Chapter 9 Household Circuits

SYLLABUS

Household circuits - main circuit; switches, fuses, earthing, safety precautions, three pin plugs, colour coding of wires.

Scope of syllabus : House wiring (ring system), power distribution; main circuit (3 wires – live, neutral, earth) with fuse/MCB, main switch and its advantages, circuit diagram, two-way switch, staircase wiring, need for earthing, fuse, 3-pin plug and socket, conventional location of live, neutral and earth points in 3-pin plugs and sockets; safety precautions, colour coding of wires.

(A) TRANSMISSION OF POWER AND HOUSE WIRING

9.1 TRANSMISSION OF POWER FROM THE GENERATING STATION TO THE CONSUMER

Electric power is generated at the power generating stations which are usually located very far from the areas where it is consumed. *At the generating station, the electric power is generated at* 11 kV because generation at voltage higher than 11 kV causes insulation difficulties, while generation at voltage lower than 11 kV involves a very high current. Since it is not possible to step up or step down the d.c. voltage, the voltage generated is alternating of frequency 50 Hz (*i.e.*, its polarity at the terminals changes 100 times a second, 50 times + and 50 times –).

The power from the generating station is transmitted to the consumer over the long distances not at 11 kV, *but at a voltage higher than* 11 kV *so as to reduce the loss of energy in form of heat in the line wires used for transmission.*

From relation $P = VI$, for a given power P, current $I = P/V$ *i.e.*, higher the voltage, lower is the current. Thus by supplying a given electric power at a high voltage, the current becomes low and therefore the loss of energy due to heating ($= I^2Rt$) in the line wires becomes less. Thus, *the alternating voltage generated is first stepped up from* 11 kV *to* 132 kV *at the generating station* (or called the grid sub-station) using the *step up transformer*. It is then transmitted to the main sub-station. *At the main sub-station, the voltage is stepped down from* 132 kV *to* 33 kV using the *step down* transformer and is then transmitted to the heavy industries and intermediate sub-station. *At the intermediate sub-station, the voltage is again stepped down from* 33 kV to 11 kV using

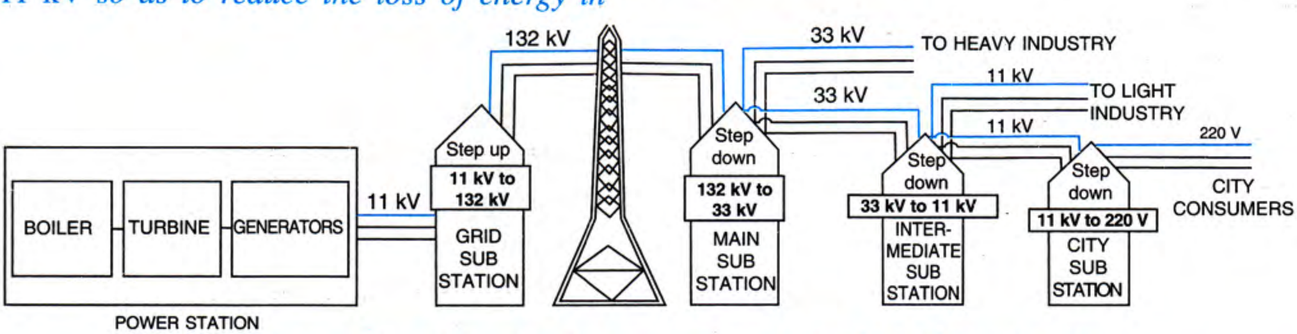


Fig. 9.1 Transmission of electricity from power generating station to the consumers

the *step down transformer* and from here it is transmitted to light industries and city sub-station. *At the city sub-station, it is further stepped down from* 11 kV *to* 220 V *using the step down transformer to supply it to the domestic consumers*. The transmission of electric power from the generating station to the consumer is shown in Fig. 9.1.

Fig. 9.2 shows the simple block diagram of the transmission of electric power from the generating station to the consumer.

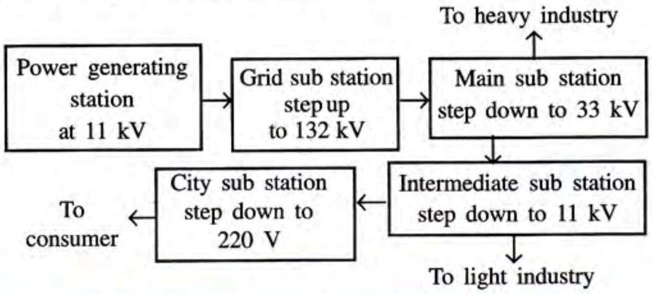


Fig. 9.2 Block diagram of transmission of electricity from power station to the consumer

9.2 POWER DISTRIBUTION TO A HOUSE

To supply the electric power to a house from the city sub-station, either the overhead wires* or a cable on poles or an underground cable is used. The cable has *three* wires : (1) *live* (or *phase*) *wire* (L), (2) *neutral wire* (N), and (3) *earth wire* (E). The neutral and the earth wires are connected together at the local sub-station so that *the neutral and earth wires are at the same potential* (*i.e.*, at 0 V). The live wire, also called the *phase wire*, carries current from the source to the distribution board, while the neutral wire is for the return of current to the source.

Before connecting the cable from pole to the meter in a house, first a fuse of high rating (≈ 50 A) is connected in the live wire at the pole (or just before the meter). This fuse is called the *company fuse* (or *pole fuse*). Only the persons of the electric supply company are authorised to handle it. The rating of the fuse depends on the load for which the connection is taken from the company. After the company fuse, the cable is connected to a *kWh meter*. The kWh meter is usually mounted on the front (or outside) wall of the house. From the meter, connections are made to a *main switch* (or earth leakage circuit breaker ELCB) and to a *main fuse* (or miniature circuit breaker MCB). The main switch (or ELCB) is connected in both the live and neutral wires, while the main fuse (or MCB) is connected only in the live wire.

The main switch is a *double pole switch*. It has an iron covering. The covering is earthed (*i.e.*, connected to the earth wire E). The advantage of using the main switch is that it breaks the connections of the live as well as the neutral wires simultaneously from the main supply. The earth wire from the meter is locally earthed (in the compound of the house). From the distribution board, the wires go to the different parts of the house. Now a days a *consumer unit* is connected after the kWh meter. This unit contains a double pole switch or an earth leakage circuit breaker (ELCB) and MCB for each circuit in the house.

Fig. 9.3 shows the connections from the electric pole to the distribution box in a house.

