



KINGDOM OF CAMBODIA

NATION RELIGION KING



Ministry of Labour and Vocational Training

Competency-based Learning Materials, Level 5

Core COMPETENCY

High Diploma

Module 1

Installing and Testing Electrical in Residential Building



2022

CORE COMPETENCY

Module 1

Installing and Testing Electrical in Residential Building



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PREFACE

Reference to Cambodian Qualifications Framework (CQF), it has identified two sets of competencies: basic competencies and core competencies for Technical and Vocational Education and Training (TVET). Currently, the National Training Board (NTB) has approved and promulgated 44 standard training packages with 188 qualifications from CQF Level 1 to Level 4. In the implementation of the Technical and Vocational Education and Training Development Project (TVETSDP) has encountered a number of problems, including the basic competencies (soft skills) defined in the national competency standard as part of the problem of implementing the competency-based training program as a reforming program in technical and vocational education and training, it is also required the project to develop the learning materials for basic competencies.

The practical integration of basic competencies (soft skills) into technical and vocational education and training has proved difficult recently. While industry employers often satisfy the technical skills of trainees who have completed technical skills or hard skills training, the industry has found that the performance of the trainees for basic competencies (soft skills) do not yet meet job requirements.

Seeing this, the General Directorate of Technical and Vocational Education and Training, the Ministry of Labor and Vocational Training, which get the mission from the Royal Government of Cambodia, received funding from the Technical and Vocational Education and Training Development Project (TVETSDP) through ADB Loan 3167-CAM and AFD Loan 8305-CAM has initiated the idea of developing the basic competency modules or soft skills modules for technical and vocational training institutions to integrate into technical and vocational education and training. Therefore, This is done to meet the needs of the use of qualified skilled labourers, defined jointly between industries and the public sectors in setting of competency profiles for the development of competency standards (CS), which CS become a national competency standard (NCS). NCS is the results of close collaboration of employers and technical practitioners, training providers and TVET partners. Subsequent discussions with key stakeholders, including the Sector Skills Councils in construction, Electrical work, Manufacturing, and Auto-mechanics; Centers of Excellence (COEs), and training providers jointly developed these basic competencies (soft skills) modules for CQF Level 5 training programs, as "**High Diploma**".

These Basic Competencies (Soft Skills) Modules are designed to implement for all CQF level 5 functional occupations of Technical and Vocational Education and Training. These modules are flexible and can be updated by a series of technicians, scholars and stakeholders in response to local needs.

These 7 core competencies (hard skills) modules as follows:

1. **Installing and Testing Electrical in Residential Building**
2. **Installing and Testing Electrical in Commercial and Industrial Buildings**
3. **Maintaining Electrical Machines and Applications**
4. **Maintaining Power System and Switchboards**
5. **Maintaining Electrical Auxiliary Systems**
6. **Programming Intelligent Building Control System**
7. **Maintaining Solar Photovoltaic Systems**

TVETSDP Coordinating Team, comprises of project technical team, soft skills team and COEs have reviewed and approved on the contents of the modules, which developed by Young Development Research & Consultants Co., Ltd. Now the above-mentioned modules were integrated into CQF Level 5 training programme.

The project hopes and believes that the implementation of these basic competencies modules will improve the quality of technical and vocational education and training programs to meet the needs of skilled Labour Market of Cambodia.

Phnom Penh,2021

**Minister attached to Prime Minister,
Permanent Secretary of State and Project director**

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HOW TO USE THIS COMPETENCY-BASED LEARNING MATERIALS

Welcome!

This module contains training materials and activities for you to fulfill the “**Apply of problem-solving techniques in the workplace**” comprises of knowledge, skills and attitudes required for basic competencies of qualification level 5 of the Cambodian National Qualification Framework.

You need to perform a series of learning activities to achieve each learning outcome of the module. In each learning outcome, there is an information sheet and / or operation sheet or job sheet or performance criteria checklist (additional reading references to help you better understand the required activities). Perform these activities yourself and answer the self-check at the end of each learning outcome. You can take out the answer sheet at the end of each module (or take from your facilitator / trainer a piece of white paper) to write your answer for self-check. If you have any questions, do not hesitate to ask your facilitator or trainer/instructor for help.

Remember to:

- Talk to your trainer and agree on how you will organize this training. Read the module carefully. It is divided into sections that cover all the skills and knowledge you need to complete this module successfully.
- Work through all the information and complete the activities in each section.
- Read information sheets and complete the self-check. Suggested references are included to supplement the materials provided in this module.
- Most probably, your trainer will also be your supervisor or manager. He is there to support you and show you the correct way to do things.
- You will be given plenty of opportunities to ask questions and practice on the job. Make sure you practice your new skills during regular work shifts. This way, you will improve your speed/pace, memory, and your confidence.
- Talk to a more experienced coworker or classmate and ask for advice.
- Use the Self-Checks at the end of each section to test your own progress. Use the Performance Criteria Checklist found after the information sheet to check your own performance.
- When you complete, please ask your trainer to see your demonstration this module.
- When you work through activities, ask for written feedback on your progress. Your trainer will continue to provide feedback / pre-assessment. When you have successfully completed each item, ask your trainer to take note of the report you are preparing for the assessment.
- When you feel confident that you have had sufficient practice, ask your Trainer to evaluate you. The results of your assessment will be recorded in your **Progress Chart and Achievement Chart**.
- You need to be competent in this module before you can perform the next module.

Recognition of Prior Learning (RPL)

You may have some or most of the knowledge and skills covered in this learner’s guide because you have:

- Been working for some time.
- Already completed training in this area.

If you can demonstrate to your trainer that you are competent in a particular skill, you don’t have to do the same training again.

If you have qualification or Certificate(s) of Competency from previous training present it to your trainer. If the skills you acquired are still relevant to the module, they maybe become the

part of the evidence you can present for RPL. If you are not sure about the validity of your skill(s), please talk to your trainer.

At the end of this module is a *Trainer's Record Book*. Use this to record important dates, jobs undertaken and other workplace events that will assist you in providing further detail to your trainer or assessors. A Record of achievements is also provided for your trainer to fill-up once you completed the module.

Detailed module content

Course : Installation and Maintenance Power and Control System in Building

Unit of Competency : Install and Test Electrical in Residential Building

Module Title : Installing and Testing Electrical in Residential Building

Module Descriptor : This module contains learning outcome, which are requirements for advanced and interactive communication that meet the specific needs of internal and external clients, conduct interviews, facilitate group discussions, and contribute to the development of communication.

Learning Outcome (L.O):

Upon completion of this module, students or participants will have the following competencies:

L.O 01: Maintain safety and electrical standards

L.O 02: Prepare electrical drawings of electrical installation / equipment

L.O 03: Install electrical final residential circuits and wiring systems

L.O 04: Install AC incoming supply system

L.O 05: Inspect and test electrical installations

L.O 01: Maintain safety and electrical standards

Upon completion of this learning outcome, students or trainees will have the following competencies:

- Assess the risk involved in electrical works
- Carry out risk prevention and supervision
- Maintain electrical installation in accordance with requirements and regulations
- Access to relevant code of practice for electrical installation correctly
- Observe and adhere to safety rules and precautions at work area

Information Sheet No. 5.1.1-1: Workplace Safety and Health

Workplace Safety and Health (WSH) is included as one of the employability skills. The generic occupational safety and health competencies described as below.

1. Objectives and Importance of WSH

The Workplace Safety and Health Act (the “Act”) which came into force on 1st March 2006, will replace the Factories Act as the legal framework regulating occupational safety and health in the country.

The Act aims to reduce workplace accidents (through higher penalties for poor safety management), avoid risks at source and allow industries to take greater ownership of safety outcomes.

The Act imposes liability directly on stakeholders, in other words, all parties who create and have control over safety and health risks. It is particularly pertinent to note that Part IV of the Act imposes liability on the following stakeholders:

- i. Occupiers for dangers arising from the physical environment under their control;
- ii. Employers and self-employed persons for the safety and health of their employees and other persons who may be affected by any undertaking carried out by the employers and self-employed persons in the workplace;
- iii. Principals for the safety and health of any contractor engaged by them, any direct or indirect subcontractor engaged by them and any employee employed by such contractor or subcontractor when at work;
- iv. Manufacturers and suppliers of machinery, equipment or hazardous substances used at work who are to ensure that the machinery, equipment or hazardous substances are safe for their intended use, and provide adequate information on use and the precautions to be taken;
- v. Persons who erect, install, modify or maintain the same high-risk machinery or equipment who are to carry out such maintenance responsibly; and
- vi. Occupiers of common areas.

2. Duties and Responsibility of People at Work

It shall be the duty of every person at work —

(a) to use in such manner to provide the protection intended, any suitable appliance, protective clothing, convenience, equipment or other means or thing provided (whether for his use alone or for use by him in common with others) for securing his safety, health, and welfare while at work; and

(b) to co-operate with his employer or principal and any other person to such extent as will enable his employer, principal, or the other person to comply with the provisions of this Act.

No person at work shall wilfully or recklessly interfere with or misuse any appliance, protective clothing, convenience, equipment or other means or thing provided (whether for his use alone or for use by him in common with others) pursuant to any requirement under this Act for securing the safety, health, or welfare of persons (including himself) at work.

Any person at work who, without reasonable cause, wilfully or recklessly does any act which endangers the safety or health of himself, or others shall be guilty of an offence.

Any person who contravenes subsection (1) or (2) shall be guilty of an offence and shall be liable on conviction to a fine not exceeding \$1,000 and, in the case of a second or subsequent conviction, to a fine not exceeding \$2,000.

3. Duties of Manufacturers and Suppliers of Machinery, Equipment, or Hazardous Substances used at Work

(1) (a) that the following information about the safe use of the machinery, equipment or hazardous substance is available to any person to whom the machinery, equipment or hazardous substance is supplied for use at work:

- (i) the precautions (if any) to be taken for the proper use and maintenance of the machinery, equipment or hazardous substance;
- (ii) the health hazards (if any) associated with the machinery, equipment, or hazardous substance; and
- (iii) the information relating to and the results of any tests or examinations of the machinery, equipment or hazardous substance under paragraph (c) that are relevant to its safe use;

(b) that the machinery, equipment or hazardous substance is safe, and without risk to health, when properly used;

(c) that the machinery, equipment, or hazardous substance is tested and examined to comply with the obligation imposed by paragraph (b).

(2) The duties imposed on any person specified in subsection (1) shall —

- (a) apply only if the machinery, equipment or hazardous substance is manufactured or supplied in the course of trade, business, profession or undertaking carried on by the person, whether for profit or not;
- (b) apply whether or not the machinery, equipment or hazardous substance is exclusively manufactured or supplied for use by persons at work; and
- (c) extend to the supply of the machinery, equipment, or hazardous substance by way of sale, transfer, lease or hire and whether as principal or agent, and to the supply of the machinery, equipment, or hazardous substance to a person for the purpose of supply to others.

(3) The duties imposed on any person specified in subsection (1) shall not apply to a person by reason only that the person supplies the machinery or equipment under a hire-purchase agreement, conditional sale agreement or credit-sale agreement to another (referred to in this section as the customer) during a business of financing the acquisition of the machinery or equipment by the customer from others.

(4) Where a person (referred to in this subsection as the ostensible supplier) supplies any machinery or equipment for use at work to a customer under a hire-purchase agreement, conditional sale agreement or credit-sale agreement, and the ostensible supplier —

- (a) carries on the business of financing the acquisition of goods by others by means of such agreements; and
- (b) in the course of that business acquired his interest in the machinery or equipment supplied to the customer as a means of financing its acquisition by the customer from a third person (referred to in this subsection as the effective supplier), the effective supplier shall be treated for the purposes of this section as supplying the machinery or equipment to the customer instead of the ostensible supplier, and any duty imposed by subsection (1) on a supplier shall accordingly apply to the effective supplier, and not on the ostensible supplier.

(5) Where a person designs, manufactures or supplies any machinery, equipment or hazardous substance for use at work and does so for or to another on the basis of a written undertaking by that other to take specified steps sufficient to ensure, so far as

is reasonably practicable, that the machinery, equipment or hazardous substance will be safe and without risk to health when properly used, the undertaking shall have the effect of relieving the first-mentioned person from the duty imposed by subsection (1) (b) to such extent as is reasonable having regard to the terms of the undertaking.

(6) Any person required under subsection (1) (c) to ensure that any machinery, equipment, or hazardous substance is examined and tested so as to comply with the obligation imposed by subsection (1) (b) shall be regarded as having complied with subsection (1) (c) to the extent that —

(a) the examination or test has already been carried out otherwise than by, or on behalf of, the person; and

(b) it is reasonable for the person to rely on that examination or test.

(7) For the purposes of this section, an absence of safety, or a risk to health, shall be disregarded in so far as the case in or in relation to which it would arise is shown to be one the occurrence of which could not reasonably be foreseen.

(8) In this section, “supplier”, in relation to any machinery, equipment or hazardous substance, does not include a manufacturer of those items when supplying, but includes an importer when supplying those items.

4. Duties of Persons Who Erect, Install, or Modify Machinery or Equipment and Persons in Control of Machinery for use at Work

It shall be the duty of any person who erects, installs, or modifies any machinery or equipment for use at work to ensure, so far as is reasonably practicable, that the machinery or equipment is erected, installed, or modified in such a manner that it is safe, and without risk to health, when properly used.

The duty imposed on a person erecting, installing, or modifying any machinery or equipment under subsection (1) shall apply only if the machinery or equipment is erected, installed, or modified during the person’s trade, business, profession or undertaking.

Any person required under subsection (1) to ensure that any machinery or equipment is erected, installed or modified in such a manner that it is safe, and without risk to health, when properly used shall be regarded as having complied with that subsection to the extent that — the person ensured, so far as is reasonably practicable, that the erection, installation or modification was in accordance with the information supplied by the designer, manufacturer or supplier of the machinery or equipment regarding its erection, installation or modification; and it is reasonable for the person to rely on that information.

Where any machinery moved by mechanical power is used in any workplace, then notwithstanding anything in this Act, it shall be the duty of the owner of the machinery to ensure — so far as is reasonably practicable, that the machinery is maintained in a safe condition; and that the precautions (if any) to be taken for the safe use of the machinery and the health hazards (if any) associated with the machinery is available to any person using the machinery.

Where the owner of any machinery moved by mechanical power has entered a contract of hire or lease with a hirer or lessee, the duty imposed under subsection (4) shall apply to the hirer or lessee of the machinery instead of the owner.

Where the owner, hirer or lessee of any machinery moved by mechanical power has entered a contract with another person to maintain the machinery, the duty under subsection (4) (a) shall apply to that other person instead of the owner, hirer, or lessee of the machinery.

5. Housekeeping

Effective housekeeping can eliminate some workplace hazards and help get a job done safely and properly. Poor housekeeping frequently contributes to accidents by hiding hazards that cause injuries.

Housekeeping is not just cleanliness. It includes keeping work areas neat and orderly; maintaining halls and floors free of slip and trip hazards; and removing of waste materials (e.g., paper, cardboard) and other fire hazards from work areas. It also requires paying attention to important details such as the layout of the whole workplace, aisle marking, the adequacy of storage facilities, and maintenance. Good housekeeping is also a basic part of accident and fire prevention.

Effective housekeeping is an ongoing operation: it is not a hit-and-miss cleanup done occasionally. Periodic "panic" cleanups are costly and ineffective in reducing accidents.

The Workplace Safety and Health Act aims to cultivate good safety habits and practices in all individuals at the workplace – from top management to the last worker. It requires every person at the workplace to take reasonably practicable steps to ensure the safety and health of the workplace.

Obligations of various stakeholders under the WSH Act to ensure good housekeeping

5.1 If You are an Employer or Principal

You must, as far as reasonably practicable, protect the safety and health of your employees or workers working under your direct control and all who may be affected by their work.

This includes:

- conducting risk assessments to remove or control risks to workers at the workplace;
- maintaining safe work facilities and arrangements for the workers at work;
- ensuring safety in machinery, equipment, plant, articles, substances and work processes at the workplace;
- developing and putting into practice control measures for dealing with emergencies;
- providing workers with adequate instruction, information, training, and supervision.

5.2 If You are an Occupier

You must, as far as reasonably practicable, ensure the following are safe and without risks to the health of any person within those premises, even if the person is not one of your employees.

- the workplace;
- all entrances to or exits from the workplace;
- any machinery, equipment, plant, article or substance kept on the workplace.

As an occupier, you may also be responsible for the common areas used by your employees and contractors. In particular, the following items, if they are used by persons working at your workplace, are your responsibility.

- electric generators and motors located in the common area;
- hoists and lifts, lifting gear, lifting appliances and lifting machines located in the common area;
- means of entry to or exit from the common area;
- any machinery or plant located in the common area.

5.3 If You are a Manufacturer or Supplier

You must ensure that any machinery, equipment, or substances you provide are safe for use. Hence, you are required to:

- provide proper information on the safe use of the machinery, equipment or hazardous substance;
- ensure that the machinery, equipment or hazardous substance is safe for use;
- ensure that the machinery, equipment, or hazardous substance has been tested and examined so that it is safe for use.

Note: A list of the machinery, equipment, and substances to which this requirement is applicable is provided in Annex C and D of the WSH Act.

5.4 If You are an Installer or Erector of Machinery

You must ensure, as far as reasonably practicable, the machinery or equipment erected, installed or modified is safe and without health risks when properly used.

Note: A list of the machinery, equipment, and substances to which this requirement is applicable is provided in Annex C.

5.5 If You are an Employed Worker

- You must adhere to safe working procedures and principles introduced at the workplace.
- You should not endanger yourself or others working around you through unsafe behaviour.
- You should not tamper with any safety device or undertake any wilful or reckless acts.
- You should also always correctly use any personal protective equipment provided at work.

5.6 If You are a Self-Employed Person

As a self-employed person, you are still required to take measures, as far as reasonably practicable, to ensure the safety and health of others such as members of the public.

6. Defined Machinery and Equipment

The following are defined as machinery or equipment under WSH

- Scaffolds and any materials or components used to erect them
- All lifting equipment
- Forklifts
- Power presses
- Bar-benders
- Any equipment or piping intended for operation under pressure, including all statutory pressure vessels
- Any equipment or piping intended to contain corrosive, toxic or flammable substances
- Welding equipment, including any accessory, apparatus or fitting necessary to enable its use
- Materials or components used for the construction of support structures
- Explosive powered tools

- Equipment used for abrasive blasting, including any accessory, apparatus or fitting necessary to enable its use and operation.

7. Defined Hazardous Substances

The following are classified as hazardous substances under WSH.

- Corrosive substances
- Flammable substances
- Explosives
- Oxidising substances
- Pyrophoric substances
- Gases under pressure
- Organic peroxides
- Self heating substances
- Self-reactive substances
- Substances which in contact with water, emit flammable gases
- Toxic substances
- Mutagens
- Carcinogens
- Teratogens
- Sensitizers
- Irritants
- Substances hazardous to aquatic environment.

Self-Check No. 5.1.1-1

1. What are duties of people at work?
2. What are define of Machinery and Equipment?
3. What are defined of Hazardous Substances?

Answer Key No. 5.1.1-1

1. It shall be the duty of every person at work —
 - to use in such manner to provide the protection intended, any suitable appliance, protective clothing, convenience, equipment or other means or thing provided (whether for his use alone or for use by him in common with others) for securing his safety, health, and welfare while at work; and
 - to co-operate with his employer or principal and any other person to such extent as will enable his employer, principal, or the other person to comply with the provisions of this Act.
2. The following are defined as machinery or equipment under WSH
 - Scaffolds and any materials or components used to erect them
 - All lifting equipment
 - Forklifts
 - Power presses
 - Bar-benders
 - Any equipment or piping intended for operation under pressure, including all statutory pressure vessels
 - Any equipment or piping intended to contain corrosive, toxic or flammable substances
 - Welding equipment, including any accessory, apparatus or fitting necessary to enable its use
 - Materials or components used for the construction of support structures
 - Explosive powered tools
 - Equipment used for abrasive blasting, including any accessory, apparatus or fitting necessary to enable its use and operation.
3. The following are classified as hazardous substances under WSH.
 - Corrosive substances
 - Flammable substances
 - Explosives
 - Oxidising substances
 - Pyrophoric substances
 - Gases under pressure
 - Organic peroxides
 - Self heating substances
 - Self-reactive substances
 - Substances which in contact with water, emit flammable gases
 - Toxic substances
 - Mutagens
 - Carcinogens

- Teratogens
- Sensitizers
- Irritants
- Substances hazardous to aquatic environment.

Information Sheet No. 5.1.1-2: Safety at Home and in the Workplace

1. Safety to the Equipment

Equipment and instruments used in mechanical and electrical, while durable, are quite sensitive to abuse. When connecting an electrical instrument into a circuit, make sure that the instrument and its setting are within the voltage and current range of the instrument. An instrument adjusted to measure a voltage within a 220V range will be ruined if connected into a 440 V circuit.

2. Code of Practices Requirements for Safety on Workmanship and Materials

Clearly the type and arrangement of the equipment used, together with the quality of workmanship provided, will go a long way to minimizing danger. The following is a list of basic requirements:

- Good workmanship, **approved** materials and equipment shall be used.
- Ensure that the correct type, size and current-carrying capacity of cables are chosen.
- Ensure that equipment is suitable for the maximum power demanded. Equipment once constructed, installed and protected shall be able to be maintained, inspected and tested.
- Make sure that conductors are insulated, and sheathed or protected if necessary, or are placed in a position to prevent danger.
- Joints and connections should be properly constructed to be mechanically and electrically sound.
- Always provide over-current protection for every circuit in an installation, and ensure that protective devices are suitably chosen for their location and the duty they have to perform.
- Where there is a chance of metalwork becoming live owing to a fault, it shall be earthed, and the circuit concerned should be protected by an over-current device or a residual current device (RCD).
- Ensure that all bonding of services is carried out.
- Do not place a fuse, a switch or a circuit breaker, unless it is a linked switch or circuit breaker, in a **neutral** conductor. The linked type must be arranged to **break** all the phase conductors.
- All single pole switches must be wired in the **phase** conductor only.
- A readily accessible and effective means of isolation must be provided, so that all voltage may be cut off from an installation or any of the circuits.
- All motors must have a readily accessible means of disconnection.
- Ensure that any item of equipment which may normally need operating or attending to by persons is accessible and easily operated.
- Any equipment required to be installed in a situation exposed to weather or corrosion, or in explosive or volatile environments, should be of the correct type for such adverse conditions.
- Before adding to or altering an installation, ensure that such work will not impair any part of the existing installation. No alteration shall be made to an existing installation unless it has been ascertained that the rating and condition are adequate.
- After completion of an installation or an alteration to an installation, the work must be inspected and tested by authorized personnel to ensure, as far as reasonably practicable, that the fundamental requirements for safety have been met.
- Safe means of access and working space shall be considered for installation.

These requirements form the basis of the Electrical Regulations in the Code of Practices.

3. Safety Precautions to be Observed When using Portable Electrical Power Tools

When using electric tools, basic safety precautions should always be followed to reduce the risk of fire, electric shock, and personal injury, including the following:

- Keep work area clean.
- Don't use power tools in damp or wet locations.
- Don't expose power tools to rain.
- Don't use tool in presence of inflammable liquids or gases.
- Keep children away.
- Store unused tools.
- Don't force tool.
- Use correct tool.
- Dress appropriately.
- Use safety glasses, face, or dust mask if necessary.
- Don't abuse cord.
- Secure work.
- Don't over-reach.
- Maintain tool with care.
- Disconnect tools from the supply when not in use.
- Remove adjusting keys and wrenches from machines before operation.
- Don't carry plugged-in tool with **finger** on switch.
- When tool is used outdoors, use only extension cord intended for use outdoor.
- Watch what you are doing, use common **sense**.
- Check for damaged parts before using any tools.
- Guard against electric shock.
- When servicing, use only identical replacement parts.

4. Voltage Warning

Before connecting the tool to a power source, be sure the voltage supplied is the same as that specified on the nameplate of the tool. A power source with voltage greater than that specified for the tool can result in **SERIOUS INJURY** to the user as well as damage to the tool. If in doubt, **DO NOT PLUGGED IN THE TOOL**.

5. Additional Safety Rules

- Wear a hard hat, safety glasses and/or face shield. It is also highly recommended that you wear a dust mask, ear protector and thickly padded gloves if required.
- Under normal operation, vibration is expected when using tools. The screws of the tool can come loose easily, causing a breakdown or accident. Check **tightness** of screws carefully before operation.
- Always be sure you have a **firm footing**. Ensure no one is below when using the tool in high locations.
- Hold the tool **firmly** with both hands. Always use the side grip.

- Keep hands away from **rotating** parts.
- Do not leave the tool running unattended. Operate the tool only when hand-held.
- When drilling into walls, floors or wherever “live” electrical wires may be encountered. **DO NOT TOUCH ANY METAL PARTS OF THE TOOL!** Hold the tool by the insulated gripping surfaces to prevent electric shock if you drill into “live” wire.
- Do not touch the drill bit or the work piece immediately after operation; they may be extremely hot and could burn your skin.

Remember: **Safety starts with YOU!** You are responsible for your own safety as well as the people around you!

Self-Check No. 5.1.1-2

1. How to reduce the risk of fire, electric shock, and personal injury?

Answer Key No. 5.1.1-2

1. to reduce the risk of fire, electric shock, and personal injury, including the following:
 - Keep work area clean.
 - Don't use power tools in damp or wet locations.
 - Don't expose power tools to rain.
 - Don't use tool in presence of inflammable liquids or gases.
 - Keep children away.
 - Store unused tools.
 - Don't force tool.
 - Use correct tool.
 - Dress appropriately.
 - Use safety glasses, face or dust mask if necessary.
 - Don't abuse cord.
 - Secure work.
 - Don't over-reach.
 - Maintain tool with care.
 - Disconnect tools from the supply when not in use.
 - Remove adjusting keys and wrenches from machines before operation.
 - Don't carry plugged-in tool with **finger** on switch.
 - When tool is used outdoors, use only extension cord intended for use outdoor.
 - Watch what you are doing, use common **sense**.
 - Check for damaged parts before using any tools.
 - Guard against electric shock.
 - When servicing, use only identical replacement parts.

