UNIT 9 ELECTRICAL MATERIALS

Structure

9.1 INTRODUCTION

You have already learned about Plastics & Boards in previous unit. Now you will learn about the electrical materials, and their installation in building in this unit.

While providing electrification to private and public buildings, it is imperative for an installation engineer and his technical hands, to have full knowledge of the various materials used in carrying out the job in a satisfactory way. The primary objective is to guide electricity from the street poles (for overhead installation) or from feeder pillar (in case of underground cable system) into the premises, with utmost considerations of safety and reliability. It is for safety aspects (both the shock hazard and fire hazard to the premises) standards Institution specify the dimensions of the materials and the electrical and mechanical properties to which the materials should conform. Further, the IS code (No. 732 of 1963) specifies the method of wiring for industrial, commercial and residential premises with a view to obtaining safety to the personnel and to the property. In addition, the end utilisation of electricity depends on the electrical appliances i.e. lamps, fans, healers and other domestic gadgets for each of which standards exist for safety and interchangeability,

In India, the standard voltage for domestic purposes is 230V single phase and 415 V three phase with an allowable variation of ±6%. The frequency of supply is 50 Hertz with allowable fluctuation of ±1.5 Hz. These voltages arc classified as low voltage (upto 250 V) and medium voltage (above 250 V and upto 650 V) as per the Indian Electricity rules. All the manufactured electrical materials are then tested so that they withstand these voltage levels indefinitely.

In this unit of Electrical Materials, the following categories of materials are covered in each section.

Objectives

At the end of this unit, you should be able to

* describe electrical materials, which are commonly used in residential, commercial and industrial buildings,
* choose the right material, specify it as a part of building activity, and
* explain the practical wiring installation without involving the design of installation.

9.2 ELECTRICAL CONDUITS

Conduits used in electrical wiring can be classified as rigid and flexible conduits. Both kinds are available in steel and PVC. Each of these four kinds has its own merits and demerits which are explained in the following sections.

9.2.1 Rigid Conduits

The tubing through which electrical cables are drawn are called conduits. The rigid steel conduits are covered by IS 1653 of 1964, and have the following standard sizes.

Table 1: Specifications of Rigid Steel Conduits

Nominal size of conduit		Outside diameter		Thickness		Weight per meter
mm	inch	Max.mm	Min. mm	Max.mm	Min. mm	Kilograms
16	–	16.900	15.606	1.6	1.5	0.580
19	3/4	19.075	18.763	1.8	1.7	0.780
25.4	1	25.425	25.113	1.8	1.7	1.080
31.8	$1\frac{1}{4}$	31.775	31.463	1.8	1.7	1.380
38.0	$1\frac{1}{2}$	38.125	37.795	2.0	1.9	1,840
51	2	50.825	50.495	2.24	2.14	2.850
63.5	$2\frac{1}{2}$	63.525	63.195	2.50	2.4	3.600

It may be noted, from Table 1 that the size in electrical conduits always refers to the oulside diameter. They can be made either by extrusion or by rolling a sheet into circular shape and welding along the longitudinal joint. The later is called welded conduit and the former is called solid or seamless type. The welded conduits are used for domestic and normal industrial applications.The seamless conduits are specified in situations where hazardous or explosive materials are encountered. Electrical conduits are specially annealed so that they may be readily bent without cracking, splitting or kinking. They arc stove enamelled bolh inside and outside. The inside enamel ensures that the cable insulation is not damaged while drawing them through the conduit. The Outside enamel protects from rusting and gives smoothappearance.

Galvanised Iron Conduits

Though stove enamelled conduits are commonly used, but galvanised iron conduits are recommended in specific situations like damp, acid or corrosive atmospheres, salt or sea water atmospheres. The galvanised treatment of surface gives the necessary prolection against hostile atmospheres.

All the metal conduits have principal advantage of a high degree of mechanical protection to the cables, and an effective path for leakage current. Any leakage current from defective cable will be returned to the earth through the conducting path of metal conducts. Thus human safety is obtained. It, however, requires good electrical continuity at the joints of the conduits (see 9.2.21) and earthing of conduit at switch board.

Rigid PVC Conduits

PVC stands for polyvinyl chloride, which is a polymer having good mechanical and electrical properties. PVC conduits have come into common use, as alternative to steel conduits mainly on account of lower cost (about one third of the cost of metal conduits). The other advantages are : (i) ease of handling and jointing, (ii) non-corrosive and unreactive to most of the chemicals. The main disadvantages are : (i) PVC starts softening above 70° C and, hence, cannot be used near furnaces or high temperature situations, (ii) they harden and become brittle below 15°C and hence prone to cracking, (iii) mechanical strength is poor and cannot protect wires inside under heavy blows and crushing fores, (iv) they cannot suppress radiating fields (at high frequencies) emanating from current carrying wires held inside them.

PVC conduits are available in outside diameters of 15mm, 20mm, 25mm, 40mm and 50mm and in lengths of **3-4** metres. Jointing of these conduits is clone by using unscrewed couplers and special solvents. They can aiso be joined by threaded couplers (this aspect is referred to conduit fittings, i.e., 9.3) or by welding. In welding, special flameless torch with heater element and PVC rods of 3-5mm size are used. This is not in common use.

9.2.2 Flexible Conduits

In contrast with the rigid typc, flexible conduits can take any bent shapes to facilitate thc connection from the switch boards on the walls to the terminals of equipment on the floor. This is necessary, hccausc at the time of installing the wiring, in most cases, the location of terminals of the equipment is not known with reference to the switch board on the walls. On the contrary, the connection by the rigid conduits will involve a number of bends under such situations and pulling the wires through rigid conduit bends will present problems. This is avoided by using flexible conduits. There arc **two** types of conduits namely (i) metallic (ii) PVC.

Metallic Flexible **Conduits**

It is made from stepped strip, which is wound in a continuous spiral so as to produce a long cylinder with spiral corrugations. The material used is galvanisecl steel. Figure 9.1 shows the physical shape.

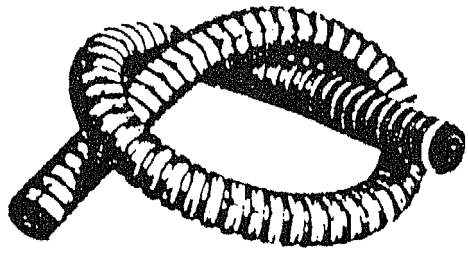


Fig. 9.1 Metallic flexible conduit

Flexible metallic conduits cannot provide earth continuity, and hence, separate earth wire is to be run all along the flexible inside or outside.

W C Flexible Conduit

Flexible PVC conduits are available in two types. In one type, thc flexibility is conferred by corrugated construction as in the casc of metallic conduit. In the other kind, PVC tube of thin plasticised grade is used so that flexibility is the property of material itself. The primary advantage of the later type is that it prevents ingress of moisture.

9.3 CONDUIT FITTINGS (CONCEILED AND SEMI-CONCEALED)

A large number of conduit fittings arc used for producing a salisfaclory wiring installation.

9.3.1 Conduit Fittings

Some of them are like couplers, in boxes, elbows, 'T's, bends. These are described on later.

Conduit Coupler

This is used for extending rigid conduit lengths. It has internal threads matching with outside threads of the conduit. Light gauge conduits are not joined by threaded couplers but by means of slip sockets. In the PVC kind of couplers, a solvent is used to make rigid coupling between conduits. In metallic conduits, no such technique is available and, hence, where light gauge conduits with slip on couplers are used, there is no rigidity in the coupling, nor is there any electrical continuity through the coupler. Figure 9.2 illustrates both kinds of couplers.

