ELECTRICAL SYMBOLS AND INDIAN ELECTRICITY RULES

1

LEARNING OBJECTIVES

After the completion of this chapter, the students or readers will be able to understand the following:

- How an electrical device, machine or equipment is represented on a paper to convey a message to other engineer?
- What is IS 5032 code?
- What are Indian electricity rules and what is their necessity?
- Why Indian electricity rules are enforced for various electrical installations?

1.1 INTRODUCTION

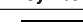
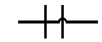
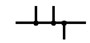
Symbol is an arbitrary sign (written or printed) that acquires a conventional significance.

In engineering, symbols are used to represent an object, component, instrument, or equipment graphically on a paper. Symbols are used since it is difficult to draw the complete drawings of various components in use.

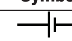
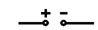
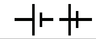
In case of electrical installations, electrical and electronic circuits, graphical symbols are used to represent an electrical equipment and components. Some of the important symbols and sign conventions of electrical equipment and components taken from IS 5032 (Part VII): 1974 and IS 2032 (Part XI) : 1969 are shown below:

1.2 SYMBOLS AND SIGN CONVENTIONS

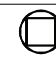
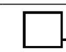
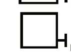
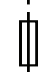
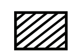
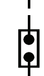
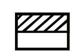
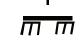
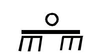
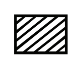
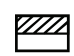
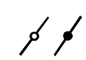
1.2.1 Wires and Connections

S. No.	Component	Symbol	S. No	Component	Symbol
1.	Wire		3.	Wire no joined	
2.	Wire joined				

1.2.2 Power Supplies

S. No.	Component	Symbol	S. No	Component	Symbol
4.	Cell		6.	DC supply	
5.	Battery		7.	AC supply	

1.2.3 Wiring Installations

S. No.	Component	Symbol	S. No	Component	Symbol
8.	Energymeter		17.	Main switch 'Power'	
9.	Main fuse board without switches 'Power'		18.	Main switch lighting	
			19.	Rewirable fuse	
10.	Main fuse board with switches 'Power'		20.	Catridge fuse	
11.	Distribution fuses board without switches 'Power'		21.	Natural link	
12.	Distribution fuse board with switches 'Power'		22.	Wiring on wall surface	
			23.	Wiring below wall surface (concealed wiring)	
13.	Main fuse board without switches 'Lighting'		24.	Surface conduit wiring	
14.	Main fuse board with switches 'Lighting'		25.	Concealed conduit wiring	
			26.	Wiring going upward	
15.	Distribution fuse board without switches 'Lighting'		27.	Wiring going download	
16.	Distribution fuse board with switches 'Lighting'		28.	Wiring passing vertically through a room	

1.2.4 Switches

S. No.	Component	Symbol	S. No	Component	Symbol
29.	Singlepole switch		44.	Two-way switch	
30.	Two-pole switch				
31.	Three-pole switch		45.	Isolator	
32.	Single pole pull switch				
33.	Multiposition switch		46.	Circuit breaker	
34.	Two-way switch				
35.	Intermediate switch		47.	Change-over contact (make before break)	
36.	Period limiting switch		48.	Break contact general symbol	
37.	Time switch				
38.	Pendent switch				
39.	Push button or bell push		49.	Contactor normally open	
40.	Luminous push button		50.	Contact breaks with delay	
41.	Restricted access push button		51.	Contactor normally closed	
42.	Make contact normally open		52.	Break contact delayed operation	
43.	Break contact normally closed		53.	Make contact	

1.2.5 Socket Outlets

S. No.	Component	Symbol	S. No	Component	Symbol
54.	Socket outlet 5 ampere		57.	Socket outlet 15 ampere with switch	
55.	Socket outlet 15 ampere		58.	Interlocking switch and socket outlet 5 ampere	
56.	Socket outlet 5 ampere with switch		59.	Interlocking switch and socket outlet 15 ampere	

1.2.6 Lighting Fixtures

S. No.	Component	Symbol	S. No	Component	Symbol
60.	Lamp or lamp outlet		70.	Panic lamp	
61.	Group of 3 lamps of 60 watt each		71.	Water tight light fitting	
62.	Lamp on wall bracket or light bracket		72.	Reverse head fitting	
63	Lamp mounted on a ceiling		73.	Batton lamp holder (lamp on wall)	
64.	Counter weight lamp fixture		74.	Projector	
65.	Chain lamp fixture		75.	Spot light	
66.	Rod lamp fixture		76.	Flood light	
67.	Lamp fixture with switch		77.	Flourescent lamp	
68.	Lamp operating at variable voltage		78.	Group of fluorescent lamps each of 40 watt	
69.	Emergency lamp		79.	Choke with iron core	

1.2.7 Electrical Appliances and Accessories

S. No.	Component	Symbol	S. No	Component	Symbol
80.	General electrical appliances		85.	Siren	
81.	Heater		86.	Horn or Hooter	
82.	Storage type electrical water heater		87.	Indicator	
83.	Bell				
84.	Buzzer		88.	Ceiling fan	

S. No.	Component	Symbol	S. No	Component	Symbol
89.	Bracket fan		94.	Bell connected to fire alarm switch	
90.	Exhaust fan		95.	Fire indicator	F
91.	Fan regulator		96.	Earth point	
92.	Manually operated fire alarm push button		97.	Chassis ground	
93.	Automatic fire detector switch	!	98.	Digital/Common ground	

1.2.8 Resistors, Inductors and Capacitors

S. No.	Component	Symbol	S. No	Component	Symbol
99.	Resistor *(As per IEC)** (As per IEEE)	R or	108.	Inductor	L or
100.	Variable resistor		109.	Variable inductor	L or
101.	Variable resistor in steps		110.	Impedance	Z
102.	Variable resistor (potentio-meter)		111.	Capacitor	
103.	Variable resistor in steps (potentio-meter)		112.	Electrolytic capacitor	+
104.	Thermistor		113.	Variable capacitor	
105.	LDR (Light-dependent Resistor)		114.	Trimmer capacitor	
106.	Variable resistor (preset)		115.	Gang capacitor	
107.	Shunt resistor				

1.2.9 Contractors and Relays

S. No.	Component	Symbol	S. No	Component	Symbol
116.	SPST relay	NC NC	118.	Thermal overload relay contact	
117.	SPDT relay	NC COM NO	119.	Time delay relay contact	

S. No.	Component	Symbol	S. No	Component	Symbol
120.	Limit switch		123.	Electrically operated 3-pole contactor	
121.	Thermal overload relay		124.	Electrically operated 3-pole contactor with thermal over-load devices in all 3 sides	
122.	Relay with time delay	T t			

1.2.10 Indicating Instruments and Relative Symbols

S. No.	Component	Symbol	S. No	Component	Symbol
125.	Electrostatic screening		138.	Power factor motor	COS∅
126.	Magnetic screening		139.	Phase meter	∅
127.	Zero adjustment		140.	Frequency meter	Hz
128.	Refer to a separate document		141.	Current direction indicator	±
129.	General symbol of indicating instrument		142.	Ohm meter	Ω
130.	Instrument with pointer indicator		143.	Synchroscope	or SYN
131.	Indicating instrument with digital display		144.	Wave meter	
132.	Voltmeter	V	145.	Oscilloscope	or OSC
133.	Ammeter	A	146.	Galvanometer	
134.	Wattmeter	W	147.	Salimtymeter	Nacl
135.	Multimeter	V.AΩ	148.	Thermometer, Pyrometer	t°
136.	Null indicator for AC		149.	Techometer	η
137.	Var meter	Var			

1.2.11 Symbol use to Show Type of Instrument as per Operating Phenomenon

S. No.	Component	Symbol	S. No	Component	Symbol
150.	Permanent-magnet moving coil instrument		162.	Thermal (hot-wire) instruments	
151.	Moving permanent-magnet instrument		163.	Bimetallic instrument	
152.	Moving permanent magnet ratio meter or quotient meter		164.	Electrostatic instrument	
153.	Moving iron instrument		165.	Vibrating reed instrument	
154.	Polarized moving iron instrument		166.	Non-insulated thermo-couple (thermal converter)	
155.	Moving iron ratio meter or quotient meter		167.	Insulated thermo-couple (thermal converter)	
156.	Ironless electro-dynamic instrument		168.	Moving coil instrument with insulated thermal converter incorporated in the instrument	
157.	Iron core electro-dynamic (ferrodynamic instrument)		169.	Moving coil instrument with non-insulated thermal converter incorporated in the instrument	
158.	Ironless electro-dynamic ratio meter or quotient meter		170.	Rectifier	
159.	Iron core electro-dynamic (ferrodynamic) ratio meter or quotient meter		171.	Moving coil 'instrument' with rectifier	
160.	Induction meter		172.	DC only	
161.	Induction ratio meter (quotient-meter)		173.	AC only	
			174.	Both DC and AC	

1.2.12 Transformers

S. No.	Component	Symbol	S. No	Component	Symbol
175.	Transformer with two separate windings		179.	Single phase auto transformer	
176.	Transformer with three separate windings		180.	Three phase auto transformer	
177.	Three phase transformer with two separate windings (connections star-delta)		181.	Three phase transformer with four tappings	
178.	Three phase transformer with three separate windings (connection: star-star-delta)		182.	Three phase transformer with on-load tap changer	

1.2.13 Rotating Machines

S. No.	Component	Symbol	S. No	Component	Symbol
183.	Generator	G	191.	DC 2-Wire shunt generator or motor	
184.	Motor	M	192.	DC 2-wire series generator in motor	
185.	Machine capable to be as generator or motor	MG	193.	DC 2-wire generator or motor compound excited short shunt	
186.	Mechanically coupled machines		194.	AC generater general symbol	
187.	Direct current (DC) generator (general symbol)		195.	AC motor general symbol	
188.	DC Motor (general symbol)				
189.	2-Wire premanent-magnet generator or motor				
190.	DC 2-wire generator or motor separately excited				

1.2.14 Induction Machines

S. No.	Component	Symbol	S. No	Component	Symbol
196.	AC induction motor general symbol		198.	Squirrel cage single phase induction motor	
197.	AC induction motor with wound rotor general symbol		199.	Squirrel cage single phase induction motor, leads of split phase brought out	

S. No.	Component	Symbol	S. No	Component	Symbol
200.	Squirrel cage induction motor, three phase		202.	Three phase induction motor with wound rotor	
201.	Squirrel cage induction motor, three phase, both leads of each phase brought out		203.	Induction motor, three phase, star connected with automatic starter in the rotor	

1.2.15 Synchronous Machines

S. No.	Component	Symbol	S. No	Component	Symbol
204.	Synchronous generator general symbol		209.	Three phase synchronous generator or synchronous motor star connected neutral taken out	
205.	Synchronous motor general symbol		210.	Three phase synchronous generator or synchronous motor two wires of each phase taken out	
206.	Permanent magnet, synchronous generator (G.S.) or synchronous motor (M.S.) three phase		211.	Brush on slip ring	
207.	Single phase synchronous generator or synchronous motor		212.	Brush on commutator	
208.	Three phase synchronous generator or synchronous motor star connected neutral not taken out		213.	AC series motor, single phase	
			214.	Repulsion motor single phase	
			215.	AC series motor three phase	

1.2.16 Power Equipment

S. No.	Component	Symbol	S. No	Component	Symbol
216.	Gas filled circuit breaker		221.	Current transformer	
217.	Vacuum circuit breaker (VCB)		222.	Lightening arrestors	
218.	Minimum oil circuit breaker (MOCB)		223.	Potential transformer	
219.	Isolator		224.	Power transformer	
220.	Capacitive voltage transformer		225.	Isolator with earth terminal	

1.2.17 Tele Communication apparatus

S. No.	Component	Symbol	S. No	Component	Symbol
226.	Aerial (or Antenna)		231.	Amplifier	
227.	Socket outlet for tele-communication		232.	Microphone	
228.	Load speaker		233.	Earphone	
229.	Amplifying equipment		234.	Handset	
230.	Television		235.	Headphone, single	
			236.	Headphone, double	

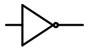
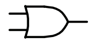
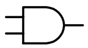
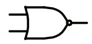
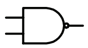
1.2.18 Some electronic devices

S. No.	Component	Symbol	S. No	Component	Symbol
237.	Diode		240.	Varactor/Varicap diode	
238.	Zener diode		241.	Tunnel diode	
239.	Schottky diode		242.	Light Emitting Diode (LED)	
			243.	Photodiode	

1.2.19 Transistor Symbols

S. No.	Component	Symbol	S. No	Component	Symbol
244.	NPN Bipolar transistor		248.	JFETP-Channel	
245.	PNP Bipolar transistor		249.	NMOS Transistor	
246.	Darlington transistor or Dalington pair		250.	PMOS Transistor	
247.	JFETN-Channel				

1.2.20 Some electronic devices-digital (Logic Gates)

S. No.	Component	Symbol	S. No	Component	Symbol
251.	NOT		254.	OR	
252.	AND		255.	NOR	
253.	NAND		256.	EX-OR	
			257.	EX-NOR	

PRACTICE EXERCISES

Short Answer Questions

1. What is IS 5032 code?
2. What are the symbols of the following electrical components?
   (i) Fuse (ii) Main switch-lighting (iii) Single pole switch
   (iv) Distrubution fuse board with switches for lighting (v) Energy meter
3. Why Indian electricity rules are being framed?

Test Questions

1. What is the necessity of electrical symbols and conventions?
2. Draw the symbols for the following:
   (i) Energy meter (ii) Main fuse board with switches (power)
   (iii) Main fuse board without switches (lighting) (iv) Main switch-power
   (v) Distribution fuse board with switches-lighting
3. Draw the symbols for the following:
   (i) Catridge fuse (ii) Neutral link (iii) Double pole switch (iv) Two-way switch
   (v) Intermediate switch (vi) Tripple-pole switch

1.3 INDIAN ELECTRICITY RULES

The idea of studying the Indian Electricity Rule is that one may come to know what type of information is available in these rules. Before studying the Indian Electricity Rules and precautions, it is better to discuss why these rules and regulations have been framed.