Information Sheet No. 5.1.1-3: Ergonomics and Workplace Injuries

Musculoskeletal disorders (MSD) are injuries or disorders of the muscles, nerves, tendons, joints, cartilage, and spinal discs. Work-related musculoskeletal disorders (WMSD) are conditions in which:

- The work environment and performance of work contribute significantly to the condition; and/or
- The condition is made worse or persists longer due to work conditions

Ergonomics is the science of fitting workplace conditions and job demands to the capability of the working population.¹ The goal of ergonomics is to reduce stress and eliminate injuries and disorders associated with the overuse of muscles, bad posture, and repeated tasks.

WMSD Risk factors include awkward postures, repetition, material handling, force, mechanical compression, vibration, temperature extremes, glare, inadequate lighting, and duration of exposure.

1. Awkward Posture

Awkward posture refers to positions of body while performing work activities that deviate significantly from the neutral position. Examples are twisting, bending, over-reaching, working with the hands above the head, elbows above the shoulders, neck or back bent more than 30° without support and lack of ability to vary posture.

2. Forceful and Sustained Exertions

Forceful exertion involves the use of high-level force while transporting or Supporting load, including “lifting, lowering, pushing, pulling, carrying and moving a load using hands or through the application of bodily force. Forceful exertion can also exist in sustained postures which place excessive force on joints and overload the muscles and tendons.

3. Repetitive Motion

Repetitive motion involves repeated movements of the same groups of joints and muscles too frequent, too quickly and over a long duration. A job is considered highly repetitive if the cycle time is 30 seconds or less. Tasks with repetitive movements usually involve other risk factors such as fixed body position and forced.

4. Static and Sustained Posture

This refers to minimal or restricted or no movement where the body held on to a particular position over a prolonged period. Examples are prolonged standing more than 2 hours and sitting more than 30 minutes. This can give rise to fatigue, pain and injuries which give rise to various disorders.

5. Vibration

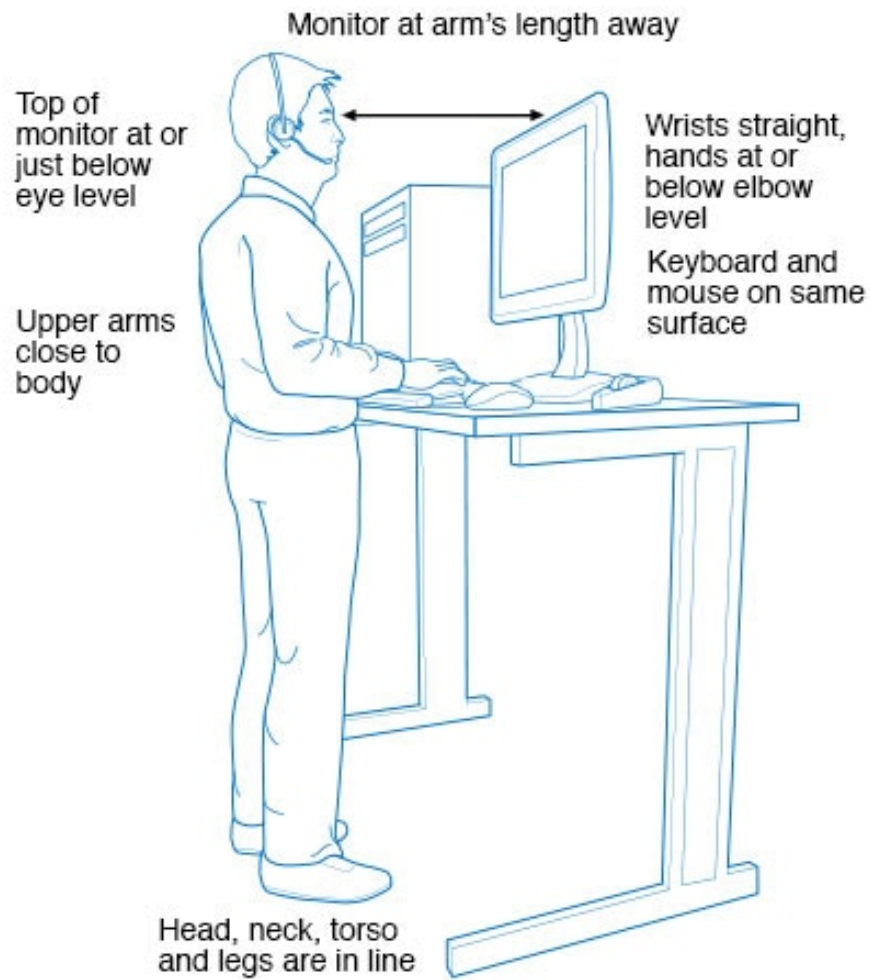
Vibration includes whole-body vibration (WBV) and hand-arm vibration (HAV). WBV refers to the kinetic energy which is mechanically transmitted through the seat or feet of people such as driving mobile machine, or other vehicles, over rough and uneven surfaces. HAV refers to the exposure of the hands and arm to kinetic energy from vibrating and percussive handheld power tools.

6. Contact Stress

Contact stress can be internal or external. Internal refers to a condition when a tendon, nerve, or blood vessel is stretched or bent around a bone or tendon. External contact stress refers to a condition when part of the body rubs against a component of the workstation, such as the chair seat pan or edge of the desk.

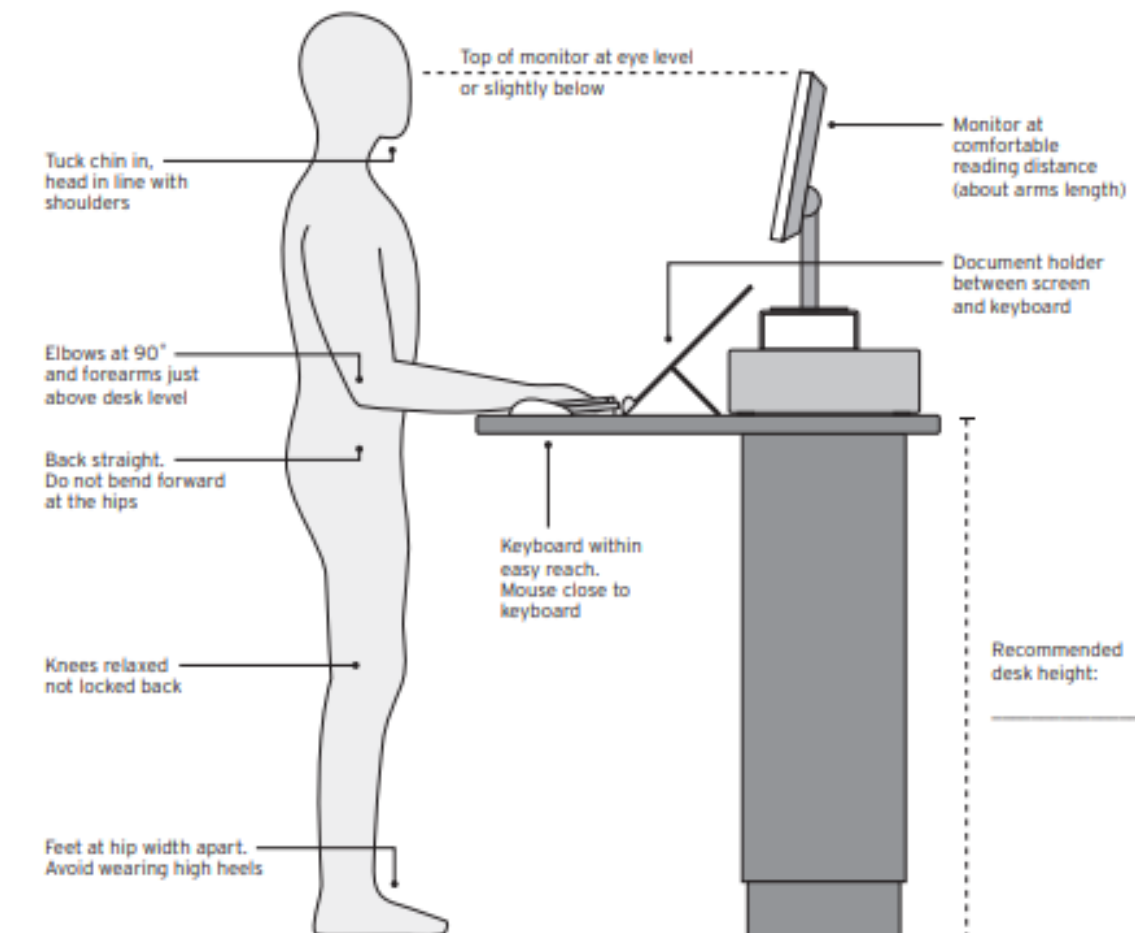
7. Ergonomic Guideline

Sit=standing guidelines



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Sit-Standing Workstation Guidelines



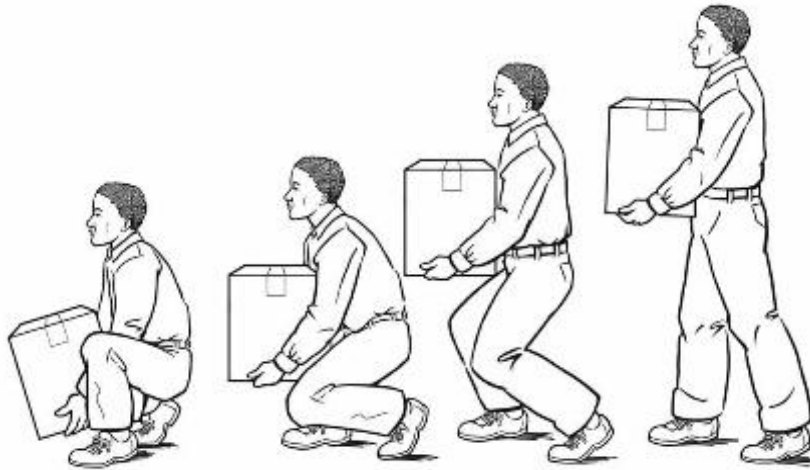
GUIDELINES

- Frequently vary your posture between sitting and standing during the day. Start with 10 - 15 minutes standing every few hours and gradually build up to a comfortable level. This could be 15, 30, 60 minutes or longer several times per day depending on your standing tolerance, whether you have an injury and your comfort levels when standing
- If you feel any discomfort when standing, sit down to rest your back and legs. Do not continue to stand with pain or discomfort
- Ensure you take regular pause breaks to stretch and vary your posture
- Avoid standing still in one position. Move around your workstation, walk to the printer, fill up your water bottle, shift your weight from leg to leg
- Practise good standing posture. Stand straight and do not bend forward at the hips
- Wear appropriate footwear and avoid high heels
- Position your chair in an appropriate place when not being used to avoid it becoming a trip hazard
- Apply principles of monitor, keyboard, mouse and document holder positioning as per seated workstation guidelines

Guidelines for Lifting, Lowering, and Carrying

- Reduce the weight of an object whenever possible by reducing the container size/capacity.
- Reduce the hand distance from the body by changing the shape of the container or providing grips or handles enabling the load to be held closer to the body.
- Use carts, hand trucks, etc. to convert load lifting to a push or pull task.
- Reduce the carrying distance by moving the storage area closer to production areas.

- Assess an item before lifting it. Get help if the item is too heavy, large, or awkward.
- Store heavy objects on shelves below shoulder height and no lower than knee-height.
- Store materials that are frequently used on shelving units that are located no higher than shoulder height.



Lifting a heavy object

To pick up the item, secure it firmly in your hands, keep the item close to the body, bend your knees, keeping your back in its natural arched position, and lift with your legs; leg muscles have more power than the smaller muscles in the back. The object to be lifted should be directly in front of you. Lift it straight up, using a smooth motion. Avoid asymmetric lifting (twisting while lifting).

Self-Check No. 5.1.1-3

1. What are WMSD Risk factors?
2. How to be lifting a heavy object?

Answer Key No. 5.1.1-3

1. WMSD Risk factors include awkward postures, repetition, material handling, force, mechanical compression, vibration, temperature extremes, glare, inadequate lighting, and duration of exposure.
2. To pick up the item, secure it firmly in your hands, keep the item close to the body, bend your knees, keeping your back in its natural arched position, and lift with your legs; leg muscles have more power than the smaller muscles in the back. The object to be lifted should be directly in front of you. Lift it straight up, using a smooth motion. Avoid asymmetric lifting (twisting while lifting).

Information Sheet No. 5.1.1-4: Occupational Diseases

In **India**, major **occupational diseases** are pneumoconiosis (including silicosis, bagassosis, anthracosis and byssinosis), asbestosis, other chronic lung **diseases**, musculoskeletal injuries, noise-induced hearing loss, pesticide poisoning and accidents.

1. Lung Diseases

Occupational lung diseases include asbestosis among asbestos miners and those who work with friable asbestos insulation, as well as black lung (coalworker's pneumoconiosis) among coal miners, silicosis among miners and quarrying and tunnel operators and byssinosis among workers in parts of the cotton textile industry.

Occupational asthma has a vast number of occupations at risk.

Bad indoor air quality may predispose for diseases in the lungs as well as in other parts of the body.

2. Skin Diseases

Occupational skin diseases and conditions are generally caused by chemicals and having wet hands for long periods while at work. Eczema is by far the most common, but urticaria, sunburn and skin cancer are also of concern.

Contact dermatitis due to irritation is inflammation of the skin which results from a contact with an irritant. It has been observed that this type of dermatitis does not require prior sensitization of the immune system. There have been studies to support that past or present atopic dermatitis is a risk factor for this type of dermatitis. Common irritants include detergents, acids, alkalies, oils, organic solvents and reducing agents.

Another occupational skin disease is Glove related hand urticaria. It has been reported as an occupational problem among the health care workers. This type of hand urticaria is believed to be caused by repeated wearing and removal of the gloves. The reaction is caused by the latex or the nitrile present in the gloves.

High-risk occupations include:

- Hairdressing
- Catering
- Healthcare
- Printing
- Metal machining
- Motor vehicle repair
- Construction

Self-Check No. 5.1.1-4

1. What are High-risk occupations?

Answer Key No. 5.1.1-4

1. High-risk occupations include:

- Hairdressing
- Catering
- Healthcare
- Printing
- Metal machining
- Motor vehicle repair
- Construction

Information Sheet No. 5.1.1-5: Risk Assessment

1. Risk Identification

The following categories of hazards should be considered:

- Physical (eg, fire, noise, ergonomics, heat, radiation, and manual handling).
- Mechanical (eg, moving parts, rotating parts)
- Electrical (eg, voltage, current, static charge, magnetic fields)
- Chemical (eg, flammables, toxics, corrosives, reactive materials)
- Biological (eg, blood-borne pathogens, virus)
- Others (eg, hazard peculiar to the industry)

Note: Bloodborne pathogens are infectious microorganisms in human blood that can cause disease in humans. These pathogens include, but are not limited to, hepatitis B (HBV), hepatitis C (HCV) and human immunodeficiency virus (HIV). Needlesticks and other sharps-related injuries may expose workers to bloodborne pathogens.

2. Risk Evaluation

Level	Severity	Description
5	Catastrophic	Fatality, fatal diseases or multiple major injuries.
4	Major	Serious injuries or life-threatening occupational disease (includes amputations, major fractures, multiple injuries, occupational cancer, acute poisoning).
3	Moderate	Injury requiring medical treatment or ill-health leading to disability (includes lacerations, burns, sprains, minor fractures, dermatitis, deafness, work-related upper limb disorders).
2	Minor	Injury or ill-health requiring first-aid only (includes minor cuts and bruises, irritation, ill-health with temporary discomfort).
1	Negligible	Not likely to cause injury or ill-health

Table 1: Guidelines for Severity rating.

Level	Likelihood	Description
1	Rare	Not expected to occur but still possible.
2	Remote	Not likely to occur under normal circumstances.
3	Occasional	Possible or known to occur.
4	Frequent	Common occurrence.
5	Almost Certain	Continual or repeating experience.

Table 2: Guidelines for Likelihood rating.

3. Risk Prioritization Number (RPN)

RPN was obtained by multiplying the "S" and "L" columns., ie, $RPN = S \times L$ Decimal numbers are acceptable.

4. Classification of Risk – Risk Matrix

Compare the RPN against the risk matrix given in Table below.

Additional risk controls must be implemented such that the hazards are no longer in the red zone (High risk) before work commences.

This should be implemented till:

- Risk control for the hazard in the yellow zone (“Medium risk”) are already as reasonably practicable; or
- The hazard is in the green zone (“Low risk”)

Likelihood Severity	Rare (1)	Remote (2)	Occasional (3)	Frequent (4)	Almost Certain (5)
Catastrophic (5)	5	10	15	20	25
Major (4)	4	8	12	16	20
Moderate (3)	3	6	9	12	15
Minor (2)	2	4	6	8	10
Negligible (1)	1	2	3	4	5

Table 3: Guidelines to Risk Classification Matrix

5. Risk Controls

Risk level	Risk Acceptability	Recommended Actions
Low Risk	Acceptable	<ul style="list-style-type: none"> • No additional risk control measures may be needed. • Frequent review and monitoring of hazards are required to ensure that the risk level assigned is accurate and does not increase over time.
Medium Risk	Tolerable	<ul style="list-style-type: none"> • A careful evaluation of the hazards should be carried out to ensure that the risk level is reduced to as low as reasonably practicable (ALARP) within a defined time period. • Interim risk control measures, such as administrative controls or PPE, may be implemented while longer term measures are being established. • Management attention is required.
High Risk	Not acceptable	<ul style="list-style-type: none"> • High Risk level must be reduced to at least Medium Risk before work commences. • There should not be any interim risk control measures. Risk control measures should not be overly dependent on PPE or appliances. • If practicable, the hazard should be eliminated before work commences. • Management review is required before work commences.

Table 4: Recommended actions for Risk Levels

6. Example of risk assessment checklist:

Risk Identification			Risk Evaluation					Risk Controls				
Ref	Sub Activity	Hazard	Possible Injury	Existing Risk	S	L	RPN	Additional Control(s)	S	L	RPN	Remarks

			/ Ill-health	Control								
Eg.	Cutting Copper Tube	Faulty tube cutter may injure user fingers.	Injury to user's finger.	No existing control	2	3	6	Visual inspection of tube cutter before using.	2	1	2	
1.	a) Drilling b) Replaced broken basin	Pointed & Sharp Object	Injury to user's finger	No existing control	3	2	6	a) Secured workpiece by vice b) Wear hand glove	3	1	3	
2.	Hammering wall plug	Pointed & Blunt Object	Injury to user's finger	No existing control	3	2	6	Use proper hammer size and type	3	1	3	
3.	Punching hole on gasket	Punching Object	Injury to user's finger	No existing control	3	2	6	Wear leather glove	3	1	3	
4.	Stored WH, plumbing accessories at high storage rack	Falling Object	Head or body injury	No existing control	4	2	8	Heavy and bulky object stored at low level	3	1	3	
5.	Repair WH	Fall from Height	Head or body injury	No existing control	4	2	8	a) Working in pair, one person supporting the ladder b) 3 point method	2	2	4	
6.	Pipes, Extension wire, Tile cutter on the floor	Tripping Object	Head or body injury	No existing control	4	3	12	a) Placed a warning sign b) Proper pipe storage	2	2	4	
7.	Fixing leaking pipe	Slippery Surface/ Object	Head or body injury	No existing control	4	3	12	Dry the floor before work commence	2	2	4	
8.	Thread cutting on threading m/c	Rotating Object	Hand injury	No existing control	3	3	9	Providing a cover to prevent hand touching rotating pipe	2	2	4	

9.	Using power handtool	Electrical Shock from Object	Electrocuted	Earthing of tools Installed RCCB	4	3	12	Used portable RCCB socket for power tool	3	1	3	
10.	Heating PVC pipe by hot air blower	Heat Producing Objects	Burn	No existing control	3	3	9	Check temperature setting of blowers	3	2	6	

Self-Check No. 5.1.1-5

1. Describe the guidelines for Severity rating.
2. Describe the Recommended actions for Risk Levels.

Answer Key No. 5.1.1-5

1. The guidelines for Severity rating described below:

Level	Severity	Description
5	Catastrophic	Fatality, fatal diseases or multiple major injuries.
4	Major	Serious injuries or life-threatening occupational disease (includes amputations, major fractures, multiple injuries, occupational cancer, acute poisoning).
3	Moderate	Injury requiring medical treatment or ill-health leading to disability (includes lacerations, burns, sprains, minor fractures, dermatitis, deafness, work-related upper limb disorders).
2	Minor	Injury or ill-health requiring first-aid only (includes minor cuts and bruises, irritation, ill-health with temporary discomfort).
1	Negligible	Not likely to cause injury or ill-health

2. The Recommended actions for Risk Levels described below:

Risk level	Risk Acceptability	Recommended Actions
Low Risk	Acceptable	<ul style="list-style-type: none"> No additional risk control measures may be needed. Frequent review and monitoring of hazards are required to ensure that the risk level assigned is accurate and does not increase over time.
Medium Risk	Tolerable	<ul style="list-style-type: none"> A careful evaluation of the hazards should be carried out to ensure that the risk level is reduced to as low as reasonably practicable (ALARP) within a defined time period. Interim risk control measures, such as administrative controls or PPE, may be implemented while longer term measures are being established. Management attention is required.
High Risk	Not acceptable	<ul style="list-style-type: none"> High Risk level must be reduced to at least Medium Risk before work commences. There should not be any interim risk control measures. Risk control measures should not be overly dependent on PPE or appliances. If practicable, the hazard should be eliminated before work commences. Management review is required before work commences.

L.O 02: Prepare Electrical Drawings of Electrical Installation / Equipment

Upon completion of this learning outcome, students or trainees will have the following competencies:

- Interpret electrical drawings and diagrams for electrical installation, systems, and equipment correctly.
- Electrical symbols for devices are correctly selected.
- Establish correct current/ load demands based on requirements.
- Establish size of main and sub-main protective device in accordance with requirements.
- Establish size of main and sub-main cables in accordance with requirements.
- Produce the electrical drawing and diagrams in accordance with specifications and relevant standards and code of practice.
- Update electrical drawings as required arising from changes or modifications in requirements in accordance with specifications and relevant standards and code of practice using CAD software.

Information Sheet No. 5.1.2-1: Type of Electrical Drawing

1. Generally

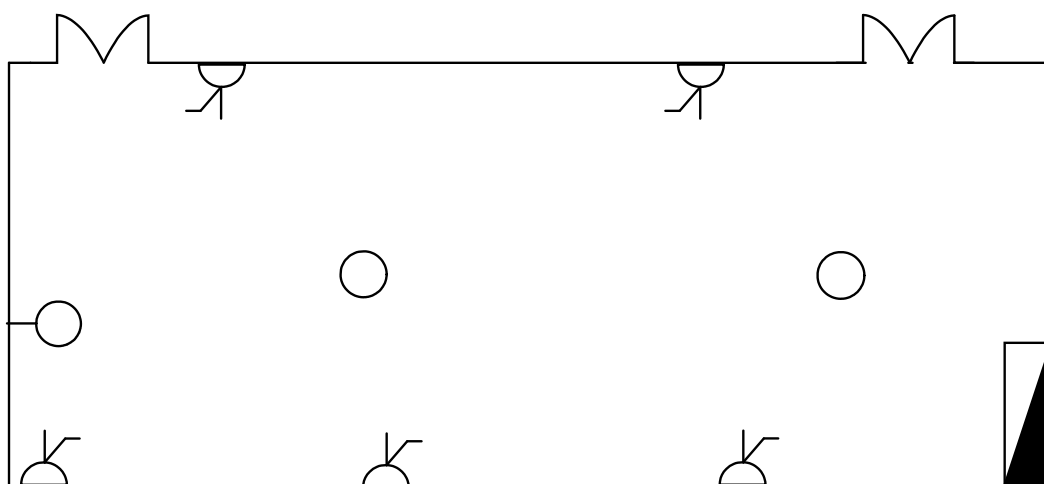
There are four types of electrical drawings:

- Layout Drawing
- Single line diagram
- Schematic diagram
- Wiring diagram

2. Layout Drawing

A layout drawing shows the

- plan of the building / room
- location of fans, lights, switches, and power points etc.
- wiring and circuitry of electrical apparatus
- standard symbols according to CP83 part 2



Level 1 Layout Drawing

Legend	Description
	Distribution Board
	13A Switch Socket Outlet
	Circular Light Fitting
	Wall Mounted Light Fitting

Figure 3-1 Example of a Layout Drawing

3. Single Line Diagram

A single line diagram is drawn upon completion of an electrical layout. A single line diagram show

- the details of the incoming power supply
- the grouping of lighting and power sub-circuits

- c. one line to represent each set of incoming and outgoing circuit

A single line diagram usually includes rating of consumers' switchgear, circuit breakers, kilowatt meter and cable sizes.

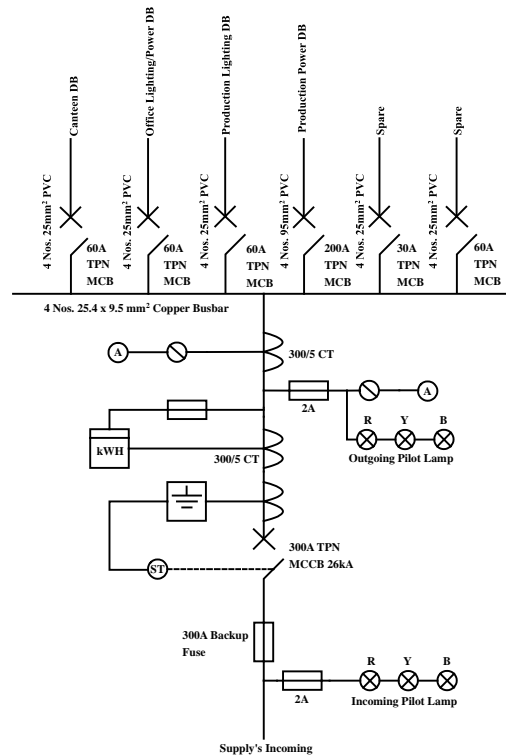


Figure 3-2 Example of a Single line diagram

4. Schematic Diagram

Sometimes is also called Circuit diagram. Schematic diagram shows the relationship between the control and the circuit. It shows the logical progression from the supply to the output.