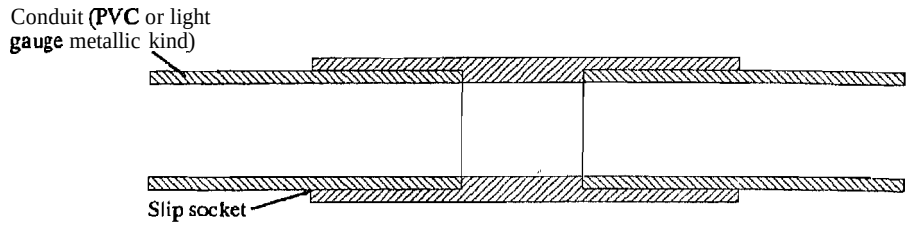


Fig 9.2 (a) Slip Socket Joint Coupler

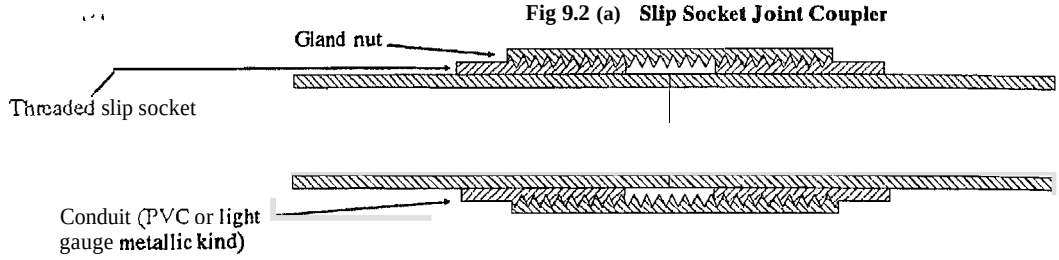


Fig 9.2 (b) Slip Sockcl with a gland nut at top Coupler

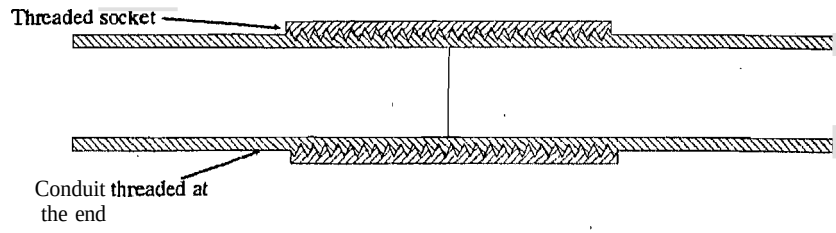


Fig 9.2 (c) Rigid Conduit Coupling

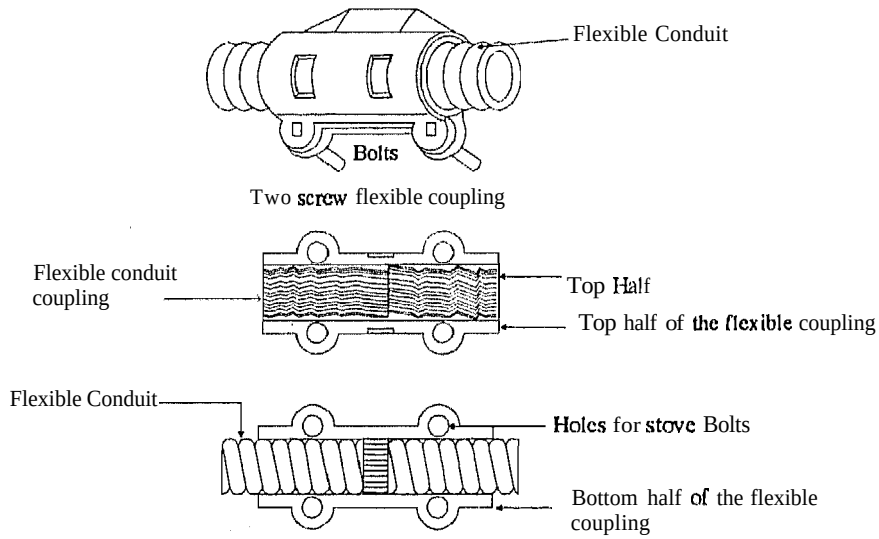


Fig 9.2 : Conduit Coupler

Conduit Box

The purpose of these boxes is to provide multiple outlets from one conduit. Also, they are used to terminate the wiring at the switch boards. These boxes are available, either made up of PVC or of steel materials. Their shapes can be either square or round, and are shown in Figure 9.3.

The junction boxes have detachable knockouts (shown in the figures) which are removed and the conduits terminated during installation. This fact is true for metallic junction boxe. In the case of PVC junction boxes, small projections are moulded integral with boxes. The conduits terminate into these projections, as shown in Figure 9.3.

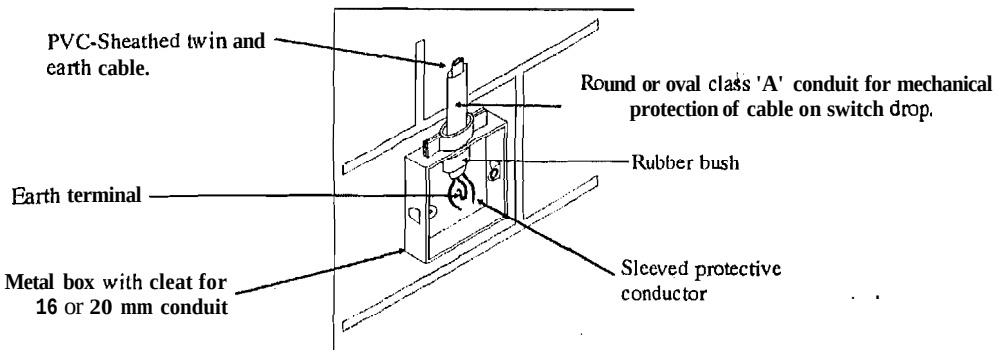
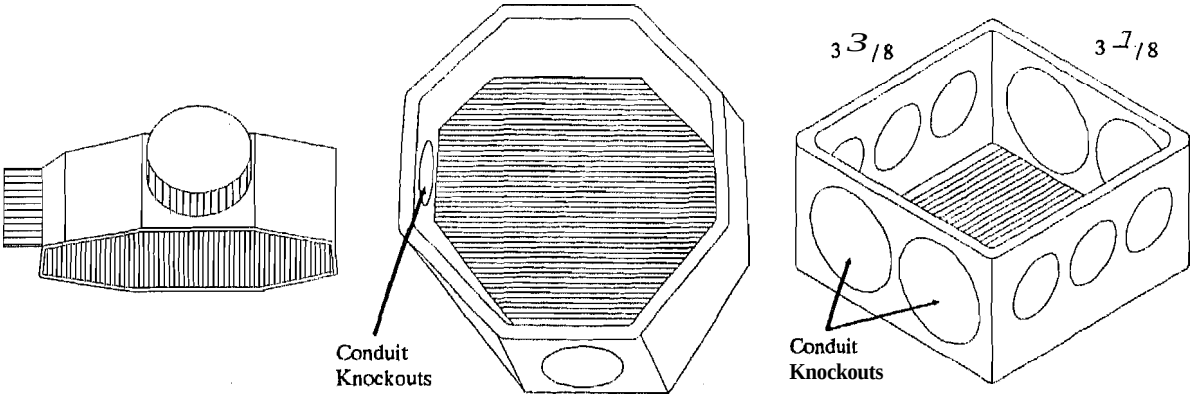


Figure 9.3 (a) Square Metalic Conduit Box

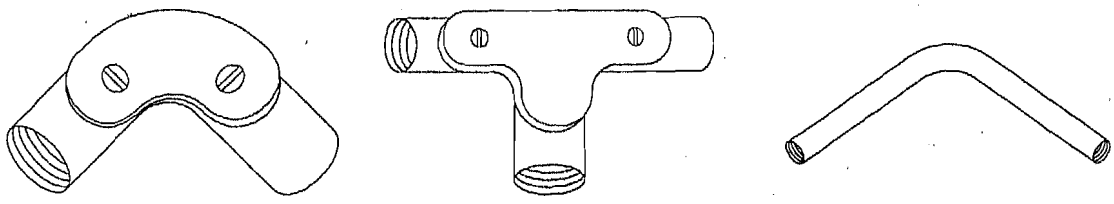


PVC Junction Box | Metallic Junction Box | Square Conduit Box

Flg. 9.3 (b) Metallic Conduit Box

Conduit Elbows, Tees and Bends

The elbows and bends are used lo change the conduit routing by 90°. The Tees are used when a perpendicular branching of wiring is needed. In the use of Tee, the wiring through one conduit can be branched into two conduits in opposite directions. An elbow is used where there is a need of sharp change in the direction of wiring whereas a bend is used in situations where there is a gradual change in the direction of wiring. The elbows can be solid form or as an inspection kind; in the later case, a detachable cover is provided which is held in position by screws to the elbow. Bends are invariably in the solid form, i.e., without



Metallic Elbow With Inspection cover | Metallic Tee with Inspection Cover | Solid Metallic bend

Pig. 9.4 Solid and Inspection types of Bends, Tee and Elbow.

any inspection cover. These descriptions of solid or inspection kinds given above are completely true in metallic conduit system. Figure 9.4 illustrates the three kinds. It may be noted that these kinds of accessories have threads into which the threaded conduits engage. All these three kinds of accessories are available in PVC material, but no detachable cover is provided in any of them. Also, the PVC conduits are only slipped into the elbows, Tees and bends by using the normal joining solution and no threads are provided in them. Due to lack of inspection cover for a PVC Tee, drawing wires through the Tee sometimes becomes a problem. In such situations a PVC junction box is used in lieu.

9.3.2 Conduit Fixing Accessories

These accessories are used for fixing the conduits in position either in concealed or surface systems of wiring. Figure 9.5 illustrates the three kinds of accessories.

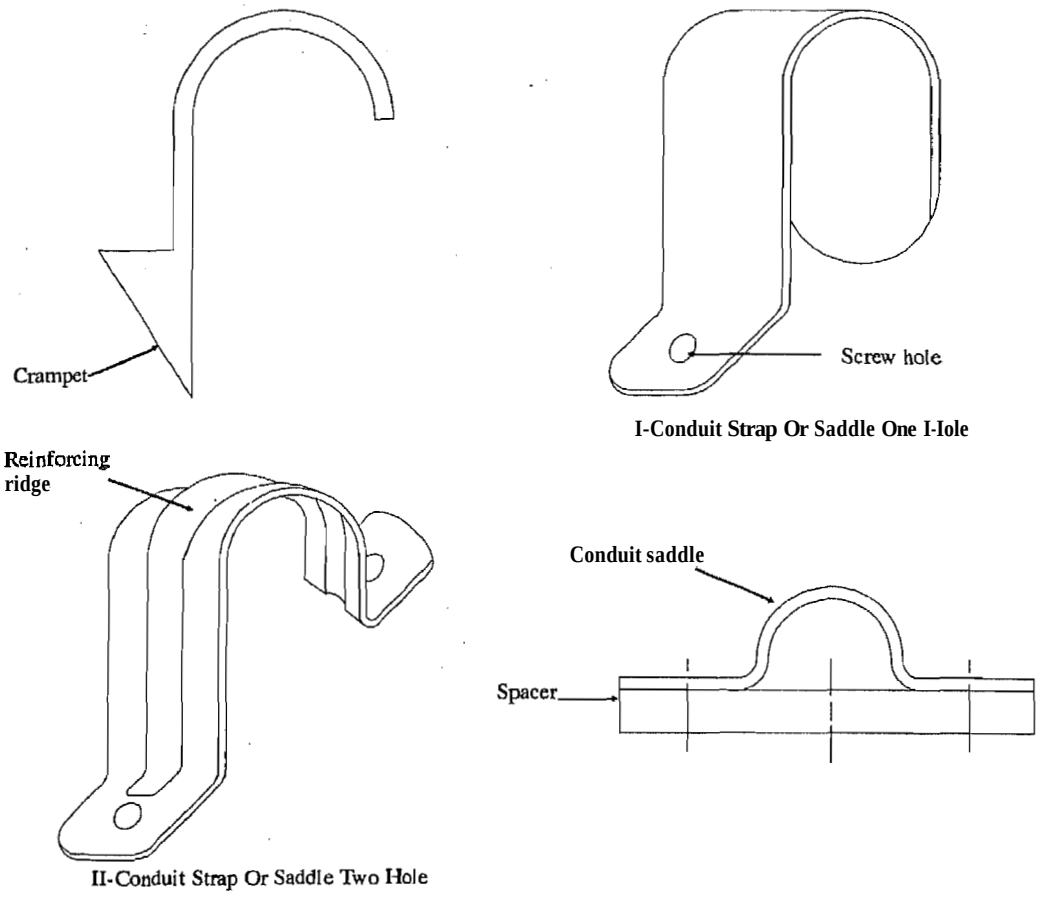


Fig. 9.5 Crampets, spacers and saddles

Crampets are used in concealed conduit system to fix the conduit in position before plastering the surface. It is made of steel forging and has the shape of a hook. The spacers and saddles are used in the case of surface conduit system to fix the conduit to the wall. These spacers and saddles are made of steel in case of metallic conduit application and are made of PVC in case of PVC conduit application. The spacer is meant for keeping the conduit clear off the wall thus preventing corrosion, in case of metallic conduits. It is also useful for fixing the saddles by screws driven into the spacer, so that the conduit is kept in position.