These rules and regulations have been framed by Institution of Electrical Engineers to

1. minimize any risk of fire, etc.,
2. safe guard the consumers from electric shock,
3. ensure, as far as possible, satisfactory operation of equipment and apparatus used, and
4. to improve reliability of electric supply.

Rule 33. Earthed terminal at consumer's premises

(1) The supplier shall provide and maintain on the consumer's premises for the consumer's use a suitable earthed terminal in an accessible position at or near the point of commencement of supply as defined under rule 58.

Provided that in the case of medium, high, or extra high voltage installation, the consumer shall, in addition to the aforementioned earthing arrangement, provide his own earthing system with an independent electrode:

Provided further that the supplier may not provide any earthed terminal in the case of installations already connected to his system on or before the date to be specified by the State Government in this behalf if he is satisfied that the consumer's earthing arrangement is efficient.

(2) The consumer shall take all reasonable precautions to prevent mechanical damage to the earthed terminal and its lead belonging to the supplier.

(3) The supplier may recover from the consumer the cost of installation of such earthed terminal on the basis laid down in the sub-rule (2) of rule 82.

Rule 46. Periodical inspection and testing of consumer's installation

(1) (a) Where an installation is already connected to supply system of the supplier, every such installation shall be periodically inspected and tested at intervals not exceeding five years either by the Inspector or by the supplier as may be directed by the State Government in this behalf or in the case of installations in mines, oil-fields, and railways by the Central Government.

(b) Where the supplier is directed by the Central or the State Government, as the case may be, to inspect and test the installation. He shall report on the condition of the installation to the consumer concerned in a form approved by the Inspector and shall submit a copy of such report to the Inspector.

(2) (a) The fee for such inspections and tests shall be determined by the Central or the State Government, as the case may be, in the case of each class of consumers and shall be payable by the consumer in advance.

(b) In the event of the failure of any consumer to pay the fee on or before the date specified in the fee-notice, supply to the installation of such consumer shall be liable to be disconnected under the direction of Inspector. Such disconnection, however, shall not be made by the supplier without giving to the consumer even clear day's notice in writing of his intention so to do.

(3) Not withstanding the provisions of this rule, the consumer shall at all times be solely responsible for the maintenance of his installation in such condition as to be free from danger.

Rule 47. Testing of consumer's installation

(i) Upon receipt of an application for a new or additional supply of energy and before connecting the supply or reconnecting the same after a period of six months, the supplier shall inspect and test the applicant's installation.

The supplier shall maintain a record of test results obtained at each supply point to a consumer, in a form to be approved by the inspector.

(2) If as a result of such inspection and test, the supplier is satisfied that the installation is likely to constitute danger, he shall serve on the applicant a notice in writing requiring him to make such modifications as are necessary to render the intallation safe. The supplier may refuse to connect or reconnect the supply until the required modifications have been completed and he has been notified by the applicant.

Rule 61. Connection with earth

(1) The following provisions shall apply to the connection with earth of systems at low voltage in cases where the voltage normally exceeds 125 volt and of systems at medium voltage.

(a) The neutral conductor of a three-phase four-wire system and the middle conductor of a two-phase three-wire system shall be earthed by not less than two separate and distinct connections with earth both at the generating station and at the sub-station. It may also be earthed at one or more points along the distribution system or service line in addition to any connection with earth which may be at the consumer's premises.

(b) In case of a system comprising electric supply lines having concentric cables, the external conductor of such cable shall be earthed by two separate and distinct connections with earth.

(c) The connection with earth may include a link by means of which the connection may be temporarily interrupted for the purpose of testing or for locating a fault.

(d) (*i*) In a direct current three-wire system, the middle conductor shall be earthed at the generating station only, and the current from the middle conductor to earth shall be continuously recorded by means of a recording ammeter, and if at any time the current exceeds one-thosandth part of the maximum supply current, immediate steps shall be taken to improve the insulation of the system.

(*ii*) Where the middle conductor is earthed by means of a service-breaker with a resistance connected in parallel the resistance shall not exceed 10 ohm and on the opening of the circuit-breaker immediate steps shall be taken to improve the insulation of the system and the circuit-breaker shall be reclosed as soon as possible.

(*iii*) The resistance shall be used only as a protection for the ammeter in the case of earths on the system and until such earths are removed, immediate steps shall be taken to locate and remove the earth.

(e) In the case of an alternating system, there shall not be inserted in the connection, with earth any impedance (other than that required solely for the operation of switch-gear or instruments), cut-out or cirucuit-breaker, and the result of any test made to ascertain whether current (if any) passing Through the connection with earth is normal, shall be duly recorded by the supplier.

(f) No person shall make connection with earth by the aid of, nor shall he kept it contact with, any water main not belonging to him except with the consent of the owner thereof and of the Inspector.

(g) Alternating current systems which are connected with earth as aforesaid may be electrically interconnected.

Provided that each connection with earth is bounded to the metal sheathing and metallic armouring (if any) of the electric supply lines concerned.

(2) The frame of every generator, stationary motor, and so for as is practicable, protable motor, and the metallic parts (not intended as conductors) of all transformers and any other apparatus used for regulating or controlling energy and all medium voltage energy consuming apparatus shall be earthed by the owner by two separate and distinct connections with earth.

(3) All metal casings or metallic coverings containing or protecting any electric supply line or apparartus shall be connected with earth and shall be so joined and connected across all junction boxes and other openings as to make good mechanical and electrical connection throughout their whole length:

Provided that where the supply is at low voltage, the sub-rule shall not apply to the isolated wall tubes or to brackets, switches, fans regulator covers or other fittings (other than protable hand lamps and protable and transportable apparatus) unless provided with earth terminal.

This sub-rule shall come into force immediately in the case of new installations and in case of existing installation the provision of this sub-rule shall be complied with before the expiry of a period of two years from the commencement of those rules.

(4) All eathing system shall, before electric supply lines or apparatus are energized, be tested for electrical resistance to ensure effcient earthing.

(5) All earthing systems belonging to the supplier shall, in addition, be tested for resistance on dry day during the dry season not less than once every two years.

(6) A record of every earth test made and the result there of shall be kept by the supplier for a period of not less than two years after the day of testing and shall be available to the Inspector when required.

Rule 67. Connection with earth

(1) The following provisions shall apply to the connection with earth of three-phase systems for use at high or extra-high voltages:

In the case of star-connected systems with earthed neutrals or delta connected systems with earthed artificial neutral point:

(a) the neutral point shall be earthed by not less than two separate and distinct connections with earth each having its own electrode at the generating station and at the sub-station and may be earthed at any other point, provided that no interference of any description is caused by such earthing;

(b) in the event of an appreciable harmonic current flowing in the neutral connections so as to cause interference with communication circuits, the generator or transformer neutral shall be earthed through a suitable impedance.

(2) Single-phase or extra-high voltage systems shall be earthed in a manner approved by the Inspector.

(3) In the case of a system comprising electric supply lines having concentric cables, the external conductor shall be the one to be connected with earth.

(4) Where a supplier purpose to connect with earth an existing system for use at high or extra-high voltage which has not either be so connected with earth, he shall give not less than fourteen days notice in writing together with particulars to the telegraph authority of the proposed connection with earth.

(5) Where the earthing lead and earth connection are used only in connection earthing guards erected under high or extra-high voltage overhead lines where they cross a telecommunication line or a railways line, and where such lines are equipped with earth leakage relays of a type

(6) In so far as the provisions of rule 61 are consistent with the provisions of this rule, all conections with earth shall also comply with the provisions of that rule.

PRACTICE EXERCISES

Short Answer Questions

1. What do you mean by Indian electricity rules?

Test Questions

1. What is the necessity of Indian electricity rules and setting approved by the Inspector, the resistance shall not exceed 25 ohm?

SUMMARY

1. *Symbols:* The graphical representation of an electrical equipment or component on a paper is called electrical symbol.
2. *Indian electricity rules:* Indian electricity rules ensure safety of operators and equipment from electricity.

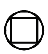
TEST YOUR PREPARATION

FILL IN THE BLANKS

1. The graphical representation of an electric component is called its __________.
2. The electrical symbol for an energy meter is __________.
3. The electrical symbol for a three-pole switch is __________.
4. The electrical symbol used to represent a main switch (power) is __________.
5. The rules that ensure the safety of operator and equipment from electricity are called __________.

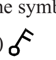
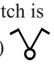
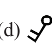
OBJECTIVE TYPE QUESTIONS

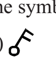
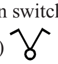
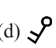
1. Electrical symbols are just
   (a) graphical representation of a switch yard
   (b) graphical representation of a circuit
   (c) graphical representation of wiring installation
   (d) graphical representation of an electric component

2.  is a symbol of
   (a) main switch-power (b) main switch-lighting
   (c) energy meter (d) distribution board with switch-lighting

3.  is a symbol of
   (a) main switch-power (b) main switch-lighting
   (c) energy meter (d) distribution board with switch-lighting

4.  is a symbol of
   (a) main switch-power (b) main switch-lighting
   (c) energy meter (d) distribution board with switch-lighting

5. The symbol for two-way switch is
   (a)  (b)  (c)  (d) 

6. The symbol for multiposition switch is
   (a)  (b)  (c)  (d) 

7. The safety of operator and electrical equipment is ensured by
   (a) Govt. of India (b) State Government
   (c) Trade unions (d) Indian Electricity Rules

VIVA VOCE OR REASONING QUESTIONS

1. Is there any necessity of electrical symbols?
2. Is there any necessity of Indian electricity rules?

SHORT ANSWER TYPE QUESTIONS

Short Answer Questions

1. What is IS 5032 code?
2. What are the symbols of the following electrical components?
   (i) Fuse (ii) Main switch-lighting (iii) Single pole switch
   (iv) Distrubution fuse board with switches for lighting (v) Energy meter
3. Why Indian electricity rules are being framed?
4. What do you mean by Indian Electricity Rules?

Test Questions

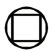
1. What is the necessity of electrical symbols and conventions?
2. Draw the symbols for the following:
   (i) Energy meter (ii) Main fuse board with switches (power)
   (iii) Main fuse board without switches (lighting) (iv) Main switch-power
   (v) Distribution fuse board with switches-lighting
3. Draw the symbols for the following:
   (i) Catridge fuse (ii) Neutral link (iii) Double pole switch (iv) Two-way switch
   (v) Intermediate switch (vi) Tripple-pole switch
4. What is the necessity of Indian electricity rules and setting approved by the Inspector, the resistance shall not exceed 25 ohm?
5. Draw the symbols of the following:
   (a) Main fuse board with switches lighting (b) Lighting arrester (c) Siren
   (d) Fluorescent lamp (e) Buzzer (f) Exhaust fan (g) Rewirable fuse
   (h) Resistance variable in steps (i) Induction motor (j) Instrument transformer
6. Draw graphical symbols for the following electrical components and instruments:
   (a) Main fuse board without switches (power)
   (b) Two-way contact with neutral link (c) Circuit breaker
   (d) Wiring under surface (e) Three-pole one-way switch
   (f) Combined switch and socket (15 ampere) (g) Emergency light
   (h) Buzzer (i) Siren (j) Exhaust fan
7. Draw graphical symbols for the following electronic/electrical components and instruments:
   (a) Lightening arrester
   (b) Distribution on fuse board with switches 'power'
   (c) Two-way switch (d) Socket outlet 5 ampere with switch
   (e) Battery (f) Fan regulator (g) Zero adjuster (h) PNP transistor
   (i) Cartridge fuse (j) Permanent magnet moving coil instrument

8. Draw the symbols of the following:
(a) Flood light (b) Lamp or lamp out set (c) Bell (d) Emergency light
(e) Energy meter (f) Frequency meter (g) Three-phase induction motor, wound rotor
(h) Circuit breaker (i) Two-way contact with neutral position
(j) Distribution fuse board with switches 'POWER'

9. Draw the symbols for the following:
(a) Chocke (b) Earth point (c) Radio outlet (d) Siren
(e) Belt (f) Flood light (g) Two-way switch (h) Road lamp fixture
(i) Contactor normally closed (j) Lightning arrester

ANSWERS

Fill in the Blanks

(i) electrical symbol (ii)  (iii) 

(iv)  (v) Indian Electricity Rules

Objective Type Questions

1. (d) **2.** (c) **3.** (a) **4.** (d)
5. (c) **6.** (b) **7.** (d)

ELECTRICAL SAFETY AND DOMESTIC WIRING 2

LEARNING OBJECTIVES

After the completion of this chapter, the students or readers will be able to understand the following:

- What is an electric shock?
- When does a person experience an electric shock?
- How a victim of electric shock is treated?
- What precautions should be made against electric shock?
- What are the electric safety measures?
- What is earthing and its purpose?
- What are different methods of earthing?
- What is double earthing and its purpose?
- What is a fuse and an MCB? What are their roles in electrical installations?
- What is an ELCB or RCCB?
- What are different types of cables used in wiring installations?
- Which are different types of wiring systems used in domestic, commercial and industrial installations?
- How different wiring circuits are designed?
- What is the power rating of various domestic appliances?

- How to select a cable or insulated wire for domestic, commercial or industrial wiring installation?
- How to estimate the material required for a wiring installation.
- What is difference between an earth wire and neutral?
- How domestic appliances are being earthed?

2.1 INTRODUCTION

The rapid industrial growth in twentieth century is mainly due to utilization of electrical energy in various fields. Now, electrical energy becomes a part of our day-to-day life.

Electricity is a good servant but a bad master if not handled properly. Therefore, while working with electrical installation and handling electrical equipment, one should always take care of his own and of other's safety. A little carelessness may result in an accident that may be fatal. Therefore, certain safety measures must be observed before dealing with electricity. In this chapter, various common safety measures and earthing of the equipments are discussed.

2.2 ELECTRIC SHOCK

When a person comes in contact with a live conductor, directly or indirectly, he gets a shock. The shock may be minor or severe. The severity of shock depends upon the following:

1. **Nature of the current whether AC or DC:** Since DC flows continuously and does not pass through zero current value as in AC, so DC is considered more dangerous than AC supply.
2. **Duration of flow of current:** Shock will be more severe if duration of contact with the live wire of a person is more. However, the severity of shock can be reduced by disengaging the person from live wire contact immediately.
3. **Path of current through human body:** Severity of shock also depends upon the path of the electric current through human body. A person has severe shock if current path involves his heart.

