

## Electricity basics

Static electricity is the accumulation of electric charges on the bodies of various equipment, and it is a normal phenomenon. The problem lies in the accumulation of charges on a body to the extent that their transfer to another body constitutes the occurrence of an electric spark. In nature, the movement and transfer of charges from one body to another is freely controlled by only a law or a simple property, which is their transfer from one body to another in order to equalize and balance the amount of accumulated charges .

When these charges move, an instantaneous flow of electric current occurs, and an electric spark occurs when the charges move from one location to another through the air, i.e. when those charges jump from a body with a high amount of charges to the other body with less charges

This phenomenon can also be observed when we bring our hairy forearm close to the TV screen, so we will notice the hair standing up and being attracted to the TV screen. Likewise, when you comb your hair on a dry day, you will notice that the hair is attracted to the comb

## There is damage to static electricity

This phenomenon constitutes a major problem in industry and laboratories, especially in the oil and gas industry, for example. The transfer of charges may cause a spark that may be sufficient to ignite the gases and vapors present at the site.

## dinamic electricity

We call it moving as a result of the presence of an electric current and a flow of negative charges, which are electrons.

This type of electricity is called current, and its unit of measure is the ampere

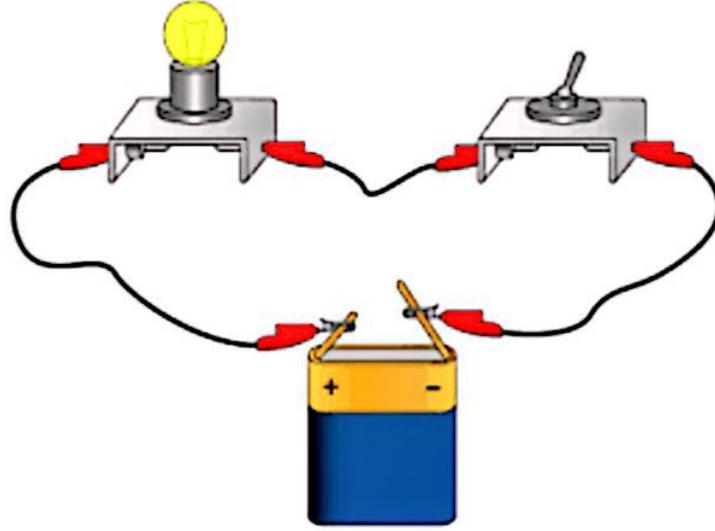
The electric current is divided into two types: constant electric current, known as DC, and alternating electric current, also known as AC.

## Definitions, units and electrical symbols

- Potential difference (V): It is the amount of electrical motive energy for the electrons between the positive and negative electrodes. This movement results in an electric current, also called (voltage).
- Electric current (I): It is the flow of electric charges such as electrons or ions when the electrical conduction of the load (closed circuit) occurs, whether the load is resistive, coil or capacitive
- Electrical resistance (R): It is a physical property that characterizes metal conductors in electrical circuits. It is defined as the ability of materials to resist the passage of electric current through them, which is to impede the passage of electric current in them.

## simple electrical circuit

A simple electrical circuit consists of a voltage source, a switch to open and close the circuit, and an appropriate load, as shown in the following figure:

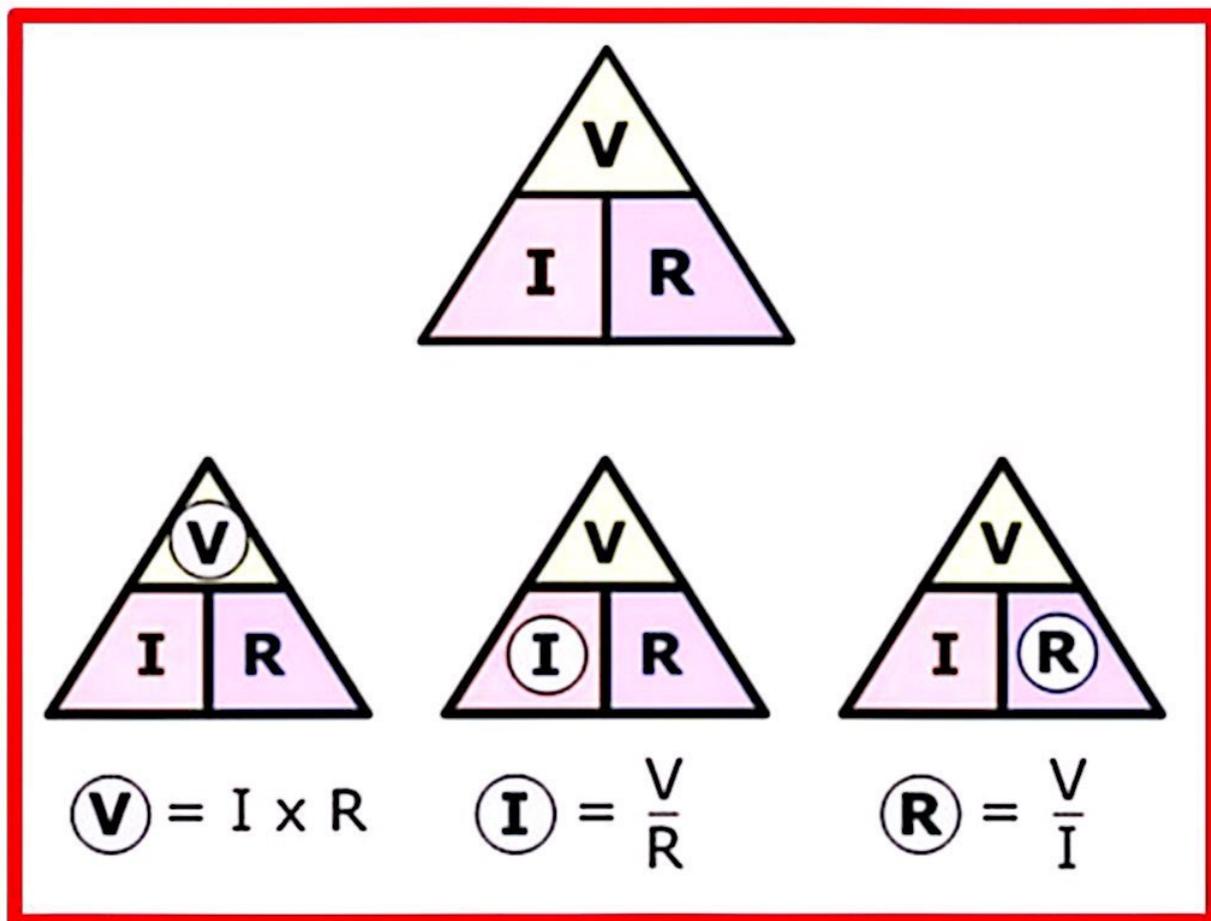


## Ohm's law

Ohm's law states that the current passing through a resistance is directly proportional to the value of the voltage applied to the resistance and inversely to the value of the resistance. Flow is the current measured in amperes, and mathematically this relationship is represented as follows:

$$V = I * R \rightarrow I = \frac{V}{R}$$

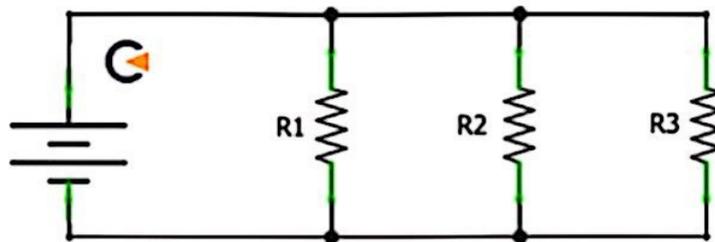
Ohm's law is one of the most important laws of physics that are used in electronic and electrical circuit applications, and this law can be summarized as if an electric current of one ampere passes through an element whose resistance is one ohm, the voltage will be one volt, and from this we conclude that by knowing and measuring two circuit determinants, the voltage can be one volt. The measurement of all other determinants, using Ohm's law, and the method of connecting resistors in an electrical circuit affects the method of calculating the amount of total resistance, so the total resistance is calculated as follows



## Connect the resistors

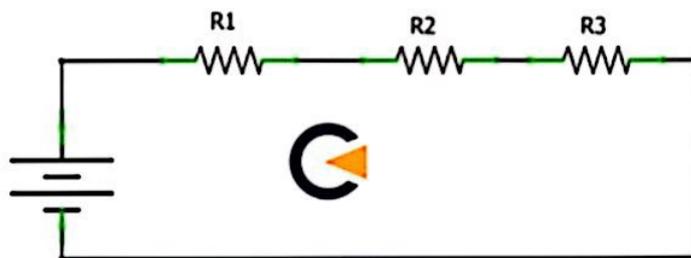
Connecting resistors in parallel: where the value of the equivalent total resistance of all resistors is less than the smallest connected resistance, and it is calculated by the following equation

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$



Connecting the resistors in series: In this case, the resistors can be converted into one total resistance whose value is equivalent to the values of all the resistors, by summing the values of these resistors, and when a voltage is applied to the resistors connected in series, the value of the current passing through all the resistors is fixed and can be calculated from the law the following.

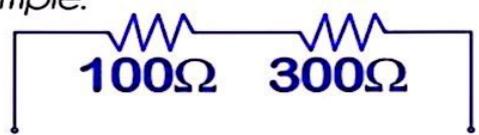
$$R_T = R_1 + R_2 + R_3 + \dots$$



Example/find equivalent resistance( $R_{eq}$ ) for the figures below

**$R_{eq} = R_1 + R_2 + \dots R_n$**

Example:

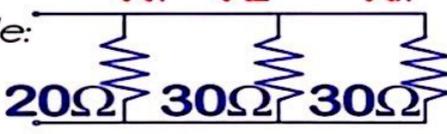


$= 100\Omega + 300\Omega$   
 $= \mathbf{400\Omega}$

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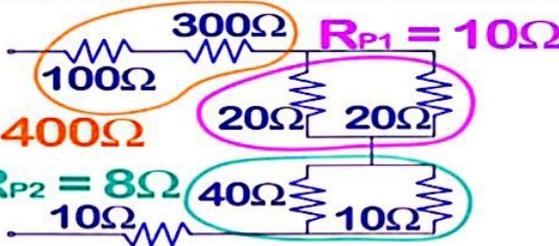
**$R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \dots \frac{1}{R_n}}$**

Example:



$\frac{1}{\frac{1}{20\Omega} + \frac{1}{30\Omega} + \frac{1}{30\Omega}} = \mathbf{8.57\Omega}$

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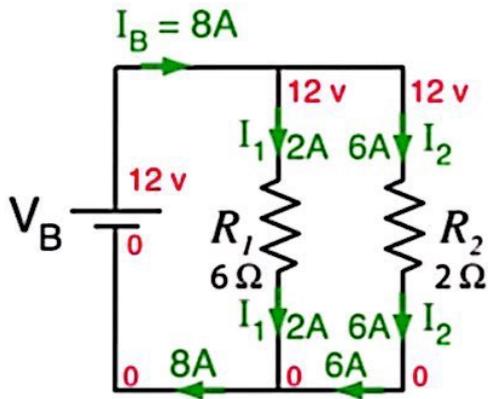
$R_s = 400\Omega$

$R_{P1} = 10\Omega$

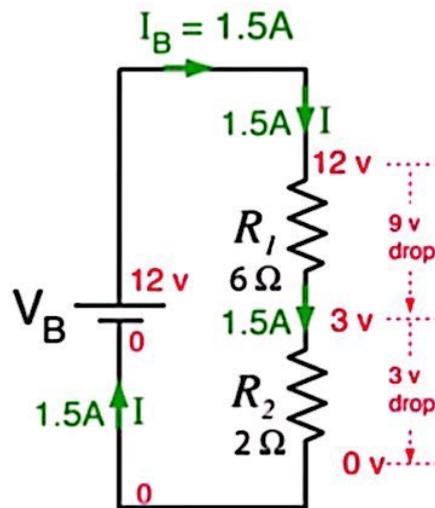
$R_{P2} = 8\Omega$

$= 400\Omega + 10\Omega + 8\Omega + 10\Omega$   
 $= \mathbf{428\Omega}$

Example/ for the figures below find the current and voltage in each resistance



The voltages across elements in parallel are equal. This is one of the implications of the voltage law - since the change across either  $R_1$  or  $R_2$  must be equal to the battery voltage  $V_B$ , then they are equal to each other.



