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Department of PHYSICS

I B.Sc., SEMESTER-I
(MPC/MPCs/MECs/MSCs)

SDC Paper: ELECTRICAL APPLIANCES

STUDY MATERIAL

Name of the Student : ________________________________

Roll Number : ________________________________

Group : ________________________________

Academic Year : ________________________________

ELECTRICAL APPLIANCES

Skill Development Course

For

I Semester Students

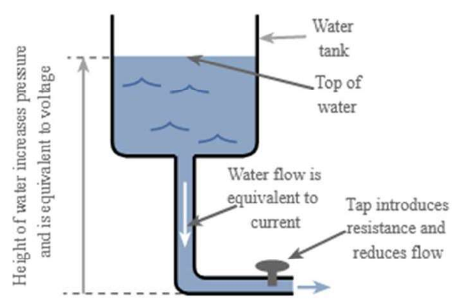
B.Sc. (MPC/MPCs/MECs/MSCs)

UNIT-I

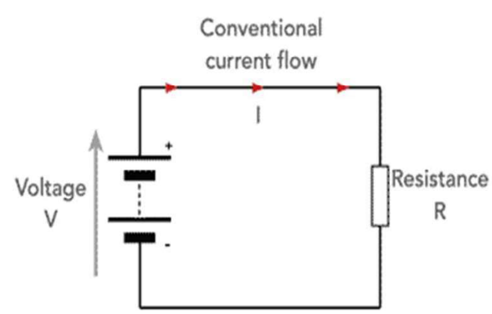
VOLTAGE:

Voltage is one of the fundamental parameters associated with any electrical or electronic circuit. Voltage is the pressure from an electrical circuit's power source that pushes charged electrons (current) through a conducting loop, enabling them to do work. In early days, voltage was known as electromotive force (emf).

The concept of voltage can be easily understood from below figure. Consider a water tank at some height containing water. Its bottom end is opened through a pipe and the water flow is controlled by a tap. Here height of the water produces some pressure on the water to flow through the pipe. The pressure is equivalent to voltage, water flow resembles current and the control tap is just like resister.



The higher the level of water, the greater the pressure forcing water through the system



Voltage shown within a simple circuit

Technically, voltage can be defined as the amount of potential energy difference between two points on a circuit. One point has more charge than another. The unit "volt" is named after the Italian physicist Alessandro Volta who invented the first chemical battery. Normally the letter V is used for volts, but occasionally the letter E may be used - this stands for EMF or electro-motive force. Potential difference is defined as the amount of work done in moving unit positive charge from one point to another.

It is observed that negatively charged objects are pulled towards higher voltages, while positively charged objects are pulled towards lower voltages. Therefore, the conventional current in a wire always flows from higher voltage to lower voltage.

Volt is defined as the potential difference between two points, if 1 watt power is dissipated in transporting 1 ampere of current between the two points.

ELECTRIC CURRENT

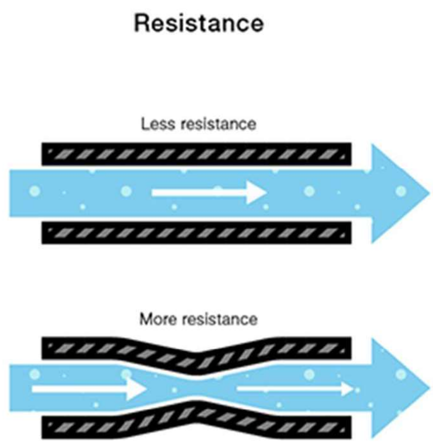
Electric current is the rate of charge flow through a given point in an electric circuit. It is measured in Coulombs/second which is named Amperes. The charge can be negatively charged electrons or positive charge carriers including protons, positive ions or holes. The standard abbreviations for the units are 1A = 1C/s. Current is usually denoted by the symbol *I*.

In many contexts the direction of the current in electric circuits is taken as the direction of positive charge flow. It is the direction opposite to the actual electron drift. This is called conventional current.

In a circuit, if flow of electric charge is 1 coulomb (6.2×10^{18} electrons) in one second through a point or region then the current through the circuit is 1 ampere.

There are two types of currents, one is alternating current while the other is direct current. Alternating current periodically reversing its direction as positive half cycle and negative half cycle. But direct current have a single direction, i.e, positive cycle only.

RESISTANCE



Resistance may be defined as the property of a substance due to which it opposes (or restricts) the flow of electricity *(i.e.,* electrons) through it. Metals, acids and salts solutions are good conductors of electricity so they can allow the current to pass through it. Amongst pure metals, silver, copper and aluminum are very good conductors in the given order. These materials have less resistance. This value is usually represented with the Greek letter "Ω", which is called omega, and pronounced "ohm". A piece of conducting material of a particular resistance designed to use in a circuit is called a resistor. Mechanically it is similar to the property of friction.

A conductor is said to have a resistance of one ohm if it permits one ampere current to flow through it when one volt potential difference is applied across its terminals. For insulators the resistance values are very high, a much bigger unit is used *i.e.* mega-ohm $=10^6\ \Omega$ or kilo-ohm = $10^3\ \Omega$ (kilo means thousand). In the case of very small resistances, smaller units like milli-ohm = 10^{-3} ohm or micr-ohm = 10^{-6} ohm are used.

Laws of Resistance

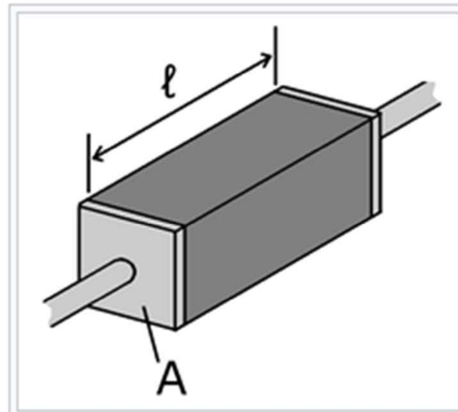
The resistance R offered by a conductor depends on the following factors:

(i) It varies directly as its length *l*.

(ii) It varies inversely as the cross-section *A* of the conductor.

(iii) It depends on the nature of the material.

(iv) It also depends on the temperature of the conductor.



$$R = \rho \frac{l}{A}$$

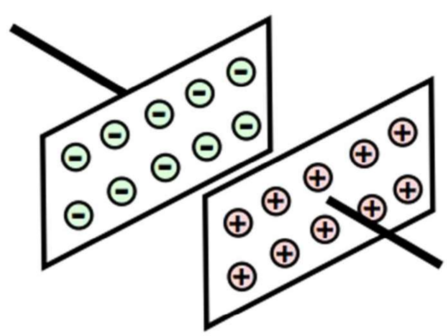
where ρ is the specific resistance or resistivity of the material.

Temperature dependence

Resistance of the material depends on temperature. In Pure metals, the resistance increases with temperature. So the conductors have *positive* temperature-coefficient of resistance. But Insulators are different, the resistance of electrolytes, insulators (such as paper, rubber, glass, mica etc.) and partial conductors such as carbon decreases with rise in temperature. These insulators are have a *negative* temperature-coefficient of resistance.

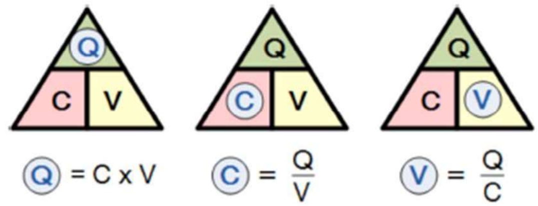
<u>CAPACITANCE:</u>

Capacitance is the property of an electric conductor or set of conductors, measured by the amount of separated electric charge that can be stored on it per unit change in electrical potential. Capacitance associated with storage of electrical energy. If electric charge is transferred between two initially uncharged conductors, both become equally charged, one positively, the other negatively, and a potential difference is established between them.



The capacitance C is the ratio of the amount of charge q on either conductor to the potential difference V between the conductors.

Simply C = Q/V



The unit of electric charge is the coulomb and the unit of potential difference is the volt, so that the unit of capacitance is one coulomb per volt called as farad (symbolized F) named after Michael Faraday. One farad is an extremely large capacitance. So commonly microfarad (μF), picofarad (pF) are used to measure capacitance.

Capacitance can also be determined from the dimensions or area A of the plates and the properties of the dielectric material between the plates. So another way of expressing the capacitance of a capacitor is:

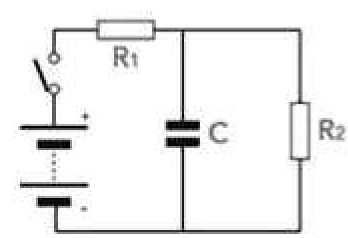
Capacitor with Air as its dielectric:

$$C = \frac{Q}{V} = \varepsilon \frac{A}{d}$$

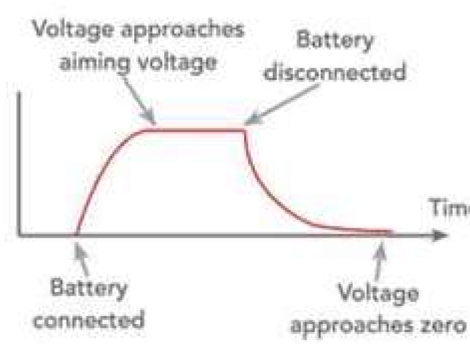
Capacitor with a Solid as its dielectric

$$C = \frac{Q}{V} = \varepsilon_0 \varepsilon_r \frac{A}{d}$$

where d is the distance or separation between the two plates. The larger the area or smaller the distance, the higher is the ability of the plates to store charge.



Capacitors require insulator between the two plates, otherwise the charge could not remain on the plates, it would dissipate through the medium between the two plates. Air is a good insulator, often the capacitor plates need to be kept apart by some rigid insulators. The material between the two plates is called the dielectric. This dielectric affects the level of capacitance achievable for a given capacitor plate size and spacing.



When a voltage is applied to a capacitor, it would instantly charge up and the voltage across it would be the same as that of the source of the electric potential. In reality there will always be some resistance in the circuit, and therefore the capacitor will be connected to the voltage source through a resistor. So it will take a finite time to charge up the capacitor, but does not take place instantly. Similarly the capacitor will always discharge through a resistance. The rate at which the voltage rises or decays is dependent upon the resistance in the circuit. As the charge on the capacitor falls, the voltage across the capacitor falls in an exponential fashion, gradually approaching zero.

Energy in a Capacitor

When a capacitor charges up from the power supply connected to it, an electrostatic field is established which stores energy in the capacitor. The amount of energy in Joules.

$$\text{Energy, } W = \frac{1}{2}CV^2 \text{ or } \frac{CV^2}{2} \text{ in Joules, (j)}$$

Types of capacitor

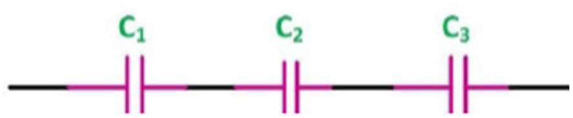
Depending on shape, size and properties, there are various types of capacitors available.

(i) Paper Capacitor (ii) Air capacitor (iii) Plastic Capacitor (iv) Silver mica capacitor

(v) Ceramic capacitor (vi) Electrolytic capacitor (v) Porcelain capacitor.

Series Capacitor Circuit

If the number of capacitors, for example, C_1, C_2, C_3…..connected together in a series is called a series capacitor circuit. The current flowing in this type of circuit will be the same across all the capacitors as they are connected in series.

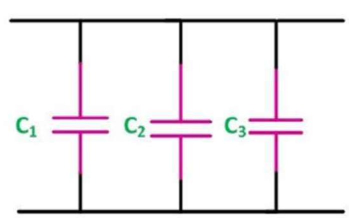


The equivalent capacitance is

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots\dots\dots$$

Parallel Capacitor Circuit

If the number of capacitors is connected to each other as in parallel connection, the circuit is said to be a parallel capacitor circuit. The circuit is shown below:



The equivalent capacitance in a parallel circuit is given by

$$C_{eq} = C_1 + C_2 + C_3 + \dots\dots\dots$$

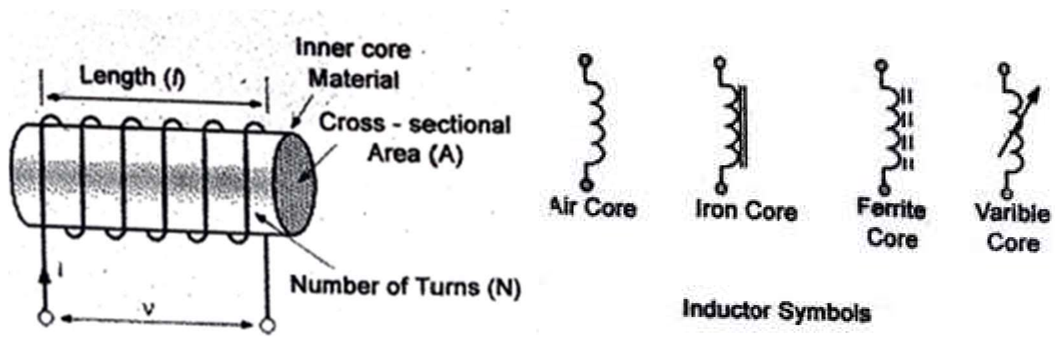
INDUCTANCE

Inductance is the property of an electric conductor or circuit that causes an electromotive force to be generated by a change in the current. In electromagnetism and electronics, inductance is the tendency of an electrical conductor to oppose a change in the electric current flowing through it. The flow of electric current creates a magnetic field around the conductor. The field strength depends on the magnitude of the current, and follows any changes in current. From Faraday's law of induction, any change in magnetic field through a circuit induces an electromotive force (EMF) in the conductors, known as electromagnetic induction. This induced EMF opposes the original change in current and the voltage is called back EMF.

Inductance is defined as the ratio of the induced voltage to the rate of change of current causing it. It depends on the geometry of circuit conductors and the magnetic permeability of nearby materials. An electronic component designed to add inductance to a circuit is called an inductor.

In construction, Inductors consisting of coils of insulated copper wire wound around a metal core such as iron which can be easily magnetized or in high frequency inductors, it will more likely to be just air.

The resistance offered by an inductor is called inductive reactance (X_L) similar to ordinary resistance but it depends on frequency, directly proportional to the applied frequency of the supply.



Inductors are extensively used in alternating current (AC) applications such as radio, TV and communications equipment, and in these systems, how inductors react to AC signals of different frequencies is very useful.

<u>TYPES OF MATERIALS</u>

ELECTRICAL CONDUCTORS:

Electric Conductors are the materials or substances which allow electricity to flow through them. They conduct electricity because they allow electrons to flow easily inside them from atom to atom. An object made of a conducting material will permit charge to be transferred across the entire surface of the object so the charge is quickly distributed across the entire surface of the object.

Since conductors allow for electrons to be transported from particle to particle, a charged object will always distribute its charge until the overall repulsive forces between excess electrons is minimized.

Examples of Conductors:

(i) Material such as silver is the best conductor of electricity. Gold is also a conductor. But, it is costly and so, we don't use them in industries and transmission of electricity. Copper, Brass, Steel, and Aluminum are good conductors of electricity. We use them in electric circuits and systems in the form of wires.

(ii) Mercury is an excellent liquid conductor. Thus, this material finds use in many instruments.

(iii) Gases are not good conductors of electricity because the atoms are quite far away. Thus, they are unable to conduct electrons.

ELECTRIC INSULATORS:

Insulators are the materials or substances which resist the current to flow through them. In general, they are solid in nature. Resistivity is the property which makes insulators different from conductors.

Insulators are materials that obstruct the free flow of electrons from atom to atom and molecule to molecule. If charge is transferred to an insulator at a given location, the excess charge will remain at the same initial location of charging. The particles of the insulator do not permit the free flow of electrons subsequently charge is rarely distributed evenly across the surface of an insulator.

Examples of Insulators:

Glass is the best insulator as it has the highest resistivity.

Plastic is a good insulator and it finds its use in making a number of things.

Rubber is a common material used in making fire-resistant clothes and slippers. This is because it is a very good insulator.

OHM'S LAW

Ohm's Law states that the current flowing through a conductor is directly proportional to the potential difference applied across its ends, provided the temperature and other physical conditions remain unchanged.

Mathematically it can be represented as

$$\text{Potential difference} \propto \text{Current}$$

$$V \propto I$$

$$V = IR$$

Where, V is Voltage in volts (V), R is Resistance in ohm (Ω) and I is Current in Ampere (A).

Different Applications of Ohm's Law:

(i) To determine the voltage, resistance or current of an electric circuit.

(ii) Ohm's law is used to maintain the desired voltage drop across the electronic components

(iii) Ohm's law is also used in dc ammeter and other dc shunts to divert the current.

Limitations of Ohm's Law:

Ohm's law is not applicable for

(i) Unilateral electrical elements like diodes and transistors as they allow the current to flow through in one direction only.

(ii) For non-linear electrical elements with parameters like capacitance, inductance, etc. the voltage and current won't be constant with respect to time.

AMMETER

As we know a word “meter” is associated with the measurement system. Meter is an instrument which can measure a particular quantity. As we know, the unit of current is Ampere. Ammeter means Ampere-meter which measures ampere value. Ampere is the unit of current so an ammeter is a meter or an instrument which measures current.

The main principle of ammeter is that it must have a very low resistance and also inductive reactance. It has very low impedance because it must have very low amount of voltage drop across it and must be connected in series connection because current is same in the series circuit. Also due to very low impedance the power loss will be low and if it is connected in parallel it becomes almost a short circuited path and all the current will flow through ammeter so the instrument may burn. Due to this reason it must be connected in series. For an ideal ammeter, it must have zero impedance so that it has zero voltage drop across it so the power loss in the instrument is zero. But the ideal is not achievable practically.

Classification or Types of Ammeter

Depending on the constructing principle, there are many types of ammeter we get, they are mainly

1. **Permanent Magnet Moving Coil (PMMC) ammeter**.
2. **Moving Iron (MI) Ammeter**.
3. **Electrodynamometer type Ammeter**.
4. **Rectifier type Ammeter**.

Depending on this types of measurement we do, we have

1. **DC Ammeter**.
2. **AC Ammeter**.

DC Ammeter are mainly PMMC instruments, MI can measure both AC and DC currents, also Electrodynamometer type thermal instrument can measure DC and AC, induction meters are not generally used for ammeter construction due to their higher cost, inaccuracy in measurement.

1. PMMC Ammeter

Principle PMMC Ammeter:

When current carrying conductor placed in a magnetic field, a mechanical force acts on the conductor, if it is attached to a moving system, with the coil movement, the pointer moves over the scale.

As the name suggests it has permanent magnets which are employed in this kind of measuring instruments. It is particularly suited for DC measurement because here deflection is proportional to the current and hence if current direction is reversed, deflection of the pointer will also be reversed so it is used only for DC measurement. This type of instrument is called DArnsonval type instrument. It has major advantage of having linear scale, low power consumption, high accuracy. Major disadvantage of being measured only DC quantity, higher cost etc.

Deflecting torque,

$$\tau = \text{NBilb } Nm$$

Where, B = Flux density in Wb/m².

i= Current flowing through the coil in Amp.

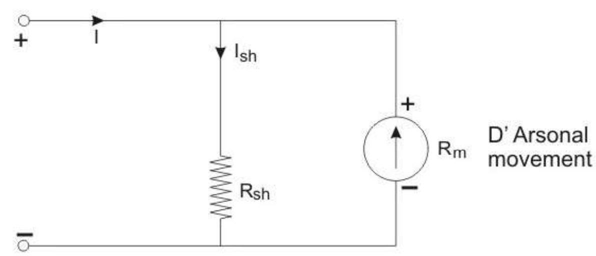
l = Length of the coil in m.

b = Breadth of the coil in m.

N = No of turns in the coil.

Extension of Range in a PMMC Ammeter:

We can extend the range of measurement in this type of instrument. To measure higher amount of current, we just have to connect a shunt resistance in parallel and the range of that instrument can be extended, this is a simple solution provided by the instrument.



$$Then,\ R_{sh} = \frac{R_m}{\frac{I}{I-I_{sh}} - 1}$$

In the figure, I is total current flowing in the circuit in Amp.

I_{sh} is the current through the shunt resistor in Amp.

R_m is the ammeter resistance in Ohm.

2. MI Ammeter

It is a moving iron instrument, used for both AC and DC, It can be used for both because the deflection θ proportional square of the current so whatever is the direction of current, it shows directional deflection, further they are classified in two more ways-

1. Attraction type. 2. Repulsion type.

Its torque equation is: $T = \frac{1}{2} I^2 \frac{dL}{d\theta}$

Where,
I is the total current flowing in the circuit in Amp.

L is the self inductance of the coil in Henry.

θ is the deflection in Radian.

i.) Attraction Type MI Instrument Principle:

When an unmagnetised soft iron is placed in the magnetic field, it is attracted towards the coil, if a moving system attached and current is passed through a coil, it creates a magnetic field which attracts iron piece and creates deflecting torque as a result of which pointer moves over the scale.

ii.) Repulsion Type MI Instrument Principle:

When two iron pieces are magnetized with same polarity by passing a current than repulsion between them occurs and that repulsion produces a deflecting torque due to which the pointer moves.

The advantages of MI instruments are they can measure both AC and DC, cheap, low friction errors, robustness etc. It is mainly used in AC measurement because in DC measurement error will be more due to hysteresis.

3. Electrodynamometer Type Ammeter

This can be used to measure both i.e. AC and DC currents. Electrodynamometer instruments have the same calibration for both AC and DC i.e. if it is calibrated with DC, then also without calibrating we can measure AC.

Principle Electrodynamometer Type Ammeter:

There we have two coils, namely fixed and moving coils. If a current is passed through two coils it will stay in the zero position due to the development of equal and opposite torque. If somehow, the direction of one torque is reversed as the current in the coil reverses, an unidirectional torque is produced.