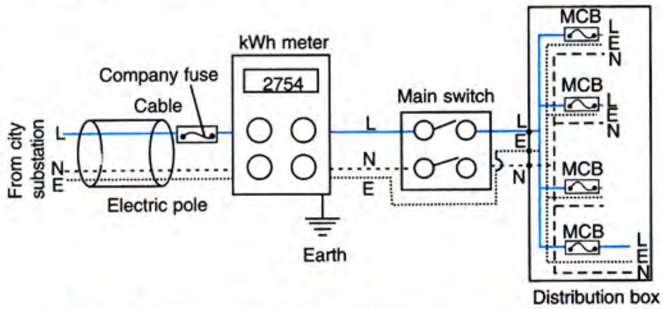


Fig. 9.3 Connections by cable from electric pole to the distribution box

9.3 HOUSE WIRING (RING SYSTEM)

In a house, the wiring is commonly done by the ring system. In this system, we have a separate ring for each portion of the house. In a portion, the wires starting from the distribution box run around all the rooms of that portion and then come back to the distribution box, thus

* There is usually a set of six wires stretched one above the other from one pole to the other pole. From the top, their sequence is : first neutral wire; second, third and fourth the three phase (or live) wires; fifth the street light live wire and then sixth the earth wire. The live (or phase) wires are thicker than the neutral and earth wires. Live (or phase) wires are generally made by twisting the several wires together.

forming a ring. The distribution box contains a MCB of rating about 30 A. Fig. 9.4 shows a ring system of wiring connecting a lamp, socket with switch and fan with regulator.

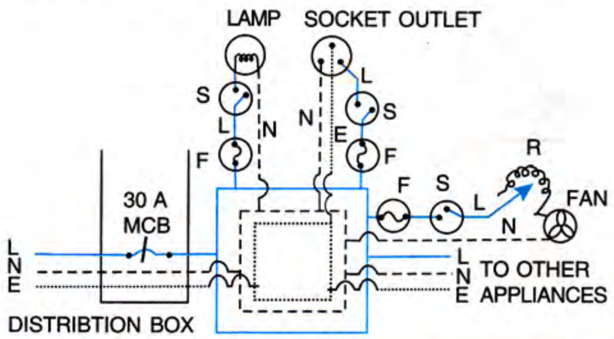


Fig. 9.4 The ring system of house wiring showing circuit for lamp, socket and fan with fuse and switches in the live wire

A separate connection is taken for each appliance from the live wire of the ring. One terminal of the appliance is connected to the live wire through a separate fuse and a separate switch, while the other terminal of the appliance is directly connected to the neutral wire. The earth terminal or metal covering of the appliance is connected to the earth wire. For each appliance, the wires used for connection should be of proper current carrying capacity.

Advantages of the ring system : The ring system has the following *four* advantages :

(1) In the ring system, the current from mains can reach to an individual appliance through *two* separate paths. Thus each appliance gets connected to the mains effectively through a thick wire. Therefore, the wire required for main ring is of a lower current carrying capacity than that which would be required for a direct connection to the mains. This considerably reduces the cost of wiring.

(2) Each appliance has a separate fuse. Therefore if due to some fault, the fuse of one appliance burns, it does not affect the operation of other appliances.

(3) In this system, all the plugs and sockets used can be of same size, but each socket should have its own fuse of rating suitable for the appliances to be connected with it.

(4) While installing a new appliance in a room, a new line up to the distribution box is not required, but it can be directly connected to the ring circuit in that room. The care is taken that the total current drawn from the mains in the ring circuit does not exceed the rating of the main fuse (viz. 30 A).

Connection of all appliances (bulb, fan, socket, etc.) with the mains

We note that *all the electrical appliances* (say, bulbs, fans, sockets, *etc.*) *are connected in parallel with the mains. In the live wire before each appliance there is a separate switch and a separate fuse connected in series.*

Advantages of connecting the appliances in parallel

It has the following *two* main advantages :

(1) Each appliance gets connected to 220 V supply (= its voltage rating) for its normal working.

(2) Each appliance operates independently without being affected whether the other appliances are operated or not.

Disadvantages of connecting the appliances in series

Appliances are not connected in series to the mains for the following *three* reasons.

(1) The voltage of the source gets divided in all the appliances connected in series, in ratio of their resistances, so each appliance does not operate at its rated voltage.

(2) On connecting one more appliance in the same circuit, the resistance of the circuit will increase. Hence it will reduce the current in the circuit, so each appliance will get less power.

(3) All appliances connected in series operate simultaneously. None of the appliance can be operated independently. If one appliance is switched off (or not operated), no other appliance connected with it in series will then operate.

EXAMPLES

1. How will you connect a bulb and a socket in a room to the mains ? Draw a labelled diagram in support of your answer. Use switch and fuse wherever necessary.

In a room, the bulb and socket are connected in parallel with the mains as shown in Fig. 9.5 below.

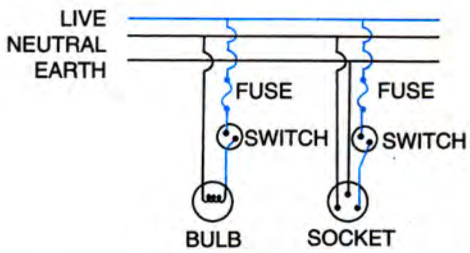


Fig. 9.5

2. The diagram in Fig. 9.6 shows a battery, a switch and two bulbs. (a) Complete the diagram to show the electric connections of the bulbs to the battery. (b) How have you joined the bulbs in part (a) ? Give reason.

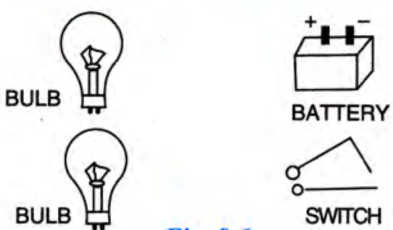


Fig. 9.6

(a) The completed diagram is shown in Fig. 9.7.

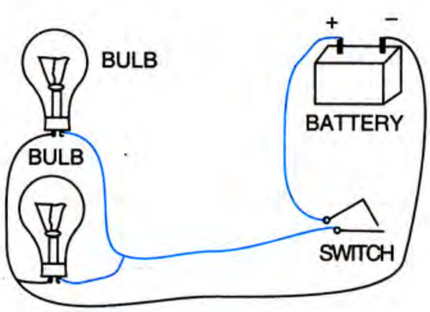


Fig. 9.7

(b) The two bulbs are connected **in parallel**.

Reason : (1) Both the bulbs glow at the same voltage. (2) If one bulb ceases to glow, the other bulb remains glowing.

3. The diagram in Fig. 9.8 shows the electrical system of a car to operate the two head lights and two rear lights by a switch.

(ground symbol) shows a connection to the body of the car.

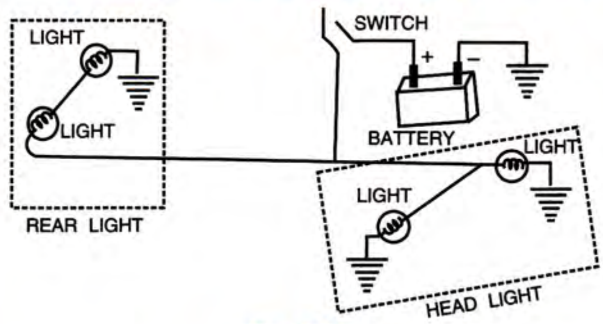


Fig. 9.8

(i) The diagram shows only one lead from the battery to each bulb, but a complete circuit must have two leads. How does the current get back to the battery ?

