ELECTRICAL APPLIANCES

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First edition

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VIJAYAWADA

ELECTRICAL APPLIANCES

UNIT-1

Voltage:

Voltage or electric potential difference is an amount of work done between two points to bring unit positive charge in an electric field.

Voltage is then work from an electrical circuit's power source that pushes charged electrons (current) through a conducting loop.

Voltage would be "the ability to cause electricity to flow."

The work required to move per unit of charge between two points is known as voltage. Mathematically, the voltage can be expressed as,

Voltage = Work done (W)/Charge (Q)

SI units of Voltage are Volt.

Current:

Current is the rate at which electrons flow through a point in an electrical circuit.

An electric current is a stream of charged particles, such as electrons or ions, moving through an electrical conductor. It is measured as the net rate of flow of electric charge through a surface.

In electric circuits the charge carriers are often electrons moving through a wire. In semiconductors they can be electrons or holes.

Current I= Charge(Q)/Time(t)

SI units of current is Ampere

Ohms law:

"At Constant temperature, the Potential is directly proportional to current flowing through the conductor." This is called Ohms law.

Potential α Current

$$V \propto I$$

$$V=IR$$

This is called ohm's law. Where, proportional constant R is called resistance of the conductor.

Resistance:

The electrical resistance of a circuit component or device is defined as the ratio of the voltage applied to the electric current which flows through it.

Resistance R= Voltage(V) /Current(I)

Resistance is a measure of the opposition to current flow in an electrical circuit.

SI units of resistance are Ohm (Ω).

The resistance of conducting material is found to be—

1. directly proportional to the length of the material
2. inversely proportional to the cross-sectional area of the material
3. depends on the nature of the material
4. It depends on the temperature

The resistance of a conductor is directly proportional to its length and inversely proportional to area of cross section.

$$R \alpha l/A$$

$$R=\rho l/A$$

Where L represents the length of the wire (in meters), A represents the cross-sectional area of the wire (in meters^2), and ρ represents the resistivity of the material (Ohm-meter).

Resistivity $\rho=RA/l$

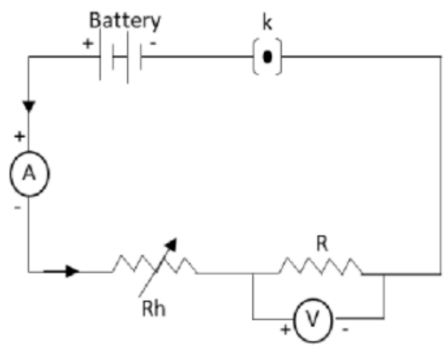
The resistivity is equal to the resistance of the conductor whose length is unit and unit area of cross section.

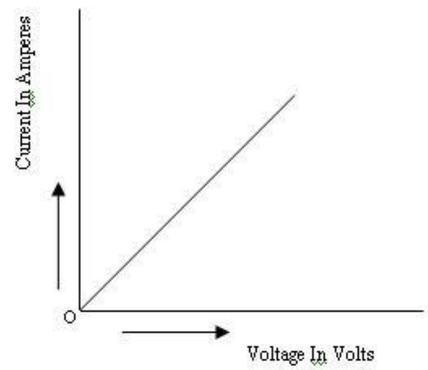
Verification of Ohms law:

To verify Ohms law circuit diagram is connected as shown in figure, In which Voltmeter V, ammeter A, Rheostat Rh, Resistance R along with battery B.

Initially, the key K is closed and the rheostat is adjusted to get the minimum reading in Ammeter A and voltmeter.

The current in the circuit is increased gradually by moving the sliding terminal of the rheostat. During the process, the current flowing in the circuit and the corresponding value of potential difference across the resistance R is recorded.





This way different sets of values of voltage and current are obtained.

For each set of values of V and I, the ratio of V/I is calculated.

When you calculate the ratio V/I for each case, you will come to notice that it is almost the same. So V/I = R, which is a constant.

Plot a graph of the current against the potential difference; it will be a straight line. This shows that the current is proportional to the potential difference. So Ohms law is verified.

Capacitance:

In a conductor, an electric charge is directly proportional to the potential difference.

Electric charge (Q) α Electric potential (V)

$$Q=CV$$

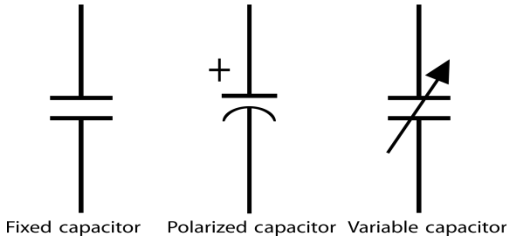
Where, the proportional constant C is called capacity or capacitance of the conductor.

$$\text{Capacitance } C=Q/V$$

Capacitance is the ratio of the amount of electric charge stored on a conductor to a difference in electric potential.

Units of capacitance are Farad.

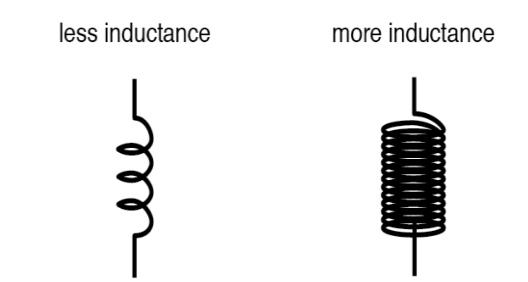
Farad is a big unit and hence micro farad (μF) or Pico Farad (pF) will be used as capacity units.



Inductance (L):

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) (voltage) in the conductors, a process known as electromagnetic induction. This induced voltage created by the changing current has the effect of opposing the change in current.

Inductance is the tendency of an electrical conductor to oppose a change in the electric current flowing through it.



Lenz’s law states that “The polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produced it.”

The magnetic flux linked with the circuit is proportional to Current flowing through it.

Magnetic flux(φ) αCurrent (I)

Φ=LI

Where proportional constant L is called coefficient of self-induction or simply called self-inductance.

Self-inductance L=φ/I

Inductance is defined as the ratio of the magnetic flux linked with the circuit and current flowing through it.

The induced emf in a coil happens to be equal to the negative of the rate of change of magnetic flux times the number of turns that exist in the coil.

$$Induced\ emf\ e = \frac{d\varphi}{dt}$$

$$Induced\ emf\ e = \frac{d(LI)}{dt}$$

$$Induced\ emf\ e = L\frac{dI}{dt}$$

$$Coefficient\ of\ self\ inductance\ L = \frac{\varphi}{\frac{dI}{dt}}$$

Inductance is defined as the ratio of the induced voltage to the rate of change of current causing it.

SI units of self-inductance are Henry.

Electrical Conductors:

Depending on the electrical conductivity materials can be classified into three types

1. Conductors
2. Insulators
3. Semiconductors

Conductors:

Materials that allow electricity to flow through them easily are called conductors. This property of conductors that allow them to conduct electricity is known as conductivity.

- silver
- copper
- gold
- aluminum
- iron
- steel
- brass
- bronze
- mercury
- graphite
- sea water
- concrete

Insulators:

Materials that do not allow electricity to flow through them easily are called insulators.

- glass
- rubber
- oil
- asphalt
- fiberglass
- porcelain
- ceramic
- quartz
- (dry) cotton
- (dry) paper
- (dry) wood
- plastic
- air
- diamond
- pure water

Difference between Conductors and insulators:

Conductor	Insulator
Materials that permit electricity or heat to pass through it	Materials that do not permit heat and electricity to pass through it
A few examples of a conductor are silver, aluminum, and iron	A few examples of an insulator are paper, wood, and rubber
Electrons move freely within the conductor	Electrons do not move freely within the insulator
The electric field exists on the surface but remains zero on the inside	The electric field doesn't exist

Series combination of Resisters:

Two or more resistances are said to be connected in series when they are connected end to end and the same current flows through each resistance is called series combination of resisters.

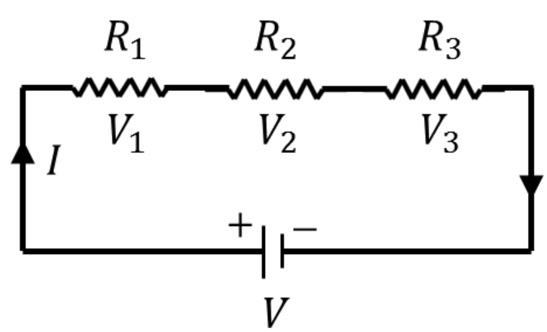
In series combination current through each resistor is constant. In series combination Potential difference across each resistor is different depending upon the value of resistance.

We know from Ohms law

$V=IR$, $V_1=IR_1$, $V_2=IR_2$ and $V3=IR_3$

But the potential difference

$V=V_1+V_2+V_3$



$$IR= IR_1+ IR_2+ IR_3$$

$$R= R_1+ R_2+ R_3$$

Equivalent resistance of circuit is equal to the sum of individual resistances in the series combination of resistances.

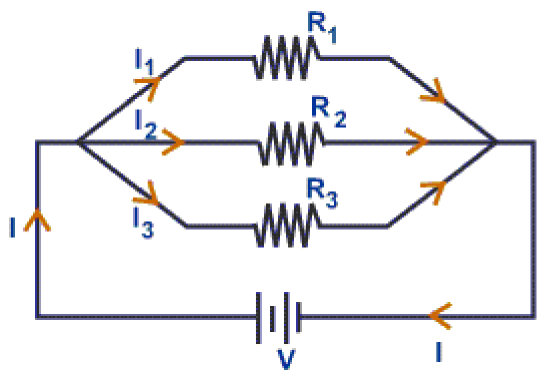
Parallel combination of Resisters:

Two or more resistances are said to be parallel connection when, first terminals are connected to one point and second terminals are connected to another point and having different current direction is called parallel combination of resisters.