For ammeter, the connection is a series one and $\varphi = 0$.

$$T = I^2 \frac{dM}{d\theta}$$

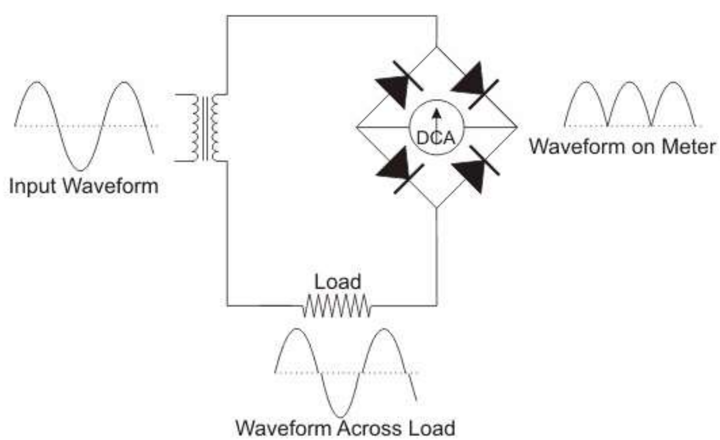
Where, φ is the phase angle.

I is the amount of current flowing in the circuit in Amp.

M = Mutual inductance of the coil.

They have no hysteresis error, used for both AC and DC measurement, the main disadvantages are they have low torque/weight ratio, high friction loss, expensive than other measuring instruments etc.

4. Rectifier Ammeter



Principle of Rectifier Ammeter:

They are used for AC measurement which is connected to secondary of a current transformer, the secondary current is much less than primary and connected with a bridge rectifier to a moving coil ammeter.

Advantages:

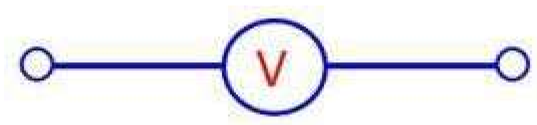
1. It can be used in high frequency also.
2. Uniform scale for most of the ranges.

Disadvantages are being error due to temperature decrease in sensitivity in AC operation.

VOLTMETER

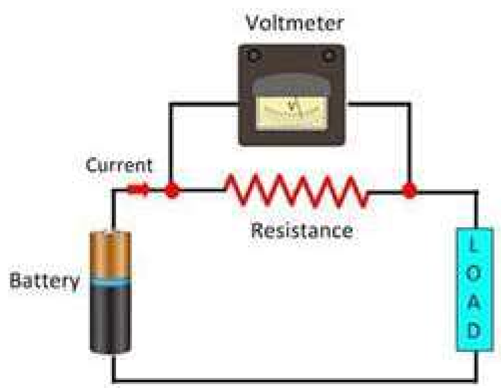
The instrument which measures the voltage or potential difference in volts is known as the voltmeter. It works on the principle that the torque is generated by the current which induces because of measurand voltage and this torque deflects the pointer of the instrument. The deflection of the pointer is directly proportional to the potential difference between the points. The voltmeter is always connected in parallel with the circuit.

The voltmeter is represented by the alphabet V inside the circle along with the two terminals.



Voltmeter in parallel connection

The voltmeter constructs in such a manner that their internal resistance always remains high. If it connects in series with the circuit, it minimises the current which flows because of the measurand voltage. Thus, disturb the reading of the voltmeter.



The voltmeter always connects in parallel with the circuit so that the same voltage drop occurs across it. The high resistance of the voltmeter combines with the impedance of the element across which it is connected. And the overall impedance of the system is equal to the impedance that the element had. Thus, no obstruction occurs in the circuit because of the voltmeter, and the meter gives the correct reading.

The voltmeter is constructed with very high internal resistance because it measures the potential difference between the two points of the circuit. The voltmeter does not change the current of the measuring device.

If the voltmeter has low resistance, the current passes through it, and the voltmeter gives the incorrect result. The high resistance of the voltmeter does not allow the current to pass through it and thus the correct reading is obtained.

Types of Voltmeter

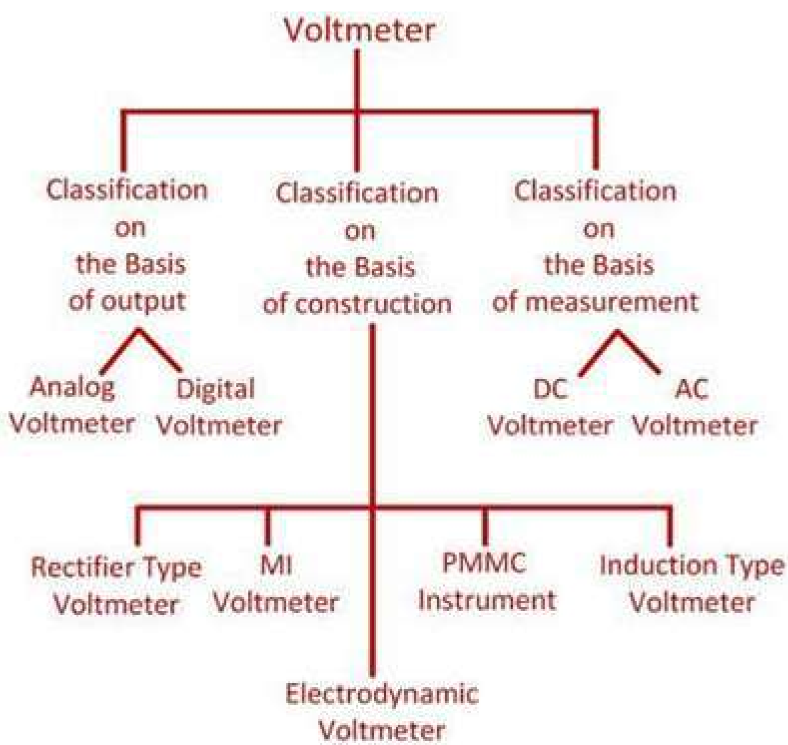
The voltmeter is classified into three ways. The classification of the voltmeter is shown in the figure below.

On the basis of the construction, the voltmeter is of the following types.

i) PMMC Voltmeter

It works on the principle that the current carrying conductor placed in the magnetic field and because of the current the force acting on the conductor. The current induces in the PMMC instrument because of the measurand voltage, and this current deflects the pointer of the meter.

The PMMC voltmeter uses for DC measurement. The accuracy of the instrument is very high and having low power consumption. The only disadvantage of the instrument is that it is very costly. The range of the PMMC voltmeter increases by connecting the resistance in series with it.



ii) MI Voltmeter

The MI instrument means moving iron instrument. This instrument uses for the measurement of both the AC and DC voltage. In this type of instrument, the deflection is directly proportional to the voltage of the coil. The moving iron instrument is classified into two types.

- Attraction Type Moving Iron Instrument
- Repulsion Type Moving Iron Instrument

iii) Electro-dynamometer Voltmeter

The electro-dynamometer voltmeter is used for measuring the voltage of both AC and DC circuit**.** In this type of instruments, the calibration is same both for the AC and DC measurement.

iv) Rectifier voltmeter

Such type of instrument is used in AC circuits for voltage measurement. The rectifier instrument converts the AC quantity into the DC quantity by the help of the rectifier. And then the DC signal is measured by the PMMC instrument.

The following are the classification of instruments regarding the displays of output reading.

i) Analogue Voltmeter

The analogue voltmeter uses for measuring the AC voltage. It displays the reading through the pointer which is fixed on the calibrated scale. The deflection of the pointer depends on the torque acting on it. The magnitude of the developed torque is directly proportional to the measuring voltage.

ii) Digital Voltmeter

The voltmeter which displays the reading in the numeric form is known as the digital voltmeter. The digital voltmeter gives the accurate result.

The instrument which measures the direct current is known as the DC voltmeter, and the AC voltmeter is used in the AC circuit for alternating voltage measurement.

GALVANOMETER

A galvanometer is a device that is used to detect small electric current or measure its magnitude. The current and its intensity is usually indicated by a magnetic needle's movement which is an important part of a galvanometer.

Since its discovery in the 1800s, galvanometer has seen many iterations. Some of the different types of galvanometer include Tangent galvanometer, Astatic galvanometer, Mirror galvanometer and Ballistic galvanometer.

Moving Coil Galvanometer

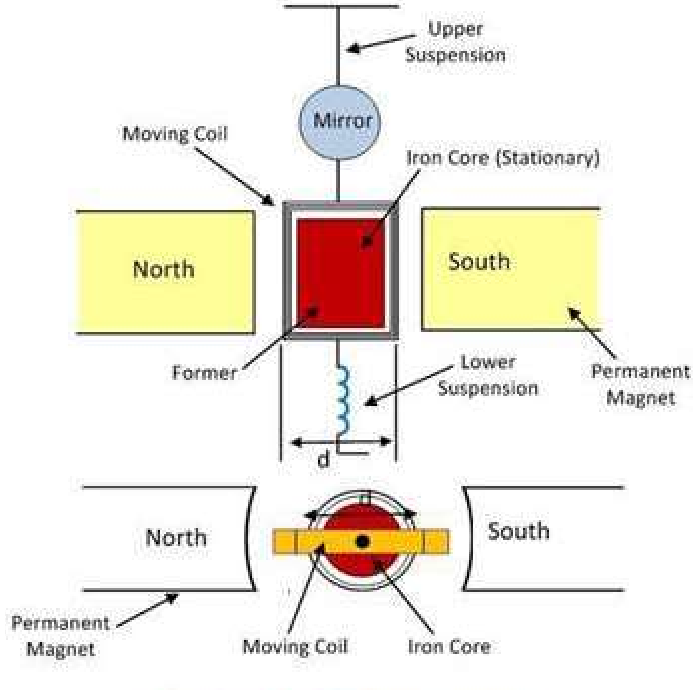
A moving coil galvanometer is an instrument which is used to measure electric currents. It is a sensitive electromagnetic device which can measure low currents even of the order of a few microamperes. When a current-carrying coil placed in an external magnetic field it experiences magnetic torque. Due to this magnetic torque, the coil is deflected through an angle which is proportional to the magnitude of current in the coil.

Moving Coil Galvanometer Construction And Diagram

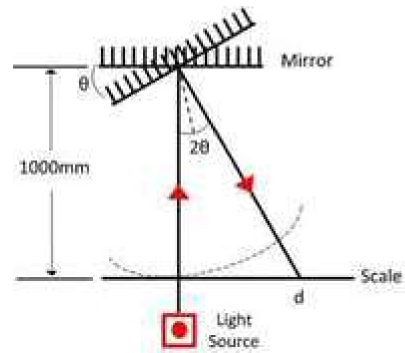
The moving coil galvanometer is made up of a rectangular coil that has many turns and it is usually made of thinly insulated or fine copper wire that is wounded on a metallic frame. The coil is free to rotate about a fixed axis. The coil is suspended in a uniform radial magnetic field with the help of a phosphor-bronze strip that is connected to a movable torsion head.

The material used for suspension of the coil must have conductivity with a low value of the torsional constant. A cylindrical soft iron core is symmetrically positioned inside the coil to improve the strength of the magnetic field and to make the field radial. The lower part of the coil is attached to a phosphor-bronze spring having a small number of turns. The other end of the spring is connected to binding screws.

The spring is used to produce a counter torque which balances the magnetic torque and hence helps in producing a steady angular deflection. A plane mirror which is attached to the suspension wire, along with a lamp and scale arrangement, is used to measure the deflection of the coil. Zero-point of the scale is at the centre.



Moving Coil Galvanometer

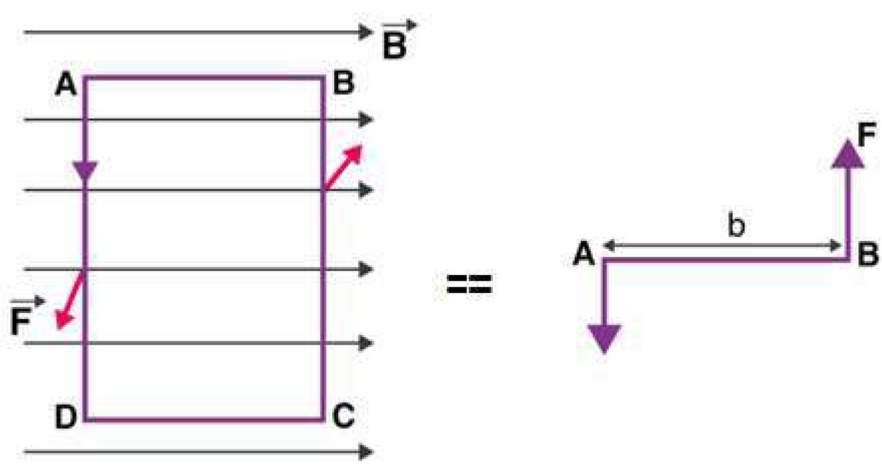


Measurement of Deflection with lamp and scale Arrangement

Working of Moving Coil Galvanometer

Let a current I flow through the rectangular coil of n number of turns and a cross-sectional area A. When this coil is placed in a uniform radial magnetic field B, the coil experiences a torque τ.

Let us first consider a single turn ABCD of the rectangular coil having a length l and breadth b. This is suspended in a magnetic field of strength B such that the plane of the coil is parallel to the magnetic field. Since the sides AB and DC are parallel to the direction of the magnetic field, they do not experience any effective force due to the magnetic field. The sides AD and BC being perpendicular to the direction of field experience an effective force F given by $F = BIl$



Using Fleming's left-hand rule we can determine that the forces on AD and BC are in opposite direction to each other. When equal and opposite forces F called couple acts on the coil, it produces a torque. This torque causes the coil to deflect.

We know that torque τ = force x perpendicular distance between the forces

$$\tau = F \times b$$

Substituting the value of F we already know,

Torque τ acting on single-loop ABCD of the coil = $BIl \times b$

Where l x b is the area A of the coil,

Hence the torque acting on n turns of the coil is given by

$$\tau = nIAB$$

The magnetic torque thus produced causes the coil to rotate, and the phosphor bronze strip twists. In turn, the spring S attached to the coil produces restoring torque $k\theta$ which results in a steady angular deflection.

Under equilibrium condition:

$$k\theta = nIAB$$

here k is called the torsional constant of the spring (restoring couple per unit twist).

The deflection or twist θ is measured as the value indicated on a scale by a pointer which is connected to the suspension wire.

$$\theta = (nAB / k)I$$

$$\text{Therefore } \theta \propto I$$

The quantity nAB / k is a constant for a given galvanometer. Hence it is understood that the deflection that occurs the galvanometer is directly proportional to the current that flows through it.

<u>Sensitivity Of Moving Coil Galvanometer</u>

The general definition of the sensitivity experienced by a moving coil galvanometer is given as the ratio of change in deflection of the galvanometer to the change in current in the coil.

$$S = d\theta/dI$$

The sensitivity of a galvanometer is higher if the instrument shows larger deflection for a small value of current. Sensitivity is of two types, namely current sensitivity and voltage sensitivity.

Current Sensitivity

The deflection θ per unit current I is known as current sensitivity θ/I

$$\theta/I = nAB/k$$

Voltage Sensitivity

The deflection θ per unit voltage is known as Voltage sensitivity θ/V. Dividing both sides by V in the equation $\theta = (nAB / k)I$;

$$\theta/V = (nAB / V k)I$$

$$= (nAB / k)(I/V)$$

$$= (nAB / k)(1/R)$$

R stands for the effective resistance in the circuit.

It is worth noting that voltage sensitivity = Current sensitivity/ Resistance of the coil.

Therefore, under the condition that R remains constant; voltage sensitivity ∝ Current sensitivity.

Figure of Merit of a Galvanometer

It is the ratio of the full-scale deflection current and the number of graduations on the scale of the instrument. It also the reciprocal of the current sensitivity of a galvanometer.

Factors Affecting Sensitivity of a Galvanometer

a) Number of turns in the coil

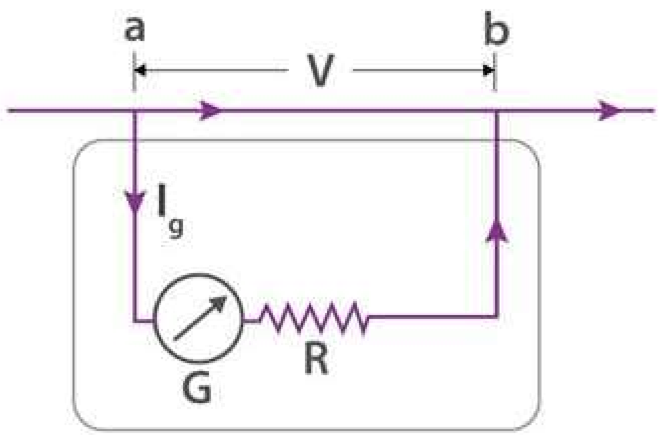
b) Area of the coil

c) Magnetic field strength B

d) The magnitude of couple per unit twist k/nAB

Conversion Of Galvanometer To Voltmeter

A galvanometer is converted into a voltmeter by connecting it in series with high resistance. A suitable high resistance is chosen depending on the range of the voltmeter.



Voltmeter

In the given circuit

R_G = Resistance of the galvanometer

R = Value of high resistance

G = Galvanometer coil

I = Total current passing through the circuit

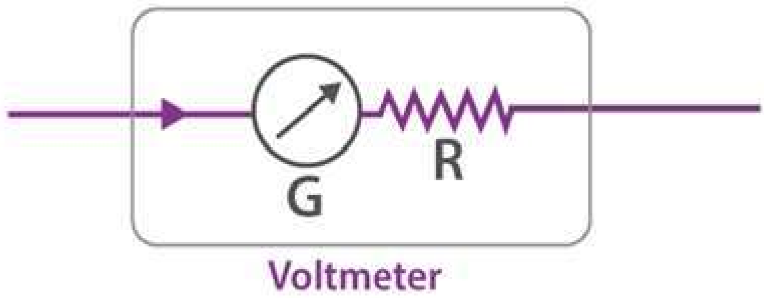
I_G = Total current passing through the galvanometer which corresponds to a full-scale deflection.

V = Voltage drop across the series connection of galvanometer and high resistance.

When current I_G passes through the series combination of the galvanometer and the high resistance R; the voltage drop across the branch ab is given by

$$V= R_G.I_G + R.I_G$$

The value of R can be obtained using the above equation.



Advantages and Disadvantages of a Moving Coil Galvanometer

Advantages

- High sensitivity.
- Not easily affected by stray magnetic fields.
- The torque to weight ratio is high.
- High accuracy and reliability.

Disadvantages

- It can be used only to measure direct currents.
- Develops errors due to factors like aging of the instrument, permanent magnets and damage of spring due to mechanical stress.

MULTIMETERS

Multimeters an instrument designed to measure electric current, voltage, and usually resistance typically over several ranges, of value.

Uses of Multimeter

Multimeters can be used as an ammeter, voltmeter, an ohmmeter by operating a multi-position knob on the meter. They can measure DA as well as AC. There are also special functions in a multimeter like 'Detecting a Short Circuit', testing transistors and some have additional features for measuring capacitance & frequency also.

Types of Multimeters

They are two types of multimeters available in market.

(a). Analog Multimeter:

Analogue meters take a little power from the circuit under test to operate their pointer. They must have a high sensitivity of at least 20k/V or they may upset the circuit under test and give an incorrect reading.

(b). Digital Multimeter:

All digital meters contain a battery to power the display so they use virtually no power from the circuit under test. The have a digital display. There DC voltage ranges have a very high resistance of 1M or more, usually 10 M, and they are very unlikely to affect the circuit under test.

Working of digital multimeter

There are three sockets of wire, the black lead is always connected into the socket marked COM, short form for COMMON. The red lead is connected into the socket labeled V mA. The 10A socket is very rarely used.

Measuring resistance with a multimeter

(1) Set the meter to a resistance range greater than you expect the resistance to be.

(2) Touch the meter probes together and check that the meter reads zero.

(3) Put the probes across the component.

Measuring Voltage with Voltmeter

(1) Select a voltage range with a maximum greater than you expect the reading to be. If the reading goes off the scale immediately disconnect and select a higher range.

(2) Connect the red (positive +) lead to the point you where you need to measure the voltage

(3) The black lead can be left permanently connected to 0 V while you use the red lead as a probe to measure voltages at various points.

Similarly you can measure the current by choosing a suitable range. If it displays a 1' at left, choose higher current range.

Testing a diode with a DIGITAL multimeter

(a) Digital multimeters have a special setting for testing a diode, usually labeled with the diode symbol.

(b) Connect the red (+) lead to the anode and the black (-) to the cathode.. The diode should conduct and the meter will display a value.

(c) Reverse the connections. The diode should NOT conduct this way so the meter will display "off the scale"

Testing a transistor with a multiméter:

Set a -digital multimeter to diode test and an analogue multimeter to a low resistance range such as x 10 ohm as described above for testing a diode.

Test each pair of leads both ways:

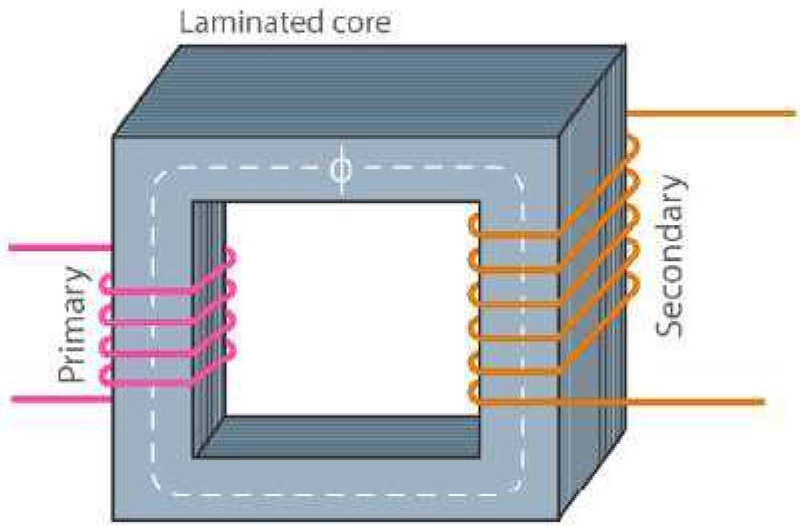
(1) The base-emitter (BE) junction should behave like a diode and conduct one way only.

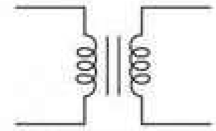
(2) The base-collector (BC) junction should behave like a diode and conduct one way only. (3) The collector-emitter (CE) should not conduct either way.