(ii) The two rear lights as connected in diagram glow faintly. Why do they glow faintly ? How should they be connected to glow brightly ? Show by a separate diagram.

(iii) If the lights are on, they become dim when the car is started. Give a reason.

(i) One lead of the battery and one terminal of the appliance (*i.e.*, bulb) is connected to the body of the car (*i.e.*, to the earth). The current gets back to the battery **through the body of the car (*i.e.*, earth)**. Thus the body of the car behaves like the other lead.

(ii) The two rear lights are connected in **series** so each light glows at half the voltage of the battery (if the resistance of filament of each bulb is same). Hence they glow faintly. They must be connected in **parallel** to glow properly as shown below in Fig. 9.9.

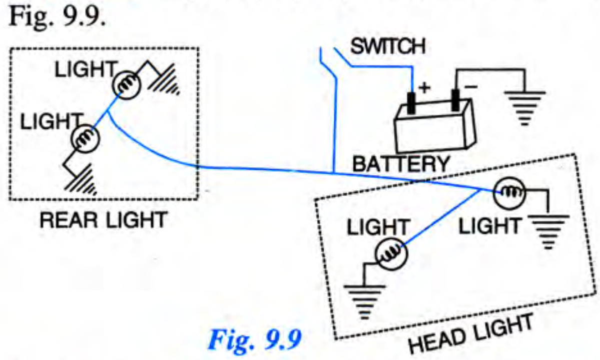


Fig. 9.9

(iii) When the car is started, it **draws heavy current from the battery**. The terminal voltage of the battery falls due to voltage drop. As a result, the voltage across each bulb falls and they become dim.

4. An electric bulb rated '220 V, 60 W' glows when connected with 220 V mains.

(i) Find the resistance of the filament of the bulb.

(ii) Another identical bulb is connected in series with the first one and the system is connected across the 220 V mains. Draw a diagram to show the arrangement and find : (a) the rate of consumption of energy in each bulb, and (ii) total power consumed.

(iii) If two bulbs are connected in parallel, draw a diagram of this arrangement. What will then be the total power consumed ?

Given : rating of bulb is 220 V, 60 W *i.e.*, voltage $V = 220$ volt and power $P = 60$ watt.

(i) Resistance of filament of the bulb

$$R = \frac{V^2}{P} = \frac{(220)^2}{60} = \mathbf{806{\cdot}67\ \Omega}$$

(ii) The arrangement of two identical bulbs in series with the mains is shown in Fig. 9.10. In this

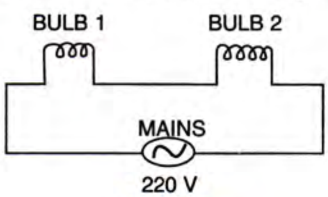


Fig. 9.10

arrangement voltage across each bulb will be $V = 110$ volt.

(a) Rate of consumption of energy in each bulb

$$= \frac{V^2}{R} = \frac{(110)^2}{806{\cdot}67} = \mathbf{15\ W}$$

Assuming that the resistance of bulb does not change on glowing.

(b) Total power consumed in the two bulbs = 15 W + 15 W = **30 W**

(iii) The arrangement of two identical bulbs in parallel with the mains is shown in Fig. 9.11. In this arrangement, voltage across each bulb will be $V = 220$ volt and then power spent in each bulb will be 60 W.

∴ Total power consumed in the two bulbs

= 60 W + 60 W = **120 W**

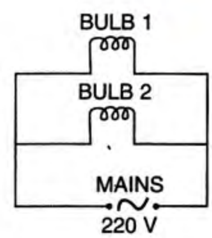


Fig. 9.11

EXERCISE–9(A)

1. At what voltage and frequency is the electric power generated at the power generating station ?

Ans. Voltage – 11 kV, Frequency – 50 Hz

2. Explain with the aid of a simple diagram, the transmission of electric power from the generating station to your house.

3. (a) At what voltage is the electric power from the generating station transmitted ? Give reason to your answer.

(b) What is the nature of current transmitted from the power station ?

4. At what (i) voltage and (ii) frequency is the a.c. supplied to our houses ?

Ans. (i) 220 V, (ii) 50 Hz

5. Name the device used to (a) increase the voltage at the generating station, and (b) decrease the voltage at the sub station for its supply.

6. (a) Name the *three* connecting wires used in a household circuit.

(b) Which of the two wires mentioned in part (a) are at the same potential ?

(c) In which of the wire stated in part (a), the switch is connected ?

7. What is the pole fuse ? Write down its current rating.

8. State the function of each of the following in a house circuiting :

(a) kWh meter, (b) main fuse, and (c) main switch.

9. In what unit does the electric meter in a house measure the electrical energy consumed ? What is its value in S.I. unit ? **Ans.** kWh, 1 kWh = $3{\cdot}6 \times 10^6$ J

10. Where is the main fuse connected in a house circuit ? **Ans.** In live wire before the ring system.

11. State *one* advantage of using the main switch in house wiring.

12. Draw a circuit diagram to explain the ring system of house wiring. State *two* advantages of it.

13. Draw a labelled diagram with the necessary switch, regulator, *etc.* to connect a bulb and a fan with the mains. In what arrangement are they connected to the mains : series or parallel ?

14. How should the several electric lamps be connected with the mains so that the switching on or off a lamp has no effect on the operation of other lamps ?

Ans. In parallel

15. Fig. 9.12 shows three bulbs A, B and C each of rating 100 W, 220 V connected to the mains of 220 V. Answer the following :

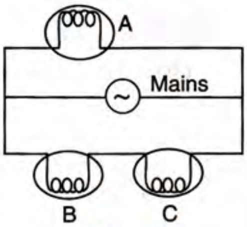


Fig. 9.12

(a) How is the bulb A connected with the mains ? At what voltage does it glow ?

(b) How are the bulbs B and C connected with the mains ? At what voltage does the bulb B glow ?

(c) How is the glow of bulbs A and C affected if bulb B gets fused ?

(d) How is the glow of bulbs B and C affected if bulb A gets fused ?

Ans. (a) parallel, 220 V, (b) series, 110 V, (c) A—no effect, C—does not glow (d) both unaffected

16. Two sets A and B each of four bulbs are glowing in two separate rooms. When one of the bulbs in set A is fused, the other three bulbs also cease to glow. But in set B, when one bulb fuses, the other bulbs continue to glow. (i) Explain the difference in the two sets. (ii) Which set of arrangement is preferred in housing circuit and why ?

[**Hint :** In set A, the bulbs are in series; while in set B, the bulbs are in parallel].

MULTIPLE CHOICE TYPE

1. The main fuse is connected in :
(a) live wire
(b) neutral wire
(c) both the live and earth wires
(d) both the earth and neutral wires.

Ans. (a) live wire.