For a series combination, the sum of the voltage drops across  $R_1$  and  $R_2$  must sum to equal  $V_B$ .

Example/ find current in resistance 3 ohm for figure below



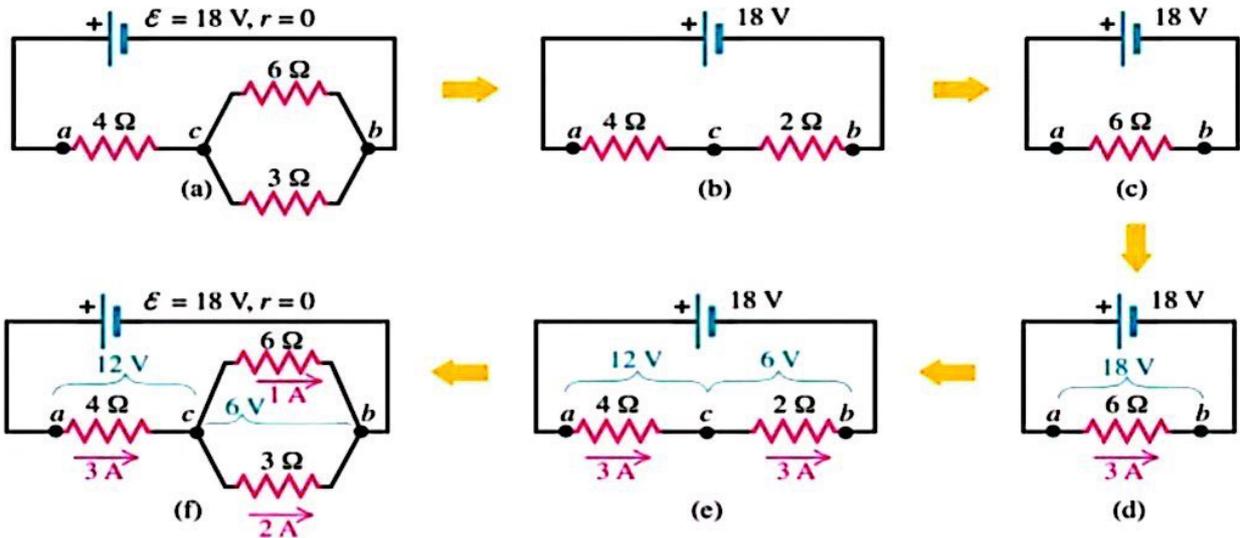
$$V = 12 \text{ V}$$

$$R = 3 \text{ ohms}$$

$$I = V/R = 12/3$$

$$I = 4 \text{ A}$$

Example/ for the figures below find the current in each resistance



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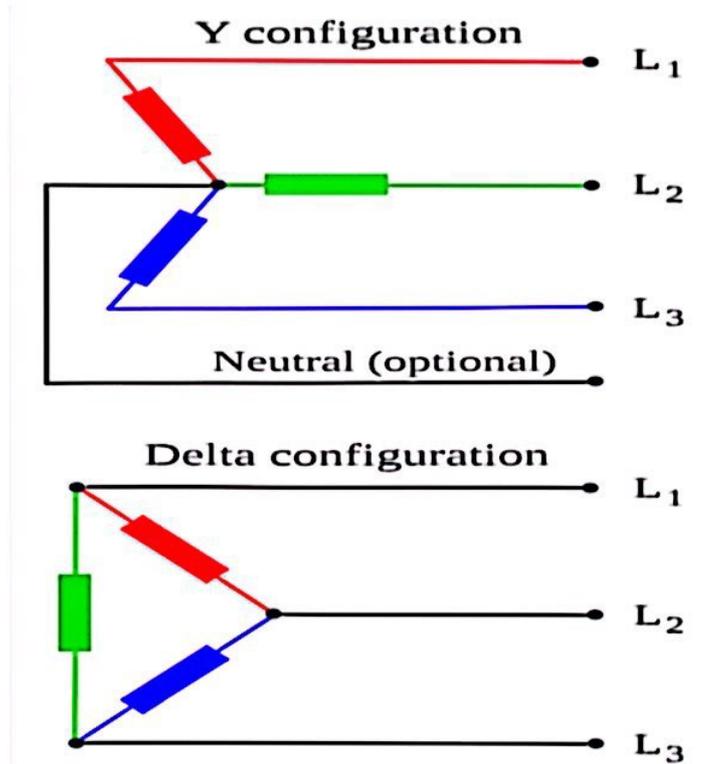
## Connect star delta resistor

### Star connection

- Connecting the endings or beginnings together to form the neutral line
- Connects the source to the remaining ends
- The value of the resistances is equal, so the load is balanced, or the resistances are unequal, so the load is unbalanced

### Delta connection

- Connect the end of each resistance to the end of the second rectifier
- Connects the source to the common parties
- The value of the resistances is equal, so the load is balanced, or the resistances are unequal, so the load is unbalanced