The effect of electric current when passes through human body is given in Table 2.1.

Table 2.1 Effect of Electric Current Through Human Body

1–10 mA	Prickling sensations
10 mA	Muscle contraction: The person remains 'stuck' to the conductor
20–30 mA	Muscles contraction can cause respiratory paralysis
70–100 mA	Cardiac fibrillation: The heart begins to vibrate and no longer beats at steady rate. This situation is dangerous since it is irreversible.
500 mA	Immediate cardiac arrest resulting in death

However, electrocution should not be viewed in terms of 'current' alone but in terms of 'current and voltage'. A person gets electrocuted by coming in contact with an object that has a different potential from his/her own. The difference in potential causes the current to flow through the body.

The human body has known limits:

Under normal dry conditions, voltage limit = 50 V

In damp surroundings, voltage limit = 25 V

2.3 ELECTRIC SHOCK TREATMENT

The victim of electric shock should be immediately treated as suggested below:

1. Victim should be removed immediately from the contact of live conductor.
2. Artificial respiration should be given immediately.
3. Treat the burns, if any, on recovery of the victim.
4. Finally, give call to a doctor.

For removing the victim from the contact of L.T. (Low Tension) live wire, any one of the following procedures can be followed:

1. Immediately 'Switch OFF' the supply. If switch is far away, then pull out the plug top.
2. Pull the victim by using wooden stick, dry clothes, dry rope, etc.
3. One can pull victim directly by standing on well-insulated footing such as rubber mat, dry board, dry wooden chair, electrician rubber gloves or even pull directly (to some extent) if wearing rubber sole shoes.
4. Cut the conductor by an axe, or axe like device having a large wooden handle.

For removing the victim from the contact of HT (high tension) live conductor, any one of the following procedures can be followed:

1. 'Switch OFF' the circuit breaker, if it is nearby.
2. Short the live conductors by throwing a bare wire or chain upon them. This will result in tripping of the circuit breaker, at the substation or power station,as the case may be.

2.4 METHODS OF ARTIFICIAL RESPIRATION

Once the victim has been removed from the contact of the live wire, next step is to give him artificial respiration. There are various methods of giving artificial respiration, which are detailed in this section.

2.4.1 Schafer's Method

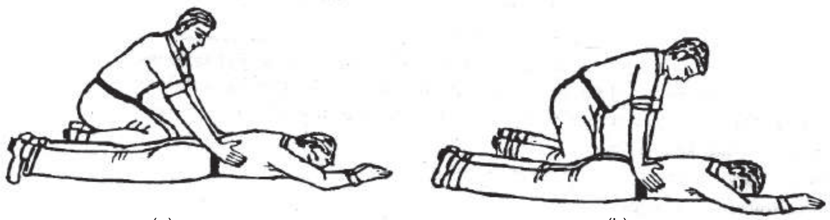
The Schafer's method is the best method to give artificial respiration to the victim of electric shock. The various steps of this method are as follows:

1. Victim is laid on the stomach, with his face on one side and pull the arms forward as shown in Figure 2.1(a).
2. To allow proper breathing, victim's neck is cleared from clothing.
3. Clear the mouth of the victim from pan, tobacco, artificial teeth, etc.

4. Kneel over the victim as shown in Figure 2.1(b) and place both your hands flat on his back. Place your hand in such a manner that both of your thumbs nearly touch each other and fingers are spread on each side of the victim's lower ribs.
5. Lean forward over the victim gradually and gently by putting your weight on the victim for a moment as shown in Figure 2.1(b).
6. Now slowly release the pressure and come to original position.

Repeat the process at least 12 to 15 times in one minute, till the victim starts natural breathing.

Schafer's method of artificial respiration is better method as compared with other two methods to be followed. Hence, this method should be adopted as and when required. However, this method cannot be used if it is not possible due to burns to lay the victim on his stomach.



(a) (b)

Fig. 2.1 Schafer's method of artificial respiration (a) Lay the victim on the stomach (b) Kneeling over the victim

2.4.2 Silvestre's Method

Schafer's method is the best method of artificial respiration; however, if the victim got some burns on the chest or anywhere on the front side of the body, only then this method is adopted. This method can be proceeded as follows:

1. Lay the victim on his back, as shown in Figure 2.2(a).
2. Remove the victim's clothes around his neck.
3. Clear the mouth of the victim from pan, tobacco, artificial teeth, etc.
4. Use pillow or rolled coat or any other cloth under the shoulders of the victim, so that his head falls backwards.
5. Tilt the head a little back. It will keep the tongue out of the throat allowing passage to air for breathing.
6. Now kneel in the position near the head of the victim as shown in Figure 2.2(b).
7. Stretch both arms of the victim backward by holding them below the elbows.
8. Keep the arms in this position for about 2 to 3 s.
9. Now bring the arms of the victim on each side of his chest (Fig. 2.2(b)), so as to compress his chest. Keep the victim's arms in same position also for 2 to 3 seconds.

10. Repeat the process for about 12 to 15 times in a minute, till victim starts natural breathing.

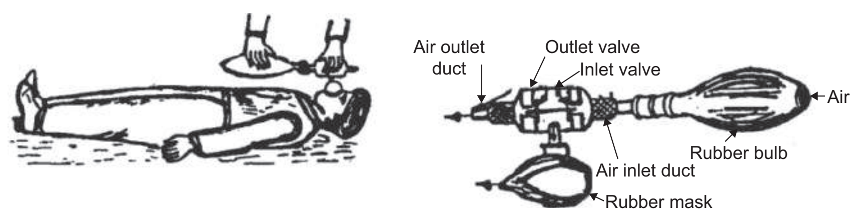
It should be assure that this method is to be adopted only when it is not convenient to make the victim lie on his stomach due to burns.

(a) (b)

Fig. 2.2 Silvestre's method of artificial respiration (a) Lay the victim on the back (b) Kneeling near the victim's head

2.4.3 Third Method (Artificial Respirator Method)

It is the easiest and most hygienic method of artificial respiration, if the apparatus is available. When the victim has suffered an electric shock and is unconscious, an artificial respirator may be used. An artificial respirator consists of a rubber bulb mask and an air filter along with a transparent celluloid valve arrangement as shown in Figure 2.3(b). The air enters through the holes of rubber bulb and goes out through the outlet valve. The mask is placed on the mouth and nose of the patient as shown in Figure 2.3(a). The rubber bulb is pressed at the rate of 12 to 15 times per minute to bring his respiration back. This process should be continued regularly till the doctor advises to stop.



(a) (b)

Fig. 2.3 (a) Artificial respiration (b) Respirator

The working principle of respirator is as follows: The rubber mask is fitted on the mouth and nose of the victim. When the rubber bulb is pressed, the air of the bulb passes through the air filter that lifts the inlet valve and closes the outlet valve. Now, this filtered air enters the lungs of the patient through the mask and nose. When the pressure on the bulb is released, the inlet valve closes and the outlet valve is opened, which gives path to the used air to go out.

Special Instructions for treatment are as follows:

1. Never give any drink to the unconscious man.
2. Violent operation of the process must be avoided because an internal injury in the affected organ may be harmed due to quick and excessive pressure.
3. If there is a burn on the body, it should be properly dressed after the recovery of the patient.
4. The patient should be kept warm.
5. No medicine should be given without the consent of the doctor.
6. An owner of the factory must provide and fix a chart explaining the methods of artificial respiration The chart should carry the name of the nearest doctor and his telephone number. Preferably, the address of the hospital and residential address of the doctor to be contacted should be given in the chart.

2.5 PRECAUTIONS AGAINST ELECTRIC SHOCK

The following precautions should be taken as preventive measures from electric shock while dealing with electrical equipment fittings or appliances:

1. Never work on live circuit.
2. Always stand on the insulating material, such as rubber mat, wooden board, etc., while switching on the main switch, motor switch, etc.
3. While switching ON the circuit, equipment, etc., ensure that your hands and feet are dry.
4. Avoid working at all those places where your head is liable to touch the live parts.
5. While working with electrical circuits/equipments, never come in contact with the metallic casing, earth conductor, cross arms, etc.
6. While working on the high-voltage circuit, avoid your direct contact with concrete flooring.
7. Never touch the person directly, while rescuing him from electric shock.
8. Consider all conductors as live, till you are not sure.

2.6 ELECTRIC SAFETY MEASURES

The following common safety measures should be followed while dealing with the electricity:

1. Always follow IER (Indian Electricity Rules) while dealing with electrical equipment and installations.
2. Consider all conductors (insulted or bare) as live conductors. So do not touch them till you are not sure.
3. Switch OFF the main switch and keep the fuse carriers with you while working on an electrical installation.
4. Single-way switches should be always connected in a live wire.

5. Fuse should be only provided in a live wire.
6. Before replacing the blown fuse or switching ON the tripped MCB (miniature circuit breaker), be sure that the defect has been rectified.
7. Do not work on live circuits. However, wherever the energized circuits are to be handled, then always use rubber mats, rubber sole shoes, rubber gloves, etc., as the case may be.
8. Never disconnect the appliance from the plug point by pulling the connecting cord.
9. Always use proper size of wire of proper voltage grade for all electrical appliances, equipments, wiring installation, etc.
10. Always use standard cable for connecting portable equipments, appliances, pendant holders, etc. Since standard conductor cable provides flexibility, so equipment can be handled conveniently.
11. All electrical connections should be made tight and these should be checked periodically, so as to avoid fire due to lose connections.
12. Always use water proof cables and fittings for all our door installations except distribution and transmission lines.
13. All non-current carrying metal parts of the equipment and of installation should be properly earthed.
14. All portable electrical equipments should be properly earthed. Therefore, for such equipments, always use three-core cable.
15. Always keep the earthing in good condition, that is, earth resistance should be kept very low all the time, since safety depends upon perfect earthing.
16. As far as possible, put off the main switch (or controlling switch), when a person is still in contact with a live conductor.
17. Do not disengage a person, who is still in contact of live circuit, by touching him directly. Push him only with a piece of dry wood or other such insulating material.
18. In case, a person is electrocuted, immediately apply artificial respiration and call the doctor.
19. Never use water for extinguishing fire due to electric current. Use only carbon tetrachloride, liquid carbon dioxide fire extinguishers. Sand can also be used for extinguishing the electric fire.

2.7 EARTHING

The process of connecting metallic bodies of all the electrical apparatus and equipment to the huge mass of earth by a wire of negligible resistance is called earthing.

When a body is earthed, it is basically connected to the huge mass of earth by a wire having negligible resistance. Therefore, the body attains zero potential, that is, potential of earth. This ensures that whenever a live conductor comes in contact with the outer body, the charge is released to the earth immediately.

2.7.1 Purpose of Earthing

The basic purpose of earthing is to protect the human body (operator) from electric shock. To illustrate the purpose of earthing, consider an electrical circuit shown in Figure 2.4 where an electrical appliance of resistance R is connected to the supply through a fuse and a switch. When an operator touches the metallic body of the apparatus [Fig. 2.4(a)] having perfect insulation, the equivalent circuit is shown in Figure 2.4(b), where two parallel paths are formed. Since the insulation resistance R_i is very high as compared with appliance resistance R, whole current flows through appliance resistance and no current flows through human body (operator's body) resistance.

When earth fault occurs, the live (phase) wire directly comes in contact with the outer body and the insulation resistance reduces to zero as shown in Figure 2.4(c). Now, the body resistance is just in parallel with the appliance resistance. A heavy current flows through the human body and operator gets a severe shock.

However, if the metallic body or outer frame of the appliance is properly earthed, then under earth fault condition, the circuit will be as shown in Figure 2.4(d), where earth resistance R_e is just in parallel with the appliance resistance R and body resistance R_b. Since earth resistance is very small as compared with body resistance, almost whole of the fault current flows through the earth resistance and no current flows through the human body. Therefore, the operator is protected from electric shock. Moreover, the fault current is much more than the full-load current of the circuit that melts the fuse. Hence, the appliance is disconnected automatically from the supply mains.

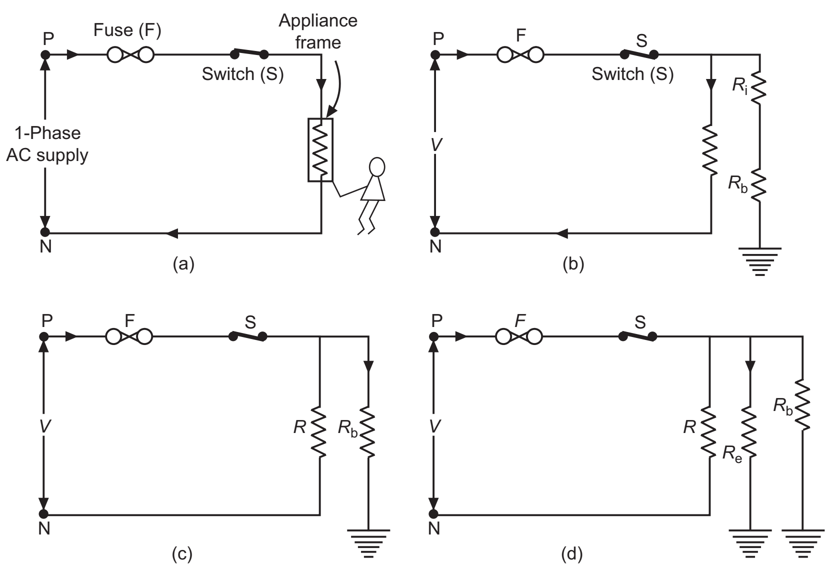


Fig. 2.4 **(a) Operator touching the metallic body of the apparatus (b) Under normal condition insulation and body resistance come in series (c) When frame comes in contact with live wire, the insulation resistance vanishes (d) When earthing is provided, low earth resistance come in parallel with body resistance**

2.7.2 Equipment Earthing

According to Rule 61 of Indian Electricity Rules 1956, it is obligatory to earth by the following points and apparatus used in the power system, where the voltage is more than 125 V:

1. All the metal frames of motors, generators, transformers, and controlling equipment.
2. The steel tower and steel tubular or rail poles carrying overhead conductors.
3. The metal frames of portable electrical equipment such as heaters, table fans, electric iron, refrigerator, air conditioners, vacuum cleaners, etc.
4. Other metal parts such as conduits, switch gear casings, etc.
5. Earth terminal of all the three-pin outlet sockets.
6. In case of concentric cables, external conductor, that is, armouring of such cables.
7. Stay wires of overhead lines if stay insulator is not provided.