2. The electrical appliances in a house are connected in:
(a) series
(b) parallel
(c) either in series or parallel
(d) both in series and parallel. **Ans.** (b) parallel.

3. The electric meter in a house records :
(a) charge (b) current
(c) energy (d) power. **Ans.** (c) energy

(B) SOME ESSENTIAL COMPONENTS OF HOUSE WIRING SYSTEM

9.4 FUSE

We have read that a main fuse (or MCB) is connected in the live wire after the kWh meter and before the main circuit. The fuse protects the circuit by blowing off when the circuit either gets over loaded (*i.e.*, total load in the house exceeds the load limit for which connection is taken from the company) or gets short circuited*. Similarly, a fuse is connected with each electrical appliance to safeguard it from the flow of current in excess of its safe limit of current.

A fuse wire permits the flow of current through it only up to a certain fixed limit which is called the *current rating* of the fuse. As the current exceeds this limit, the temperature of the fuse wire reaches the melting point and the wire melts so that the circuit gets broken. Thus,

An electric fuse is a safety device which is used to limit the current in an electric circuit. The use of a fuse safeguards the circuit and the appliances connected in that circuit from being damaged.

Principle : A fuse works on the *heating effect of current*. A fuse wire of length l, radius r and of material of which specific resistance is ρ, has its resistance $R = \frac{\rho l}{\pi r^2}$. Due to flow of current I in it, heat produced per second in the fuse wire will be $H = I^2R = I^2\rho l/\pi r^2$ .....(i)

If T is the temperature of surrounding of the fuse wire and ΔT is the rise in its temperature,

* Short circuiting occurs when the live wire comes in direct contact with the neutral wire, so a zero resistance path is provided to the current. A heavy current then passes through the live wire of the circuit.

loss of heat by radiation per second will be

$$H = 4\sigma\, T^3\, \Delta T \times 2\pi rl \qquad \text{....(ii)}$$

where σ (= $5{\cdot}67 \times 10^{-8}$ W m^{-2} K^{-4}) is a constant. In equilibrium, from eqns. (i) and (ii),

$$\frac{I^2\rho l}{\pi r^2} = 4\sigma\, T^3\, \Delta T \times 2\pi rl \qquad \text{....(iii)}$$

∴ The temperature of fuse wire above its surroundings is

$$\Delta T = \frac{\rho}{8\pi^2\sigma T^3} \times \frac{I^2}{r^3} \quad \text{or} \quad \Delta T \propto \frac{I^2}{r^3} \qquad \text{....(9.1)}$$

Thus the rise in temperature of fuse wire depends on (i) current rating I, and (ii) its radius r. It is directly proportional to the square of current and inversely proprotional to the cube of its radius. It does not depend on the length of the wire.

Example : A fuse wire of current rating 1·0 A is of radius 0·2 mm, while the fuse wire of current rating 8·0 A is of radius 0·8 mm.

Thus the thickness of fuse wire depends on its current rating. *Higher the current rating, thicker is the fuse wire.*

A fuse is a short and thin piece of wire of uniform area of cross-section and high resistance so as to produce sufficient heat to melt it. It is made up of a material of low melting point, so that it may easily melt due to overheating when current in excess to the prescribed limit, passes through it. Generally an alloy of lead and tin is used as the material of the fuse wire because its melting point is low (≈ 250°C) and specific resistance is more than that of copper, aluminium, etc.

A copper or aluminium wire is unsuitable for use as the fuse wire because they have high melting point (≈ 1080°C). Moreover the use of an ordinary copper or aluminium wire as a fuse must be avoided as it is very thick so it will not melt even if the current exceeds its safe limit.

Construction : Fig. 9.13 shows one of the most common fuse arrangement in which the fuse

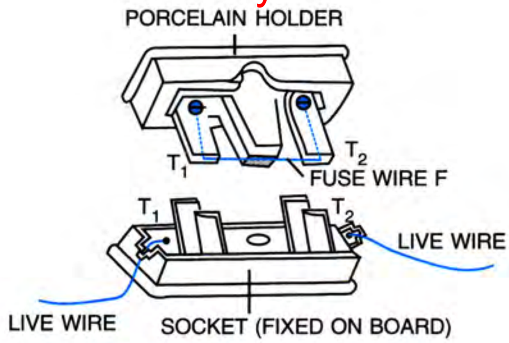


Fig. 9.13 Fuse arrangement

wire F is stretched between the two metallic terminals T_1 and T_2 in a porcelain holder (since porcelain is an *insulator* of electricity). This holder fits into a porcelain socket having two metallic terminals to each of which *the live wire of the circuit is connected.* Thus the fuse wire gets connected in the live wire.

Working : When current in the circuit exceeds the specified value (due to any reason such as high voltage, short circuiting, *etc.*) the temperature of the fuse wire rises to the extent that it melts. As a result, a gap is produced and the circuit breaks (Fig. 9.14). Now current does not flow through the live wire and the appliance (or the circuit) is saved. After removing the fault in the circuit, a new fuse wire of the same current rating is connected in the holder to complete the circuit again.

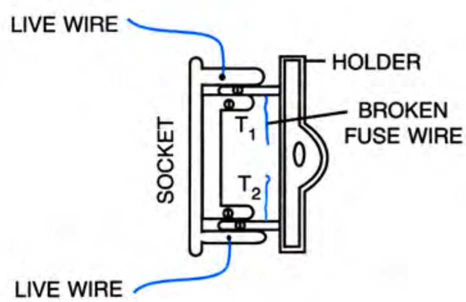


Fig. 9.14 Function of fuse (due to excessive current, fuse melts and circuit breaks)

Now a days the costly appliances such as refrigerator, air conditioner, geyser, television, *etc.* are provided with a cartridge type fuse (Fig. 9.15) of proper current rating such as 1 A, 2 A, 5 A, 10 A and 13 A.

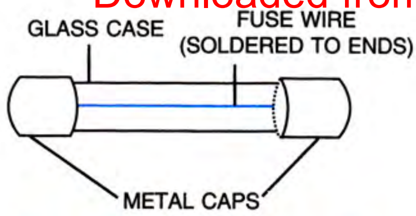
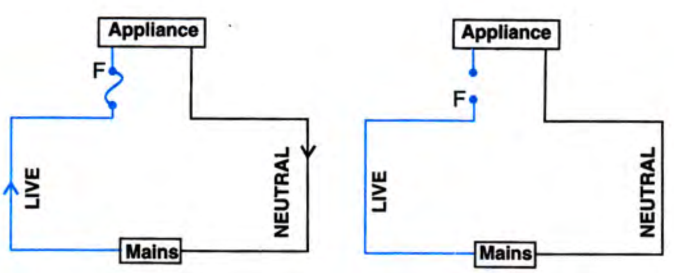


Fig. 9.15 Cartridge type fuse

Reason for connecting the fuse in the live wire

The fuse is always connected in the live wire before the appliance, so that as the current in circuit exceeds the rating of fuse, it may melt and break the circuit first, before the current reaches the appliance. Thus no current flows in the appliance.