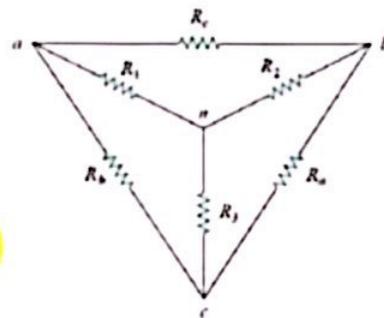
## Convert delta to star

### Delta to Wye Conversion $\Delta \rightarrow Y$

$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$$

$$R_2 = \frac{R_a R_c}{R_a + R_b + R_c}$$

$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c}$$



Example: The following constituents ( $R_a=4$ ) ( $R_b=6$ ) ( $R_c=8$ ) are connected in the form of delta, convert them to the star connection

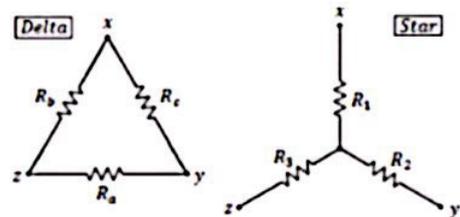
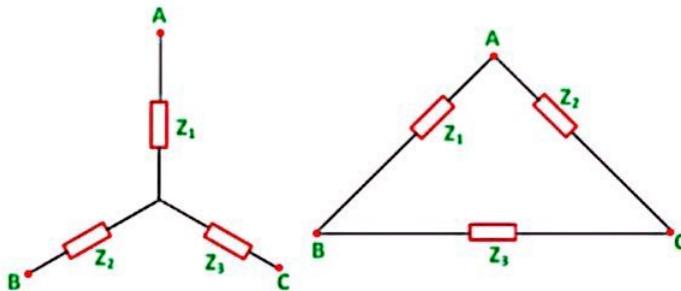
$$R_1 = \frac{8 * 6}{4 + 6 + 8} = 2.34$$

$$R_2 = \frac{4 * 8}{4 + 6 + 8} = 1.78$$

$$R_3 = \frac{4 * 6}{4 + 6 + 8} = 1.34$$

Convert star to delta

## What is the Star To Delta Conversion Formula?



$$R_a = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_1}$$

$$R_b = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_2}$$

$$R_c = \frac{R_1 R_2 + R_2 R_3 + R_3 R_1}{R_3}$$

$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$$

$$R_2 = \frac{R_a R_c}{R_a + R_b + R_c}$$

$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c}$$

**Example:** The following resistors ( $R_1=4$ ) ( $R_2=6$ ) ( $R_3=8$ ) are star connected. Convert them to a delta.

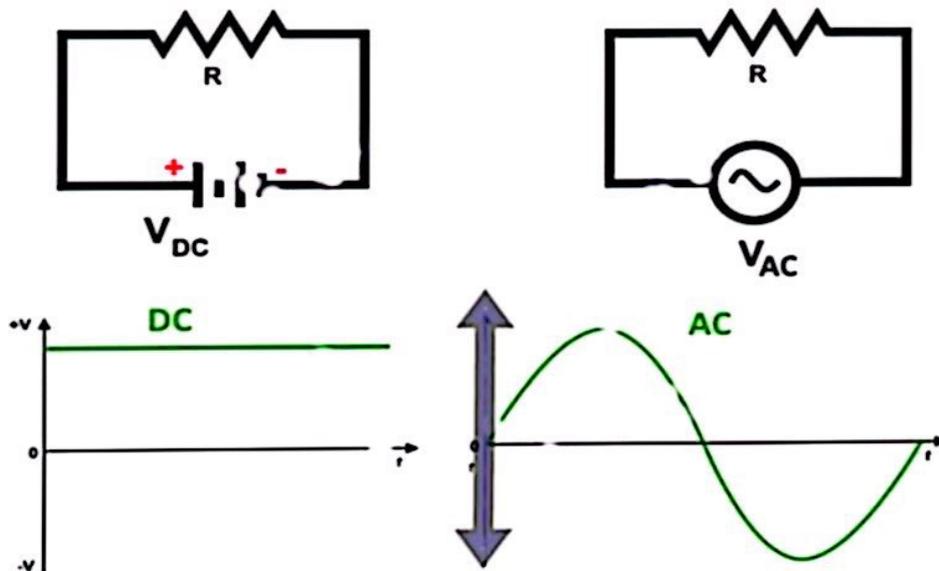
$$R_a = \frac{4 * 6 + 6 + 8 + 4 * 8}{4} = 26$$

$$R_c = \frac{4 * 6 + 6 * 8 + 4 * 8}{6} = 17.34$$

$$R_b = \frac{4 * 6 + 6 + 8 + 4 * 8}{8} = 13$$

## Alternator current (A.C)

is the current that change in value and direction with time in many times in one second (Hz)



how A.c current generated ?

A conductor moving relative to a magnetic field develops an electromotive force (EMF) in it (Faraday's Law). This EMF reverses its polarity when it moves under magnetic poles of opposite polarity. Typically, a rotating magnet, called the rotor turns within a stationary set of conductors wound in coils on an iron core, called the stator. The field cuts across the conductors, generating an induced EMF (electromotive force), as the mechanical input causes the rotor to turn

The rotor's magnetic field may be produced by permanent magnets, or by a field coil electromagnet. Automotive alternators use a rotor winding which allows control of the alternator's generated voltage by varying the current in the rotor field winding. Permanent magnet machines avoid the loss due to magnetizing current in the rotor, but are restricted in size, due to the cost of the magnet material. Since the permanent magnet field is constant, the terminal voltage varies directly with the speed of the generator. Brushless AC generators are usually larger than those used in automotive applications.

## Synchronous speeds

One cycle of alternating current is produced each time a pair of field poles passes over a point on the stationary winding. The relation between speed and frequency is

where  $f$  is the frequency in Hz (cycles per second).

$P$  is the number of poles (2, 4, 6, ...) and

$n$  is the rotational speed in revolutions per minute (r/min). Very old descriptions of alternating current systems sometimes give the frequency in terms of alternations per minute, counting each half-cycle as one *alternation*; so 12,000 alternations per minute corresponds to 100 Hz.