SAQ 1 :

1. Specify the types of conduits available for wiring.

2. State the advantages and disadvantages of the metallic conduits.

3. What is the difference between inspection elbow and solid elbow?

4. State the need of a flexible conduit.

5. What are the methods available for jointing (a) metallic conduits (b) PVC conduits ?

9.4 LIGHT FITTINGS AND SWITCHES

Electric lighting is the single most important use of electricity. We shall briefly discuss the various lighting accessories used in domestic and industrial applications. In both applications, the common types of lamps are (i) Incandescent lamp (ii) Fluorescent lamp. The other types of lamps that are used exclusively in Industry and in street lighting are (iii) High pressure mercury vapour lamps, (iv) High pressure sodium vapour lamp, (v) Low pressure sodium vapour lamp. The lamps at (iii), (iv) and (v) above are not preferred where discrimination of colour is important. In this title of study we restrict ourselves to the variety of switches, holders and other accessory used for incandescent lamps and fluorescent lamps only.

9.4.1 Lamp Holders

As the name indicates, the holder is used to hold the lamp in a convenient position, and, at the same time, make firm electrical contact belween the holder and lamp. The lamp holder is designed to ensure satisfactory electrical contact with lamp as, otherwise, the excessive heat generated at the loose contact points may damage the lamp. A loose contact also develops discontinuous current to the lamp, thus causing flicker.

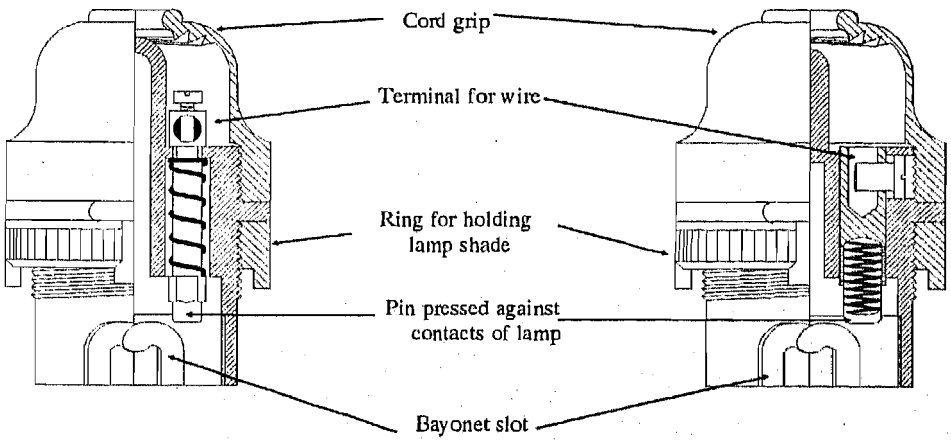


Fig. 9.6 Two Types of Pendant Lamp Holder, n Solid Plunger (left) nnd n Spring Plunger (right)

Incandescent Lamp Holders

The age old popular lamp holder is a brass pendant holder. In this, a detachable porcelain part holds two brass plungers (studs), which conduct the current from the external wires into the lamp. At present this brass porcelain combination is replaced by a hard synthetic mould which simplifies the construction. Figure 9.6 shows the details of a typical plunger type pendant-holder of moulded construction.

It consists of a solid plunger and the wire terminal forms an integral part of the plunger. The current flows directly through the plunger to the lamp. The plunger has an external spring as shown in the figure. The wire terminals move in and out as the lamp is taken out or inserted. Hence, it is imperative that a flexible wire should be used for wire connection. The alternate construction in pendant holder is with a spring plunger, as shown in Figure 9.7. The spring plunger is necessarily of a two part construction. The spring is inside a hollow plunger one end of which is a fixed wire terminal, and the other end is a brass contact, which presses against the lamp terminal. When the lamp is inserted, there is no movement of the wire terminal and hence any non-flexible PVC wire can also be used for connection to the holder unlike the case of solid plunger type.

The above description of lamp holder mechanism (solid plunger or spring plunger type) is common to all kinds of holders, which are classified as under, based on application :

a) Pendant holder (see Figure 9.7 (a))

b) Bracket holder (see Figure 9.7 (b))

c) Batten holder (two Configurations) illustrated in Figure 9.7 (c).

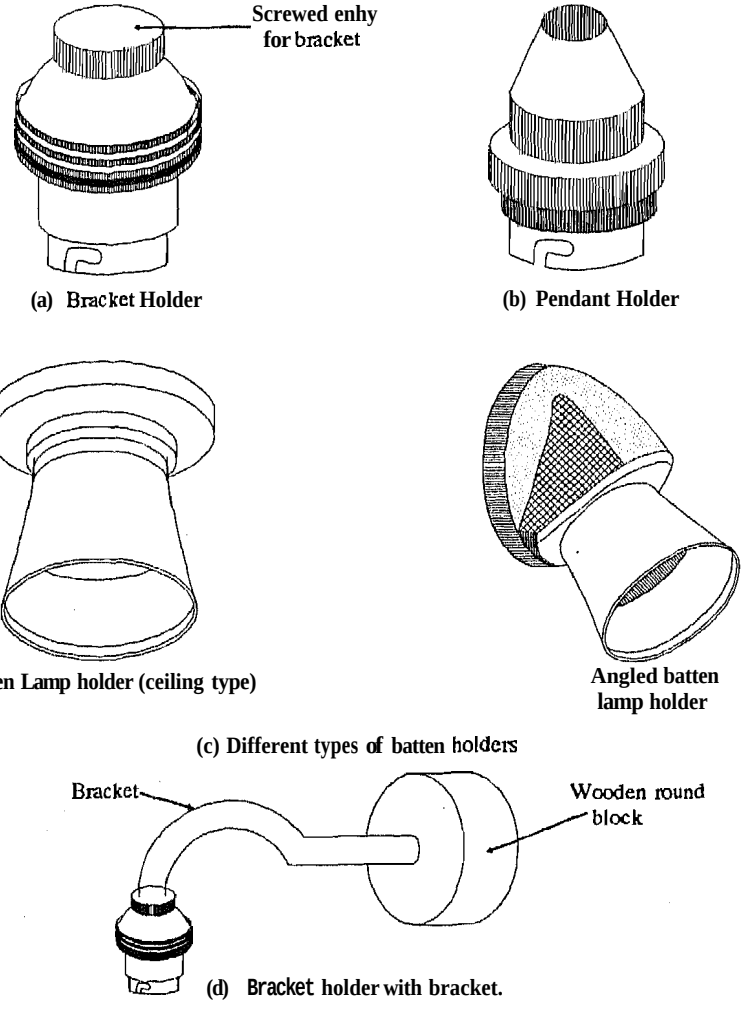


Fig. 9.7 Lamp Holders

In case of the pendant holder, the top portion of holder is modified so as to obtain a grip with incoming wire. This grip avoids strain on the connections of wires with plunger, consequent to the weight of lamp, lamp holder and shade if any.

In case of bracket holder a suitable screw arrangement is provided for fixing the holder to the wall bracket see Figure 9.7 (d).

In case of the batten holders (refer to Figure 9.7 (c)), the top portion of the holder is suitable for fixing to any plain surface; such as ceiling or wall (in this wall fixing, it is termed as angle batten holder). This obviates the use of a separate round block or a ceiling rose.

In all the present day available holders, there is a shield made of synthetic material for better appearance because it hides the metallic holder and the cap of the lamp. This shield also provides safety and prevents accidental contacts with the metallic parts of holder. Hence the use of the shielded form of holders is specifically recommended in bathrooms and kitchens where dampness may exist.

Classification of holders based on types of lamp caps

The lamp holders can also be classified, based on the method of fixing the lamp to the holder as under :

a) Bayonet cap type

b) Edison screw type

Bayonet Cap type holder :

This is generally used upto 150 watts lamps. Refer to the Figure 9.8 (a), wherein the bayonet slot is clearly shown. Into these slots, the pair of pins of lamp cap get engaged in final position. A three pin bayonet cap type of holder is also available for applications whcrc the lamp requires to be fixed in one position only. See Figure 9.8 (b).

Edison screw type holder :

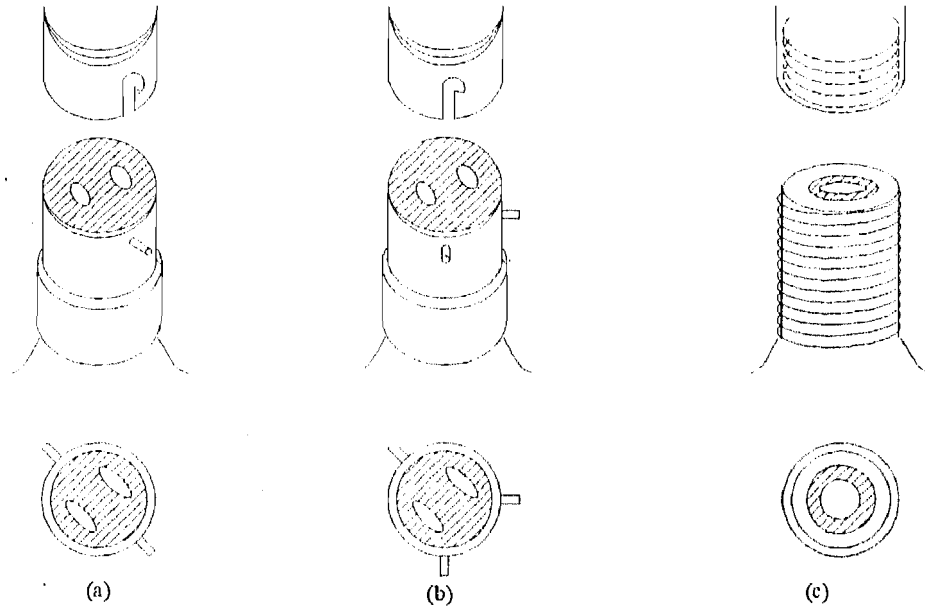


Fig. 9.8 Lamp Bolders bayonet Cap Type and Edison Screw Type.