In case of insulation failure, the primary objective of connecting all the above points and apparatus to earth is to release the charge accumulated on them immediately to earth so that the person coming in contact may not experience electric stock. The other objective is that a heavy current when flows through the circuit operates the protective device (i.e., fuse or miniature circuit breaker), which opens the circuit.

Generally, the values of earth resistance given in Table 2.2 must be achieved while earthing.

Table 2.2 Value of Earth Resistance for Different Equipment

Equipment to be earthed	Maximum Value of Resistance Under Worst Conditions
1. Large power stations	0.5 Ω
2. Major substations	1.0 Ω
3. Small substations	2.0 Ω
4. Factories substations	1.0 Ω
5. Lattice steel towers	3.0 Ω
6. Industrial machines and equipment	0.5 Ω

The earth resistance depends upon the moisture contents in the soil and varies from month to month. Therefore, earth resistance must be checked periodically by earth tester and maximum permissible value be obtained by pouring water into the funnel.

2.7.3 System Earthing

A proper system has to be adopted while earthing. In fact, all the heavy power equipment should be earthed by two separate distinct earth wires following the different routes. The two earth connections are applied to improve the reliability. If one of the earth wires breaks or fails to carry the fault current, the other carries that current and provides the required protection. Moreover, in factories and substations, where more than one equipment is to be earthed, parallel connections should invariably be used. In no case series, connections are done, as even a single bad contact or break in the earthing lead will disconnect all the succeeding equipment from the earth.

Therefore, for proper earthing of heavy power equipment, double earthing system has to be adopted. Moreover, the number of apparatus must be connected in parallel to the earth.

2.7.4 Methods of Earthing

As discussed earlier, earthing means to connect metallic bodies of the apparatus with the general mass of earth by a wire of negligible resistance. There are various methods of achieving this connection, some of them are given below:

1. **Strip earthing:** This system of earthing employs the use of 5 SWG (standard wire gauge) copper wire or strip of cross section not less than 25 mm × 1.6 mm. The strips or wires are buried in horizontal trenches. This type of earthing is used where the earth bed has a rocky soil and excavation work is difficult.
2. **Earthing through water mains:** In this type of earthing, a stranded copper lead is used that is rounded on the pipe with the help of a steel binding wire and a properly designed earthing clip. The copper lead is soldered to make it solid. Before making connection to the water main, it should be ensured that G.I. pipe is used throughout.
3. **Rod earthing:** It is the cheapest method of earthing and is employed in sandy areas. In this method, a copper rod is hammered directly into the ground, and no excavation work is required. The earthing lead is joined to this rod with the help of nuts and bolts.
4. **Pipe earthing:** Taking into consideration, the factors such as initial cost, inspection, resistance measurement, etc., G.I. pipe earthing is best form of ground connection. Iron is the cheapest material and remains serviceable even if put in salty mass of earth. The pipe used as earth electrode is galvanized and perforated. Its diameter is 38.1 mm and length is 2 m. The length may be increased to 2.75 m in case of dry soil. The diameter of pipe has very little effect on the resistance of the earth connection. To facilitate the driving in of the pipe into ground, it is provided with the tapered casting at the lower end. Another pipe of 19.05 mm diameter and of length 2.45 m is connected at the top of the above-mentioned pipe. The connection between these pipes is made through a reducing socket as shown in Figure 2.5.

   The earthing lead should be soldered and connected to the pipe. Alternate layers of charcoal and salt are provided around the G.I. pipe to keep the surroundings moist enough. The salt is poured at the bottom and thereafter alternate layers of charcoal and salt are arranged.
5. **Plate earthing:** In this type of earthing, a copper or G.I. plate of dimensions not less than 60 cm × 60 cm × 3.18 mm or 60 cm × 60 cm × 6.35 mm is used as earth electrode instead of G.I. pipe. The plate is buried into ground in such a way that its face is vertical and the top is not less than 3 m below the ground level. The G.I. wire is used for G.I. plate and copper wire for copper plate earthing. The size of wire is selected according to the installation and fault current. The earthing lead is suitably protected placing it underground in a pipe as shown in Figure 2.6.

   Alternate layers of charcoal and salt are used around the plate. The layers of charcoal shall be placed immediately over the plate, and thereafter, successive layers of salt and charcoal are laid to keep the surroundings sufficiently moist.

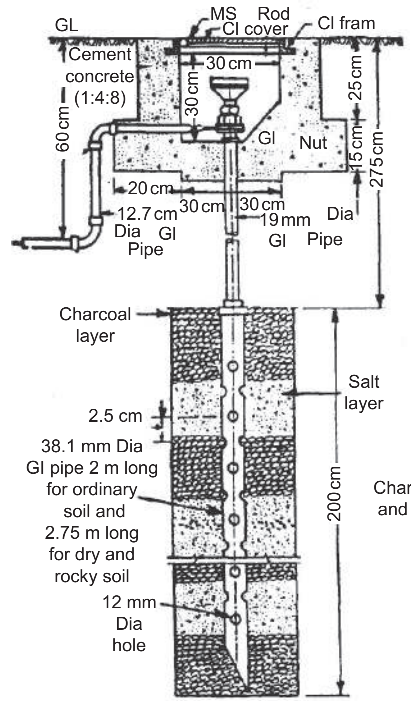


Fig. 2.5 Pipe earthing

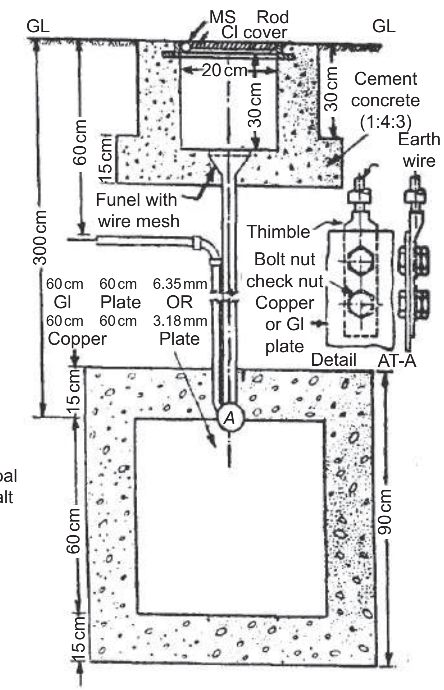


Fig. 2.6 Plate earthing

Note: Pipe earthing and plate earthing are considered to be the best as they have reasonably low value of earth resistance.

2.8 SIZE OF EARTH WIRE

In case of household wiring or installation, a 14 SWG hard drawn bare copper conductor is used as earth wire. For power installations, the size of earth wire depends upon the rating of the motors installed. For different ratings of motors, the size of earth wire can be selected from Table 2.3.

The conductor used for earthing purpose should not be of cross section less than 14 SWG and greater than 64.52 sq. mm from mechanical considerations. From electrical considerations, the copper earth wire should not be of size less than half of the largest current carrying conductor.

Table 2.3 The Size of Earth Wire for the Motors of Different Rating

Capacity of Apparatus	Size of Earth Wire in SWG		Size of Earth Electrode	
	Copper	G.I	Copper	G.I
Up to 10 H.P.	No. 8	No. 8	60 cm × 60 cm × 3.18 mm	60 cm × 60 cm × 6.35 mm
Above 10 H.P. and up to 15 H.P.	No. 8	No. 6	–do–	–do–
Above 15 H.P. and up to 30 H.P.	No. 6	No. 2	–do–	90 cm × 90 cm × 6.35 mm
Above 30 H.P. and up to 50 H.P.	No. 4	—	90 cm × 90 cm × 6.35 mm	–do–
Above 50 H.P. and up to 100 H.P.	No. 2 or strip 12.7 × 2.5 × 4 mm	—	–do–	–do–
Above 100 H.P.	Strip 25.4 × 2.5 × 4 mm	—	–do–	–do–

2.9 DOUBLE EARTHING

For providing better safety, it is advisable to provide two separate earth wires, from two separate earth electrodes, connected to same metallic body of the equipment at two different points. This is known as double earthing. Double earthing is essential, as per Indian Electricity Rule, for metallic bodies of large rating equipment such as transformer, motors, etc. working at 400 V and above.

Advantages of double earthing are as follows:

1. Surety of safety, because if at any time, one earthing is ineffective, then another will provide earth path to fault current.
2. As the two earth wires are in parallel, the effective resistance from equipment to earth electrode is reduced.

PRACTICE EXERCISES

Short Answer Questions

1. What do you mean by electric shock?
2. How to proceed with the electric shock treatment?
3. What are the rules that suggest the safety measures?
4. What is earthing?
5. What is the purpose of earthing?
6. What do you understand by equipment earthing?
7. What do you understand by system earthing?
8. What are the different methods of earthing?
9. What do you mean by double earthing?

Test Questions

1. Under what conditions, a person experiences an electric shock?
2. For electric shock treatment, what are the methods of artificial respiration? Explain any one in detail.

3. Explain Silvester's method of artificial respiration.
4. Mention 10 electric safety measures.
5. What is earthing? How does it protect a person from electric shock?
6. How will you differentiate between equipment earthing and system earthing?
7. What are the different methods of earthing? Explain plate earthing with a neat sketch?
8. Name different methods of earthing and explain pipe earthing with a neat sketch.

2.10 CAUSES OF ELECTRIC FIRE

The following are the causes of electric fire:

1. Use of inferior quality of materials.
2. Overloading of the circuits.
3. Proper protective devices are not employed.
4. Insulation of the wires is damaged.
5. When bare conductor come in contact with each other.
6. When bare conductors come in contact with the earthed points in the electrical installation.
7. Loose connections.

2.11 PREVENTION OF ELECTRIC FIRE

Fire due to electric current can be prevented by taking the following precautions:

1. Use superior quality of materials in the electrical installation and with each and every equipment.
2. By using protective devices of proper rating with the electrical circuits, so that when excessive current flows due to sustained overloading, short circuit fault or earth fault, the protective devices should operate for disconnecting the supply to faulty circuit/equipment. This prevents damage to installation/equipment and danger of fire.
3. Overloading of every equipment and electrical installation should be avoided.
4. Well insulated and proper size of wires should be used.
5. The joints in the electrical system should mechanically and electrically be sound. For electrical installation, always use looping in system instead of jointing in system of wiring. There should not be any loose connection in the installation.
6. All connections in the electrical installation should be tight and these should be checked periodically, especially when aluminium wires have been used in the installation.
7. The electrical installation should be free from moisture effect. Wiring route should not be near to the water pipe installation.
8. In case of electric fire, never use water when circuit is live. To avoid the spreading of electric fire and for rescue operation, following fire fighting equipment should be kept ready for use.
   (a) Fire extinguisher carbon tetra chloride (i.e., CTC) or foam type
   (b) Fire extinguisher carbon dioxide

These fire extinguishers employ chemicals that are insulators and do not give shock when thrown on to the live parts. Hence, these are used for extinguishing fire due to electrical short circuits and sparks.

1. Buckets filled with sand
2. Ladder
3. Rope
4. Stretcher
5. First aid box, etc.

2.12 FUSE

A short piece of metal wire, inserted in series with the circuit, which melts when predetermined value of current flows through it and breaks the circuit is called a fuse.

A fuse is connected in series (Fig. 2.7) with the circuit to be protected and carries the load current without overheating itself under normal conditions. However, when abnormal condition occurs, an excessive current (more or equal to the predetermined value for which the fuse is designed) flows through it. This raises the temperature of the fuse wire to the extent that it melts and opens the circuit. This protects the machines or apparatus from damage that can be caused by the excessive current.

Time–current characteristics: The time required to blow out a fuse depends upon the magnitude of excessive current. Larger the current, smaller is the time taken by the fuse to blow out. Hence, a fuse has inverse time current characteristic as shown in Figure 2.8, which is desirable for a protective device.

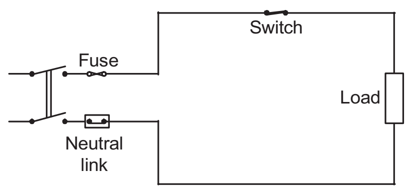


Fig. 2.7 Electric circuit with fuse and switch

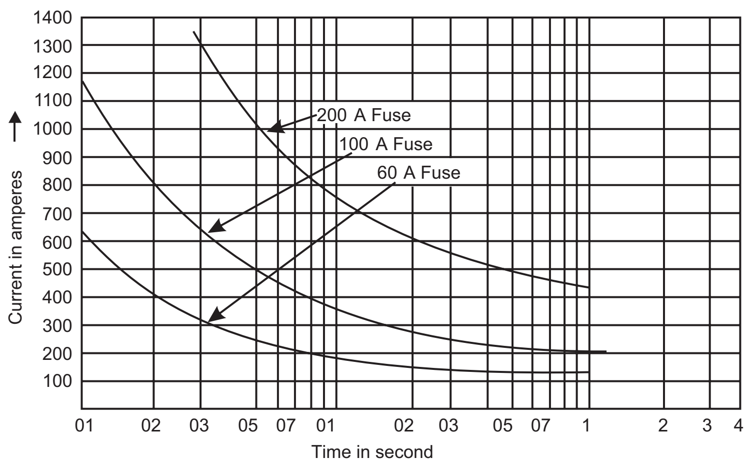


Fig. 2.8 Typical characteristics of 60A, 100A and 200A fuse

2.12.1 Advantages of Fuse

1. The cost of this protective device is very low.
2. It requires no maintenance.
3. It interrupts heavy current without noise or smoke.
4. The smaller size of fuse element imposes a current-limiting effect under short circuit.
5. The minimum time of operation can be predetermined by selecting proper material of the fuse wire.
6. The inverse time–current characteristic makes it suitable for over current protection.