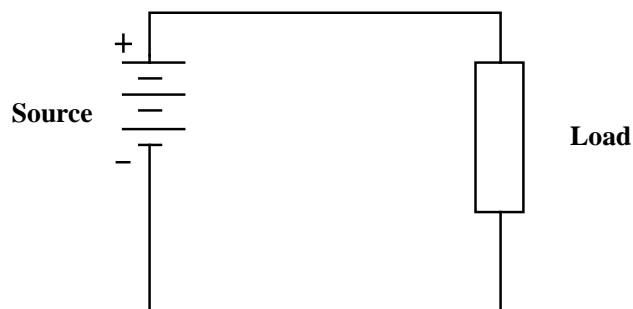


Figure 3-3 Example of a Schematic diagram

5. Wiring Diagram

Wiring diagrams shows the wiring and facilitates the checking of internal and external connections.

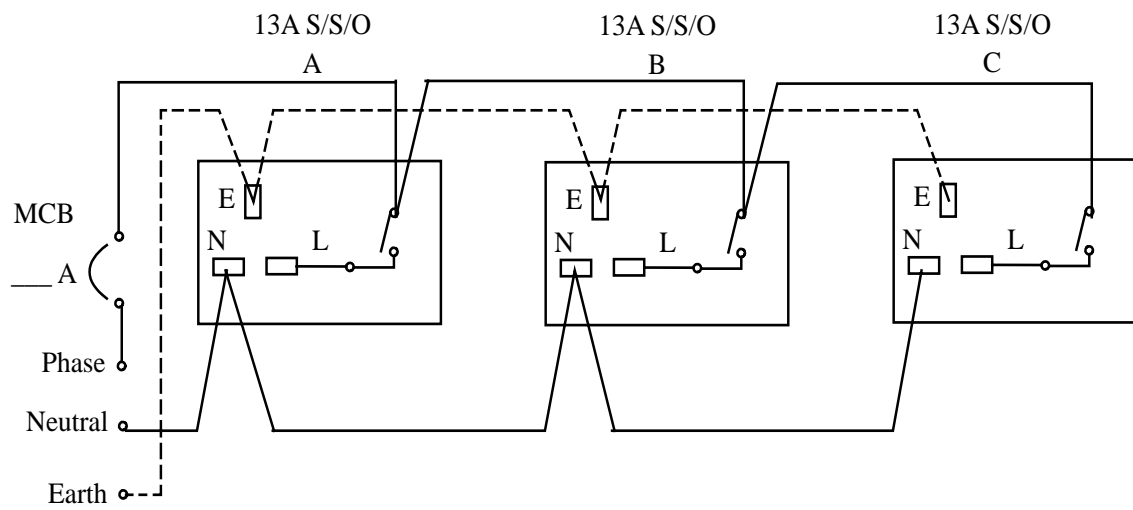


Figure 3-4 Example of a Wiring Diagram

Self-Check No. 5.1.2-1

1. How many types of electrical drawing?
2. What is single line diagram?
3. What is schematic diagram?
4. What is wiring diagram?

Answer Key No. 5.1.2-1

1. Generally, there are four types of electrical drawings.
2. A single line diagram is drawn upon completion of an electrical layout.
3. Schematic diagram shows the relationship between the control and the circuit. Sometimes is also called Circuit diagram.
4. Wiring diagram shows the wiring and facilitates the checking of internal and external connections.

Information Sheet No. 5.1.2-2: Introduction – Code of Practices in Electrical Drawing (refer to Singapore CP83 Part 2 or relevant local Code)

Before any electrical work can be carried out, one must check and ensure that the circuit design is correct. The only way to check is through reading the circuit single line diagram. In order to understand the single line diagram, one must know the graphical symbols. These graphical symbols are included in CP83 Part 2.

1. Common Electrical Symbols

This unit covers some commonly used electrical symbols. More electrical symbols can be found in CP83 Part 2 2000.

Section A3.2.1 shows the symbols of various types of lightings.

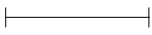


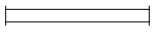
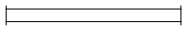


Section A3.2.2 shows the symbols of various types of lighting switches.

Section A3.2.4 shows the symbols of various types of power circuits.

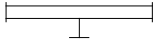
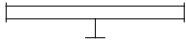




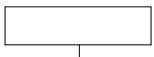



Section A3.2.6 shows the symbols of single line diagrams.

Please note that CP83 covers standard for CAD drawings, therefore it encompasses all other symbols used in building, architectural, mechanical and ventilation etc, therefore you may refer to CP83 if there are any symbols that you may see in the workplace and is not covered in this unit.



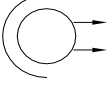
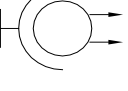

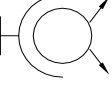




A.3.2.1 Lighting symbols

No.	Graphic image (2D representation)	Description of symbol
1.		Fluorescent fitting (18W–Batten)
2.		Fluorescent fitting (36W–Batten)
3.		Fluorescent fitting (58W–Batten)
4.		Fluorescent fitting (2 x 18W–Batten)
5.		Fluorescent fitting (2 x 36W–Batten)
6.		Fluorescent fitting (2 x 58W–Batten)
7.		Fluorescent fitting (18W–Wall Mounted batten)
8.		Fluorescent fitting (36W–Wall Mounted batten)
9.		Fluorescent fitting (58W–Wall mounted batten)
10.		Fluorescent fitting (2 x 18W–Wall mounted batten)











A.3.2.1 Lighting symbols

No.	Graphic image (2D representation)	Description of symbol
11.		Fluorescent fitting (2 x 36W Wall mounted batten)
12.		Fluorescent fitting (2 x 58W-Wall mounted batten)
13.		Fluorescent fitting (300 x 600)
14.		Fluorescent fitting (18W-Wall mounted)
15.		Fluorescent fitting (600 x 600)
16.		Fluorescent fitting (300 x 1200)
17.		Fluorescent fitting (18W-Batten)
18.		Fluorescent fitting (36W-Wall mounted)
19.		Circular light fitting
20.		Wall mounted light fitting










A.3.2.1 Lighting symbols

No.	Graphic image (2D representation)	Description of symbol
21.		Ceiling lighting point
22.		Wall lighting point
23.		Spot light
24.		Wall mounted spot light
25.		Flood light
26.		Wall mounted flood light
27.		Type of luminaire for a group (n—denotes type of light fitting)
28.		Emergency lighting
29.		Emergency lighting wall mounted
30.		Downlight











A.3.2.2 Lighting switches

No.	Graphic image (2D representation)	Description of symbol
1.		Single-pole lighting switch, 1-way (one gang)
2.		Single-pole lighting switch, 1-way (one gang, metalclad)
3.		Lighting switch, 2-way (one gang)
4.		Lighting switch, 2-way (one gang, metalclad)
5.		Intermediate lighting switch (one gang)
6.		Intermediate lighting switch (one gang, metalclad)
7.		Double-pole lighting switch, 1-way (one gang)
8.		Double pole lighting switch, 1-way (one gang, metalclad)
9.		Dimmer c/w switch
10.		20A double pole switch c/w neon indication lamp and marked "water heater"











A.3.2.2 Lighting switches symbols

No.	Graphic image (2D representation)	Description of symbol
11.		Waterproof lighting switch
12.		Splashproof lighting switch
13.		Flameproof lighting switch
14.		Lighting switch panel
15.		Dimmer switch panel (conventional type)
16.		Dimmer switch panel (digital type)
17.		Dimmer rack
18.		Three-pole lighting switch, 1-way (one gang)
19.		Three-pole lighting switch, 1-way (one gang)



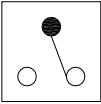







A.3.2.4 Power symbols

No.	Graphic image (2D representation)	Description of symbol
1.		Shaver unit
2.		13A fuse connection unit w/o switch
3.		13A connector unit
4.		Cooker control unit (rating as shown)
5.		15A connector unit
6.		Distribution Board (DB/DBF)/ Sub-Switchboard (SB/SBE)/ Lift Sub-Switchboard (LSBE)/ Lift distribution board (LDBE)
7.		Main Switchboard (MSB/EMSB)/ Generator control panel (GCP)
8.		13A switch socket outlet (one gang)
9.		13A switch socket outlet (one gang, metalclad)
10.		13A switch socket outlet (two gang)



A.3.2.4 Power symbols

No.	Graphic image (2D representation)	Description of symbol
11.		13A switch socket outlet (two gang, metalclad)
12.		13A weatherproof switch socket outlet
13.		15A switch socket outlet
14.		15A switch socket outlet (metalclad)
15.		13A switch socket outlet (floor mounted type)
16.		13A splashproof switch socket outlet
17.		13A switch socket outlet (mounted on floor pedestal)
18.		13A switch socket outlet (two gang) (mounted on floor pedestal)
19.		13A switch socket outlet (one gang, mounted at high level)
20.		13A switch socket outlet (one gang, metalclad, mounted at high level)

A.3.2.6 Single line diagram symbols

No.	Graphic image (2D representation)	Description of symbol
1.		Moulded case circuit breaker (MCCB)/ miniature circuit breaker (MCB) Rating as shown
2.		Residual current operated circuit breaker (RCCB) Rating and sensitivity as shown
3.		Automatic Transfer Switch Rating as shown
4.		Earth leakage relay c/w time lag
5.		IDMTL over-current protective relay with instantaneous hi-set element (without hi-set for HT feeder)
6.		IDMT earth fault relay with instantaneous hi-set element Definite time lag earth fault relay
7.		Pilot wire protection relay
8.		Maximum demand meter with alarm, ECT
9.		Kilowatt meter
10.		Kilowatt-hour meter

A.3.2.6 Single line diagram symbols

No.	Graphic image (2D representation)	Description of symbol
11.		Digital kilowatt-hour meter
12.	PG 	Kilowatt-hour meter (by Power Grid)

Self-Check No. 5.1.2-2

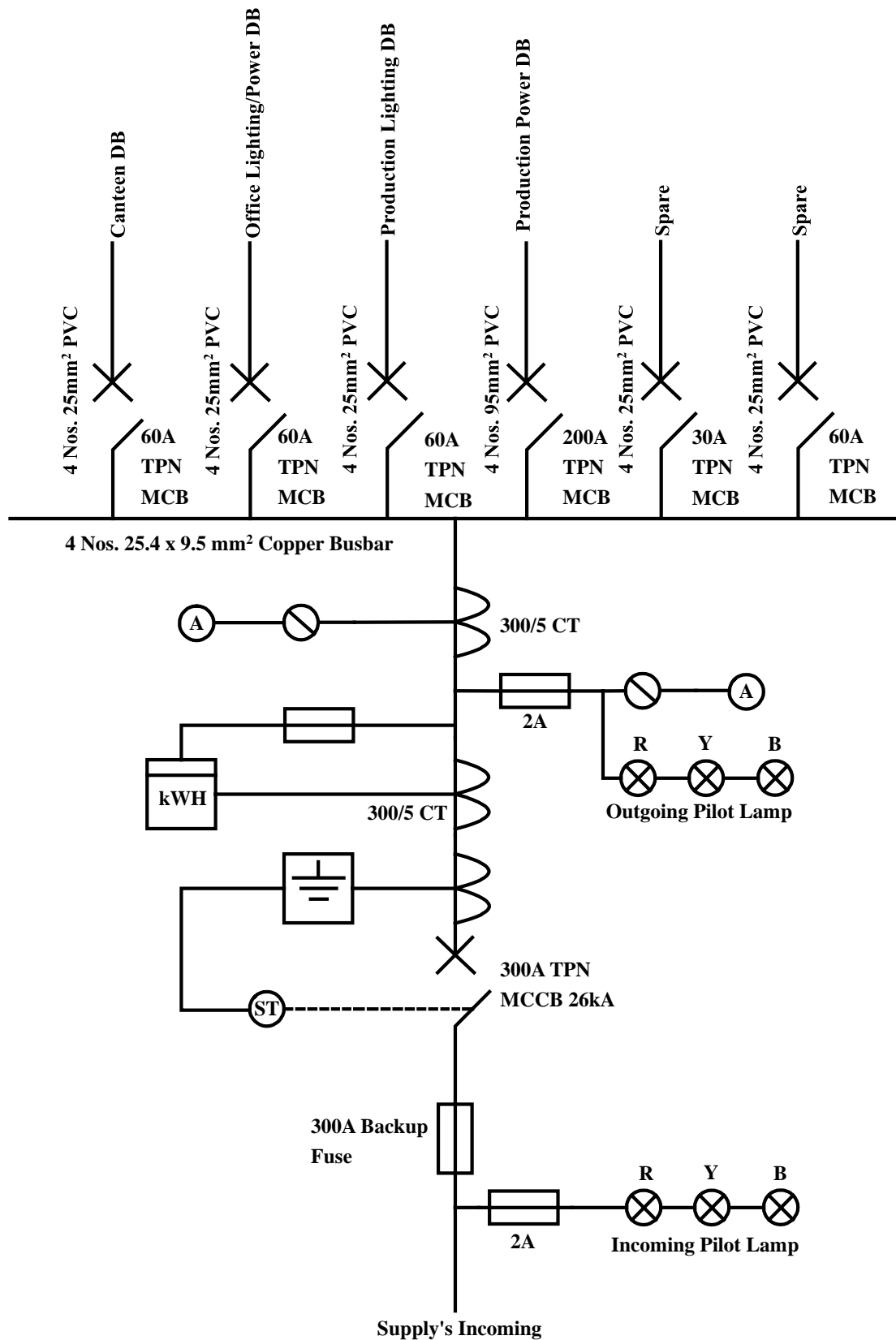
1. Draw the fluorescent fitting.
2. Draw the spot light.
3. Draw the Lighting switch, 2-way (one gang).
4. Draw the Distribution board.

Answer Key No. 4.1.2-2

1. The fluorescent fitting
2. The spot light
3. The Lighting switch, 2-way (one gang)
4. The Distribution boards

Information Sheet No. 5.1.2-3: Obtains the Cable Sizes and Capacity of Protective Devices from the Single Line Diagram (Refer to Figure shown below)

- Rating of the backup fuse: 300A
- Rating of the main MCCB: 300A TPN
- Breaking capacity of the main MCCB: 26kA
- Rating of the fuse for the pilot lamp circuit: 2A
- Type and size of the incoming cable: 4 x 150 mm² + CPC
- Size of the busbar: 4 x 25.4 x 9.5 mm copper
- Capacity of the MCCB of canteen DB: 30A TPN
- Size of the incoming cable to canteen DB: 4 x 25 mm² PVC

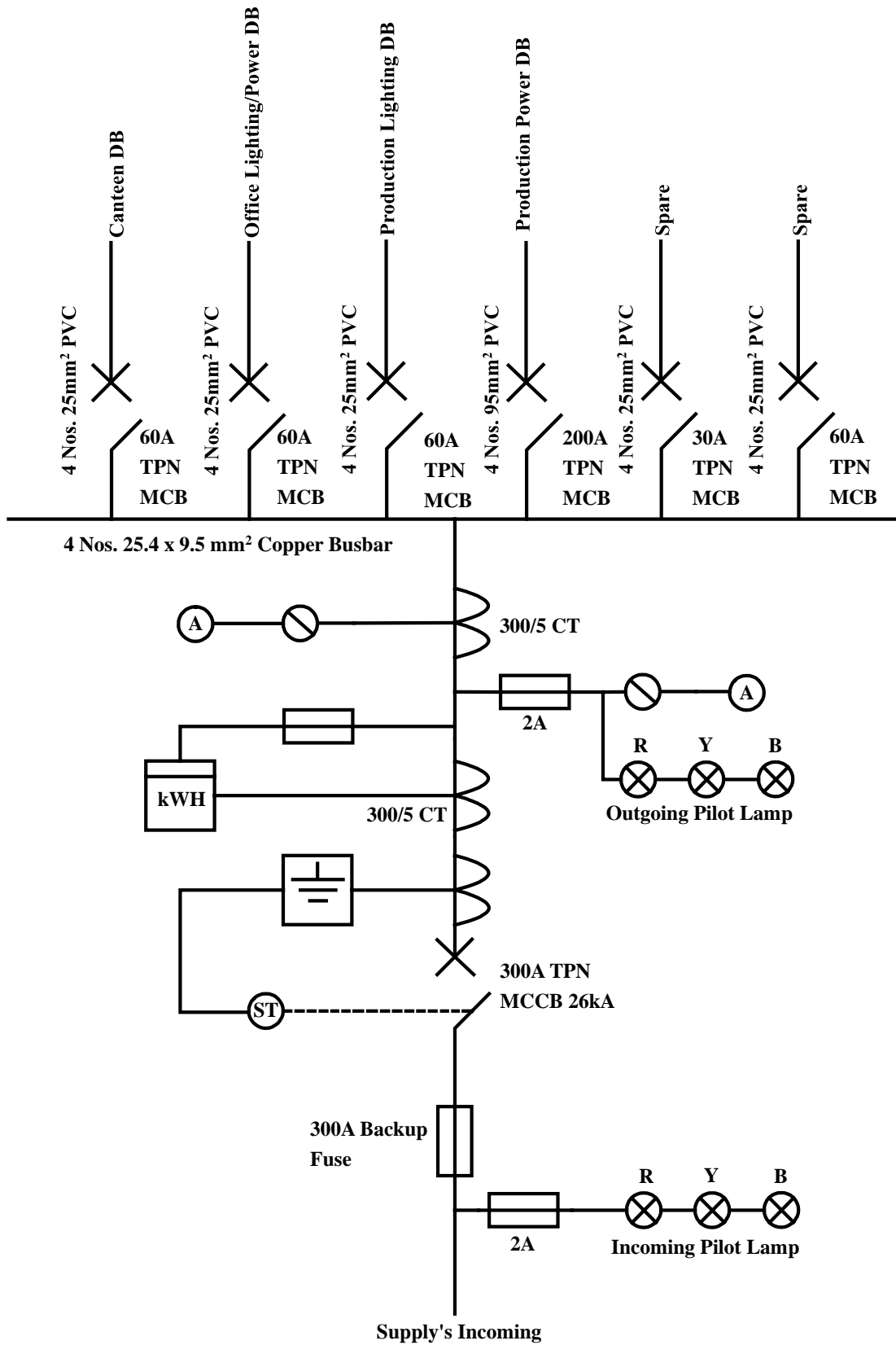


Self-Check No. 5.1.2-3

1. Please draw the single diagram of distribution board.

Answer Key No. 5.1.2-3

1.



TASK SHEET 5.1.2-1	
Title: Produce Electrical layout drawing of a residential premises	
Performance Objective/s:	
Supplies/Materials :	
Equipment :	
Steps/Procedure: <ol style="list-style-type: none"> Shows the electrical layout drawing of an apartment in fig 1B. create using AutoCAD, the electrical symbols for lighting point, wall mounted spotlight, switch socket outlet, single-pole switch, 2-way switch, 20A double pole c/w Neon light indicator lamp and marked “water heater” and insert them on apartment layout layer. Show clearly all the control switch/switches for each lighting point. Do not group more than two lights in one circuit. Complete the drawing on a Figure1B with the Electrical Symbols in AutoCAD. 	
Assessment Method: Demonstration with oral questioning	

Performance Criteria Checklist	YES	NO
Did you....		

Location	Items	Number of points to be inserted in each area
Living Room	Ceiling Lighting point	2
	Wall mounted spot light	2
	13A switch socket outlet (2 gang)	2
Dining Room	Wall mounted light fitting	2

	Ceiling lighting point	3
	13A switch socket outlet (2 gang)	3
Master Bedroom	Ceiling Lighting point	1
	Wall mounted spot light	2
	13A switch socket outlet (2 gang)	2
	15A switch socket outlet	1
Bedroom	Ceiling Lighting point	1
	13A switch socket outlet	2
Bathroom 1	Ceiling lighting point	1
	Water heater point	1
Bathroom 2	Ceiling lighting point	1
	Water heater point	1
Kitchen	Ceiling lighting point	1
	13A switch socket outlet	2
Yard	Ceiling lighting point	1
	Isolator	1
WC	Ceiling lighting point	1

TASK SHEET 5.1.2-2	
Title: Complete Single Line Drawing for a single phase and three phase circuits	
Performance Objective/s:	
Supplies/Materials :	
Equipment :	
Steps/Procedure: <ol style="list-style-type: none"> 1. Table 2 shows an incomplete table to determine the connected loads of an electrical installation of a residential unit 2. Given that the supply is a single phase 230V, 50HZ and the multiplying factor for discharging lighting is 1.8, complete Table 2 by showing your calculation for the connected loads and the total maximum demand 3. Determine the rating of the incoming main circuit breaker and RCCB. 4. Submit the completed table to the invigilator. 5. shows an uncompleted electrical single-line diagram in fig 2B 6. draw a single line drawing for a residential electrical installation based on the demand as shown in table 2. The following details must be included in the drawing (Rating of all excess current devices and RCCD, Cable sizes, Energy meter, Grouping of final circuits) 	
Assessment Method: Demonstration with oral questioning	

Performance Criteria Checklist		YES	NO
Did you....			

Load Distribution of a residential apartment

	Type of Load	Nominal Rating	Diversity Factor	Current Demand (Amp)
1	12 nos lampholders	100W	0.66	

2	4 nos 36W fluorescent luminaires	36W	0.66	
3	6 nos of 13A switched socket outlet	-	300W per outlet	
4	1 water heater	2000W	No diversity factor	
5	1 air conditioner	1500W	No diversity factor	
	Total Maximum Demand			

Table 2

Choice of protective devices as follows:

- SP MCB: 10A, 16A, 20A, 32, 63A
- DP MCB: 40A, 63, 80A

Incoming MCB rating selected = _____A

Conductor cross sectional area(mm ²)	2 cables Single phase (A)	3 or 4 cables Three phase (A)
1.5	17.5	15.5
2.5	24	21
4	32	28
6	41	36
10	57	50
16	76	68
25	101	89

Table 3: Cable size

Cable Size selected = _____Amp

Choice of earth protective device as follows:

- 2P RCCB: 40A (30mA); 63A (30mA); 100A (30mA)

RCCB rating selected = _____A

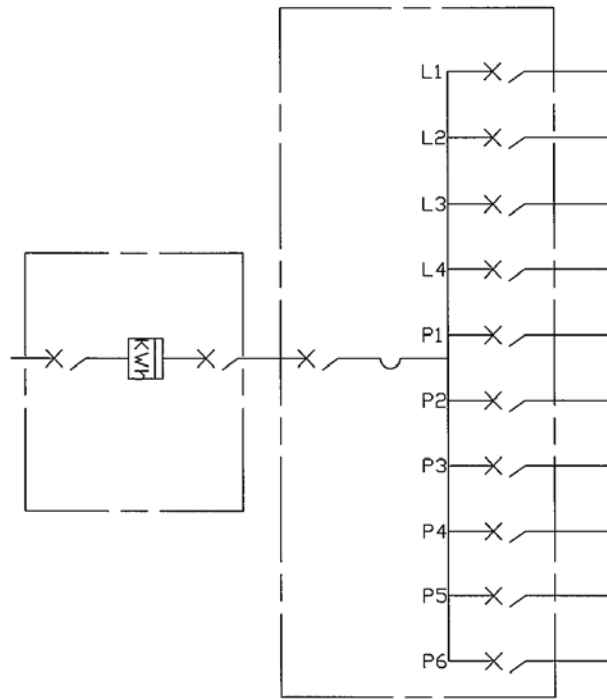


Figure 2B: Single Line Drawing

L.O 03: Install and Maintain Electrical Final Residential Circuits and Wiring Systems

Upon completion of this learning outcome, students or trainees will have the following competencies:

- Relevant codes of practices, regulations and standards are interpreted correctly.
- Interpret electrical drawings for electrical wiring in accordance with requirements and regulations.
- Draw detailed wiring diagram from layout drawing correctly.
- Locations of the electrical points and installation methods are identified and fixed according to layout plan.
- Equipment, protection devices and metering are connected in the correct sequence of control.
- Install lighting and power final circuits in accordance with electrical drawings and in compliance with relevant regulations and specifications.
- All items are securely fixed with no loose items.
- Appropriate inspections and tests are carried out in compliance with regulations and specifications.
- Test circuits for correct operation.
- Apply appropriate techniques and procedures to diagnose and rectify faults.
- Test results and description of actions taken are documented in accordance with requirements.
- Electrical installations are maintained in compliance with the NSC regulations and code of practice.
- Safety rules and precautions are observed and followed.

