5. DOMESTING WIRING

5.1 Introduction

A network of wires drawn to connect the meter board to the various energy-consuming loads (lamps, fans, motors etc) through control and protective devices for efficient distribution of power is known as **electrical wiring**.

Electrical wiring done in residential and commercial buildings to provide power for lights, fans, pumps and other domestic appliances is known as **domestic wiring**.

The distributor line runs (usually on overhead distribution lines) on the poles by the side of the streets. The cable that connects the distributor to the consumer terminals is commonly referred to as the **service mains**. The service mains terminates at the consumer premises in what is called the **service fuse** or **service cutout**. Such cutouts and several meters are the supplier property. In other words, these represent the farthest point from the supplier's responsibility.

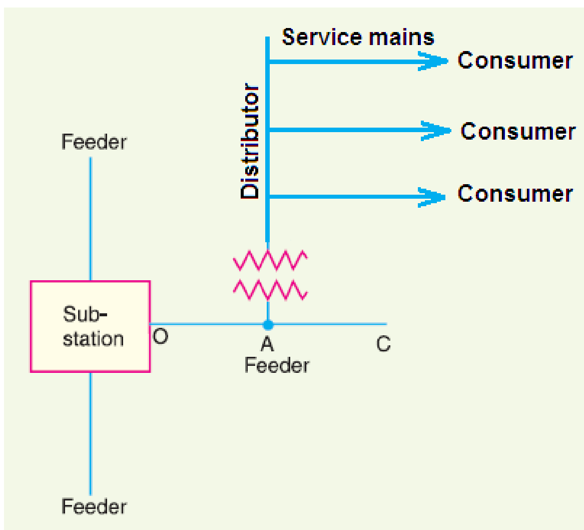


Figure 5. 1: Concept of Service Mains

The point at which the consumer's wiring is connected into the cutout is known as the *point of commencement of supply* or *consumer terminals*. From the consumer terminal onwards, the cables are entirely under the control of the consumer and are laid-out as per the consumer's needs. Figure 5.1 shows the concept of service mains.

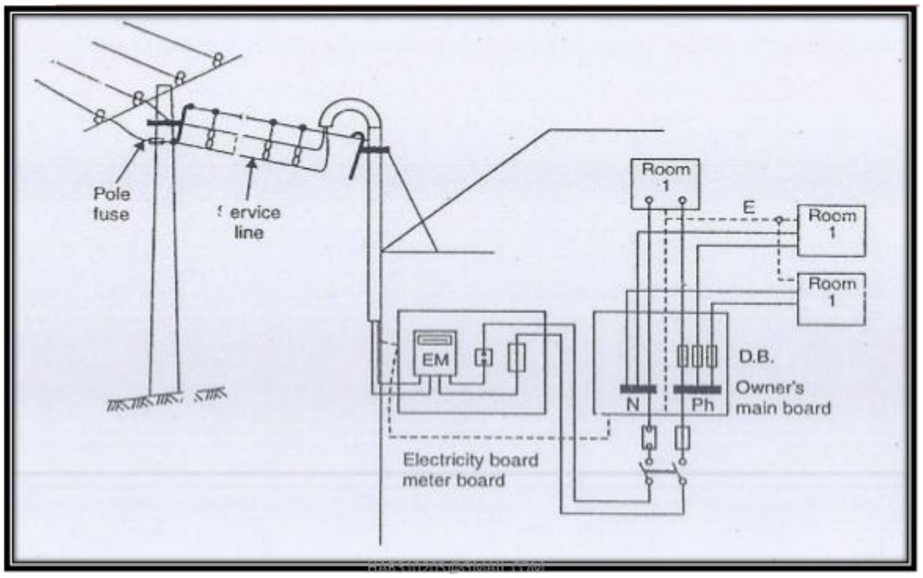


Figure 5. 2: Connection from electric pole to home

The input to the energy meter (or kWh meter, represented as EM) in the consumer premises comes from the service mains. It consists of the phase (P) and neutral (N) wires. The other two terminals of the energy meter are connected through a fuse or an MCB or a switch to the **main distribution board (MDB)** or **meter board** of the owner as shown in figure 5.2.

An MDB is a panel or enclosure that houses the fuses, circuit breakers and ground leakage protection units where the electrical energy, which is used to distribute electrical power to numerous individual circuits or consumer points, is taken in from the distribution system. An MDB typically has a single or multiple incoming power sources and includes main circuit breakers and residual current or earth leakage protection devices. Panels are assembled in a systematic manner such as incomer section and outgoing section.

The two output terminals from the main distribution board is then connected to **sub-main distribution boards (SMDBs)** which are connected to the various parts of the house. The SMDB is installed generally at the point where a large distribution cable terminates and several smaller sub-circuits start. The number of SMDBs depends on the loads present in the house. For example, one SMDB may connect the supply to three lights and two fans of the living room and a bedroom, while another SMDB might be used to connect the supply to four lights and two fans of the other bedroom and the backyard and so on. Each part of the circuit connected to one SMDB forms one sub-circuit. SMDBs are generally used in large buildings, where several points would be at a considerable distance if only one distribution board were used.

5.2 Wire

A wire is a single, usually cylindrical, flexible strand or rod of metal. Wires are used to bear mechanical loads or electricity and telecommunications signals. Wire is commonly formed by drawing the metal through a hole in a die or draw plate.

Wire gauges come in various standard sizes, as expressed in terms of a gauge number. The term wire is also used more loosely to refer to a bundle of such strands, as in "multistranded wire", which is more correctly termed a wire rope in mechanics, or a cable in electricity.

Wire comes in solid core, stranded, or braided forms. Although usually circular in cross-section, wire can be made in square, hexagonal, flattened rectangular or other cross-sections, either for decorative purposes, or for technical purposes such as high-efficiency voice coils in loudspeakers.

5.2.1 The best wire for the job

All engineers must know about wires and think about using the right design and material for the task. Here are the factors for determining wire design:

i. Durability (ability to flex repeatedly or be subject to crushing weights)
ii. Safety
iii. Voltage and Current level
iv. Suspension strength (ability to hold its own weight over long spans between support) Underground or underwater
v. Temperature of operation (like superconducting wire)
vi. Cost (initial and maintenance costs)
vii. Appearance
viii. Permanency
ix. Availability

5.2.2 Size of Wires:

Each application requires a certain wire size for installation, and the right size for a specific application is determined by the wire gauge. Sizing of wire is done by the American wire gauge system. Common wire sizes are 10, 12 and 14 – a higher number means a smaller wire size, and affects the amount of power it can carry.
For example, a low-voltage lamp cord with 10 Amps will require 18-gauge wire, while service panels or subpanels with 100 Amps will require 2-gauge wire.

5.2.3 Specification of Wires

The conductor material, insulation, size and the number of cores, specifies the electrical wires. These are important parameters as they determine the current and voltage handling capability of the wires. The conductors are usually of either copper or aluminum. Various insulating materials like PVC, TRS, and VIR are used. The wires may be of single strand or multi strand. Wires with combination of different diameters and the number of cores or strands are available.

For example, the VIR conductors are specified as 1/20, 3/22,….7/20 etc.

The numerator indicates the number of strands while the denominator corresponds to the diameter of the wire in SWG (Standard Wire Gauge). SWG 20 corresponds to a wire of diameter 0.914mm, while SWG 22 corresponds to a wire of diameter 0.737 mm.

A 7/0 wire means, it is a 7-cored wire of diameter 12.7mm (0.5 inch). The selection of the wire is made depending on the requirement considering factors like current and voltage ratings, cost and application.

Example: Application: domestic wiring

1. Lighting - 3/20 copper wire
2. Heating - 7/20 copper wire

The enamel coating (on the individual strands) mutually insulates the strands and the wire on the whole is provided with PVC insulation. The current carrying capacity depends on the total area of the wire. If cost is the criteria then aluminum conductors are preferred. In that case, for the same current rating much larger diameter of wire is to be used.

5.2.4 Methods of Wiring

There are two main methods of wiring, they are:

1. Joint-Box System (Tee-System)

2. Loop-In System

5.2.4.1 Joint box system (Tee system)

This system uses joint boxes from which the connections to lamps are made. The connections are made through connectors or joint cutouts. This method uses less wires (saving in wire is observed) but extra cost is incurred for joint boxes. Another potential limitation is that improper T-joint leads to weaker system. Presently, this system is limited to temporary installations as shown in figure 5.3.

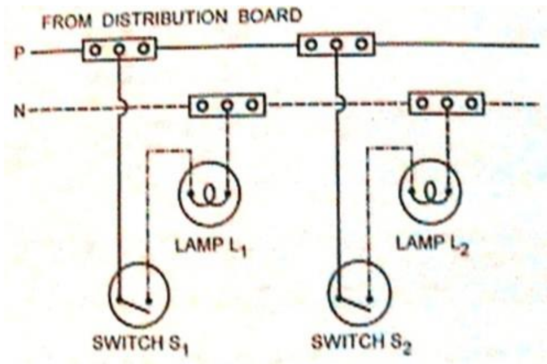


Figure 5. 3: Joint-Box System

5.2.4.2 Loop-In System

In this system when a connection is required at a light or switch, the feed conductor is ‘looped-in’ by bringing it direct to the terminal and then carrying it forward to the next point to be fed as shown in figure 5.4. This method is universally employed in residential wiring.

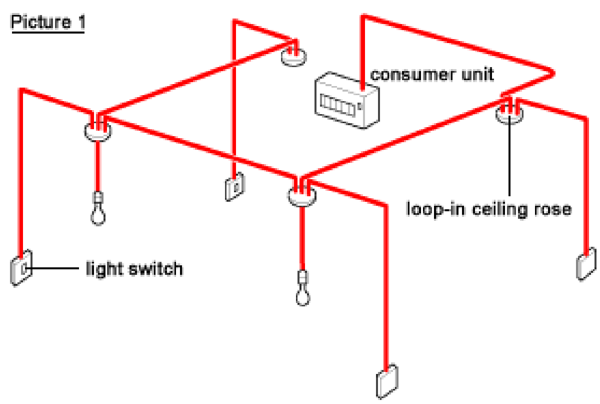


Figure 5. 4: Loop-In Wiring System

Advantages:

i. Joint boxes are not required

ii. No joint is concealed (in roof spaces). Hence, fault location is easy.