2.12.2 Disadvantages of Fuse

1. Considerable time is lost in rewiring or replacing fuses after every operation.
2. On short circuit, determination between fuses in series can only be obtained if there is considerable difference in the relative sizes of the fuse concerned.

2.13 MINIATURE CIRCUIT BREAKER (MCB)

Miniature circuit breaker (MCB) is a device that ensures definite protection of wiring system and sophisticated equipment against over current and short circuit faults. The outer view and the internal details of a MCB are shown in Figures 2.9 and 2.10, respectively.

Fig. 2.9 Outer body of a miniature circuit breaker

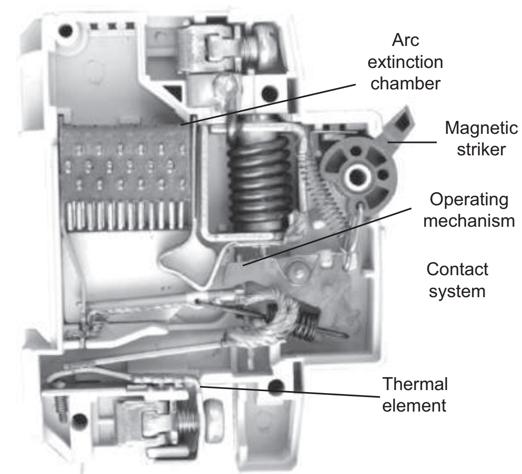


Fig. 2.10 Internal parts of a miniature circuit breaker

2.13.1 Construction

Construction of an MCB can be explained by considering the following main parts:

1. **Outer body or housing:** The outer body or housing of an MCB is moulded from a special grade glass fibre-reinforced polyester with the help of an injection-moulding machine. The outer body and other polyester components of MCB are fire-retardant, anti-tracking and non-hygroscopic. These polyester parts and housing have the ability to withstand high-temperature and mechanical impacts.
2. **Contacts:** The contacts of an MCB are made of pure silver. This provides definite advantages such as long contact life, low contact resistance, ensures quick arc removal, and low-heat generation.
3. **Operating mechanism:** All the components of the operating mechanism are made of special plastic that they are self-lubricating that eliminates wear and tear, rust, and corrosion. These components are very light in weight and have low inertia, thereby ensure snap make the break ability. The reliability and ruggedness of the operating mechanism is, thus, maintained.
4. **Arc extinguishing chamber:** The arc produced during breaking of circuit is extinguished abruptly by providing a special arc chute chamber.
5. **Fixing arrangement:** The MCB-mounting clip gets easily snapped on to the Din-bar and can be removed easily by a simple operation with a screw driver. This saves the time that would have been required for fixing it with screws.
6. **Mechanical interlocking of multiple MCBs:** The levers of all the (3 or 4) multiple MCBs are connected internally. This ensures simultaneous tripping of all poles even if the fault develops in any one of the phases.

2.13.2 Working

MCB may operate under the following two different conditions:

1. **Moderate overload condition:** Detection of moderate overload conditions is achieved by the use of a thermometal that deflects in response to the current passing through it. The thermometal moves against the trip lever, releasing the trip mechanism.
2. **Short circuit conditions:** When the current flowing through the MCB reaches a predetermined level (as per its setting or rating), it pushes the solenoid plunger that releases the trip mechanism and simultaneously separates the contacts.

Under short circuit conditions, the current-limiting action is achieved by the use of a high speed, direct acting electromagnetic mechanism.

This mechanism forcibly separates the contacts and simultaneously releases the trip mechanism. A high arc voltage drop is rapidly introduced that limits the fault current to a duration of few milliseconds and achieves almost instantaneous interruption (the facts are shown graphically in Fig. 2.11).

When the contacts are separated, the current still rises due to arc. This arc is extinguished quickly in the arc chute chamber and does not allow the current to reach theoretical maximum value. The total breaking time is reduced to less than 5 millisecond.

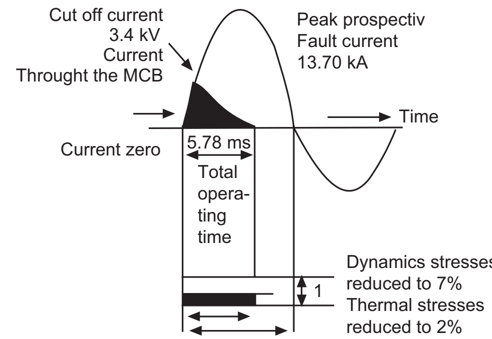


Fig. 2.11 Operating time of an MCB

2.13.3 Applications

Since MCBs are available with different current ratings of 0.5, 1.6, 2, 2.5, 3, 4, 5, 6, 7.5, 10, 16, 20, 25, 32, 35, 40, and 63 A and voltage ratings of 240/415 V AC and up to 220 V DC. Moreover, they have very small breaking time (5 millisecond), and therefore, these are generally employed to protect the important and sophisticated appliances used commercially and for domestic purposes, such as computers, air conditioners, compressors, refrigerators, and many others.

2.14 EARTH LEAKAGE CIRCUIT BREAKER (ELCB)

In the industrial, commercial, and domestic buildings, sometimes (usually in rainy season) leakage to earth occurs. This leakage may cause electric shock or fire. Hence, the leakage to earth is very dangerous and needs protection.

ELCB is a device that provides protection against earth leakage faults.

2.14.1 Construction and Internal Circuit Details

The enclosures of the ELCB is moulded from high-quality insulating material. The materials are fire-retardant, anti-tracking, non-hygroscopic, impact resistant and can withstand high temperatures. The body contains spring-loaded mounting arrangement on din-channel that ensures snap fitting of ELCB into position. However, these also have the facility to screw-on directly to any surface with the help of two screws. A two-pole ELCB is used for single-phase supply and a four-pole ELCB is used for three-phase, four-wire supply. A four-pole ELCB is shown in Figure 2.12.

Internal wiring diagram of a two-pole ELCB is shown in Figure 2.13. As shown in Figure 2.13, an ELCB contains a core-balanced transformer (ferrite ring on which one or two turns of phase and neutral wire, and a few turns of operating coil of relay are wound) and a relay. A test

Fig. 2.12 Outer body of an earth leakage circuit breaker

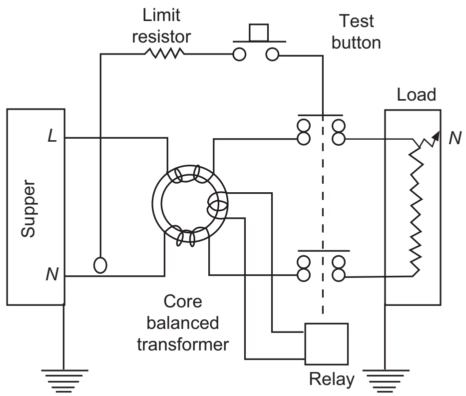


Fig. 2.13 Electrical circuit of an earth leakage circuit breaker

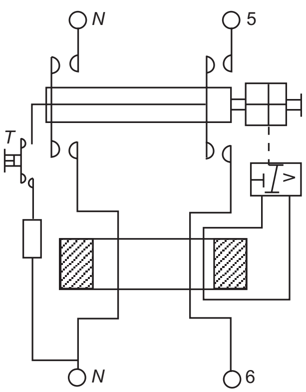


Fig. 2.14 Schematic diagram of a 2-pole ELCB

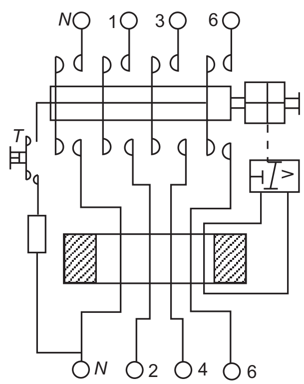


Fig. 2.15 Schematic diagram of a 4-pole ELCB

button is placed between phase and neutral in series with a limiting resistor. The terminal designation and connection diagram for a two-pole and four-pole ELCB are shown in Figures 2.14 and 2.15, respectively.

2.14.2 Principle of Operation

Under normal conditions, the magnitude of currents flowing through the phase wire and neutral are the same and core of the core-balanced transformer does not carry any flux (i.e., two

windings neutralize the flux). Therefore, no emf is induced in the operating coil of the relay wound on the same core. However, when the earth fault (earth leakage) occurs, the current in the phase wire becomes more than the neutral wire. This unbalancing sets up flux in the core of the core-balanced transformer, which in turn induces an emf in the operating coil of the relay. Hence, relay is energized and the plunger of the ELCB goes to the off position or disconnects the load from the supply. Therefore, ELCB protects the system against leakage.

Use of test knob

A test knob is provided for the periodic checking of the mechanism and function of ELCB.

PRACTICE EXERCISES

Short Answer Questions

1. What are the causes of electric fire?
2. What is a fuse?
3. What are different types of fuses?
4. What is MCB? How does it work?
5. What is the full form of RCCB and its usage in wiring system?

Test Questions

1. How electric fire can be prevented?
2. What is an electric fuse? Draw the characteristics of a fuse and mention its merits and demerits.
3. What are the different parts of an MCB and explain how it works.
4. Explain the working of an ELCB.

2.15 TYPES OF CABLES

It should be necessary to know about various types of cables (insulated conductors) that are used for internal wiring systems before considering the various types of wiring systems suitable for any installation.

A solid or stranded conductor covered with insulation is known as a cable.

The cable may be a single core or multicore depending upon the number of conductors. Various types of insulating materials are employed for covering the conductors.

Accordingly, the cables (wiring conductors) may be classified as follows:

1. Vulcanized Indian Rubber (VIR) cables
2. Polyvinyl chloride (PVC) cables
3. Tough rubber sheathed (TRS) or Cab tire sheathed (CTS) cables
4. Lead sheathed cables
5. Weather proof cables

2.16 TYPES OF WIRING SYSTEMS

The main types of wirings usually employed in residential buildings, commercial buildings, and industries are as follows:

1. Cleat wiring
2. Casing and capping wiring
3. CTS or TRS wiring
4. Metal-sheathed wiring
5. Conduit wiring

2.16.1 Cleat Wiring

In this system of wiring, usually VIR or PVC conductors are employed. The conductors are supported in porcelain cleats that are placed at least 6 mm above the walls. The porcelain cleats are made of two parts, namely base and cap, that is, the lower one is known as base being having two or three grooves for the accommodation of conductors and the upper one is known as cap as shown in Figure 2.16. The conductors are run in the grooves, cap is placed over the base, and the whole assembly is fixed on to the wall with the help of wooden screws and gutties (wooden or PVC plugs) already cemented in the wall. The screw not only fixes the cleats on the wall but also tightens the grip of the wires between the two halves of the cleat.

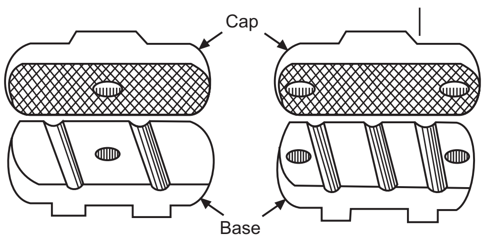


Fig. 2.16 Porcelain cleats

Advantages of cleat wiring

1. It is the cheapest system of wiring.
2. A little skill is required to lay the wiring.
3. This wiring can be installed very quickly.
4. It is the most suitable system for temporary wiring.
5. The wiring can be dismantled and recovered very quickly.
6. Inspection, alteration, and additions can be made easily.

Disadvantages of cleat wiring

1. It gives a rubbish look.
2. It is rarely employed for permanent job.
3. The insulation of wire is damaged while whitewashing or distempering the lime falls over the wires.
4. Oil and smoke are also injurious to VIR.
5. Mechanical injuries may damage the conductor since there is no protecting cover.

2.16.2 Casing and Capping Wiring

In this system of wiring, generally, VIR wires are employed. The casing is a base that consists of rectangular PVC or wooden block of seasoned teak wood and has usually two grooves to accommodate wires. The casing is fixed on the wall with the help of wooden screws and gutties already cemented in the wall. The casing is usually placed 3 mm apart from the wall by means of porcelain discs in order to protect the casing from dampness. Then, the wires of opposite polarity are laid in different grooves. After placing the wires in the grooves of casing, the casing is covered by means of a rectangular strip of seasoned wood of the same width as the casing known as copping with the help of wooden screws. The assembled view of casing and capping with the VIR wires placed in the grooves is shown in Figure 2.17.

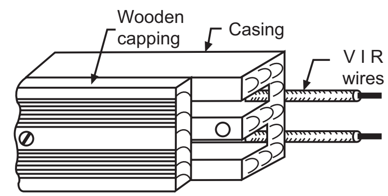


Fig. 2.17 Casing-capping wiring

Advantages of casing and capping wiring

1. It gives better appearance than cleat wiring.
2. Its cost is quite low as compared to other systems of wiring except cleat wiring.
3. It is easy to install and repair.
4. Conductors are strongly insulated.
5. Capping provides protection against mechanical injury.

Disadvantages of casing and capping wiring

1. It is not suitable in damp situations.
2. There is a risk of fire.
3. To make the job good looking highly skilled labour is required.

2.16.3 Cab Tire Sheathed or Tough Rubber Sheathed Wiring

In this system of wiring, generally CTS (Cab Tire Sheathed) or TRS (Tough Rubber Sheathed) conductors are employed These conductors are run on well-seasoned, perfectly straight, and well-varnished teak wood batten of thickness 13 mm. The width of the batten is chosen depending upon the number of wires to be run on it. While doing this type of wiring, the batten is fixed on to the wall by means of wooden screws and gutties already cemented in the wall. The wires are held on the batten with the help of clips already fixed on the batten with the help of nails as shown in Figure 2.18.

Advantages of tough rubber sheathed wiring

1. It is easy to install and repair.
2. It gives nice appearance.
3. The conductors have strong insulation, and therefore, it has longer life.
4. It is fireproof up to some extent.
5. Chemicals do not affect the conductor's insulation.