Information Sheet No. 5.1.3-1: Install Conduits and Trunking

1. Introduction

- 1.1 A wiring system is an assembly of parts used in an electric circuit; and consists of 5 parts:
- The conductor
 - The insulation
 - Wiring accessories
 - Mechanical protection
 - Earthing facilities
- 1.2 Wiring systems are named mainly in terms of the mechanical protection used. The various systems commonly used in the present days include:
- Metallic and non-metallic conduit
 - Metallic and non-metallic trunking
 - Ducting
 - Mineral-insulated metal-sheathed
 - All-insulated wiring
 - Bare conductor wiring

2. General Considerations in Choosing a Wiring System

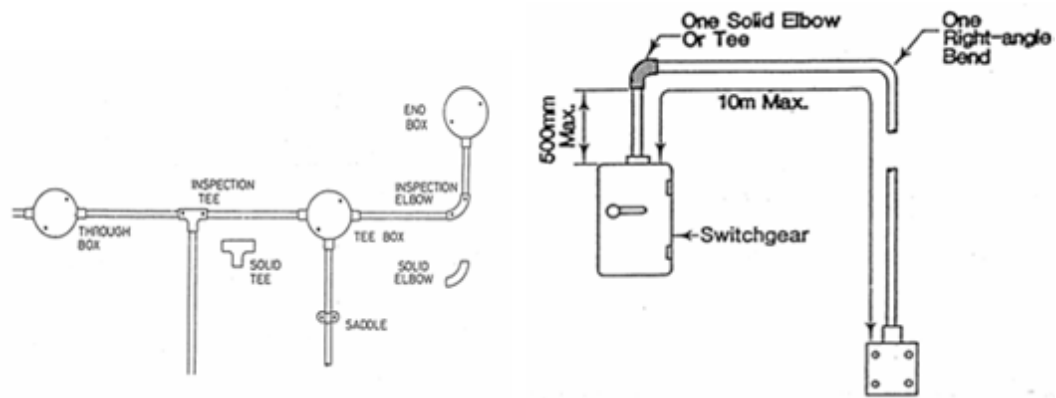
Before deciding on which wiring system to be used for an electrical installation, a number of points must be considered, such as:

- The type of building
- Flexibility
- Durability
- Cost
- Time
- Appearance
- Installation conditions
- Safety

3. Common wiring system used in building

3.1. Conduit system

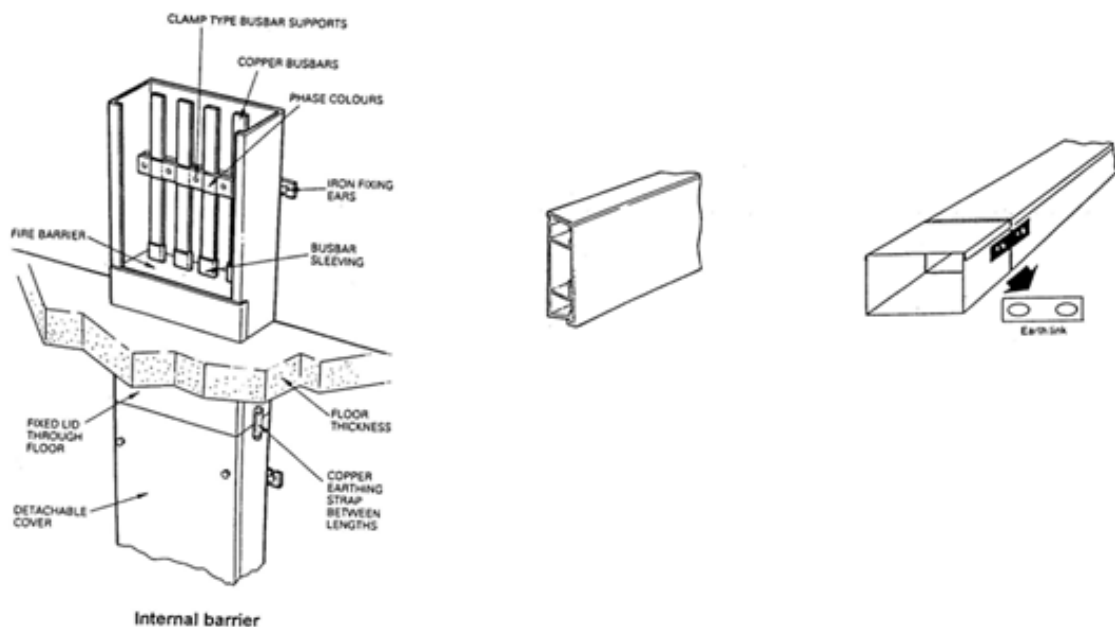
- These are metallic and non-metallic conduit system
- The system consists of conduits and boxes where cables are enclosed in it.
- Galvanised steel conduits form a major wiring method that requires great installation skill. The system consists of a series of threaded conduits with boxes for the various outlets. Cables are drawn through the conduits after erection.
- Outstanding features of steel conduit system are their sturdiness and rewirability so that obsolete cables can be replaced at any time. Conduits are indicated by external diameters.



Figure

3.2.Trunking system

- These are metallic and non-metallic trunking system.
- Trunking is used mainly in factories and commercial buildings. It consists of a channel of metal or plastic for carrying cables and has a removable cover throughout its length.
- Metallic trunking is made of zinc coated mild sheet steel. It comes in square or rectangular sections and is usually supplied in 2m length.



Figure

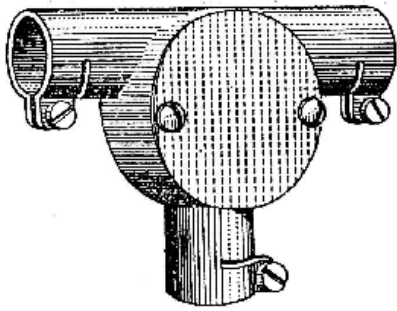
2. Classes of conduit

- Light gauge conduit (plain)
- Heavy gauge conduit (screwed)

3.1.Light gauge conduit

- Light gauge steel conduits (Class A), also called slip conduits because they are slipped into conduit fittings and not screwed.
- They are mainly used in homes with sheathed cables.

- They have thin walls and fittings are held on to the conduits by tightening the screws in the lugs; as shown in Figure 1.



- There are three types of light gauge conduits.
 1. Close joint – the tube is formed a strip of metal bent into shape with the edges (seam) butted together without mechanical joint.
 2. Brazed or welded joint – this is similar to close joint, but the seam is mechanically joined by brazing or welding.
 3. Seamless or solid-drawn – this is produced by cold drawing from the bar.

3.2. Heavy gauge conduit (screwed)

- Heavy gauge threaded steel conduits (Class B) are used mainly in blocks of flats, factories, stores, offices, and public buildings.
- There are two kinds of heavy gauge conduits:
 1. Welded joint – this is most commonly used and has an almost invisible welded seam running longitudinally along the conduit.
 2. Solid-drawn – this seamless conduit is employed in situation where the installation is required to be gas tight. It is also used for flameproof purposes such as when connection is made to petrol pump.

3. Standard sizes

3.1. Conduits are indicated by external diameters.

3.2. The common standard sizes are 15mm, 20mm, 25mm and 32mm.

4. Conduit Finishes

There are four different types of conduit finishes:

4.1. Black enamel – for general dry interior work.

4.2. Silver grey – for interior work where a good finish is required.

4.3. Hot galvanized finish – for areas where dampness and steam are present.

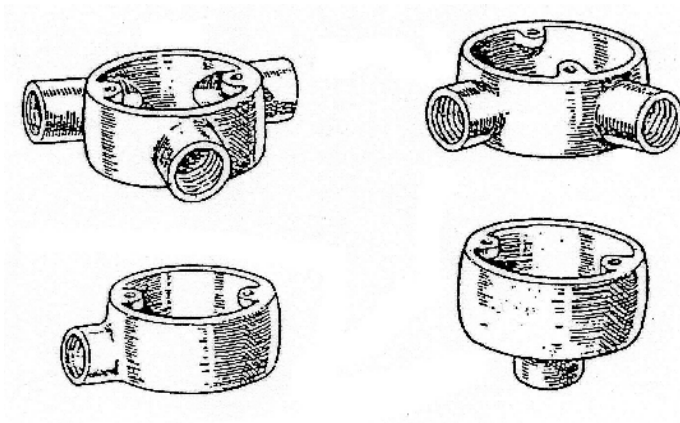
4.4. Sherardised – zinc impregnated; has good weatherproof quality and is used in outdoor works.

5. Boxes and Fittings

5.1. Boxes formed a major part of the conduit system.

5.2. They are fitted with inspection covers to enable drawing in and withdrawal of cables.

- 5.3. A great variety of boxes with alternative spout entries to meet differing job requirements are available.

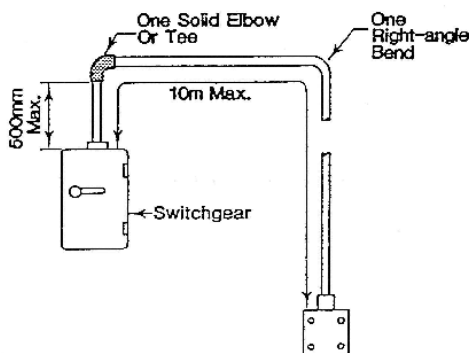


- 5.4. Box spouts are internally threaded to accept the screwed conduit. The versatility of these boxes is shown by their use in supporting ceiling roses, batten holder etc.

6. Requirements on installation of conduit system

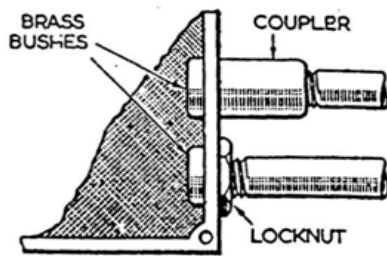
- 6.1. The use of solid elbows or tees is restricted to the following regulations.

- Located at the end of conduits immediately behind a luminaire, outlet box or conduit fitting of the inspection type.
- One solid elbow located at a position not more than 500mm from a readily accessible outlet box in a conduit run not exceeding 10m between two outlet points provided that all other bends in the conduit run are not more than the equivalent of one right angle as shown in Figure 6-3.



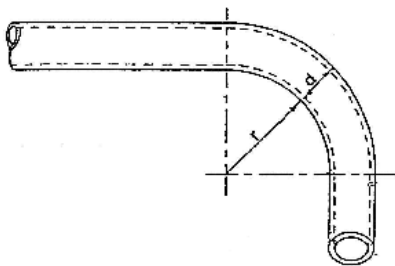
6.2. Termination of Conduit in Boxes

- Ends of lengths of conduit should be free from burrs, and where they terminate at boxes, trunking and accessories not fitted with spout entries, they should be treated so as to prevent damages to cables. (Code of practice regulations)
- Four types of accessories are used to terminate conduits at boxes.
- They are: -
 1. male brass bush
 2. female brass bush
 3. coupler
 4. locknut



6.3.Bends

- It is often necessary to bend or set the conduit to pass over an obstruction or to turn a corner. A good wireman makes very neat sets, either by means of a bending machine or by using a simple bending block.
- To minimise strain on the cables when wiring, bends should be made as easy as possible and in no case must the inner radius of the bend be less than 2.5 times the conduit outside diameter. (As complying with BS 4568 or BS 4607) i.e. $r = 2.5 \times \text{O.D. of conduit}$



6.4.Bunching (Code of practice regulations)

- All cables of an alternating current circuit must be contained in the same conduit.
- Otherwise the out-of-balance magnetic fields will cause eddy currents to be set up in the mass of steel conduit that in turn leads to the possibility of a heat rise in the protective tubing.

7. Wiring operation (code of practice requirement)

Conduit must be completely installed and firmly fixed before any cables are drawn in.

8. Flexible conduits

8.1.Flexible metal conduit is normally used in special situations such as: -

- An awkward short run under floor from main conduit to a lighting fitting.
- The connections between motor and starter.

8.2.It should not be used as a protective conductor.

9. Requirements on exemption of protection against indirect contact for certain parts of conduit wiring system

- 9.1. Metallic Conduit system should be connected to the earthing system to protect against indirect contact shock. Exemption is allowed on length of metallic conduit.
- 9.2. It is permissible to dispense with protective measures against indirect contact in the following instances:

- overhead line insulator brackets and metal parts connected to them if such parts are not situated within arm's reach.
- steel reinforced concrete poles in which the steel reinforcement is not accessible.
- exposed-conductive-parts which, owing to their reduced dimensions or their disposition cannot be gripped or cannot be contacted by a major surface of the human body, provided that connection of these parts to a protective conductor cannot readily be made or cannot be reliably maintained. This dispensation includes small isolated metal parts such as bolts, rivets, and nameplates not exceeding 50 mm x 50 mm and cable clips.
- fixing screws for non-metallic accessories provided that there is no appreciable risk of the screws coming into contact with live parts
- inaccessible lengths of metal conduit not exceeding 150mm
- metal enclosures mechanically protecting equipment complying with the Code of Practices (CP5 Clauses 413-03-01 to 413-03-09 and 471-09-01 or equivalent)
- unearthed street furniture supplied from an overhead line and inaccessible in normal use.

10. Non-metallic conduits

Non-metallic conduit system is similar to the metallic conduit system except that they are made of PVC. Non-metallic boxes for suspending luminaries. Maximum operating temperature not exceeding 60°C.

11. Constraints of metallic conduit (CP5: 1998, Clause 543-02-01 or equivalent)

Flexible conduit shall not be selected as a protective conductor. Neither a gas pipe nor an oil pipe shall be selected as a protective conductor.

12. Colour identification of electrical conduits

Where an electrical conduit is required to be distinguished from a pipeline or other service, orange shall be used as the basic identification colour in compliance with BS 1710.

Self-Check No. 5.1.3-1

1. What are the various systems commonly used in the present days?
2. What is the non-metallic conduits?

Answer Key No. 5.1.3-1

1. The various systems commonly used in the present days include:
 - Metallic and non-metallic conduit
 - Metallic and non-metallic trunking
 - Ducting
 - Mineral-insulated metal-sheathed
 - All-insulated wiring
 - Bare conductor wiring
2. Non-metallic conduit system is similar to the metallic conduit system except that they are made of PVC.

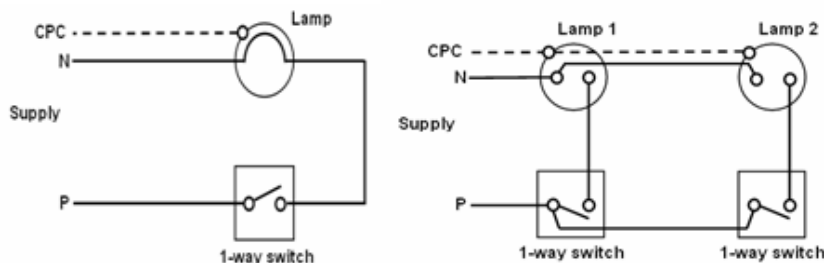
Information Sheet No. 5.1.3-2: Install lighting circuit

1. Types of Switches and Lighting Control Layout

Switches are designed for opening or closing electrical circuits. The common types of switches are:

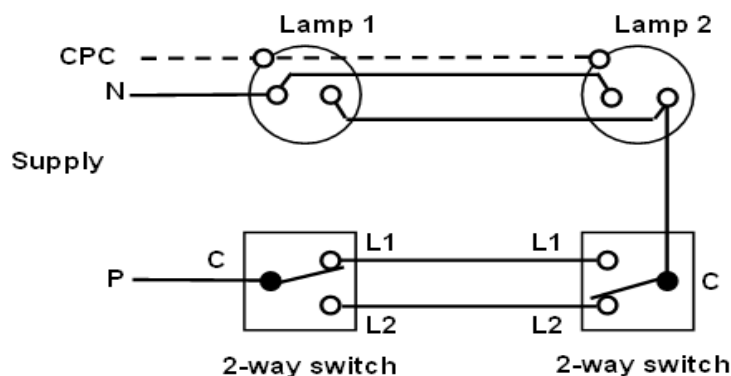
1.1 Single-Pole One-Way Switch

This type of switch is used to control the lighting points from only one position. It will break or close only one phase of the supply. All single-pole switches must be connected to the phase or positive conductor of the circuit.



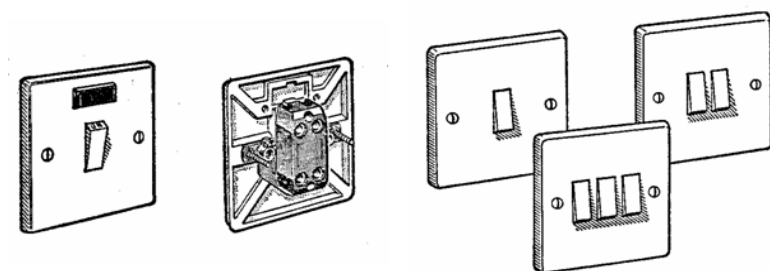
1.2 Single-Pole Two-Way Switch

The control of a light from one point is not always convenient, e.g., balcony or corridor lights. Two-point control is normally required and is obtained by the use of two-way switch.



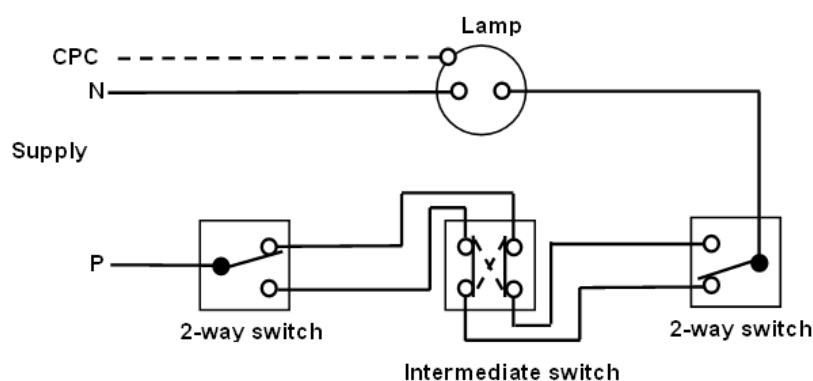
1.3 Double-Pole One-Way Switch

If both the phase and neutral conductors are to open or close at the same time, double-pole one-way switch is used. This type of switch is normally used as isolating switch for heating circuits.



1.4 Intermediate Switch

Control of a light or a number of lights from three or more separate positions is made possible by the use of one or more intermediate switches in addition to two two-way switches.



2. Common rating of switches (Voltage – 230V)

Descriptions	Descriptions
Plate switches 6 AMP	Plate switches 10 AMP
1 gang Two-way SP	1 gang Two-way SP
1 gang One-way SP	1 gang One-way SP
2 gang One-way SP	3 gang One-way SP
3 gang One-way SP	
2 gang Two-way SP	
Intermediate	
1 gang Push switch	
Switch Socket outlets	Ratings
1 gang SP	13 AMP
1 gang DP	13 AMP
2 gang SP	13 AMP
1 gang SP with pilot lamp	13 AMP
Cooker Control Units	Ratings
Main switch DP	45 AMP

An accessory is a device, other than current-using equipment, associated with such equipment or with the wiring of an installation.

In lighting circuits, the accessories commonly used are switches, lamp holders and ceiling roses.

This clause shall be applied in any installation related to lighting circuits on protection against indirect contact.

The clause covers areas such as the following whereby some are not accessible owing to one reason or two:

- Insulation of overhead line brackets and metal parts.
- Steel reinforced concrete poles.
- Exposed conductive parts.
- Fixing screws into non conductive parts.

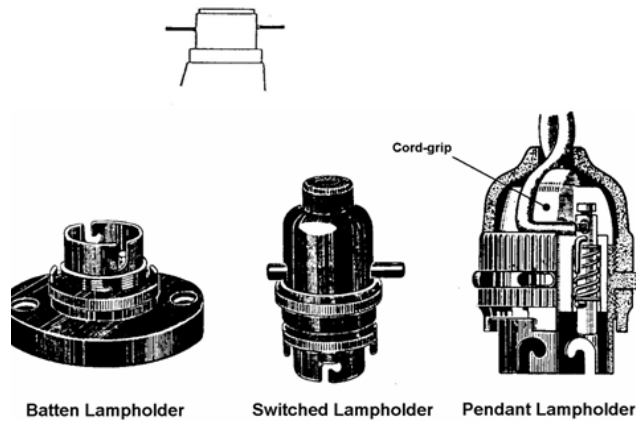
- Inaccessible metal conduits that exceed 150mm.
- Metal enclosures.

3. Lamp Holder

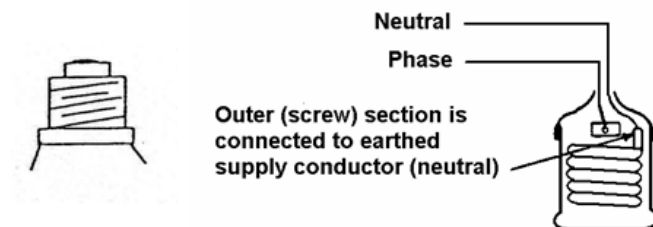
Lamp holders are designed for quick removal and replacement of the lamps. They must hold the lamps in firm metallic contact to prevent overheating.

There are THREE main sizes of lamp holders for filament lamps:

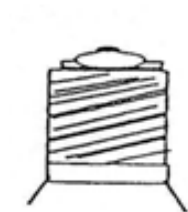
- Bayonet-cap (BC)



- Edison Screw (ES)



- Goliath Edison Screw (GES)



- Other variations include small bayonet-cap and small Edison screw for candle and fairy lamps.
- For ordinary tungsten filament lamps up to 150W the lamp caps are Bayonet-cap type; up to 200W the caps are Edison screw and above 200W they are normally Goliath Edison screw.
- Lamp holders may be either the insulated type of bakelite or the brass type with porcelain interior.

Common rating of filament lamp

Descriptions	Watts	Voltage
Bayonet cap (BC)	40	230
Bayonet cap (BC)	60	230
Bayonet cap (BC)	100	230
Bayonet cap (BC)	150	230
Edison Screw (ES)	40	230
Edison Screw (ES)	60	230
Edison Screw (ES)	100	230

4. Other regulations

Other than Clause 471-13-04 above on protection against indirect contact of lighting circuits in domestic premises, Clause 471-08-01 also states that all lighting circuits should be protected by automatic disconnection devices such as one or more residual device having a rated residual operating current not exceeding 30mA.

Clause 553-03 on lamp holders

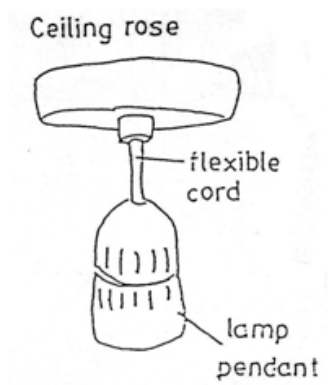
- Lamp holders should not be connected to any circuit where the rated current of the overcurrent protective device (OPD) exceeds the appropriate value stated in Table 55B(L).
 - BC – 16A maximum.
 - ES – 16A maximum.
 - GS – 16A maximum.

Type of lamp holder			Maximum rating of OPD
BC. (SS 125)	B15	SBC	6A
	B22	BC	16A
EC. (SS 126)	E14	SES	16A
	E27	ES	16A
	E40	GES	16A

- Lamp holders for filament lamps should normally be used only on circuits operating at a voltage not more than 250V.
- The outer contact of Edison screw holders should be connected to the neutral conductor.

Clause 553-04-01L to 553-04-04 Ceiling Roses

- Ceiling rose is an accessory fitted with terminals and is mainly used for connecting lamp pendants.
- It should not be installed in any circuit operating at a voltage exceeding 250V.
- Unless specially designed for multiple pendants, a ceiling rose should not be used for the attachment of more than one outgoing flexible cord.



5. Dimmer system

Dimmers are devices used to vary the brightness of lights. By increasing or decreasing the voltage, the output brightness of a light will vary.

Small domestic dimmers are generally directly controlled, although remote control systems are available. Modern professional dimmers are generally controlled by a digital control system.

There are three main types of dimmers. They are:

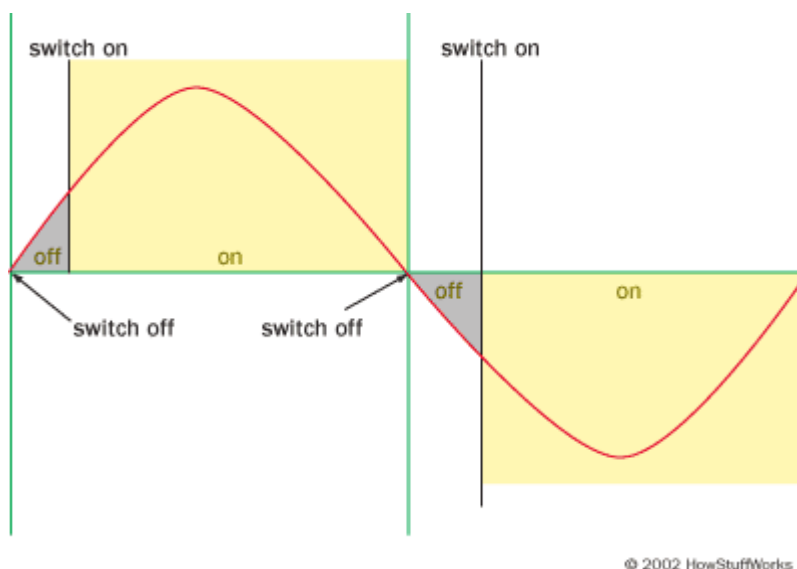
- Rheostats
- Variable autotransformer
- Thyristor (Electronic controlled)

5.1 Rheostats type

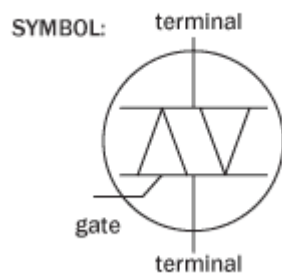
The Rheostats type used a **variable resistor** to adjusting light levels. The resistor consumed energy and caused voltage drop, hence decreased voltage across the light bulb and reduces its light output.

5.2 Triac type

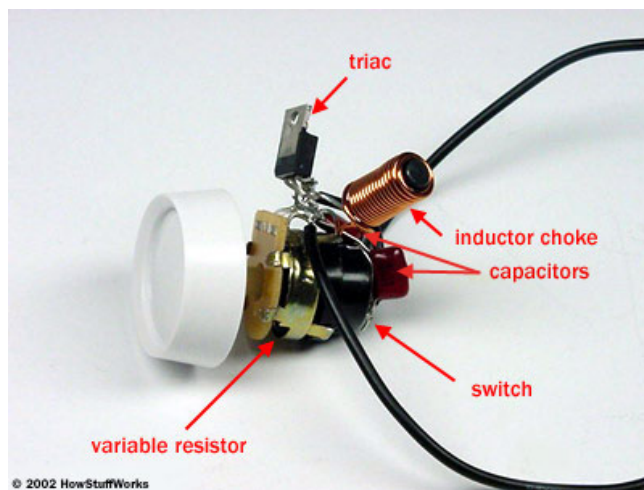
Modern dimmer switches take a more efficient approach. It used a Triac instead of diverting energy from the light bulb into a resistor. modern resistors rapidly shut the light circuit off and on to reduce the total amount of energy flowing through the circuit. It switched off the light bulb circuit many times every second. For a 50Hz AC supply, it happens 100 times a second, when there is zero voltage running through the circuit. It turns the light circuit back on when the voltage climbs back up to a certain level.



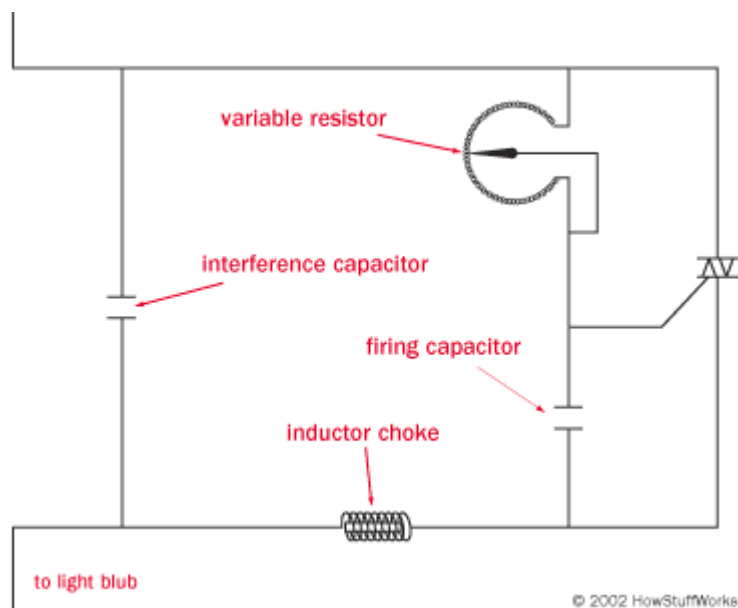
The **triode alternating current switch**, or **triac**, is a small semiconductor device
 Symbol of a triac:



Part of a Triac dimmer switch:



Triac dimmer switch connection circuit:



- The triac acts as a voltage-driven switch.
- The voltage on the gate controls the switching action.
- The variable resistor controls the voltage on the gate.
- A strange buzzing noise may be generated in a triac dimmer switch.