Limitations:

i. Length of cable required is relatively more. This causes higher voltage drops and losses.

ii. Looping-in holders and switches is relatively difficult.

5.2.5 Types of Wiring

There are four major types of wiring schemes. They are:

i. Cleat wiring
ii. CTS wiring or TRS wiring or batten wiring
iii. Metal sheathed wiring or lead sheathed wiring
iv. Casing and capping
v. Conduit wiring

5.2.5.1 Cleat Wiring

The types of wiring to be adopted is dependent on various factors, viz, durability, safety, appearance, cost, consumer's budget etc. The cleat wiring system uses insulated cables sub protected in porcelain cleats as shown in figure 5.5.

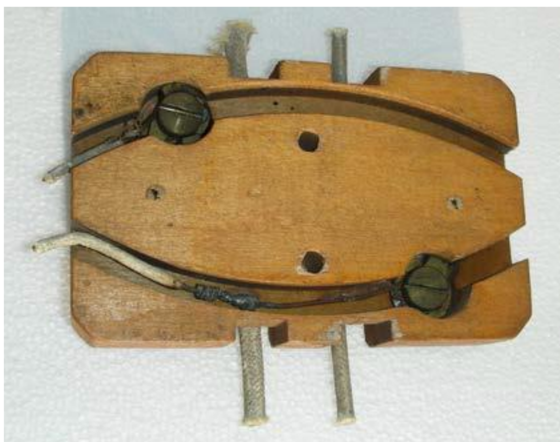


Figure 5. 5: Cleat Wiring

Cleat wiring is recommended only for temporary installations. The cleats are made in pairs having bottom and top halves. The bottom half is grooved to receive the wire and the top half is for cable grip. Initially the bottom and top cleats are fixed on the wall loosely according to the layout. Then the cable is drawn, tensioned and the cleats are tightened by the screw. Cleats are of three types, having one, two or three grooves, so as to receive one, two or three wires. Cleat wiring is one of the cheapest wiring considering the initial cost and labor, and is most suitable for temporary wiring. This wiring can be quickly installed, easily inspected and altered. When not required, this wiring could be dismantled without damage to the cables, cleats and accessories.

Advantages:

1) Easy installation.

2) Materials can be retrieved for reuse.

3) Flexibility provided for inspection, modifications and expansion.

4) Relatively economical.

5) Skilled man-power not required.

Disadvantages:

1) Appearance is not good.

2) Open system of wiring requiring regular cleaning.

3) Higher risk of mechanical injury.

5.2.5.2 Batten Wiring

In this wiring system shown in figure 5.6, wires sheathed in tough rubber are used which are quite flexible. They are clipped on wooden battens with brass clips (link or joint) and fixed on to the walls or ceilings by flat head screws. These cables are moisture and chemical proof. The CTS- Cab type Sheathed and TRS – Tough Rubber Sheathed wires are suitable for damp climate but not suitable for outdoor use in sunlight. TRS wiring is suitable for lighting in low voltage installations.

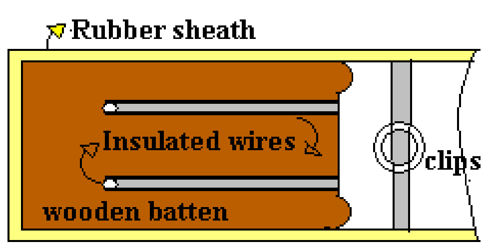


Figure 5. 6: CTS Wiring

Advantages:

1. Easy installation and is durable

2. Lower risk of short circuit.

3. Cheaper than casing and capping system of wiring

4. Gives a good appearance if properly erected.

Disadvantages:

1. Danger of mechanical injury.

2. Danger of fire hazard.

3. Should not be exposed to direct sunlight.

4. Skilled work men are required.

5.2.5.3 Metal Sheathed or Lead Sheathed wiring

The wiring is similar to that of CTS but the conductors (two or three) are individually insulated and covered with a common outer lead-aluminum alloy sheath. The sheath protects the cable against dampness, atmospheric extremities and mechanical damages. The sheath is earthed at every junction to provide a path to ground for the leakage current. They are fixed by means of metal clips on wooden battens as shown in figure 5.7. The wiring system is very expensive. It is suitable for low voltage installations.

Precautions to be taken during installation:

1. The clips used to fix the cables on battens should not react with the sheath.

2. Lead sheath should be properly earthed to prevent shocks due to leakage currents.

3. Cables should not be run in damp places and in areas where chemicals (may react with the lead) are used.

Figure 5. 7: Lead Sheathed Wiring

Advantages:

1. Easy installation and is aesthetic in appearance.

2. Highly durable.

3. Suitable in adverse climatic conditions provided the joints are not exposed.

Disadvantages:

1. Requires skilled labor.

2. Very expensive.

3. Unsuitable for chemical industries.

5.2.5.4 Casing and Capping

It consists of insulated conductors laid inside rectangular, teakwood or PVC boxes having grooves inside it. A rectangular strip of wood called capping having same width as that of casing is fixed over it. Both the casing and the capping are screwed together at every 15 cms. Casing is attached to the wall. Two or more wires of same polarity are drawn through different grooves. The system is suitable for indoor and domestic installations and is shown in figure 5.8.

Figure 5. 8: Casing and Capping

Advantages:

1. Cheaper than lead sheathed and conduit wiring.

2. Provides good isolation as the conductors are placed apart reducing the risk of short circuit.

3. Easily accessible for inspection and repairs.

4. Since the wires are not exposed to atmosphere, insulation is less affected by dust, dirt and climatic variations.

Disadvantages:

1. Highly inflammable.

2. Usage of unseasoned wood gets damaged by termites.

3. Skilled workmanship required

5.2.5.5 Conduit wiring

In this system shown in figure 5.9, PVC (polyvinyl chloride) or VIR cables are run through metallic or PVC pipes providing good protection against mechanical injury and fire due to short circuit. They are either embedded inside the walls or supported over the walls, and are known as concealed wiring or surface conduit wiring (open conduit) respectively. The conduits are buried inside the walls on wooden gutties and the wires are drawn through them with fish (steel) wires. The system is best suited for public buildings, industries and workshops.

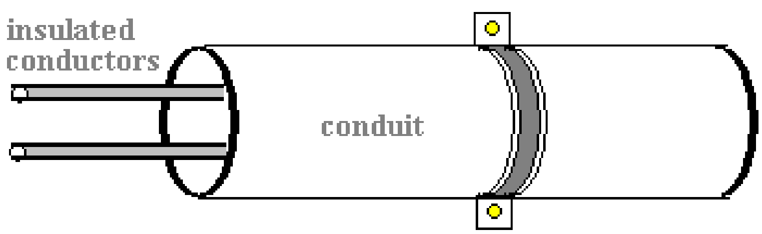


Figure 5. 9: Conduit Wiring

Advantages:

1. No risk of fire and good protection against mechanical injury.

2. The lead and return wires can be carried in the same tube.

3. Earthing and continuity is assured.

4. Waterproof and troubleshooting is easy.

5. Shock- proof with proper earthing and bonding

6. Durable and maintenance free

7. Aesthetic in appearance

Disadvantages:

1. Very expensive system of wiring.

2. Requires good skilled workmanship.

3. Erection is quiet complicated and is time consuming.

4. Risk of short circuit under wet conditions (due to condensation of water in tubes).

5.2.6 Standard Wire Gauge

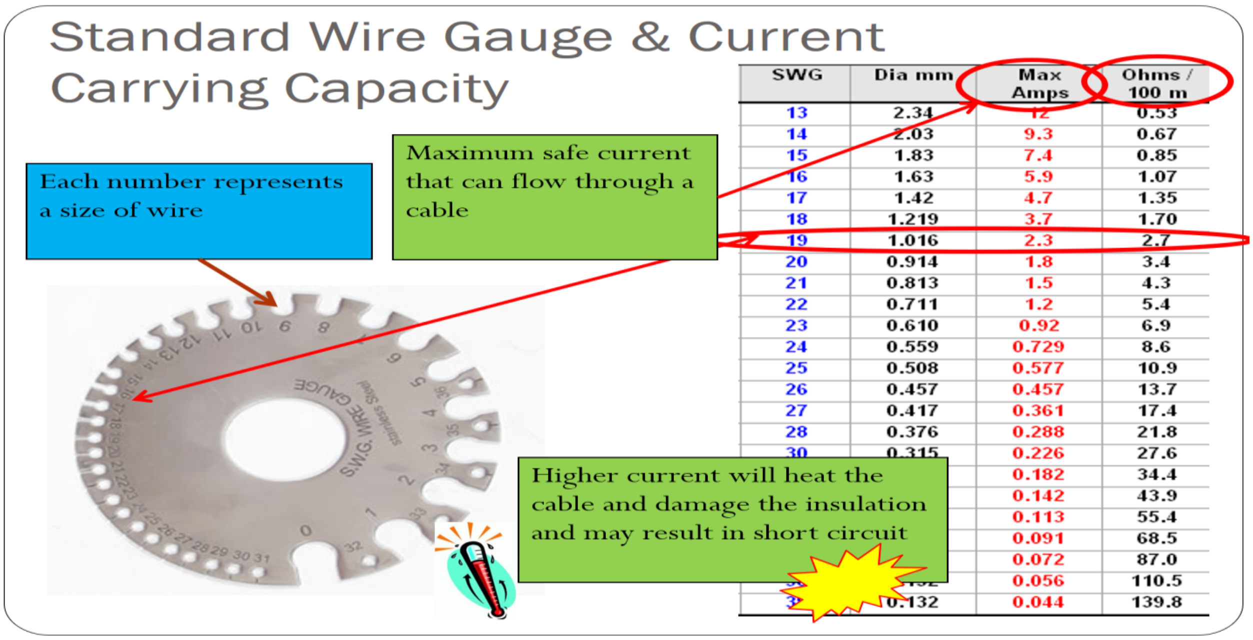


Figure 5. 10: Standard Wire Gauge & Current Carrying Capacity

Indian standards of wire gauges

Cables are specified by,

- Type of insulation
- Conductor Material
- Size of wire

The size in case of copper conductor is specified in terms of number of strands and the gauge of each strand. British Standard Wire Gauge is a set of wire sizes given by BS (British Standard) and is generally abbreviated SWF. It is also called Imperial Wire Gauge and is used in India. A list of SWG and the thickness in mm is given in table 5.1.