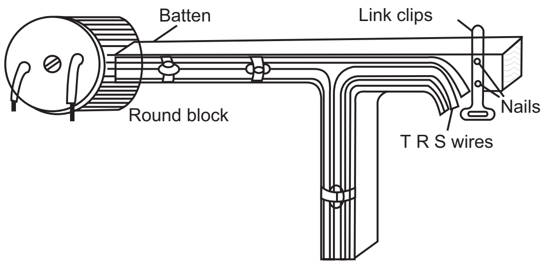


Fig. 2.18 CTS or TRS wiring

Disadvantages of tough rubber sheathed wiring

1. The conductors are open and liable to mechanical injury, and therefore, this type of wiring cannot be used in workshops.
2. Its use in places open to sun and rain in restricted.

2.16.4 Metal-sheathed Wiring

This system of wiring is similar to CTS or TRS wiring. The main difference is that, in this case, VIR conductors covered with lead alloy sheath (metal-sheathed cable) are used. The metal-sheathed cables are run on the wooden batten. The batten is fixed on the wall by means of screws and gutties already cemented into the wall. The cables are held on the batten with the help of link clips.

Advantages of metal-sheathed wiring

1. The conductors are protected against mechanical injury.
2. It can be suitably employed under damp situations.
3. It gives batter appearance.
4. It has longer life.
5. Conductors are protected against chemicals.
6. It can be installed in open space.

Disadvantages of metal-sheathed wiring

1. The metal-sheathed cables are costlier than CTS or TRS wires.
2. In case of leakage, there is every rick of shock.
3. Skilled labour and proper supervision is required.

2.16.5 Conduit Wiring

In this system of wiring, VIR or TRS conductors are run in metallic or PVC tubes called conduits. This system of wiring provides best mechanical protection, safety against fire and shock. Therefore, it is considered to be the most suitable system of wiring for workshops and commercial buildings. The conduits can be either supported over the wall by means of saddles or buried under plaster.

Accordingly, there are two types of conduit wirings, namely surface conduit wiring and concealed conduit wiring. In surface conduit wiring, the conduit is run over the wall supported by means of saddles as shown in Figure 2.19, whereas in concealed conduit wiring, the conduit is embedded in the walls and ceiling by placing it in the cavity made previously in them. After placing the conduit, the insulated conductors (or cables) are drawn into them by means of G.I. (galvanized iron) wire known as pilot wire. A number of inspection boxes (conduit boxes) are provided along the run of conduit to facilitate the drawing of wires.

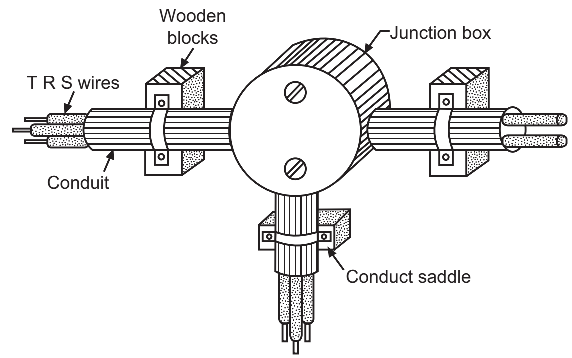


Fig. 2.19 Surface conduct wiring

Advantages of conduit wiring

1. Conduit provides protection against mechanical injury and fire.
2. Conduit provides protection against chemicals.
3. Conductors are safely secured from moisture.
4. This wiring has far better look.
5. It has a longer life.

Disadvantages of conduit wiring

1. It is costly system of wiring.
2. It requires more time for erection.
3. It requires highly skilled labour.

2.17 IMPORTANT LIGHTING ACCESSORIES

Some of the common lighting accessories are as follows:

1. **Main switch:** It is provided after the energy meter. It makes and breaks the phase and neutral connections simultaneously and controls the internal wiring circuits. In early days, switch-fuse units enclosed in iron boxes called iron clad switches were used. The following types of iron clad switches are employed in practice:

(a) **Double-pole iron clad (DPLC) switches:** These are used to control single-phase, two-wire circuits.
(b) **Triple-pole iron clad (TPIC) switches:** These are used to control three-phase, three-wire circuits.
(c) **Triple-pole iron clad switches with neutral link (TPNIC):** These are used to control three-phase, four-wire circuits.

However, nowadays, improved form of switches is employed. Fuse units with indicator light are used, which give better appearance.

2. **Switch:** Switch is a device that makes or breaks the circuit of an appliance such as lamp, fan, tube, socket, etc. There are two types of switches generally used in wiring system.
   (a) **Surface or tumbler switch:** A tumbler switch is mounted on a round block or a teak wood board.
   (b) **Flush switch:** A flush switch is generally mounted on teak wood board or Bakelite sheet.

   Mostly, it is used in concealed conduit wiring system.
3. **Ceiling rose:** It is used to connect the pendent lamp holder, fan, or fluorescent tube to the wiring installation through flexible wire.
4. **Three-pin outlet socket:** It is used to give temporary connection of electrical appliances such as radios, table tans, television sets, electric iron, etc.
5. **Lamp holder:** It is used to hold the lamp. It has two spring-loaded pins to which phase and neutral is connected. The electric supply is conveyed through these pins to the lamp. There are various types of lamp holders (e.g., batten holder, pendent holder, angle holder, bracket holder, water-tight bracket holder, swivel lamp holder, etc.) employed in the wiring system depending upon the requirement.

2.18 IMPORTANT CIRCUITS

The supplier (P.S.E.B. Department) gives electric supply to energy meter. From the energy meter, the supply is connected to the consumer's main switch as shown in Figure 2.20, which controls the supply of internal wiring. From main switch, the supply is connected to main distribution

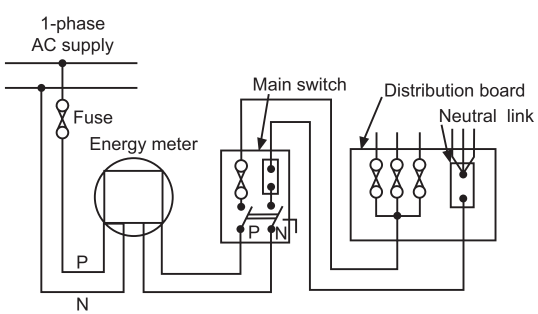


Fig. 2.20 Energymeter and distribution board

board that carries a number of fuses and neutral link. Then, the supply is given to sub-main distribution board or to switch board.

The important wiring circuits are as follows:

1. **Circuit to control one lamp with one switch:** The circuit is shown in Figure 2.21. In this figure, the switch is in the off position. The phase wire is connected to the lamp through switch, whereas the neutral wire is connected directly.

   A switch is always connected in phase, so that when switch is off and some maintenance is done at the holder, the mechanic may not get shock.

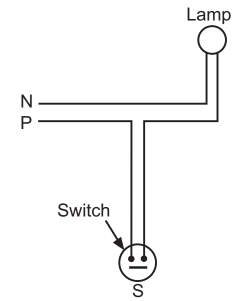


Fig. 2.21 One lamp controlled by one single-way switch

2. **Circuit to control one lamp with two two-way switches:** The circuit is shown in Figure 2.22. This circuit is used in staircase wiring. The two positions of the switches are shown. When both the switches are in the same position (i.e., either ON or OFF) as shown in Figure 2.22(a), the lamp will glow.

   When the two switches are in different positions (i.e., one is in ON position and the other is in OFF position) as shown in Figure 2.22(b), the lamp will remain dark.

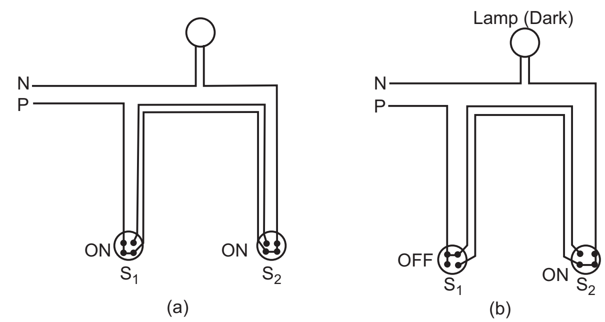


Fig. 2.22 One lamp controlled by two 2-way switches (a) Glowing position and (b) Dark position

3. **Circuit to control one lamp, fan, and three-pin outlet socket independently by single-way switches placed on a switch board:** The circuit is shown in Figure 2.23. A three-pin outlet socket, a fan regulator, and three switches are fixed on a switch board symmetrically as shown in Figure 2.23. The phase wire is given to all the appliances (i.e., lamp, fan, and three-pin outlet socket) through switches, whereas neutral wire is connected directly. An earth wire is connected to the earth terminal (large terminal) of three-pin outlet socket. In the fan circuit, a fan regulator is connected in series to regulate the fan speed.
4. **Circuit to control three-phase induction motor:** The circuit diagram to control a three-phase induction motor is shown in Figure 2.24. Only three wires are run from

meter board to main switchboard and main switchboard to motor control board. At the motor control board, a three-phase motor switch and a star/delta starter are fixed. From motor switch to starter, there are three wires, whereas six wires are run from starter to motor. Double earthing is provided in the motor installation as shown in Figure 2.24.

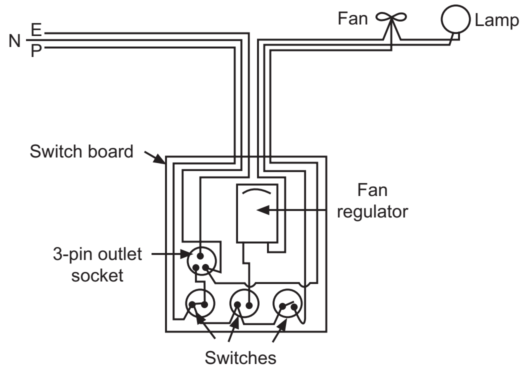


Fig. 2.23 **Switch board to control one lamp, one tube and on fan with regulator**

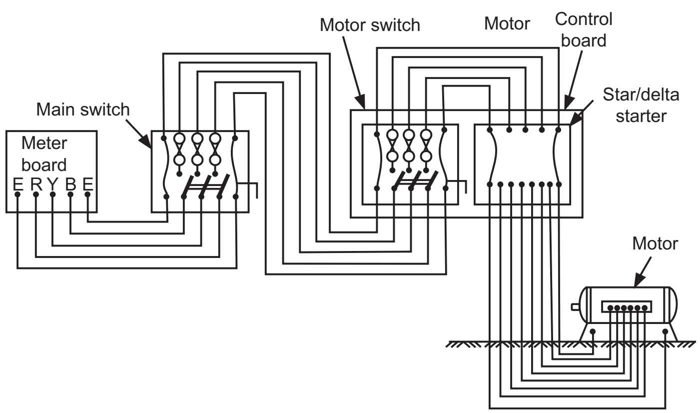


Fig. 2.24 **Electric wiring circuit to control 3-phase induction motor through a star-delta starter**

Power rating of basic house-hold equipment

To calculate the rating of the main switch and MCB_S/fuses to be used on the distribution board for a building and also for finalizing the size of the cable for service connection and internal wiring, it is necessary to assess the load of the building in ampere. For this purpose, following guidelines may be adopted after deciding the number and type of outlets installed in the building.

Incandescent light point (Bulb Point)	60 watt
Fluorescent tube 2 feet long (0.6 m)	20 watt
4 feet long (1.2 m)	40 watt
Ceiling fans	60 watt
Socket outlets (5A)	100 watt
15 ampere socket outlet (Power Socket)	1000 watt
Exhaust fan	100 watt
CFL/LED lamp	40 watt

Selection of cable or insulated wires used in wiring installations.

To find out the correct size of wire to be used at an installation, it is necessary to find out the load in ampere to be carried by the cables.

Tables 2.4 and 2.5 help us for selection of correct size of insulated wire based upon current and voltage drop of the conductors. Table shows only the copper wires used in the internal wiring system upto a current carrying capacity of 28 ampere, although, larger size wires are also available:

Table 2.4 Current Rating of Copper Conductor Single Core Cables (VIR, PVC or Polythene Insulated Including Tough Rubber Sheathed, PVC or Lead Sheathed Cables)

Size of Conductors		Two Cables d.c. or Single Phase A.C.		Three or Four Cable Balanced Three Phase A.C.	
Nominal Area mm²	No. and Dia of Wire (mm)	Current Rating (A)	Approximate Length of Run for One Volt Drop (Metre)	Current Rating (A)	Approximate Length of Run for One Volt Drop (Metre)
1.0	1/1.12	5	2.9	3	2.8
1.5	3/0.737	10	3	10	3.7
2.5	3/1.06	15	3.4	13	4.3
4.0	7/0.737	20	3.7	15	4.8
6.0	7/1.06	28	4.0	25	5.2

Aluminium core cable or insulated wires can also be used as per the current rating and size given in the following table. But aluminium core cable are avoided in the internal wiring of the buildings since they have poor mechanical strength. However, these are commonly used in seruice connections.

Table 2.5 Current Rating of Copper Conductor Single Core Cables (VIR, PVC or Polythene Insulated Including Tough Rubber Sheathed, PVC or Lead Sheathed Cables)

Size of Conductor		Two Cables DC or Single Phase AC		Three or Four Cables Balanced Three Phase		Four Cables DC or Single Phase AC	
Nominal Area mm²	No. and Dia of Wire (mm)	Current Rating (A)	Approx Run for One Volt Drop (m)	Current Rating (A)	Approx Run for One Volt Drop (m)	Current Rating (A)	Approx Run for One Volt Drop (m)
1.5	1/1.40	10	2.3	9	2.9	9	2.5
2.5	1/1.80	15	2.5	12	3.6	11	3.4
4	1/2.24	20	2.9	17	3.9	15	4.1
6	1/2.80	27	3.4	24	4.3	21	4.3
10	1/3.55	34	4.3	31	5.4	27	5.4
16	7/1.70	43	5.4	38	7.0	35	6.8
25	7/2.24	59	6.8	54	8.5	48	8.5
35	7/2.50	69	7.2	62	9.8	55	9.0
50	7/3.00	91	7.9	82	10.1	69	10.0
50	19/1.80	91	7.9	82	10.1	69	10.0
70	19/2.24	134	8.0	131	9.5	–	–
95	19/2.50	153	8.8	152	10.0	–	–

2.19 SUB-CIRCUITS

The supplier gives electric supply connection upto the energy meter placed outside the consumer premises. From the energy meter, supply is taken to the main switch. From the main switch, the supply it taken to the distribution board (Fuse box or MCB box), from distribution board, the electric supply is distributed to different rooms with the help of a pair of wires *i.e*. phase and neutral. The earth wire is also run along the sub-circuits and this wire is connected to earth terminal of each three-pin outlet socket.