This comes from vibrations in the bulb filament caused by the chopped-up current coming from the triac.

5.3 Autotransformer type

Some high-end dimmer switches, such as the ones commonly used in stage lighting, are built around an **autotransformer** instead of a triac. The autotransformer dims the lights by **stepping down** the voltage flowing to the light circuit. A movable tap on the autotransformer adjusts the step-down action to dim the lights to different levels. Since it doesn't chop up the AC current, this method doesn't cause the same buzzing as a triac switch.

There are a lot of other dimmer switch varieties out there, including **touchpad** dimmers and **photoelectric** dimmers, which monitor the total light level in a room and adjust the dimmer accordingly. Most of these are built around the same simple idea -- chopping up AC current to reduce the total energy powering a light bulb.

Self-Check No. 5.1.3-2

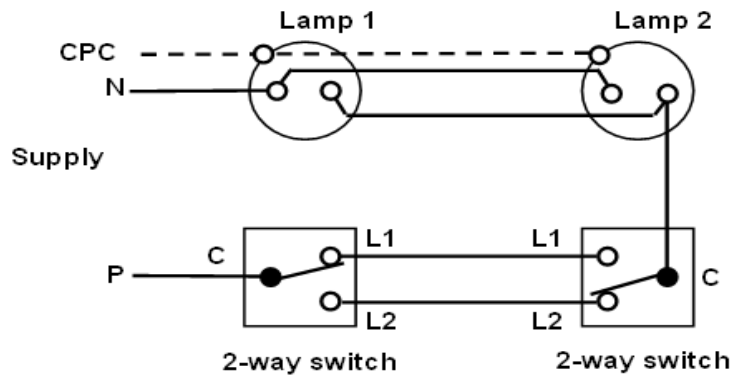
1. How many types of switches and lighting control layout? Describe.
2. Please draw the single-pole two-way switch layout.
3. How many types of dimmers? Describe.

Answer Key No. 5.1.3-2

1. Types of switches and lighting control layout have 4:

- Single-Pole One-Way Switch
- Single-Pole Two-Way Switch
- Double-Pole One-Way Switch
- Intermediate Switch

2.



3. There are three main types of dimmers. They are:

- Rheostats
- Variable autotransformer
- Thyristor (Electronic controlled)

1. Protection Against Indirect Contact – Local Requirement

All socket outlet and lighting circuits in the household should be protected by one or more residual current device having a rated residual operating current not exceeding 30mA.

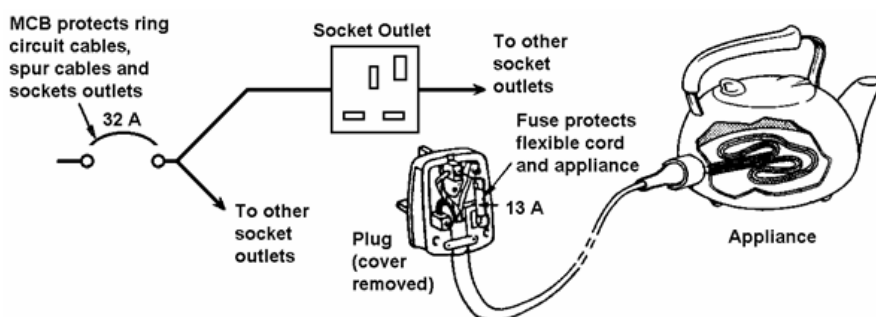
2. Standard Circuit Arrangements

The standard circuit arrangements, as recommended in the Regulation are:

- Final circuits using socket outlets complying with SS 145 or equivalent. (This consists of ring or radial circuits using 13A switched socket outlets)
- Final circuits using socket outlets complying with BS 546.
- Final radial circuits using socket outlets complying with IEC 309-2 or BS 4343.
- Cooker final circuits in household premises.

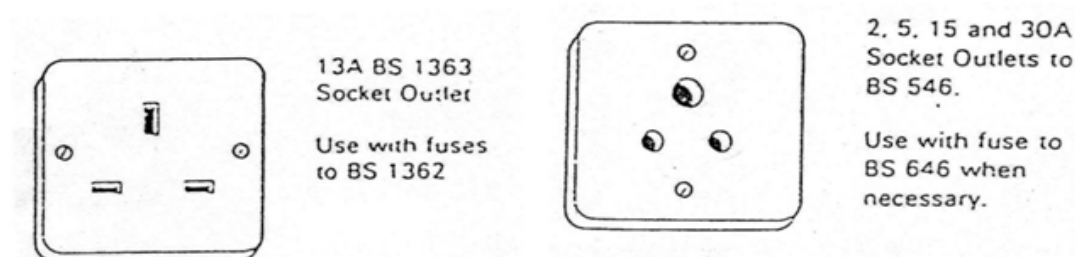
3. Definition of Terms

- Power point - A termination of the fixed wiring intended for the connection of power point.
- Plug - A device, provided with contact pins, which is intended to be with a socket outlet or with a connector.
- Socket outlet - A device, provided with female contacts, which is intended to be installed with the fixed wiring, and intended to receive a plug.



4. Socket Outlet and Plug

- Socket outlets and plugs are designed to enable portable apparatus to be connected to the final circuits.
- The socket outlet is the fixed portion connected to the fixed wiring and comprises two or more terminals.
- The plug is the movable part connected to the apparatus by flexible wire and comprises two or more contact pins to fit into the contact terminals of the socket outlet.
- They are made in many varieties, rating from 2A to 125A.



The following types of plugs and socket outlets, from the Code of Practice, are recognised as being suitable for electrical installations for low voltage circuits.

Plugs and socket outlets for low voltage circuits

Type of plug and socket outlet	Rating (amperes)	Applicable Standard
Fused plugs and shuttered socket outlets, 2-pole and earth, for a.c.	13	SS 145 (fuses to SS 167)
Plugs, fused or non-fused, and socket outlets, 2-pole and earth	2,5,15,30	BS 546 (fuses, if any, to BS 646)
Plugs, fused or non-fused, and socket outlets, protected type, 2-pole with earthing contact	5,15,30	BS 196
Plugs and socket outlets (theatre type)	15	BS 5550, Subsection 7.3.1
Plugs and socket outlets (industrial type)	16,32,63,125	BS 4343

These plugs and socket outlets are designed so that it is not possible to engage any pin of the plug into a live contact of a socket outlet. Whilst any other pin of the plug is exposed (not a requirement for ELV circuits), and the plugs are not capable of being inserted into socket outlets of systems other than its own.

Where a plug containing a fuse is required, they must be non-reversible and arranged so that the fuse cannot be connected in the neutral conductor.

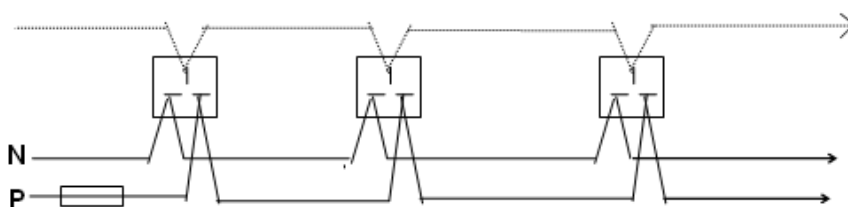
Where socket outlets are mounted vertically, they should be fixed to a height above floor level or working surface so that the plug and associated flexible cord is not subjected to mechanical damage during insertion or withdrawal of the plug.

It is recommended that the minimum mounting height of a socket outlet on a wall is 150mm from the floor level or working surface.

Plugs and socket outlets other than those shown in the CP may also be used on single phase AC or 2-wire DC circuits operating at voltages not exceeding 250V for the connection of:

- Electric clocks – use clock connecting unit incorporating a fuse not exceeding 3A.
- Electric shavers - provided that the socket outlets are either incorporated in a shaver supply unit complying with BS 3052 or, in rooms other than that of bathrooms, are a type complying with BS 4573.

5. Requirements for radial final circuit under SS 145 or equivalent



20A fuse or MCB protection with 2.5 mm² PVC or 1.5 mm² MI cables feeding a floor area of not more than 50 m².

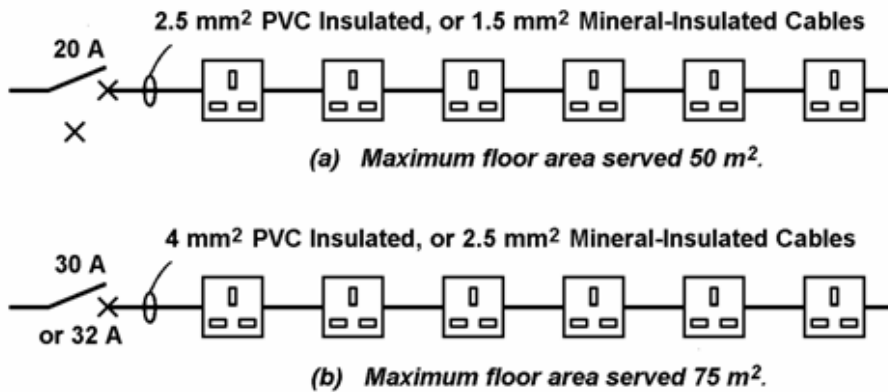
32 A fuse or MCB feeding through 4.0 mm² PVC or 2.5 mm² MI cables to supply a floor area no greater than 75 mm².

Number of socket-outlets depends on loading of circuit. If the circuit feeds a kitchen or utility room, it must be remembered that high current using equipment such as a washing machine or a tumbler dryer leaves little capacity for the rest of the sockets. Consideration should be given to the provision of a separate circuit.

The maximum demand of connected current-using equipment must not exceed the rating of the overcurrent protective device, i.e. 20A or 32A.

It may feed permanently connected equipment.

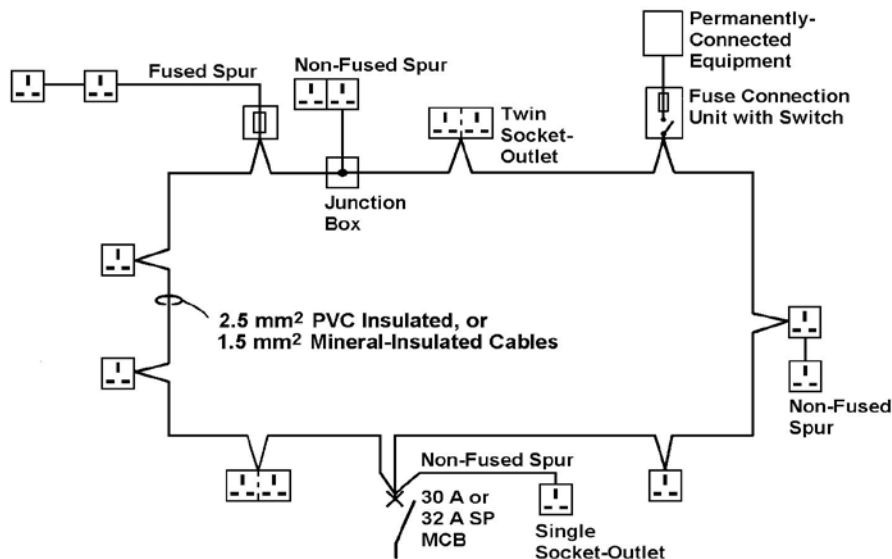
Each socket outlet of a twin or multiple socket outlet is regarded as one socket outlet.



The floor area served by the circuit is determined by the known or estimated load but should not exceed the above values.

6. Requirements for ring final circuit under SS145 or equivalent

- The floor area served by each ring must not exceed 100m² for domestic situations.
- Where ring circuits are used in commercial or industry buildings, the diversity must be assessed to ensure that the maximum demand will not exceed the rating of the protective device.
- Consideration should be given to the provision of a separate ring (or radial) circuit in a kitchen.
- Where there is more than one ring circuit in the same building, the installed sockets should be shared approximately evenly between them.
- Cable sizes for ring circuits are 2.5mm² PVC or 1.5mm² mineral insulated (MI) cables.
- Permanently connected equipment and an unlimited number of socket outlets, inclusive of spurs if any, can be fed.
- The maximum demand of connected current-using equipment must not exceed the rating of the overcurrent protective device.
- Every twin socket outlet counts as single socket outlets.



Maximum floor area served 100 m².

Type of circuit	Rating A	Overcurrent Protective device Type	Minimum conductor size mm ²			Max. Floor area served in mm ²
			Copper, PVC or Rubber	Copper claded aluminium PVC insulated	MICC	
A1 Ring	30 / 32	Any	2.5	NA	1.5	100
A2 Radial	30/ 32	Cartridge fuse or CB	4	NA	2.5	75
A2 Radial	20	Any	2.5	NA	1.5	50

7. Spur

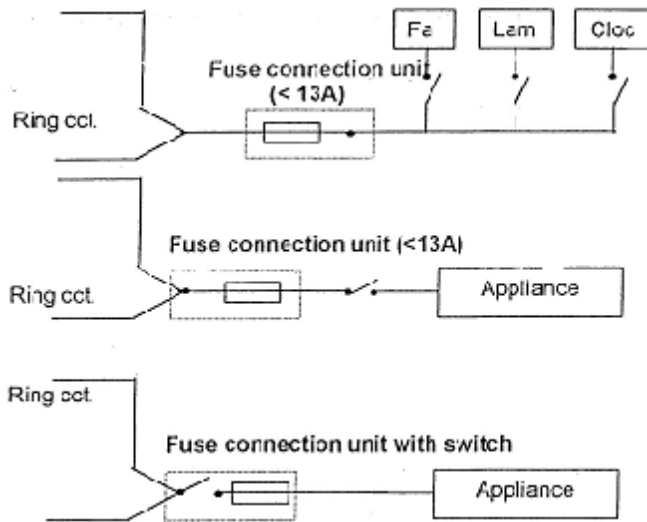
- It is a branch cable connected to a ring or radial circuit.
- Spurs can be fused or non-fused:

7.1 Fused Spur

A fused spur is connected to the circuit through a fused connection unit. The rating of the fuse should not exceed that of the cable forming the spur, should not exceed 13A. The minimum size of the conductor used for a fused spur is:

- 1.5mm² for rubber or PVC insulated copper cables.
- 1.0mm² for mineral insulated copper cables.

The total number of fused spurs is unlimited.

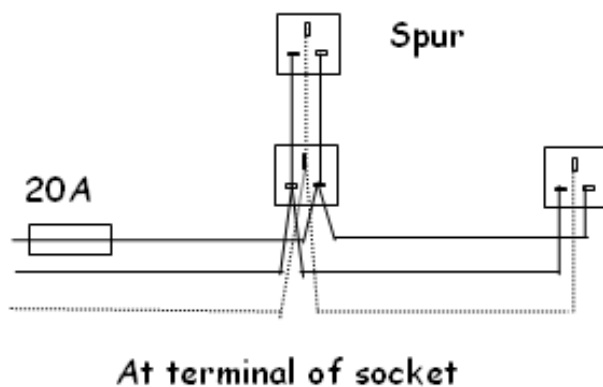


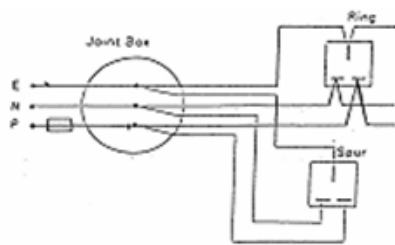
7.2 Non-fused spur

The 3 methods of connecting non-fused spurs to a circuit are:

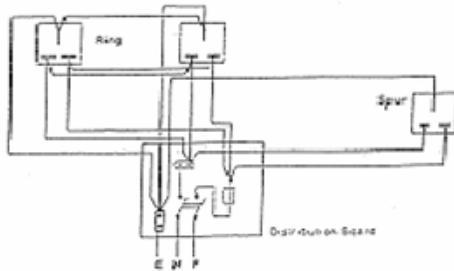
- (i) At the terminal of socket outlet.
- (ii) At joint boxes.
- (iii) At the origin of the circuit in the distribution board.

Non-fused spur may supply only one single or one twin socket outlet or one permanently connected equipment.





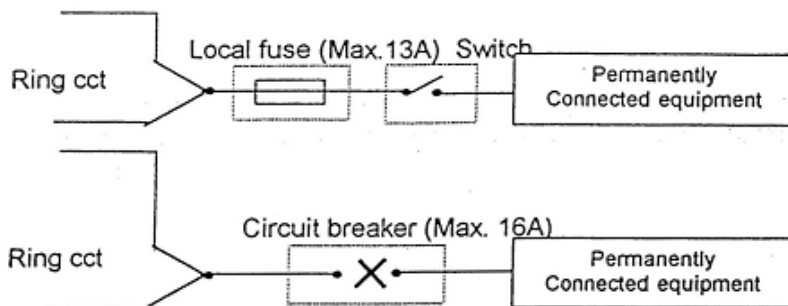
At a junction



At the origin of the circuit in the distribution board

8. Permanently Connected Equipment

Permanently connected equipment should be locally protected by fuse rating not exceeding 13A and controlled by a switch or protected by a circuit breaker of rating not exceeding 16A



9. Circuit For Immersion Heaters

Where immersion heaters are to be installed to storage vessels in excess of 15 litres capacity, or a comprehensive space heating installation, eg. electric fire are to be installed, separate circuits should be provided for each heater.

Self-Check No. 5.1.3-3

1. What is the Power point?
2. What is the Plug?
3. What is the Socket outlet?

Answer Key No. 5.1.3-3

1. Power point - A termination of the fixed wiring intended for the connection of power point.
2. Plug - A device, provided with contact pins, which is intended to be with a socket outlet or with a connector.
3. Socket outlet - A device, provided with female contacts, which is intended to be installed with the fixed wiring, and intended to receive a plug.

Information Sheet No. 5.1.3-4: Electric Cables and Cable Color

1. Electric Cable

A length of insulated conductor (solid or stranded), or of two or more such conductors, each provided with its own insulation, which are laid together.

2. Cable Construction

Cables consist of 3 essential parts:

- the conductor to carry the current,
- the insulation to provide the means to prevent leakage of current, and
- an external overall protection against mechanical damage, chemical attack, fire or other external damaging factors to the cable.

3. Conductors

The most widely used conductor material for electrical installations in buildings is copper. This is because copper has a low resistivity and is therefore a good conductor of electricity. It is easily drawn out into a wire and is comparatively cheap.

Another conductor material is the aluminum. It is cheaper than copper and is easier to handle in the bigger sizes because of its light weight. However, it is not such a good conductor of electricity as copper, having a higher resistivity, and therefore a larger cross-sectional area is required for the same current-carrying capacity. In the Energy Market Authority Electricity (Electrical Installations) Regulations and CP 5, the **use of aluminum cables in domestic installations is prohibited.**

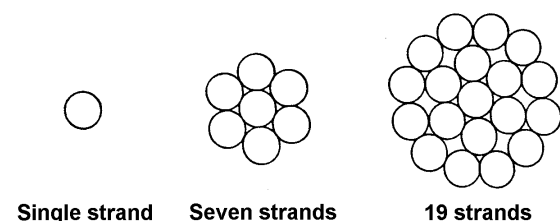
Table 8-1 shows a list of conductors, with remarks on their properties and uses are compared as follows:

Material	Properties	Application
Aluminum	Low cost and weight	Power Cables
Brass	Easily machined, resists corrosion	Terminals; plug pins
Carbon	Hard, low friction with other metals	Electrical machines brushes
Chromium and nickel	Hard; resists corrosion	Heating elements
Copper	Very good conductor; soft and easily drawn into wires; capable of hardening	All cables; busbars
Gold	Expensive; does not corrode	IC connections
Iron and steel	Common metal	Conduits; trunking, distribution board casing
Mercury	Liquid at normal temperatures; vaporizes easily	Special contacts, discharge lamps
Silver	Expensive; the best conductor	Plating of switch contacts
Tungsten	Easily drawn into fine wires	Lamp filaments

3.1 Solid and Stranded

Conductors are usually stranded to make them more flexible. Some small cables, mineral-insulated and aluminum power cables have single-strand or solid conductors.

The standard arrangements are for one, 7, 19 or 37 strands (Fig 8-1).



As aluminum cables are not as flexible as copper, CP5 states that the cross-sectional area of conductor 10 mm² or less shall be of copper.

Small cables designed for maximum flexibility have a large number of strands. They are called flexible cords (from 3 to 25A) and flexible cables (from 33A upwards). In all stranded cables, the strands are twisted together, and the direction of the twist is called the 'lay'.

Table 8-3 shows the stranding of copper cables and flexible cords / flexible cables from 0.5 mm² to 35 mm²:

Cross sectional area (mm ²)	The 1st number indicates the number of strands; and the 2nd number gives the diameter of each strand in mm	
	<i>Cables</i>	<i>Flexible Cords / Flexible Cables</i>
0.5	--	16 / 0.2
0.75	--	24 / 0.2
1.0	1 / 1.13	32 / 0.2
1.5	1 / 1.38 or 7 / 0.53	30 / 0.25
2.5	1 / 1.78 or 7 / 0.67	50 / 0.25
4	7 / 0.85	56 / 0.3
6	7 / 1.04	84 / 0.3
10	7 / 1.35	80 / 0.4
16	7 / 1.7	126 / 0.4
25	7 / 2.14	196 / 0.4
35	19 / 1.53	276 / 0.4

3.2 Annealed or Hard Drawn

When copper and aluminum are drawn out into strands, they become **hard drawn**, in which condition they are still and hard. They can be **annealed** by heat treatment making them become comparatively soft and pliable. With this, flexibility is increased so as to ease handling of cable. Hard-drawn conductors are used in busbars and overhead lines.

3.3 Factors Determining Choice of Conductor

The following guidelines shall be complied with when making the choice of conductor:

- Low electrical resistance
- Mechanically strong and flexible
- Relatively cheap

4. Cable Insulators

If materials that does not allow the free flow of electric current, they are called insulators. There are many types of insulating materials, but a few of those in common use in the electrical industry are listed in the Table 8-4:

Material	Properties	Application
Rubber flexible plastics	Flexible; life affected by excessive heat or cold;	Cable insulation (small and medium sizes)
Cross Linked polyethylene	Emit little smoke or fumes when burning	Cable insulation (medium and large sizes)
Magnesium oxide	Powder; requires containing sheath; not affected by very high temperatures; very hygroscopic	Mineral-insulated cables
Mica	Insulation not affected by high temperatures	Electric iron; toasters
Glass fibre	Reasonably flexible; not affected by high temperature	Cable insulation for rice cookers; ovens
Porcelain	Hard and brittle; easily cleaned	Overhead line insulators
Rigid plastics	Not as expensive and less brittle	Switches; socket-outlets; and other accessories

5. Mechanical Protection

Insulated conductor may be protected by:

- Sheathing (an impervious covering)
- Armouring (a wrapping of metal wires or tapes)

Note:

Cables used for fixed wiring must be protected by an enclosure or be provided with a layer of mechanical protection.

6. Types of Cables

Every non-flexible cable operating at low voltages shall be selected in accordance with the appropriate standards. A wide range of cables are now in use, below are some of the commonly used types:

- Polyvinyl chloride (PVC) insulated cables with or without sheath
- Rubber insulated cables
- Armoured PVC insulated cables
- Armoured cables with thermosetting insulation
- Impregnated paper insulated lead sheathed cables Mineral insulated cables
- Mineral insulated cables
- Silicone rubber

6.1 Polyvinyl chloride (PVC) insulated cables

PVC is the most frequently used insulating and sheathing material for internal normal-temperature applications (See Fig 8-2). It is a good insulator, tough, flexible, and cheap. It is easy to work with

and easy to install. Although it has a lower insulation resistance than rubber, it can resist attack by most industrial oils, acids and alkali.

However, PVC should not be used where extremes of temperature are likely to occur. It tends to soften when installed in working temperature exceeding 70°C. At very low temperature it becomes brittle. Care should be taken with PVC when using blow lamps or burning off old cables as this form of insulation gives off toxic fumes when burnt.

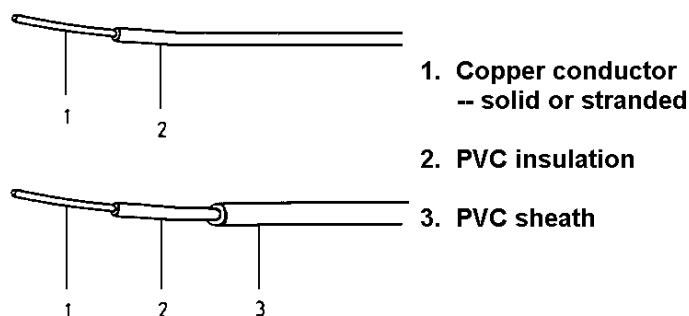


Fig 8-2 Single-Core Non-Armoured PVC insulated and PVC Insulated and sheathed cables

6.2 Rubber insulated cables

These cables have tinned copper conductors which are rubber insulated with a rubber outer sheath. They are very popular before the introduction of PVC as an insulator. The rubber insulation subjects to rapid aging and cracking due to weathering and exposure to sunlight and softens and becomes sticky in the presence of oils and greases. It also ages rapidly at high or low temperatures and will operate safely up to 85°C.

6.3 Armoured PVC insulated cables

An armoured cable is one where the conductors and insulation are protected by a layer or layers of steel or aluminum wires or tapes. This armouring protects the cable from mechanical damage while it is in service, as well as giving added strength to withstand handling during installation. The armouring is usually protected from corrosion by an overall “serving” of PVC.