SWG	mm
0	8.230
1	7.620
2	7.010
3	6.401
6	4.877
9	3.658
12	2.642
14	2.032
16	1.626
18	1.219
20	0.914

Table 5. 1: SWG and thickness in mm

Note: A copper wire of 3/20 means the number of strands are 3 and the gauge of each strand is 20 SWG.

5.2.7 Wiring diagram of a residential buildings

The wiring diagram gives the layout of the appliances and the way in which they are connected.

Following are the points to be considered during wiring installations:

1. Protective fuses and switches should be connected in live wires
2. Tappings are not allowed except in ceiling rose, boards and junctions.
3. Supply should be given to energy meter from service mains
4. Separate circuit should be drawn for lighting and heating from mains
5. For lighting, each circuit should not consists of more than 10 points or 800 watts.
6. For lighting circuits, 5 Amp outlet should be used.
7. For heating circuits, 15 Amp out lets should be used.
8. Separate earthings set should be provided for heating circuits.
9. For illuminating 1 sq.m area, 10 watt electrical power is considered.
10. Each ceiling fan is to be rated as 140 Watts.

5.3 Simple Wiring Schemes

Simple Wiring Schemes are commonly used to connect lights, fans and other electric appliances.

The domestic lighting circuits are quite simple and they are usually controlled from one point. However, in certain cases it might be necessary to control a single lamp from more than one point (Two or Three different points).

For example, staircases, long corridors, large halls etc.

5.3.1 Two-way Control of lamp

Two-way control is usually used for **staircase lighting** and used as shown in figure 5.12. The lamp can be controlled from two different points: one at the top and the other at the bottom - using two- way switches which strap wires interconnect. They are also used in bedrooms, big halls and large corridors. The circuit is shown in the figure 5.11.

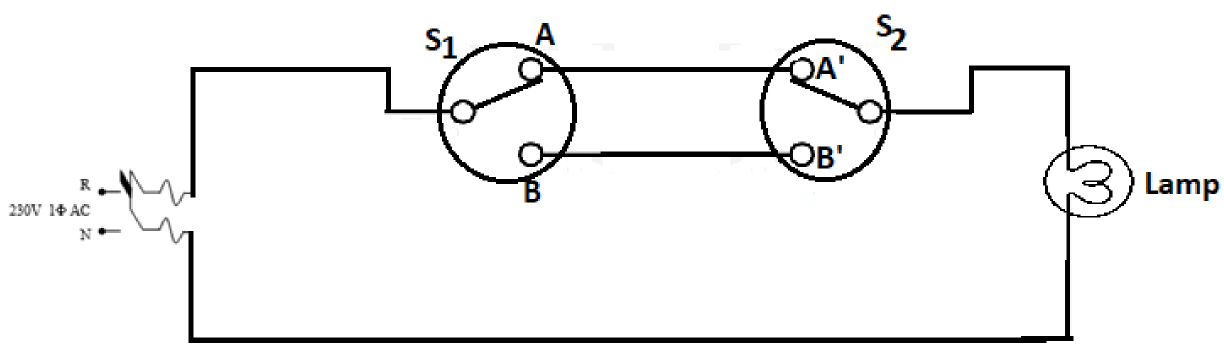


Figure 5. 11: Two-Way Control of Lamp

Switches S_1 and S_2 are two-way switches with a pair of terminals A & B, and A' & B' respectively. When the switch S_1 is in position A and switch S_2 is in position B', the circuit does not form a closed loop and there is no path for the current to flow and hence the lamp will be OFF. When S_1 is changed to position B the circuit gets completed and hence the lamp glows or is ON. Now if S_2 is changed to position A' with S_1 at position 2 the circuit continuity is broken and the lamp is off. If S_1 is in position B and S_2 is in position A', the circuit is open and the lamp is OFF. Thus, the lamp can be controlled from two different points.

This is tabulated in table 5.2.

Sl. No.	Switch 1 Position	Switch 2 Position	Lamp Condition
1.	A	A'	ON
2.	A	B'	OFF
3.	B	A'	OFF
4.	B	B'	ON

Table 5. 2: Two-Way Lamp Control Switching Table

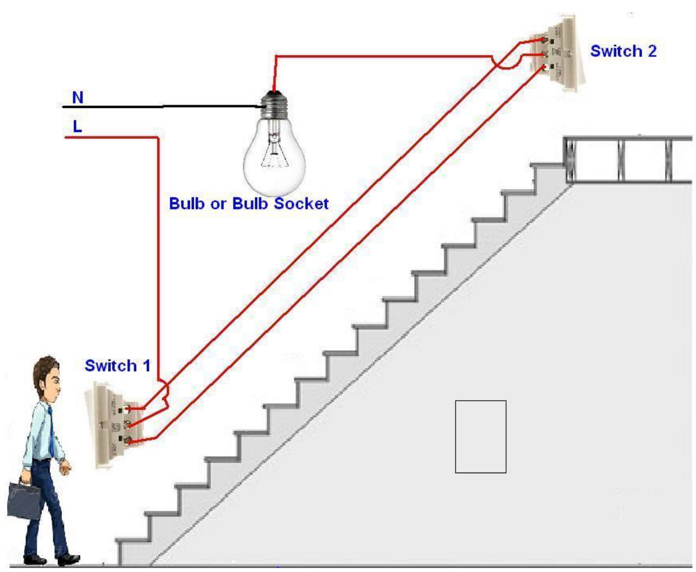


Figure 5. 12: Illustration of two-way control of lamp for staircase lamp control

5.3.2 Three- way Control of lamp:

In case of very long corridors it may be necessary to control the lamp from 3 different points. In such cases, the circuit connection requires two; two-way switches $\mathbf{S_1}$ and $\mathbf{S_2}$**,** and an intermediate switch $\mathbf{S_3}$. An intermediate switch is a combination of two, two way switches coupled together. It has 4 terminals ABCD. It can be connected in two ways

a) Straight connection
b) Cross connection

In case of straight connection, the terminals or points CD and EF are connected as shown in figure 5.13 while in case of cross connection, the terminals CE and FD are connected as shown in figure 5.14. As explained in two –way control the lamp is ON if the circuit is complete and is OFF if the circuit does not form a closed loop.

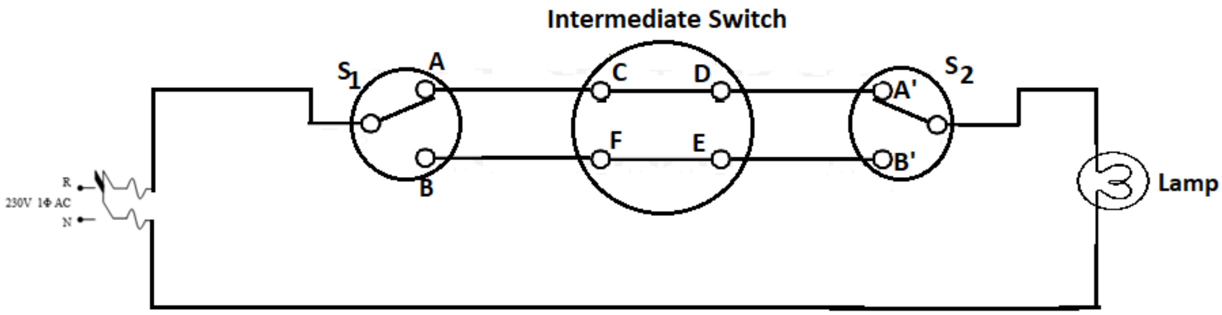


Figure 5. 13: Straight Connection in Three-Way Control of Lamp

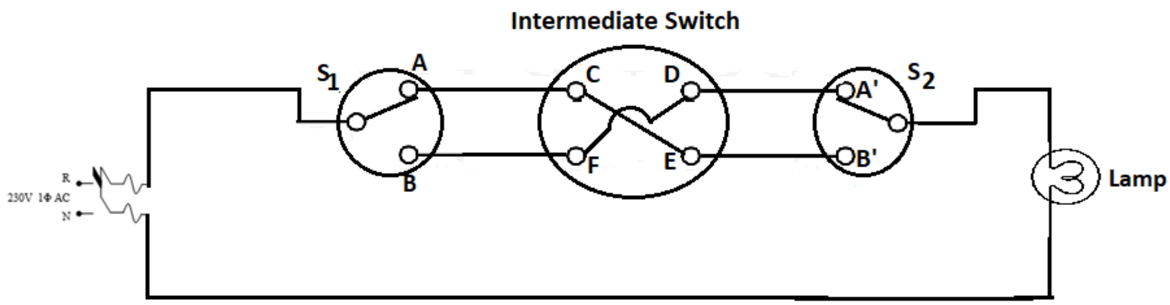


Figure 5. 14: Cross Connection in Three-Way Control of Lamp

Sl. No.	Switch 1 position	Switch 2 position	Intermediate Switch	Lamp condition
1.	A	A’	Straight Connection (CD, EF)	ON
2.	A	B’		OFF
3.	B	A’		OFF
4.	B	B’		ON
5.	A	A’	Cross Connection (CE, FD)	OFF
6.	A	B’		ON
7.	B	A’		ON
8.	B	B’		OFF

Table 5. 3: Three-Way Lamp Control Switching Table

5.4 Necessity and Types of Earthing

5.4.1 Introduction to Earthing:

Earthing is to connect any electrical equipment to earth with a very low resistance wire, making it to attain earth's potential. The body of any electrical equipment is connected to the earth by means of a wire of negligible resistance to safely discharge electric energy, which may be due to failure of the insulation, line coming in contact with the casing etc. Earthing brings the potential of the body of the equipment to ZERO i.e. to the earth's potential, thus protecting the operating personnel against electrical shock. The body of the electrical equipment is not connected to the supply neutral because due to long transmission lines and intermediate substations, the same neutral wire of the generator will not be available at the load end. Even if the same neutral wire is running it will have a self-resistance, which is higher than the human body resistance. Hence, the body of the electrical equipment is connected to earth only.

