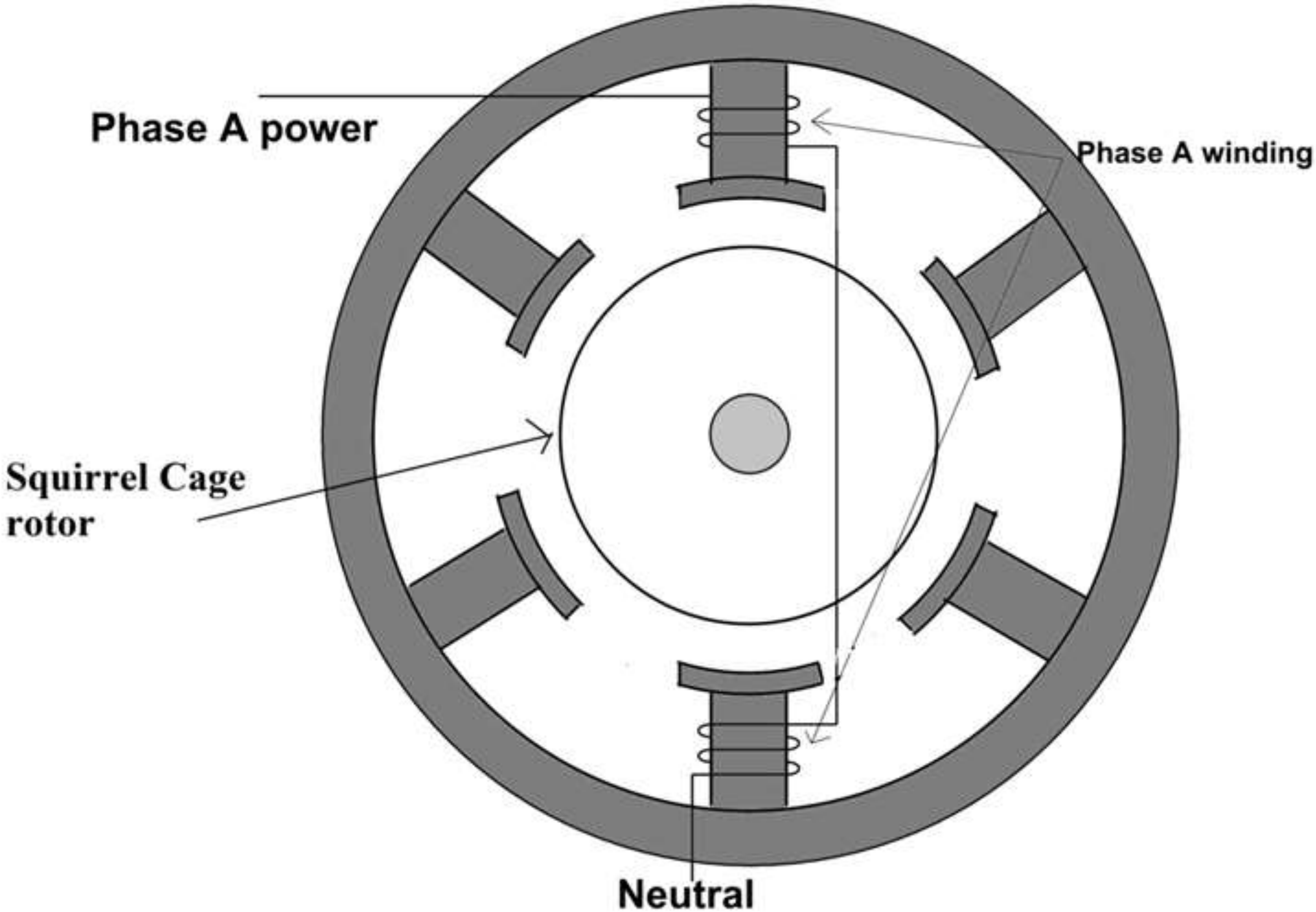
So provide a initial start so that one torque
is greater than other