In Fig. 9.16 (a), the fuse F is connected in the live wire joined to the appliance through the mains. The circuit is complete and current flows in the appliance. In Fig. 9.16 (b), due to voltage fluctuation (or short circuiting), if excessive current flows, the fuse F blows off, the circuit becomes incomplete and no current flows in the appliance.



(a) Current flowing in the appliance through the fuse.

(b) No current flowing in the appliance when the fuse blows off.

Fig. 9.16 Function of fuse.

It is unsafe to connect the fuse in the neutral wire. Fig. 9.17 (a) shows the fuse F in the neutral wire. If due to some defect in the appliance an excessive current flows in the circuit, the fuse blows and current stops flowing in the circuit, but the appliance still remains connected to the high potential point of the supply through the live wire [Fig. 9.17(b)]. Now if a person touches the faulty appliance, he gets an electric shock because the person comes in direct contact of the mains through the live wire. Thus it is highly unsafe to use fuse in the neutral wire.

(a) Current flowing in the circuit

(b) Appliance connected to the high potential even when fuse blows off

Fig. 9.17 Fuse connected in neutral wire.

Current rating of a fuse

In electric wiring for light and fan circuits a thin fuse wire of low current rating (≈ 5 A) is used because the line wire has a current carrying capacity of 5 A. A thick fuse wire of higher current rating (≈ 15 A) is used for heavy current consuming appliances such as air conditioner, geyser, washing machine, *etc.* because the line wire for such appliances has a current carrying capacity of 15 A.

The current rating of the fuse in a circuit can be obtained from the following relation :

$$\text{Current rating of fuse in a circuit} = \frac{\text{total power of appliances in circuit}}{\text{voltage of the supply}} \quad ...(9.2)$$

The table below gives the current rating of the fuse needed for various appliances.

Current rating of fuse for various appliances

Appliance	Power rating at 220 V (in watt)	Current drawn in running condition (in A)	Current rating for fuse
Electric bulb	60	0·27	5A fuse in line circuit
Television set	120	0·54	
Refrigerator	150	0·68	
Electric mixer	750	3·4	
Room heater	1000	4·5	5A
Electric iron	1000	4·5	5A
Geyser	1500	7·0	8A
Electric kettle	2000	8·3	10A
Electric oven	3000	13·6	15A

Note : The fuse provided (or connected) with an electric appliance to protect it against electric faults must be of current rating a little more than the maximum current that can be drawn by the appliance before being over heated. But some electric appliances such as mixer, water pump, etc. having an electric motor in it, draws a heavier current when it is switched on, as compared to that when it is in running condition. So the fuse for such appliances must be of current rating some what more than the starting current. For example, a water pump rated 1·5 kW, 220 V has a motor which draws current 10·4 A at the starting and then 6·8 A while running. Hence the fuse with it must have a current rating not less than 10·5 A.

MCB : Now a days instead of a fuse, a *miniature circuit breaker* (MCB) is used for each individual circuit. If due to short circuiting (or some fault), a heavy current flows in the line, the MCB falls down to switch off the circuit in a very short time (≈ 25 milli-second). After repairing the fault in the circuit, the MCB is then raised up. Thus the use of MCB is easier than a fuse because (i) it avoids the inconvenience of connecting a new fuse wire, and (ii) it is much safer due to its quick response.

9.5 SWITCHES

A switch is an on-off device for current in a circuit (or in an appliance). It is connected in the live wire.

Switches are of various kind and they are made in many fascinating designs. We classify the switches in *two* groups : (1) single pole switch, and (2) double pole switch.

(1) Single pole switch : The switch used with an appliance to start or stop the flow of current in it, is the single pole switch. *A single pole switch disconnects only the live wire from the appliance.*

(2) Double pole switch : The main switch at the distribution board, used to switch on or off the mains, is the double pole switch. *A double pole switch disconnects both the live and neutral wires simultaneously.*

The *dual control switch* used in a staircase* *etc.*, is also the *double pole* switch of special kind.

Reason for connecting the switch in the live wire

The switch should always be connected in the live wire. Fig. 9.18 (a) shows the switch S connected in the live wire and the switch S is in '*on*' position. The appliance (say, bulb) gets connected to the high potential point through the live wire and current flows in the appliance because the circuit is complete as the neutral wire provides the return path for the current. In Fig. 9.18 (b), in the '*off*' position of switch S, the circuit is incomplete and no current reaches the appliance through the live wire. The appliance does not operate (*i.e.*, the bulb does not glow). It is now safe to carry out repairs in the appliance, if required. Even the live wire connection of the appliance can be touched if the switch is in '*off*' position because both the live wire and neutral wire connected with the appliance are at zero potential.

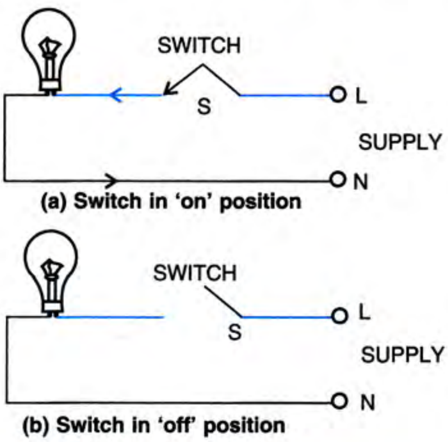
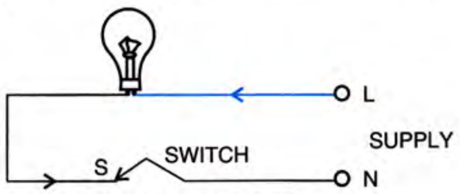


Fig. 9.18 Switch connected in live wire

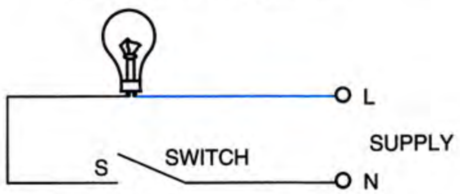
It is deceptive and dangerous to connect a switch in the neutral wire. In Fig. 9.19, switch is

* See article 9.6

connected in the neutral wire. In the '*on*' position [Fig. 9.19(a)], it allows current to flow in the bulb and in the '*off*' position [Fig. 9.19(b)], no current passes through the bulb. Thus the switch serves its purpose. But in the '*off*' position of switch, the appliance remains connected to the high potential terminal through the live wire, although no current flows through the appliance because the return path is incomplete (or broken). *In this condition, it is not safe to carry out any repairs in the appliance because on touching the live wire in the appliance, the current will pass through the body of the person and he may get a fatal shock.* Further due to some fault (or any other reason), if the live wire touches the metallic body of the appliance, then it is not safe to touch the appliance even from outside. Thus, if the switch is connected in the neutral wire, it can be quite deceptive and dangerous for the user.