This screw type ensures better electrical contact for the higher wattage lamps. The screw threads form one of the terminals. A central insulated metallic button forms the second terminal with which the corresponding central terminal of lamp makes firm contact when the lamp is gripped by the screw holder. Edison screw type holders arc made in five sizes though common sizes used arc : Goliath Edison screw (GES), small Edison screw (SES) and miniature Edison screw (MES). Bulbs of 200 W and above utilise GES cal. (Fig. 9.8c)

9.4.2 Ceiling Rose

An important light fitting is the ceiling rose. This is used to provide an outlet at chosen places for supplying electricity Io a pendant lamp holder, fan, fluorescent lamp, on any other light load.

The ceiling rose consists of a circular porcelain or bakelite base, with two or three terminal plates insulated from each other in addition to an earth terminal, if required. A threaded baklite cover with a hole for taking outlet wires, when placed in position, provides cover for the live terminals. Figure 9.9 illustrates the internal arrangement of the ceiling rose. Each of the terminal plates is provided with a metallic sleeve and a binding screw on one side through which the wiring enters from back the through a round wooden block. The other

side of the terminal plate is provided with a washer and a clamping screw for making connection to the flexible wires.

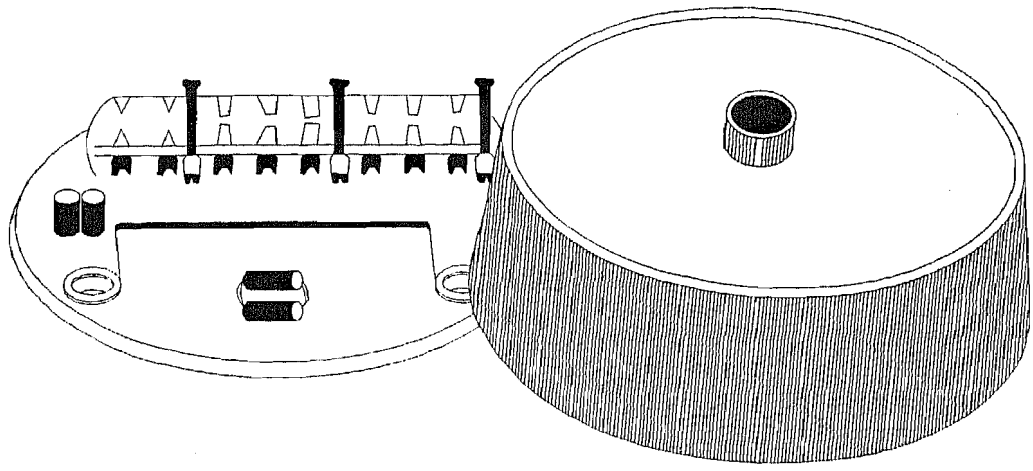
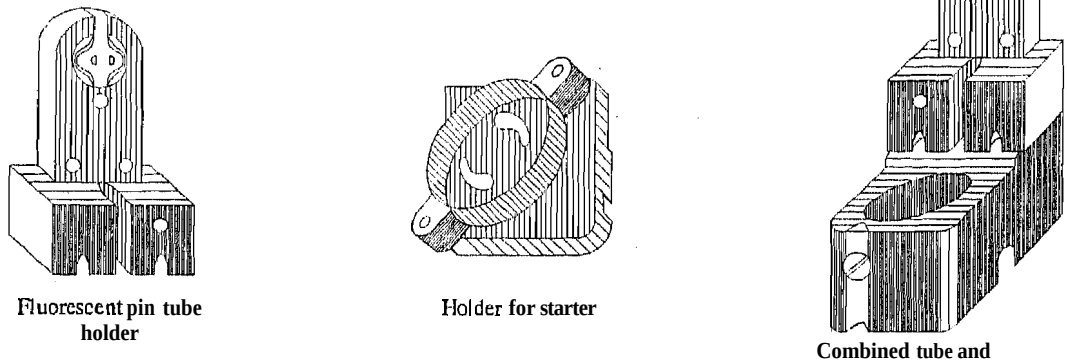


Fig. 9.9 Ceiling rose

9.4.3 Fluorescent Lamp Holders

Most common type of fluorescent lamp holder is an assembly of a pair of bi-pin holders, i.e., two holders, each having a socket Tor two pins. The two holders arc fixed on a sheet metal base at **a** distance suitable for the length of a tube lamp. A tube lamp requires, besides the holders, **a** starter and a choke. The combination of a pair of holders, a holder for a starter and a choke are all mounted on the sheet metal base. This assembly is then called a tube **light fittings.** Figure 9.10 illustrates a bi-pin holder and a slartcr holder.



Fluorescent pin tube holder

Holder for starter

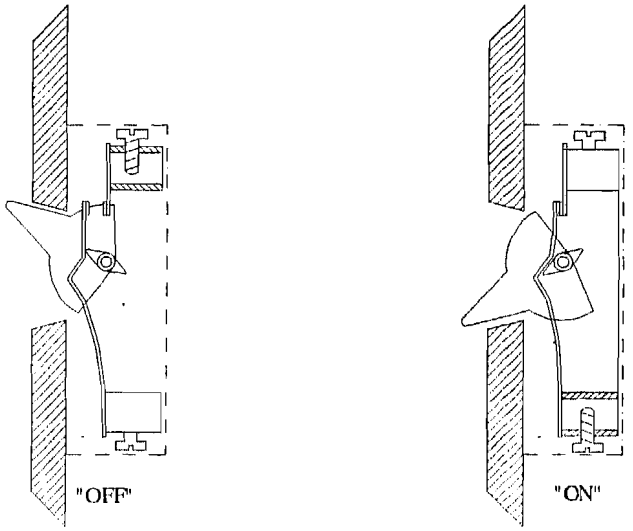
Combined tube and starter holder

Fig. 9.10 Fluorescent lamp holder

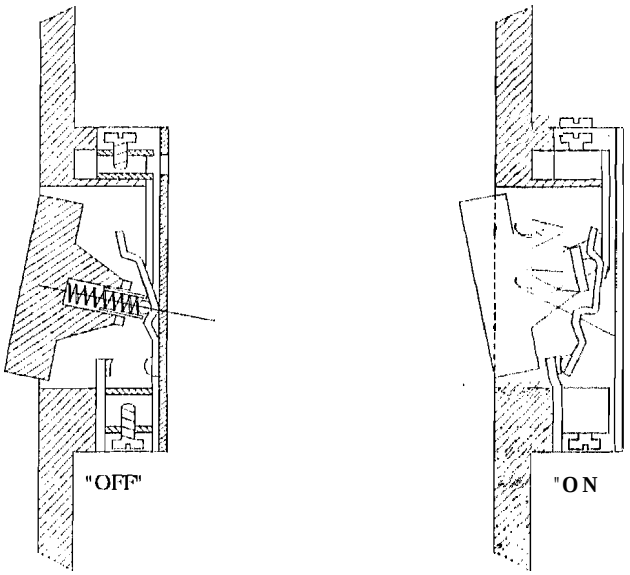
9.4.4 Switches

Switches are used to connect or disconnect electricity to an electrical appliance. Though their operation appears simple, making and breaking of electric current at a potential of 230V is accompanied by sparking and consequent burning of contact. The construction of switch takes this aspect into consideration. The size of contact, the material and spacing of contacts in the OFF position are very important. There are two main types of switches suitable for wall-mounting, namely, a tumbler type and a rocker or piano key type. Figure 9.11 illustrates both types of switches. The tumbler-operated switch has a protruding dolly with a positive up and down movement, where as a rocker (piano type) switch has a centre

pivoted dolly, which closes the microgap switch contacts when the bottom is depressed, and opens them when the top is deprcsscd.



Tumbler operated lighting switch showing cam operated mwing contact and operation of switch



Rocker-operated switch mechanism, showing moving contact and spring-loaded ball and socket operation

Pig. 9.11 Tumbler and Rocker type switches.

SAQ. 2

1. State the various types of incandescent lamp-holders and their typical applications.

2. State the classification of lamp holders based on the type of lamp caps and their typical application.

3. State the purpose of a ceiling rose.

4. State the various components of a tubelight fitting, and explain the purpose of each component.

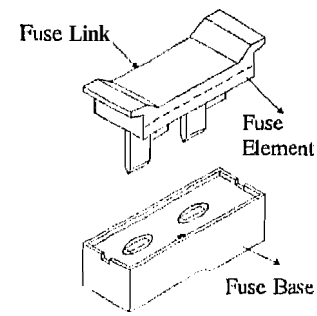
5. State the requirements of a good switch. What types are commonly used?

9.5 ELECTRICAL FUSES

Fuse is a self destructive overcurrent device, that is, these devices are destroyed when interrupting the circuit, when overcurrent condition occurs. They are made of metal of low melting temperature, such as tin. A short piece of this metallic wire is inserted in series with the wired circuit so that, when the appliance draws current beyond the fusing capability of the wire, the metal wire melts and disconnects the appliance from the mains. For 3-phase circuits, three separate fuses are used one of each phase. There are two broad classifications of fuses namely (a) rewirable fuse, (b) cartridge or High rupturing capacity (HRC) fuses, the latter version having an edge over the former kind due to reliability of operation i.e. opening of a circuit reliably at the declared rupturing (breaking current at short circuit levels) current. These fuse units are placed in the phase leads of the incoming mains to a building, and also one in each of the branch circuits of the distribution board, which is also placed near the incoming supply point.