Conducting in one way simply means it will bend as a short circuit.

TRANSFORMER

A transformer is a device used in the power transmission of electric energy. It is used widely in the distribution and transmission of alternating current power. It is commonly used to increase or decrease the supply voltage without a change in the frequency of AC from one circuit to another. So the transformer is basically a voltage control device. It works on basic principles of electromagnetic induction and mutual induction.





Working Principle of a Transformer

The transformer works on the principle of Faraday's law of electromagnetic induction and mutual induction. There are usually two coils, primary coil and secondary coil on the transformer core. The core laminations are joined in the form of strips. The two coils have high mutual inductance. When an alternating current pass through the primary coil, forms a varying magnetic flux as per faraday's law of electromagnetic induction and this change in magnetic flux induces an emf (electromotive force) in the secondary coil which is linked to the core having a primary coil. This is mutual induction. Transformer consists of a magnetic iron core serving as a magnetic transformer part and transformer cooper winding serving as an electrical part.

Overall, a transformer carries the below operations:

1. Transfer of electrical energy from circuit to another

2. Transfer of electrical power through electromagnetic induction

3. Electric power transfer without any change in frequency

4. Two circuits are linked with mutual induction

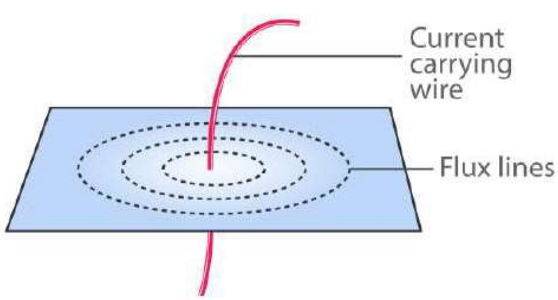


Fig (a)

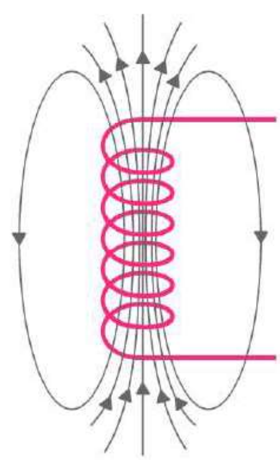


Fig (b)

The figure (a) shows the formation of magnetic flux lines around a current-carrying wire. The figure (b) shows the formation of varying magnetic flux lines around a wire wound. When the magnetic flux fluctuate around a piece of wire, a current will be induced in it.

The major parts of a transformer consist of

1. Core

The core acts as a support to the winding in the transformer. It also provides a low reluctance path to the flow of magnetic flux. The winding is wound on the core. It is made up of a laminated soft iron core in order to reduce the losses in a transformer. The factors such as operating voltage, current, power etc., decide core composition. The core diameter is directly proportional to copper losses and inversely proportional to iron losses.

2. Windings

Windings are the set of copper wires wound over the transformer core. Copper wires are used due to High conductivity of copper. This minimizes the loss in a transformer. Since conductivity increases, resistance to current flow decreases. Because of its high ductility, copper can be made into very thin long wires.

There are mainly two types of windings. One is Primary windings and the other is secondary windings.

Primary winding: The set of turns of windings to which supply current is feed (input).

Secondary winding: the set of turns of winding from which output is taken.

The primary and secondary windings are insulated from each other using insulation coating agents.

3. Insulation Agents

Insulation is necessary for transformers to separate windings from shorting the circuit and thus facilitating the mutual induction. Insulation agents have influence in durability and the stability of a transformer.

Generally Insulating oil, Insulating tape, Insulating paper and Wood-based lamination are used as an insulation medium in a transformer.

Types of Transformers

Transformers are used in various fields like power generation grid, distribution sector, transmission and electric energy consumption. There are various types of transformers which are classified based on the following factors.

(A) Phase connection

(B) Output voltage

(C) The medium used in the core

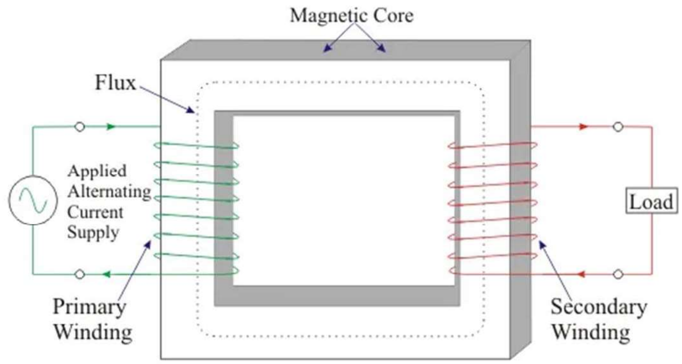
(D) Purpose of working.

(A) Depends on Phase connection

Depending on the power supply there are two types of transformers

a). Single Phase Transformer   b). Three Phase Transformer

a) Single Phase Transformer

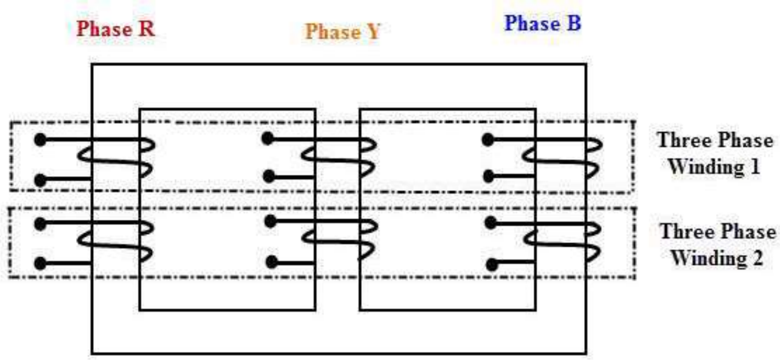


Single Phase Transformer

When a single pair of a coil, one primary and one secondary is used to produce the desired voltage is referred to as a single-phase transformer. It consists of two highly inductive coils wound on an iron or steel core, the winding which is connected to the AC supply is named the first winding and the other one is secondary. It has four terminals, two on the input (phase & neutral), and two on the output (phase & neutral), no delta or star connections are available here. In most cases, no cooling system is required for a single-phase transformer. The magnetic core of Single-phase differs from that of the 3 Phase.

Single-phase transformers are typically used for residential requirements, as they convert the high voltage into low voltage like a step-down transformer. It is most suited for residential and office requirements due to low cost and lower electricity input requirement.

b) 3 Phase Transformer



A 3-phase transformer is made by winding three single-phase transformer on one core, 3-phase transformer contains six coils, three for the primary side, and another three coils for the secondary side. To achieve the specified voltage, transformers are then placed in an enclosure and crammed with dielectric oil. With only a little conductor these transformers can transmit the required level of voltage over long distances, helping in the smooth functioning of industrial equipment. A three-phase transformer has star and delta connections & twelve terminals with different connections to connect with them. These transformers require a heavy cooling system depending on the transformer’s power rating. Here cooling is achieved by (oil\forced oil), (air\forced air), or (forced water).

3-phase transformers are well-known for their efficiency to cater to the needs of heavy-duty applications that are most suitable and highly reliable for heavy industrial applications. 3-phase transformers are most often deployed as influence or distribution transformers, with high rated KVA.

(B) Based on Output voltage

Based on Voltage Levels Commonly used transformer type, depending upon voltage they are classified as

(a) Step-up Transformer: They are used between the power generator and the power grid. The secondary output voltage is higher than the input voltage.

(b) Step down Transformer: These transformers are used to convert high voltage primary supply to low voltage secondary output.

If E_1 is supply voltage on the primary winding and E_2 is terminal voltage (theoretical or calculated) on the secondary winding, N_1 and N_2 be the number of turns of the coil in Primary and secondary windings,

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

K is called the voltage transformation ratio, which is a constant.

Case1: if $N_2 > N_1$, K>1 it is called a step-up transformer.

Case 2: if $N_2 < N_1$, K<1 it is called a step-down transformer.

(C) Based on the Medium of Core

Based on the Medium of Core Used In a transformer, we will find different types of cores that are used.

(a) Air core Transformer:

The flux linkage between primary and secondary winding is through the air. The coil or windings wound on the. non-magnetic strip.

(b) Iron core Transformer:

Windings are wound on multiple iron plates stacked together, which provides a perfect linkage path to generate flux.

(D) Based on Purpose of work

Based on Purpose of work with transformers, they are divided into 4 types.

(a) Power Transformer: It is used at power generation stations as they are suitable for high voltage application.

(b) Distribution Transformer: Mostly used at distribution lanes in domestic purposes. They are designed for carrying low voltages. It is very easy to install and characterized by low magnetic losses.

(c) Measurement Transformers: These are further classified. They are mainly used for measuring voltage, current, power.

(d) Protection Transformers: They are used for component protection purposes. In circuits some components must be protected from voltage fluctuation protection transformers ensure component etc. protection.

Applications of Transformer

1. The transformer transmits electrical energy through wires over long distances.

2. Transformers with multiple secondary's are used in radio and TV receivers which require several different voltages.

3. Transformers are used as voltage regulators.

ELECTRIC POWER

The rate at which the work is being done in an electrical circuit is called an electric power. In other Words, the electric power is defined as the rate of the transfer of energy. The electric power is produced by the generator and can also be supplied by the electrical batteries. It gives a low entropy form of energy which is carried over long distance and also it is converted into various other forms of energy like motion, heat energy etc.

The electric power is divided into two types i.e., the AC power and the DC power.

The classification of the electric power depends on the nature of the current. The electric power is consumed or sold which is the product of Power in kilowatt and the running time of the devices in hours. Type of power is measured by the electric metre which records the total energy consumed by the powered devices.

$$Electric\ Power = \frac{\text{Work done in an electrical current}}{time}$$

$$\text{Electric Power P} = \frac{V\,I\,t}{t} = V \text{ x I} = I^2 R = \frac{V^2}{R}$$

Where V is the voltage in volts I is the current in amperes, R is the resistance offered by the power devices, T is time in seconds and P is the power measured in watts. Units of electric power is watt.

The power consumed in an electric circuit is said to be 1 watt if 1 ampere current flows through the circuit when a potential difference of 1 volt is applied across it. The bigger unit of electrical power is the kilowatt it is usually used in the power system.

Types of Electric Power

1. DC Power:

The DC power is defined as the product of the voltage and current. It is produced by the fuel cell, battery and generator.

$$P = V \text{ x } I$$

where V is the voltage in volts I is the current in amperes.

2. AC Power:

The AC power is mainly classified into three types. They are the Active Power, Reactive Power and Apparent Power.

A. Active Power or true power (P):

The active power (P) is the real power which is dissipated in the circuit resistance (R). The actual amount of power being used, or dissipated, in a circuit is called *true power*, and it is measured in watts (symbolized by the capital letter P, as always). As a rule, true power is a function of a circuit's dissipative elements, usually resistances (R).

$$P = V_{rms}\, I_{rms}\, \cos\Phi$$

B. Reactive Power (Q):

We know that reactive loads such as inductors and capacitors dissipate zero power, yet the fact that they drop voltage and draw current gives the misleading impression that they actually *do* dissipate power. The power developed in the circuit reactance (X) is called reactive power (Q). It is measured in volt-ampere reactive (VAR), rather than watts. Reactive power is a function of a circuit's reactance (X).

$$Q = V_{rms}\, I_{rms}\, \sin\Phi$$

C. Apparent Power (S):

The combination of reactive power and true power is called *apparent power*, and it is the product of a circuit's voltage and current, without reference to phase angle. Apparent power is measured in the unit of *Volt-Amps* (VA) and is symbolized by the capital letter S.

$$S = V_{rms}\, I_{rms}$$

Apparent power is a function of a circuit's total impedance (Z).

The relation between the apparent, active and reactive power is shown below.

$$S^2 = Q^2 + P^2$$

The ratio of the Active Power to the Apparent Power is called Power factor (*cosΦ*), and their value lies between 0 and 1.

P = true power $\quad P = I^2R \quad P = \frac{E^2}{R}$

*Measured in units of **Watts***

Q = reactive power $\quad Q = I^2X \quad Q = \frac{E^2}{X}$

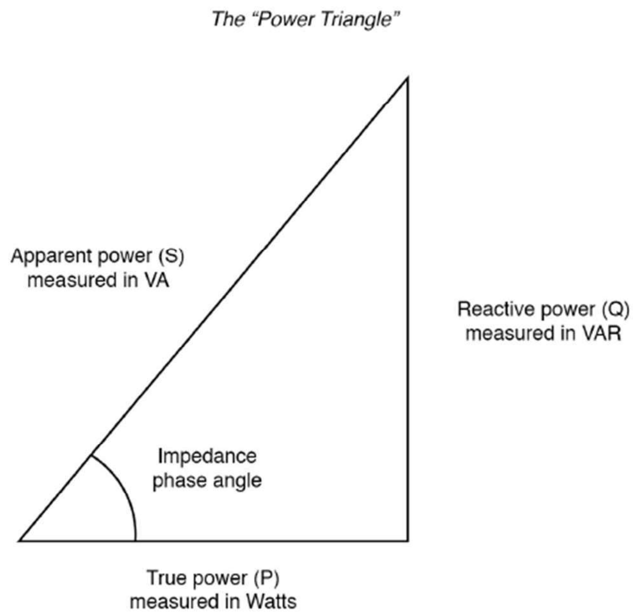
*Measured in units of **Volt-Amps-Reactive (VAR)***

S = apparent power $\quad S = I^2Z \quad Q = \frac{E^2}{Z} \quad S = IE$

*Measured in units of **Volt-Amps (VA)***

The Power Triangle

These three types of power—true, reactive, and apparent powers are relate to one another in trigonometric form. We call this the *power triangle*.



ELECTRIC POWER CONSUMPTION:

The kilowatt-hour is a unit of energy equivalent to 1 kilowatt of expended power for one hour of time. The kilowatt-hour is not a standard unit in any formal system that is commonly used in electrical appliances.

Energy expenditure of one kilowatt-hour represents 3.6×10^6 Jouls. Energy is equal to the product of power and time. To determine Energy in kilowatt hours Power must be expressed in kilowatts and time must be expressed in hours.

The consumption of electrical energy by homes and small businesses is usually measured in kilowatt hours. Larger businesses and institutions sometimes use megawatt hour. The energy of puts of large power plants over long periods of time it can be expressed in gigawatt hours.

Megawatt-hour = 1MWh = 10^6 Wh =10^3 kWh = 1000 units

Gigawatt-hour = 1GWh = 10^9 Wh= 10^6 kWh = 1000 MWh.

UNIT-2

ALTERNATING CURRENT AND DIRECT CURRENT

Depending on properties and applications, there are two types of current electricity.

- Direct Current (DC)
- Alternating Current (AC)

Direct Current

The current electricity whose direction remains the same is known as direct current. Direct current is defined by the constant flow of electrons from a region of high electron density to a region of low electron density. DC is used in many household appliance and applications that involve a battery.

Batteries: Batteries, both non-rechargeable and rechargeable can only supply direct current. The rechargeable batteries also need recharging using direct current.

Electronic equipment: All equipment like computers, radios, mobile phones, and in fact all electronic equipment uses direct current to power the electronic circuits. Bipolar transistors, FETs and the integrated circuits that use these components all need direct current to power them and will damaged if a reverse polarity is supplied. Although many of these items are powered by AC mains, there is a unit called a power supply within the unit that converts the incoming AC to direct current with the right voltage(s) within the electronic item.

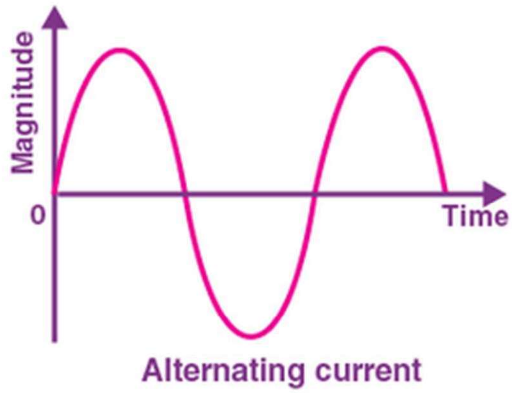
Some electrical equipment: Although a lot of electrical equipment uses AC, some uses direct current.

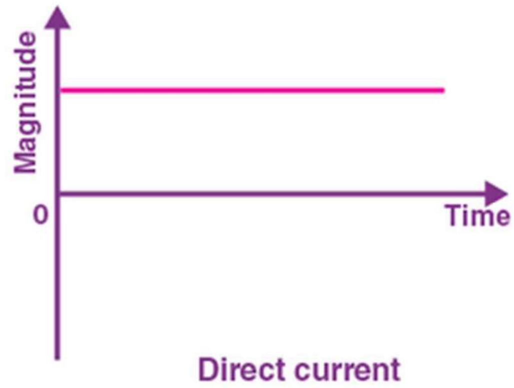
Solar panels: Solar panels used for generating electricity produce direct current directly from the solar panels themselves. When used with AC mains to feed into the mains or supply local AC power for AC supplies, a unit known as an inverter is required to enable the direct current, DC from the solar panels to be converted to AC.

Alternating Current

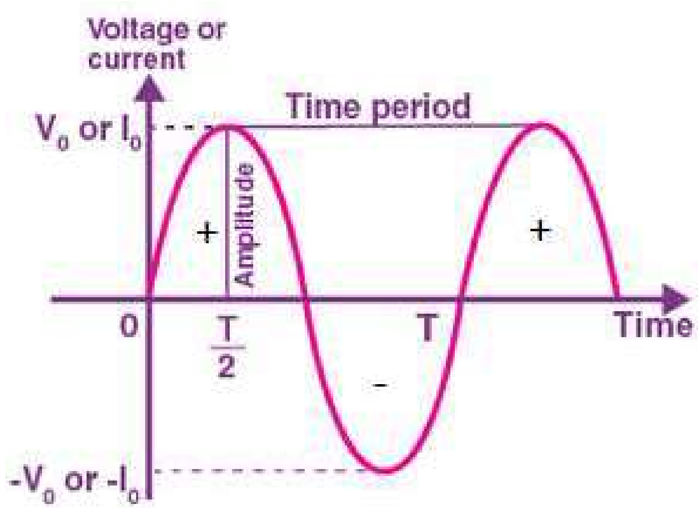
Alternating current can be defined as a current that changes its magnitude and polarity at regular interval of time. So Alternating current is an electrical current which repeatedly changes or reverses its direction (bidirectionality). The bidirectionality is caused by a sinusoidally varying current. It starts from zero, increases to a maximum, decreases to zero, reverses, reaches a maximum in the opposite direction, returns again to the original value. This cycle repeats again and again indefinitely. The time interval for one complete cycle is called the period, the number of cycles per second is the frequency of supply, and the maximum value in either direction is the amplitude of the alternating current.

Generally low frequencies, such as 50 and 60 cycles per second (hertz), are used for domestic and commercial power.





Alternating current (AC) had the distinct advantage over direct current (DC) to transmit power over large distances without great loss of energy due to resistance. DC power transmission was replaced by AC systems that transmit power at very high voltages (low current) and easily use transformers to change the voltage. However, current DC systems can easily change voltages. Current AC systems transmit power from generators at hundreds of thousands of volts and use transformers to lower the voltage to 230 volts for individual customers. The components like capacitors, inductors and resistors provide some impedance to the flow of alternating currents. In the case of capacitors and inductors, the impedance depends on the frequency of the current. With resistors, impedance is independent of frequency and is simply the resistance.



Alternating currents (AC) are also used in radio and television transmissions. In an AM (amplitude-modulation) radio broadcast, electromagnetic waves with a frequency of around one million hertz are generated by currents of the same frequency flowing back and forth in the antenna of the station.

RMS VALUE, PEAK VALUE, AVERAGE VALUE OF AC

In AC voltage/current, the positive sinusoidal half cycle of waves will be equal to the negative half cycle. So that the average value after the completion of a full cycle is equal to zero. There is a parameter to understand the effective value of the AC, i.e., RMS (Root Mean Square) value.

R.M.S Value

Definition: If a steady current (DC) flows through a resistor for a given period of time, it dissipate some power in the form of heat. If the same quantity of heat is produced by an alternating current when flows through the same resistor for the same period of time, then that current is called **R.M.S** or effective value of the alternating current. In other words, the R.M.S value is defined as the square root of means of squares of instantaneous values.

Let i be the alternating current flowing through a resistor R for time t seconds, which produces the same amount of heat as produced by the direct current (I_{eff}).

We know that $i = i_0 \sin\omega t$

From the definition of R.M.S.,

$$I_{eff}^2 R = \overline{i^2} R$$

$$I_{eff} = \sqrt{\overline{i^2}}$$

Root mean square value for complete cycle can be calculated as follows.

$$\bar{i}^2 = \frac{\int_0^T i^2 dt}{\int_0^T dt} = \int_0^T \frac{i^2\ dt}{T} = \frac{i_0^2}{T}\int_0^T i_0\ \sin^2\omega t\ dt$$

$$= \frac{i_0^2}{T}\int_0^T \left(\frac{1-\cos 2\omega t}{2}\right)dt = \frac{i_0^2}{2T}\left[t - \frac{\sin 2\omega t}{2\omega}\right]_0^T = \frac{i_0^2}{2\,T}\left[T - \frac{\sin 2\left(\frac{2\pi}{T}\right)T}{2\left(\frac{2\pi}{T}\right)}\right]$$

$$= \frac{i_0^2}{2\,T}\left[T - \frac{\sin 4T}{\left(\frac{4\pi}{T}\right)}\right] = \frac{i_0^2}{2\,T}[T-0]$$

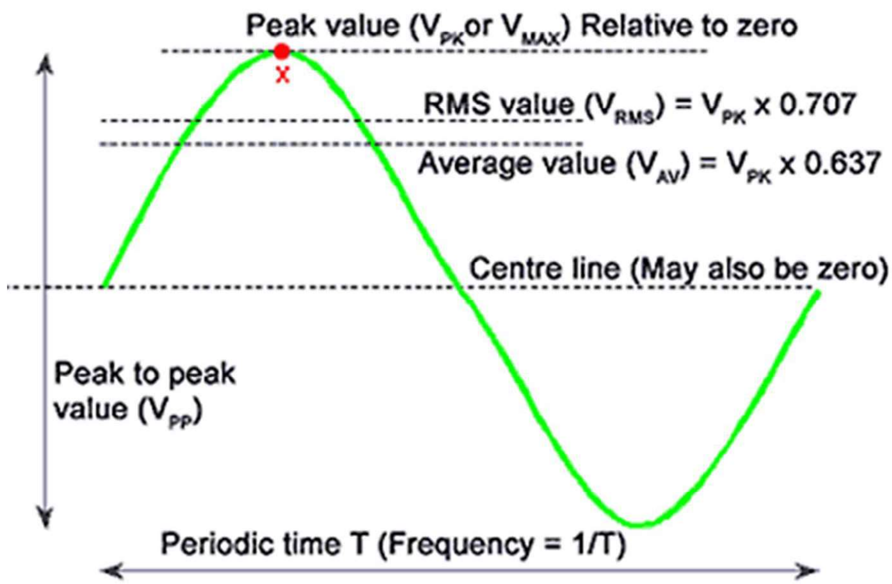
$$\bar{i}^2 = \frac{i_0^2}{2}$$

$$\therefore i_{rms} = \sqrt{\bar{i}^{\,2}} = \frac{i_0}{\sqrt{2}} = 0.707\ i_0$$

Peak Value

Definition: The maximum value attained by an alternating quantity during one cycle is called its P**eak value**. It is also known as the maximum value or amplitude or crest value. The sinusoidal alternating quantity obtains its peak value at 90 degrees as shown in the figure below.