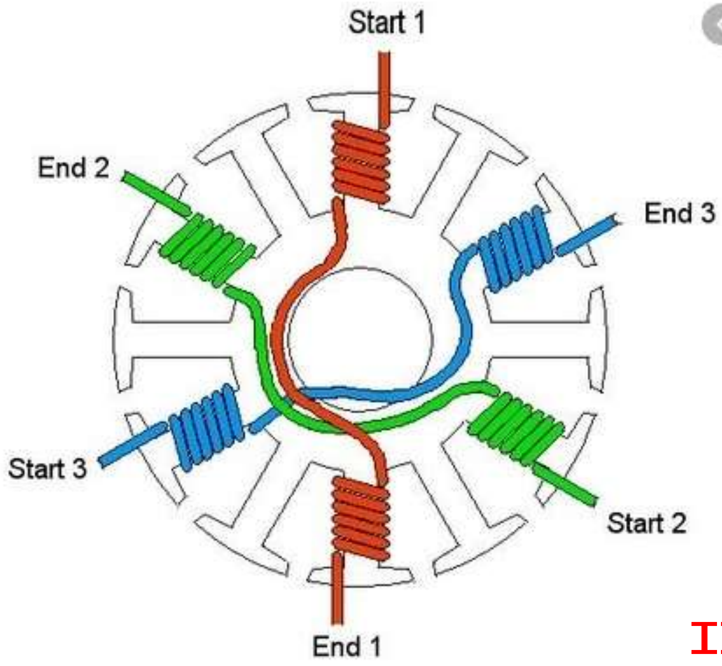
3 Phase Induction Motor

Applications of Three Phase Induction motors:

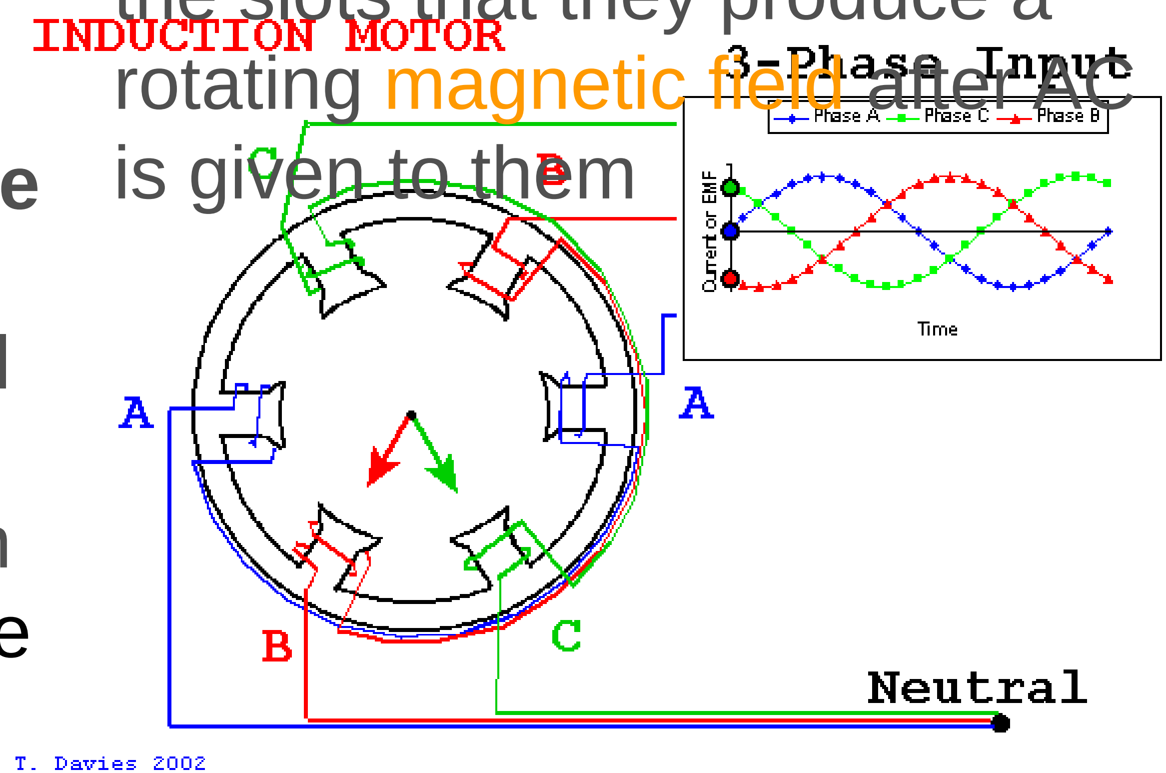
- Small scale, Medium-scale and large scale industries.
- Lifts
- Cranes
- Driving lathe machines
- Oil extracting mills
- Robotic arms
- Conveyers belt system