9.5.1 Rewirable Puse

This is the simplest type in common use in domestic circuits and, to a large extent in Industry too. Figure 9.12 gives a simple view of the fuse unit, which consists of (i) fuse link or carrier and (ii) fuse base. Each is made of incombustible material such as porcelain or moulded hard plastic. The base encloses the fixed contacts to which the incoming ancl outgoing cables are connected. The fuse link or carrier is a detachable part which holds two knife contacts of tinned copper. To these knife contacts, the fuse wire is attached by screw or nut and a pair of washers all made of brass make. The fuse wire is nomially, enclosed in a hole in the porcelain link or in a separate asbestos tube to prevent the porcelain getting damaged by spontaneous heat generated by the fuse at the time of interrupting the electrical current during short circuit.



Pig. 9.12 Rewirable Fuse Unit

Size of Fuse Wire and Nominal Current Rating

Table 2 gives normal diameter of rewirable fuse clement for the nominal fuse current. This nominal fuse current is the continuous current, which the fuse element can carry without any appreciable heating of the fuse element or wire. The wire is tinned copper which is the most commonly used material in the present day, in place of tin.

Table 2 Rating of rewirable fuse element of tinned copper wire

Nominal fuse current in amps.	Nominal diameter of wire in millimeters
3	0.15
5	0.20
10	0.35
15	0.50
20	0.60
25	0.75
30	0.85
45	1.25
60	1.53
80	1.80
100	2.00

The fuse wire of, say, 0.5mm dia can continuously carry 15 amperes without heating appreciably. Thus, a 15 amp. fuse refers to 0.5mm dia copper wire. This wire just melts at a fusing current of nearly double the rating i.e. it melts at 30 amperes. Thus, overload currents of nearly double the fuse ratings are, generally, passed through the fuse element. At currents higher than this, the fuse melts in a short time which is as low as a few milli seconds when short circuit current of the order of 20 to 40 times the rated current of 15 amps. are passed.

9.5.2 Cartridge or HRC Fuses

Except for domestic applications most of the industry applications have replaced the rewirable fuse by cartridge or HRC fuse. The fuse cartridge consists of a porcelain tube with end metallic caps (of tinned copper or brass). To these caps, the fuse element is attached which is in the form of silver wire, silver strip with a **neck** (narrow part of fuse element). The porcelain cartridge is filled with quartz in granular forms and or other suitable material to absorb and extinguish the electrical arcing current. The metallic end caps are gripped in the two metallic leaf grips, which are firmly attached to the base of HRC fuse. Some advantages of HRC fuses over the rewirable kind are :

- very compact sizes even for high current ratings such **as** 1000 amps,
- no deterioration of the fusc element, as not exposed to weather,

  unlike the tinned copper, which, when deteriorated is unreliable in its rupturing of the current capacity.

One main advantage of HRC fuse is that the operating time is very nearly inversely proportional to the fault current, where as a rewirable fuse element does not conform to this law and, hence, the circuit opening time with the later kind of fuse is not predictable. **A** main disadvantage of HRC fuse is that the cartridge is to be replaced as a whole, and the question of rewiring the cartridge does not arise. As such, the maintenance of electric circuits using HRC fuses is a costly proposition particularly for private buildings.

SAQ 3

1. State the merits and demerits of aluminium and copper as conductor material in cables.

2. What is the stranding of a conductor and need of it in cable manufacture?

3. Explain the difference between three and a half core and 4-core cable. What is purpose of the 4th conductor in a cable ?

4. State the different parts of a cable and the function of each.

5. State advantages of **cable trunking** over conduit wiring.

6. State the various accessories used in cable trunking and the purpose of each.

7. What are the various types of electronic voltage regulators that are in common use ?

8. Under what condition is an electronic regulator necessitated for a domestic appliance.

9. What is the difference between voltage booster and voltage regulator ?

10. What are the limitations of a rewirable fuse ?

9.6 SINGLE AND MULTICORE CABLES

Electricity is conveyed by metallic conductors which have to be insulated and also have to be protected against mechanical damage. These insulated conductors are referred to as cables. Often the conveyance of power by three phase supply is more economical than by single phase. In such case multi core cables (three or four core cables) are used. The conductors are insulated from each other and the bundle of the three or four insulated conductors have a common insulation and also mechanical protection. For transmitting power of single phase, twin core cables or a pair of single core cables are used. The later kind are used in internal electrification. For service mains which supply power from the feeder pillar or overhead pole into the premises, a pair of single core cables or a twin core cable is used by burying in ground or drawing overhead.

The most commonly used conductor materials are copper and aluminium, the latter having come into vogue due to scarcity of copper. When copper is the material of conductor, tlie hard drawn and annealed variety of copper is used, because this variety bas higher tensile strength without reduction in conductivity. Typically, a copper conductor of Len square millimeters crosssection has a resistance of 1.688 milliohms per meter length at 20°C whilecarrying a current of 50 amperes it produces a drop of 844 milli volts per meter length, For the size of 10 sq.mm conductor, the approximate current carrying capacity is 50 amperes.

9.6.1 Copper and aluminium as cable materials

Aluminium has greater resistance compared to copper, but it is comparatively cheaper of the two kinds. For comparison, a ten square millimeters crosssection has resistance of 2.96 milliohms per meter length at 20°C and produces a voltage drop of 109.5 milli volts per meter length while carrying current of 37 amperes, which is the approximate current carrying capacity of a ten sq. mm aluminium conductor. It may, thus, be seen that the same size of 10 sq. mm copper conductor has a current carrying capacity of 50 amperes, while in aluminium it is only 37 amperes. Aluminium conductors, thus, have about 72% current carrying capacity compared with copper.

Stranding of Conductors

For obtaining greater flexibility in laying the high current cables, the conductor of cable is never made up of a single solid cross section. The conductor is made up of strands of smaller diameter of wires bunched together. This is even more important in the case of aluminium cables, because aluminium conductors are even harder than copper conductors for mechanical handling. For example, a 10 sq. mm cable whether of copper or aluminium shall consist of seven strands of wires, each wire of 1.4 mm diameter. Had we used a single solid conductor for 10 sq.mm size, the diameter would have been 3.6 mm. Such single conductor lacks flexibility, whether as a bare conductor or forming an insulated cable.

9.6.2 Conductors in Multicore Cables

For transmitting power by three phases, four core cables are used; the fourth conductor is the neutral conductor and generally carries less current than any of the other three line conductors. Thus the four cores are constituted by three tine conductors and one neutras. The neutral conductor has approximately half of the crosssection of line conductors, Four core cables of upto 16 sq.mm size are manufactured with size of all the four conductors of the same size. For sizes greater than 16 sq.mm, the neutral conductor is approximately half the size of the line conductor. In such cases, the cable is referred to as 35 core cable.

9.6.3 Cable Rating

Table 3 Sizes and Current Capacity of 4 Core Aluminium Cable

Size of line conductor	Size of neutral conductor	Approximate current carrying capacity when the cable installed in air
10 sq. mm	10 sq. mm	40 amps.
16 sq. mm	16 sq. mm	51 amps.
25 sq. mm	16 sq. mm	70 amps.
35 sq. mm	16 sq. mm	86 amps.
50 sq. mm	25 sq. mm	105 amps.
70 sq. mm	35 sq. mm	130 amps.
95 sq. mm	50 sq. mm	155 amps.
120 sq. mm	70 sq. mm	180 amps.
150 sq. mm	70 sq. mm	205 amps.
185 sq. mm	95 sq. mm	240 amps.
240 sq. mm	120 sq. mm	280 amps.
300 sq. mm	150 sq. mm	315 amps.
400 sq. mm	185 sq. mm	375 amps.
500 sq. mm	240 sq. mm	405 amps.

Table 3 indicates the sizes of line and neutral conductors in four core kind, from 10 sq. mm to 500 sq. mm sizes of aluminium conductor cables.

To appreciate the above table, it may be noted that a service main cable of 70 sq.mm (with neutral conductor of 35 sq.mm) having a capacity of 130 amperes could feed satisfactorily, a multistoried building of 25 flats each having a load of 3 KW. Such a cable will have a drop of 70 millivolts per metre length at 70°C of operating temperature, when carrying rated current. A service main of 100 metres length is, therefore, expected to cause 7 volts drop which is $\frac{7}{230} \times 100 = 3\%$ of rated volts. This is within limits, since 4% drop is normally the upper limit for service mains.

The 4-core cables (35 core size) are available upto 500 sq.mm. For higher current ratings, three single core cables for lines plus one single core cable of half the cross section for neutral, are drawn together for conveying power to a large multi storied building.

For small size buildings, a single phase service connection is adequate. This is generally carried out by using a twin-core cable. Table 4 gives typical sizes and current ratings of twin core aluminium cables.

Table 4 Size and Current Capacity of Twin Core Aluminium Cable

Size of conductor in sq.mm	Current rating in amperes	Size of conductors in sq.mm	Current rating in amperes
1.5	16	25	78
2.5	21	35	99
4.0	27	50	125
6.0	35		
10	47		
16	59		

9.6.4 Constructional Details of Multicore Cables

The most commonly used insulating material for low voltage and medium voltage applications (250 to 1100 volts) is poly vinyl chloride in short called (PVC).

This insulating material has superceded the earlier insulating materials, like vulcanized rubber because of the following advantages :

i) High insulation property

ii) Unaffected by moisture

iii) Continuous operation upto 70°C of conductor temperature

iv) Withstands most of acids and alkalis of soil

v) Good ageing property, i.e. flexibility not deteriorated over years of use

vi) Mechanically tough and yet has the flexibility

vii) Does not spread fire.

A typical cross-section of a three and half core PVC cable is shown in Figure 9.13 showing the different layers of insulation. The function of each layer is explained here.