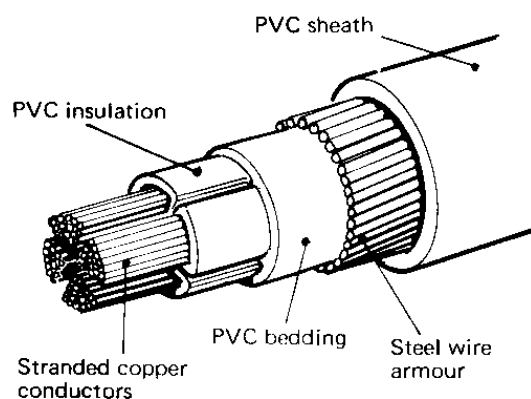


Fig 8-3 Four-Core PVC-Insulated PVC-Sheathed Steel-Wire Armoured Cable

The conductors of these cables are made of copper or aluminum, the former always stranded, but the latter often solid (See Fig 8-4). They are made to 2-; 3-; 4-; or 5-core with colour coded insulation to assist identification. Conductors are often sector-shaped to fit together more closely.

Armoured PVC insulated cables as shown in Fig 8-3 have conductors arranged in a circular configuration and surrounded with PVC in which is bedded with galvanized steel wires that form the armouring. The whole of the armouring is covered by a PVC outer sheath.

These cables are suitable for installation applications where a high degree of mechanical protection is required. It can be fitted directly on to a wall, placed in ducts, fastened to cable tray or cable ladder; or buried directly in ground. They are normally used for main distribution, sub-main distribution, supplier to industrial machinery, or the distribution of temporary supplies on construction sites.

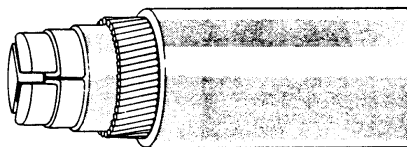


Fig 8-4 Three-Core PVC Insulated PVC-Sheathed Steel-Wire Armoured Cable with Solid Aluminum Conductors

6.4 Armoured Cables with Thermosetting Insulation or Cross-Linked Polyethylene (XLPE) Cables

This cable has either shaped stranded copper conductors or shaped solid aluminum conductors which are insulated with Cross-Linked Polyethylene (XLPE). This is surrounded by a tape bedding on which is placed galvanized steel wire armouring covered by a PVC outer sheath.

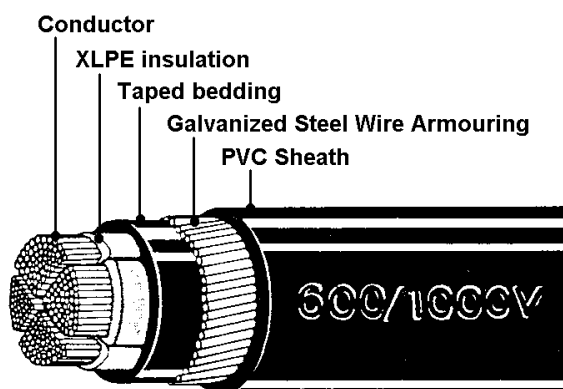


Fig 8-5 Four-Core Armoured Cable with Thermosetting Insulation

The use of XLPE means that it can operate at a higher operating temperature. The maximum continuous temperature for XLPE is 90°C compared with 70°C for PVC insulation. This increased temperature permits a reduction in conductor size if XLPE insulated cables are used in preference to cables having PVC insulation. Like armoured PVC cables, they are used mostly for mains distribution.

6.5 Impregnated-Paper Insulated Lead Sheathed Cables

Like the armoured PVC and XLPE cables, these cables are made with shaped stranded or solid copper conductors or solid aluminum conductors. The construction is quite complex, with dry or oil-impregnated paper, wound in long strips over the conductors. This is covered by a lead or lead alloy sheath over which are placed various bedding materials and galvanized steel wire or steel tape armour. The whole is covered by an outer sheath of PVC.

They were the most common method of insulating underground cables but has now been overtaken by XLPE.

6.6 Mineral - Insulated (MI) Cables

The cable consists of solid cores of copper embedded in highly compressed magnesium oxide, the whole being contained in a solid drawn copper sheath. This sheath may be further protected by an overall covering of PVC, which will prevent corrosion in the presence of moisture and of most chemicals.

The ends of the cable must be sealed against the ingress of moisture. Otherwise, it will lose its insulating properties. This is accomplished by using a pot filled with sealing compound.

Standard cables are available with 1, 2, 3, 4, 7, 12 and 19 cores with voltage ratings of 500 V and 750 V.

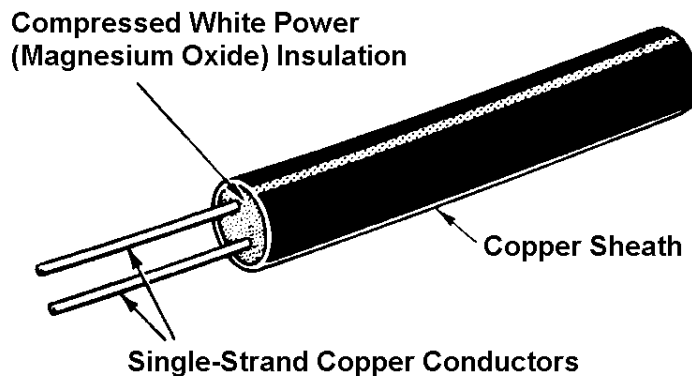


Fig 8-6 Two-Core Mineral Insulated Copper Sheathed Cable (MICS)

Mineral insulated cables are able to withstand very high temperature indeed and being metal sheathed are able to stand up to a high degree of mechanical damage too. With a PVC over sheath, they are ideal for installations such as breweries, food processing and in lift shafts. However, they should not be used in discharge lighting circuits unless suitable precautions are taken to suppress excessive voltage surges.

Advantages of MI Cables

- excellent electrical properties
- can work at high temperatures
- high mechanical strength, non-flammable and non-aging
- waterproof
- suitable for use in flameproof installations.
- very resistant to corrosion

Disadvantages of MI Cables

- Expensive
- Installation has to be done by skilled worker
- ends of the cable must be sealed against the ingress of moisture

6.7 Silicone Rubber Cables

Silicone rubber is a synthetic material with many of the advantages of natural rubber. It has good weathering properties, and will resist attack from water and mineral oils, but not from petrol. It remains elastic over extremes of temperature (-70°C to 150°C).

Silicone rubber cables have been popular in the installation of fire alarm circuits. This is due largely to the fact that it retains its insulation properties after being burned and is somewhat cheaper than mineral insulated cables.

7. Cable Identification of Non-Flexible Cables and Conductors

CP 5 states that 'every single core non-flexible cable, and every core of a non-flexible cable used as fixed wiring shall be identifiable at its terminations and preferably throughout its length by the appropriate method'.

For pvc-insulated or rubber-insulated, the use of core colours shall be in accordance with CP 5 as shown in Table 8-4 below. Coloured tapes, sleeves, or discs of the appropriate colours could also be used at the terminations of these cables and MI cables.

For multi-core thermosetting insulating and paper-insulated cables, if colouring of cores is not used, then cores to be numbered with 1, 2 and 3 for phase conductors, 0 for neutral conductor.

Table 8-5 Colour Identification of Cores of Non-Flexible Cables

Function	Colour Identification of Core
Protective (including earthing) conductor and circuits	Green-and-Yellow
Phase of a.c. single-phase circuit	Brown, Black, or Grey
Neutral of a.c. single-phase or three-phase circuit	Blue
Phase Brown of a.c. three-phase circuit	Brown
Phase Black of a.c. three-phase circuit	Black
Phase Grey of a.c. three-phase circuit	Grey
Positive of d.c. 2-wire circuit	Brown
Negative of d.c. 2-wire circuit	Blue

The protective conductor shall be a colour combination of green and yellow with one of the colours shall cover at least 30% and at most 70% of the surface being coloured, while the other colour covers the remainder of the surface. The single colour green shall not be used.

8. Flexible Cables and Flexible Cords

A **flexible cable** consists of one or more cores each containing a group of fine wires. The diameters of the wires and the construction of the cable provide great flexibility.

A **flexible cord** is also a flexible cable, but the cross-sectional area of each conductor **does not exceed 4 mm²**.

8.1 Application

Flexible cables and cords are used for connection to movable accessories, equipment, appliances and lighting fittings. They are two-, three-, four- or five-core. However, most flexible cords are either 2-core or 3-core used in connect all movable appliances, other than an electric cooker which is wired with cable instead. Typical examples of using 3-core flexible cords with single-phase AC are:

Size	Amps	Watts	Typical Use
0.5 mm ²	3 A	690 W	Lights and appliances up to 480W
0.75 mm ²	6 A	1,380 W	Lights and appliances up to 986 W
1 mm ²	10 A	2,300 W	Kettles and other appliances up to 1.9 kW
1.25 mm ²	13 A	2,990 W	Heavy duty extension leads, kettles and other appliances up to 2.4 kW

1.5 mm ²	16 A	3,680 W	Air-conditioners and water machines with heaters
---------------------	------	---------	--

CP 5 states that every core of a flexible cable or cord shall be identifiable throughout its length as appropriate to its function as listed in Table 8-6 below:

No. of Cores	Function	Colour of Core
1	Phase Neutral Protective	Brown Blue Green-and-Yellow
2	Phase Neutral	Brown Blue
3	Phase Neutral Protective	Brown Blue Green-and-Yellow
4 or 5	Phase Neutral Protective	Brown or Black Blue Green-and-Yellow

Table 8-6 Colour Identification of Cores of Flexible Cables and Flexible Cords

In the Energy Market Authority Electricity (Electrical Installations) Regulations 2004, all 3-core flexible core that is designed for the purpose of connection to any appliance must conform with international colour code i.e. brown for line, blue for neutral and green-yellow for earth.

Flexible cables should not normally be used for fixed wiring, but if they are, they must be visible throughout their length. The maximum mass which can be supported by each flexible cord is listed in Table 8-7 below:

Cross-Sectional Area (mm ²)	Max Mass to be supported (kg)
0.5	2
0.75	3
1.0 to 1.5	5

Table 8-7 Maximum Mass Support of Flexible Cord

8.2 Types of Flexible Cables

- 60°C rubber-insulated flexible cables
- 85°C rubber-insulated flexible cables
- 150°C rubber-insulated cables

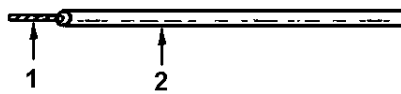
Types of Flexible Cords

- 60°C rubber and PVC cords
- 85°C rubber cords having a HOFR (heat resisting, oil resisting and flame retarding) sheath or a heat-resisting PVC sheath
- 86°C and 90°C heat-resisting PVC cords
- 150°C rubber cords

- Glass fibre cords

Below are illustrated examples of commonly used flexible cords for domestic installations:

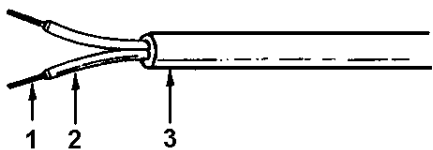
8.2.1 PVC Insulated and Sheathed Flexible Cords



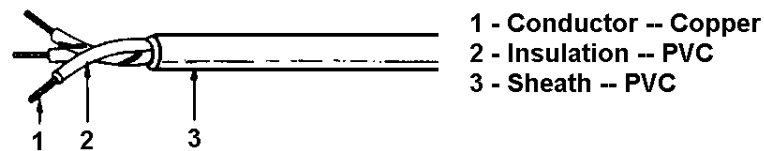
a) Single-Core Non-Sheathed Flexible Cord



b) Parallel 2-Core Unsheathed Flexible Cord



c) 2-core Sheathed Flexible Cord



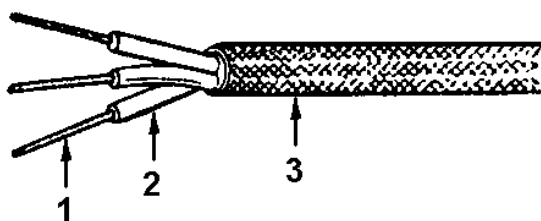
d) 3-Core Sheathed Flexible Cord

1 - Conductor -- Copper
2 - Insulation -- PVC
3 - Sheath -- PVC

Fig 8-7 Types of PVC-Insulated Flexible Cords With or Without Sheath

8.2.2 Heat Resistant Braided Flexible Cord

Heat-resistant braided flex is used on irons, luminaires with filament lamps, and any other appliances that might become hot and burn or melt a normal PVC sheathed flexible cord.



1 - Conductor -- Copper
2 - Insulation -- Rubber
3 - Sheath -- Heat Resistant
Rubber or PVC
with Braided
Textile Covering

Fig 8-8 Heat-Resistant Braided Flexible Cord

8.2.3 Tough Rubber Sheath Flexible Cord

This has a thick black rubber outer sheath and rubber insulated cores. It is a standard flexible cord for power tools, and extension leads, where there is a risk of the lead becoming damaged.

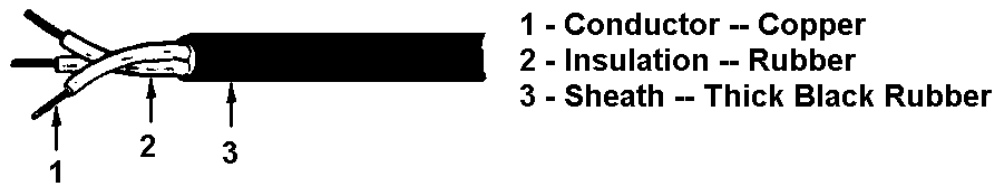


Fig 8-9 Tough-Rubber Sheath flexible Cord

8.3 Types of Network Cables

The types of cablings used in voice and data networks are

- Unshielded Twisted Pair (UTP) cables.
- Shielded Twisted Pair (FTP) cables.
- Pair in metal foil (Pimf) cables.
- Optical Fiber Cables

8.3.1 Unshielded Twisted Pair (UTP) cables (22-24 AWG)

Unshielded twisted-pair (UTP) cable is used in a variety of networks. The UTP cable is shown in Fig 8-10. The most common number of pairs is four as is used for Category 3, 5e, and 6. This type of cable relies solely on the cancellation effect, produced by the twisted wire pairs, to limit signal degradation caused by EMI (Electromagnetic Interference) and RFI (Radio Frequency Interference).



Fig 8-10

More twists in the cable will result in fewer problems with signal degradation, but it can be costly as the cable uses more copper. Further, the path the electrons travel is longer. In addition, the number of twists varies between pairs in the same cable. Hence, the signals arriving at the end of the cable for the different pairs will have slightly different timing interval due to the different length of the cable. . When this problem occurs, it is called *skew*.

There are a few types which are classified into different category depending on the bandwidth range that cable is designed and characterized. The commonly used are:

- | | | | |
|----|-------------------|---|-------------------------|
| a. | Category 3 Cable | - | Specified up to 16MHz |
| b. | Category 5e Cable | - | Specified up to 100 MHz |
| c. | Category 6 Cable | - | Specified up to 250 MHz |
| d. | Category 6A Cable | - | Specified up to 500 MHz |
| e. | Category 7 Cable | - | Specified up to 600 MHz |

The different type and categories of cable typically have an impedance of 100 ohm. Another criterion in classifying cable is in the cable jacket sheath constructions.

Category 3

It applies to 100 ohm unshielded twisted-pair (UTP) cables with four pairs of 24AWG solid copper wire in twisted pairs. It is tested for attenuation and crosstalk through 16MHz. At one time, it was considered to be the minimum acceptable cable to use for 10BASE-T installations, but its use is no longer recommended. Category 5e cable is available at a reasonable cost and is far superior in term of performance for data applications. Category 3 is still widely used for telephone wirings.

Category 5e

Category 5e (the e stands for enhanced) has more twists than Category 5 wiring. These extra twists improve performance by allowing the cable to better resist interference from outside sources, as well as from the other wires within the cable. Tighter twisting also allows the cables to resist separation and bunching during installation. It has since replaced Category 5.

Category 6

Category 6 cable consists of four pairs of 24 AWG copper wires. The pairs have even more twists than Category 5e cable. Category 6 cable is considerably more expensive than either Category 5e because of the extra twists, but the reduction of crosstalk forms a more reliable medium for 1000Base-TX.

Category 7 and beyond

Cables that can move traffic at 1000 Megabit per second (Gigabit Ethernet) are available and many leading firms have already installed them. Speeds of 10 Gbps are already being developed. Such data rates could allow twisted-pair cable to provide all the functions of the wired desktop such as phones, faxes, networked computers, and even video conferencing.

Shielded Twisted Pair (FTP) cables

Shielded twisted pair has only a single shield, usually foil, that protects all the pairs of the cable. Each pair is not wrapped in a shield like Pimf. Since it does not have the extra shielding around the pairs, FTP is less expensive, has a lighter weight, has a smaller diameter, and is easier to ground than Pair in metal foil cable.



Fig 8-11

Pair in metal foil (Pimf) cables

It is basically UTP with a screening layer to further protect the wires from outside interference. All the individual pairs are wrapped in a shield and then the entire four pairs wrapped in another shield. It is shown in Fig 8-12.

The disadvantages of Pair in metal foil are

- It is more expensive than UTP due to the extra shielding.
- It is less flexible than UTP because of the shielding and is more difficult to install.

- It required special plugs and jacks

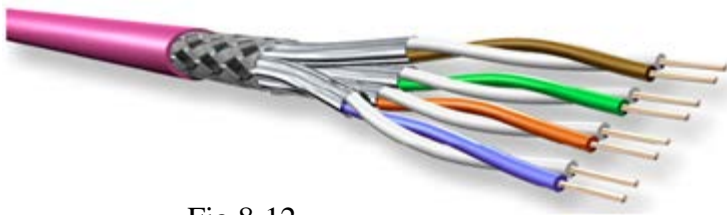


Fig 8-12

Optical Fiber Cables

Fiber-optic cable is a networking medium that uses modulated light for data transmissions through thin strands of glass. There are many characteristics of fiber-optic media that are superior to copper in terms of performance, excellent bandwidth, long life span, excellent security and not subjective to electromagnetic interferences. It is smaller and lighter. The disadvantages are its high cost of

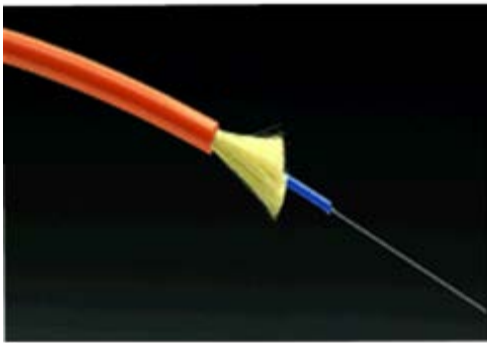


Fig 8-13

installation as there are more electronic interfaces to them. Fig 8-13 shows a fiber optic cable.

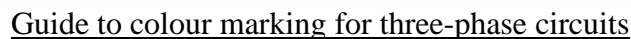
9. Revised Cable Color Code

The new colours for identification of three-phase conductors are brown, black and grey. The new colour for neutral conductor is blue. The green-and-yellow identification for protective conductor remains unchanged.

New Cable Colour Code		
	Single Phase	Three Phase
Phase Conductor (Line)	Brown	Line 1 Brown Line 2 Black Line 3 Grey
Neutral Conductor	Blue	
Protective Conductor (Earth)	Green-and-Yellow	

Old Cable Colour Code		
	Single Phase	Three Phase
Phase Conductor (Line)	Red or Yellow or Blue	Line 1 Red Line 2 Yellow Line 3 Blue
Neutral Conductor	Black	
Protective Conductor (Earth)	Green-and-Yellow	

EXISTING NEW



Self-Check No. 5.1.3-4

1. How many types of cables? Describe.
2. How many types of network cables? Describe.

Answer Key No. 5.1.3-4

1. Types of cables have 7:

- Polyvinyl chloride (PVC) insulated cables with or without sheath
- Rubber insulated cables
- Armoured PVC insulated cables
- Armoured cables with thermosetting insulation
- Impregnated paper insulated lead sheathed cables Mineral insulated cables
- Mineral insulated cables
- Silicone rubber

2. The types of cablings used in voice and data networks are

- Unshielded Twisted Pair (UTP) cables.
- Shielded Twisted Pair (FTP) cables.
- Pair in metal foil (Pimf) cables.
- Optical Fiber Cables

Information Sheet No. 5.1.3-5: Common Wiring Systems

1. Wiring System

A wiring system is an assembly of parts used in the formation of one or more electric circuits. It consists of the conductor, together with its insulation, its protection against mechanical damage, certain wiring accessories for fixing the system, joints, and terminations.

2. Points to be considered in deciding for a wiring system

- Cost
- Time required
- Durability
- Future extensions and alterations
- Neatness of the finished job
- Special conditions to be withstood, eg fumes, dampness, corrosion, mechanical damage, etc
- Damage to the fabric of the building by cutting away
- Compliance with regulations

3. Surface wiring system

Sheathed cables and armoured cables are used for surface wiring systems (Fig 9-1) and are fixed at intervals by clips or saddles on teak batten or on wooden surface directly. Accessories used are all-insulated type.

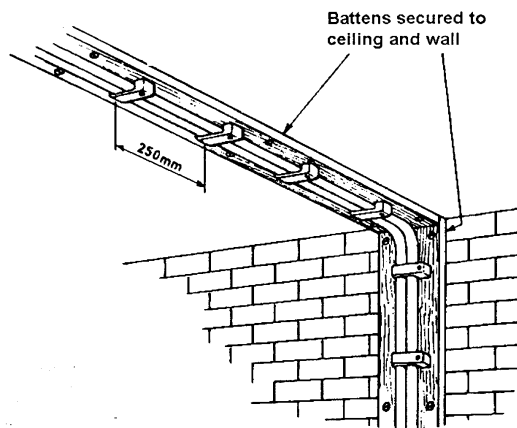


Fig 9-1 Sheathed Cables run on Battens

Advantage

Cheaper in cost

Disadvantage

Unable to offer adequate mechanical protection

4. Concealed Wiring System

In the concealed (or flush) wiring system, sheathed cables are buried beneath the plaster or cement in walls or floors.

However, under the Energy Market Electricity (Electrical Installations) Regulations, where concealed wiring is installed in an electrical installation at a depth of less than 50 mm from the surface, no person shall use for such concealed wiring a non-metallic sheathed electricity cable or non-sheathed cable without any metallic conduit or trunking protecting for such cable. Where concealed wiring is

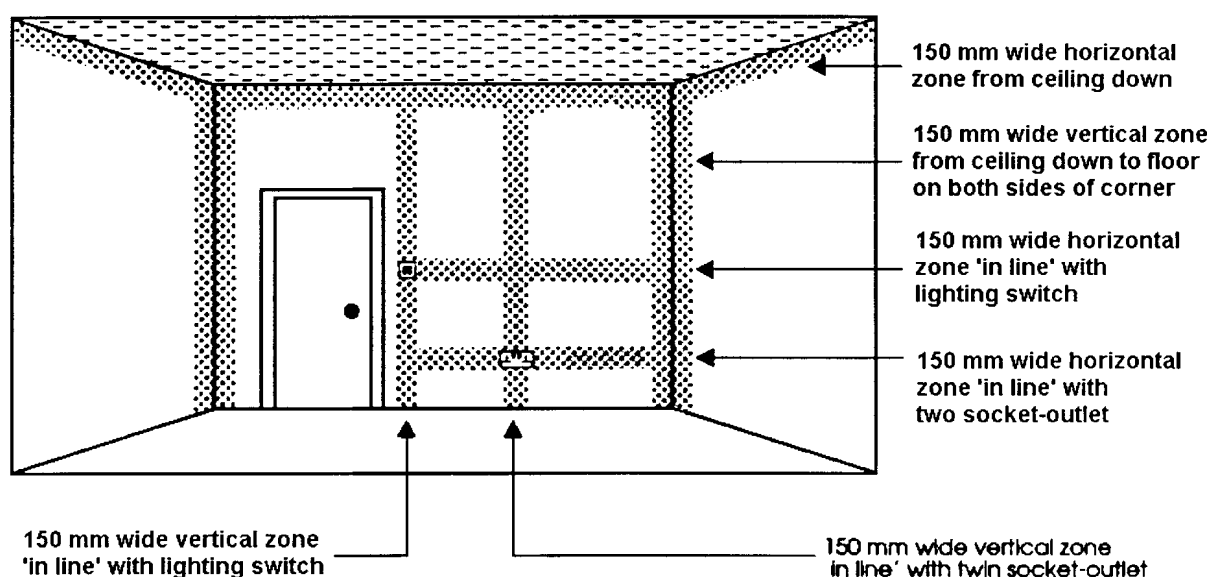
installed in an electrical installation at a depth of 50 mm or more from the surface, a person may use for such concealed wiring without any mechanical protection.

The Authority may require the use of high-sensitivity residual current circuit breaker, RCCB.

CP 5 gives a method of floating such cables in recognised zones of 150 mm wide as shown in Fig 9-2, that is:

- 150 mm from the ceiling horizontally
- 150 mm from the corner between two adjoining vertical walls in both directions
- 150 mm vertically and horizontally from an accessory or electrical point

Where the above is not possible to locate such cables in a prescribed zone, local mechanical protection, like earthed conduit, is sufficient to prevent penetration of cables by nails, screws and the like.