One end of the winding is connected to Phase A power line of three-phase power supply while the other end is connected to the neutral line. The other two-phase windings follow the same pattern as

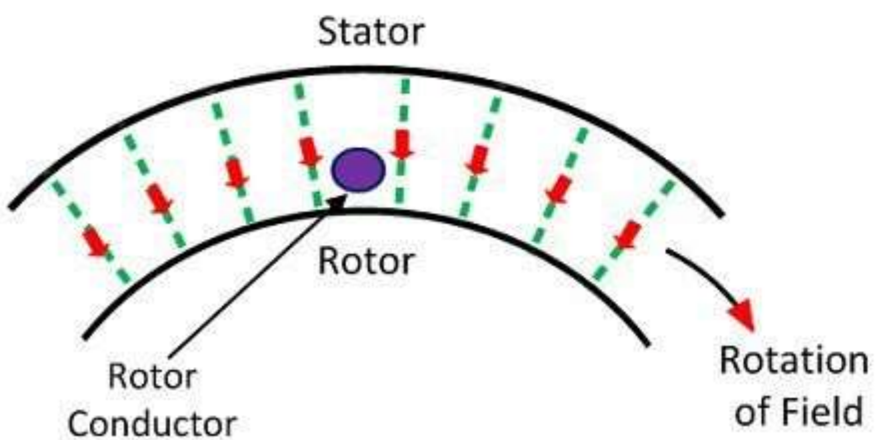


Stator of three phase induction motor is made up of no. of slots which is connected to 3 phase AC source. The three phase winding are arranged in such a manner in the slots that they produce a rotating magnetic field after AC is given to them



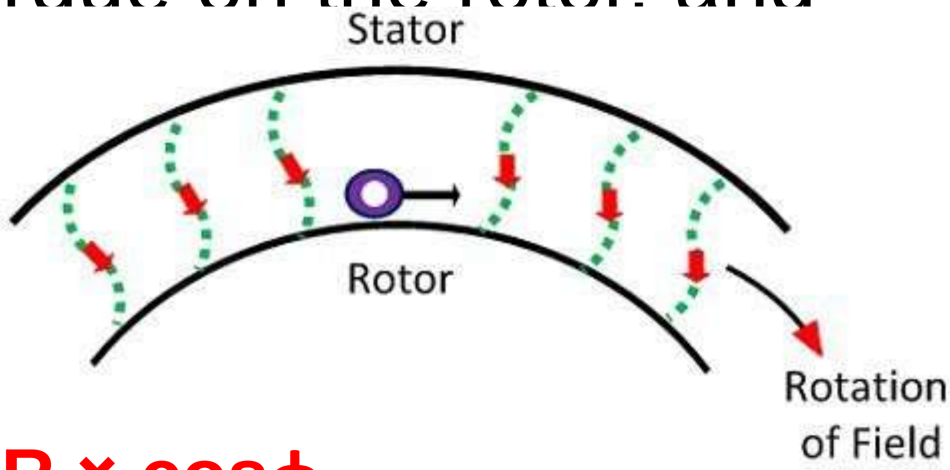
Rotor of three phase induction motor consists of cylindrical laminated core with parallel slots that can carry conductors. The slots are not exactly made parallel to the

- The stator of the motor consists of overlapping winding offset by an electrical angle of 120°.
- When the primary winding or the stator is connected to a 3 phase AC source, it establishes a rotating magnetic field which rotates at the synchronous speed.
- The rotor winding are either closed through an external resistance or directly shorted by end ring.
- They cut the rotating m
induced in the rotor cor
emf a current flows thrc



As a result there are two fluxes created: one is the rotating stator flux and the other is the rotor flux.

The interaction between these two magnetic fluxes will produce a torque on the rotor, and the rotor rotates in the rotating magnetic flux.



Torque on rotor = $\Phi \times IR \times \cos\phi$

- Φ is the stator flux.
- IR is the rotor current.
- φ is the phase difference between the stator flux