We know from Ohms law

V=IR, $V=I_1R_1$, $V=I_2R_2$ and $V=I_3R_3$

$$I=\frac{V}{R}\ and\ I_1=\frac{V}{R_1}, I_2=\frac{V}{R_2}\ and\ I_3=\frac{V}{R_3}$$



The potential difference across the two terminal points of the circuit remains the same.

The equivalent current through the circuit is the sum of individual currents through each branch of the circuit.

$$I=I_1+I_2+I_3$$

$$\frac{V}{R}=\frac{V}{R_1}+\frac{V}{R_2}+\frac{V}{R_3}$$

$$\frac{1}{R}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}$$

In parallel combination of resistances, The reciprocal of the resultant resistance is equal to the reciprocal of the individual resistances in a circuit.

Galvanometer:

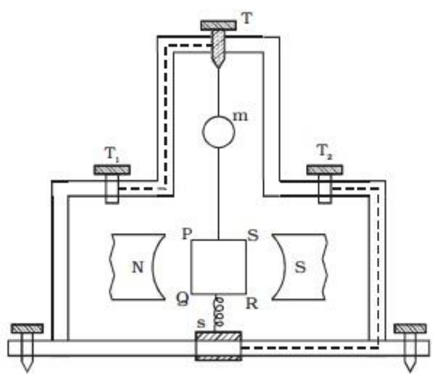
A galvanometer is an instrument that can detect and measure small amounts of current in an electrical circuit.

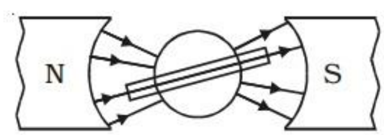
The moving coil galvanometer is made up of a rectangular coil that has many turns and it is usually made of thinly insulated or fine copper wire that is wounded on a metallic frame. The coil is free to rotate about a fixed axis. A phosphor-bronze strip that is connected to a movable torsion head is used to suspend the coil in a uniform radial magnetic field. Essential properties of the material used for suspension of the coil are conductivity and 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.

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

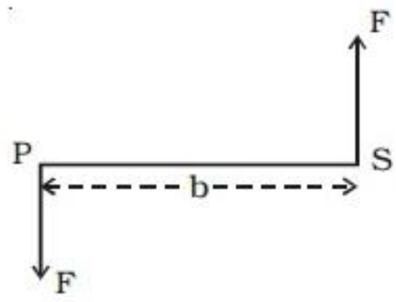
Using Fleming's left-hand rule we can determine that the forces on AD and BC are in opposite direction to each other. When equal and opposite forces F called couple acts on the coil, it produces a torque. This torque causes the coil to deflect.

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 × b



Torque τ acting on single-loop ABCD of the coil = BIA

Where lx b is the area A of the coil,

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

$$\tau = BIAn$$

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 a counter torque or restoring torque $k\theta$ which results in a steady angular deflection.

Under equilibrium condition:

$$k\theta = BIAn$$

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.

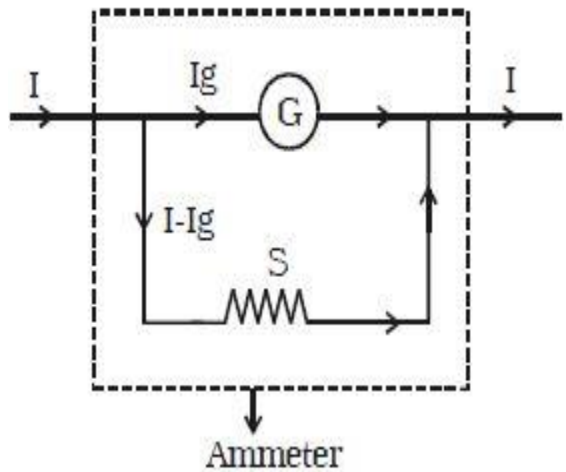
$$\theta = (BAn / k)I$$

Therefore $\theta \propto I$

The quantity BAn / 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.

Conversion of Galvanometer to Ammeter:

A galvanometer is converted into an ammeter by connecting it in parallel with a low resistance called shunt resistance. Suitable shunt resistance is chosen depending on the range of the ammeter.



In the given circuit

G – Resistance of the galvanometer

G- Galvanometer coil

I – Total current passing through the circuit

I_G – Total current passing through the galvanometer which corresponds to full-scale reading

S – Value of shunt resistance

When current I_G passes through the galvanometer, the current through the shunt resistance is given by $I_S = I - I_G$. The voltages across the galvanometer and shunt resistance are equal due to the parallel nature of their connection.

Therefore $G.I_G= (I- I_G).S$

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

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.

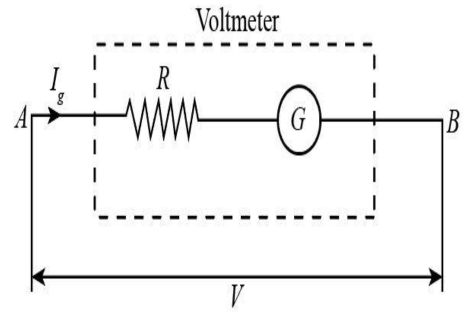
In the given circuit

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.

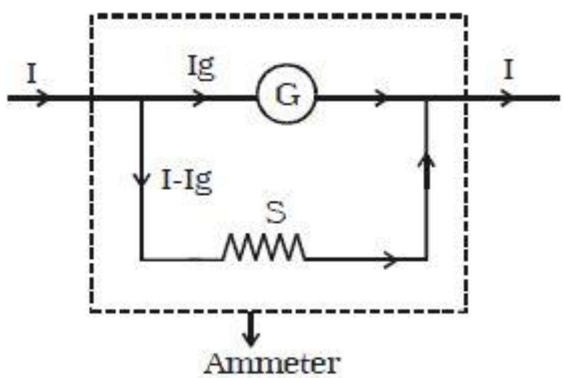
When current IG passes through the series combination of the galvanometer and the high resistance R; the voltage drop across the branch ab is given by

$$V = GI_G + R.I_G$$

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

Multimeter:

A multimeter is a measuring instrument that can measure multiple electrical properties. A typical multimeter can measure voltage, resistance, and current, in which case it is also known as a volt-ohm-milli ammeter (VOM), as the unit is equipped with voltmeter, ammeter, and ohmmeter functionality. Some feature the measurement of additional properties such as temperature and volume.



Analog multimeters use a microammeter with a moving pointer to display readings. Digital multimeters (DMM, DVOM) have numeric displays and have made analog multimeters obsolete as they are cheaper, more precise, and more physically robust than analog multimeters.

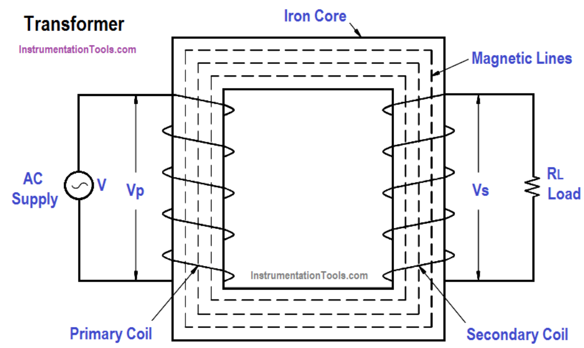
Digital Multimeter gives accurate measurements, consistent, reliable performance, attention to safety and the strongest warranty available.

Transformer:

A transformer is a passive component that transfers electrical energy from one electrical circuit to another circuit, or multiple circuits. A varying current in any one coil of the transformer produces a varying magnetic flux in the transformer's core, which induces a varying electromotive force across any other coils wound around the same core. Electrical energy can be transferred between separate coils without a metallic (conductive) connection between the two circuits.

Transformers are most commonly used for increasing low AC voltages at high current (a step-up transformer) or decreasing high AC voltages at low current (a step-down transformer).

By Faraday's law of induction



$$Induced\ emf\ E = N\frac{d\varphi}{dt}$$

In case of primary circuit

$$Induced\ emf\ E_P = N_P\frac{d\varphi}{dt}$$

In case os secondary circuit

$$Induced\ emf\ E_s = N_s\frac{d\varphi}{dt}$$

From the above two equations

$$\frac{E_P}{E_s} = \frac{N_P}{N_s} = a$$

Where:

E_P – is the Primary Voltage

E_S – is the Secondary Voltage

N_P – is the Number of Primary Windings

N_S – is the Number of Secondary Windings

Where for a step-down transformer a > 1, for a step-up transformer a < 1, and for an isolation transformer a = 1.

Electrical Energy

Electrical energy is energy derived as a result of movement of electrically charged particles. This energy is supplied by the combination of electric current and electric potential that is delivered by an electrical circuit.

Electrical energy used in a resistance is equal to energy liberated from the resistance.

$$Energy\ Q = E = I^2Rt$$

Or

$$Energy\ Q = E = IVt$$

Where V=IR

The basic unit of electrical energy is the joule or watt-second.

1 kwh = 36 × 10^5 Ws or Joules

Power(P):

The rate of transfer of electrical energy by an electrical circuit is called electrical power.

Or

The transfer of electrical energy per unit time in an electrical circuit is called electrical power.

$$Power\ P = \frac{W}{t} = \frac{Q}{t}$$

$$Power\ P = \frac{I^2Rt}{t}$$

$$Power\ P = I^2R$$

$$Power\ P = VI$$

SI Units of Power is Watt.

The watt is the rate of energy conversion and it is equivalent to one joule per second.

Electrically one watt is equal to an amount of work done when one Ampere of current flowing and one Volt of voltage exists in a circuit.