The output frequency of an alternator depends on the number of poles and the rotational speed. The speed corresponding to a particular frequency is called the *synchronous speed* for that frequency

Example : find the speed of generator in (50Hz) when number of pole (2,4,6,8)

$$N = \frac{120f}{p}$$

where  $p = 2$        $N = \frac{120 * 50}{2} = 3000 \text{ r.p.m}$

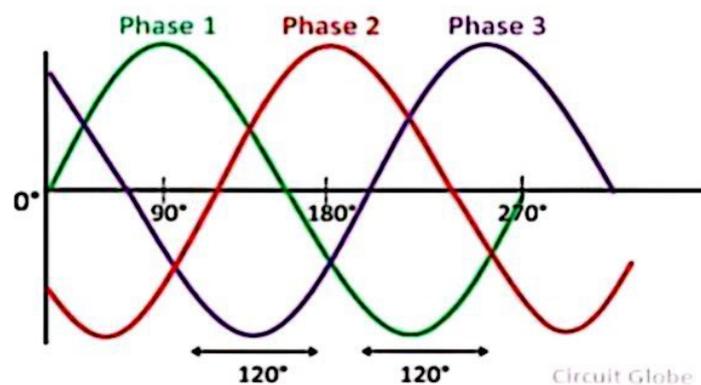
where  $p = 4$        $N = \frac{120 * 50}{4} = 1500 \text{ r.p.m}$

where  $p = 6$        $N = \frac{120 * 50}{6} = 1000 \text{ r.p.m}$

where  $p = 8$        $N = \frac{120 * 50}{8} = 750 \text{ r.p.m}$

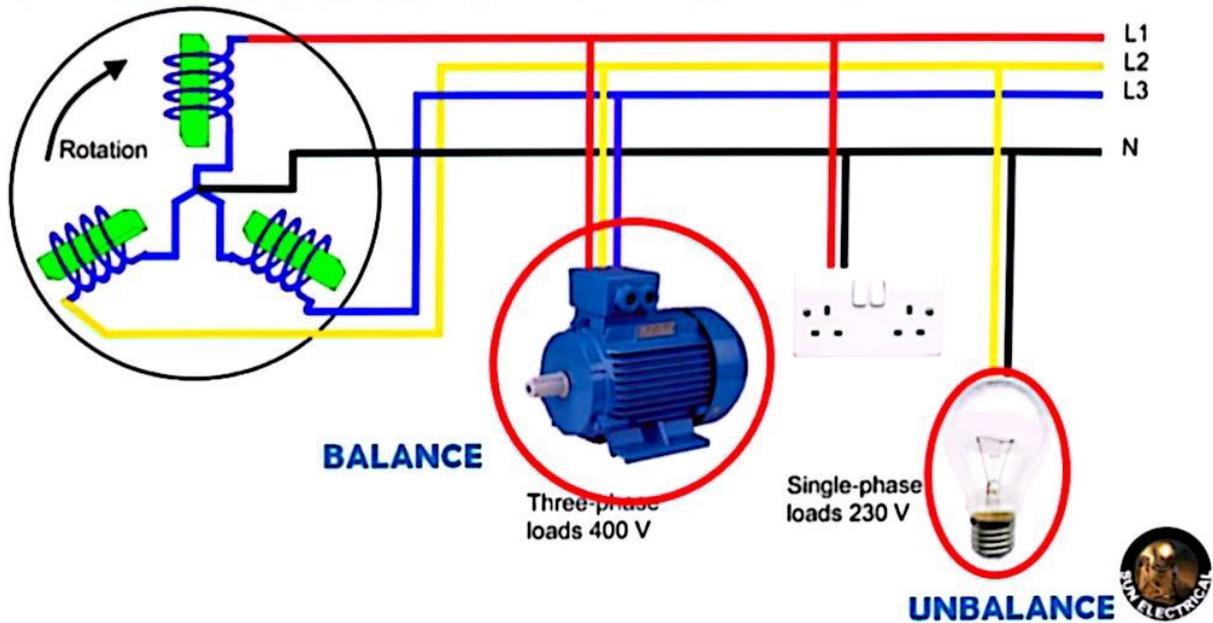
three phase alternator current

is same of three single phase but the phase angle between the phases is  $120^\circ$



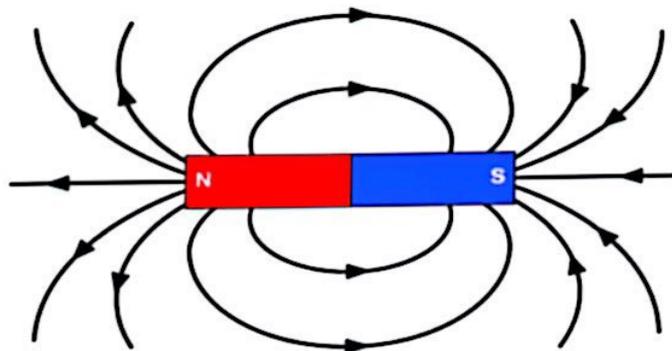
how connect load to three phase source ?

# BALANCE & UNBALANCE LOAD



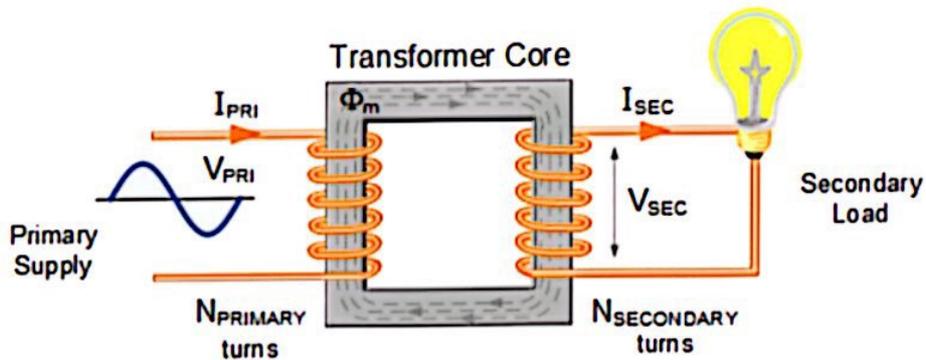
## magnetic field

A magnetic field can be produced by either a current, a flow of charged particles or a magnetized material. ... The magnitude of the force on a wire carrying current  $I$  with length  $L$  in a magnetic field is given by the equation.  $F=ILB\sin\theta$  where  $\theta$  is the angle between the wire and the magnetic field.