As per the Indian Standard Institution, each sub-circuit should not carry a load of more than 800 watt or 10 electrical light/fan/socket (5-ampere) points.

Types of sub-circuits

The sub circuits beyond the distribution board can very well be divided into two groups:

1. **Light, fan and 5 A socket outlet sub-circuits:** It should not contain 10 points or 800 watt.
2. **Sub-circuit of 15 ampere socket points:** In this sub-circuit the load should not exceeding two sockets of 1000 watt each. But practically there is an independent supply sub circuit to each 15 ampere sub circuits.

The neutral wire of each circuit may not be looped from one circuit to another, However, looping of neutral within the sub circuit is allowed. All equipment used on light/fan/5 ampere. socket outlets is rated at 5 ampere.

2.20 SELECTION, RATING AND INSTALLATION OF NECESSARY EQUIPMENT ON THE MAIN SWITCH BOARD

The single line representation showing installation of necessary equipment on the main switch board distribution board will give very clear indication about the number of sub circuits and load on each sub circuit for the purpose of selection and rating of equipment. This is necessary for large installation for providing a scheme for requirement of different sub circuits.

According to I.S.I., the rating of important equipment normally employed in every house wiring such as lamp, fans and socket outlets (5 ampere and 15 ampere) are considered for calculating the current for each sub-circuit.

Example 2.1

There are four sub circuits in an installation of a house wiring One of them is a sub circuit for 15 ampere socket. Draw the single line diagram showing cutout, meter, main switch, main distribution board and other equipment. Make your own assumptions for number of electrical points in each sub-circuit and find out the rating of main switch and distribution board.

Solution:

The single line diagram as per the question is shown in Figure 2.25.

Let the total load of all the four sub circuits be as under:

Load in sub circuit No. 1

Light points = 2 × 60 = 120 watt
Fan points = 2 × 60 = 120 watt
Socket 5-ampere = 3 × 60 = 180 watt
Tube points = 2 × 40 = 80 watt
Total connected load = 500 watt

Load in sub circuit No. 2

Light points = 4 × 60 = 240 watt
Fan points = 2 × 60 = 120 watt
Socket 5-ampere = 3 × 60 = 180 watt
Total connected load = 540 watt

Load in sub circuit No. 3

Light points = 2 × 60 = 120 watt
Fan points = 2 × 60 = 120 watt
socket 5-ampere = 4 × 60 = 240 watt
Total connected load = 480 watt

Load in sub circuit No. 4

Sub circuit for 15 ampere socket outlet at 1000 watt

Total connected load on all four sub circuits in the house

= 500 + 540 + 480 + 1000 = 2520 watt.

$$\text{Total load in ampere} = \frac{\text{waltage}}{\text{voltage}} = \frac{2520}{230} = 11\text{ A}$$

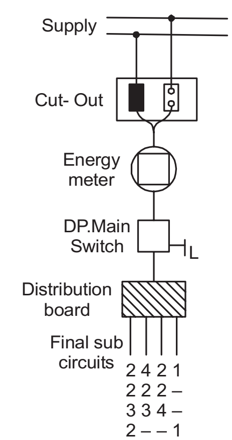


Fig. 2.25

A load of 11 ampere shall have to be carried by the main switch if all the points are put to on position. Therefore, keeping in view the future expansion a main switch of higher rating is suggested.

A 30 ampere, 250 V grade two-pole iron clad switch is therefore suggested.
Or D.P. MCB Unit of 15A, 250 V rating is suggested.
An iron clad distribution board, 4 way with neutral link is suggested.

Example 2.2

A newly constructed lecture block of the building of an engineering college is to be provided with electrical connections. A three phase four wire supply is given to meet the full load and future expansion.

Solution:
Draw the single line diagram of the supply, three-phase energy meter, different main switches, distribution boards and sub distribution boards. Figure shows all the above noted equipment in a systematic manner.

The voltage across any two phase wires is 400 volt and between any phase and neutral is 230 volt. The power loads are connected across three-phases and lighting loads across phase and neutral. The three phase four wire supply is given to bulk consumers i.e. hospitals, institutions, hostels, industries and other large consumers. having load more than 10 kW.

Estimate No. 2.1

The plan of a single room of size 4 m × 4 m is given in Figures 2.26. and 2.27. The room is required to be provided with one lamp, one fan, one fluorescent tube and one 5 ampere. socket-outlet. Each of the points is controlled by its individual switch. Mark the location of the electrical points suitably and draw the installation plan and the wiring diagram. Prepare complete list of material required for wiring the room in concealed conduit system of wiring.

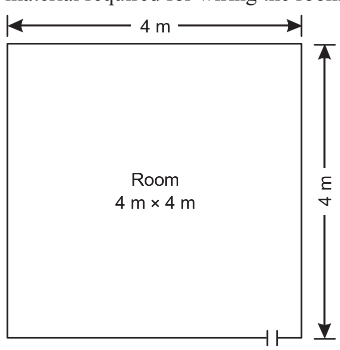


Fig. 2.26

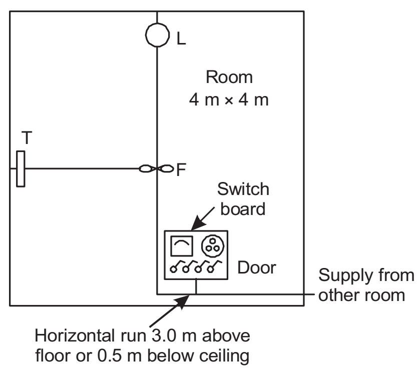


Fig. 2.27

Solution:
The switch board is located near the entry door for convenience, generally, the socket outlet is installed on the same switch board. The fan point on the ceiling is usually installed in the centre of the room. The light points are located on the walls about half metre below ceiling.

The switch board has been shown in original form. This is drawn to know the actual position of the switch board.

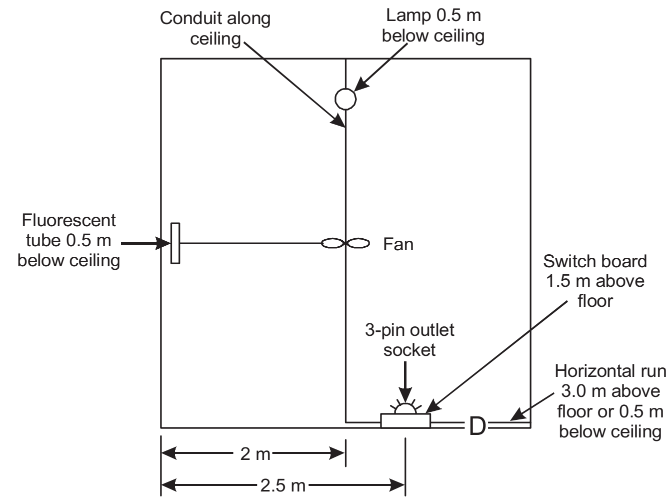


Fig. 2.28 Installation plan

Assume

(a)	Height from floor to ceiling	= 3.5 m
(b)	Height of horizontal run (*HR*) from floor	= 3.0 m
(c)	Height of switch board (*SB*) from floor, *i.e.*, Vertical run (*VR*)	= 1.5 m
(d)	Light and tube points from ceiling i.e downward run (DR)	= 0.5 m

Calculations for length of conduit pipe of 20 mm diameter

From *SB* to *HR*	= 1.5 m
From entry of circuit into room upto switch board	= 1.5 m
From HR to lamp point = 0.5 + 0.5 (Rise) + 4.0 + 0.5 (drop)	= 5.5 m
From fan to tube point = 2.0 + 0.5 (drop)	= 2.5 m
Total length of conduit pipe	= 11 m
Taking 10% wastage	= 1.1 m
Total length of conduit pipe required for wiring the room	= 12.1 m Say 12.0 m

Calculations for length of phase wire

From point of entry of circuit into room upto *SB* = 1.5 (*HR*) =1.5 (*VR*)	= 3.0 m
From *SB* upto Fan = 1.5 (*VR*) + 0.5 *HR* + 0.5 (rise) + 2.0 along ceiling upto fan	= 4.5 m
From *SB* to lamp = 4.5 m upto fan + 2.0 + 0.5 (drop)	= 7.0 m
From *SB* to tube point = 4.5 upto fan + 2.0 along ceiling + 0.5 drop	= 7.0 m
Total length of phase wire	= 21.5 m

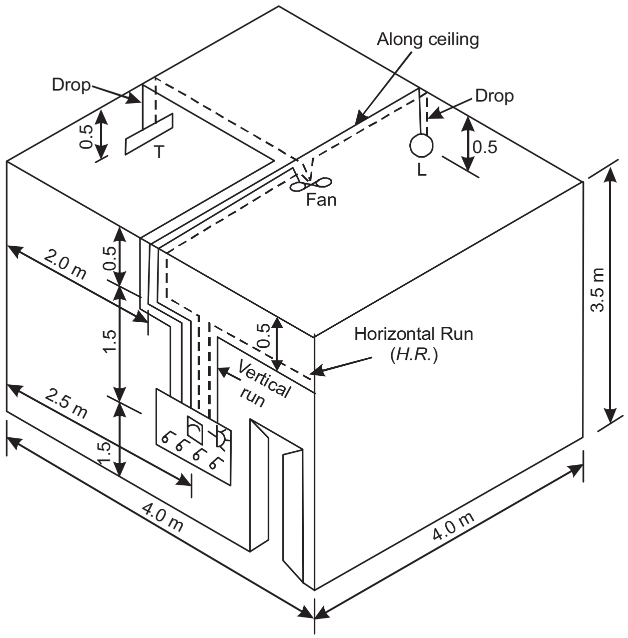


Fig. 2.29

Calculations for length of neutral wire

(The neutral wire is shown as dotted line on the isometric view of the room)

From point of entry of circuit into room upto switch board = 1.5 along HR +1.5 (VR) = 3.0 m

From SB to fan = 1.5 + 0.5 + 0.5 (rise) + 2.0 along ceiling = 4.5 m

From fan to lamp point = 2.0 (along ceiling) + 0.5 (drop) = 2.5 m

From fan to tube point = 2.0 + 0.5 = 2.5 m

Total length of neutral wire = 12.5 m

Total length of wire required for wiring the room (phase + neutral) = 21.5 + 12.5 = 34 m

Allowing 15% extra for wastage and connections = 5.1 m

Total wire required for wiring the room = 34.0 + 5.1 = 39.1 m

Say 39 m

Calculations for length of earth wire

The earth wire is run from each switch board to the other to connect the earth terminal of three-pin outlet socket to the solid earth. Usually an earth wire of 145 SWG is used for wiring installation. In this case, the earth wire is coming from the other room reaches the switch board, from this switch board it is to run to the other switch board. Say the length of earth wire is 7 m. The electric wiring circuit for the room is shown in Figure 2.30.

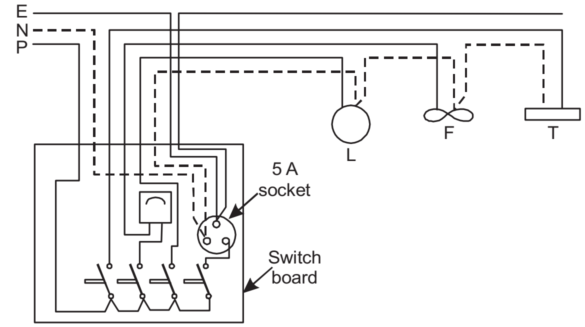


Fig. 2.30

Table 2.5 Material and costing

S. No.	Material and Others	Quantity	Rate
1.	PVC conduit 20 mm dia.	12 m	As per the market
2.	PVC insulated, aluminium conductor, single core, 250 volt grade wire of size 1.5 mm/ or 1/1,40 mm dia.	39 m	
3.	Earth wire 14 SWG, G.I	7.0 m	value
4.	Iron clad, concealed type, switch boards with bakelite sheets 15 cm × 20 cm	1 No.	
5.	Conduit pipe accessories for 20 mm dia. conduit		
	1-way junction box	2 No.	
	2-way junction box	1 No.	
	3-way junction box	2 No.	
	Conduit bends	3 No.	
	Conduit sockets to connect two pieces of conduit		
	(one per 3 metre of conduit approximately	8 No.	
	Crumpets of MS (Hooks) to hold conduit in wall recess		
	at 1.5 m interval but along walls only	8 No.	
6.	Flush switch, 5 A rating, one way	4 No.	
7.	Flush socket 5 A rating, 3 pin	1 No.	
8.	Ceiling roses, 2-plate, bakelite (for tubes and fans)	2 Nos.	
9.	Junction box covers, bakelite for covering unused junction boxes	2 Nos.	
10.	Lamp holder	1 No.	

(*Continued*)

Table 2.5 (*Continued*)

11.	Machine screws 25/30 mm long for fixing ceiling roses, lamp sockets, lamp holders etc.	10 Nos.
12.	Machine screws 15 mm long for fixing bakelite sheets on SB	8 Nos.
13.	Earthing thimbles 5 ampere rating	1 No.
14.	Hexagonal headed bolt and nut 6 mm dia. 25 mm long for fixing	
15.	Machine screws for fixing bakelite sheet covers with switch board	10 Nos.
16.	Labour charges (as per market rate)	
17.	Miscellaneous expenses @ 10% of total cost	
	(including supervision charges and profits) Total cost of wiring	

2.21 NEUTRAL AND EARTH CONNECTION

Neutral

At the sub-station, the star point of the transformer *LT* is connected to the earth and a line is connected to this point is called **neutral wire** as shown in Figure 2.31. This wire is not connected to earth at any other place in the distribution system. It provides the return path of the current. In fact, it carries the unbalanced current of the system. Usually, its size is half (or equal) of the line or phase wire. All measuring and protective instruments are connected between line and neutral.