Commercial units of electrical power is Horse Power (HP)

1HP=746W

Kilo watt hour (KWH):

Kilo watt Hour is a unit of electrical energy.

$1KWH = 1x1000xWx3600sec$

$1KWH = 3600000Wsec$

$1KWH = 3.6x10^3 Wsec$

$1KWH = 3.6x10^3 J$

Consumption of Electric Power:

Electric energy consumption is the form of energy consumption that uses electric energy. Electric energy consumption is the actual energy demand made on existing electricity supply.

Electric devices and electronic devices consume electric energy to generate desired output.

The total consumption of electric energy can be divided into several categories, such as driving (electric motors), lighting, heating, communication, information, and others. Concerning the worldwide situation, it is estimated that electric motor driven systems (EMDSs) account for between 43% and 46% of the global electricity consumption. This amount is more than twice that of the second largest, which is lighting, contributing by 19% to the total consumption.

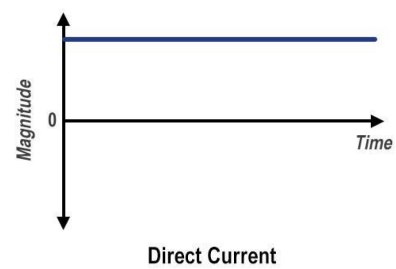
ELECTRICAL APPLIANCES

UNIT-2

Direct Current:

Direct current (DC) is one-directional flow of electric charge. An electrochemical cell is a prime example of DC power. Direct current may flow through a conductor such as a wire, through semiconductors and insulators.

Direct current may be converted from an alternating current supply by use of a rectifier. Direct current may be converted into alternating current by using an inverter. Direct current has many uses, from the charging of batteries to large power supplies for electronic systems, motors, and more.

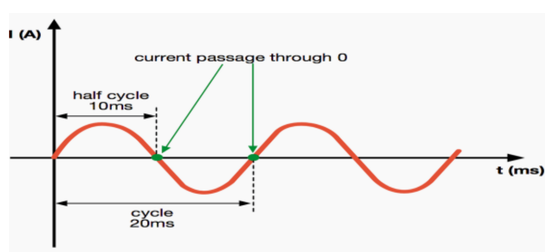


Very large quantities of electrical energy provided via direct-current are used in smelting of aluminum and other electrochemical processes. High-voltage direct current is used to transmit large amounts of power from remote generation sites or to interconnect alternating current power grids.

DC is commonly found in many low-voltage applications, especially where these are powered by batteries or solar power systems.

Alternating Current (AC)

Alternating current (AC) is an electric current which periodically reverses direction and changes its magnitude continuously with time.



Alternating current is sinusoidal or triangular or rectangular. The sinusoidal alternating current can be written as

$$Alternating\ current\ I = I_o Sin\ (\omega t + \varphi)$$

Where Io is maximum current, ω is angular frequency and φ is initial phase.

The main differences between AC and DC:

	Alternating Current (AC)	**Direct Current (DC)**
The direction of flow of current	When an alternating current flowing through a circuit, it reverses its direction.	When a direct current flowing through the circuit, it will not change the direction.
Frequency	The frequency of alternating current decides how many times it reverses its direction. If the frequency is 50 Hz, it means the current changes direction 50 times.	The frequency of the direct current is always zero. Because it never changes its direction.
Movement of Electron	Electrons keep changes its direction from forward to backward	Electrons move only in a forward direction.
Current magnitude	The magnitude of the instantaneous current is varying with time.	The magnitude is constant at each instant of time for pure DC. But it is variable for pulsating DC.
Power factor	It ranges between 0 and 1.	It is always 1.
Passive Parameter	Impedance (Combination of Reactance and Resistance).	Resistance only.
Types	Sinusoidal, Trapezoidal, Square, Triangular	Pure DC and Pulsating DC

Convert	It can convert from DC supply with the help of Invertor.	It can convert from AC supply with the help of a rectifier.
Source	AC Generator	DC Generator and battery
Dangerous	It is dangerous.	But it is more dangerous than AC for the same power rating.
Application	Most of the household, industrial and commercial equipment operate on DC.	Cell phones, Electric Vehicle, Electroplating, Flashlight, etc.

RMS value of Alternating current:

RMS stands for Root-Mean-Square of instantaneous current values. The RMS value of alternating current is given by direct current which flows through a resistance. The RMS value of AC is greater than the average value.

We know

$$Alternating\ current\ I = I_o Sin\ \omega t$$

Where, Io is maximum value or peak value of alternating current.

By definition the RMS value of alternating current

$$I_{RMS}^2 = \frac{\int_0^T (I)^2 dt}{\int_0^T dt}$$

$$I_{RMS}^2 = \frac{\int_0^T (I_o Sin\ \omega t)^2 dt}{\int_0^T dt}$$

$$I_{RMS}^2 = \frac{\int_0^T I_o{}^2 Sin^2 \omega t\ dt}{\int_0^T dt}$$

$$I_{RMS}^2 = I_o{}^2 \frac{\int_0^T Sin^2\omega t\, dt}{(t)_0^T}$$

$$I_{RMS}^2 = I_o{}^2 \frac{\int_0^T \left(\frac{1 - cos2\omega t}{2}\right) dt}{T}$$

$$I_{RMS}^2 = \frac{I_o{}^2}{2T} \int_0^T (1 - cos2\omega t) dt$$

$$I_{RMS}^2 = \frac{I_o{}^2}{2T} (T)$$

$$I_{RMS}^2 = \frac{I_o{}^2}{2}$$

$$I_{RMS} = \frac{I_o}{\sqrt{2}}$$

RMS value of alternating current $I_{RMS} = \frac{I_o}{\sqrt{2}}$

Power factor:

The power factor of an alternating current is defined as the ratio of the true power flowing through the circuit towards the evident power present in the circuit.

It usually ranges from the intervals of -1 to 1 and is dimensionless.

It is denoted by the expression as follows-

$$Power\ factor = \frac{True\ Power}{Evident\ Power}$$

or, cos ø= R/Z

Where R= resistance in the circuit and Z= hindrance in the circuit.

For a purely inductive or capacitive circuit, it is 0 and for a purely resistive circuit, it is taken to be 1.

$$Power\ factor = \frac{Actual\ power}{Apparant\ Power}$$

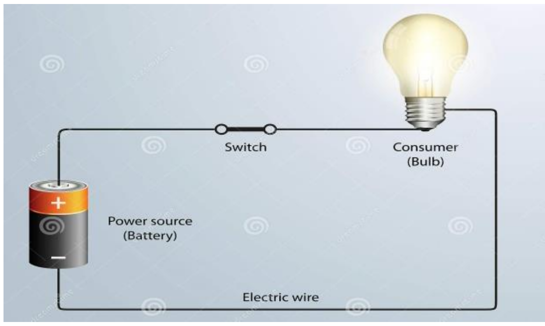
$$Power\ factor = \frac{VI\ Cos\ \varphi}{VI}$$

$$Power\ factor = Cos\ \varphi$$

Single Phase Connection:

The alternating current power supply can be classified into single-phase(1-phase) and three-phase(3-phase). In general, a single-phase power is used where electricity requirement is low. In short, it is for running small equipment. The three-phase power carries a heavy load and can run large machinery in factories.

When it comes to single phase vs three phase, the main difference is that the former is used for household electricity requirements and the latter one is used to run heavy machinery.



In single phase electricity, the supply voltage of the power changes simultaneously. In general, a single-phase current is called “residential voltage” because it is mostly used in homes.

When it comes to distributing power, a single-phase connection uses neutral and phase wires. The neutral wire acts as a returning path for the current and the phase wires carry the load.

In a single-phase connection, the voltage starts at 230 Volts and has a frequency of about 50 Hertz. Because the voltage in a single-phase connection rises and falls constantly, constant power isn't delivered to the load. Let's discuss the advantages and disadvantages of using a single-phase power.

Advantages

Single-phase connections are intended for domestic supplies and residential homes. That's because, most of the appliances require a small amount of electricity to perform such as television, lights, fans, refrigerator, etc.

The functioning of a single-phase connection is simple and ordinary. It comprises a compact and lightweight unit where the flow of electricity through the wires will be lower if the voltage is higher.

Because of the reduction in power, it ensures that the power from a single-phase connection operates at optimum and transmit power effectively.

A single-phase connection work best with units for up to 5 Horse Power.

Disadvantages

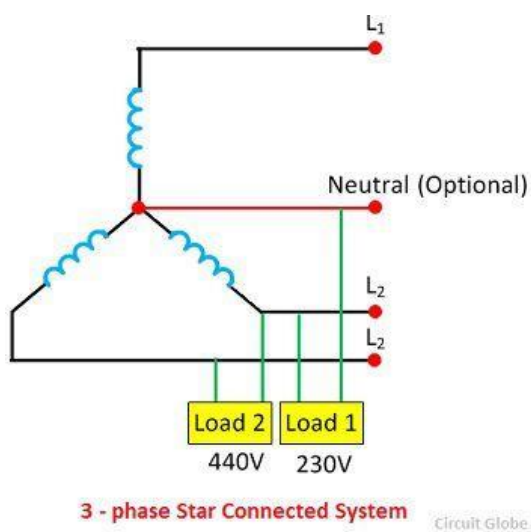
Heavy equipment such as industrial motors and other machinery alike cannot run by using a single-phase power supply.