1) Conductor :

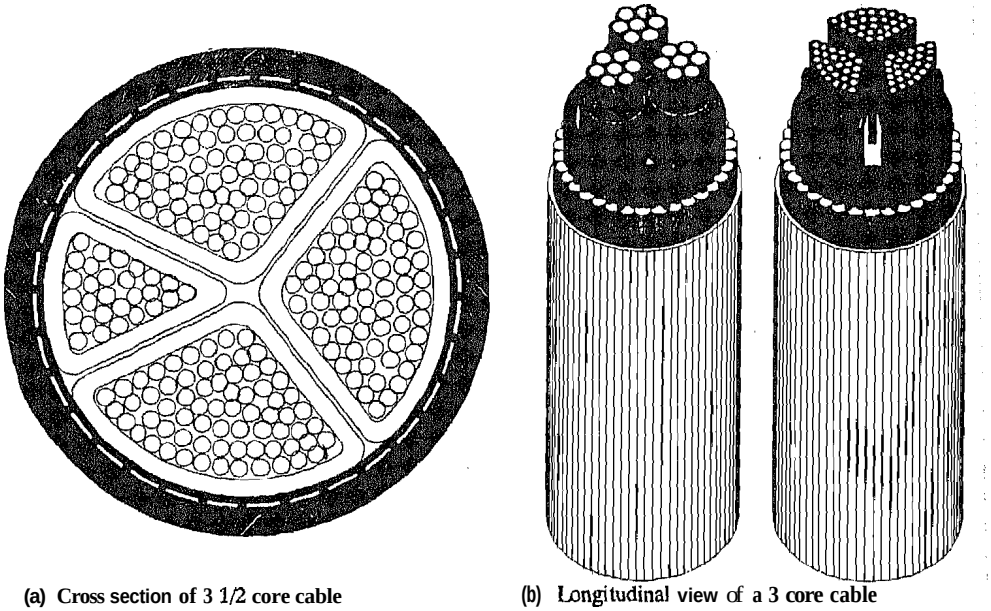
As explained earlikr, each conduclor is made up of a number strands of smaller diameter wires. In case of multicore cables, sector shaped conductors are used to obtain an overall circular shape of compact size.

2) **Conductor Insulation**

PVC is used as insulation on each core. Each core including neutral is insulated to withstand the full line voltage which appears across any two line conductors.

3) **Belt Insulation**

This is also made up of PVC and is meant for binding the insulated cores together and also it insulates each core from the armour of cable.



(a) Cross section of 3 1/2 core cable (b) Longitudinal view of a 3 core cable

Fig 9.13 : Multicore Cable

4) **Armour**

Cables used for underground application require armouring to obtain mechanical protection, The armouring normally consists of galvanized steel wires or steel strips. The wires or strips are applied in one or two layers depending on thestrength required. Unarmoured cables are also available for applications where mechanical protection is not needed. For example, when cables are laid in conduits in the floor or when run along walls in trunking.

5) **Outer PVC** layer

A PVC layer is provided over the armour to prevent corrosion of armour. Such PVC layer is of tougher variety compared with the PVC material over the conductor since the sole purpose of outer PVC layer is to give mechanical protection. Such toughness for PVC is obtained by adding suitable hardeners, though such hardeners somewhat reduce the dielectric strength. Such reduction is of no consequence as the outer YVC layer is exclusively for mechanical protection.

9.7 CABLE TRUNKING

Cable trunking is also reffered to as race ways; wire ways or trays. When a large number of cables have to be run together on a common route from one location of building to different locations, it is often convenient to house these multiple cables in a common container called cable trunking. The advantagesof such an arrangement are as under :

i) In a multistoried building or industrial complex, a large number of conduits are run in parallel and cables routed for different locations through these conduits. This is a costly proposition and also unesthetic in appearance. Much simplification arises by using cable trunking.

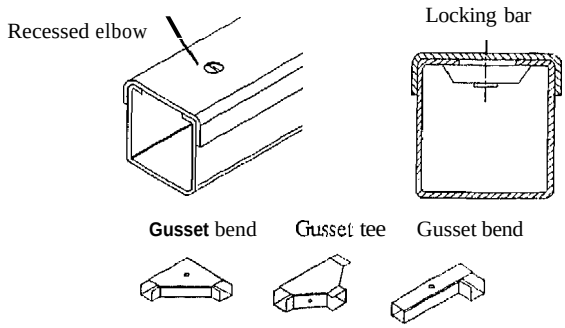
ii) Sometimes insulated multicore cables are run in parallel in a building, and it is more difficult to find satisfactory support for them on roof trusses, or ceilings, The sagging cables have ugly appearance Holding them in Cable Trunking is satisfactory.

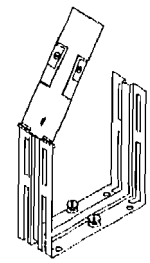
iii) . Where extensions, rerouting and modifications of existing wiring is needed, it is easier to do so when using cable trunking than by modifying conduit wiring.

iv) There is complete accessibility to the wiring at any stage, when housed in trunking than when housed in surface conduits.

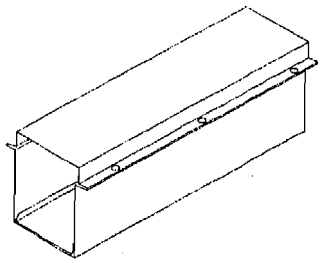
Trunking and its accessories

The cable trunking for electrical purposes is made from 18 gauge sheet steel and is available in sizes ranging from 50 mm ×50 mm to 600 mm x 150 mm, It is usually supplied in two metre lengths and consists of a channel and a lid forming the fourth side. The lid is screwed on or clamped on by snap action on to the channel part of Trunking . A variety of Bends, Elbows, Tees, Junctions, connectors and hangers are available as shown in

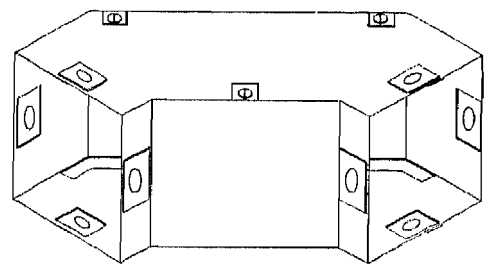




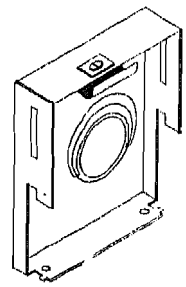
(c) Connector



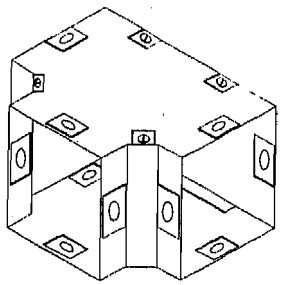
(d) Screwed *type* wireway



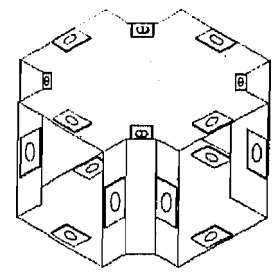
(e) Wirewny fitting elbow



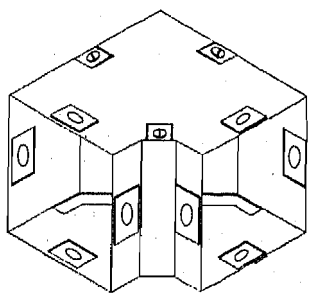
(I) Closing plate of wirewny



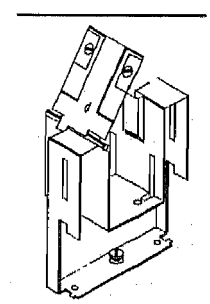
(I) Wireway Tee



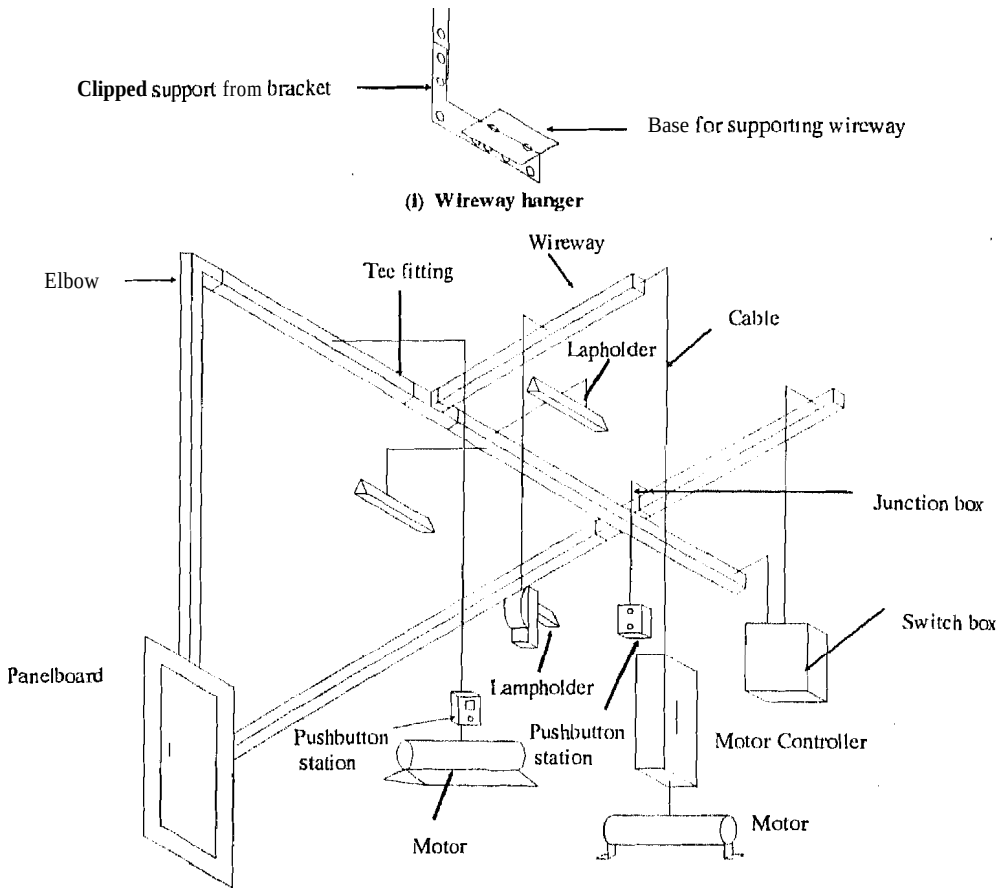
(I) Four way Junctionbox



(g) Wiring elbow



(h) Wireway fitting reducer



(i) **Wireway hanger**

(j) **Typical Industrial** Wircwny **Installation**

Fig 9.14 : **Typical Industrial Wireway Installation**

gure 9.14 (a) to (j), as accessories to trunking. Such acccssorics enable the trunking to be taken round the corners, to reduce the size of trunking, as tlic number of cahlcs is reduced, and to allow a main trunking to serve a number of branches. To put cables in such trunking, one normally Lakes the lid off, lays the cable in it,and replaces the lid. For short distances or for straight lengths, it is possible to pull the cables through the trunking as done in case of conduits. Whichever method is adopted, the number of cables and tlic size of trunking must be such that a space factor (defined as the ratio of space occupied by cables to the total space of trunking) of 45% is not exceeded. The Figure 9.14, (a) to (j) illustrates the various accessories of cable trunking systems. A further illustration of use of wire ways in a typical industrial installation is given in Figure 9.14 (j).