5.4.2 Necessity of Earthing:

1. To protect the operating personnel from danger of shock in case they come in contact with the charged frame due to defective insulation.
2. To maintain the line voltage constant under unbalanced load condition.
3. Protection of the equipments
4. Protection of large buildings and all machines fed from overhead lines against lightning.

5.4.3 Methods of Earthing:

The earth resistance for copper wire is 1 ohm and that of Galvanized Iron (G I) wire less than 3 ohms. The earth resistance should be kept as low as possible so that the neutral of any electrical system, which is earthed, is maintained almost at the earth potential. The typical value of the earth resistance at powerhouse is 0. 5 ohm and that at substation is 1 ohm.

1. Plate earthing
2. Pipe earthing

5.4.3.1 Plate Earthing

In this method, a copper plate of 60cm x 60cm x 0.32cm or a GI plate of the size 60cm x 60cm x 6.35cm is used for earthing. The plate is placed vertically down inside the ground at a depth of 3m and is embedded in alternate layers of coal and salt for a thickness of 15 cm. In addition, water is poured for keeping the earth electrode resistance value well below a maximum of 5 ohms. The earth wire is securely bolted to the earth plate. A cement masonry chamber is built with a cast iron cover for easy regular maintenance. Figure 5.15 shows the detailed diagram.

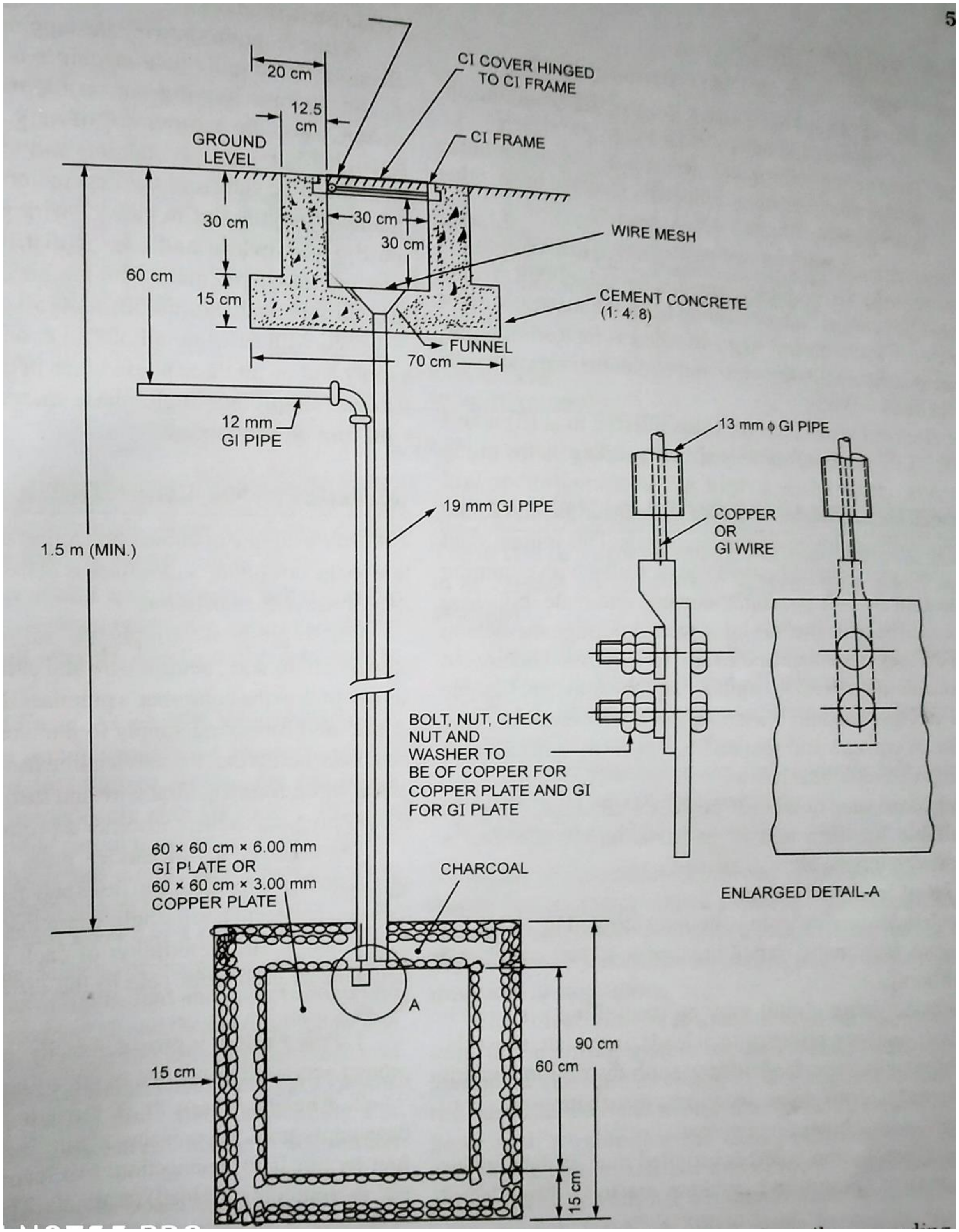


Figure 5. 15: Plate Earthing

5.4.3.2 Pipe Earthing

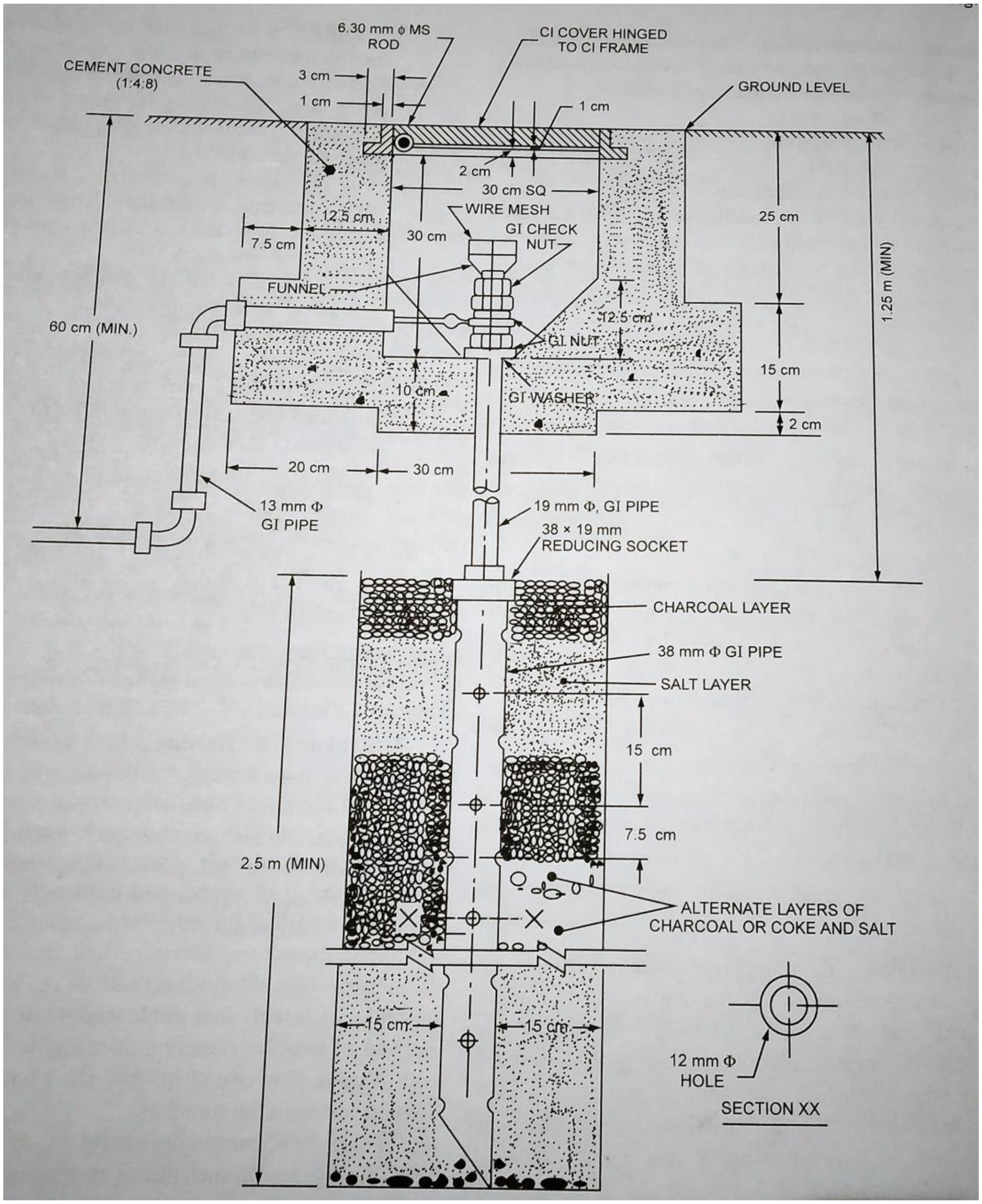


Figure 5. 16: Pipe Earthing

Earth electrode made of a GI (galvanized) iron pipe of 38mm in diameter and length of 2m (depending on the current) with 12mm holes on the surface is placed upright at a depth of 4.75m in a permanently wet ground. To keep the value of the earth resistance at the desired level, the area (15cm) surrounding the GI pipe is filled with a mixture of salt and coal.. The efficiency of the earthing system is improved by pouring water through the funnel periodically. The GI earth wires of sufficient cross- sectional area are run through a 12.7mm diameter pipe (at 60cms below) from the 19mm diameter pipe and secured tightly at the top as shown in the figure 5.16.