The peak values of alternating voltage and current is represented by E_m or E_0 and I_m or I_0 respectively



Average Value

Definition: The average of all the instantaneous values of an alternating voltage and currents over one complete cycle is called **Average Value.**

If we consider symmetrical waves like sinusoidal current or voltage waveform, the positive half cycle will be exactly equal to the negative half cycle. Therefore, the average value over a complete cycle will be **zero.**

So, the only positive half cycle is considered to determine the average value of alternating quantities of sinusoidal waves.

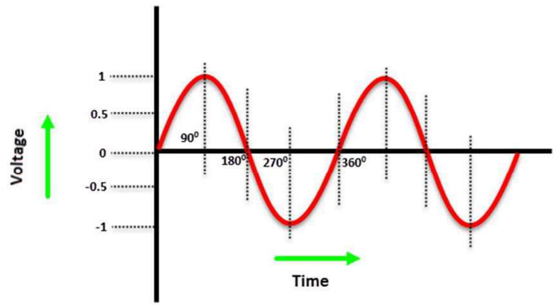
SINGLE PHASE & THREE PHASE CONNECTIONS

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 amount of power is required.

One of the major difference between the single phase and the three phase is that the single phase consists one conductor (or sometimes a Line or Live or Hot) and one neutral wire whereas the three phase supply uses three conductors and one neutral wire for completing the circuit.

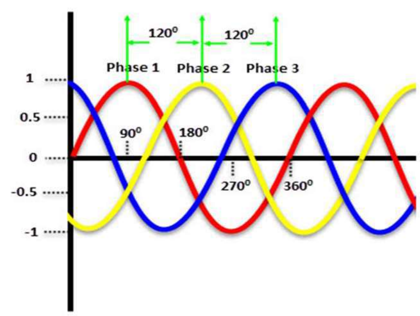
Single phase connection

The single phase requires two wires for completing the circuit, i.e., the conductor and the neutral. The conductor carries the current and the neutral is the return path of the current. The single phase supplies the voltage up to 230 volts. It is mostly used for running the small appliances like a fan, cooler, grinder, heater, etc

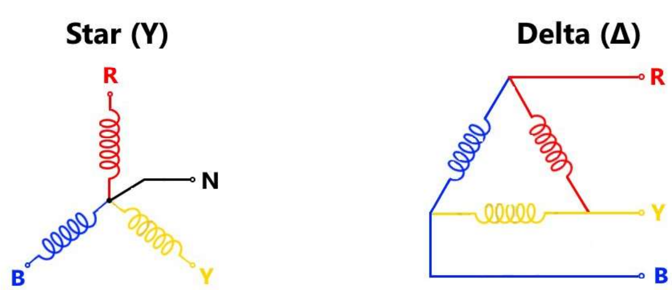


Three Phase connection

The three phase system consist four wires, three conductors and one neutral. The conductors are out of phase and space 120º apart from each other. The three phase system is also used as a single phase system. For the low load, one phase and neutral can be taken from the three phase supply.



The three phase supply is continuous and never completely drops to zero. In three phase system power can be drawn either in a star or delta configuration. The star connection is used for long distance transmission because it has neutral for the fault current. The delta connection consists three phase wires and no neutral.



Star and Delta Connections

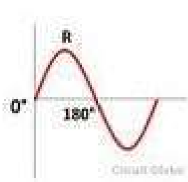
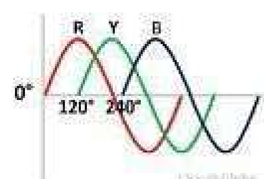
Key points in Single Phase connection

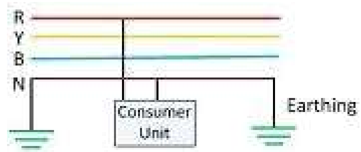
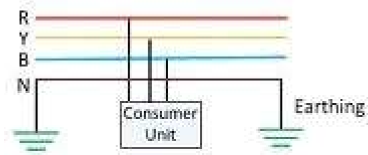
1. In single phase supply, the power flows through one conductor only.
2. This connection requires two wires (one phase and one neutral) for completing the circuit.
3. The single phase supplies the voltage up to 230V, so it is used in residential power needs.
4. In single phase supply, the power transferred is minimum compared to three phase supply.
5. The single phase has two wire which makes the network simple.
6. The single phase system has only one phase wire, and if the fault occurs on the network, then the power supply completely fails.
7. The efficiency of the single phase supply is less as compared to three phase supply. Because the single phase supply requires more conductor as compared to three phase supply for the equivalent circuit.
8. The single phase supply requires more maintenance because of easy interruption with power.
9. The single phase supply is mostly used in the house and for running the small loads.

Key points in Three Phase connection

1. Three phase supply consists of three conductors for power supply.
2. The three phase requires three phase wires and one neutral wire for completing the circuit.
3. The three phase supply carries the voltage up to 415V.
4. The maximum power is transferred through three phases as compared to single phase supply.
5. The three phase network is complicated as it consists four wires.
6. In three phase system the network has three phases, and if the fault occurs on any one of the phases, the other two will continuously supply the power.
7. The efficiency of the three phase supply is moe as compared to single phase supply. Because the three phase supply requires less conductor as compared to single phase supply for the equivalent circuit.
8. The three phase supply requires less maintenance and economical as compared to single phase supply.
9. The three phase supply is used in large industries and for running the heavy loads because of high voltage supply.

Comparison Chart for Single Vs Three phase connection

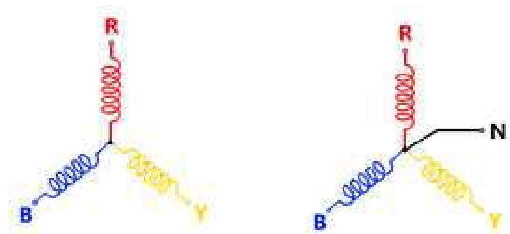
Basis For Comparison	Single Phase	Three Phase
Definition	The power supply through one conductor.	The power supply through three conductors.
Wave Shape		
Number of wire.	Require two wires for completing the circuit.	Requires four wires for completing the circuit.
Voltage	Carry 230V	Carry 415V

Phase Name	Split phase	No other name
Power Transfer Capability	Minimum	Maximum
Network	Simple	Complicated
Power Failure	Occurs	Do not occur
Loss	Maximum	Minimum
Power Supply Connection		
Efficiency	Less	High
Economical	Less	More
Uses	For home appliances.	In large industries and for running heavy loads.

STAR CONNECTION AND DELTA CONNECTION

Star connection

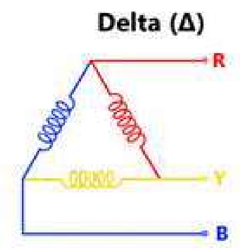
In a Star Connection, the 3 phase wires are connected to a common point or star point and Neutral is taken from this common point. Due to its shape, the star connection is sometimes also called as Y or Wye connection. If only the three phase wires are used, then it is called 3 Phase 3 Wire system. If the Neutral point is also used (which often it is), the it is called 3 Phase 4 Wire system. The following image shows a typical Star Connection



Star Connections

Delta connection

In a Delta Connection, there are only 3 wires for distribution and all the 3 wires are phases (no neutral in a Delta connection). The following image shows a typical Delta Connection.



Delta Connection

Star Connection (Y or Wye)	Delta Connection (Δ)
A Star Connection is a 4 – wire connection (4th wire is optional in some cases)	A Delta Connection is a 3 – wire connection.
Two types of Star Connection systems are possible: 4 – wire 3 – phase system and 3 – wire 3 phase system.	In Delta Connection, only 3 – wire 3 phase system is possible.
Out of the 4 wires, 3 wires are the phases and 1 wire is the neutral (which is the common point of the 3 wires).	All the 3 wires are phases in a Delta Connection.
In a Star Connection, one end of all the three wires are connected to a common point in the shape of Y, such that all the three open ends of the three wires form the three phases and the common point forms the neutral.	In a Delta Connection, every wire is connected to two adjacent wires in the form of a triangle (Δ) and all the three common points of the connection form the three phases.
The Common point of the Star Connection is called Neutral or Star Point.	There is no neutral in Delta Connection
Line Voltage (voltage between any two phases) and Phase Voltage (voltage between any of the phase and neutral) is different.	Line Voltage and Phase Voltage are same.
Line Voltage is root three times phase voltage i.e. $V_L = \sqrt{3}\, V_P$. Here, V_L is Line Voltage and V_P is Phase Voltage.	Line Voltage is equal to Phase Voltage i.e. $V_L = V_P$.
With a Star Connection, you can use two different voltages as V_L and V_P are different. For example, in a 230V/400V system, the voltage between any of the phase wire and neutral wire is 230V and the voltage between any two phases is 400V.	In a Delta Connection, we get only a single voltage magnitude.
Line Current and Phase Current are same.	Line current is root three times the phase current.

In Star Connection, $I_L = I_P$. Here, I_L is line current and I_P is phase current.	In Delta connection, $I_L = \sqrt{3}\ I_P$
Total three phase Power in a Star Connection can be calculated using the following formulae. $P = 3 \times V_P \times I_P \times \cos(\Phi)$ or $P = \sqrt{3} \times V_L \times I_L \times \cos(\Phi)$	Total three phase Power in a Delta Connection can be calculated using the following formulae. $P = 3 \times V_P \times I_P \times \cos(\Phi)$ or $P = \sqrt{3} \times V_L \times I_L \times \cos(\Phi)$
Since Line Voltage and Phase Voltage are different ($V_L = \sqrt{3}\ V_P$), the insulation required for each phase is less in a Star Connection.	In a Delta Connection, the Line and Phase Voltages are same and hence, more insulation is required for individual phases.
Usually, Star Connection is used in both transmission and distribution networks (with either single phase supply or three – phase.	Delta Connection is generally used in distribution networks.
Since insulation required is less, Star Connection can be used for long distances.	Delta Connections are used for shorter distances.
Star Connections are often used in application which require less starting current	Delta Connections are often used in applications which require high starting torque.

Difference Between Star and Delta Connection

1. The terminals of the three branches are connected to a common point. The network formed is known as **Star Connection**. The three branches of the network are connected in such a way that it forms a closed loop known as **Delta Connection**.
2. In a star connection, the starting and the finishing point ends of the three coils are connected together to a common point known as the neutral point**.** But in Delta connection, there is no neutral point. The end of each coil is connected to the starting point of the other coil that means the opposite terminals of the coils are connected together.
3. In Star connection, the line current is equal to the Phase current, whereas in Delta Connection the line current is equal to root three times of the Phase Current.
4. In Star connection, line voltage is equal to root three times of the Phase Voltage, whereas in Delta Connection line voltage is equal to the Phase voltage.
5. The Speed of the star connected motors is slow as they receive $1/\sqrt{3}$ of the voltage but the Speed of the delta connected motors is high because each phase gets the total of the line voltage.
6. In Star Connection, Phase voltage is low as $1/\sqrt{3}$ times of the line voltage, whereas in Delta Connection Phase voltage is equal to the line voltage.
7. Star Connections are mainly required for the Power Transmission Network for longer distances, whereas in Delta connection mainly in Distribution networks and is used for shorter distances.
8. In Star Connection, each winding receives 230 volts and in Delta Connection, each winding receives 415 volts.
9. Both 3 phase 4 wire and 3 phase 3 wire system can be derived in the star connection, whereas in Delta Connection only 3 phase 4 wire system can be derived.

10. The amount of Insulation required in Star Connection is low and in Delta Connection high insulation level is required.

In a three-phase circuit, star and delta connection can be arranged in four different ways:

1. Star-Star connection
2. Star-Delta connection
3. Delta-Star connection
4. Delta-Delta connection

ELECTRIC SHOCK

Electric shock refers to the electricity passing through the human body, affecting the normal function of the heart, lungs and nervous system. Ventricular fibrillation caused by electricity is the main reason for death from electric shocks. Ventricular fibrillation involves a series of disordered contractions of the heart's ventricular muscle fibers, which prevents regular heartbeat. Under normal conditions, the human heart rate is from around 60 to 100 times per minute. During an electric shock, heartbeat may increase up to several hundred times per minute. When the heart cannot sustain such rapid contraction and relaxation, it may stop beating and cause death.

The effects of currents when passing through various parts of the body:
1. *Respiratory Failure*: Electric shock may affect normal brain function and stop respiration.
2. *Suffocation:* Most accidents due to electric shocks are caused by Current passing through the chest. When such accidents occur, chest muscles cramp, leading to suffocation and death.
3. *Heartbeat Failure:* If current passes through the heart, it will disrupt the rhythmic pumping action and eventually stop the heartbeat.
4. *Unable to get free after an electric shock*: An electric shock causes continuous contraction of the forearm muscles, thus, stopping the victim getting free electric from the electric source.
5. *Burns:* During an electric shock, the current passing through the body may lead to burns on the skin, muscles or internal organs. As electric shocks and burns are closely related, preventative measures should be considered together.

Fires and explosions: High temperatures caused by currents under abnormal conditions, may result in accidental fires and explosions. Leading to high temperatures include:
The common causes
(a) Overloading of electricity.
(b) Insulator breakdowns or short, circuits
(c) Improper contact of, electrical circuit.
(d) Improper maintenance of electrical appliances or wiring
(e) Poor ventilation, etc.
Protective measures
(a) Insulation: Shield the electrical conductor with an insulator to prevent direct contact.
(b) Obstacles: Place obstacles to prevent any accidental contact with the electrical conductor.
(c) Barriers or enclosures: Create barriers or enclosures that prevent any direct contact with the electrical conductor.
(d) Placing out of reach: This prevents accidental contact with the electrical conductor.

First-aid for electric shock

If anyone suffers an electric shock, the electricity source should be cut off immediately. Only conduct the first-aid when the victim is in a safe place. Check the victim's breath and pulse. If the person is unconscious but is breathing normally, he or she should be placed in a recovery position. If the victim is not breathing and has no pulse, cardiopulmonary resuscitation should be conducted.

Treatment

1. *Open the airway:* lift the jaw and tilt to the head back open the airway. Clear any obstacles.
2. *Check the breath:* See if the chest rises and falls. Listen for breathing. Feel breathing on your cheek.
3. *Check the pulse:* use your fingers to feel pulse.
4. If the person is unconscious but is breathing normally, place them in the recovery position.
5. *Mouth-to mouth resuscitation:* If the person is not breathing, mouth-to mouth resuscitation should be used to help the resumption of breathing.
6. *External chest compression:* If the casualty has no pulse, Cardiopulmonary resuscitation should be carried out.

ELECTRIC SHORT CIRCUIT:

A short circuit is a specific condition where electricity strays outside the established pathway of an electrical circuit. A short circuit happens when electrical flow completes its circuit journey via a shorter distance than specified path in the established wiring.

The term short circuit is most commonly used by electricians to refer to the situation in which a hot wire carrying live current touches a neutral wire. When this happens, resistance drops instantly and a large volume of current flows through an unexpected pathway. When this classic short circuit occurs, spark sometimes fly, you may hear crackling and sometime smoke and flames happen.

A ground fault is a type of short circuit that occurs when the hot wire carrying current comes into contact with some grounded portion of the system. For example, contact of hot wire with a bare ground wire, metal wall box, or a grounded portion of an appliance. Generally, a ground-fault causes resistance to lessen, which allows a large amount of current to flow through the unexpected pathway. Here, there is less chance of flame and fire, but a notable chance of shock.

There are several causes for short circuits, including three that are most often to blame.

(1) Faulty Circuit Wire Insulation
(2) Loose Wire Connections
(3) Faulty Appliance Wiring.

Protection against Short Circuits:

(1) By using Circuit Breakers or Fuses
(2) By using Ground-Fault Circuit Interrupters (GFCIs)
(3) By using Arc-Fault Circuit Interrupters (AFCIs).

ELECTRIC OVERLOAD

Electrical circuits are designed to handle a limited amount of electricity. Circuits are made up of wiring, a breaker or a fuse. The electricity usage of each device adds to the total load on the circuit. Exceeding the rated load for the circuit wiring causes the circuit breaker to trip, shutting off the power to the entire circuit. If there were no breaker in the circuit, an overload would cause the circuit wiring to overheat, which could melt the wire insulation and lead to a fire. Different circuits have different load ratings so that some circuits can provide more electricity than others.

Home electrical systems are designed around typical household usage, but there's nothing to prevent us from plugging in too many devices on the same circuit. However, by understanding the layout of the home's circuits, we can easily prevent overloads.

Signs of Overloaded Circuits

The most obvious sign of an electrical circuit overload is a breaker tripping and shutting off all the power. Sometimes the following may also be observed.

(a) Dimming lights
(b) Buzzing outlets or switches.
(c) Outlet or switch covers that are warm to the touch.
(d) Burning odors from outlets or switches.
(e) Scorched plugs or outlets.
(f) Power tools, appliances, or electronics that seem to lack sufficient power.

These also can indicate other wiring problems, such as loose connections or short circuits. If any of these problems continue even after you've taken steps to prevent circuit overloads, contact an electrician.

BASICS OF HOUSE WIRING

Residential electrical wiring systems start with the utility's power lines and equipment that provide power to the home, known collectively as the service entrance. The power is run through an electric meter, which records how much energy is used in the home and is the basis for the monthly electric bill. The following are the basic parts of house wiring.

(i) Service Entrance:

The service entrance is the equipment that brings electrical power to the home. Most residential service includes three wires: two cables carrying 120 volts each (for a total of 240 volts) and one grounded neutral wire. If the cables hanging to an overhead, they are collectively called a service drop. If they are routed underground, they are known as a service lateral. A service drop connects to the home at a service head, or weather head, on the roof or exterior wall of the house.

(ii) Electric Meter: Once the power reaches the house via the service drop or service lateral cables, it passes through the electric meter, which may be mounted on an exterior wall or may be located inside the home's breaker box. The meter records all electricity used by the home, measured in kilowatt-hours, or kWh.

(iii) Main Service Panel: The main service panel, commonly known as the breaker box or circuit breaker panel, distributes power to all circuits throughout the building. Each circuit has a breaker that can shut itself off in the event of a short circuit or overload to cut power to the circuit. Old homes may have fuses instead of breakers. Fuses are just as effective as breakers, but most of the new MSPs today use breakers instead of fuses.

(iv) Electrical Boxes: An electrical box is a plastic or metal box used to connect wires and install devices such as switches, holders and fixtures. An electrical box is almost always required for mounting devices and for housing wiring connections. Boxes come in many different sizes and several different shapes.

(v) Hot and Neutral Wires: Each electrical circuit contains at least one "hot" wire that carries the electrical current from the service panel to the circuit devices and a neutral wire that carries current back to the service panel. Hot wires typically are black or red but can be other colors. Neutral wires typically are white. In some circuits, the neutral wire is used as a hot wire when the circuit has no dedicated neutral.

(vi) Ground: An electrical ground is a safety system that provides a safe path for electricity to follow into the earth when a short circuit, electrical surge or other fire hazard happen. In modern home wiring systems, each circuit has its own ground wire that leads back to the service panel. After the panel, the ground system terminates at a ground rod driven into soil or to another ground conductor where electricity is safely dissipated into the earth.

EARTHING

The process of transferring the immediate discharge of the electrical energy directly to the earth by the help of the low resistance wire is known as the **electrical earthing**. The electrical earthing is done by connecting the non-current carrying part of the equipment or neutral of supply system to the ground. This is one of the significant features of electrical networks. Mostly, the galvanised iron is used for the earthing. The main intention of electrical earthing is to keep away from the danger of electric shock due to the outflow of current.

Earthing process

The earthing provides the simple path to the leakage current. The short-circuit current of the equipment passes to the zero potential earth. So, it protects the system and equipment from damage. The electrical equipment mainly consists of two non-current carrying parts. These parts are neutral of the system and frame of the electrical equipment. The following are the components necessary for earthing a system.

Charcoal, Underground Power Cable based on distance from the electric pole to the meter panel, Industrial Salt, Copper Wire, MS Earthing Pipe, Copper Plate.

Procedure for any earthing

1. First of all, dig a pit about 3-4 m in the ground.
2. Bury an appropriate conducting materal which acting as electrode (plate/rod/wire etc) in that pit in vertical position.
3. To maintain the moisture condition around the earth plate, put a 1ft layer of powdered charcoal, salt and lime mixture around the earth plate.
4. Tight earth lead through nut bolts from two different places on earth plate.
5. Earth continuity conductor should be tightly connected to earth lead, body and metallic parts of all installation. Make sure to use the continuity by using continuity test.

Basically there are two types of earthing depending on the parts of the system.

Neutral Earthing

In this type, the system's neutral is connected directly toward the earth using GI wire. The alternate name of this system is system earthing and this kind of earthing is generally given to the system which contains star winding. Eg. Earthing is offered in transformer, the generator, motor, etc.