Figure 9.14 **(a)** depicts cable trunking (wircway) of screwed lid type alongwith accessories like gusset bend gusset Tee and elbow bend. In Figure 9.14 (b), the say wircways are shown in the hinged form. Figure 9.14 (c) shows a connector which joins two wircways. It is also helpful for drawing the cables in long straight lengths by opening the lid of connector. Figure 9.14 (d) shows another typical screwed wireway. Figure 9.14 (c) shows an elbow and a closing plate. The elbows are available in angles of 22.5^{o}, 45^{o} and 90^{o}. In the closing plate, there is a knockout which is useful for extending wiring through use of conduit tubing. Also an armoured cable can directly make entry into the wireway through the knockout. Figure 9.14 (f) depict a Tee and a Junction box, which enable branching of the wireways. Figure 9.14 (g) shows a section of wireway which permits a 90^{o} turn of wiring, still permitting the retention of the pattern of cables laid in the wircway. It is similar lo an inspection bend of a conduit. Figure 9.14 (h) is a reducer fitting, joining different sizes of wireways. Figure 9.14 (j) is a hanger, which is used for supporting the wireway either from ceiling or wall.

Cable trunking is also made out of rigid high impact PVC. It is light in weight compared with the sheet gauge metal type. Accessories similar to steel cable trunking are available. Most of these PVC wireways are **clip on type**, and not screw type.

9.8 ELECTRONIC VOLTAGE REGULATORS

In the past 20 years the rapid advent of Electronic voltage regulators has taken place for domestic and specific industrial applications so as to ensure efficient utilization of electricity and also to ensure long life of certain appliances. Some of the domestic appliances for which these regulators arc used are television sets, washing machines, refrigerators, VCRs and personal computers. Thcsc arc called step correction type regulators. In the industry, a different kind of electronic rcgulator is used (called servo regulator or stabilizer) for appliances such as instrument of sophisticated kind, like computers and small motors. Thus two kinds of Electronic regulators are identified :

1) Step correction type Electronic voltagc regulator or stabilizer.
2) Servo type electronic regulator or stabilizer.

The relevance of these kinds of regulators in the, present context of building materials is only indirect. Their installation for certain appliances requires provisioning of well ventilated space for these regulators. To the extent that they are local correcting devices for supply outlets, they Corn a part of the electrical installation wherever incorporated.

9.8.1 Need for Electronic Regulators

According to Indian Electricity rule 54, the declared voltage of supply to the consumer (at the meter point of the consumer) shall not vary by more than 5%. For a declarcd voltage of 230V, a variation of 11.5 volts on either side is permissible. All above mentioned electrical appliances can take this variation of voltagc without adversely affecting the performance. However, in the present situation of power distribution, the fluctuations of voltages at consumer end are far beyond the specified 5%, primarily because of overloading of the distribution networks. This has resulted in excessive voltage variations at consumer enrl adversely affecting the performance of appliances. Hence the use of a voltage rcgulator at the consumer end has become a necessity. The rcgulator ensures maintenance of voltage to the appliance within a small range of declarcd voltage despite supply voltage variations from 210 volts to 250 volts.

9.8.2 Step Correction Type of Voltage Regulator

These are small size, light weight devices usually available in wattages of 125, 250 and 500 watts. There is a 3-pin input plug through which supply is given to the rcgulator and a 3-pin socket on the regulator outlet for obtaining regulated output. In the older manual version, a voltmeter for monitoring output and a multi-point switch arc provided for manually correcting the output to obtain output nearest to the declared voltagc. In the latter automatic models, step corrections of output take place automatically depending on the value of input voltage. The corrections take place in 4 steps each of about 10 volts, maintaining output within 230 ±10 volts, for input variations from 210 volts Io 250 volts. Thus over voltages on supply side arc bucked and under voltages are boosted.

There are some remote area electrical installations whcrc the consumer end voltagc is always much lower than thc declared voltage. Typically such voltages arc 180 to 230 volts. In these cases, the voltage regulator is in the form of **booster** only. It means the booster brings input level of voltage to the dcclarcd voltagc of 230V by boosting. It may bc noted that the boosters are not meant for bucking i.e. for reduction of volts if output is already above the declared voltagc.

9.8.3 Stepless or Servo Type voltage Regulators

For higher wattages above 500 watts upto as much as 25 KW, and also for correcting three-phase output voltages, industry generally use the Servo type regulators. These are bulky, but have the following advantages :

a) Stepless or smooth correction of voltage and faster rate of correction.
b) The output is maintained at the set voltage of 230V ±1%.
c) Limit switches switch off the output from the mains if the **input** level is below 210 volts and above 250 volts, because correction is not possible outside this range.

There are specially built stabilizers which take care of the input voltage variations in the range of 170 volls to 260 volts.

9.9 CIRCUIT BREAKERS

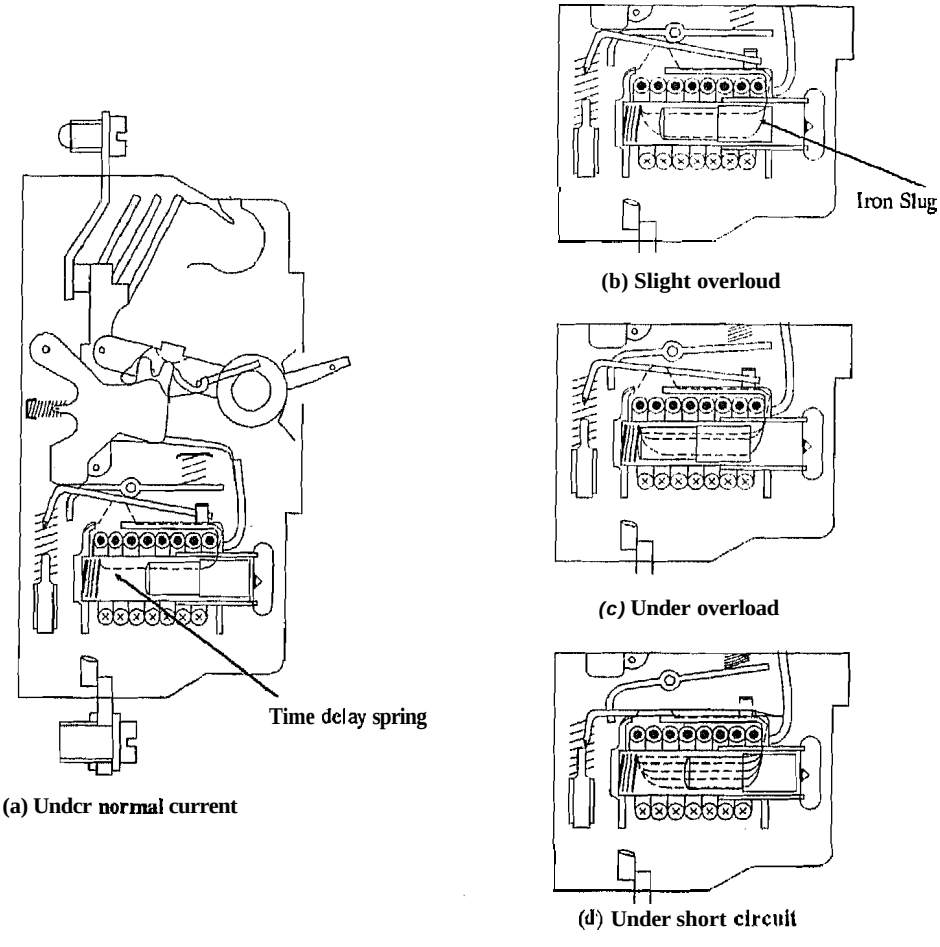
As you have noticed that the rewirable fuse and the HRC fuse require replacement each time it gets melted. An alternative to a fuse which melts when overheated is a circuit breaker.

9.9.1 Miniature Circuit Breaker

A miniature circuit breaker is one which has a rating similar to that of a fuse, i.e. in terms of rated current, and is about the same physical size as the fuse carrier of same rating. However, a miniature circuit- breaker is far superior to a fuse in the sense that the former can interrupt short circuit currents repeatedly by tripping the circuit, and it can be closed manually for restoring the electrical supply. A fuse on the contrary requires replacing each time when an interruption takes place. When a circuit breaker operates or **trips,** a visual indication is immediately given, since the switch **dolly** moves automatically to the off position. Once the fault has been traced and rectified or isolated, circuit breaker can simply be switched ON again. Even if the circuit breaker is closed with the fault still existing, and the switch dolly is held in ON position, it will still switch itself off automatically.

A typical miniature circuit breaker is shown in Figure 9.15. It has a magnetic - hydraulic time delay and the essential component a fitting iron plug. Under normal operating conditions, the time delay spring keeps the plug at one end of tube (see Figure 9.15 (a)). When an overload occurs, the magnetic pull of the coil surrounding the tube increases and the slug moves through the tube, the speed of travel depending upon the magnetic force which in turn depends upon the magnitude of current.