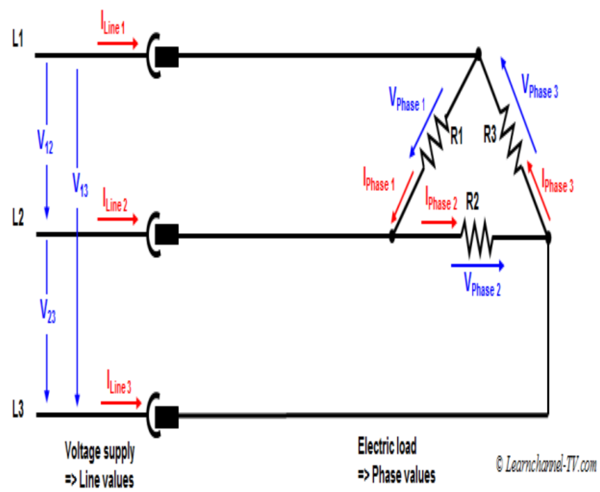
Small motors, which are less than single Kilowatt cannot run on a single-phase power supply because of the absence of initial torque required by the motor. So, for the smooth running of the motor, extra equipment called a motor starter is required.

Three Phase connections:

The three phases connection system contains the current will pass through the three wires, and there will be one neutral wire for passing the fault current to the earth. In other words, the system which uses three wires for generation, transmission and distribution is known as the three phase system. It means the three-phase system has four wires, i.e., the three current carrying conductors and the one neutral.

The three-phase systems are connected in two ways, i.e., the star connection and the delta connection.





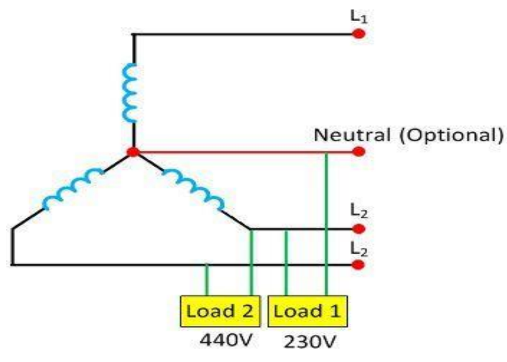
The three phase system induces in the generator which gives the three phase voltage of equal magnitude and frequency. The sum of the line currents in the 3-phase system is equal to zero, and their phases are differentiated at an angle of 120º. It provides an uninterruptible power, i.e., if one phase of the system is disturbed, then the remaining two phases of the system continue supplies the power. The magnitude of the current in one phase is equal to the sum of the current in the other two phases of the system.

The three-phase system has several advantages like it requires fewer conductors as compared to the single phase system. It also gives the continuous supply to the load. The three-phase system has higher efficiency and minimum losses.

Star Connection:

The three-phase systems are connected in two ways, i.e., the star connection and the delta connection.

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

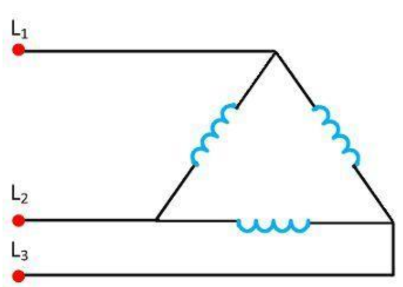


3 - phase Star Connected System

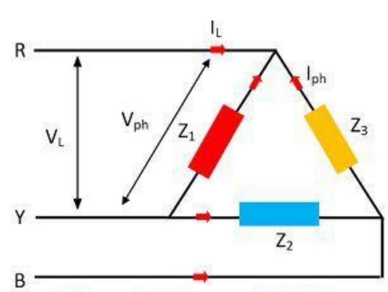
The star connected three phase systems gives two different voltages, i.e., the 230 V and 440V. The voltage between the single phase and the neutral is 230V, and the voltage between the two phases is equal to the 440V.

Delta Connection

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



3 - Phase Delta Connection



3 - Phase Load Connected in Delta

The three phase load may be balanced or unbalanced. If the three loads (impedances) Z_1, Z_2 and Z_3 have the same magnitude and phase angle then the three phase load is said to be a balanced load. Under balance condition, all the phases and the line voltages are equal in magnitude.

Basics of House Wiring

1. Electrical Service Connection and Meter

Home electricity starts with the power service and electric meter. The meter measures the amount of electricity your home uses and is the basis for the charges on your electric bill. The meter runs only when electricity is used in the house.

2. Disconnect Switch

Some home electrical systems include a dedicated disconnect switch that is mounted on an outside wall of the home near the electric meter. In the event of a fire or flash flood, or if work needs to be done on the system, a disconnect switch allows you to shut off the power from outside the home so you don't have to enter the home to turn off the power.

3. Main Service Panel

After passing through the meter, your electrical service feeds into your home's main service panel, commonly known as the breaker box. Two large "hot" wires connect to big screw terminals, called lugs, inside the service panel, providing all the power to the panel. A third service wire, the neutral, connects to the neutral bus bar inside the panel.

4. Main Circuit Breaker

The service panel contains a large main breaker that is the switch controlling the power to the rest of the circuit breakers inside the panel. It is sized according to your home's service capacity A main breaker of 200 amps will allow a maximum of 200 amps to flow through it without tripping. In a tripped state, no current will flow to the panel.

5. Branch Circuit Breakers

The breakers for the branch circuits fill the panel (usually below) the main breaker. Each of these breakers is a switch that controls the flow of electricity to a branch circuit in the house.

Turning off a breaker shuts off the power to all of the devices and appliances on that circuit. If a circuit has a problem, such as an overload or a fault, the breaker automatically trips itself off.

6. **Devices**

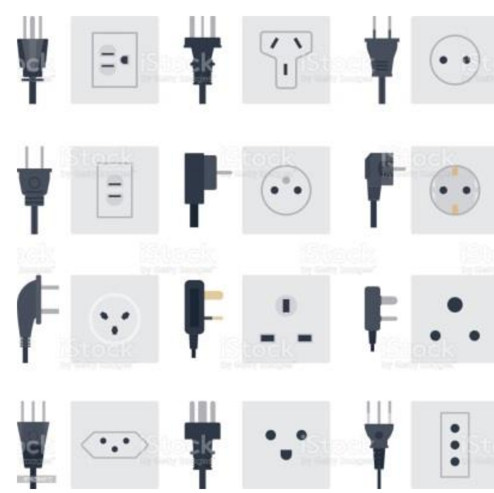
Devices are all the things in the house that are connected to electricity, including switches, receptacles (outlets), light fixtures, refrigerators, furnaces, and water heaters and appliances. Devices are connected to the individual branch circuits that start at the breakers in the main service panel.

7. **Switches**

Switches are the devices that turn on and off lights and fans in your home. They come in many different styles and colors to suit your design needs. There are single-pole, two-way, three-way, four-way, and dimmer switches. When you flip a switch off, it "opens" the circuit, meaning the circuit is broken or not complete and the power is interrupted. When the switch is on, the circuit is "closed," and power flows beyond the switch to the light or another device it is controlling.

8. **Outlets**

Electrical outlets, technically called receptacles, provide power to plug-in devices and appliances. Televisions, lights, computers, freezers, vacuums and toasters are all good examples of devices that can be plugged into an outlet. Standard outlets in a home are either 15-amp or 20-amp; 20-amp outlets can provide more electricity without tripping a breaker.



9. **Wiring**

Your home's wiring consists of a few different types of wiring, including non-metallic cable (commonly called Romex), Box cable, and wiring concealed in conduit. NM cable is the most common type of circuit wiring. It is suitable for use in dry, protected areas (inside stud walls, on the sides of joists, etc.) that are not subject to mechanical damage or excessive heat.

Electric Shock

Like salt water and metal, the human body is a conductor of electricity. Therefore, it’s important to avoid situations where you might come into contact with electricity. An electric shock occurs when a person comes into contact with an electrical energy source. Electrical energy flows through a portion of the body causing a shock. Exposure to electrical energy may result in no injury at all or may result in devastating damage or death.

Burns are the most common injury from electric shock. Adolescents and adults are prone to high voltage shock caused by mischievous exploration and exposure at work. Low voltage electricity may result in only superficial burns or possibly more severe injuries depending on the variables above. Exposure to high voltage electricity (greater than 500 volts) has the potential to result in serious damage.

If you are going to help someone who has sustained a high voltage shock, you need to be very careful that you don't become a second victim of a similar electrical shock. If a high voltage line has fallen to the ground, there may be a circle of current spreading out from the tip of the line. A victim who has fallen from a height or sustained a severe shock causing multiple jerks may have a serious neck injury and should not be moved without first protecting the neck.

Following a low-voltage shock, go to the emergency department for the following concerns:

1. Any noticeable burn to the skin
2. Any period of unconsciousness
3. Any paralysis, vision, hearing, or speech problems
4. Confusion
5. Difficulty breathing
6. Injury may occur to muscles, the heart, or the brain from the electricity or to any bones or other organs from being thrown from the electric source.

First Aid for Electric Shock Victims

1. Don't touch them!
2. Unplug the appliance or turn off the power at the control panel.
3. If you can't turn off the power, use a piece of wood, like a broom handle, dry rope or dry clothing, to separate the victim from the power source.
4. Do not try to move a victim touching a high voltage wire. Call for emergency help.
5. Keep the victim lying down. Unconscious victims should be placed on their side to allow drainage of fluids. Do not move the victim if there is a suspicion of neck or spine injuries unless absolutely necessary.
6. If the victim is not breathing, apply mouth-to-mouth resuscitation. If the victim has no pulse, begin cardio pulmonary resuscitation (CPR). Then cover the victim with a blanket to maintain body heat, keep the victim's head low and get medical attention.

Over Loading

Overloading of an electric circuit means when current flows in a circuit it becomes more than the capacity of components in the circuit to resist the current. When too much current passes an electric overload occurs through electric wires. This results in the heat in the wire and the wire gets melted moreover it increases the risk of fire.