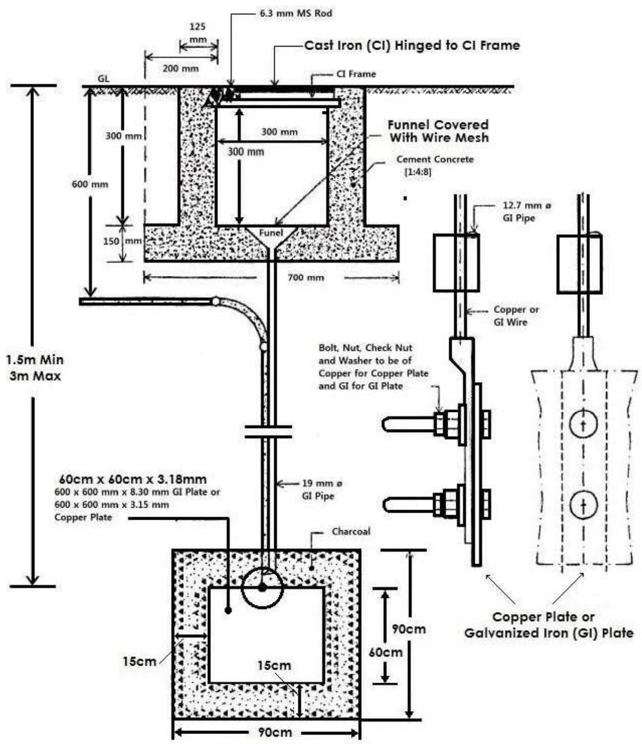
Equipment Earthing

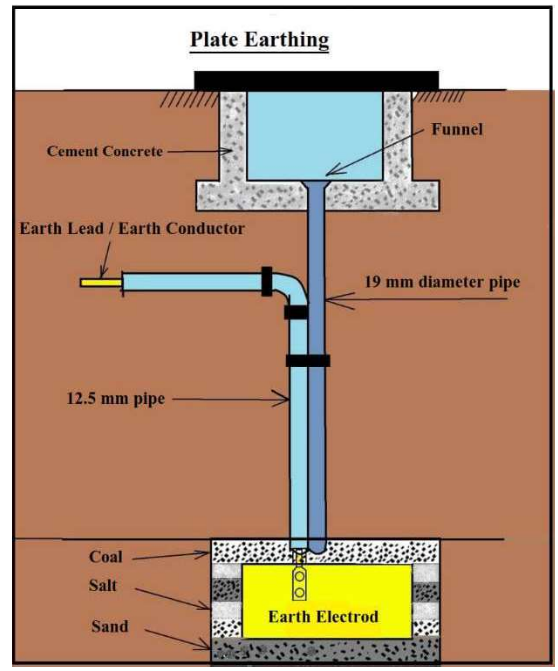
This kind of earth is given to electrical devices. The device that doesn't carry current like a metallic frame is connected to the earth using the conducting wire. If any error occurs within the device then the short-circuit current will be supplied to the earth by using wire to guard the system against injure.

Conventionally there are different types of electrical earthing systems depending on the type of conductor used

(i) Plate Earthing System

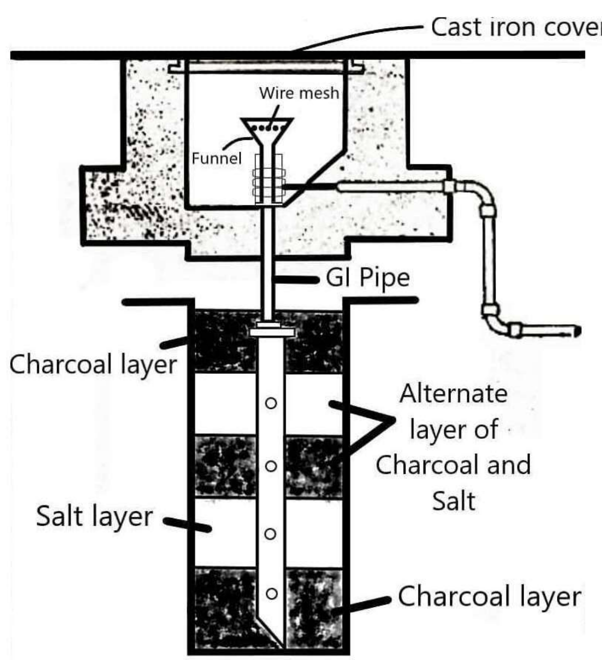
In this type of system, a plate is made up of copper or GI (galvanized iron) which are placed vertically in the ground pit less than 3 meters from the earth. For a better electrical grounding system, the earth moisture condition around the plate must be good.





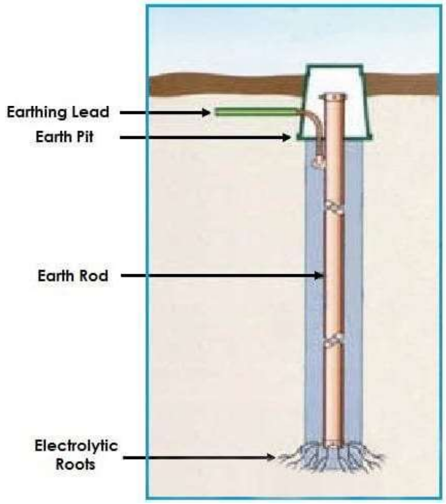
(ii) Pipe Earthing System

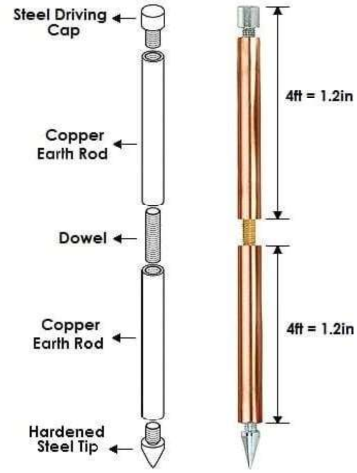
A galvanized steel-based pipe is placed vertically in a wet soil is known as pipe earthing, and it is the most common type of earthing system. The pipe size mainly depends on the soil type and magnitude of the current. The soil moisture will decide the pipe's length placed in the earth. Usually, for the ordinary soil, the pipe dimension should be 1.5 inches in diameter and 9 feet in length. For rocky or dry soil, the diameter should be greater than the ordinary soil pipe.



(iii) Rod Earthing System

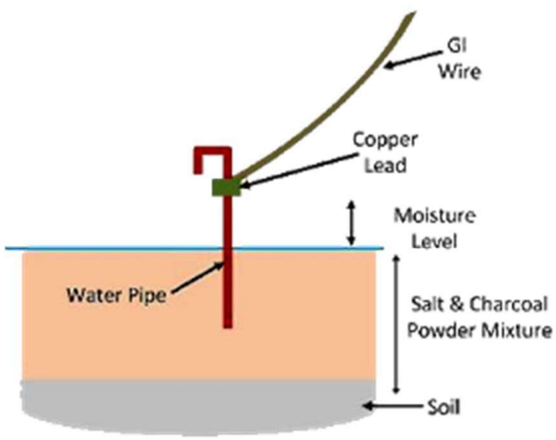
This type of earthing system is similar to a pipe earthing system. A copper rod with galvanized steel pipe is placed upright in the ground using a hammer. The embedded electrode lengths in the earth decrease the resistance of the earth to a preferred value.





(iv) Earthing through the Waterman

In this method of earthing, the waterman (Galvanized GI) pipes are used for earthing purpose. Make sure to check the resistance of GI pipes and use earthing clamps to minimize the resistance for proper earthing connection. If stranded conductor is used as earth wire, then clean the end of the leads of the wire and connect tightly to the waterman pipe.



Earthing Through Water Mains

(v) Strip or Wire Earthing:

In this method of earthing, strip electrodes are buried in a horizontal trenches of a minimum depth of 0.5m. If copper with a cross-section of 25mm x 4mm is used and a dimension of 3.0 mm^2 if it's a galvanized iron or steel. Here the cross sectional area should not much less than $6.0mm^{2.}$ The length of the conductor buried in the ground would give a sufficient earth resistance and this length should not be less than 15m.

Electricity Rules for Earthing

i. In house wiring system, the earthing should be continuous through a single solid conductor. The main switch, electrical equipment, distribution box, ceiling fans with the walls socket's earth must be earthed.
ii. The resistance of the earthing conductor should not be above 1 ohm during the system.
iii. All the machine metallic covers including average voltage must be earthed through two separate earth connections.
iv. The electrodes earth resistance should not go beyond 3 ohms for normal earth. The resistance of the earth for the electrode should not go beyond eight ohms for rocky soil.

Importance of Earthing

The earthing is essential because of the following reasons

i. It provides safety for electrical devices and appliances from the extreme electric current.
ii. The earthing protects the personnel from the shortcircuit current.
iii. It helps in avoiding the risk of fire in electrical installation systems.
iv. The earthing provides the easiest path to the flow of shortcircuit current even after the failure of the insulation.
v. The earthing protects the apparatus and personnel from the high voltage surges and lightning discharge.
vi. The Earthing assists in detecting any fault in phase & neutral conductors.

FUSES

Fuse is an electrical device that self-destructs and stops the current flow in a circuit whenever the current exceeds the predefined value. A fuse works based on the thermal property of materials conducting electric current. It consists of a metal wire or conductor material which can conduct a predefined amount of current through it. The metallic wire normally made up of tin, lead, silver, copper, aluminum etc. Whenever excessive current flows through the fuse, the conducting material inside it melts down and therefore the current flow through it is interrupted and further opens the circuit. Once a fuse has operated, it is an open circuit, and it must be replaced or rewired, depending on the type. The operating time of the fuse during short circuits is around 2ms. There are a wide variety of fuses available in the market at various voltage and current ratings and can be used for the protection of almost all equipment, starting from small electronic circuits to heavy-duty electric motors.

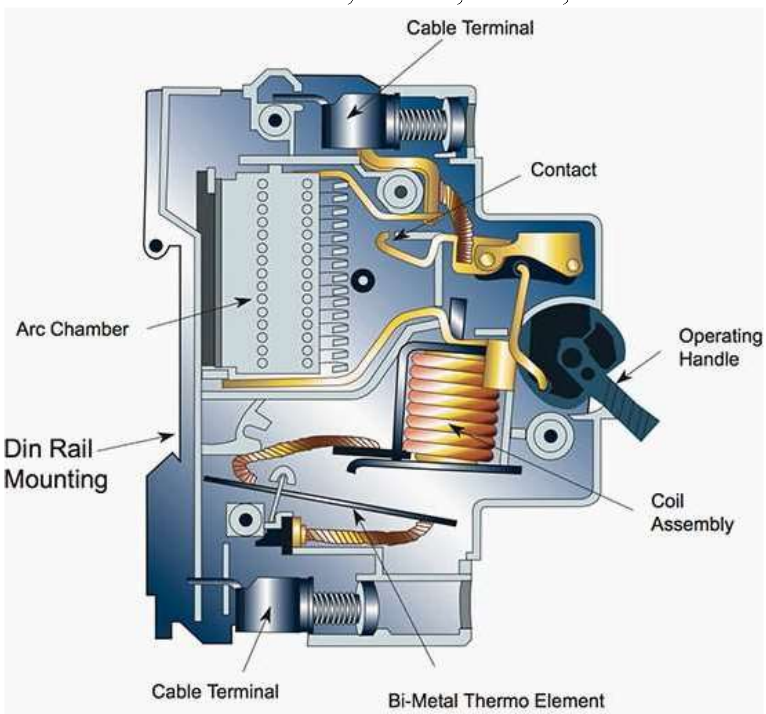
CIRCUIT BREAKER

A circuit breaker is a switching device which also offer protection against short circuit. Unlike fuse the circuit breaker do not blows off, but trips whenever there is a fault. A circuit breaker can offer a no. of protections against Overload, Short Circuit, Under Voltage and Neutral Earth Fault. Depending on operating method, there are different types of Circuit Breakers.

MCBs

MCB stands for Miniature Circuit Breaker. MCB is resettable circuit protection device against the occurrence of faults, stops the current flow in a circuit. It is an electromechanical device that works based on the electromagnetic as well as the thermal properties of the electric current. An electromagnetic mechanism of the MCB helps it to interrupt the current flow during short circuits

and the bimetallic strip present in it helps it to interrupt the current flow during overloads. The operating time of the MCB during short circuits is around 20ms greater than fuse.
Miniature circuit breakers contain an electromagnetic core with plunger arrangement for short circuit protection and a bimetallic strip for overload protection. MCBs can be reset and reused after they trip. MCBs can also be operated like a switch to interrupt power supply to the load. MCBs are quite easy and much safer to handle; it also quickly restores the supply of currents. MCBs are low voltage circuit protection devices. These are used for protection of lighting circuits, residential applications and industrial applications with short circuit current rating not exceeding 15kA. There are different enhanced types of MCBs available like MCCB, RCCB, ELCB, etc.



Unlike a Fuse, MCB does not have to be replaced every time after a fault occurs and it can be reused. Also, there is an improved operational safety without incurring any large operating cost. MCB is more sensitive to current than Fuse. The tripping of MCB can easily be identified under overload or short circuit condition as its operating knob moves from ON to OFF position. To reset it, you just need to push the knob of MCB back to the On position.

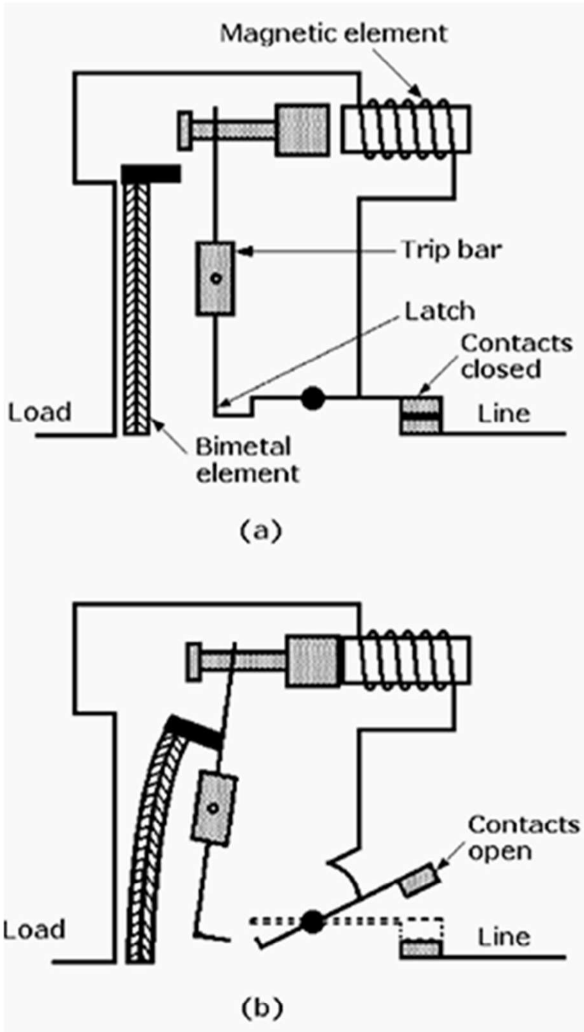
Working of MCB

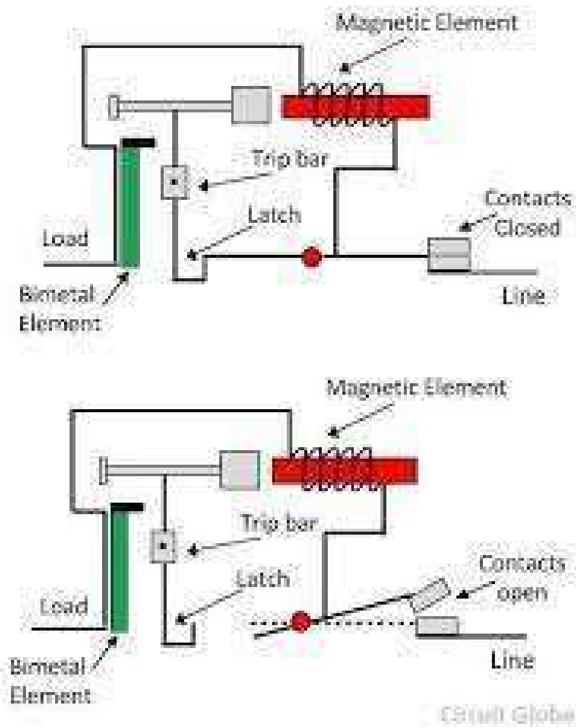
The operation of the MCB includes two stages, i.e., thermal operation and short circuit operation. The thermal operation is based on the thermal effect of over current while the later operation is based on the electromagnetic effect of the over current.

(i) When overload current flows through the MCB, the bimetallic strip gets heated and causes to deflect or bend. Now it moves the trip lever and releases the latch mechanism. Hence the contacts open under spring mechanism that interrupts power supply.

(ii) During the short circuit conditions, the large fault current energizes the solenoid and the magnetic field of the solenoid attracts the plunger then it strikes the trip lever. Hence the immediate release of the latch mechanism causes the interruption of the power supply.

All MCBs operate on the air-break principle. The arc is produced during the separation of the contacts at overload as well as short circuit conditions. This arc is moved into the arc-cute stack under the influence of a magnetic field. So the arc broken down into partial arcs in arc chutes and they no longer exist due to the voltage drop of the arcs. So the quenching of the arc takes place further cooled down.





Types of MCBs

There are three standard MCBs are available. They are Type B, C and D. Each type has its own function.

(i)Type B MCBs are mainly used in domestic applications and light commercial applications. These are designed to trip at fault currents in the range of 3 to 5 times the rated current. Suppose if the rated current is 10 A, then the MCB trips at 30-50 A.

(ii) Type C MCBs are designed for high inductive circuits where surge currents are expected. These are generally used for commercial and industrial applications. These are less sensitive than type B MCBs and causes reduced nuisance trips. Type C MCBs are designed to operate or trip at the fault currents of 5-10 times that of rated current. For 10 A type C MCB, the operating current range is 50-100 A.

(iii) Type D MCBs are designed for heavy industrial applications where normal surge currents are very high. These are ideal for electric welders and site transformers. The most common applications of type D MCBs include motors, UPS systems, X-ray machines, transformers and battery charging systems. These are designed to trip at 10-20 times the rated current. For 10 A type D MCB, the operating current range is 100-200 A.

ELCB

This stands for Earth Leakage Circuit Breaker. An ECLB is one kind of safety device used for installing an electrical device with high earth impedance to avoid shock. These devices identify small stray voltages of the electrical device on the metal enclosures and interrupt the circuit if a dangerous voltage is identified. The main purpose of the Earth leakage circuit breaker (ECLB) is to stop damage to humans & animals due to electric shock.

Working Principle

An electrical circuit breaker is a particular kind of latching relay. It has the mains supply of buildings that are connected throughout its switching contacts. The ELCB notices fault currents of human or animal to the earth wire in the connection. If any ample voltage seems across the ELCB's sense coil, it will turn off the power, and remain off until manually rearrange.

Types of Earth Leakage Circuit Breaker (ELCB)

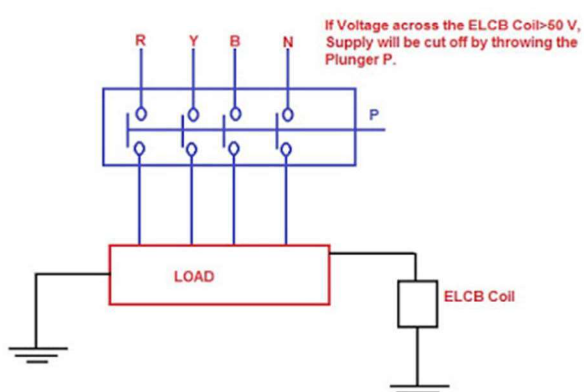
There are two types of Earth Leakage Circuit Breaker (ELCB)

Voltage Operated ELCB

Current Operated ELCB

Voltage Operated ELCB

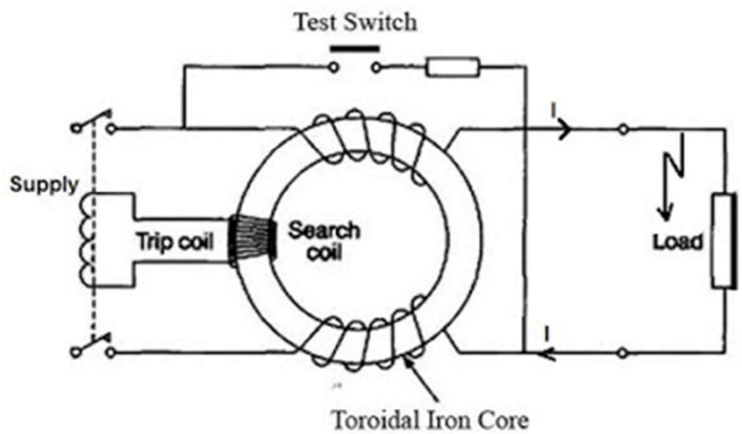
A voltage-operated ELCB device is used to detect a voltage to choose the Earth leakage. A single-phase voltage ELCB includes 6-terminals namely line in, line out, neutral in, neutral out, Earth, and fault. The metal body of the load is associated with the fault terminal of the Earth Leakage Circuit Breaker (ELCB) & the Earth terminal is associated with the ground. For usual working, the voltage across the trip coil is '0', as the Load's body is isolated from the supply line.



When an Earth fault happens on the load due to the interaction of line wire to the metal body, a current will run through the fault to the ground. The flow of current will set up a voltage across the trip coil, which is associated between Earth & Fault. The energized trip coil will trip the circuit to guard the load device & the user.

Current Operated ELCB

RCCB (Residual Current Circuit breaker) is the generally used as Current Operated ELCB and it comprises of a three winding transformer, that has two primary windings and also one secondary winding. Neutral & line wires work as the two main windings. A wire-wound coil is the minor winding. The flow of current through the minor winding is "0" in the stable condition. In this condition, the flux due to the current over the phase wire will be deactivated by the current through the neutral wire, meanwhile the current, that flows from the phase will be refunded to the neutral.