(a) Switch in 'on' position



(b) Appliance at high potential even when switch is in 'off' position

Fig. 9.19 Switch connected in neutral wire

Safety precaution while using a switch : *A switch should never be touched with wet hands. If water reaches the live wire, it forms a conducting layer between the hand and the live wire of the switch due to which a current passes to the hand through it and the person may get a fatal shock.*

9.6 CIRCUITS WITH DUAL CONTROL SWITCHES (STAIRCASE WIRING)

We have read that the switch used in the live wire with the appliances to put them 'on' or 'off' is the single pole type switch. Dual control switch is the double pole type switch of special kind which is generally used one at the top and other at the bottom of a staircase, or one each at the opposite ends of a long corridor, *etc*. With such switches, the appliance (say, a bulb) can be switched on or off from two different places.

The connections of a dual control switch are illustrated in Fig. 9.20. It is operated in *two* ways : (1) by shifting the knob of switch to the right (or up), the live wire L connected at the terminal 'b' makes contact to the terminal 'a' so as to make the connection 'ba' through the spring metal strip, and (2) by shifting the knob to the left (or down), the terminal 'b' makes contact with the terminal 'c' so as to make the connection 'bc'.

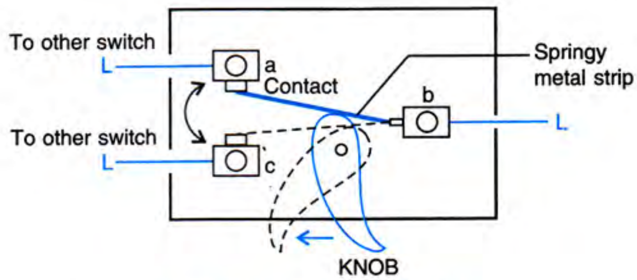
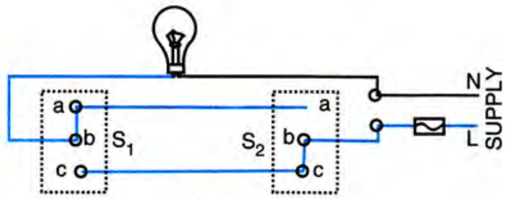


Fig. 9.20 Dual control switch

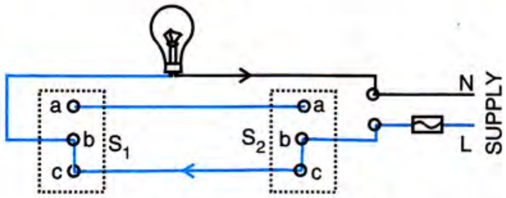
Fig. 9.21 illustrates the working of a dual control switch. Two such switches S_1 and S_2 are used. The switch S_1 is fitted at the bottom and the switch S_2 at the top of the staircase. Fig. 9.21(a) shows the '*off*' position of the bulb.

The bulb can now be switched '*on*' independently by either the switch S_1 or the switch S_2. If the switch S_1 is operated, the connection 'ba' is changed to 'bc', which completes the circuit and the bulb lights up [Fig. 9.21(b)]. Similarly, on operating the switch S_2 from the position shown in Fig. 9.21(a), the connection 'bc' changes to 'ba', which again completes the circuit [Fig. 9.21(c)] and the bulb lights up.

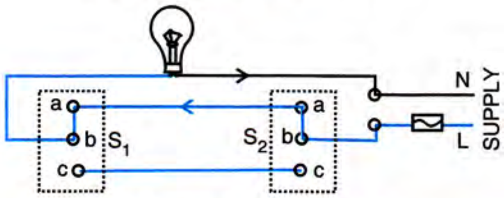
Similarly, if the bulb is in '*on*' position as shown in Fig. 9.21(b), one can switch '*off*' the bulb by changing the connections 'bc' to 'ba' either by operating the switch S_1 or the switch



(a) Bulb off



(b) Bulb on through switch S_1



(c) Bulb on through switch S_2

Fig. 9.21 Working of a dual control switch

S_2. But if the bulb is in *'on'* position as shown in Fig. 9.21(c), it can be switched 'off' by changing the connections 'ba' to 'bc' either by the switch S_1 or the switch S_2.

In a staircase, while going up a person puts *'on'* the light by operating the switch S_1 so that the connection 'ba' changes to 'bc' and makes the current to flow in the circuit. On reaching at the top he operates the switch S_2 to put *off* the light so that the connection 'bc' changes to 'ba' and the flow of current stops.

The same system is operative when a person puts *on* light by operating the switch S_2 to change the connection 'bc' to 'ba' and swtich *'off'* the light by operating the switch S_1 to change the connection 'ba' to 'bc'.

9.7 EARTHING (GROUNDING)

(a) Local earthing

We have read that the local earthing is done in the house near the kWh meter. For this purpose, a hole nearly 2-3 metre deep is dug in the ground. A copper rod (or a thick copper wire) covered by a hollow insulating pipe, is inserted in the hole. A thick copper plate of dimensions 50 cm × 50 cm is welded to the lower end of the copper rod and it is buried in the ground as shown in Fig. 9.22. The plate is surrounded by a *mixture of charcoal and salt* to make a good contact between the plate and the earth. To keep the ground damp, water is poured through the pipe from time to time. This forms a conducting layer between the plate and the ground. The upper end of the copper rod is joined to the earth connection at the kWh meter.

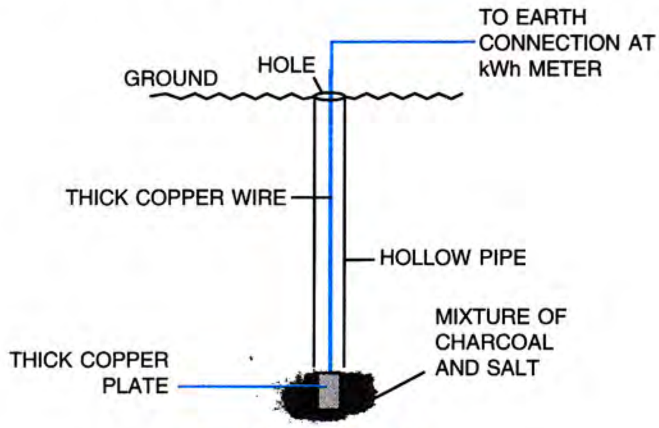


Fig. 9.22 Local earthing

Safety by the local earthing : If due to some reason such as short circuiting, an excessive current flows through the line wires, it will pass to earth through the earth wire if there is local earthing, otherwise the line wires may get over heated and it may cause a fire.

(b) Earthing of an appliance

It is essential to provide a connection for earthing an electrical appliance having a metallic case (such as refrigerator, toaster, geyser, electric iron, electric cooler, *etc.*) which we handle physically. For this, the earth wire of the cable is connected to the terminal provided on the outer metallic case of the appliance. Fig. 9.23 shows

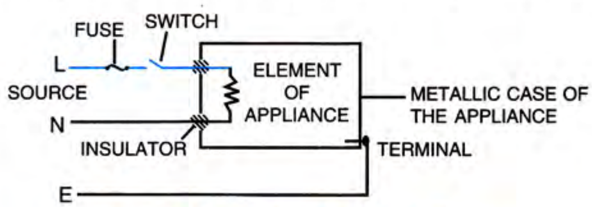


Fig. 9.23 Earthing of an appliance

the live and neutral wires connected from the source to the element of appliance through the insulating plugs on its metallic case. The switch and the fuse are connected in the live wire. The earth wire is connected to the metallic case of appliance.