Note: When compared to the plate earth system the pipe earth system can carry larger leakage currents as a much larger surface area is in contact with the soil for a given electrode size. The system also enables easy maintenance as the earth wire connection is housed at the ground level.

5.5 Elementary ideas of Fuses and MCB

5.5.1 Fuse

The electrical equipments are designed to carry a particular rated value of current under normal circumstances. Under abnormal conditions such as short circuit, overload or any fault the current raises above this value, damaging the equipment and sometimes resulting in fire hazard. Fuses are pressed into operation under such situations.

Fuse is a safety device used in any electrical installation, which forms the weakest link between the supply and the load. It is a short length of wire made of lead / tin /alloy of lead and tin/ zinc having a low melting point and low ohmic losses. Under normal operating conditions it is designed to carry the full load current. If the current increases beyond this designed value due any of the reasons mentioned above, the fuse melts (said to be blown) isolating the power supply from the load as shown in the following figures 5.12 and 5.13.

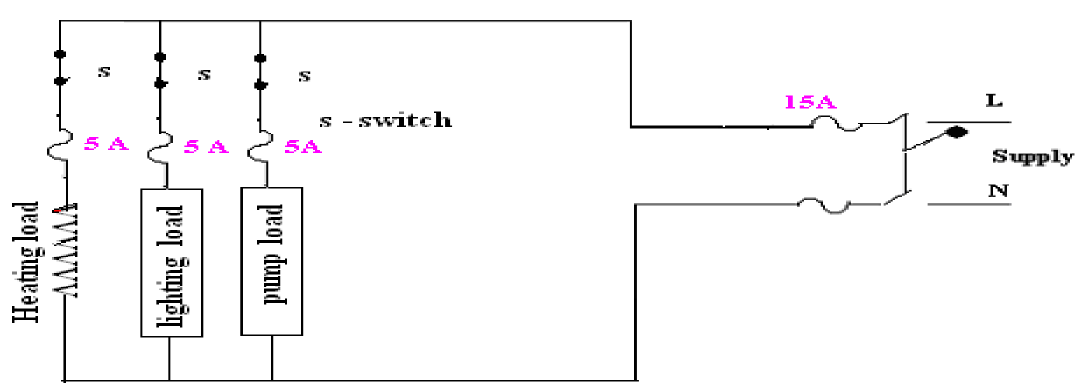


Figure 5. 17: Under normal conditions

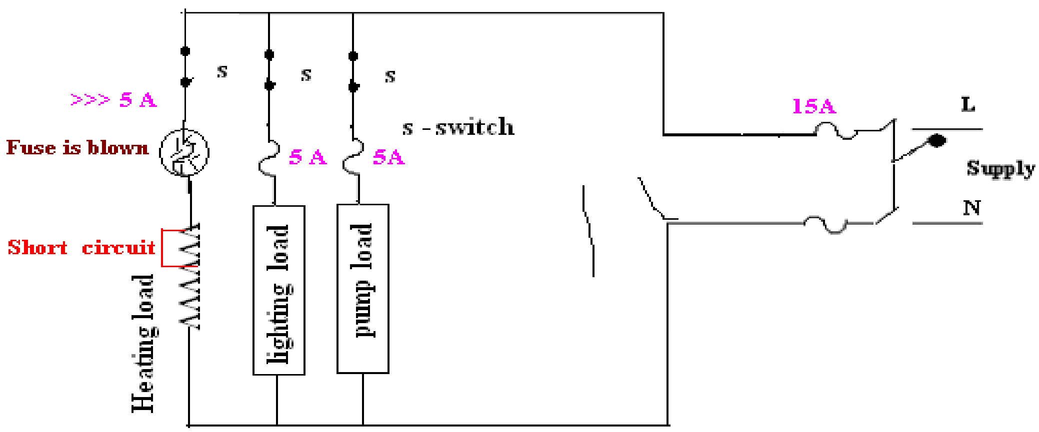


Figure 5. 18: Under abnormal conditions

5.5.2 Terms Related with Fuses

1. **Rated current:** It is the maximum current, which a fuse can carry without undue heating or melting.
   It depends on the following factors:

   a. Permissible temperature rise of the contacts of the fuse holder and the
   b. fuse material
   c. Degree of deterioration due to oxidation

2. **Fusing current:** The minimum current at which the fuse melts is known as the fusing current. It depends on the material characteristics, length, diameter, cross-sectional area of the fuse element and the type of enclosure used.

3. **Fusing Factor:** It is the ratio of the minimum fusing current to the rated current. It is always greater than unity.

$$\text{Fusing factor} = \frac{\text{Minimum fusing current}}{\text{Current rating of fuse}}$$

5.5.3 Characteristics of Fuse Material

The material used for fuse wires must have the following characteristics:

1. Low melting point
2. Low ohmic losses
3. High conductivity
4. Lower rate of deterioration

5.5.4 Fuse Characteristics

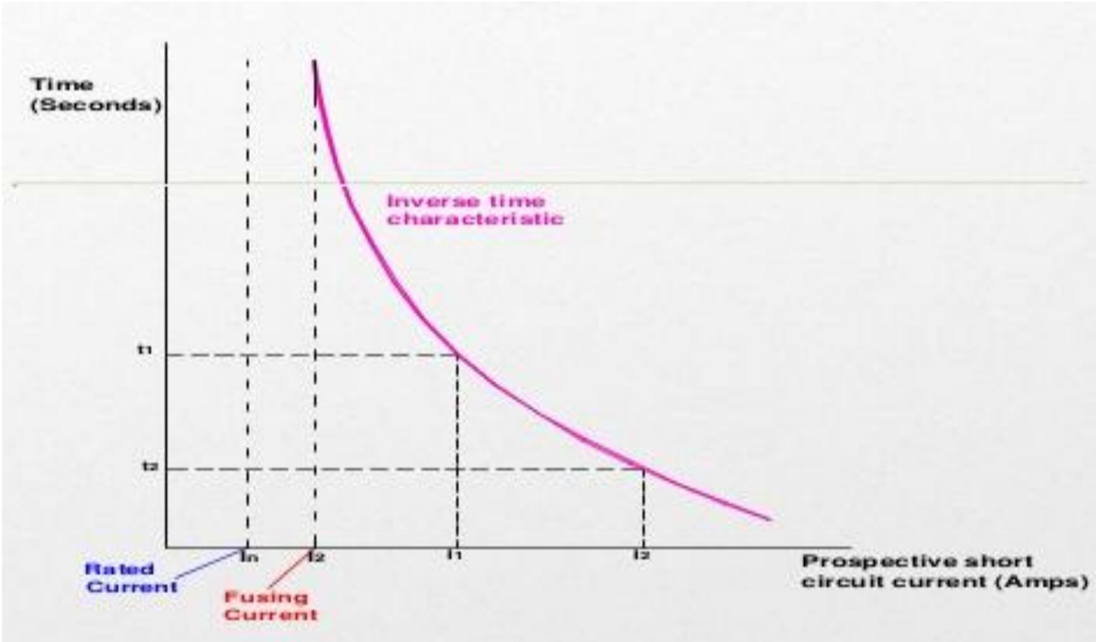


Figure 5. 19: Time-Current Characteristics of a Fuse

This time-current characteristic chart (figure 5.19) shows how fast the fuse responds to different levels of overcurrent condition. The fuse does not open if the current is within the limits (i.e. less than the fuse rating). The current at which the fuse starts melting is called the fusing current. All fuses have an *inverse time/current characteristic*. As overcurrent increases, time-to-open the fuse decreases. Put more simply, the fuse will open faster when the overcurrent problem is severe.

5.5.5 Advantages of Fuses

1. Fast acting
2. Highly reliable
3. Relatively cheaper in comparison to other high current interrupting device

5.5.6 Disadvantages of Fuses:

2. Requires replacement
3. The associated high temperature rise will affect the performance of other devices.

5.6 Miniature Circuit Breaker (MCB)

Nowadays we use more commonly **miniature circuit breaker** or **MCB** in low voltage electrical network instead of fuse.

5.6.1 Working Principle Miniature Circuit Breaker

There are two arrangement of operation of miniature circuit breaker. One due to thermal effect of over current and other due to electromagnetic effect of over current. The thermal operation of miniature circuit breaker is achieved with a bimetallic strip.

Whenever continuous over current flows through MCB, the bimetallic strip is heated and deflects by bending. This deflection of bimetallic strip releases mechanical latch. As this mechanical latch is attached with operating mechanism, it causes to open the miniature circuit breaker contacts. But during short circuit condition, sudden rising of current, causes electromechanical displacement of plunger associated with tripping coil or solenoid of MCB. The plunger strikes the trip lever causing immediate release of latch mechanism consequently open the circuit breaker contacts.

A simple explanation of miniature circuit breaker working principle is shown in figure 5.20.