When an error occurs, a slight current will run into the ground also. This creates confusion between line and neutral current and that makes an unstable magnetic field. This encourages a current flow through the minor winding, which is associated with the sensing circuit. This will detect the outflow and direct the signal to the tripping system.

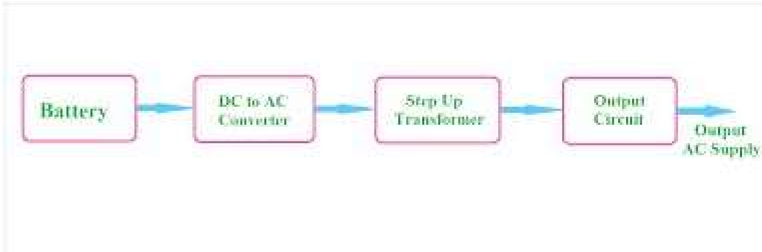
Earth Leakage Circuit Breaker for Home

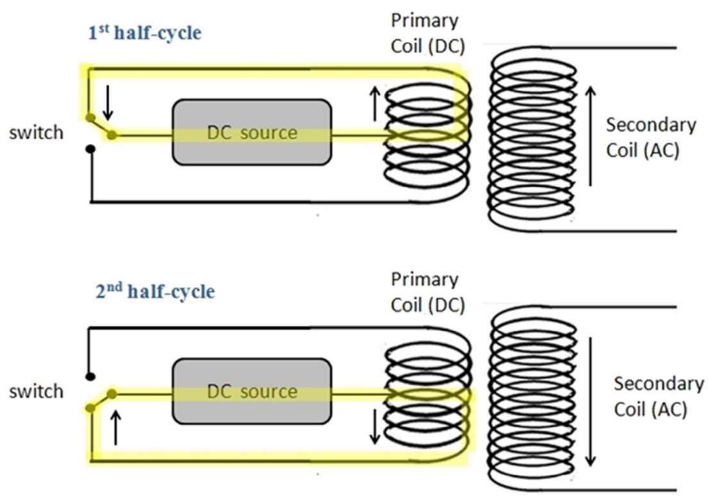
Earth leakage circuit breaker is used for homes for safe power supply. At present automation is used in independent houses, apartments & villas for controlling home appliances. But, the pressure on security is more because every year the death percentage is increasing in cities due to electrocution. To overcome this issue, installing an ELCB (Earth Leakage Circuit Breaker) is very important.

INVERTER

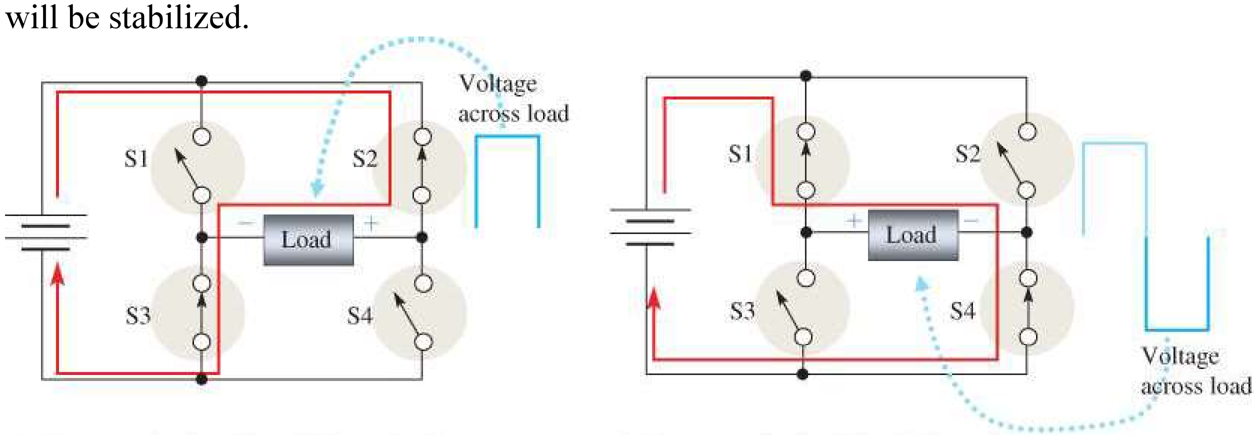
Although DC power is used in small electrical gadgets, most household equipment runs on AC power. Hence we need an efficient way to convert DC power into AC power. An inverter is a power electronics device which used to convert DC voltage into AC voltage. The inverter is a static device. It can convert one form of electrical power into other forms of electrical power. It can be used as a standalone device such as solar power or back power for home appliances. The inverter takes DC power from the batteries and converts into AC power at the time of the power failure.

Working of Inverter





Inverter convert DC into AC. The process of conversion of the DC current into AC current is based on the phenomenon of electromagnetic induction. A suitable transformer is used in this operation. The variation of DC current can produce magnetic field around the conductor. If the direction of the current is reversed frequently (via a switch device), the alternating magnetic field will induce AC current in the secondary coil. This is the working of Inverter. Generally, inverter produces square wave as AC signal. By proper switching mechanism (to change the direction of current), we can adjust the frequency of the output. Using filters, the output of the current to load will be stabilized.



(a) Current path when S2 and S3 are closed (b) Current path when S1 and S4 are closed

Types of Inverters

The three most common types of inverters made for powering AC loads include:
(1) Square wave inverter (for some resistive loads),
(2) Modified square wave inverter (for resistive, capacitive, and inductive loads), and
(3) Pure sine wave inverter (for general applications).

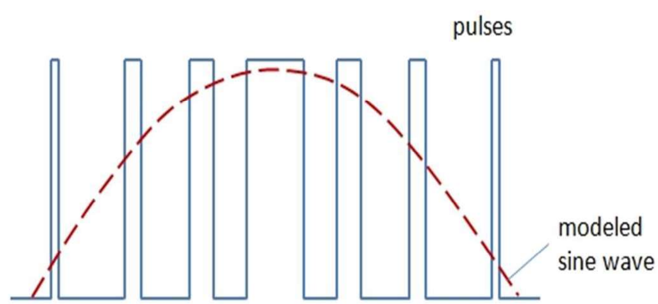
(1) Square wave inverter

This is the least used but simplest type of inverter. The output waveform of this inverter is a square wave. It converts the straight DC signal to a phase-shifting AC signal. But the output is not a pure AC signal. This is the cheapest type of inverter. This type of output is not very efficient and can be even detrimental to some loads. So, the square wave can be modified further using more sophisticated inverters to produce a modified square wave or sine wave.

(2) Modified square wave inverter

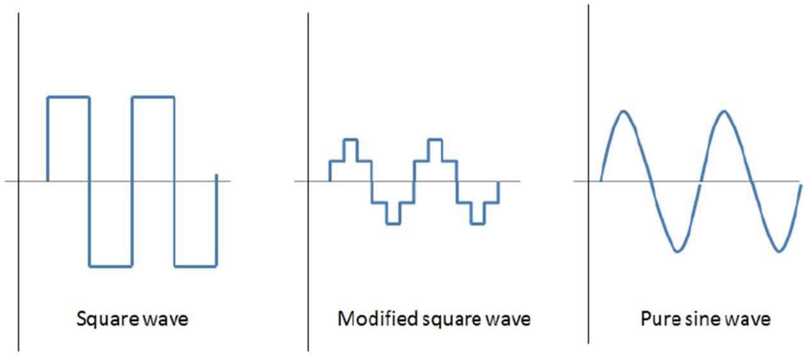
This inverter is also known as quasi wave inverter. This inverter generates the signal near to the sine wave. But it cannot generate the smooth sine wave. To produce a modified square wave output, low frequency waveform control can be used in the inverter. This feature allows adjusting the duration of the alternating square pulses. Also, transformers are used here to vary the output voltage. Combination of pulses of different length and voltage results in multi-stepped modified square wave, which closely matches the sine wave shape. The low frequency inverters typically operate at ~60 Hz frequency. A modified sine wave inverter creates some pauses before phase shifting. It doesn’t shift phase directly from positive to negative like a square wave.

(3) Pure sine wave inverter



The home appliances and most of all equipment that works on AC, designed for the sine wave. This inverter generates the pure sine wave which is a similar waveform of the grid power. This is the most efficient and complex type of inverter. A sine wave can be generated from the square wave inverter by modifying the output waveform. To produce a sine wave output, high-frequency inverters are used. These inverters use the pulse-width modification method: switching currents at high frequency, and for variable periods of time. For example, very narrow (short) pulses simulate a low voltage situation, and wide (long pulses) simulate high voltage. As per this method narrow spacing pulses analogues to low voltage and large spacing pulses resembling high voltage. Due to this pulse width modulation, the output wave is appeared as almost pure sine wave.

This inverter made the least losses. But the cost of this inverter is very high. This type of inverters is widely used in residential and commercial applications.



There are two types of AC power; single-phase and three-phase. Therefore, there are two types of inverters:

(i) Single-phase Inverter

If the load is a single-phase, the inverter used to run the load that is the single-phase inverter. There are two types;

- Half-bridge inverter
- Full-bridge inverter

(ii) Three-phase Inverter

Generally, three-phase AC supply used in industries and the load is three-phase. In this case, a three-phase inverter used to run this load.

In a three-phase inverter, six diodes and six thyristors used. According to the conduction time of thyristor, this inverter divides into two types;

- 120-degree mode of operation
- 180-degree mode of operation

UNINTERRUPTIBLE POWER SUPPLY (UPS)

An **Uninterruptible Power Supply** (UPS) is an electrical equipment which can be used as an immediate power source to the connected load when there is any failure in the main input power source. In a **UPS**, the energy is generally stored in flywheels, batteries, or super capacitors. When compared to other immediate power supply system, UPS have the advantage of immediate protection against the input power interruptions. It has very short on-battery run time; however this time is enough to safely shut down the connected apparatus (computers, telecommunication equipment etc) or to switch on a standby power source.

UPS can be used as a protective device for some hardware which can cause serious damage or loss of data with a sudden power disruption. The available size of UPS units ranges from 200 VA to several large units up to 46 MVA also.

Role of UPS

This is the prime role of UPS is to supply the power for a short time, when there is any failure in main power source. In addition to that, it can also able to correct some general power problems like power fluctuations, voltage spike, Noise, Quick reduction in input voltage, Harmonic distortion and the instability of frequency in mains etc.

Types of UPS

Generally, the UPS system is categorized into Off- line UPS, On-line UPS, and Line interactive UPS.

(i) Off-line UPS

This UPS is also called as Standby UPS system. When the power breakage of primary source occurs, the transfer switch will select the backup source (UPS). So this UPS works only when there is any failure in mains. In this system, the AC voltage is first rectified and stored in the battery connected to the rectifier. When power breakage occurs, this DC voltage is converted to AC voltage by means of a power inverter, and is transferred to the load connected to it. This is the least expensive UPS system and it provides surge protection in addition to back up. The transfer time about 25 milliseconds to detect the utility voltage that is lost.

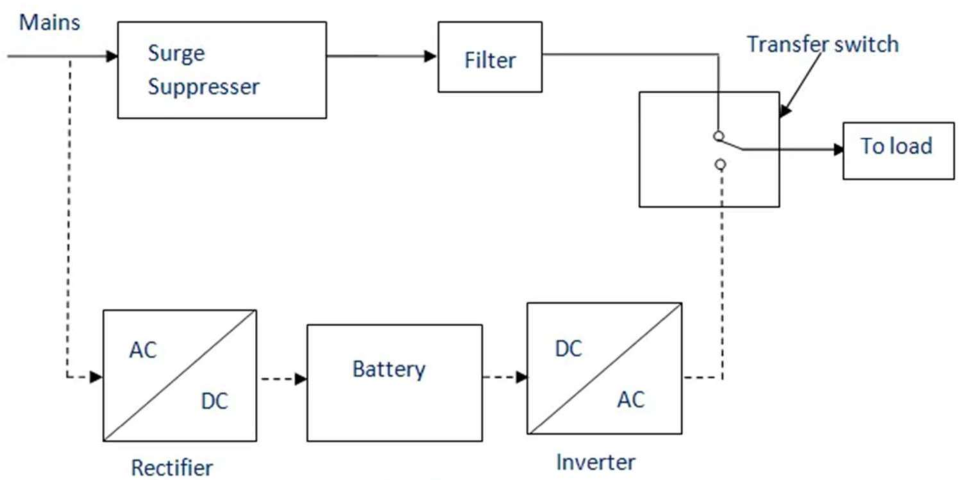


Figure 1

(ii) On-line UPS

In this **type of UPS**, double conversion method is used. Here, first the AC input is converted into DC and stored in the rechargeable battery by rectifying process. This DC is converted into AC by the process of inversion and given to the load or equipment. This type of UPS is used where electrical isolation is mandatory. This system is a bit more costly due to the design of constantly running converters and cooling systems. Here, the rectifier driving the inverter. Hence it is also known as Double conversion UPS.

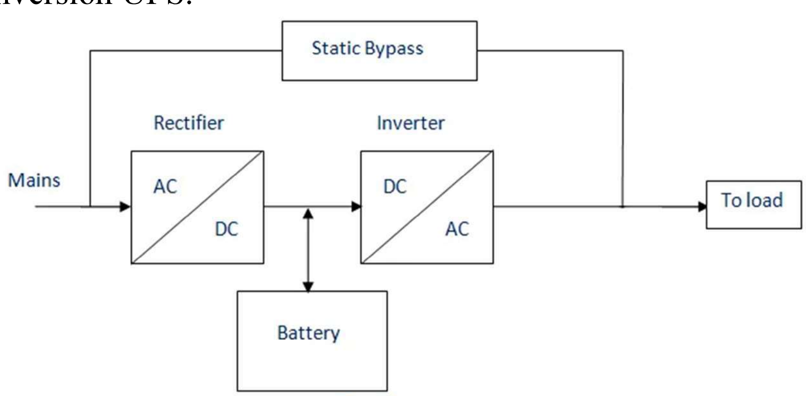


Figure 2

When there is any power failure, the rectifier have no role in the circuit and the steady power stored in the batteries is given to the load by means of transfer switch. Once the power is restored, the rectifier begins to charge the batteries. To prevent the batteries from overheating due to the high power rectifier, the charging current is limited. During a main power breakdown, this UPS system operates with zero transfer time. Because the backup source acts as a primary source. But the inrush current and large load step current can result in a transfer time of about 4-6 milliseconds in this system.

(iii) Line Interactive UPS

For small business and departmental servers and webs, line interactive UPS is used. This is more or less same as that of off-line UPS. The difference is the addition of tap changing transformer. Voltage regulation is done by this tap-changing transformer by changing the tap depending on input voltage. Additional filtering causes lower transient losses in the UPS.

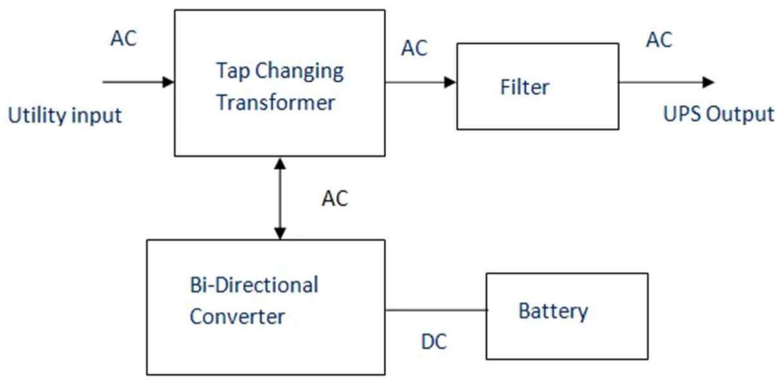


Figure 3

UPS Applications

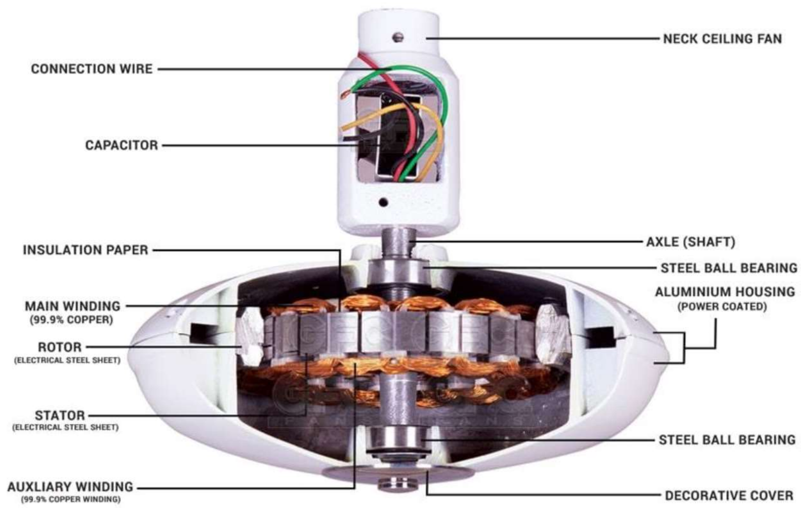
Applications of a UPS include:

- Data Centers
- Industries
- Telecommunications
- Hospitals
- Banks and insurance
- Some special projects (events)

UNIT-3

ELECTRIC FAN

If Electric fan rotates, blows away air around it towards the corners of room, and thus speeds up the evaporation process resulting in the cooling of human body and room.



Components of electric fan:

Capacitor: Start capacitor is used in electric fans, as we know capacitors stores energy and this stored energy is used to rotate the fan from rest state. This capacitor increases electric fan motor torque and allows motor to rotate rapidly. This capacitor stays in to circuit until only the electric fan reaches predetermined speed, this predetermined speed is usually the 75% of the full speed of fan and when fan reaches the predetermined speed this capacitor is taken out of the circuit and will again be incorporated into circuit when fan comes at rest state.

Axle: Axle or Shaft is the metallic rod mostly made up of mild steel. Axle is connected from ceiling to fan housing. It stays at rest motion while bearings supporting the housing over it rotate. It also as arrangement for transfer of current to the stator windings.

Bearings: Ball bearings are used in the electric fan. Two bearings which are link between housing and axle give the rotary motion to the housing.

Stator: Stator winding is simply the stationary winding in the electric fan motor winding. Stator winding means thousands of turns of conducting wire on any non-conducting structure like a coil. This winding has very low resistance. Main purpose of stator winding is to convert electric current into magnetic field.

Rotor: Rotor in the electric motor is the permanent magnetic in the shape of half circles. Usually two pieces of Magnets are used in Electric fan but this can change to 3 pieces or to single pc depending upon size and capacity of electric fan.

Housing: Housing is the outer part of the electric fan which carries stator, rotor and drive shaft bearing assembly on inside and blades on outer sides.

Blades or wings are the hanging part bolted on the outer area of housing. Three blades are mostly used and their length and the angle of air throw depends upon the size and capacity of electric motor.

Working principle of Electric fan:

Electric fan works on the principle of conversion of electric energy into mechanical energy and in this case mechanical energy is the rotary motion. When AC is supplied to electric fan it first reaches the capacitor and Capacitor delivers high energy to the stator windings. When stator winding energizes, it develops the rotating magnetic field and which forces the rotor to rotate in the direction of rotating magnetic field.

In this way electrical energy is converted into mechanical energy which causes the rotor and the housing to spin and the blades attached to the house throws away the air nearby it while creating cooling effect.

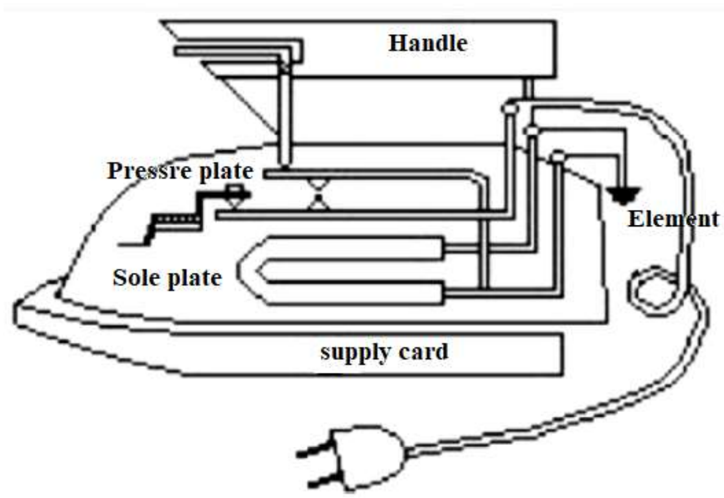
Servicing:

Trouble	Cause	Remedy
Fan 'dead'	a) Open circuit in the regulator.	a) Check and repair if defective
	b) Common lead broken.	b) Check and rewire.
	c) Switch trouble.	c) Repair or replace.
	d) Faulty Capacitor.	d) Check and replace if defective
Fan rotates with rough sound	a) Defective bearings.	a) Replace the bearing.
	b) Incorrect alignment of blades.	b) Align the blades properly.
Fan rotates but slow	a) Under voltage.	a) Check
	b) Weak Capacitor.	b) Check the capacitor by connecting to a.c. Supply and replace if defective
	c) Burnt winding.	c) Check and rewind
Fan 'hums'	a) Faulty Capacitor.	a) Check the capacitor by connecting to a.c supply and replace if defective
	b) Stuck bearings.	b) Check and apply grease or replace
	c) Burnt winding.	c) Check and rewind.
Fan gets no speed regulation	a) Regulator resistance shorted or faulty electronic regulator	a) Replace the regulator resistance or regulator
Fan vibrates while working	a) Incorrect alignment of blades	a) Align the blades properly.
Fan rotates slow in reverse direction	a) Faulty Capacitor	a) Check and replace.

	b) Reversed connection	b) Check and rewire.
Electric shock on the fan body	a) Bare live wire in contact with the metal body of fan	a) Test with series test lamp set for ground. Locate the defective wiring and repair

ELECTRIC IRON

The electric iron box is a device used for to press the creases out of our garments. It contains a thermostat which control Iron doesn't get too hot if it's kept switched on and left unattended for a long period of time. An electric iron box depends on a basic combination of heat and pressure to remove creases from clothes. When an electric current is passed through a coil it gets very hot. This heat is then transferred to the base plate through conduction, which elegantly and exactly irons your clothes. However, if the iron is continuously drawing electricity from the power supply, the heating element continues getting hotter. This causes a lot of energy wastage, as an iron consumes a lot of electricity even in a few minutes, ruins your clothes, and in the worst cases, causes na sty accidents. Therefore, thermostat is essential that an iron box doesn't heat up to hazardous temperatures.