> ***Note :*** **(1)** The symbol ⏚ can also be used for showing the earthing of an appliance. **(2)** Most often the metallic case of appliance is painted. The paint provides an *insulating* layer on the metallic body of appliance. To make the earth connection, *it is necessary to remove paint from the body part where connection is to be made.*

Safety by earthing of an appliance : When the live wire of a faulty appliance comes in direct contact with its metallic case due to break of insulation after constant use (or otherwise), the appliance acquires the high potential of the live wire. A person touching it will get a fatal shock because current flows through his body to the earth. But if the metallic case of appliance is properly earthed, then as soon the live wire comes in contact with the metallic case of the appliance, a heavy current flows to the earth through the case of the appliance (since the metallic case has almost zero resistance) and the fuse connected in the circuit of appliance blows off, and the appliance gets disconnected. Thus, the person touching the defective appliance does not get any shock and the appliance is also saved from being damaged.

9.8 THREE-PIN PLUG AND SOCKET

Three-pin plug

All electric appliances are provided with a cable having a plug at one end to connect the appliance to the electric supply. It is a fixture provided with *three* metallic (usually brass) pins in an ebonite case as shown in Fig. 9.24.

In a three pin plug, *the top pin is for earthing, the pin on the left is for live and the pin on the right is for neutral.* In the good quality plugs, these are marked as E, L and N respectively [Fig. 9.24]. The pins are splitted at the ends to provide a spring action so that they fit in the socket holes tightly.

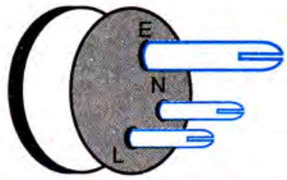


Fig. 9.24 Three-pin plug

The earth pin is thicker and longer than the other two. The earth pin is made long so that the earth connection is made first. This ensures the safety of the user because if the appliance is defective, then as soon as the live pin gets connected, the current passes to the earth and the fuse blows off. Further the earth pin is thicker so that even by mistake it cannot be inserted into the hole of the socket for the live or neutral connection.

The plug is inserted into the socket so as to obtain current from the mains.

> ***Note :*** Sometimes the plug used with an appliance (such as table lamp or night lamp) consuming low power, has only two pins, the live pin on the left and the neutral pin on the right.

Socket :

Fig. 9.25 shows a socket. It is a fixture in an electric circuit in which the plug is inserted. The socket has *three* holes. The inner wall of each hole is made of hollow metallic tube usually of brass, forming the terminal at its back. These terminals are connected to the live, neutral and earth wires of the supply line. *The upper bigger hole in the socket is for earth connection, while the hole on the right side is for connection to the*

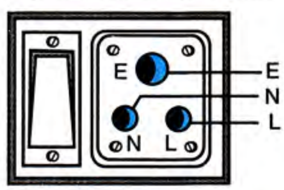


Fig. 9.25 Socket

live wire and the hole on the left side is for connection to the neutral wire of electric supply.

Safety precautions for plug and socket : While inserting the plug into a socket, the following *two* main precautions are taken :

(1) *The hands must be completely dry.*

(2) *The plug pins should fit in the socket tightly.* Any loose connection will give rise to sparking and burning of either the socket or the plug.

9.19 COLOUR CODING OF WIRES IN A CABLE

Each electric appliance is provided with a *three-core* flexible cable. The insulation on the three wires is of different colours : red (or brown), black (or light blue), and green.

Old convention of colours of insulation : *Red for live, black for neutral, and green for earth.*

New international convention : *Brown for live, light blue for neutral, and green (or yellow) for earth.*

Colour coding of wires in a cable

Wire	Colour	
	old convention	new convention
Live	Red	Brown
Neutral	Black	Light blue
Earth	Green	Green or Yellow

The colour coding of wires helps us to connect the switch, fuse, socket etc. through proper wire in house wiring.

9.10 HIGH TENSION WIRES

Each wire in a cable is capable to withstand up to a specific limit of current. If current exceeds this limit (due to short circuiting or high voltage fluctuations), the wire may burn due to excessive heating, and it may cause a fire. To avoid it, for high voltage and heavy current, a special wire, called the ***high tension wire***, is used. *A high tension wire has a low resistance and large surface area.* Therefore, instead of taking a single thick wire of *low resistance* as the high tension wire, it is made by twisting together a number of thin wires insulated from each other. This provides a *large surface area* so that it radiates the heat produced more readily to the surroundings as compared to a single thick wire.

9.11 SAFETY PRECAUTIONS WHILE USING THE ELECTRICITY

While using the electricity, precautions are taken to avoid the *two* major dangers : (1) *a fire,* and (2) *an electric shock.*

(1) A *fire* is caused when there is over heating of the line wires (or cable) for various reasons such as break of insulation or short circuiting, etc. To avoid it, one must use wires (or cable) of current carrying capacity higher than the total current which can flow through the circuit while using all the appliances simultaneously.

(2) An *electric shock* may be caused from an appliance due to (a) poor insulation of wires, (b) touching the appliance with wet hands, (c) no earthing of the appliance, (d) no fuse provided with the appliance, (e) no local earthing. To avoid it, *five* precautions are taken : (i) The insulation of wires must be of good quality and it should be checked from time to time. The reason is that with the passage of time, the insulation over the wire becomes brittle and it cracks off leaving the wire naked. (ii) *The appliance should never be operated (or touched) with wet hands. The hands should always be kept dry.* (iii) Each appliance must have its metallic case earthed. (iv) Each appliance must be provided with a proper fuse in its live wire before the appliance. (v) There must be proper local earthing near the kWh meter.

EXAMPLES

1. An electric motor of power 3 kW is to be operated at mains of 220 V. Find the current rating of the fuse to be comected with the motor.

Given $P = 3$ kW = 3000 W, $V = 220$ V

Current drawn by the motor $I = \frac{P}{V} = \frac{3000}{220} = 13.6$ A

Current rating of fuse to be used with motor = **15 A**

2. A house has main fuse of 5 A rating. 5 bulbs each of 60 W and 2 tube lights each of 40 W are used simultaneously. Find :

(i) the current drawn from the mains of 220 V, and (ii) the number of additional bulbs each of 100 W which can also be lighted on a festival day?