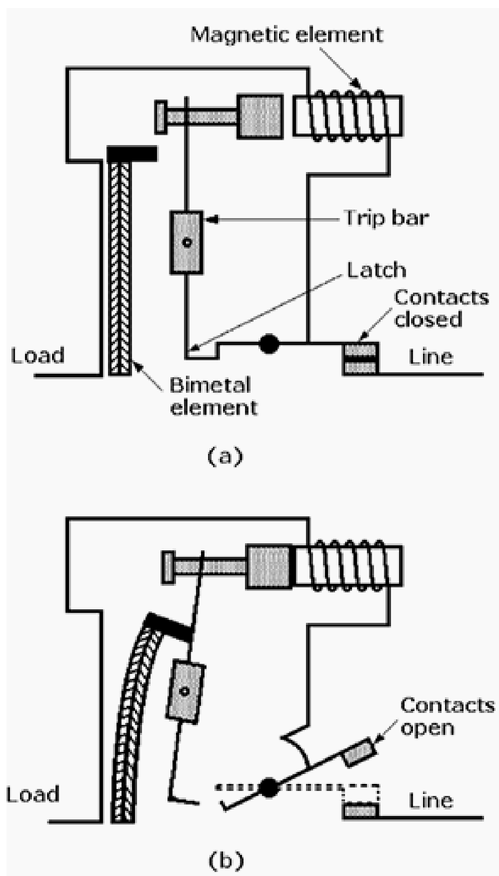


Figure 5. 20: MCB Operation

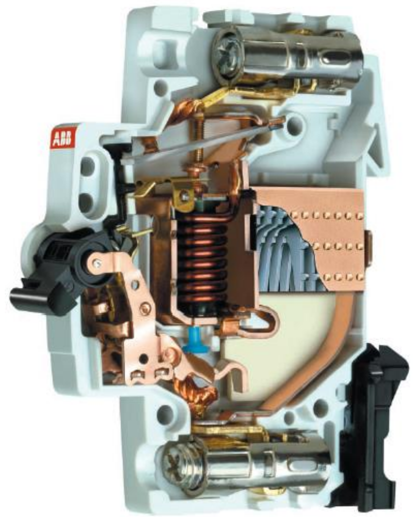


Figure 5. 21: Cross-sectional view of an MCB

The **MCB** has some advantages compared to fuse.

i. It automatically switches off the electrical circuit during abnormal condition of the network means in over load condition as well as faulty condition. The fuse does not sense but **miniature circuit breaker** does it in more reliable way. MCB is much more sensitive to over current than fuse.
ii. Another advantage is, as the switch operating knob comes at its off position during tripping, the faulty zone of the electrical circuit can easily be identified. But in case of fuse, fuse wire should be checked by opening fuse grip or cutout from fuse base, for confirming the blow of fuse wire.
iii. Quick restoration of supply can not be possible in case of fuse as because fuses have to be rewirable or replaced for restoring the supply. But in the case of MCB, quick restoration is possible by just switching on operation.
iv. Handling MCB is more electrically safe than fuse.

Because of the many advantages of MCB over fuse units, in modern low voltage electrical network, miniature circuit breaker is mostly used instead of backdated fuse unit.

Only one disadvantage of MCB over fuse is that this system is more costlier than fuse unit system.

5.7 Electric Shock and Precautions:

5.7.1 Electrical Shock & Its Effects

Electric shock occurs when the body becomes part of an electrical circuit. Shocks can happen in three ways.

- A person may come in contact with both conductors in a circuit.
- A person may provide a path between an ungrounded conductor and the ground.
- A person may provide a path between the ground and a conducting material that is in contact with an ungrounded conductor.

The severity of the shock received when a person becomes a part of an electric circuit is affected by three primary factors:

- The amount of current flowing through the body
- The path of the current through the body
- The length of time the body is in the circuit.

Current in milliamperes	**Effects**
1 or less	No sensation; probably not noticed
1 to 3	Mild sensation not painful
3 to 10	Painful shock.
10 to 30	Muscular control could be lost or muscle clamping
30 to 75	Respiratory paralysis
75mA to 4 **amps**	Ventricular Fibrillation
Over 4 **amps**	Tissue begins to burns. Heart muscles clamp and heart stops beating

Effects of Electrical Current On the Human Body

5.7.2 Precautions against Electric Shock

1. Avoid water at all times when working with electricity. Never touch or try repairing any electrical equipment or circuits with wet hands. It increases the conductivity of electric current.
2. Never use equipment with frayed cords, damaged insulation or broken plugs.
3. If you are working on any receptacle at your home then always turn off the mains. It is also a good idea to put up a sign on the service panel so that nobody turns the main switch ON by accident.
4. Always use insulated tools while working.
5. Electrical hazards include exposed energized parts and unguarded electrical equipment, which may become energized unexpectedly. Such equipment always carries warning signs like “Shock Risk”. Always be observant of such signs and follow the safety rules established by the electrical code followed by the country you are in.
6. Always use appropriate insulated rubber gloves and goggles while working on any branch circuit or any other electrical circuit.
7. Never try repairing energized equipment. Always check that it is de-energized first by using a tester. When an electric tester touches a live or hot wire, the bulb inside the tester lights up showing that an electrical current is flowing through the respective wire. Check all the wires, the outer metallic covering of the service panel and any other hanging wires with an electrical tester before proceeding with your work.
8. Never use an aluminium or steel ladder if you are working on any receptacle at height in your home. An electrical surge will ground you and the whole electric current will pass through your body. Use a bamboo, wooden or a fibreglass ladder instead.
9. Know the wire code of your country.
10. Always check all your GFCIs once a month. A GFCI (Ground Fault Circuit Interrupter) is a RCD (Residual Current Device). They have become very common in modern homes, especially damp areas like the bathroom and kitchen,

as they help avoid electrical shock hazards. It is designed to disconnect quickly enough to avoid any injury caused by over current or short circuit faults.

11. Always use a circuit breaker or fuse with the appropriate current rating. Circuit breakers and fuses are protection devices that automatically disconnect the live wire when a condition of short circuit or over current occurs. The selection of the appropriate fuse or circuit breaker is essential. Normally for protection against short circuits, a fuse rated of 150% of the normal circuit current is selected. In the case of a circuit with 10 amperes of current, a 15A fuse will protect against direct short circuits whereas a 9.5A fuse will blow out.
12. Working outside with underground cabling can be dangerous. The damp soil around the cable is a good conductor of electricity and ground faults are quite common in the case of underground cabling. Using a spade to dig at the cable can damage the wiring easily so it is better to dig at the cable by hand while wearing insulated gloves.
13. Always put a cap on the hot/live wire while working on an electric board or service panel as you could end up short-circuiting the bare ends of the live wire with the neutral. The cap insulates the copper ends of the cable thus preventing any kind of shock even if touched mistakenly.
14. Take care while removing a capacitor from a circuit. A capacitor stores energy and if it is not properly discharged when removed, it can easily cause an electric shock. An easy way to discharge low voltage capacitor is that after removal from the circuit is to put the tip of two insulated screwdrivers on the capacitor terminals. This will discharge it. For high voltage ones a 12 Volts light bulb can be used. Connecting the bulb with the capacitor will light up the bulb using up the last of the stored energy.
15. Always take care while soldering your circuit boards. Wear goggles and keep yourself away from the fumes. Keep the solder iron in its stand when not in use; it can get extremely hot and can easily cause burns.

5.8 Common Household Appliances and Their Ratings

1) Central Air Conditioner (60,000 BTU/Hour): (8520±1123) kWh
2) Refrigerator/Freezer (Sub Zero 48-in): (1,402±178) kWh
3) Swimming Pool Pump (3/4 Horse Power): (1,305±120) kWh
4) Computers, Printers, Routers: (781±97) kWh
5) Cloth Dryer: (769±94) kWh
6) Lighting: (723±93) kWh
7) Range with Oven: (701±89) kWh
8) Dish Washer: 31.12 kWh
9) Sprinkler System: 28.97 kWh
10) Television: 27.11 kWh
11) Hair Dryer: 26.21 kWh
12) Ceiling Fan: 12.31 kWh
13) Washing Machine: 11.04 kWh
14) Cloth Iron: 10.12 kWh
15) Toaster: 5 kWh
16) Tablet & Phone: 3.12 kWh

5.8.1 BEE Star Rating (Energy Rating) on appliances

The Energy Rating Label shows the energy performance of particular appliances and equipment. It allows consumers to understand how much a particular model will cost to run, and how energy efficient it might be in comparison to similar models. It is mandatory for the Energy Rating Label to be displayed on these products:

- Air Conditioners (single phase, non-ducted)
- Clothes washers
- Clothes dryers
- Dishwashers
- Televisions
- Refrigerators
- Freezers
- Computer Monitors

The label has two key pieces of information on it: the energy consumption figure and the star rating as shown in figure 5.22.

The Energy Rating Label provides an estimate of how much energy (in kilowatt-hours or kWh) the appliance will use over a year. This is based on assumptions about 'average usage' and allows consumers to estimate how much it will cost them to run that appliance. However, actual energy consumption will depend on how an appliance is used and how often it is used. Factors like climate can also have a big influence on energy consumption (and efficiency) for some appliances.

The more stars on the Energy Rating Label, the more energy efficient the appliance is. Efficient appliances use less electricity to achieve the same level of performance of similar models with the same size or capacity. The more energy efficient a model, the less energy it will use and the less it will cost you to run.

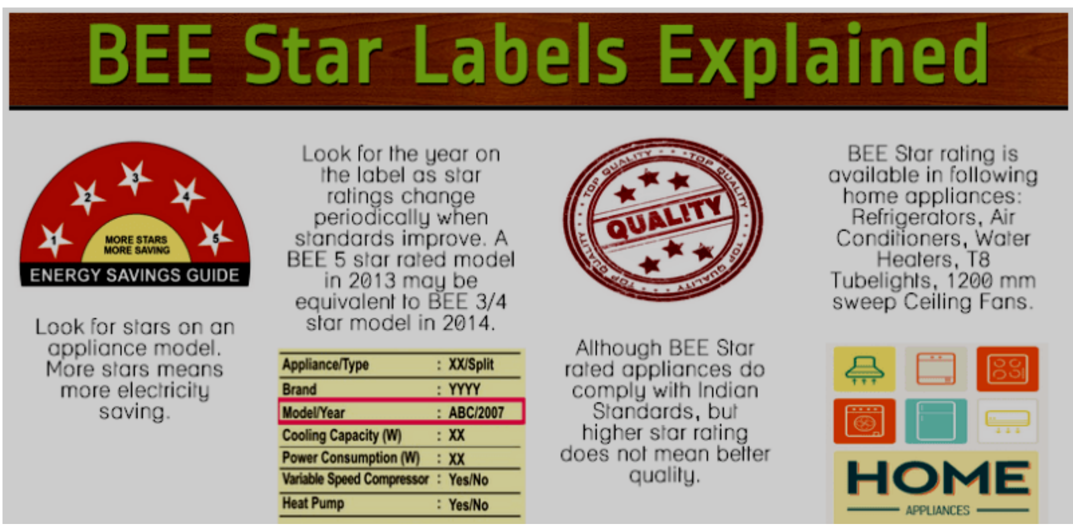


Figure 5. 22: BEE Star Ratings Explained

5.8.2 Energy Estimation of Common Household Loads:

The Electrical energy consumed is metered by energy meter connected on the premises of the residence, residential complex or Industry. The energy is measured in terms of “Units”. One unit of energy is the energy consumed when a load of one kilowatt runs for one hour i.e., **1 unit = 1 kWh**.