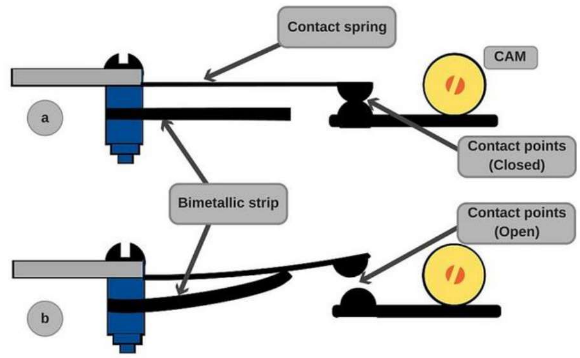


The original thermostat conceived in the seventeenth century consisted of a float in a mercury thermometer tied to a damper cover. Whenever the ambient temperature around the thermometer surpassed a certain limit, mercury would rise, displacing float such that it would close the damper. This premise led to the modern thermostats we use.

Bimetallic strip:

The thermostat in an iron, generally uses a bimetallic strip. The bimetallic strip is made up of two different type metals with dissimilar coefficients of expansion that are bonded together. This means that in the presence of heat, they expand differently. This bimetallic strip is connected to a contact spring through small pins.

At moderate temperatures, the contact point remains in physical contact with the bimetallic strip, however, when the temperature of the iron exceeds a certain limit, the strip begins to bend towards the lower thermal expansion metal. As a result, the strip physically detached from the contact point, the circuit opens and current ceases to flow. After some time, the temperature of the iron drops, the strip acquires its original shape, and the current reflowing again. So, a bimetallic strip works like a bridge to connect or disconnect the circuit. This cyclic on and off the iron keeps repeating until you switch off its power supply from the main electricity source. This is why your iron seems to the power on and off intermittently as you iron your clothes.



(a) Under normal temperature, (b) When the iron becomes too hot

Adding capacitor:

Although a thermostat helps in regulating the temperature within safe limits, frequent making and breaking of the circuit causes the contact points to gradually wear out. To prevent this, a capacitor is connected across two contact points. The role of the capacitor is to smooth out the electromagnetic interference.

Servicing

- Iron not working:
  The cord wire defective. Remove the cover of the three pin top and check the continuity of the three wires. Change the cord if defective.
- Thermostat is not making contact:
  Dismantle the iron and check by shorting the thermostat. If the contact is defective clean using emery paper or replace it.
- Element is burnt:
  Dismantle the iron and connect the supply to the ends of the element. If there is spark when connecting and if the element is heating up, it is not defective. If the element is defective, change it if replaceable.
- There is shock on the iron body:
  Check the earthing and shorted wires.
- Iron is sticking on the garments:
  Iron bottom is dirty. Clean the bottom using emery paper.
- Iron is working, but the indicator does not glow:
  Check and repair the indicator bulb and its connections.
- Fuse blown off as soon as the iron is switched on:
  Check for touching of wire ends in the plug top or touching of elements ends together. If so separate and insulate them. Check the capacity of the fuse. If it is of low capacity replace it with correct one.

ELECTRIC WATER HEATER

The electric heaters used to heat up water are called electric water heater. It is of three types. (a) Normal Plate Heater, (b) Immersion Heater, (C) Geyser Heater.

(a) Normal Plate Heater:

It is used for heating a small amount of water, such as water for shaving, face washing etc. Its construction is very simple. It consists of two round shaped nickel plates separated by a gap of 2 mm with an insulation.

Precautions about Normal Plate Heater

i. This type of heater is very dangerous. While using this heater one should always keep on watching that it does not come into contact with any metallic substance.

ii. Do never try to immerse your finger in the water to check the warmness of the water.

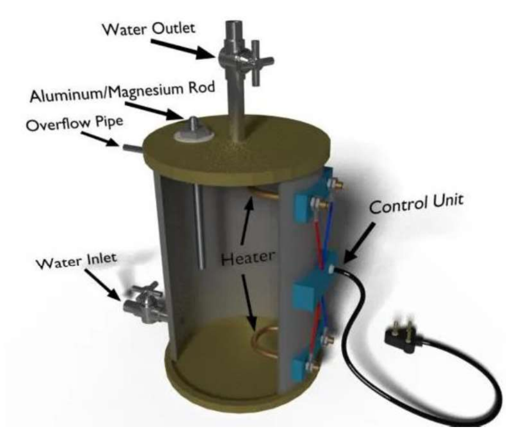
(b) Immersion Water Heater:

The electric heater which is immersed in water for heating the water is called Immersion Heater. In market from 250 watt to 2.0 kilo watt immersion heaters are available. The body is made of metallic substance, and the heating element is made of copper which is installed inside a capillary tube. The tube is found in U or, coil shape. The capillary tube is filled with magnesium oxide works as insulator. Both the end of the tube is sealed. The supply connection is given through 3 pin socket and plug.

Precautions for Immersion Heater:

i. Without immersing the water heater in water, supply cannot be given.
ii. One should not touch the immersion rod when supply is ON.
iii. Before removing the immersion rod from water it should be disconnect from the plug socket.
iv. The water filled bucket should not be touched while the supply is ON.
v. Except water no other liquid substance should be heated by immersion heater.

(c) Geyser Heater:



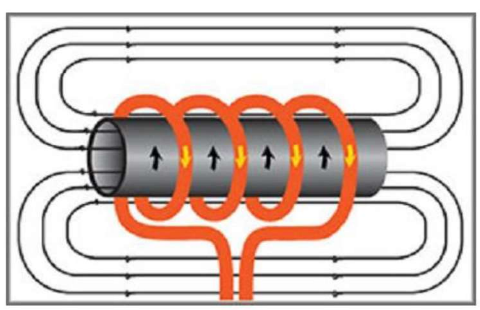
The basic principle of the water geyser is not very complex one. It is simple. Here electric heating element is used to heat up the water stored in a storage tank. The only deference from normal immersion type water heater, that it can automatically control the water temperature by controlling the operating period of the heating elements in geyser. It cannot be possible in normal immersion type water heater.

Generally, Geyser heater is used for heating large quantity of water from 20 to 90 liters capacity of water. In the storage tank, one or two heaters are fixed. For supplying of cold or hot water, Specific pipe lines are fitted with the storage tank. That means there are inlet cold water and outlet hot water pipe. To control the flow of water, a valve is installed in the pipeline. To control the heat one thermostat switch is there. The switch gets automatically OFF to avoid misuse of heat. The entire body of the geyser is insulated. When the geyser storage tank is filled up, the water starts owing through an overflow pipe, and then the inlet valve gets automatically OFF. An anode rod made of aluminum or magnesium is screwed in the storage tank to reduce corrosion of metal body. This is because the metal of anode rod is more sensitive to corrosive reactions than the metal of the body structure of the system. Body of the storage tank is generally made of steel. As aluminum or magnesium is corroded faster, it makes the water soften before it can corrode the steel.

Servicing

- Heater is not working.
  If there is power supply in the plug and the service cord is not defective, thermal cut out or thermostat is faulty. Test by shorting each and change the defective. If thermostat is not cutting off thermal cut out may open. Reset the thermal cut out after cooling. If there is no spark when the supply wires touching the heating element terminals directly, it is defective. Replace the element with same power.
- Water is not heating well and indicator glows continuously.
  Element is weak. If the current drawn by the element is low it is weak. Change it.
- Indicator goes off before water is heating well.
  Thermostat is cutting off. Adjust its screw for the higher temperature.
- High pressure steam forces out, opening the pressure release valve.
  Thermostat is not cutting off and water changes to high pressure steam. Change the thermostat.
- Water leakage through inner tank.
  Leakage may be through the packing below the element, doorplate packing, element sheath, thermostat sheath. If the leak is through packing, change it. If the leakage is through element or thermostat sheath, weld that point after removing door plate. If the leak is through the sheath of open coil element, the element also may be damaged. Check it and repair.
- There is electric shock on the heater body
  Check the earthing. The body should be connected to the earth pin and power supply should be connected to earth. Wires are wet because of the leakage of inner tank. Check and repair.

INDUCTION HEATER



Induction Heating

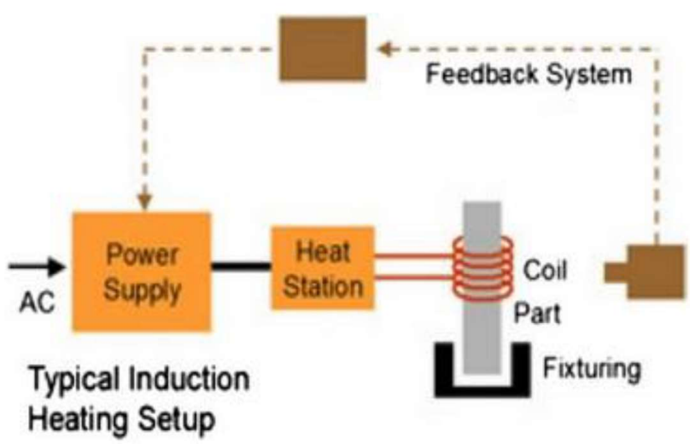
Working Principle

The **working principle** of the induction heating process is a combined method of Electromagnetic induction and Joule heating. Induction heating process is the non-contact process of heating an electrically conductive metal by generating eddy currents within the metal, using electromagnetic induction principle. As the generated eddy current flows against the resistivity of the metal, by the principle of Joule heating, heat is generated in the metal. According to Faraday's law of electromagnetic induction, changing the electric field in the conductor gives rise to an alternating magnetic field around it, whose strength depends on the magnitude of the applied electric field. This principle also works vice-versa when the magnetic field is changed in the conductor. Now the principle of Joule heating is observed. According to this when a current is passed through a material heat is generated in the material. So, when current is generated in the material due to the induced magnetic field, the flowing current produces heat from within the material. This explains the process of non-contact inductive heating.

Here a solid state RF frequency power supply is applied to an inductor coil and the material to be heated is placed inside the coil. When Alternating current is passed through the coil, an alternating magnetic field is generated around it as per Faraday's law. When the material placed inside the inductor comes in the range of this alternating magnetic field, eddy current is generated within the material.

Induction Heating Circuit Diagram

The setup used for the induction heating process consists of an RF power supply to provide the alternating current to the circuit. A copper coil is used as inductor and current is applied to it. The material to be heated is placed inside the copper coil. By altering the strength of the applied current, we can control the heating temperature. As the eddy current produced inside the material flows opposite to the electrical resistivity of the material, precise and localized heating is observed in this process. Besides eddy current, heat is also generated due to hysteresis in magnetic parts. The electrical resistance offered by a magnetic material, towards the changing magnetic field within the inductor, cause internal friction. This internal friction creates heat.



Typical Induction Heating Setup

As the induction heating process is a non-contact heating process, the material to be heated can be present away from the power supply or submerged in a liquid or in any gaseous environments or in a vacuum. This type of heating process doesn't require any combustion gases.

Induction Heating Formula

The depth penetrated by eddy current into the material is determined by the frequency of the inductive current. For current carrying layers, the effective depth can be calculated as

$$D = 5000 \sqrt{\rho/\mu f}$$

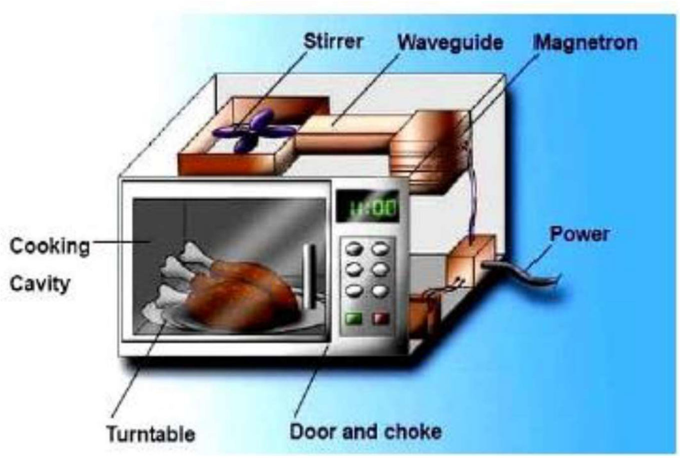
Here D indicates depth (cm), the relative magnetic permeability of the material is denoted by **μ, ρ** is the resistivity of the material in ohm-cm, f indicates AC field frequency in Hz.

Applications of Inductive Heating

- ✓ Targeted heating for surface heating, melting, soldering is possible with the inductive heating process.
- ✓ Besides metals, heating of liquid conductors and gaseous conductors is possible by inductive heating.
- ✓ For heating of silicon in semiconductor industries, the inductive heating principle is used.
- ✓ This process is used in inductive furnaces for to heat metal to its melting point.
- ✓ As this is a contactless heating process, vacuum furnaces make use of this process for making specialized steel and alloys that would get oxidized when heated in the presence of oxygen.
- ✓ Induction heating process is used for welding of metals and sometimes plastics when they are doped with ferromagnetic ceramics.
- ✓ Induction stoves used in the kitchen works on the inductive heating principle.
- ✓ For brazing carbide to shaft induction heating process is used.
- ✓ For tamper resistant cap sealing on bottles and pharmaceuticals, the induction heating process is used.

MICROWAVE OVEN

Microwave oven is one of the most widely used household appliances. Most of homes and most of conveniences store, bakeries and restaurants have microwave oven. The reason is that it cooks food in an amazingly short amount of time. They are also extremely efficient in their use of electricity because a microwave oven heats only the food – nothing else.



Main Components of Microwave Oven

High Voltage Transformer: The microwave oven requires more power than the normal voltage that the home's electrical wiring carries. To accomplish this, a step-up transformer with a high-voltage output is placed inside the oven. The 240V supply is jumped to a few thousand volts, which is then fed to the cavity magnetron.

Cavity Magnetron: A cavity magnetron is a high-powered vacuum tube that transforms the electrical energy into long-range microwave radiations, and hence it is the most important component of a microwave oven.

Micro-controller: A microcontroller is something that enables communication between a user and a machine. It processes the instructions that a user gives to the microwave oven and also displays them on a seven-segment display or a LED screen, depending on the model of the oven.

Wave Guide: As the name suggests, a waveguide is a hollow metallic tube that guides the waves generated at the magnetron's output toward the cavity (the place where we place the food).

Cooling Fan: Cooling fans reduce the magnetron's operating temperature and ensure its efficacy and longevity.

Operating Principle

Microwave oven uses microwaves to heat food. Microwaves are radio waves. In the case of microwave ovens, the commonly used radio wave frequency is roughly 2,500 megahertz (2.5 gigahertz). Radio waves in this frequency range have an interesting property: they are absorbed by water, fats and sugars. When they are absorbed they are converted directly into atomic motion and motion is converted into heat. Microwaves in this frequency range have another interesting property: they are not absorbed by most plastics, glass or ceramics. And metal reflects microwaves, which is why metals cause spark in a microwave oven. The reason that metal reflects microwaves is that no electronic waves resident in inside of conductor because conductor's conductivity is infinity. It is possible because the frequency 2,500 megahertz is resonance frequency of water. Molecules of all food are consist of a dipole and have positive charge in one side and have negative charge in another side. If we put electromagnetic fields in this, all molecules are rearranged: +charge is to negative pole and –charge is to positive pole. In this process heat is produced by friction. As the frequency of microwaves are 2,500 megahertz, the change in the direction of electromagnetic fields occur 2,500,000,000 times in 1 second. Consequently the heat efficiency of a microwave oven is greatly high.

The microwave ovens cook food from the inside out while in traditional method it happens from outside in. For example if we bake a cake, first, it burns outside then gradually inside. In microwave cooking, the radio waves penetrate the food and excite water and fat molecules pretty much evenly throughout the food. There is heat everywhere all at once because the molecules are all excited together.

Advantages

1. Cooking time is short
2. Destruction of nutrients is less
3. No physical change of foods
4. Melting process is easy
5. Sterilization effect exists
6. There is no flame, then treatment is easy

Disadvantages

1. Constraint with metal container
2. Heat force control is difficult
3. Water evaporation
4. Closed container is dangerous because it could be burst

5. Surface toasting is impossible

Servicing:

The microwave isn't working.

- ✓ Check microwave is plugged in and the door is closed properly
- ✓ Check whether fuse may have blown or not. If replacing the fuse doesn't work, you may also have a faulty door switch.

There are sparks inside the microwave (also called arcing).

- ✓ Sparks can occur if you put foil or utensils in the microwave, if food splatters ignite, if a high-voltage diode shorts out, or if a defective stirrer causes heat to concentrate in one area.

The turntable is not rotating.

- ✓ If your turntable isn't rotating, the carousel may need to be re-aligned on the turning mechanism.
- ✓ It may also be caused by a worn-out or split turntable drive bushing. Another issue that can cause this is a defective tray motor.

Microwave isn't heating food.

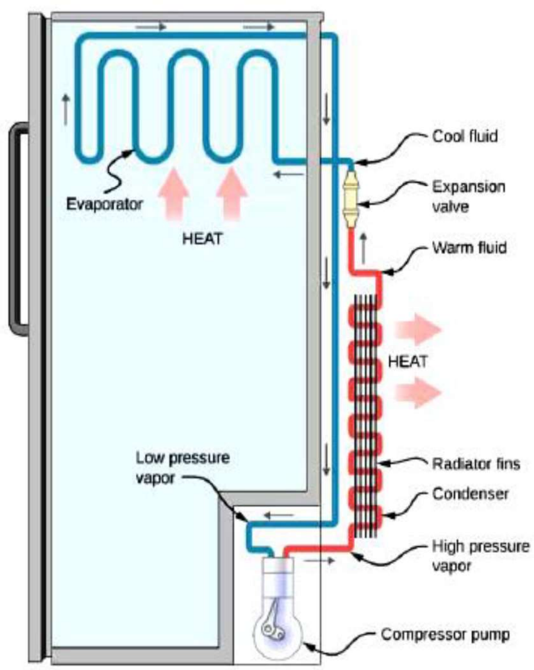
- ✓ If your microwave is turning on but not heating your food, and you hear a loud buzzing noise, you could have a defective magnetron, capacitor, or diode.

The touch pad only works intermittently.

- ✓ Your microwave's touch pad may be damaged from water or insect infestation, preventing you from properly selecting settings for your food. This means you will need to either replace or repair the touch pad to ensure proper function.

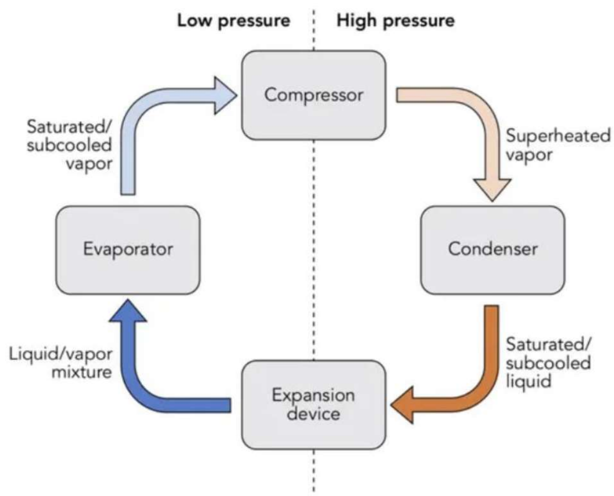
REFRIGERATOR

Refrigerator is a device used for refrigeration i.e. to maintain a system or body at a temperature lower than that of its surrounding (atmospheric temperature). Refrigerator is one invention that has certainly changed the way we live. It has made it possible for everyone to preserve food for days together. The cold temperature inside the refrigerator slows down the bacterial growth in food and thus preserves the food for longer.



Working Principle

Principle on how does a refrigerator work is pretty simple. Gases get hotter when you compress them into less volume because you have to work to push their energetic molecules together. When you expand a gas, it is suddenly able to occupy much more volume. The heat energy its molecules contain is now divided over a much bigger volume of space, so the temperature of the gas falls (it gets cooler). The other principle at work in a refrigerator is that when you have two things that are different temperatures that touch or are near each other, the hotter surface cools and the colder surface warms up. This happens between evaporator and refrigerant. This is a law of physics called the Second Law of Thermodynamics.



The compressor in the refrigerator compressing the vapor and rising its pressure and temperature, and pushes, it into the coils of the condenser on the outside of the refrigerator. When the hot gas in the coils of the condenser meets the cooler air temperature of the kitchen, it becomes a liquid. Now in liquid form at high pressure, the refrigerant cools down as it flows through the expansion valve into the evaporator coils inside the freezer and the fridge. The refrigerant absorbs the heat inside the fridge when it flows through the evaporator coils, cooling down the air inside the fridge. Last, the refrigerant evaporates to a gas due to raised temperature, and then flows back to the compressor, where the cycle starts all over again.

Construction and Parts

A refrigerator consists of several components like Compressor, Condensers, Expansion devices, evaporator and some accessories for proper functioning like controls (temperature controlling devices), filters, defrost system etc. Every component performs their own function so it is necessary to assemble all in proper sequence.

1. Compressor:

Compressor is the most important part in any refrigerator. Without it the working of refrigerator is not possible. Compressor is a mechanical device which transfers mechanical energy to working fluids i.e. refrigerant. The function of the compressor is same as heart in human body i.e. heart pump blood in whole body same as compressor regulate the refrigerant in whole unit by increasing the pressure of the working fluid i.e. refrigerant.

2. Condenser:

Condenser is an important component of any refrigeration system. It is a type of heat exchanger. Refrigerant comes from compressor is at high temperature and pressure is cooled in condenser and then condensed by rejecting heat to an external medium. Condenser rejects the heat from working fluid (refrigerant) by means cooling coils made up of copper into the atmosphere. The refrigerant may leave the condenser as a saturated or a sub-cooled liquid.

3. Throttling/Expansion devices:

The basic functions of an expansion device are to reduce the pressure of working fluid which comes from condenser and goes into the evaporator. It also regulates the flow of refrigerant into the evaporator and maintains the flow rate equal to the rate of evaporation in the evaporator. We can regulate and control the temperature of refrigerator using expansion devices by varying the opening as per our requirements.