## Transformer

That transfers electrical energy from one electrical circuit to another circuit, or multiple circuits. A varying current in any coil of the transformer produces a varying magnetic flux in the transformer's core, which induces varying electromotive force across any other coils wound around the same core. Electrical energy can be transferred between separate coils without a metallic (conductive) connection between the two circuits. Faraday's law of induction, discovered in 1831, describes the induced voltage effect in any coil due to a changing magnetic flux encircled by the coil



(transformer equation)

Let

$N_1$  = number of tures of primary winding

$N_2$  = number of tures of secondary winding

$E_1$  = inducted voltage in primary winding

$E_2$  = inducted voltage in secondary winding

$$e. m. f = -n \frac{d\phi}{dt} \text{ (farady low)}$$

$$e. m. f_1 = -n_1 \frac{d\phi_1}{dt} \text{ (from primary) } \dots \dots \dots (1)$$

$$e. m. f_2 = -n_2 \frac{d\phi_2}{dt} \text{ (from secondary) } \dots \dots \dots (2)$$

$$\frac{e. m. f_2}{e. m. f_1} = \frac{-n_2 \frac{d\phi_2}{dt}}{-n_1 \frac{d\phi_1}{dt}} \text{ (divided eq 2 by eq1)}$$

$$\frac{E_2}{E_1} = \frac{N_2}{N_1}$$

$$K = \frac{N_2}{N_1} = \frac{E_2}{E_1} = \frac{I_1}{I_2} \text{ (transformer ratio)}$$

$$K > 1, \quad N_2 > N_1, \quad E_2 > E_1 \quad \text{step up}$$

$$K < 1, \quad N_2 < N_1, \quad E_2 < E_1 \quad \text{step down}$$

(General equation)

$$E_1 = 4.44 * N_1 * \Phi_m * f$$

$$E_2 = 4.44 * N_2 * \Phi_m * f$$

$\Phi_m = \text{maximum flux}$

$B_m = \text{maximum flux density}$

$$B_m = \frac{\Phi_m}{A} \quad A = \text{cross section area}$$

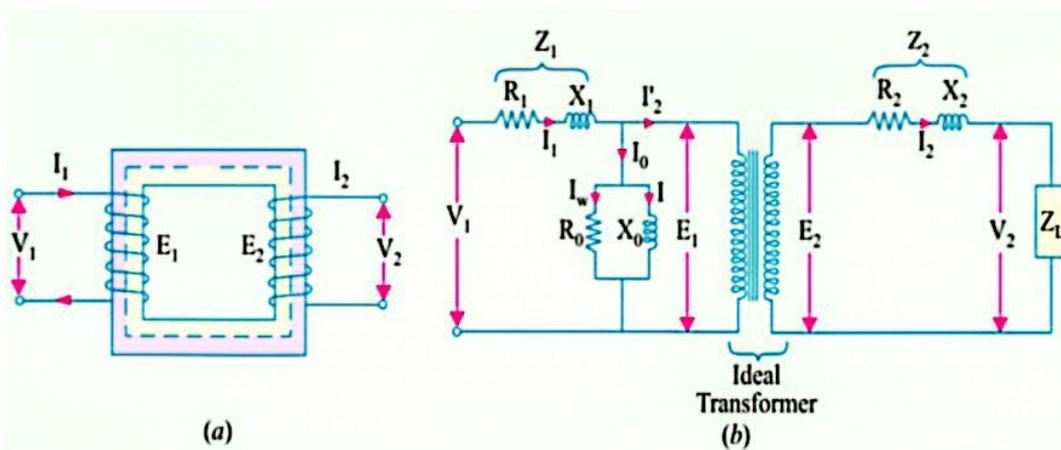
Example : single phase transformer has  $N_1=300$ ,  $N_2= 750$  and crose section area= $64\text{cm}^2$  < tha source  $440\text{v}$  ,  $50 \text{ Hz}$  find ( $B_m, e_2$ )

$$E_1 = 4.44 * N_1 * \Phi_m * f$$

$$\Phi_m = \frac{440}{4.44 * 300 * 50} = 6.606 \text{ mwb}$$

$$B_m = \frac{\Phi_m}{A} = \frac{6.606 * 10^{-3}}{64 * 10^{-4}} = 1.0321 \text{ wb/m}^2$$

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} \Rightarrow E_2 = \frac{440 * 750}{300} = 1100 \text{ V}$$



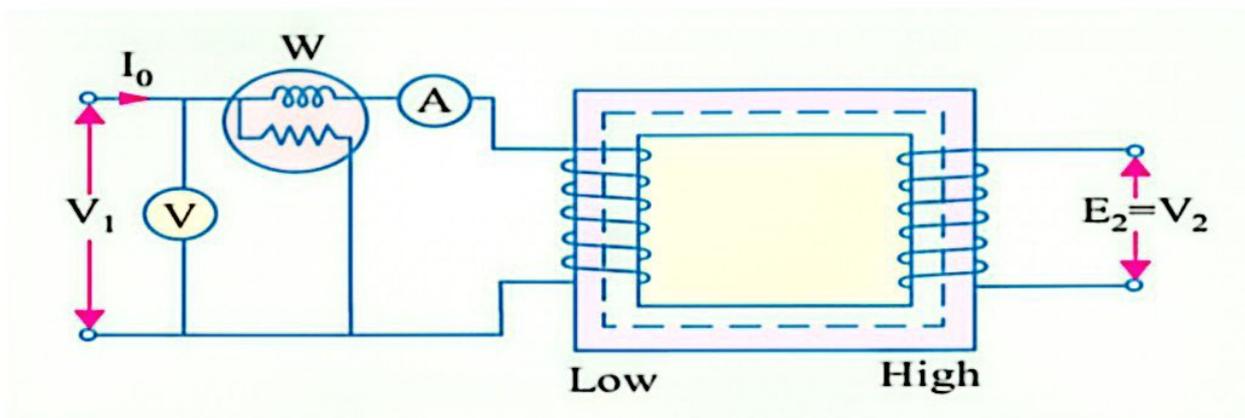
(test of transformer)