(i) Total power of appliances used simultaneously

$$P = (5 \times 60) + (2 \times 40) = 380 \text{ W}$$

Voltage of mains $V = 220$ volt

Current drawn from the mains

$$I = \frac{P}{V} = \frac{380}{220} = \mathbf{1.73\ A}$$

(ii) Excess current available which can be safely used = 5 A – 1·73 A = 3·27 A

Current drawn by each bulb of 100 W at 220 V,

$$I = \frac{P}{V} = \frac{100}{220} = 0.45 \text{ A}$$

∴ Number of additional bulbs of 100 W which can be lighted on a festival day

$$n = \frac{\text{excess current available}}{\text{current drawn by each bulb}}$$

$$= \frac{3.27}{0.45} = 7.3$$

i.e., **Seven** more bulbs can be lighted.

EXERCISE–9(B)

1. What is a fuse ? Name the material of fuse. State *one* characteristic of material used for fuse.
2. Name the device used to protect the electric circuits from over loading and short circuit. On what effect of current does it work ?
3. Complete the following sentences :

   (a) A fuse is a short piece of wire of high .... and of material of low ....

   (b) A fuse wire is made of an alloy of .... and .... If the current in a circuit exceeds the current rating of the fuse wire, it ....

   (c) A fuse is connected in .... with the .... wire.

   (d) Higher the current rating, ... is the fuse wire.

   Ans. (a) resistance, melting point (b) lead, tin, melts (c) series, live, (d) thicker
4. Why is the fuse wire fitted in a porcelain casing ?

   Ans. porcelain is an insulator of electricity
5. How is a fuse put in an electric circuit ? State the purpose of using a fuse in a circuit.
6. Describe with the aid of a diagram some form of a fuse which is used in the electric lighting circuit of a house. Give *two* reasons why a fuse must not be replaced by an ordinary copper wire.
7. A fuse is always connected in the live wire of the circuit. Explain the reason.
8. (a) Two fuse wires are rated 5 A and 20 A. Which of the two is (i) thicker, (ii) longer ?

   Ans. (i) 20 A fuse wire (ii) both may be of same length.
9. Explain the meaning of the statement 'the current rating of a fuse is 5 A'.
10. 'A fuse is rated 8 A'. Can it be used with an electrical appliance of rating 5 kW, 200 V ?

    Ans. No
11. An electric kettle is rated 3 kW, 250 V. Give reason whether this kettle can be used in a circuit which contains a fuse of current rating 13 A.

    Ans. Yes, because safe limit of current for kettle is 12 A
12. (a) What is the purpose of a switch in a circuit ?

    (b) Why is the switch put in the live wire ?

    (c) What precaution do you take while handling a switch?
13. (a) A switch is not touched with wet hands while putting it on or off. Give a reason for your answer.

    (b) Name the wire to which a switch is connected.

14. Draw a circuit diagram using the dual control switches to light a staircase electric light and explain its working.

15. What purpose is served by the terminals of a three way pin plug ? Draw a diagram and name the pins.

16. The diagram in Fig. 9.26 shows a three pin plug. Label the three pins.

(a) Why is the top pin thicker and longer than the other two ?

(b) Why are the pins splitted at the ends ?

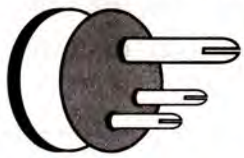


Fig. 9.26

17. Draw a labelled diagram of a three pin socket.

18. The diagram in Fig. 9.27 shows a three-pin socket marked as 1, 2 and 3.

(a) Identify and write live (L), neutral (N) and earth (E) against the correct number.

(b) To which part of the appliance is the terminal 1 connected ?

Fig. 9.27

(c) To which wire joined to 2 or 3, is the fuse connected ?

Ans. (a) 1 → E, 2 → N, 3 → L, (b) metal body, (c) 3

19. What do you mean by the term local earthing ? Explain how it is done.

20. To which wire is the metallic case of an electric appliance connected ? Give the reason.

21. (a) The earthing of an electric appliance is useful only if the fuse is in the live wire. Give the reason.

(b) Name the part of the appliance which is earthed.

22. For earthing an electric appliance, one has to remove the paint from the metallic body of the appliance where the electric contact is made. Explain the reason.

23. What is the colour code for the insulation on the (a) live, (b) neutral, and (c) earth wire ?

Ans. (a) brown (b) blue (c) green

24. How does the colour code of wires in a cable help in house wiring ?

25. A power circuit uses a cable having *three* different wires.

(a) Name the *three* wires of the cable.

(b) Between which of the *two* wires should the heating element of an electric geyser be connected ?

(c) To which wire should the metallic case of the geyser be connected ?

(d) To which wire should the switch and fuse be connected ?

Ans. (a) live, neutral and earth (b) live and neutral (c) earth (d) live

26. State *two* circumstances when one may get an electric shock from an electric gadget. What preventive measure must be provided with the gadget to avoid it ?

27. Why is it necessary to have an earth wire installed in a power circuit, but not in a lighting circuit ?

28. Give *two* characteristics of a high tension wire.

29. Which of the cables, one rated 5 A and the other 15 A will be of thicker wire ? Give a reason for your answer.

[**Hint :** To carry heavy current, the resistance of wire should be low, so its area of cross section should be large]. **Ans.** 15 A cable

30. The diagram in Fig. 9.28 shows three lamps and three switches 1, 2 and 3 connected with two cells.

(a) Name the switch/switches to be closed so as to light all the three lamps.

(b) How are then the lamps connected : in series or in parallel ?

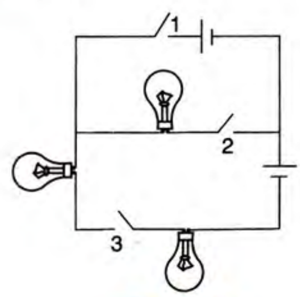


Fig. 9.28

Ans. (a) 2 and 3, (b) in series

31. Fig. 9.29 below shows two bulbs with switches and fuse connected to the mains through a three pin socket by means of a three wires cable.

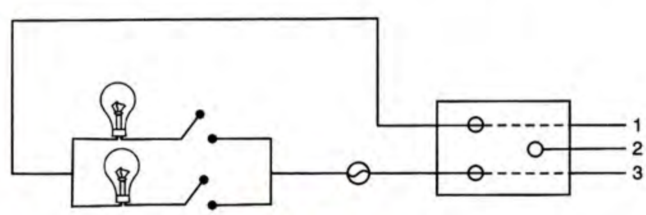


Fig. 9.29

(a) Label each component – bulb, switch, fuse and socket.

(b) Name and state the colour of insulation of each wire 1, 2 and 3.

(c) How are the two bulbs joined : in series or in parallel ?

Ans. (b) 1-neutral, blue, 2-earth, green, 3-live, brown (c) parallel

MULTIPLE CHOICE TYPE

1. The rating of a fuse connected in the lighting circuit is :

(a) 15 A (b) 5 A

(c) 10 A (d) zero. **Ans.** (b) 5 A

2. A switch must be connected in the :

(a) live wire (b) neutral wire

(c) earth wire (d) either earth or neutral wire.

Ans. (a) live wire.

Downloaded from https:// www.studiestoday.com