As the plug approaches the other end of the lube, the air gaps in the magnetic circuits are reduced and the magnetic force is increased many fold, great enough to trip the circuit



(a) Undcr normal current

(b) Slight overloud

(c) Under overload

(d) Under short circuit

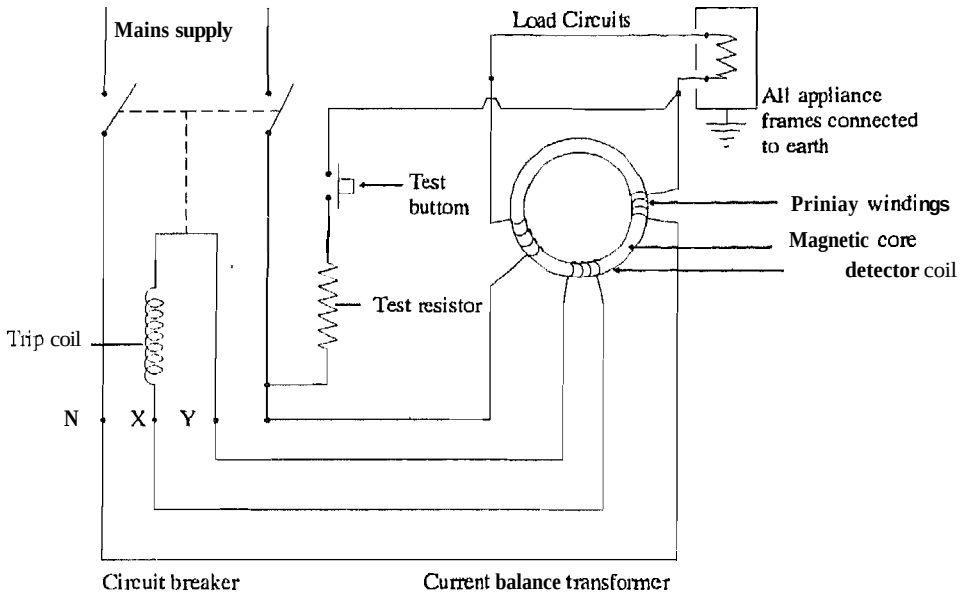
Fig. 9.15 : Miniature Circuit Breaker

(Figure 9.15(c)). With this mechanism, the time taken to trip is inversely proportional to magnitude of the overload. When a heavy overload or a complete short circuit occurs, the magnetic force is sufficient to trip the circuit breaker instantaneously in spite of a-large air gap (Figure 9.15 (d)). In this way, time delayed tripping is achieved upto about seven times rated current and instantaneous (nearly 0.01 Sec.) tripping above this current level. An alternale trip arrangement (not shown in figure) is by dual tripping mechanism, i.e., by

thermal bimetal for overload conditions and magnetic coil for short circuit tripping of the breaker.

9.9.2 Earth Leakage Circuit Breaker (ELCB)

in electrical equipment, the enclosing metallic covers, which are normally well insulated, but which acquire dangerous potentials due to leakage caused by deteriorated insulation, pose hazards to human beings resulting in injury or death. In the present day context a large



Pig. 9.16 : Current Operated Earth Leakage Circuil Brenker

number of electrical appliances are of common use, and hence, there has been necessity of detecting such leakages and tripping the mains. Earth leakage circuit breakers are specially designed to detect minute leakage currents from the metallic parts to the earth. The IE rules **61-A** modified in 1984 had made it now mandatory for all consumers having installed capacity exceeding five kilowatts to provide ELCB in the consumer premises.

The Figure 9.16 illustrates the principle under which ELCB operates and the method of installing the same in consumer premises. The load currents passing through the phase as well as the neutral leads are fed through two equal and opposing coils wound on a closed magnetic core. The core also carries a fault detector coil in which the current is induced and this current operates the trip coil. In a healthy circuit (when no earth leakage exists i.e. the insulation is sound), the line and neutral currents feeding the load arc same and hence they produce equal and opposing fluxes in the magnetic core. However, if there earth leakage or earth fault, the neutral current is diminished in comparison with line current, because some of the currcnt leak through the body of the equipment to the earth. This imbalance though minor, produces the resultant magnetic flux in the magnetic core, and it induces a current in the fault detector coil, which operates the trip mechanism and disconnects the electrical supply to the installation.

SAQ. 4

1. Explain the features of a miniature circuit breaker. Where are they incorporated in a wiring installation'?

2. Explain the purpose of an ELCB.

9.10 SUMMARY

In this unit, the essential electrical materials relevant to a building are introduced. The qualitative aspects of these materials are discussed with the view to enable the reader to choose the right material for a given situation. No attempt is made to discuss the methods of wiring installation or the design of building wiring, because this design is the next aspect after understanding the materials used.

In 9,2and **9.3,** the various types of Electrical conduits and their accessories have been introduced. In 9.4, the different kinds of light fittings and switches which are commonly used are discussed. Section 9.5 discusses the commonly used rewirable fuse and its later version of HRC fuse. Section 9.6 discusses single and multicore PVC cables of common use. Section 9.7 discusses the cable trunking and PVC trays as a relatively new concept. Section 9.8 gives a brief exposure to the need and types of electronic voltage regulators. In Section 9.9, the function and necessity of the miniature circuit breaker and the earth leakage circuit breakers, which are increasingly being used are discussed. The installation of ELCB has now been made mandatory for installations above five KW capacity installation.

9.11 KEY WORDS

Electrical conduit :	Acircular protective tubing to carry insulated conductors.
Flexible conduit :	A conduit having flexibility to take a zig-zag path.
Junction **box**	A square or a circular box, metallic or otherwise for branching the wiring into two or more branches.
Crampet	**A** mild steel device for holding the conduit in place in a concealed wiring.
Conduit **elbow**	**A** metallic or a PVC accessory for smoothly taking a sharp 90^{o} deviation in wiring.
Conduit bend	A steel or PVC accessory for changing the direction of wiring at right angle smoothly.
Bayonet **cap**	The metallic outer part of the lamp with twin projections at diametrically opposite sides of cap.
Ceiling rose :	A covered outlet for electrical wires fixed on wall or ceiling, and used.for extending supply.
Leakage current :	Minute currents, which pass from live conductor through defective insulation to the ground.
Earthing	A low resistance path to the ground.
Armour	**A** metallic strip or wire giving mechanical protection to a group of insulated conductor.
Raceway	**A** metallic or PVC channel with a lid for housing insulated conductors.
Space factor	The ratio between the volume occupied by the cable to the total volume of cable trunking.
IE	Indian Electricity

9.12 FURTHER READING

The Design of Electrical Services for Buildings by F. Porges E & F. N. Spon, London.

Modern Wiring Practice, W.E. Steward and J. Watking, Newras Butterworths, London,

Electrical Wiring, Estimating and Costing by S.L. Uppal, Khanna Publishers, Delhi-6.

Electric Wiring, Domestic, A.J. Coreer Newness Technical Books, London.

Handbook of Simplified Commercial and Industrial Wiring Design by John D. Lenth, Prentice Hall Inc Engalwood Cliffs, N.J.

9.13 ANSWER TO SAQs

SAQ 1

1. The main types available are metallic and PVC.
2. **Advantages**
   - i) They give better mechanical protection.
   - ii) The conduit can carry the earth leakage currents.
   - iii) They will not allow electromechanical radiations to come out.

   Disadvantages
   - i) They may corrode in damp weather.
   - ii) They are costly.
3. In the inspection elbow there is a removable cover which can be used for drawing the wires.
4. When wiring is to be Taken from a terminal point on the wall to the equipment terminals the wiring may have to follow a zigzag path which cannot be laid through a rigid conduit. In such places rigid conduit cannot be used.
5. For joining metallic conduits either threaded or slip sockets are used. PVC conduits are generally joined by unscrcwcd couplers and special solvents.

SAQ 2

1. The various types of lamp holders are :
   - i) Pendant holders – for hanging a light in the middle of a room from wiring.
   - ii) Bracket holders – for fixing on wall.
   - iii) Batten holders – for fixing on walls or ceiling.
2. i) Bayonat cap

   2 Pin → for lamps upto 150 W.

   3 Pin → used where lamp is lo he fitted in one position only.

   ii) Edison screw type :

   Generally used for lamps of 200 W and above.

   Small screw sizes arc also available for lower wattage lamps.
3. The ceiling rose is used to terminate the wiring on the ceiling so that an appliance or a fitting can be connected.
4. The various components arc (i) choke (ii) Tube (iii) Starter (iv) Tube holder (v) Starter holder.
5. It should be able to with stand the arcing when the contacts are opened and the contact gap should withstand the voltage of the system. The two types commonly used are Tumbler Type and Piano key or rocker type.

SAQ 3

1. Copper is more flexible, mechanically strong, and has higher conductivity but more costly.

   Aluminium is cheaper, bur less conductive and less flexible.
2. The conductor does not consist of a single solid material but is built of a number of wires of smaller diameter. This is called stranding. This gives flexibility to the cable so that it can be bent at corners easily.
3. In the multicore cables larger than 25 sq.mm, the size of the fourth core is approximately half of the size of other three conductors. These are called 3.5 core cables. In cables smaller than 25 sq.mm all the cores are of the same size. These are called four core cables. The fourth core is used as a neutral.

4. i) Conductor : To carry the current.
   ii) Conductor Insulation : To insulate the conductors.
   iii) Belt Insulation : To give a circular shape to the conductor.
   iv) Armour : To give mechanical protection.
   v) Outer layer : To prevent corrosion of armour.

5. The advantages are :
   i) Cheaper than conduit wiring.
   ii) To cover the sagging cables.
   iii) Extensions are easy.

6. i) Elbow : To take a 90^{o} change in direction.
   ii) Reducer : To reduce the size of trunking.
   iii) Hanger : To give support to trunking.
   iv) Junction Box : To branch the trunking into two or more directions.
   v) Closing Plate : To close the trunking at the end.

7. i) Step correction type electronic voltage regulator.
   ii) Servo type electronic regulator.

8. If the voltage variation is beyond permissible limits a voltage regulator is required to bring the voltage with in permissible limits to improve the performance and protect the equipment.

9. A booster can only be used to increase the voltage where as a regulator can increase or decrease the voltage.

10. They cannot give reliable protection. They cannot be used in hazardous areas.

SAQ 4

1. The main features are over load and short circuit tripping. They are incorporated at the main switch board and also in the distribution boards from where the circuits start.

2. Whenever small damage to insulation occurs a leakage current flows which will not be able to blow the fuse. In such cases the metallic casing of the appliances gets charged to the supply voltage and is dangerous to persons working. Even if a major damage to insulation occurs the current will be small if the earth resistance is high and will not bc able to blow the fuse. In such cases the Earth leakage circuit breaker detects thc small earth leakage currents and disconnects the equipment from supply.