**(Open circuit test)**

In this test we connect one side of transformer to source and other side to voltmeter and tack the result of device

$$\text{Reading of wattmeter} = P_{iron} + I_o^2 * R_1$$

$$\text{Reading of wattmeter} \approx P_{iron}$$

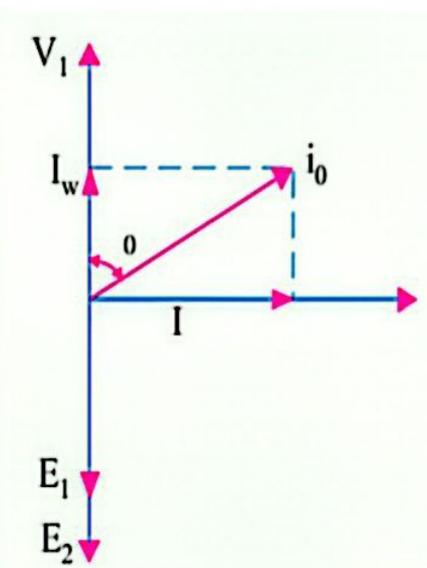


$$\text{Reading of wattmeter} = P_{iron}$$

$$\text{Reading of voltmeter} = V_{oc}$$

$$\text{Reading of ammeter} = I_{oc}$$

to find  $R_o$   $X_o$  We must be use this way



$$\cos\phi_o = \frac{P_{iron}}{V_{oc} * I_{oc}}$$

$$I_w = I_o * \cos\phi_o$$

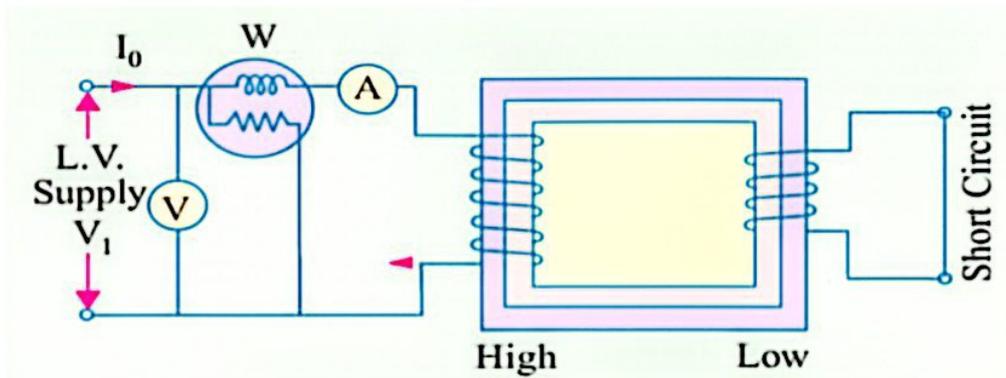
$$I_m = I_o * \sin\phi_o$$

$$R_o1 = \frac{V_{oc}}{I_w}$$

$$X_o1 = \frac{V_{oc}}{I_m}$$

(short circuit test)

In this test we connect one side of transformer to source and other side to ameter and tack the result of device



Reading of wattmeter =  $P_{cu}$

Reading of voltmeter =  $V_{sc}$

Reading of ameter =  $I_{sc}$

$$Z_{sc} = \frac{V_{sc}}{I_{sc}}$$

$$R_{1T} = \frac{P_{cu}}{I_{sc}^2}$$

$$X_{1T} = \sqrt{Z_{sc}^2 - R_{1T}^2}$$

Example: 10KVA single phase transformer has (E1=450,E2=110)