PRECAUTIONS SHOULD BE TAKEN FOR OVERLOADING IS GIVEN BELOW:

1. Avoid using too many appliances at the same time.
2. Make sure the appliance you are using must be within the safe limit of the electric circuit.
3. Avoid connecting too many appliances in one socket.
4. Electric fuse should be connected in series, it will protect the circuit from overloading and short circuiting.
5. Proper earthing of all electric circuits must be done.

OVERLOADING SIGNS:

1. Flickering, blinking of lights
2. Burning odor

3. Warm or discolored wall plates.
4. Mild shock or tingle from switches.

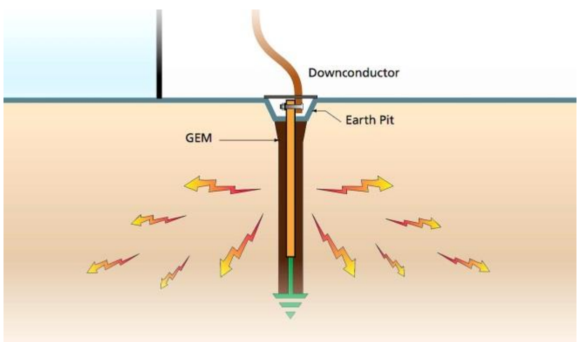
Continued overload can result from defective motors, overloaded equipment or we can say too many loads on one circuit. Such overloads are destructive and must be cut off by protective devices as soon as possible before they damage the circuit.

There is a key difference between short circuit and overloading that is;

When the neutral and the live wire come in contact with each other the short circuit takes place whereas when the number of equipment connected to one socket the overloading takes place.

Earthing and its necessity

Earthing is system in which the part of the equipment is connected to the earth with the help of the wires or cables. Earthing is also known as the grounding system. Earthing is defined as the disharge of electric current in the earth with the help of the wires or cables having low resistance. Mostly Galvanised iron (G.I) strips are used for the earthing. Earthing protects the humans from getting electric shock from the leakage current and when a live wire or cable comes in the contact of the body of the equipment or from the short circuit current.



It also causes the protective device (either a circuit-breaker or fuse) to switch off the electric current to the circuit that has the fault.

For example, if a cooker has a fault, the fault current flows to earth through the protective (earthing) conductors. A protective device (fuse or circuit-breaker) in the consumer unit switches off the electrical supply to the cooker. The cooker is now safe from causing an electric shock to anyone who touches it.

Types of Earthing

There are two types of earthing in electrical system:-

1. Pipe earthing
2. Plate earthing
3. Chemical earthing

Pipe earthing

A galvanized steel and a perforated pipe of approved length and diameter is placed vertically in a wet soil in this kind of system of earthing. It is the most common system of earthing.

Plate earthing

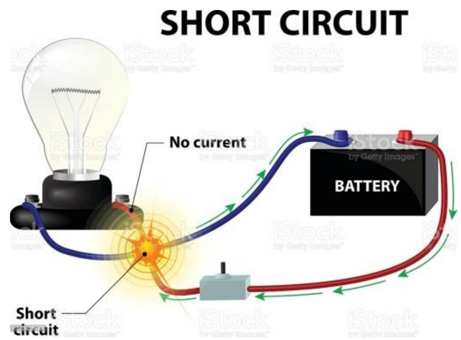
In plate earthing system, a plate made up of either copper with dimensions 60cm x 60cm x 3.18mm or galvanized iron (GI) of dimensions 60cm x 60cm x 6.35 mm (2ft x 2ft x ¼ in) is buried vertical in the earth which should not be less than 3m (10ft) from the ground level.

Chemical earthing

Chemical earthing is recently introduced. In this type of earthing arrangements are same like pipe earthing but the charcoal and salt replaced by the chemical. In this type of earthing there is less chance of loosing resistivity and also demands less maintenace as compared to other type of earthing.

Short circuiting

A short circuit is an abnormal condition in an electrical circuit where the electrical current flows through an unintended, shorter pathway instead of following the circuit.



It can cause serious damage, fire, and even small-scale explosions. In fact, short circuits are one of the leading causes of structural fires around the world.

There are number of factors that can lead to a short circuit. Here are some of the most common causes.

1. The wiring encounters water or some other liquid.
2. Faulty insulation or loose connections can result in the live and neutral wires coming in contact with each other.
3. Nail and screw punctures that cause the wire casings to deteriorate.
4. An abnormal build-up of electrical currents within your home's electrical wiring system.
5. Common pests like rats, mice, and squirrels, chew the wires.
6. Old or malfunctioning appliances with damaged plugs or power cords can also cause a short circuit. That's because when an appliance is plugged into a wall outlet its wiring essentially becomes an extension of the circuit.

Protection against Short Circuits

Short circuits pose a danger of shock and fire. Fortunately, your home's wiring system has various means in place to safeguard against these dangers.

Circuit breakers or fuses use an internal system of springs or compressed air to detect changes in electrical current flow. They are designed to break the circuit connection when any irregularity occurs.

Fuses

In electronics and electrical circuits, a fuse is an electrical safety device that operates to provide overcurrent protection of an electrical circuit. Its essential component is a metal wire or strip that melts when too much current flows through it, thereby stopping or interrupting the current.

The Fuse is made up of a material which has high resistivity and low melting point, so that it melts down due to overheating of the wire during high current flow. The thickness of the Fuse wire is determined based on the amount of current flow in the circuit. Normally an alloy of tin and lead is used as the Fuse wire, as it has high resistivity and low melting point.

Working Principle

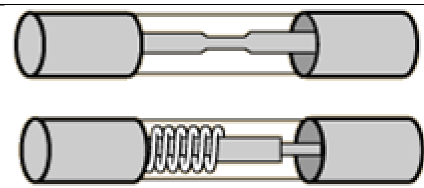
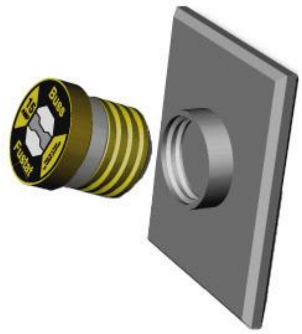
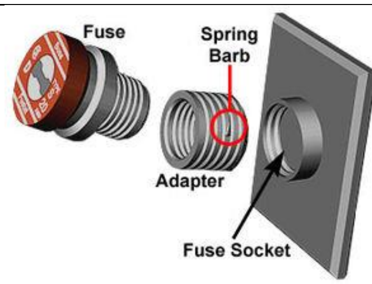
The Electric Fuse works on the basis of the heating effect of the Electric Current. It is composed of a non-flammable thin metallic wire with a low melting point.

If a high amount of Electricity is passed from the Electric Fuse, there is a production of heat which causes the Fuse to melt which leads to the opening of the Circuit and the blockage of Current.

Once a Fuse melts, it can be changed or replaced with a new Fuse.

A Fuse is normally made up of elements like zinc, copper, aluminum and silver.

A Fuse acts as a circuit breaker and breaks the circuit in case any fault occurs in the circuit. It acts as a protector of Electric appliances and also as a safety measure for humans.

Fuse type	Description	Picture
Cartridge	Contains a thin conductor designed to melt at a low temperature. Once the current reaches a level that can generate enough heat to match or surpass the designed melting point, the connection will break.	
Blade	Contains two electrical connectors that plug into a circuit and a wire inside that will melt at a certain current.	
Plug	Screwed directly into a standard fuse socket.	
Adapter	Referred to as a rejection base (also called type-S), it requires an adapter to fit into a standard fuse socket. Once it is installed it cannot be removed.	

MCB (Miniature Circuit Breakers)

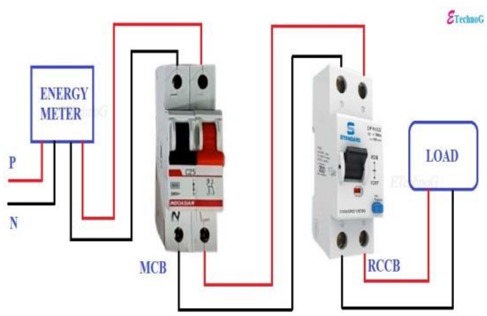
MCB stands for Miniature Circuit Breakers. The MCB is an electromechanical device that switches off the circuit automatically if an abnormality is detected. The MCB easily senses the over current caused by the short circuit. The miniature circuit has a very straight forward working principle.

If the current increases, the movable contacts are disconnected from the fixed contacts, making the circuit open and disconnects them from the main supply.

Working of Miniature Circuit Breaker (MCB)

Mini circuit breakers are triggered by over current - electrical current that exceeds a designated safe current and makes use of a relatively robust mechanical mechanism designed to minimize failures and false alarms.

Excess current causes the bimetallic strip within the MCB to heat, bends, and trip. This releases a switch which moves the electrical contact points apart to confine the arc (electrical discharge). The arc is divided and cooled by an insulated metal strip called the arc chute. The contacts close again once the fault has been fixed and the MCBs are reset.

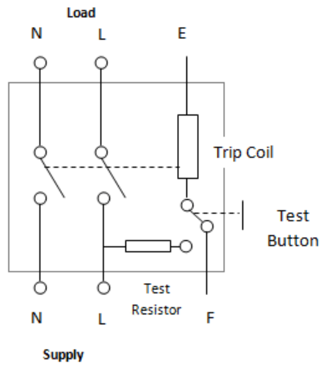


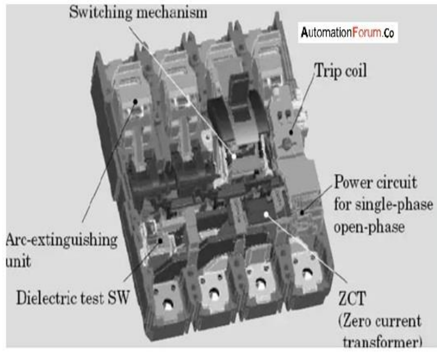
An MCB is designed to protect against both overloading and short-circuiting. These are detected differently using separate processes. Overload protection is provided by the bimetallic strip using thermal operation, whereas short-circuits protection is provided by the tripping coil via electro-magnetic operation.