The domestic consumer is billed for the energy consumed. An industrial consumer is billed both for the load as well as for the energy consumed. Table 5.4 shows a few common appliances and calculate the energy they consume.

Sl. No.	Name of The Appliance	Range of Power (Watts)	No. of Appliances	Total Power = (W x No. of Appliance) in W	No. of Hours	Total Energy=(Total Power X No. of Hours) in Wh
1	Incandescent Lamp	15 - 100				
2	Tube Light	30 - 50				
3	CFL	3 – 30				
4	Ceiling Fan	30 - 70				
5	AC(Room)	1000 - 1500				
6	AC(Central)	2000 - 5000				
7	CD Player	15 - 20				
8	TV	60 - 300				
9	Laptop	50 -75				
10	Desktop	80 - 250				
11	Washing Machine	500 - 1000				
12	Refrigerator	50 - 300				
13	Geyser	1000 - 3000				
14	Iron Box	270 - 350				

Table 5. 4: Common Household Appliances & Their Ratings

Example 1: Estimate Total Daily Energy Requirement for the following loads.

Name of the Appliance	Power Rating (W)	Avg. Daily Usage Hrs	No. of Appliances
CFL	12	6	3
Fan	50	8	2
TV (21”)	150	2	1
Computer	250	3	1

Take electricity cost to be Rs.6 per unit.

Solution:

Name of the Appliance	Power Rating (W)	Avg. Daily Usage Hrs	No. of Appliances	Daily Energy Required (Wh)
CFL	12	6	3	216
Fan	50	8	2	800
TV (21”)	150	2	1	300
Computer	250	3	1	750
Total Energy				2066 Wh

Hence Monthly Energy Requirement = Daily Energy Required X Days per Month

= 2066 X 30

= 61980 Wh

= 61.98 kWh or 61.98 Units

Therefore, the monthly electricity bill is

Monthly Bill = 61.98 units X Rs.6/- per unit

= **Rs.371.88 /-**

***Exercise 1**: Repeat example 1 if the billing tariff is*

Rs.6/- per unit for the first 20 units, Rs.4/- per unit for the next 30 units and Rs.2/- per unit for the next 50 units.

Example 2: A geyser is rated at 3kW, 230V, 50Hz. If it is switched ON for one hour daily, what would be the energy cost saving, at the rate of Rs. 2.50 per unit if it is replaced by a solar water heater?

Solution:

Solar water heaters use energy from the Sun. Though their initial investment is high, the running cost is very low and are environmental friendly.

A 3kW geyser running for 1 hour daily would consume 3 units daily. The energy consumed per month is 3 units X 30 days = 90 units per month. The cost of energy per month is 90 units per month X Rs. 2.50 per unit = Rs. 225.

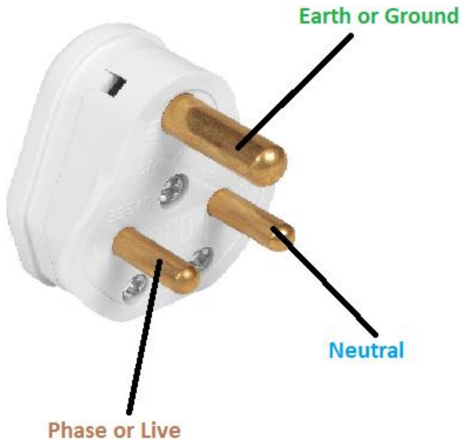
This would be the saving in electricity bill if solar water heater replaces the electric geyser.

***Exercise 2**: Find out the wattage of the appliances in your house, their average use per month and estimate the electricity bill of your house based on the BESCOM tariff.*

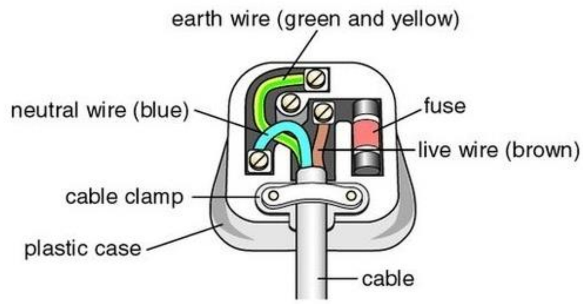
5.8.3 AC Power Plugs and Sockets

AC power plugs and sockets allow electric equipment to be connected to the primary alternating current (AC) power supply in buildings and at other sites. Electrical plugs and sockets differ from one another in voltage and current rating, shape, size, and connector type. Different systems of plugs and sockets have been standardized, and different standards are used in different parts of the world.

5.8.3.1 Three-Pin Plug & Socket



(a)



(b)

Figure 5. 23: (a) External and (b) Internal views of a three-pin plug

These plugs have three round pins arranged in a triangle (figure 5.23), with the larger top pin being the earthing pin. Plugs are non-interchangeable between current ratings. Introduced in 1934, they are also called as Type-D plugs.

Figure 5. 24: Three-Pin Socket

This 5A plug has three round prongs that form a triangle. The central earth pin is 20.6 mm long and has a diameter of 7.1mm. The 5.1mm line and neutral pins are 14.9mm long, on centres spaced 19.1 mm apart. The centre-to-centre distance between the grounding pin and the middle of the imaginary line connecting the two power pins is 22.2 mm. Type M, which has larger pins and is rated at 15 amps, is used alongside type D for larger appliances in India, Sri Lanka, Nepal and Pakistan. Some sockets can take both type M and type D plugs.

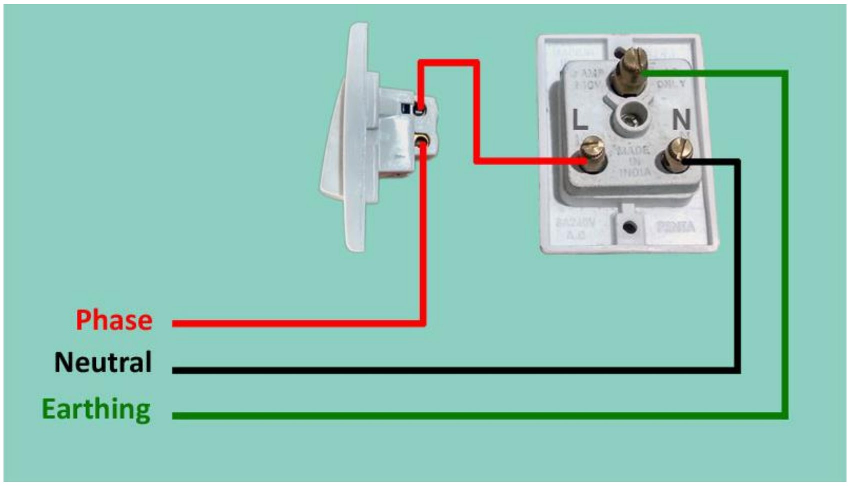


Figure 5. 25 Connecting a three-way socket and a switch

The use of a 3-pin socket in house wiring is as shown in figure 5.25. The detailed connection of a 3-pin plug is as shown in figure 5.26.

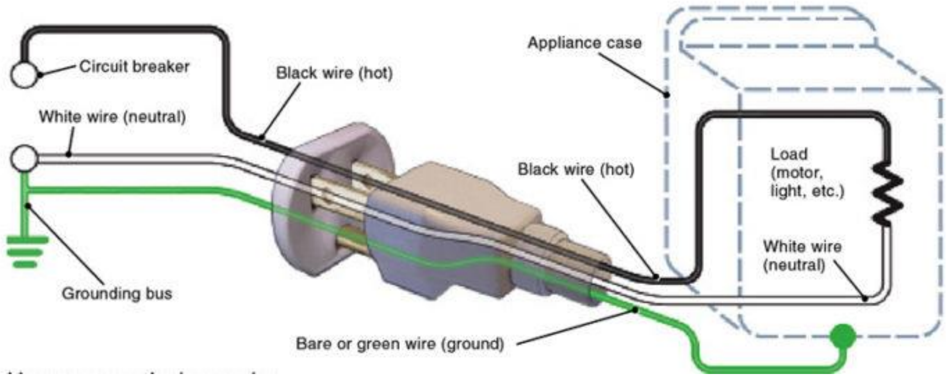


Figure 5. 26: Connecting a 3-wire plug to a load

5.8.3.2 Two-Pin Plug & Socket

The two-pin plug or type-C is probably the single most widely used international plug. This two-wire plug is ungrounded and has two round prongs. The plug has two 4 mm round pins, measuring 19 mm in length on centres spaced 18.6mm apart at the base and 17.5 mm apart at the tip. The two pins have 10 mm long insulated sleeves. They converge slightly, but they are relatively flexible which allows the plug to mate with any socket that accepts 4.0 – 4.8mm-round contacts on 17.5 – 19mm centres. The plug is generally limited for use in class II applications that require 2.5A or less.