Advantage

Neat in appearance

Disadvantage

More costly

Longer installation time

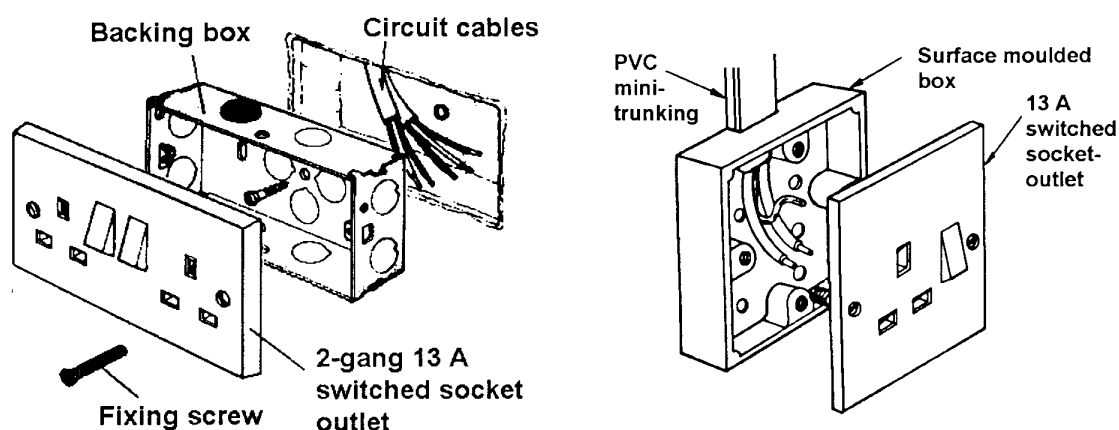


Fig 9-3 Installation of Socket-outlets with Concealed and Surface Wiring System

5. Bare Conductor Wiring System

Bare conductors are installed in buildings for the following purposes:

- Earthing connections
- Protected rising-main and busbar systems
- Collector wires for travelling cranes and trolleys

In rising-main and busbar systems, the conductors are enclosed in a steel trunking and be supported by porcelain or insulators. Provision is made for supplies to be tapped off at intervals. This system is often used as main-supply distributor for multi-storey factories or high-rise commercial buildings.

When bare conductors are used as collector wires for overhead cranes and the like, the conductors must be well out of reach, and clearly labelled to indicate the danger.

6. Conduit System

It consists mainly of a series of tubes connected together with the use of boxes and fittings.

Insulated cables are used for conduit systems. Conduits must be erected before any cables are drawn in.

There are two main types of conduits:

- PVC conduit
- Steel conduit

6.1 PVC Conduit (Rigid Type)

It is similar to the rigid type of steel conduit. All conduit boxes and fittings are slip-in types. If it is necessary to seal the system, adhesive may be used. PVC conduits are used in commercial and domestic installations. They are made in all sizes from 16 mm to 50 mm in external diameter.

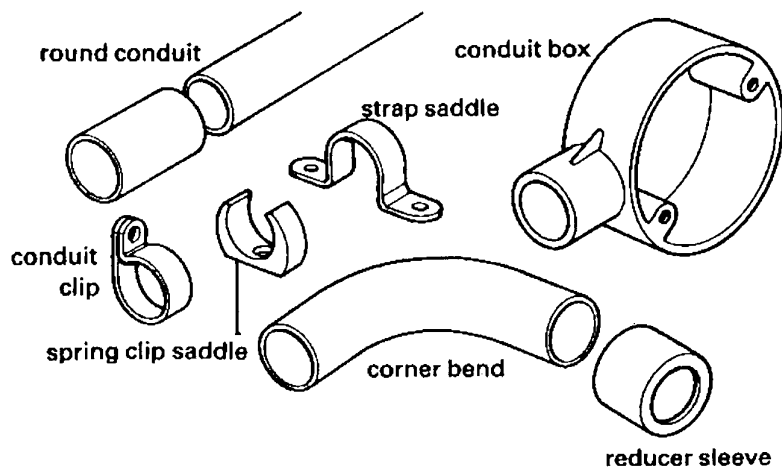


Fig 9-4 PVC Conduit and Fittings

Advantages

- Reduction of risks in electric shocks
- Absence of fire risks
- Resistance to corrosion from most industrial liquids
- No internal condensation takes place

- Can be easily installed

Disadvantages

- Unable to provide great mechanical protection
- Not suitable for working temperature exceeding 60 °C or below - 5 °C

6.2 Installation of PVC Conduit

PVC conduits are easy to work with compared with the steel type. They can be cut by the use of a junior hacksaw held in the hand and do not require the use of a vice. Burrs are easily removed by inserting the side cutters into the tube and twisting.

PVC conduits of 20 mm and 25 mm diameter can be bent with the use of a steel spring. Bending is done by placing the spot to make the bend across the knee and pull evenly with both hands to obtain the desired angle.

6.3 Steel Conduit

Steel conduit is one of the most popular systems of wiring for commercial and industrial premises. It is entirely suitable for installation in production plants, workshops and those types of installation subjected to high mechanical damage.

Many modern buildings are constructed of in situ concrete and the conduits can be installed in the shuttering prior to the pouring of the concrete; this results in a completely concealed installation which can be wired after removal of the shuttering. Conduit sizes are measured by the external diameters. The common sizes are 16mm, 20mm, 25mm and 32mm.

Conduit finishes

- Sherardised is zinc impregnated and has good weatherproof qualities. It is suitable for both external use and internal use especially in wet or damp situations.
- Galvanised is mainly for external use.
- Black enamelled is for internal use in dry situations.
- Silver grey is for inner wall of conduit and used where good finish is required.

Advantages and Disadvantages of Steel Conduit Wiring System

Advantages

- Good protection against mechanical damage
- Easy rewiring in which circuits can be added or removed with ease
- Fire risks minimized

Disadvantages

- More costly as compared with other systems
- Liable to corrode in acidic, alkaline and other fumes
- Prone to condensation within conduit, resulting in dangerous fault conditions

Identification Colour for Conduit

Where an electrical conduit is required to be distinguished from a pipeline or another services, orange shall be the basic identification colour

BUNCHED

The phase and neutral cables of a.c. circuit must be bunched together in the same enclosure. This is to prevent the setting up of magnetic fields which gives rise to heat loss due to eddy currents.

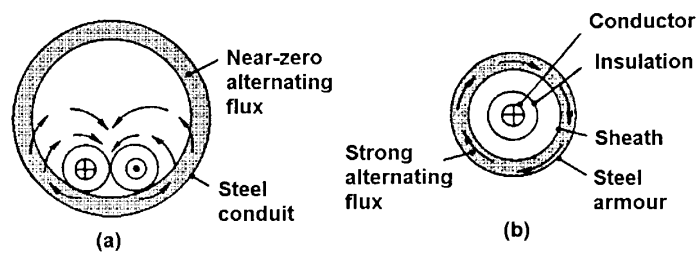


Fig 9-5 Iron Loss in Steel Surrounding a Cable in ac Circuit

Conduit boxes

Conduit boxes formed a large part of a conduit system. They come in many sizes and types and have the following functions:

- As draw-in boxes for drawing in cables
- As junction or termination point
- As a mounting base for accessories, eg switch, socket outlet, ceiling rose, etc

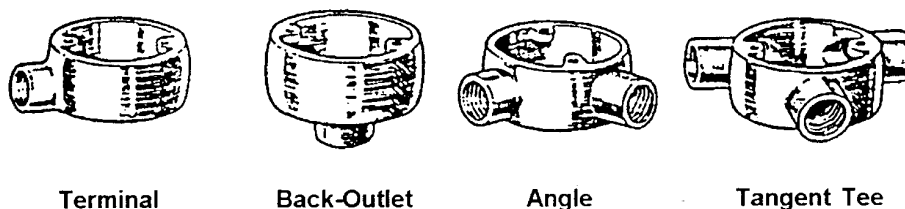


Fig 9-6 Types of Circular Conduit Boxes

Conduit fittings

They are used to enable continuous runs of conduit to follow the curves and varied paths. They can be classified into "inspection" and "solid" types. Inspection fitting has a removable cover, held in place by two or more screws which fit into tapped holes.

Solid (Non-inspection) elbows or tees should be restricted to the locations behind a lighting fittings, outlet box or accessory of the inspection type.

Types of inspection conduit fittings are shown in Fig 9-7

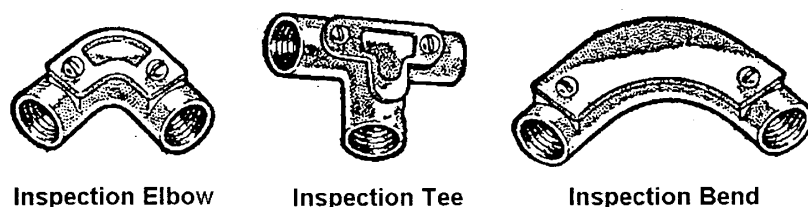


Fig 9-7 Types of Inspection Conduit Fitting

Conduit termination

Conduit ends are terminated by:

- Male bush and coupler or
- Female bush and locknuts

The ends of conduits are reamed to prevent abrasion of cables. Conduits terminating at a box or trunking shall be bushed for the same reason by means of male or female bushes.

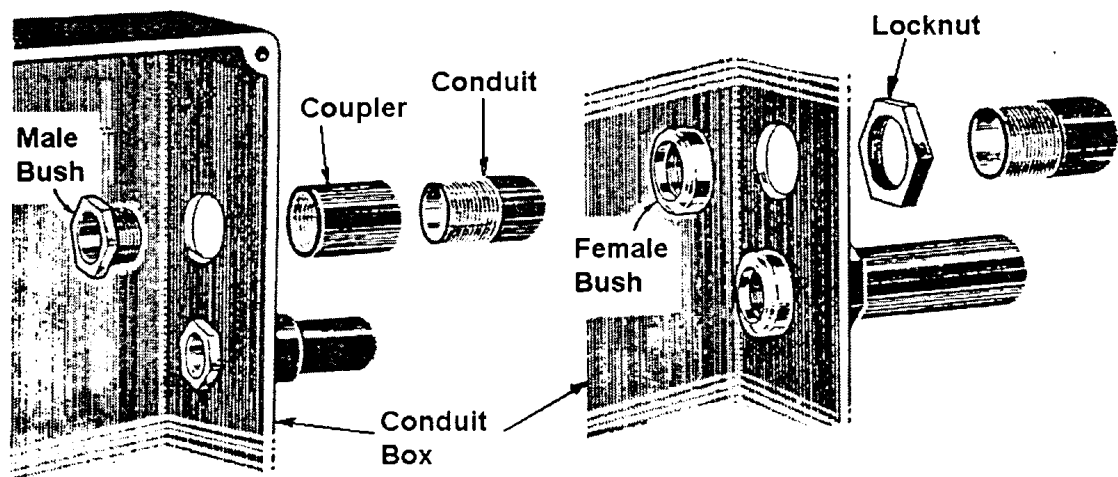


Fig 9-8 Methods of Conduit Termination

Conduit fixings

Conduits are securely supported by the following fixings.

- (i) **Conduit clips** - satisfactory in saving an additional fixing screw, if the conduit is not subjected to any strain.
- (ii) **Ordinary saddles** - provide a very secure fixing by means of 2 screws, not nails.
- (iii) **Spacer bar saddles** - are ordinary saddles mounted on a spacing plate of 3 mm thick. This plate is approximately the same thickness as the other conduit fittings and therefore serves to keep the conduit straight. Some types of saddles have slots instead of holes so that the fixing screws need only be loosened to enable the saddle to be removed, slipped over the conduit and replaced.
- (iv) **Distance saddles** - made of malleable cast iron and are designed to space conduits approximately 10 mm from the wall or ceiling for better protection against corrosion. They are also used to eliminate the possibility of dust and dirt collecting behind and near the top of the conduit where it is generally inaccessible.

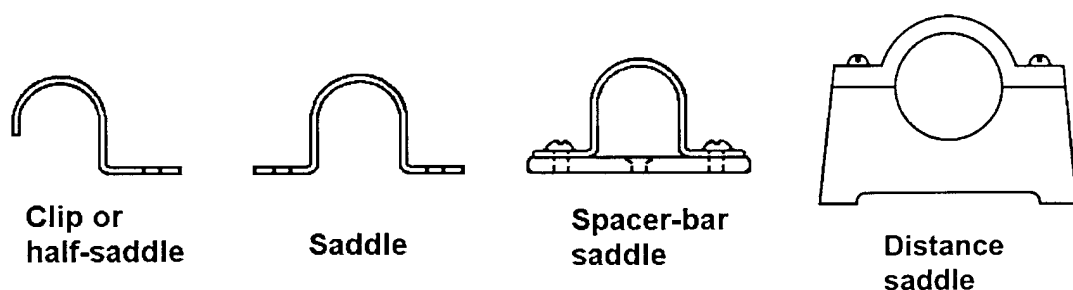


Fig 9-9 Types of Conduit Saddles

Installation of Steel Conduits

The conduit wiring system consists of 2 parts: (i) the conduit itself, and (ii) the conductors or cables which it contains. Therefore, it is clear that the conduit system should be erected complete before any cables drawn in.

The type of cables normally installed in conduits are PVC and single-core. PVC and sheathed cables are sometimes installed in conduits when an extra insulation and protection is desirable. A 20 mm conduit will accommodate easily up to eight 2.5 mm² (stranded) cables.

The number of cables which may be drawn into any conduit must be such that it allows easy drawing in. Otherwise, if the number of cables in a given conduit increases, the current-carrying capacity of the cable decreases. It is therefore advisable not to increase the size of conduit in order to accommodate more cables, but to use 2 or more conduits.

Screwed conduit installations can be installed on the surface of walls, ceilings or trusses, or sometimes it is concealed in concrete or run under floors.

FLEXIBLE CONDUIT

Flexible conduit can be made by steel, PVC or nylon material. It is used for:

- Final connections to machinery where there is vibration and also the possible frequent need to adjust the position of an equipment
- It is used for short runs

A separate CPC must be run between the special adaptors (used to join the flexible conduit to the rigid conduit) and termination box.

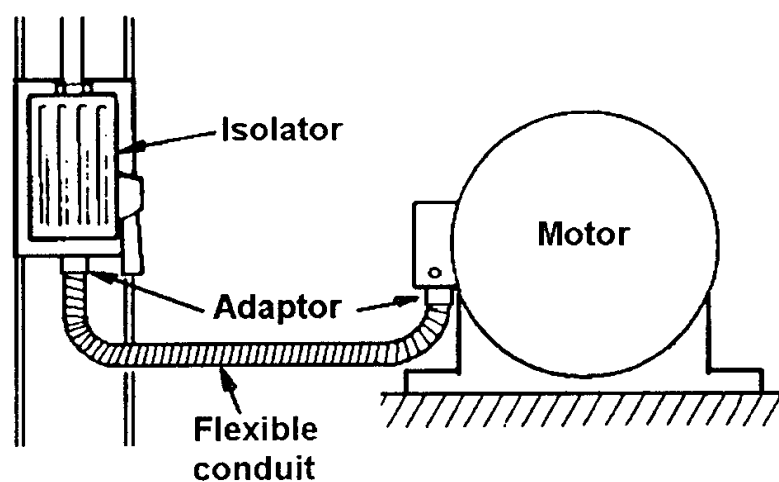


Fig 9-10 Flexible Conduit Installation

TRUNKING

Trunking is available either in rectangular or square section. It has a removable cover and can house more cables.

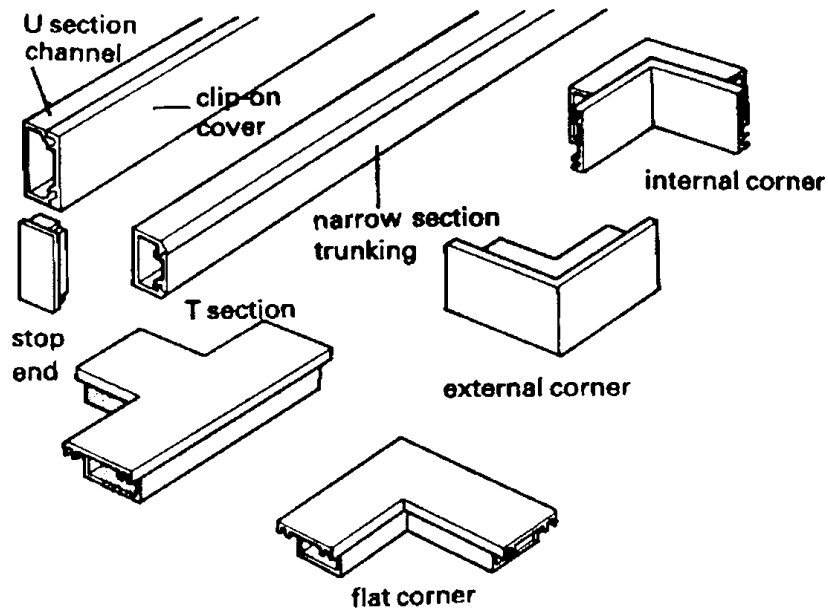
There are two main types of trunking :-

- PVC trunking
- Steel trunking

MINI-PVC TRUNKING

PVC trunking can form a neater surface enclosure for cables than large conduits. PVC cable trunking is mostly provided with clip-in covers. Common sizes available are 16 mm x 16 mm; 25 mm x 16 mm; 40 mm x 16 mm; and 40 mm x 25 mm. A range and its accessories are shown in Fig 9-11.

Fig 9-11 Mini-Trunking



Advantages

- Easier to install
- Non-corrosive
- Non-conductive
- More flexible as extension can be readily carried out

Disadvantages

- Expands and contracts with changes in temperature
- Not as robust as steel conduit

PVC TRUNKING

PVC trunking in larger size are also available in square, rectangular skirting, dado, cornice and angled bench sections. Skirt-mounting trunking is most suitable in dwelling premises.

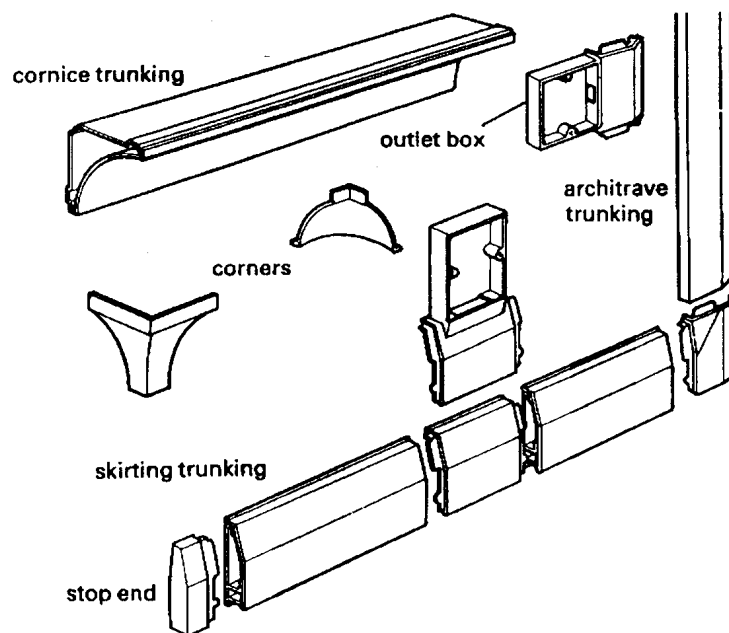


Fig 9-12 Cornice and Skirting Trunking

Multi-Compartment Trunking

CP 5 requires that cables of different categories of electrical circuit shall not be contained in the same enclosure. As a result of this, multi-compartment trunking is used. Multi-compartment trunking is also widely used as horizontal mains in multi-storey buildings.

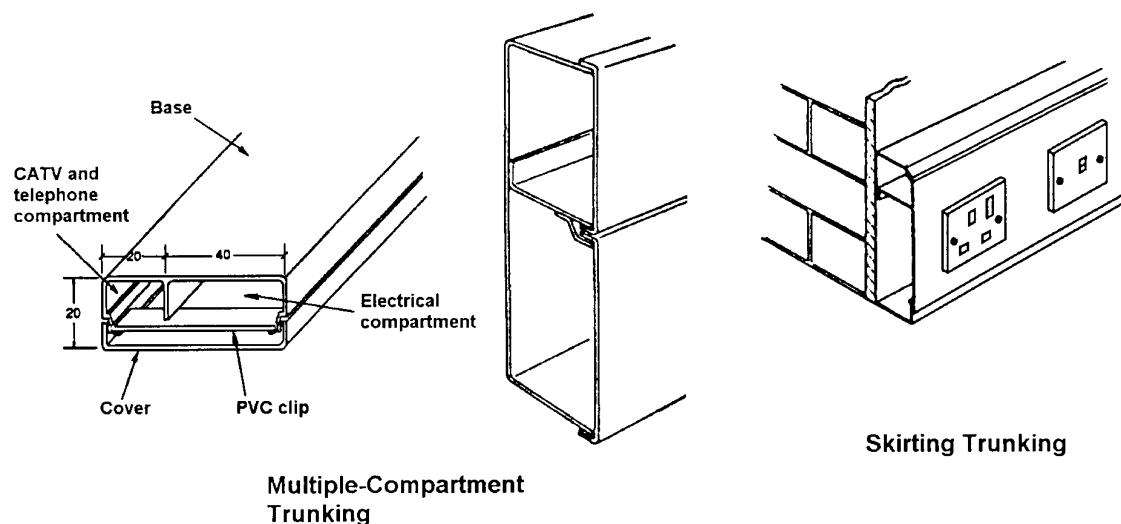


Fig 9-13 Multi-Compartment Trunking

STEEL TRUNKING

Steel trunking is a rectangular-section enclosure, made of sheet steel. Where large number of cables follow the same route, a steel trunking system will be used instead of a very large conduit, or multiple runs of smaller conduits. It provides good mechanical protection to cables, so it is entirely suitable for installations in workshops or industrial premises.

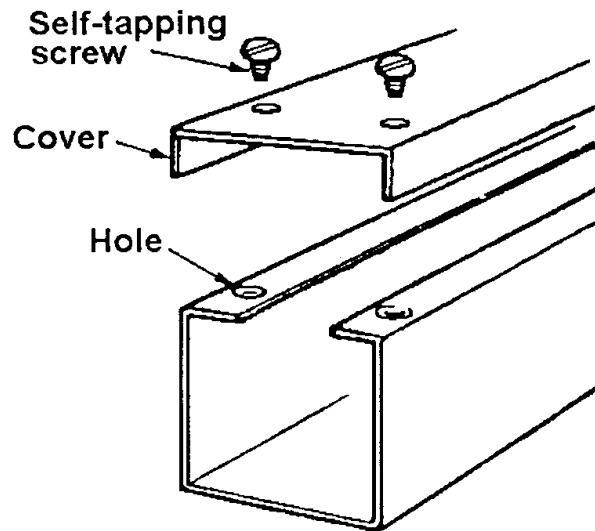


Fig 9-14 Parts of Trunking

Metal trunking is usually supplied in 2.5 m or 3 m length. Examples of standard bends, tees, and reducer are available as shown in Fig 9-14

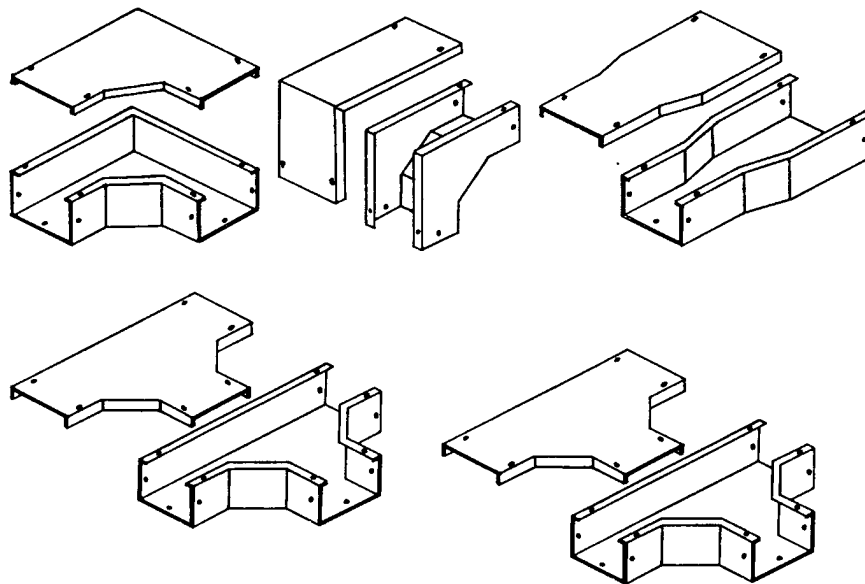


Fig 9-15 Standard Trunking Accessories

Advantages and Disadvantages of Steel Trunking Wiring System

Advantages

- More flexible than conduit systems
- Extensions can be readily made during life of the installation
- Easily and quickly erected
- Use to accommodate PVC insulated cable that are too large to be drawn into conduit

Disadvantages

- Expensive compared to some other wiring systems
- Requires a certain amount of skill in its installation and therefore labour intensive

- Liable to corrode by acidic, alkaline and other fumes
- Not suitable in damp situation

Installation of Metal Trunking

Cable trunking is first and foremost a metal enclosure for the protection from mechanical damage of cables installed in it. Therefore, it should be installed in such a way as to afford continuous protection for the cables and allow safe and easy installation or withdrawal of such cables.

The trunking system should be fully fabricated and erected before any attempt is made to install the cables into it.

SPACE FACTOR

The ratio (expressed as a percentage) of the sum of the overall cross-sectional areas of cables (including insulation and any sheath) to the internal cross-sectional area of the conduit or other cable enclosure in which they are installed

$$\text{Space factor} = \frac{\text{Sum of overall c.s.a. of cables}}{\text{Internal c.s.a. of conduit or trunking}} \times 100\%$$

- For trunking system, the space factor shall not exceed 45%.
- For conduit system, a bend is classified as 90° and a double off-set is equivalent to one right-angled bend

BUSBAR TRUNKING SYSTEM

Busbar trunking system consists of copper or aluminium busbars mounted on the insulators inside the steel trunking.

There are two main types of busbar trunking system:

- Overhead (or horizontal) busbar trunking system
- Rising mains (or vertical) busbar trunking system

Overhead busbar trunking system

It is used normally used to distribute electrical energy to machines in factories. Tap-off units which consist of fuses or circuit breakers, are then fitted onto the busbars. Connections to machines are taken from the tap-off boxes.