If the discharge is especially high, the MCB will trip very quickly – within one-tenth of a second. When the over current is closer to the safety limits, the component will be slower to respond.

ELCB (Earth Leakage Circuit Breaker)

An Earth-leakage circuit breaker (ELCB) is a safety device used in electrical installations with high earth impedance to prevent shock. It detects small stray voltages on the metal enclosures of electrical equipment and interrupts the circuit if the voltage level exceeds danger threshold.





The main purpose of ELCB is to detect Earth leakages and prevent injury to human beings from electrical shocks and prevent electrical fires that are caused by short Circuit.

An ELCB is a specialized type of latching relay that has a building's incoming mains power connected through its switching contacts so that the ELCB disconnects the power in an earth leakage condition. The ELCB detects fault currents from live (hot) to the earth (ground) wire within the installation it protects. If high voltage appears across the ELCB's sense coil, it will switch off the power, and remain off until manually reset. Thus, protecting the electrical system in the building.

ELCB Operation

An electrical circuit breaker is a particular kind of latching relay and it has a mains supply of buildings that are connected throughout its switching contacts so that this circuit breaker will disconnect the power once earth leakage is identified. By using this, the fault current can be detected from life to the ground wire in the fitting it guards. If ample voltage comes out across the sense coil of the circuit breaker, then it will shut down the power & remain off until physically reset. An ELCB which is used for voltage-sensing does not detect fault currents.

Insulation

Insulators have a high resistance, we can also describe them as having "low electrical conduction". Insulators come in solid, liquid and gas forms.

Clay (ceramic) - This is the standard material for high voltage and RF insulators.

Plastics - PVC, Cresyl Pthalate, DEHP and other plastics replaced rubber as an insulator for wires and other parts. PVC and nylon are now standard in most types of wire.



1. Glass (silica, soda ash and limestone) - This material worked fine for telegraph and other low voltage apparatus.
2. Paper/Cardboard - paper and cardboard are used as insulators in certain circumstances as these materials are cheap and can work in situations without high heat or high voltages.
3. Mica - This is a good stable material even when exposed to the elements. It is a good thermal conductor while being an insulator. Sheet mica is easily stamped and shaped for electrical components.
4. Teflon - Slippery, durable and resistant to corrosion this Dupont made material is used in cable jackets.
5. Rubber - Rubber in its natural and synthetic forms was used as an insulator from before the 1870s until the 1950s. Plastics (especially PVC) replaced rubber.
6. Wax and oil - in the 1880s Edison used trinidad asphaltum with linseed oil, beeswax and paraffin to insulate copper wires mounted inside of iron pipes. This was used for durable underground power lines. This was used at the famous Pearl Street Station in NYC.

Importance of Insulation

1. Electrical insulation is not only important, but necessary. The main reason for electrical insulation is to maintain safety and to avoid electric shock.

2. Electric shock can result in fatal injuries resulting from involuntary movement. It can also cause death from ventricular fibrillation (heart pumping problems) or muscle contraction.
3. In addition to preventing electric shock, insulation also protects the materials through which electric current flows. Electrical insulation limits current flow between different electrical conductors.

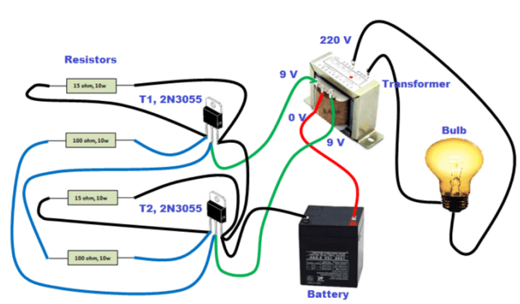
Application of Insulator

Since the Electrical Insulator materials bind the electrons tightly, it prevents the electrons from floating from atom to atom. Thus, they prevent the conduction of Electric charges. Given the benefits of there are multifold applications of the Electrical Insulator. They are applied to-

1. Circuit boards
2. Coating of Electric wires
3. High voltage appliances
4. Coating of cables
5. Coating for Electric poles on the streets

Invertor

An inverter is one of the most important devices in a solar energy system. It's a device that converts direct current (DC) electricity, which is what a solar panel generates, to alternating current (AC) electricity.



Fundamentally, an inverter accomplishes the DC-to-AC conversion by switching the direction of a DC input back and forth very rapidly. As a result, a DC input becomes an AC output. In addition, filters and other electronics can be used to produce a voltage that varies as a clean, repeating sine wave that can be injected into the power grid.

The basic circuits include an oscillator, control circuit, drive circuit for the power devices, switching devices, and a transformer.

The conversion of D.C to alternating voltage is achieved by converting energy stored in the dc source such as the battery, or from a rectifier output, into an alternating voltage. This is done using switching devices which are continuously turned on and off, and then stepping up using the transformer.

Uninterruptible Power Supply (UPS)

An uninterruptible power supply or uninterruptible power source (UPS) is an electrical apparatus that provides emergency power to a load when the input power source or mains power fails.

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.

A UPS is typically used to protect hardware such as computers, data centers, telecommunication equipment or other electrical equipment where an unexpected power disruption could cause injuries, fatalities, serious business disruption or data loss.

Most UPS units are also capable of correcting common utility power problems:

1. Voltage spike or sustained overvoltage
2. Momentary or sustained reduction in input voltage
3. Voltage sag
4. Noise, defined as a high frequency transient or oscillation, usually injected into the line by nearby equipment
5. Instability of the mains frequency.

ELECTRICAL APPLIANCES

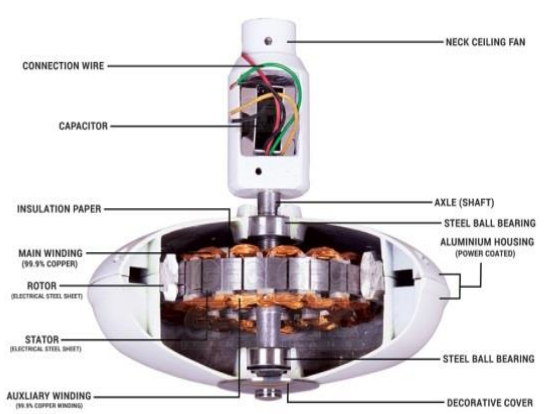
UNIT III

Electric Fan

Working principle of Electric Fan:

The ceiling fan's operation is based on the law of electromagnetic induction. The ceiling fan's induction motor converts electrical energy into mechanical energy. The motor requires a 250v single-phase alternating current supply.

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.



Components of electric fan:

Capacitor: 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.

Fan Blades: The blades are one of the most identifiable features of most fans. These are the paddle-shaped objects that spin and move air through the fan. They're angled to carry air from one point to another.

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.

Bearings: Ball bearings are used in the electric fan. As shown in the picture, 2 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 2 pcs of Magnets are used in Electric fan but this can change to 3 pcs 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.

Servicing of Electric fan

Electric fans can benefit from periodic cleaning. Follow these Electric fans maintenance tips to learn how to clean a fan motor, wipe down fan blades, and lubricate fan bearings to keep all components in working order.

1. Vacuum and Dust the Fan

Use a vacuum wand attachment or cloth or feather duster to remove all dust from the blades and exposed parts of the fan.

2. Tighten Screws

If you hear rattling while your fan is turned on, there's a chance a screw or other part of the fan system is loose. Check all components and tighten anything that may have come loose with a screwdriver.

3. Clean the Fan Motor

An essential part of your ceiling fan maintenance is to periodically check the motor. The ceiling fan motor's cover should keep most dust out, but some may still get in.

4. Lubricate Ceiling Fan Bearings

The final step in fan maintenance is lubrication. Many fans, especially newer models, are designed to be maintenance-free and never require oiling.

5. When a ceiling fan doesn't work at all, the first thing to do is to make sure it is receiving electrical power from its switch and from your home's circuit breaker or fuse box.

6. Most often, if the fan can be turned on but the blades don't spin, only run at one speed, or change speeds unexpectedly, the fan capacitor is defective or going bad.

Electric Iron Box

Principle of working:

An electric iron is based upon the principle of heating effect of current. This principle states that when an electric current is passed through a conductor, it generates heat because of the resistance present in it. The resistance converts electrical energy into heat energy.

The formula for the heat produced due to resistance and current is given by $Q=I^2RT$.

Parts of Electric Iron Box:

An electric iron box has following common parts:

1. Handle: The handle of an electric iron is made with plastic or wood. The reason is that these materials are insulators, current doesn't pass through them, so person who touch the handle while ironing would be saved to get shocked.

2. Sole plate: Soleplate, also called the hot plate, is the thick and flat triangular shaped surface made of aluminum that forms the base over which the electric iron is built up. Aluminum allows corrosion not to occur.

3. Cover Plate: The cover plate is made of thin sheet of iron. It is placed on top of the base plate and it covers all the internal parts of the iron. The handle and connector are only attached to the cover plate.

4. Pressure Plate: This plate is generally called the top plate as it follows the shape of sole plate. The pressure plate has some holes through which the studs form the base plate passes through.

5. Pilot Lamp: The pilot lamp is housed on the cover plate of the electric iron. One end of the pilot lamp is connected to supply, while the other end is connected to the heating element. A shunt resistance is provided across the pilot lamp which assists in providing a voltage drop.