4. Evaporator:

It is the storage space or freezer. Refrigerant comes from throttling device enters into the evaporator at very low temp and pressure. In evaporator refrigerant goes through cooling coils. In evaporator heat is absorbed by the refrigerant. Now cooling effect is produced inside the refrigerator. Due to this temperature of the refrigerant increases and liquid refrigerant expends and converts into vapour after that this refrigerant goes to the compressor.

This cycle repeats continuously.

5. Refrigerants:

A special gas called the refrigerant is used in the vapor compression cycle of a refrigerator. It used to be CFC (chlorofluorocarbon). But due to environmental concerns with CFC, namely, the depletion of ozone layer, the gas used nowadays is HFC-134a, also called tetrafluoroethane. The refrigerant passes through the various components of the refrigeration cycle. When the refrigerant enters into the evaporator, it absorbs heat from the storage space and evaporates. This process includes a phase change process which maximizes the cooling effect.

6. Temperature controlling devices:

These types of devices are used to control the temperature in the refrigerator. These devices are attached with expansion devices. A thermostat is attached to the evaporator which helps to maintain a specific temperature.

<u>Applications of Refrigerator</u>

Refrigerator maintains the lower temperature than that of its surroundings by absorbing heat from the refrigerated space and reject it into the surrounding. In past time the main use of refrigerator was only produce ice which is used for many purposes but now days the application of the refrigerator increases day by day as the new technology develops. Some major application of the refrigerator are given as follow

1. Refrigerator is used in the processing and preservation of food items.
2. Refrigerator is used in industrial applications like in chemical and petroleum industry.
3. Refrigerator is used to Storage of Fruits and Vegetables
4. Refrigerator is used to store the Meat and poultry in short term (0^oC) and long term (-25^oC) purposes.
5. These are used to preserve Dairy Products milk, butter, ice crème, etc., for more time against bacterial growth.
6. To enrich the taste and nutritional values of certain beverages like soft drinks, fruit juices, etc refrigeration is used : Some beverages like beer, wines and soft
7. To preserve food items, chacholates, Candy etc.

8. In Construction, to avoid exothermic process of concrete chilled water is passed through pipes.
9. It is used in Ice manufacturing.
10. In medical science, refrigeration is used to store the Blood plasma and some antibiotics at low temperature. Some other drugs also require less temperature for storage which can't be stored at room temperature.

Servicing:

- ✓ **Will not start**
  Fixing a fridge that will not start begins by checking the relay capacitor, the temperature control, and the electronic control board.
- ✓ **Noisy**
  The refrigerator fan motor may be in need of replacing when it makes too much noise. You may also notice the fridge is not as cool as it normally is.
- ✓ **Leaking**
  If the fridge is leaking water, the problem could be a gasket, the water inlet valve (which supplies the fridge with dispensable water and ice), or even the ice maker itself.
- ✓ **Fridge and Freezer are too warm**
  Temperature control is paramount for refrigerators. Check the evaporator fan motor, temperature sensor, or temperature control switch if your fridge or freezer is too warm.
- ✓ **Freezer or fridge too cold**
  If your freezer is too cold, it may mean that you need to replace the temperature sensor or thermistor. It may also be that the air damper is letting in too much cold air, and needs fixing.
- ✓ **Not dispensing water**
  A broken water inlet valve or water dispenser actuator could be to blame when water is not available from your refrigerator's water dispenser.
  A broken water inlet valve or water dispenser actuator could be to blame when water is not available from your refrigerator's water dispenser.
- ✓ **Light not working**
  A fridge without a working light will usually mean one thing: you need a new light bulb or socket.
- ✓ **Door Sweating**
  A door emitting water can be solved through a simple diagnosis. The gasket on the door could have a broken seal, or it could be in need of a new door assembly

ILLUMINATION

As a body is gradually heated above room temperature, it begins to radiate energy in the surrounding medium in the form of electromagnetic waves of various wavelengths. The nature of this radiant energy depends on the temperature of the hot body. It is found that as body is gradually heated above room temperature, it begins to radiate energy in the surrounding medium in the form of electromagnetic waves of various wavelengths.

The nature of this radiant energy depends on the temperature of the hot body. Thus, when the temperature is low, the radiated energy is in the form of heat waves only, but when a certain temperature is reached, light waves are also radiated out in addition to heat waves and the body becomes luminous. Further increase in the temperature produces an increase in the amount of both kinds of radiations but the colour of light or visual radiations change from bright red to orange, to yellow and finally, if the temperature is high enough, to white. As the temperature is increased, the wavelength of visible radiation goes on becoming shorter. It should be noted that heat waves are identical to light waves except that they are of longer wavelength and hence produce no impression on retina. Obviously, from the point of view of light emission, heat energy represents wasted energy.

Radiant efficiency of the luminous source is defined as the ratio of "energy radiated in the form of light" to "total energy radiated out of the hot body" and it depends on the temperature of the source. When emitted light becomes white, i.e. it includes all the visible wavelengths, from extreme red to extreme violate, then a further increase in temperature produces radiations which are of wavelengths smaller than that of violate radiations. Such radiations are invisible and are known as ultra-violate radiations.

ELECTRIC BULB

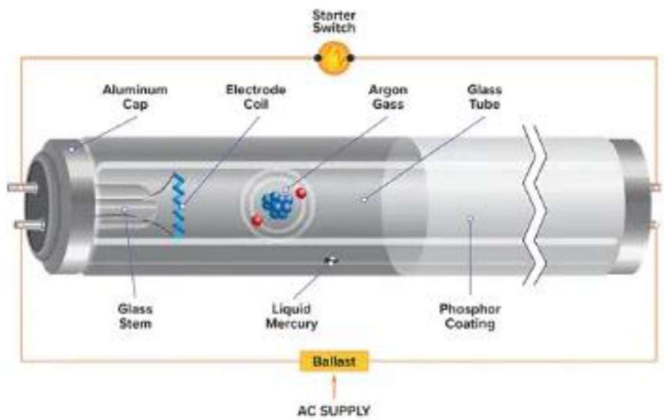
Electric bulb refers to a device which produces light on the application of electricity. Such a bulb is certainly powerful enough to lighten up a dark place. The most common type bulb is the incandescent light bulb. The construction of lamp is quite simple. It has one filament surrounding which, a transparent glass made spherical cover is provided. A lamp emits light energy as the thin filament of lamp glows without being melted, while current flows through it. These types of light bulbs are the oldest and simplest form of bulb technology, dating back to Thomas Edison's experiments with filament types back in 1879.

Working of Incandescent Bulb:

An incandescent bulb works on the principle of incandescence (light produced by heat). In an incandescent type of bulb, an electric current is passed through a thin metal filament, heating the filament until it glows and produces light. Incandescent bulbs typically use a tungsten filament because of tungsten's high melting point. A tungsten filament inside a light bulb can reach temperatures as high as 4,500 ^{o}F. A glass enclosure by vacuum, prevents oxygen in the air to reach the hot filament to avoid oxidation. After the electricity has made its way through the tungsten filament, it goes down another wire and out of the bulb via the metal portion at the side of the socket. It goes into the lamp or fixture and out a neutral wire. This is an elegantly simple system and it works quite well at producing light. It's perfect for a wide range of applications, cheap and easy to manufacture, and is compatible with either AC or DC current.

FLUORESCENT LAMP

A fluorescent lamp is a low weight mercury vapour lamp that uses fluorescence to deliver visible light. An electric current in the gas energizes mercury vapor which delivers ultraviolet radiation through discharge process and the ultraviolet radiation causes the phosphor coating of the lamp inner wall to radiate visible light. Fluorescent lamps have been widely used in commercial buildings for decades, because they use considerably less power and last much longer than



incandescent lighting. The normal luminous viability of fluorescent lighting frameworks is 50 to100 lumens per watt, which is a few times the competence of incandescent lamps. However, due to their tubular design and cooler color temperatures, they have not been generally welcome in the home.

COMPACT FLUORESCENT LAMP (CFL)

The term 'CFL' stands for Compact Fluorescent Lamp. It is also known as compact fluorescent light, energy-saving light, and compact fluorescent tube.

The CFL was initially designed to replace the incandescent lamp in terms of its compactness as well as energy efficiency. The basic construction of a CFL consist a tube which is curved or spiraled to fit into the space of an incandescent bulb, and compact electronic ballast in the base of the lamp. In older fluorescent lamps the ballast is located in the lamp, separate from the bulb, and causes the audible humming or buzzing, but in newer, compact fluorescent lamps (CFLs), the fluorescent tube is coiled into a shape similar to an incandescent bulb, the ballast is nested into the cup at the base of the bulb assembly and is made of electronic components that reduce or eliminate the buzzing sound.

Working Principle:

A CFL uses vacuum pipe which is principle wise same to the strip lamps (commonly known as Tube light). Tube has two electrodes on both ends which is treated with Barium. Cathode is having a temperature of about 900° C and generates a beam of electrons which is further accelerated by potential difference between electrodes. These accelerated electrons strike Mercury and Argon atoms which in turn results in the arc, initiates radiation of Mercury in Ultra violet form. Tube's inside face contains 'Luminophore' whose function is to convert Ultra violet light into visible light.

CFLs use about a quarter of the power that a typical incandescent bulb does. This means that a 13 watt bulb (a watt is a unit of power) produces the same high-quality light as a 60 watt incandescent. These bulbs have the same brightness of 800 lumens, therefore the CFL bulb accomplishes the same goal while using less power. CFLs are rated by energy use (in watts) and light output (in lumens), frequently in specific comparison with incandescent bulbs. Specific CFLs are configured for use with dimmer switches and three-way switches and in recessed fixtures.

LEDS (LIGHT-EMITTING DIODES)

LED stands for Light Emitting Diode. It is the fastest developing lighting technologies today. An LED bulb produces light by passing the electric current through a semiconducting material—the diode—which then emits photons (light) through the principle of electroluminescence. The fact that LED lights do not rely on heat to produce its light means it runs cooler and is much more energy-efficient than an incandescent light bulb.

LEDs are solid-state semiconductor devices that convert electrical energy directly into light. LEDs can be extremely small and durable; some LEDs can provide much longer lamp life than other sources. The composition of the materials determines the wavelength and therefore the color of light. LEDs can generate red, yellow, green, blue or white light and are widely used in traffic signals and for decorative purposes. White light LEDs are a recent advance and may have a great potential market for some general lighting applications. The average LED light bulb lifespan is 25,000 hours. This is much longer than the average incandescent bulb lifespan (1,000 hours) and the average CFL bulb lifespan (10,000 hours). Not only are LED bulbs the most energy efficient design, they're also the most durable and long lasting. While LED bulbs are more expensive to purchase than their incandescent and CFL counterparts, they're actually more cost effective in the long term, as they last longer and consume less energy.

White LED color temperature normally ranges from cool white to warm yellow, though LED lights tend to be cooler than other types of light bulbs. The higher the color temperature, the "cooler" the light is, which means it produces a whiter light. When the color temperature is lower, the bulb gives off a "warm" or yellow light output.

They are also the most efficient lights on the market. Also called luminous efficacy, a light bulb's efficiency is a measure of emitted light (lumens) divided by power it draws (watts). A bulb that is

100 percent efficient at converting energy into light would have an efficacy of 683 lm/W. To put this in context, a 60- to 100-watt incandescent bulb has an efficacy of 15 lm/W, an equivalent CFL has an efficacy of 73 lm/W, and current LED-based replacement bulbs on the market range from 70-120 lm/W with an average efficacy of 85 lm/W.

EFFICIENCY OF APPLIANCES

A small set of appliances such as fans, televisions, refrigerators, air-coolers, air conditioners, and water heaters contribute about 50-60% of the total residential electricity consumption in India. Large scale adoption of energy efficient models of these appliances can thereby significantly reduce future electricity consumption in homes. The government's Standards and Labelling (S&L) programme and three aspects of its effectiveness giving a proper rating for achieving efficiency in the Indian appliances market.

The S&L programme is run by the Bureau of Energy Efficiency (BEE), under the Ministry of Power. Since 2006, the programme promotes efficient appliances through informative labels and by eliminating lower efficiency models through mandatory standards. BEE gives a 5-star rating to the most efficient models and a 1-star rating to the least efficient ones based on a predetermined schedule, communicated through a label affixed on the appliance. Eight appliance categories, including air-conditioners and refrigerators are mandated to carry these labels, and no model can be sold unless it meets the 1-star rating, at minimum. The programme is voluntary for 13 appliance categories, including ceiling fans and washing machines, and manufacturers can sell these models without BEE labels and with an efficiency less than a 1-star rating.

Mandate and tighten standards: For any appliance, BEE starts with a voluntary S&L programme and usually makes it mandatory in two-three years. BEE's mandatory list has increased from two to eight and now covers most major appliances including, refrigerators and air-conditioners Ceiling fans and air-coolers are notable exceptions. More than 95% of the ceiling fans sold do not carry labels and consume more than twice the most efficient model available in India. The programme has been voluntary for ceiling fans since 2010. Air-coolers guzzle much more electricity and are increasingly becoming popular but have not yet been included in the S&L programme. Making a programme mandatory for an appliance category ensures that inefficient models are not sold in the market.

Mandatory Appliances	Voluntary Appliances
Frost Free Refrigerators	Induction Motors
Tubular Fluorescent Lamps	Agricultural Pump Sets
Room Air Conditioners	Ceiling Fans
Distribution Transformers	Domestic LPG stoves
Room Air Conditioners (Cassette, Floor standing, Tower, Ceiling)	Washing Machine
Direct Cool Refrigerators	Computer
Colour TV	Diesel engine moonset pumps for agriculture
	Solid state inverters

	Diesel Generators
	Variable capacity Air Conditioners
	LED lamps

BEE also periodically tightens the standards and labels to keep up with and promote the most efficient commercially available technologies. So, today's 5-star model may become a 3-star model in the next phase and more efficient models can get the new 5-star tag. BEE has periodically tightened ratings for frost-free refrigerators and the current 5-star ratings are comparable with international standards, but the 1-star rating still has a scope for improvement. The ratings for air-conditioners on the other hand can *be* tightened further to align with the most efficient models available in India as well as abroad.

IEC CODES

The International Electro technical Commission (IEC) is an international standards organization that prepares and publishes international standards for all electrical, electronic and related technologies collectively known as electro technology. IEC standards cover a vast range of technologies from power generation, transmission and distribution to home appliances and office equipment, semiconductors, fiber optics, batteries, solar energy, nanotechnology and marine energy as well as many others. The IEC also manages four global conformity assessment systems that certify whether equipment, system or components conform to its international standards.

All electro technologies are covered by IEC Standards, including energy production and distribution, electronics, magnetic and electro-magnetics, electro-acoustics, multimedia, telecommunication and medical technology, as well as associated general disciplines such as terminology and symbols, electromagnetic compatibility, measurement and performance, dependability, design and development, safety and the environment.

EC standards have numbers in the range 60000-79999 and their titles take a form such as IEC 60417. Graphical symbols for use on equipment. Following the Dresden Agreement with CENELEC the numbers of older IEC standards were converted in 1997 by adding 60000, for example IEC 27 became IEC 60027. Standards of the 60000 series are also found preceded by EN to indicate that the IEC standard is also adopted by CENELEC.

This Guide is based on relevant IEC standards, in particular IEC 60364. IEC 60364 has been established by engineering experts of all countries in the world comparing their experience at an international level. Currently, the safety principles of IEC 60364 series, IEC 61140, 60479 series and IEC 61201 are the fundamentals of most electrical standards in the world.

INDIAN STANDARDS CODES

In the field of electrical engineering, engineers and other professionals get exposed to electricity indirectly during generation, transportation, installation and usage. Such conditions might cause hazards if accurate safety measures are not taken.

To promote the safety and the right usage of equipment, there are certain rules and regulations formulated by the Bureau of Indian Standards (BIS). BIS follows the following five principles −

- Safety
- Ease of use and adaptability

- Simple technology
- Value for money products
- Energy efficiency and environment

BIS has published the following code of practice for public safety standards in order to promote the right to information, transparency and accountability in a proper manner to the public.

Code of Practice for Electrical Wiring Installation

- **IS** − 732 (1989)
- **Section** − Electrical Installation
- **Application** − Design of installation, selection and erection of equipment, inspection and testing of wiring system

Code of practice for Earthing

- **IS** − 3043 (1987)
- **Section** − Electrical Installation
- **Application** − Design, installation and calculation of Earthing system

Lightning arrester for Alternating Current System

- **IS** − 3070 (1993)
- **Section** − Electro technical: Surge Arresters
- **Application** − Identification, ratings, classification and testing procedure of Arrester

Let us now consider other important codes of practice established by BIS for the purpose of electrification. The codes are listed in the table below −

General Requirements	
Sr. No.	**Standards & Application**
1	**IS:900** Installation and maintenance of Induction motors
2	**IS:1271** Classification of insulating materials for electrical machinery
3	**IS:1646** Fire safety of buildings (general) electrical installation
4	**IS:1882** Outdoor installation of Public Address System (PAS)
5	**IS:1886** Installation and maintenance of Transformers
6	**IS:1913** General and safety requirements of electric lighting fittings
7	**IS:2032** Graphical symbols related to electrical technology
8	**IS:2274** Electrical wiring installations where system voltage is more than 658 volts
9	**IS:3034** Fire safety of industrial buildings (Electrical generation and distribution stations)
10	**IS:3072 (part-1)** Installation and maintenance of switchgear where system voltage is less than 1000 volts
11	**IS:3106** Selection, installation and maintenance of fuse where system voltage is less than 650 volts

12	**IS:3638** Guide for gas operated relays
13	**IS:3646** Practice for interior illumination
14	**IS:3716** Guide for insulation coordination
15	**IS:3842** Guide for electrical relays for AC system
16	**IS:4004** Guide for lightening arrestors (non-linear) for AC system
17	**IS:4146** Guide for voltage transformers
18	**IS:4201** Guide for current transformers
19	**IS:5571** Selection of electrical equipment in hazardous area
20	**IS:5572** Types of hazardous areas for electrical installations
21	**IS:5780** Intrinsically safe electrical apparatus and circuit
22	**IS:5908** Measurement of electrical installations in buildings

Switchgear

The following table lists down the codes of practice for the maintenance of switchgear −

General Requirements	
Sr. No.	**Standards & Application**
1	**IS:375** Making and arrangement for switchgear bus-bars, main connections and auxiliary winding
2	**IS:694(part-1)** PVC insulating cables with copper conductors (where voltage is up to 100v)
3	**IS:1248** Direct acting electrical indicating instruments
4	**IS:2147** Degrees of protections for enclosures for switchgear and control gear (low voltage)
5	**IS:2208** Guide for HRC fuse (up to 650v)
6	**IS:3202** Guide for climate proofing of electrical equipment
7	**IS:3231** Guide for electrical relays of power system protection
8	**IS:4047** Guide for heavy duty air break switches and fuses for voltage less than 1000v
9	**IS:4237** Requirements for switchgears and control gears for voltage up to 1000v

10	**IS:5987** Selection of switches where voltage is up to 1000v
11	**IS:335** Insulating oil for transformers and switch gear
12	**IS:2516(part-1,sec-2)** AC circuit breakers (Tests for the voltage range 1000v to 11000v)
13	**IS:3427** Metal enclosed switch gear and control gear for voltage within 1000v to 11000v
14	**IS:722** AC electricity meters for 415 volts
15	**IS:1951** PVC sleeving for electrical works
16	**IS:2516(part-1sec-1 & part-2sec2)** AC circuit breaker (Tests for voltage within 1000v)
17	**IS:2419** Guide for dimension of electrical indicating instruments

Motor Control Centre (MCC)

The following table lists down the codes of practice for the maintenance of Motor Control Centre −

General Requirements	
Sr. No.	**Standards & Application**
1	**IS:1554(part-1)** PVC insulated heavy duty electric cables for the voltage up to 1100v
2	**IS:1822** AC motor starters of voltage less than 1000v
3	**IS:2959** AC contactors of voltage less than 1000v
4	**IS:3961(part-2)** Recommended current ratings for PVC insulated and PVC sheathed cables
5	**IS:5124** Installation and maintenance of AC induction motor starters within 1000v
6	**IS:2959** Guide for AC contactors of voltage less than 1000v

Invertors

The following table lists down the codes of practice for the maintenance of invertors −

General Requirements	
Sr. No.	**Standards & Application**
1	**IS:391** Mains transformers for electronic equipment

Transformers

The following table lists down the codes of practice for the maintenance of transformers

General Requirements	
Sr. No.	**Standards & Application**
1	**IS:335** Insulating oil for transformer and switch gear
2	**IS:2026** Power transformers
3	**IS:2099** High voltage porcelain bushings
4	**IS:3637** Gas operated relays
5	**IS:3639** Fitting and accessories for power transformers

Motors

The following table lists down the codes of practice for the maintenance of motors −

General Requirements	
Sr. No.	**Standards & Application**
1	**IS:325** 3-ph induction motors
2	**IS:4691** Degrees of protection provided by enclosures for rotating machinery
3	**IS:4722** Guide for rotating electrical machines

Batteries

The following table lists down the codes of practice for the maintenance of batteries −

General Requirements	
Sr. No.	**Standards & Application**
1	**IS:1652** Guide for stationery cells and batteries, lead-acid type with plante positive plates

Cables

The following table lists down the codes of practice for the maintenance of cables –

General Requirements	
Sr. No.	**Standards & Application**
1	**IS:1753** Aluminum conductors for insulated cables
2	**IS:3961(part-2)** Guide for current ratings for cable
3	**IS:3975** Guide for mild steel wires, strips and tapes for armoring cables
4	**IS:5819** Guide for short circuit ratings of high voltage cables
5	**IS:5831** Guide for PVC insulation and sheath of electric cables

Alternators

The following table lists down the codes of practice for the maintenance of alternators

General Requirements	
Sr. No.	**Standards & Application**
1	**IS:7132** Guide for testing synchronous machines
2	**IS:5422** Guide for turbine type generators
3	**IS:7306** Methods for determining synchronous machine quantities

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