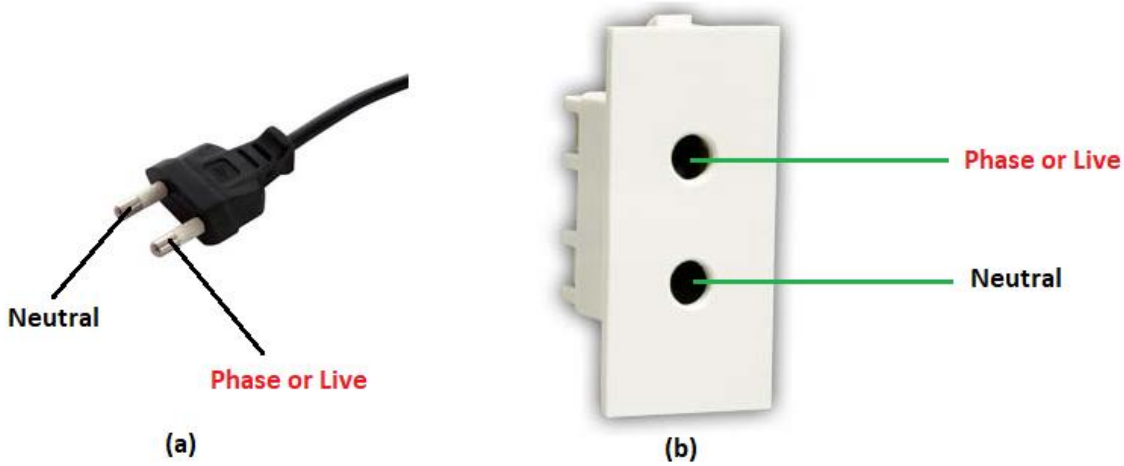


Figure 5. 27: Two-Pin (a) Plug & (b) Socket

5.8.4 Basic House Wiring Connection

In basic wiring connection of the house, we must understand how lights and fans are connected. In this section, these two connections are first explained individually and then they are combined to form the basic house-wiring connection.

Wiring a light and a switch

The phase wire from the supply is connected to one terminal of the switch. The other terminal of the switch is connected to one terminal of the bulb. The other terminal of the bulb is connected to neutral of the supply. This is shown in figure 5.28. The figure shows a CFL but the connection remains the same regardless of the light type (incandescent, fluorescent, CFL, etc.)

Wiring a ceiling fan with regulator (dimmer)

The phase wire from the supply is connected to one terminal of the switch. The other terminal of the switch is connected to one terminal of the dimmer. The other terminal of the dimmer is connected to one of the supply terminals in the motor of the ceiling fan. Finally, the other terminal of the motor is connected to the neutral of the supply. This has been shown in figure 5.29.

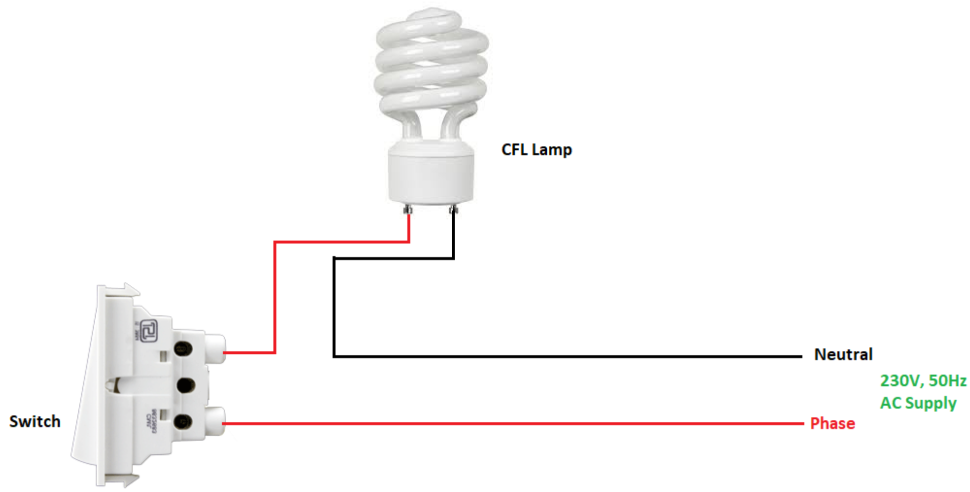


Figure 5. 28: Wiring a Light Bulb

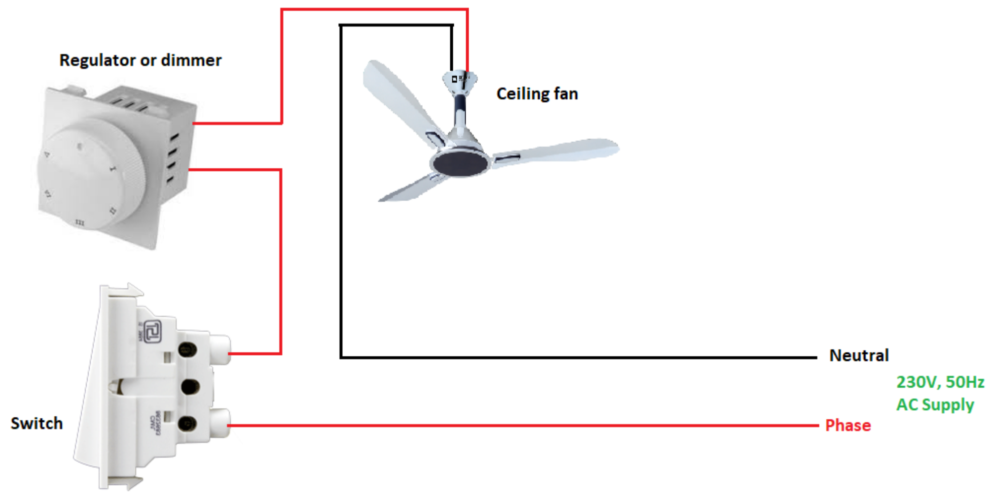


Figure 5. 29: Wiring a ceiling fan with regulator

Wiring combining fans and lights

- The neutral and phase wires for the room are first drawn from the distribution board.
- Then the neutral wire from the supply is connected to one terminal of the outlets, one terminal of each bulb and one terminal of ceiling fan as shown figure 5.30. These wires are represented in black.
- Then the phase wire (hot wire/ live wire) from the supply is connected to the one terminal of every switch and to the other terminal of the outlets as shown in the figure 5.27.

- Next connections are made form the other terminal of the first switch to one bulb and form the other switch to the second bulb. Then the open terminal from the third one-way switch is connected to the regulator and then the other terminal of the regulator is connected to the ceiling fan as shown.
- If the base body of the board is made of metal, then it is necessary to connect the earth wire (green wire) to board base body.
- The power outlet / three-pin socket connection is made as shown in the above room wiring diagram.
- Such a scheme is followed to connect all the sockets, switches and lights in the entire house.

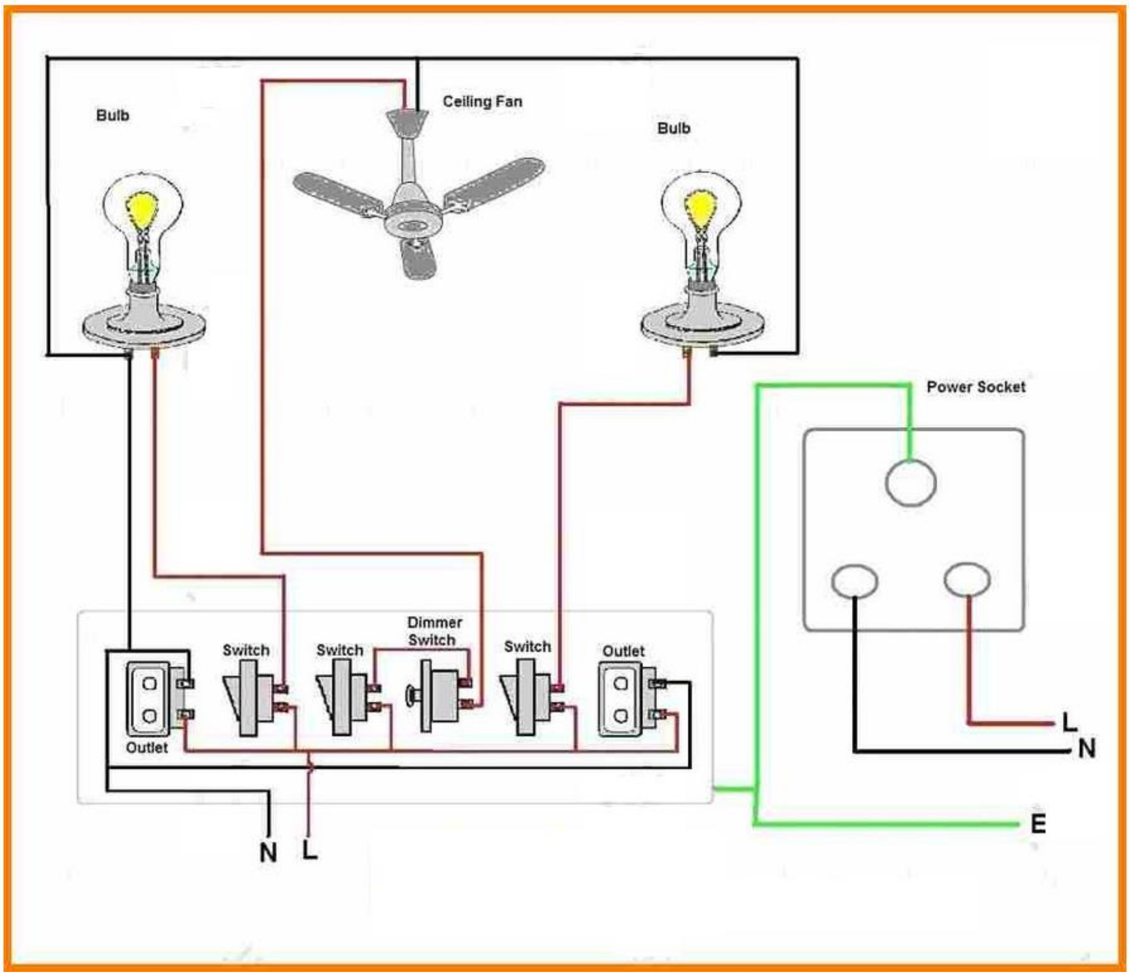


Figure 5. 30: Wiring Combining Fans & Lights in a Room

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