6. Heating Element: Most heating elements are made with a nickel-chromium wire, having both tensile strength and high resistance to current flow. Heating elements are available in many sizes and shapes. In an electric iron, the heating element is present between the sole plate and pressure plate. It is pressed hard between the two plates.

7. Thermostat: Thermostat is an important component of an electric iron that regulates its temperature. The main function of thermostat is to keep heat constant in a given setting.

Working

When a current is passed through the heating element which is placed between the sole plate and pressure plate, the element gets heated up and transfers its heat to the sole plate through conduction and in-turn the sole plate also gets heated up. Now to remove the wrinkles in clothing, we should apply heat and pressure. Heat is formed due to the coil and when we press the clothes with iron, the wrinkles are removed. For maintaining the optimum temperature, a thermostat is used along with pilot lamp which serves as an indicator. The formula for the heat produced due to resistance and current is given by $Q=I^2RT$. This principle has many applications like heater, electric iron etc.

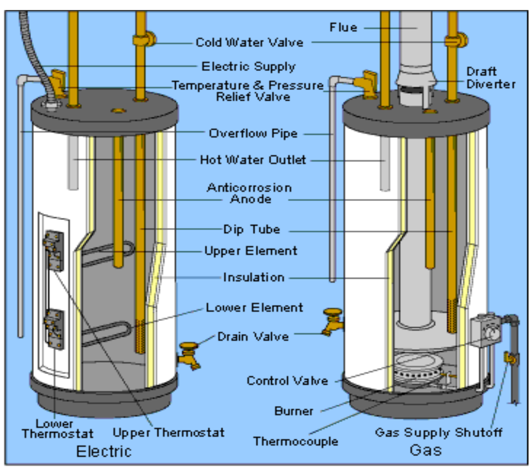
Water Heater

Principle of working:

Most water heaters work simply by converting the electrical energy into heat through the heating element to raise the temperature of the water to a particular degree. Obviously this is not much different from a common immersion rod which you can dip into your bucket, plug into the power socket and get going. The only difference is the level of sophistication and slight automation in the geyser. The formula for the heat produced due to resistance and current is given by $Q=I^2RT$.

Parts of the water heater

1. Tank - The inner shell of a water heater is a heavy metal tank containing a water protective liner that holds 10 to 50 liters of hot water at within the pressure range of a typical residential water system. The exterior of the tank is covered in an insulating material like polyurethane foam. Over that, there's a decorative outer shell and possibly an additional insulating blanket.



2. Dip tube - Water enters the water heater through the dip tube at the top of the tank and travels to the tank bottom where it's then heated.

3. Shut-off valve -The shut-off valve stops water flow into the water heater. It's a separate component from the heater located outside and above the unit.

4. Heat-out pipe -Suspended toward the top of the tank's interior, the heat-out pipe allows the hot water to exit the water heater.

5. Thermostat - This is a thermometer- and temperature-control device. Some electric water heaters have a separate thermostat for each element.

6. Heating mechanism - Electric water heaters have heating elements inside the tank to heat the water. Gas water heaters use a burner and chimney system instead.

7. Drain valve - Located near the bottom of the exterior housing, the drain valve makes it easy to empty the tank to replace the elements, remove sediment or move the tank to another location.

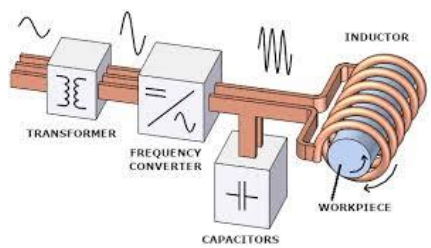
8. Pressure relief valve - This safety device keeps the pressure inside the water heater within safe limits.

Working

The dip tube feeds cold water from your home's water lines to the bottom of the tank's interior, where the water starts to warm up. The heating mechanism, either a burner or an element, stays on until the water reaches temperature. As the water heats, it rises to the top of the tank. The heat-out pipe is located near the top of the tank. Water exiting the water heater at the top is always the hottest in the tank at any given moment because it's the nature of hot water to rise above denser, cold water.

Induction Heater

An induction heater is a key piece of equipment used in all forms of induction heating. Typically an induction heater operates at either medium frequency (MF) or radio frequency (RF) ranges.



Components of an Induction Heater

Main component systems form the basis of a modern induction heater

a) Power Supply: Power supplies are one of the most important parts of an induction heater system. They are typically rated by their operating frequency range and power.

b) Impedance Matching: Induction heating power supplies, like every other electronic device, have maximum voltage and current values which should not be exceeded. In order to deliver the maximum power from the power supply to the load, the impedance of the power supply and the load must be as close as possible.

c) Resonance Tank: The resonance tank in an induction heating system is normally a parallel set of capacitor and inductor which resonates at a certain frequency. The frequency is obtained from the following formula:

Frequency formula $f = \frac{1}{2\pi\sqrt{LC}}$

where L is the inductance of the induction coil and C is the capacitance.

d) Induction Heater Inductors: A typical induction heater system includes a power supply, impedance matching circuit, tank circuit, and applicator. The applicator which is the induction coil can be a part of the tank circuit.

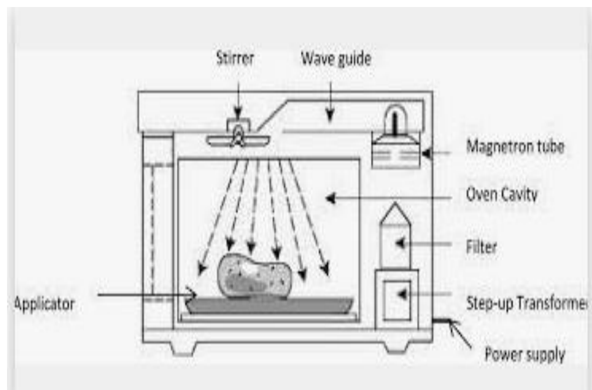
Working Procedure

The induction heating coil is specifically shaped copper tubing or other conductive material which alternating electrical current is passed through, creating a variable magnetic field. Metal parts or other conductive materials are placed within, through or close to the induction heating coil, without touching the coil and the variable magnetic field that is generated causes a friction within the metal causing it to heat.

Microwave Oven

Working Principle of Microwave Oven

A microwave oven (commonly referred to as a microwave) is an electric oven that heats and cooks food by exposing it to electromagnetic radiation in the microwave frequency range.



Microwave ovens work on the principle of conversion of electromagnetic energy into thermal energy. Electromagnetic (EM) energy refers to the radiation (waves) comprising an electrical field and magnetic field oscillating perpendicular to each other.

Main Components of Microwave Oven

1. **High Voltage Transformer**: Unlike many other household appliances, 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.

2. **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.
3. **Micro-controller**: A microcontroller is something that enables communication between a user and a machine. It is a controlling unit that contains one or more processing cores along with memory and programmable input/output peripherals.
4. **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).
5. **Cooling Fan**: Cooling fans reduce the magnetron's operating temperature and ensure its efficiency.

Working Mechanism

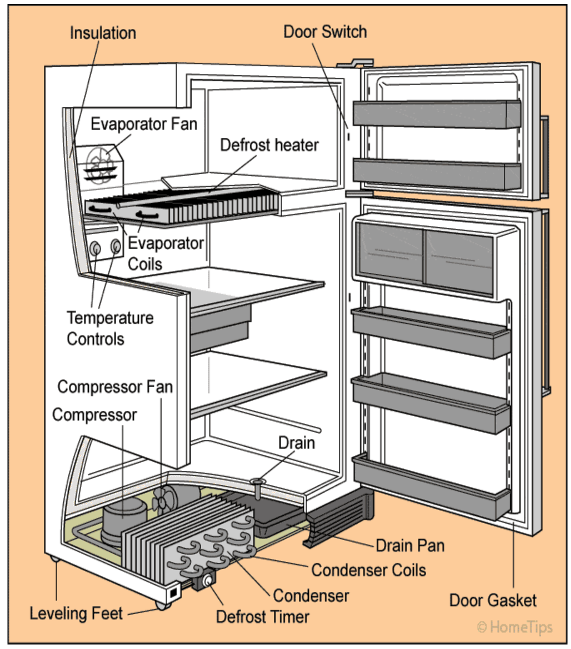
Microwave ovens work on the principle of conversion of electromagnetic energy into thermal energy. Electromagnetic (EM) energy refers to the radiation (waves) comprising an electrical field and magnetic field oscillating perpendicular to each other. When a polar molecule, i.e., a molecule containing opposite charges, falls in the path of these EM radiations, it oscillates to align with them. This causes the energy to be lost from the dipole by molecular friction and collision, resulting in heating. The water molecules present inside our food products go under a similar phenomenon when they come in contact with microwave radiations, heating the food from inside out. Microwaves are electromagnetic radiations with frequencies between 300MHz and 300 GHz, and the corresponding wavelengths ranging from 0.9m to .0009m, respectively. In most of the ovens, the microwave used is of 2.24GHz frequency.

Refrigerator

Working Principle of a Refrigerator

The principle of refrigeration and cooling is very simple: it involves removing heat from one region and depositing it in another. When you pass a low-temperature liquid close to objects that you want to cool, heat from those objects is transferred to the liquid, which evaporates and takes away the heat in the process.

The basic principle behind the working of a refrigerator is the second law of thermodynamics; more specifically, which states, "Heat can never pass from a colder to a warmer body without some external engine, occurring at the same time."