O.C	120v	4.2A	80w
S.C	9.65	22.2A	120w

Find equivalent circuit of transformer

#### For open circuit

$$\cos\phi_o = \frac{P_{iron}}{V_{oc} * I_{oc}} = \frac{80}{120 * 4.2} = 0.159$$

$$\phi = \cos^{-1}(0.159) = 80.86^\circ$$

$$I_w = I_o * \cos\phi_o = 4.2 * 0.159 = 0.667A$$

$$I_m = I_o * \sin\phi_o = 4.2 * \sin 80.86 = 4.1465A$$

$$R_{o1} = \frac{V_{oc}}{I_w} = \frac{120}{0.667} = 179.7\Omega$$

$$X_{o1} = \frac{V_{oc}}{I_m} = \frac{120}{4.1465} = 28.95\Omega$$

#### For short circuit

$$Z_{sc1} = \frac{V_{sc}}{I_{sc}} = \frac{9.65}{22.2} = 0.4346\Omega$$

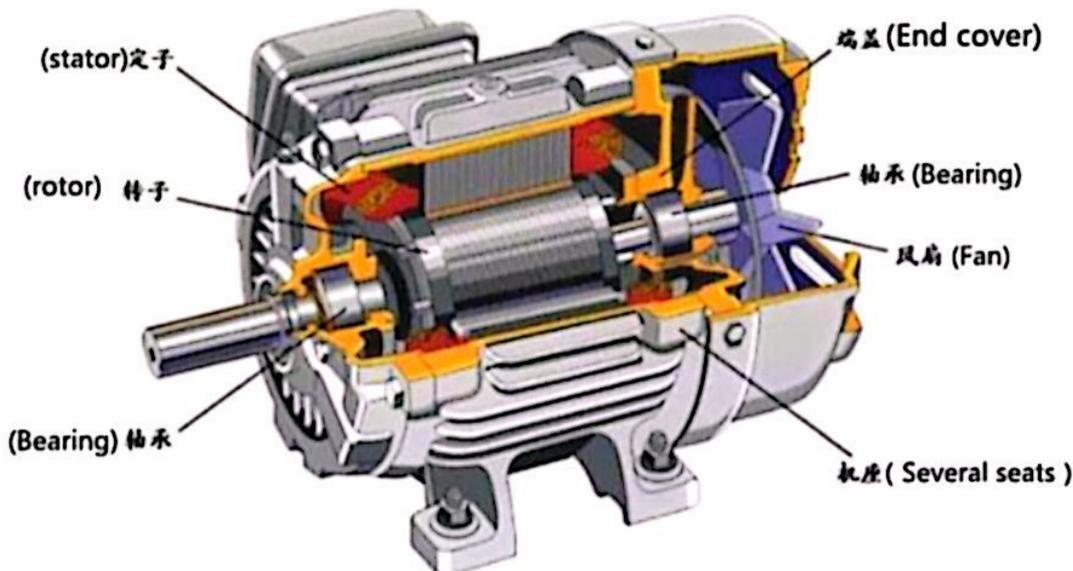
$$R_{1T} = \frac{P_{cu}}{I_{sc}^2} = \frac{120}{22.2^2} = 0.24\Omega$$

$$X_{1T} = \sqrt{Z_{sc}^2 - R_{1T}^2} = \sqrt{0.4346^2 - 0.24^2} = 0.36\Omega$$

### (3 phase Induction Motor)

An **induction motor** is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding.<sup>[1]</sup> An induction motor can therefore be made without electrical connections to the rotor. An induction motor's rotor can be either wound type or squirrel-cage type.

Three-phase squirrel-cage induction motors are widely used as industrial drives because they are self-starting, reliable and economical. Single-phase induction motors are used extensively for smaller loads, such as household appliances like fans. Although traditionally used in fixed-speed service, induction motors are increasingly being used with variable-frequency drives (VFD) in variable-speed service. VFDs offer especially important energy savings opportunities for existing and prospective induction motors in variable-torque centrifugal fan, pump and compressor load applications. Squirrel-cage induction motors are very widely used in both fixed-speed and variable-frequency drive applications



In both induction and synchronous motors, the AC power supplied to the motor's stator creates a magnetic field that rotates in synchronism with the AC oscillations. Whereas a synchronous motor's rotor turns at the same rate as the stator field, an induction motor's rotor rotates at a somewhat slower speed than the stator field. The induction motor stator's magnetic field is therefore changing or rotating relative to the rotor. This induces an opposing current in the induction motor's rotor, in effect the motor's secondary winding, when the latter is short-circuited or closed through an external impedance. The rotating magnetic flux induces currents in the windings of the rotor, in a manner similar to currents induced in a transformer's secondary winding(s).

For rotor currents to be induced, the speed of the physical rotor must be lower than that of the stator's rotating magnetic field otherwise the magnetic field would not be moving relative to the rotor conductors and no currents would be induced. As the speed of the rotor drops below synchronous speed, the rotation rate of the magnetic field in the rotor increases, inducing more current in the windings and creating more torque. The ratio between the rotation rate of the magnetic field induced in the rotor and the rotation rate of the stator's rotating field is called "slip". Under load, the speed drops and the slip increases enough to create sufficient torque to turn the load. For this reason, induction motors are sometimes referred to as "asynchronous motors".<sup>[31]</sup>

An induction motor can be used as an induction generator, or it can be unrolled to form a linear induction motor which can directly generate linear motion. The generating mode for induction motors is complicated by the need to excite the rotor, which begins with only residual magnetization. In some cases, that residual magnetization is enough to self-excite the motor under load. Therefore, it is necessary to either snap the motor and connect it momentarily to a live grid or to add capacitors charged initially by residual magnetism and providing the required reactive power during operation. Similar is the operation of the induction motor in parallel with a synchronous motor serving as a power factor compensator. A feature in the generator mode in parallel to the grid is that the rotor speed is higher than in the driving mode. Then active energy is being given to the grid.<sup>[2]</sup> Another disadvantage of the induction motor generator is that it consumes a significant magnetizing current  $I_0 = (20-35)\%$ .

## Synchronous speed

An AC motor's synchronous speed,  $N_s$ , is the rotation rate of the stator's magnetic field,

The number of magnetic poles, is equal to the number of coil groups per phase. To determine the number of coil groups per phase in a 3-phase motor, count the number of coils, divide by the number of phases, which is 3. The coils may span several slots in the stator core, making it tedious to count them. For a 3-phase motor, if you count a total of 12 coil groups, it has 4 magnetic poles. For a 12-pole 3-phase machine, there will be 36 coils. The number of magnetic poles in the rotor is equal to the number of magnetic poles in the stator.

The two figures at right and left above each illustrate a 2-pole 3-phase machine consisting of three pole-pairs with each pole set 60° apart.

$$N_s = 120 * \frac{f}{p}$$

## Slip

Slip, is defined as the difference between synchronous speed and operating speed, at the same frequency, expressed in rpm, or in percentage or ratio of synchronous speed. Thus

$$S = \frac{N_s - N}{N_s} * 100\%$$

$$N_s = 120 * \frac{f}{p}$$

$$N = N_s(1 - S)$$

where  $N_s$  is stator electrical speed,

$N$  is rotor mechanical speed. Slip,

which varies from zero at synchronous speed and 1 when the rotor is stalled, determines the motor's torque. Since the short-circuited rotor windings have small resistance, even a small slip induces a large current in the rotor and

produces significant torque. At full rated load, slip varies from more than 5% for small or special purpose motors to less than 1% for large motors. These speed variations can cause load-sharing problems when differently sized motors are mechanically connected. Various methods are available to reduce slip, VFDs often offering the best solution.