Earth connection

The outer frame or tank of the transformer is properly earthed atleast at two places at the sub-station and a line is connected to this point and run along the distribution line as shown in Figure 2.31. This line is called earth wire or earth connection. This line is earthed all along the

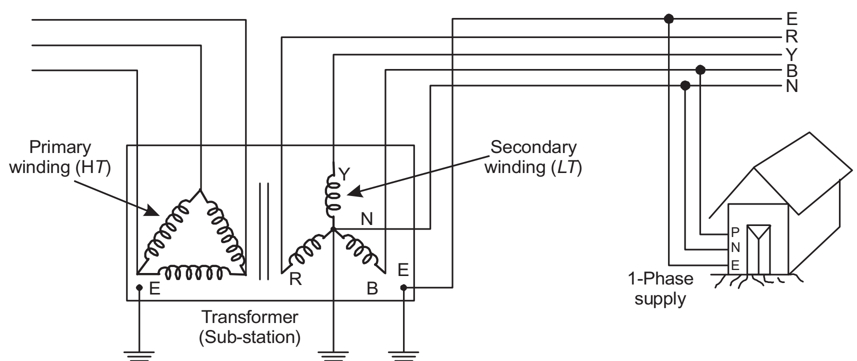


Fig. 2.31

distribution line usually after four spans. It provides an easy path for the leakage current and protects the human beings from electric shock.

2.22 EARTHING OF DOMESTIC FITTINGS AND APPLIANCES

All domestic fitting and metallic bodies of appliances must be properly earthed. For this purpose, an earth wire is run all along the domestic wiring and all electrical appliances are connected through three-core cable to the earth terminal of a three-pin outlet sockets as shown in Figure 2.32. The three cores of the cable are for phase (Red), neutral (Black) and earth (green).

In this case, if due to any reason a line wire comes in contact with the outer metallic body of the appliance, it will be immediately earthed and a heavy current will flow through the circuit. The MCB (or fuse) of the relative circuit will trip and disconnects the appliance from the supply and protects the operator from electric shock.

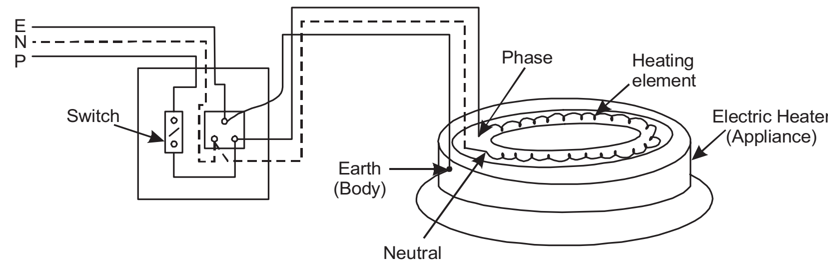


Fig. 2.32

PRACTICE EXERCISES

Short Answer Questions

1. Where do you prefer casing-caping wiring and way?
2. Where will you prefer PVC-batten wiring and way?
3. What factorswill you consider while selecting a cable for wiring installations.

Test Questions

1. Which type of wiring will you suggest of high-class residential building? Justify your answer.
2. Extimate the materal for 6 × 5 × 3.5 m hall having two lamp holders, 4-tube 2 fans and 4 three pin outlet socket placed on two switch boards placed on two opposite watts.

SUMMARY

1. *Electric shock*: When more than 10 mA current passes through a human body, one experiences an electric shock.

2. *Electric shock treatment*: When a person experiences an electric shock, first of all he/she should be removed from the electric contact and then artificial respiration should be given to the patient till doctor reaches at the spot.
3. *Safety measures*: Indian electricity Rules have suggested various safety measures while dealing with electricity.
4. *Earthing*: The process of connecting metallic bodies of all the electrical apparatus and equipment to the huge mass of earth by a wire of negligible resistance is called earthing.
5. *Purpose of earthing*: The basic purpose of earthing is to protect the human body (operator) from electric shock.
6. *Equipment earthing*: According to Indian Electricity Rules, it is obligatory to earth the metallic bodies of all the electrical equipment/apparatus/appliance which is operated at 125 V or more than this.
7. *System earthing*: All the electrical equipment/apparatus/appliance operated at 125 V or more must be properly earthed atleast at two places called double earthing.
8. *Methods of earthing*: The following method may be employed for earthing: (i) strip earthing, (ii) earthing through water mains, (iii) rod earthing, (iv) pipe earthing, (v) plate earthing. Pipe earthing is considered the best method.
9. *Causes of electric fire*: Electric fire may be caused: (i) By using inferior quality material. (ii) Due to overloading of circuit. (iii) Use of improper protective devices. (iv) Poor quality of insulation of wiring cables. (v) Loose connection, *i.e.*, sparking. (vi) Bare conductor coming in contact with earth.
10. *Fuse*: A short piece of metal wire, inserted in series with the circuit, which melts when more than predetermined value of current flows through it and breaks the circuit is called a fuse.
11. *Types of fuses*: (i) Low voltage fuses, *i.e.*, (a) rewirable fuses, (b) high breaking capacity fuses (*HRC*) or high rupturing capacity (*HRC*) fuses, (iii) high voltage fuses, *i.e.*, *HBC* fuses.
12. *Miniature Circuit Breakers* (*MCBs*): It is a protective device, connected in series with load in phase wire. It trips or disconnects the load as and when current through it flows more than its predetermined value.
13. *Earth Leakage Circuit Breaker* (*ELCB*) or *Residual Current Circuit Breaker* (*RCCB*): It is a protective device which disconnects the circuit or load from the mains when earth fault develops in the circuit.
14. *Types of wiring*: (*i*) Cleat wiring – best method for temporary wiring.
    (*ii*) *Casing capping wiring* – best suited for rural domestic wiring.
    (*iii*) *C.T.S. or T.R.S. wiring* – best suited for urban domestic wiring.
    (*iv*) *Metal sheathed wiring* – best suited for workshops.
    (*v*) *Conduit wiring* – (*a*) Surface conduit wiring – best suited for workshops, industries, laboratories etc.
    (*b*) Concealed conduit wiring – best suited for commercial and high first class buildings.
15. *Power rating of basic house-hold equipment:* Each house-hold equipment has its power rating and load of a consumer is accessed accordingly.
16. *Selection of cable:* On the basis of current rating and voltage drop per metre run, a suitable size of the cable or insulated wire for wiring installation is selected.
17. *Estimating of material:* On the basis of size of room building and lighting arrangement, the quantity of material is estimated.
18. *Earth wire and neutral:* Earth wire is earthed at many places all along its run but neutral is earthed only at sub-station.
19. *Earthing of domestic appliances:* The outer metallic frame of all the electrical appliances is properly earthed through the earth terminal of a three-pin outlet socket.

TEST YOUR PREPARATION

FILL IN THE BLANKS

1. One experiences an electric shock when the current passing through one's body is more than______.
2. A short piece of wire connected in series with the circuit which melts when excessive current flows through it is called _________.
3. A fuse is always connected in _________ with the circuit to be protected.
4. A fuse element should have _________ melting point.
5. The fuse wire having low melting point is an alloy of _________.
6. The minimum value of current at which the fuse element melts is called _________.
7. The basic purpose of earthing is to _________.
8. For a good earthing system, the value of earth resistance should be _________.
9. Fuses and switches should be inserted in the __________.
10. Voltage between any one phase wire and neutral is called __________.

OBJECTIVE TYPE QUESTIONS

1. In motor wiring installations, double earting is required.
   (a) single (b) double (c) tripple (d) all of these
2. The material used for fuse element is
   (a) copper (b) aluminium (c) tin-lead alloy (d) any of (a), (b) or (c)
3. The material used for fuse must have
   (a) low melting point and low specific resistance
   (b) low melting point and high specific resistance
   (c) high melting point and low specific resistance
   (d) low melting point with any specific resistance
4. Fuse is always connected
   (a) in series with the circuit to be protected
   (b) in parallel with the circuit to be protected
   (c) either (a) or (b)
   (d) none of these
5. Fuse is always connected in
   (a) neutral (b) earth (c) phase (d) any (a), (b) or (c).
6. The basic purpose of earthing is that
   (a) it avoids faults
   (b) it allows the current to flow in the circuit
   (c) it protects the operator from electric shock
   (d) it stops current to flow in the circuit
7. When more than one equipment is to be earthed
   (a) parallel connections should invariably be used
   (b) series connections should invariably be used
   (c) either (a) or (b)
   (d) none of these
8. For proper earthing, according to I.E. Rules, of heavy power equipment:
   (a) Single earthing is sufficient. (b) Double earthing system has to be adopted.
   (c) Half earthing is sufficient. (d) Any one of above.

9. Earth resistance should be
(a) very low (b) 10 ohm (c) 100 ohm (d) very high

10. The cheapest internal wiring system is
(a) cleat wiring (b) casing-capping wiring
(c) C.T.S. wiring (d) conduit wiring

11. The wiring system generally employed in public buildings (offices) is
(a) cleat wiring (b) casing-capping wiring
(c) C.T.S. wiring (d) conduit wiring

12. From economy point of view, mostly the wiring employed in residential building is
(a) cleat wiring (b) casing-capping wiring
(c) C.T.S. wiring (d) conduit wiring

13. From safety point of view, the most suitable wiring system is
(a) cleat wiring (b) casing-capping wiring
(c) C.T.S. wiring (d) conduit wiring

14. For temporary fitting, the most suitable wiring system is
(a) cleat wiring (b) casing-capping wiring
(c) C.T.S. wiring (d) conduit wiring

15. In concealed conduit wiring, the switches used are
(a) tumbler switches (b) flush switches (c) both (a) and (b) (d) none of these

16. In wiring installations, the appliances are always controlled by the switches connected in
(a) phase wire (b) neutral wire (c) earth wire (d) none of the above

17. In stair case wiring circuit, the lamp glows when two two-way switches are in the similar position.
(a) two, single-way switches
(b) two, two-way swicthes
(c) one single way and one two-way switches
(d) two, two pole switches

18. In a three-pin outlet socket, all the three terminals (pins) are of the same size.
(a) one short two long (b) two long one short
(c) one long two short (d) all are of same length

VIVA VOCE OR REASONING QUESTIONS

1. Electric shock in dangerous for a human body, why?
2. All the metallic bodies or frames of all the electrical equipment/apparatus are properly earthed, why?
3. Fuse is always provided in phase wire, why?
4. MCB is always provided in phase wire, why?
5. Double earthing is provided for all the electrical equipment operated at 400 V and above, why?
6. Pipe earthing is preferred over other types of earthing, why?
7. For domestic wiring, concealed condui wiring system is preferred, why?
8. One lamp is controlled by two switches in stair case wiring circuit, why?
9. In three-pin outlet socket, why earth terminal is made of larger diameter.

SHORT ANSWER TYPE QUESTIONS

1. What do you mean by electric shock?
2. How one can prevent himself from electric shock?
3. If a person is electrocuted, what steps will you take?
4. What do you mean by earthing?

5. How earth resistance can be kept low in dry summer season?
6. What do you mean by double earthing?
7. Which type of earthing will you prefer: pipe earthing or plate earthing? Give reasons.
8. What is fuse wire?
9. How a fuse protects appliances?
10. A fuse wire should have low- or high-melting point, explain why?
11. An *MCB* is just like a fuse or switch, explain.
12. What is an *ELCB*? Mention its function.
13. What is CTS and VIR wire?
14. Name the various types of wiring systems commonly used in residential and commercial buildings. Explain any one in detail.
15. Explain different types of wiring systems with reference to their field of applications, advantages and disadvantages.
16. What are the advantages of conduit wiring?
17. What types of wiring is used in workshops and why?
18. Distingish between neutral and earth wire.
19. How the outer metallic bodies of electrical appliances are connected to earth?

TEST QUESTIONS

1. Give brief description of any five safety measures you will take while handling the electrical equipment.
2. What do you understand by electric shock? Explain how it damages the human body.
3. How a person is disengaged from electrical line in case of an accident?
4. Explain in brief the action you will take in restoring a person who has suffered an electrical shock and is unconscious.
5. What are the causes of electric fire?
6. How can we prevent electric fire?
7. How can we prevent electric shock?
8. What is meant by a fuse? Enlist the desirable properties of a fuse wire.
9. Write short note on a rewirable fuse.
10. How does a fuse protect and maintain the life of an electrical equipment?
11. Write short note on HRC (or HBC) fuse.
12. Enumerate the disadvantages of a rewirable fuse.
13. What is earthing?
14. What is the purpose of earthing?
15. Explain system earthing and equipment earthing.
16. What do you understand by double earthing?
17. What are the various methods of earthing? Explain pipe earthing.
18. Name the most commonly used wiring system in (i) residential buildings and (ii) workshops. Compare the advantages and disadvantages of concealed conduit wiring and batten wiring.
19. What is meant by DPIC and TPIC switch? Where are they used?
20. Draw the circuit diagram showing one, three-pin outlet socket controlled by a single way switch.
21. Draw the circuit diagram showing one lamp controlled by two two-way switches and explain its working.
22. Why is the earth point of a three-pin plug made thicker and longer?
23. Estimate the materal for 6 × 5 × 3.5 m hall having two lamp holders, four-tube two fans and four three-pin outlet socket placed on two switch boards placed on two opposite watts.

ANSWERS

Fill in the Blanks

1. 10 mA	**2.** fuse	**3.** series	**4.** low	**5.** tin and lead
6. fusing current	**7.** protect the operator	**8.**very small below 1 ohm		
9. phase	**10.** phase voltage			

Objective Type Questions

1. (b)	**2.** (d)	**3.** (a)	**4.** (a)	**5.** (c)
6. (c)	**7.** (a)	**8.** (b)	**9.** (a)	**10.** (a)
11. (d)	**12.** (c)	**13.** (d)	**14.** (b)	**15.** (b)
16. (a)	**17.** (b)	**18.** (c)		