Components of Refrigerator

1. **Refrigerant Fluid:** Refrigerant fluid is usually a gas or a liquid that facilitates the conversion of thermal energy into mechanical energy by undergoing a phase change. The most commonly used refrigerant fluids have extremely low boiling points, e.g., hydro chloro fluoro carbon chemicals that are generically referred to as freons.
2. **Compressor:** The compressor is considered the heart of the refrigeration system. In technical terms, a compressor is a device that increases the pressure of a gas by reducing its volume. The compressor is usually located at the lower part of the backside of a refrigerator.
3. **Condenser:** The condensing coils are a mesh of pipes that one can find on the backside of the refrigerator. The main function of the condenser is to remove the inner heat of the refrigerator, just like a radiator. It is called a condenser because the removal of heat is

achieved by the condensation of the refrigerant fluid from vapor to liquid state inside the condensing coils.

4. **Thermostatic Expansion Valve**: A thermostatic expansion valve acts as a regulator that controls the flow of the liquid refrigerant into the evaporator. A thermostat controls the cooling process by switching the compressor on and off. When the sensor senses that it's cold enough inside a refrigerator, it turns off the compressor
5. **Evaporator**: This is the part of the refrigeration system that does the cooling inside the refrigerator. Its function is to absorb heat into the refrigeration system from the inside, which then radiates out of the system through the condenser. The evaporation coils are present inside the refrigerator where we put our food items.
6. **Receiver:** The receiver, or liquid receiver as it is commonly known, is a pressure vessel designed to hold liquid refrigerant. The function of a receiver is to store liquid refrigerant and provide a continuous flow of refrigerant to the expansion device.

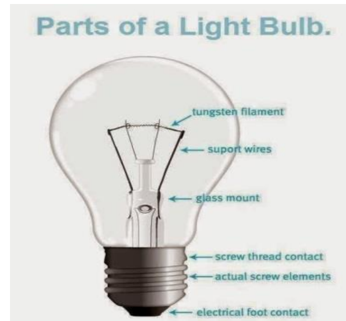
A refrigerator works in the following steps:

1. The compressor compresses the refrigerant gas. The compressed gas heats up as it is pressurized.
2. The coils on the back of the refrigerator let the hot refrigerant gas dissipate its heat. The refrigerant gas condenses into liquid at high pressure.
3. The high-pressure liquid flows through the expansion valve.
4. The liquid immediately boils and vaporizes, its temperature dropping to about -25°F, as the cold gas flows through the expansion coils (inside the refrigerator) it makes the inside cold by absorbing heat.
5. The low pressure refrigerant gas is sucked up by the compressor, and the cycle repeats.

Electric bulb

Thomas Alva Edison invented electric bulb in 1879 with a very high-resistance filament to increase the life of the light.

The light bulb has a tungsten filament as the light emitting media and is specially manufactured by precision machines to give the correct cross sectional area. The tungsten filament is coiled to give a very high resistance and is encased in a glass envelope. This glass envelope or bulb is filled with a low pressure inert gas such as nitrogen or argon.



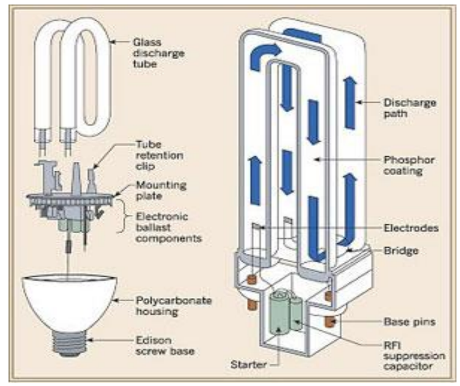
When electricity passes through the coiled tungsten filament, it becomes hot and glows.The inert gas conducts the heat generated by the filament to the glass bulb from where the heat is radiated into the atmosphere.

Parts of the Light Bulb

1. Glass bulb
2. Inert gas
3. Tungsten filament
4. Contact wire (goes to foot)
5. Contact wire (goes to base)
6. Support wires
7. Glass mount/support
8. Base contact wire
9. Screw threads
10. Insulation

Compact Fluorescent Light (CFL) Bulb

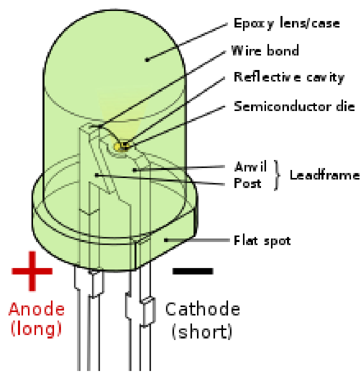
Compact Fluorescent Light (CFL) bulbs pose a marginally smaller risk of fire and are more efficient and long-lasting than both incandescent and halogen bulbs. While halogen bulbs can last up to 5,000 hours, CFLs are known to last as long as 8,000 hours.

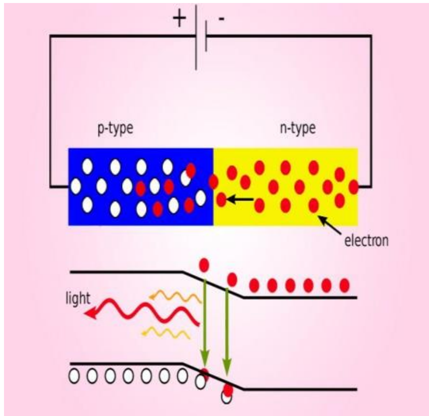


CFL bulbs contain mercury gas, which is converted to plasma when a high current passes through it. The reaction produces ultraviolet light, which our eyes are incapable of detecting. However, when this light interacts with the fluorescent coating inside the bulb on its way out, it is converted to bright white, visible light. Of course, CFLs cost more than halogen bulbs, which means they cost much more than incandescent bulbs.

Light Emitting Diode (LED)

Two blocks of semiconductors, one comprising more electrons than the other to form a p-n junction. When a voltage is applied to this junction, the electrons from the excessively negative block are pushed towards the positive block. When these electrons occupy the vacancies inside the neighboring block, they are relegated to a lower level of energy. This lost energy is released as light.





LEDs are 75% more efficient than CFLs and can last for more than 15,000 hours because the mechanism lacks any joule heating, they guarantee equal or greater luminosity with absolutely no risks of fire hazards.

Efficiency Of electrical Appliances

Efficiency is defined as the ratio of energy output to energy input.

$$\text{Efficiency } \eta = (E_{out} / E_{in}) * 100\%$$

where:

η is the efficiency (expressed as a percentage),

E_{out} is the energy output (in Joules), and

E_{in} is the energy input (also in Joules).

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.

Energy efficiency use is aimed at reducing the amount of energy used in the working of products and services. It refers to exhausting every ounce of power out of as little energy as possible as a step towards cleaner energy practices. For instance, replacing an incandescent light bulb with a fluorescent one to get the same amount of illumination can be considered a step towards energy efficiency.

The Main Benefits for Energy Efficient Appliances

1. Energy Savings

2. Money Savings

3. Environmentally Friendly

Using energy efficient appliances minimizes the exploitation of natural resources, such as natural gas, oil, coal, and water. Energy efficiency works to enhance conservation of these resources as a way to achieve sustainable development. Energy efficient appliances can also help in controlling pollution because appliances that utilize water, oil, coal, and natural gas can lead to water, soil, and air pollution through industrial effluents and emissions.

IS codes- Indian Standards & IE 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 −

1. Safety
2. Ease of use and adaptability
3. Simple technology
4. Value for money products
5. 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.

Some of the IS Codes of Practice for Electrical Wiring Installation

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

IE Codes - Indian Electric Code:

An electrical code is a set of regulations for the design and installation of electrical wiring in a building. The intention of a code is to provide standards to ensure electrical wiring systems that are safe for people and property.

Such wiring is subject to rigorous safety standards for design and installation. Wires and electrical cables are specified according to the circuit operating voltage and electric current capability, with further restrictions on the environmental conditions, such as ambient temperature range, moisture levels, and exposure to sunlight and chemicals. To ensure both wiring and associated devices are designed, selected and installed so that they are safe for use, they are subject to wiring safety codes or regulations, which vary by locality, country or region.

Some of the IE Rules given below

IE Rule – 3 Authorizations

IE Rule – 29 Constructions, Installation, Protection, Operation and Maintenance of Electrical Supply Lines and Apparatus

IE Rule – 30 Service Lines and apparatus on consumer's premises

IE Rule – 31 Cut-out on consumer premises

IE Rule – 32 Identification of earthed and earthed neutral conductors and position of switches and cut-out's therein

IE Rule – 33 earthed terminals on consumer's premises

IE Rule – 34 Accessibility of bare conductors

IE Rule – 35 Danger notices

IE Rule – 36 handling of electric supply lines and apparatus

IE Rule – 37 Supply to vehicles cranes etc.

IE Rule – 38 Cables for portable or transportable apparatus

IE Rule – 41 Distinction of different circuits

IE Rule – 41A Distinction of the Installations having more than one feed

IE Rule – 42 Accidental charges

IE Rule – 43 Provision applicable to protective equipment

IE Rule – 44 Instruction for restoration of persons suffering from electric shock

IE Rule – 44A Intimation of accidents

IE Rule – 45 Precautions to be adopted by consumers, owners, occupiers, electrical contractors, electrical workmen and suppliers

IE Rule – 46 Periodical Inspection and testing of consumer’s Installation

IE Rule – 48 Precaution against leakage before connection

IE Rule – 49 Leakage on consumer’s premises

IE Rule – 50 Supply and use of energy

IE Rule – 54 declared voltage of supply to consumer

IE Rule – 55 declared frequency of supply to consumer

IE Rule – 56 sealing of meters and cut-outs

IE Rule – 60 Test for resistance of insulation

IE Rule – 61 Connection with earth

IE Rule – 64A Additional Provisions for use of energy at high and extra high voltage

IE Rule – 67 Connection with earth

IE Rule – 70 Condensers