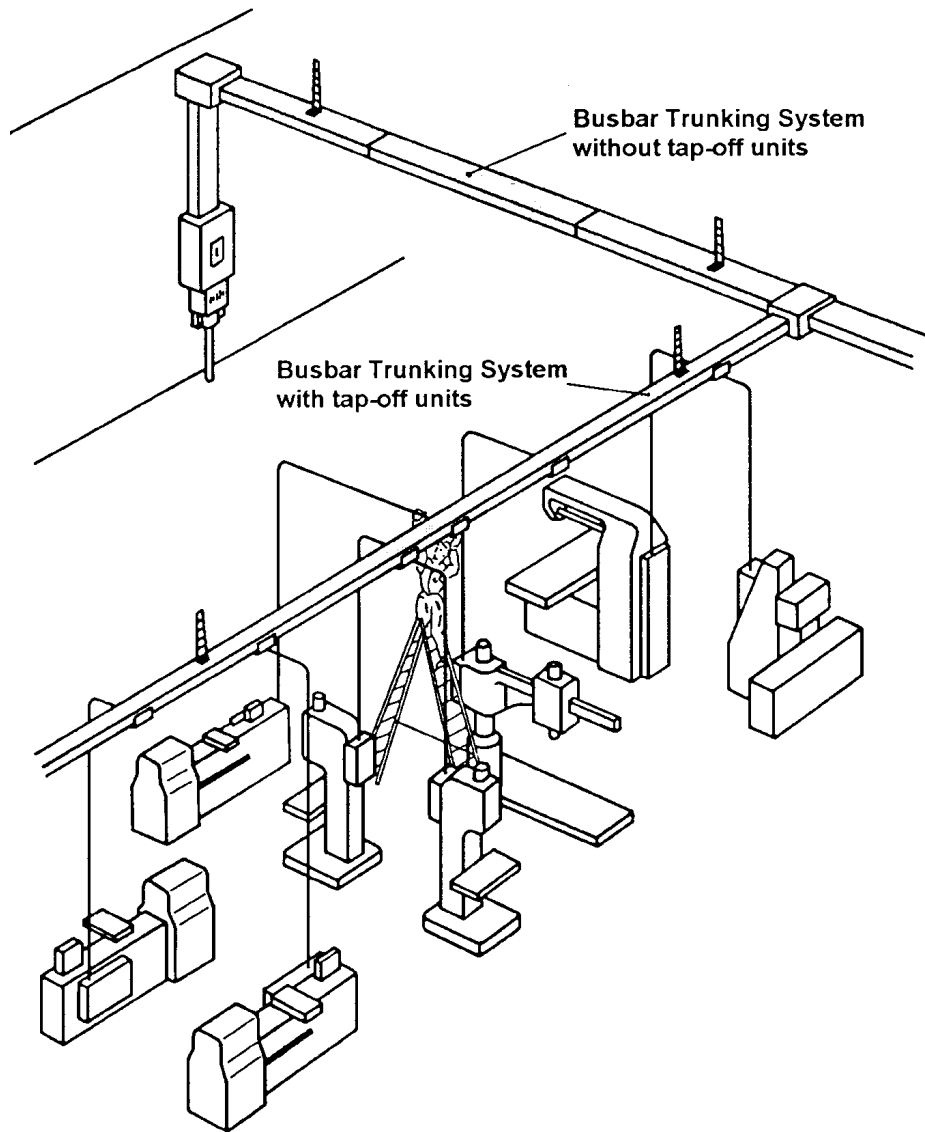


Fig 9-16 Overhead Busbar Trunking System

At intervals, usually every 1 m, a tap-off unit is provided. The tap-unit is equipped fuse switch or circuit breakers. Connection from tap-off unit to motor or other equipment can be made by flexible connections or cables in conduit.

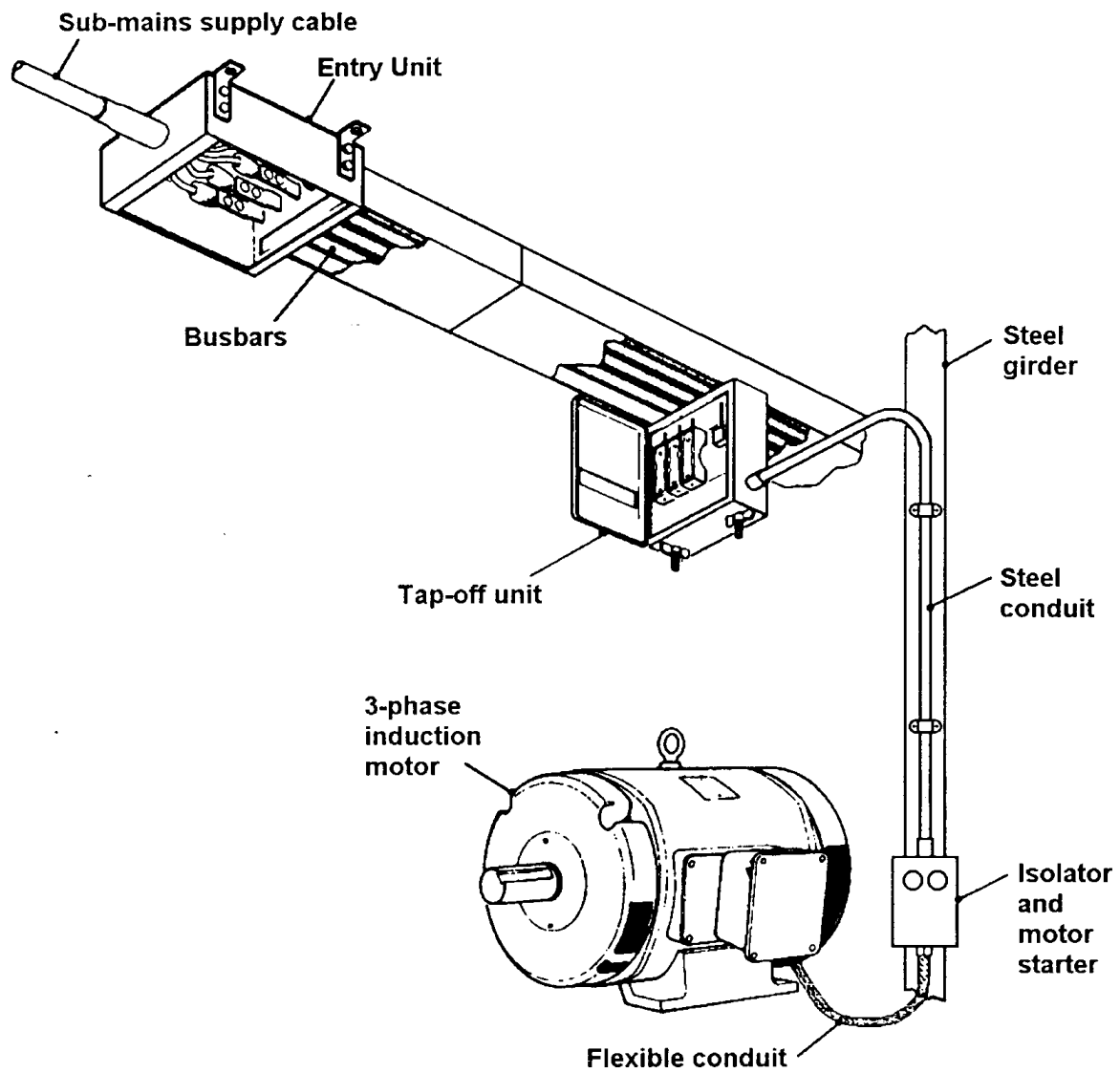


Fig 9-17 Detail Connection of Tap-off Unit

Rising mains busbar trunking system

This vertical trunking system is often used as vertical rising mains for multi-storey buildings. They are usually metal clad and made in 1.5 m and 3 m lengths. Power for consumers at every floor is

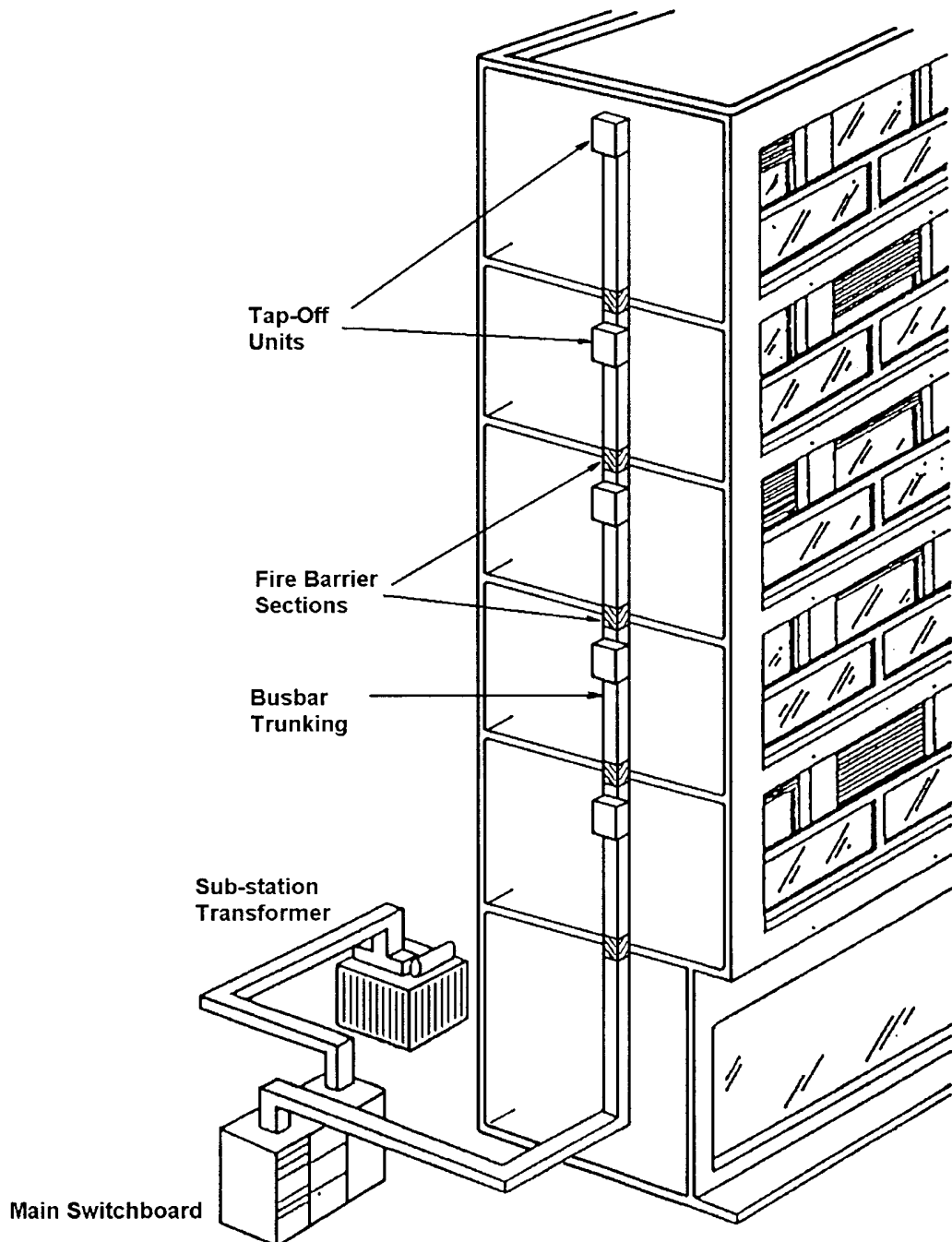
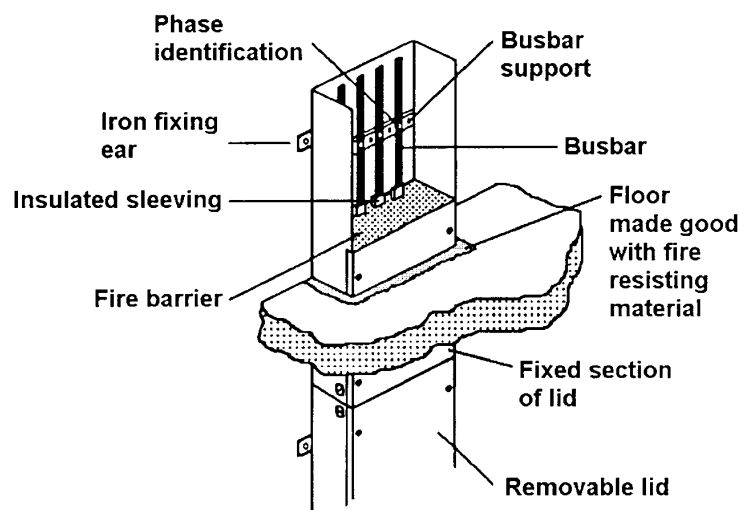


Fig 9-18 Rising Mains Busbar Trunking System

For these vertical runs, it is very important that fire barriers be fitted inside the trunking at the level of each floor. Also, where trunking passes through floors, whether in a riser or run on the surface of a wall, it is necessary to ensure that the floors is 'made good' by non-combustible material round the outside of the trunking to prevent the spread of fire.

A very long vertical trunking run may thus become extremely hot at the top as air heated by the cables rise. Fire stop barriers will act as barriers to rising hot air.

Fig 9-19 Details of Rising Mains



Advantages

- Quick installation time
- In the case of overhead system, plug-in facilities make it convenient for machines to be re-arranged in factories without the need for rewiring the supply
- Reliable, safe, easy to operate and maintain
- Can be easily dismantled, re-positioned, and extended if the need arises
- Can be erected even before the installation of machinery

Disadvantages

- Not suitable where inflammable vapours are present
- Comparatively expensive

CABLE DUCTING AND DUCT SYSTEMS

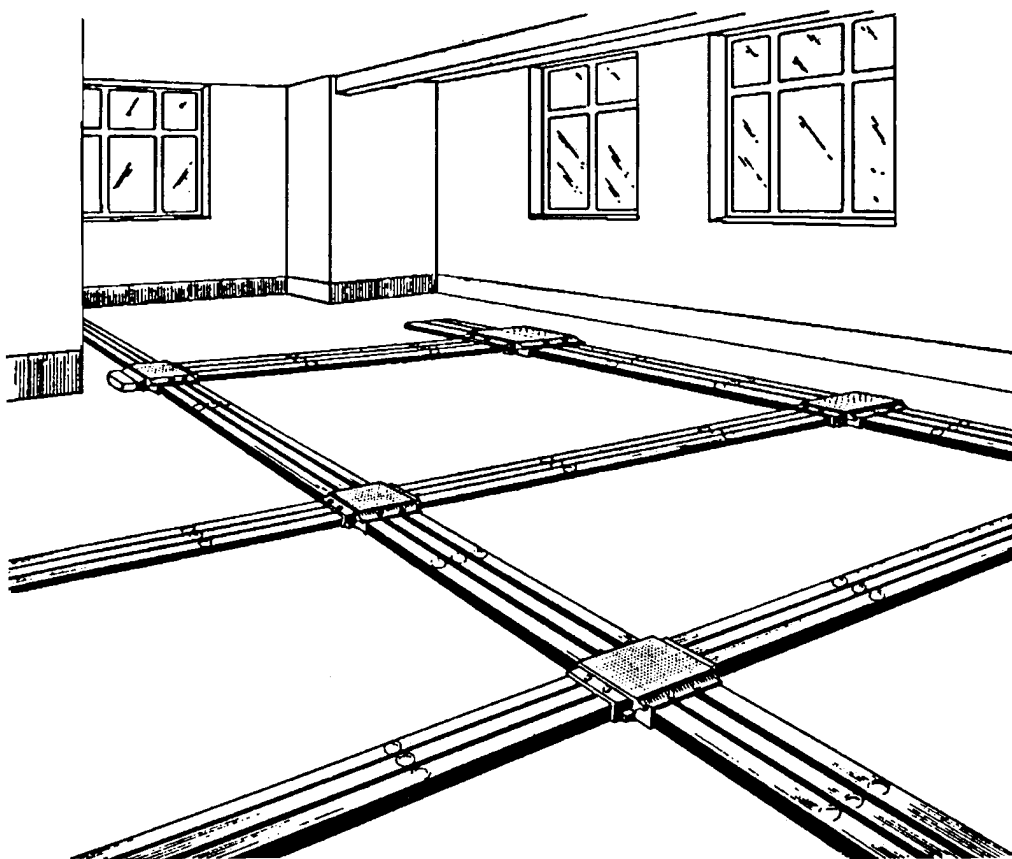
Cable ducting is a manufactured enclosure intended for the protection of cables which are drawn-in after erection of the ducting but which is not specifically intended to form part of a building structure.

Basically, a cable ducting system consists of a number of inter-section boxes, buried in the floor and connected by ducting together. Tapping points are provided at required positions for feeding socket outlets and lighting outlets.

Duct is a closed passageway formed underground or in a structure and it is intended to receive one or more cables which may be drawn in.

Cable ducting and duct systems are used widely for commercial installations.

Fig 9-20 Underfloor System



Advantages

Mechanical protection for cables

Nice appearance

Disadvantages

Not suitable to be used where it is subjected to water washing

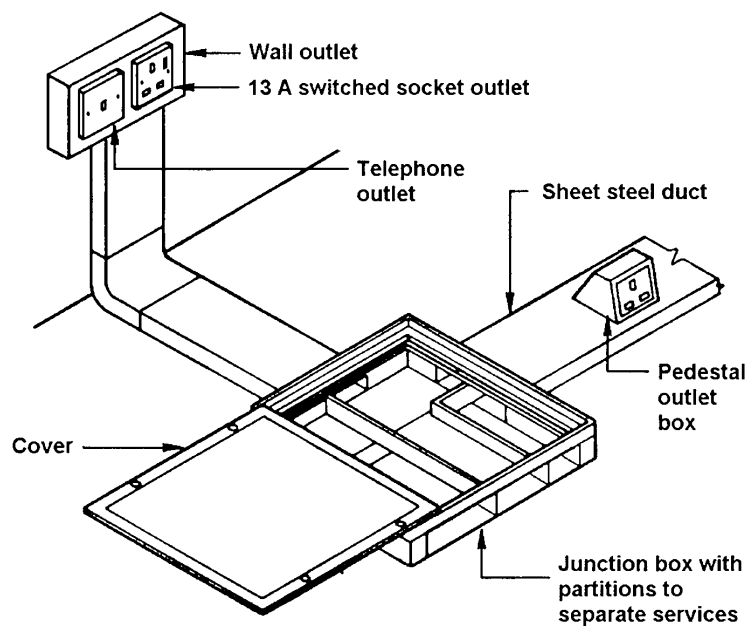


Fig 9-21 Detailed View of a Junction Box floor Trunking

MINERAL INSULATED CABLE SYSTEM

Copper clips and saddles are used to fix MI copper cables on surfaces and cable tray. A wide range is available. Special copper strip is used to make multiple saddles needed to suit site conditions.

After uncoiling the cable and if it is still wavy, roller-straightener can be used. For neatness on the surface, cables may be "dressed" by using a wooden block and hammer.

Note: Cables should never be struck directly with a hammer.

Where connection is made to machines or to other units (which are subjected to vibration), a loop or bend should be made in the cable near the terminations. When bending a cable to enter a gland into a fitting, a bold off-set should be made leaving 25mm to 50mm of straight cable between the gland and the bend.

MI cables should be adequately protected by trunking, or be over-sheathed by PVC if necessary.

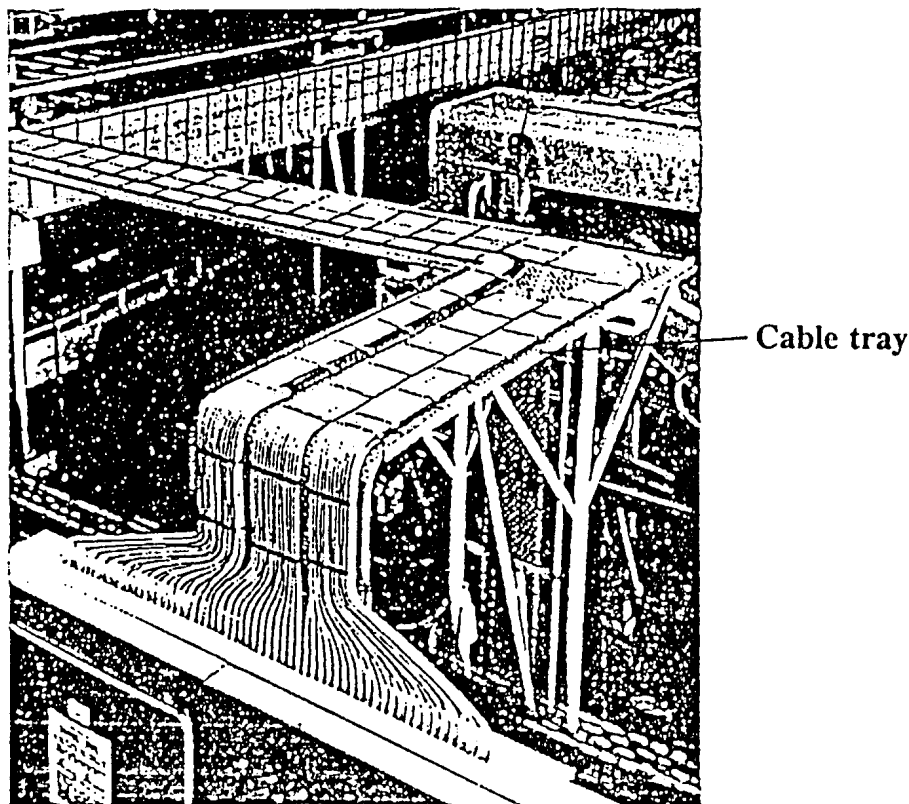


Fig 9-22 Mineral-insulated Cables run on Cable Tray

Advantages

- Heat resistant. Capable to withstand temperature up to 250⁰C
- Sheath provides excellent CPC
- Impervious to water and oil
- Mechanically strong but must be protected against sharp edges
- Virtually ageless
- Higher current carrying capacity

Disadvantages

- Expensive
- Terminations take time and must be done by skilled workers

CONDUIT PREPARATION

Conduit comes in lengths (usually about 3.5 m) and is threaded at both ends.

Cutting

Lengths should be cut to size with a hacksaw having a fine-tooth blade. The blade must be held at right angles to the conduit during cutting. Conduit should always be cut in a pipe vice.

Threading

The thread is cut by using stocks and dies. The stock contains a handle and a holder for the dies. The dies are held in position by a guide. Both the dies and the guide are anchored with two knurled nuts. The dies are made of cast steel and being brittle, are easily chipped. The thread on the dies is tapered to ease the threading of conduit.

The procedure for threading is as follows:

1. Cut the conduit square.
2. Taper the end of the conduit with a flat file.
3. Lubricate the part to be threaded.
4. Press the dies on to the conduit and start the thread: the dies should be 'self -feeding' after the thread has been started.
5. The dies should be reversed half a turn at regular intervals to prevent choking of the thread swarf.
6. When the thread is complete, the end of the conduit should be smoothed with either a reamer or a rat-tail file. Failure to do this may lead to a serious 'burring' of the cables during drawing-in.
7. The threaded end should now be wiped with a clean rag to remove any excess lubricant or metal filings.

Bending conduit

Conduit can be bent with a bending machine. (Fig 15-1) Conduit is bent in the bending machine by placing it between a steel former and a movable steel roller. When the roller is pulled down, it presses the conduits round the former, producing an even bend. A set is produced by bending the conduit at two different points, in opposing directions. The angle of 'set' is usually 45°. Both sides of a set should be parallel.

Examples of good practice for conduit work are:

- a) conduits ends should be cut squarely;
- b) any burrs should be removed either with a round file or a reamer
- c) they should be threaded correctly, using stocks and dies
- d) the radius should be bent not less than 2.5 times the diameter of the conduit
- e) use of solid elbows or tees should be limited
- f) all entries into enclosures should be correctly bushed
- g) correct space factors should be applied to the number of cables installed
- h) unused conduit entries should be blanked off
- i) drainage holes should be provided to avoid collection of condensation
- j) all covers and box lids should be in place and securely tightened
- k) all bushes, couplings and accessories should be securely tightened
- l) all recommendations regarding corrosion should be taken into consideration

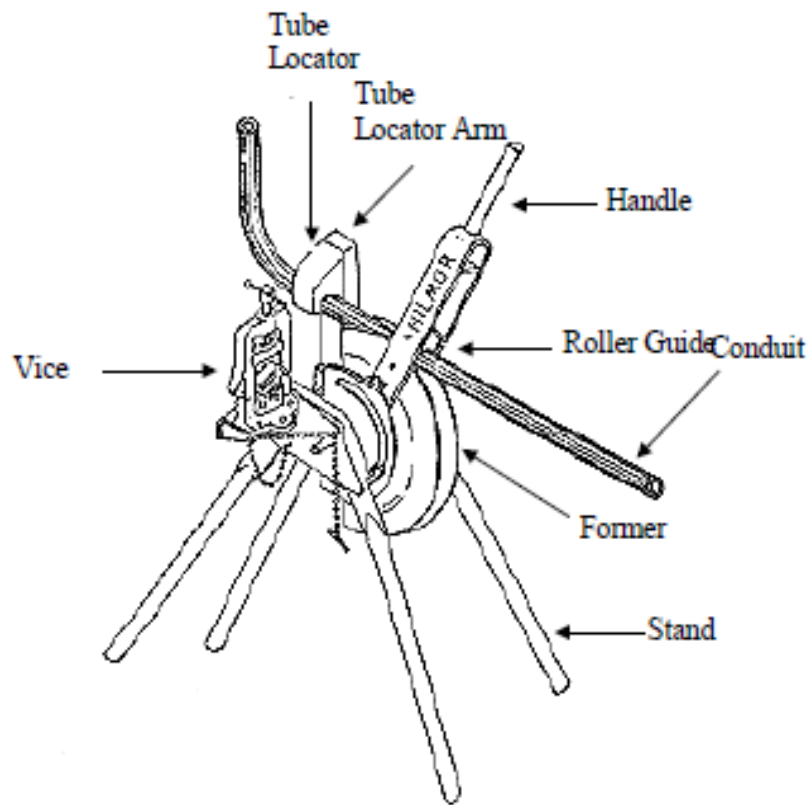


Fig 15-1 Conduit Bending Machine

STEEL TRUNKING PREPARATION

Steel trunking can be cut by hacksaw or snip. After cutting to the required length, construct the bend on the trunking. Remove the unwanted parts. Remove burrs before making the bend. Examples of good practice are:

- a) Trunking ends must be cut square to ensure a good fit into accessories.
- b) Any burrs must be removed with a flat file, to avoid abrasion of cables.
- c) Where cables are likely to come into contact with trunking edges, grommet strips should be fitted.
- d) Round-headed fixing screws should only be used to avoid snagging the cables when installed.
- e) Any bends should have a diameter such that the radius of the cables are contained within them.
- f) Where trunking passes through walls or floors, fire barriers should be fitted and at every 5 m on vertical runs to avoid heat collecting at the top.
- g) Holes for the connection of conduit accessories to the trunking must be cut or punched using appropriate tools.
- h) Cables in vertical trunking exceeding 5 m in length should be supported with intermediate cable supports.
- i) All lids for the trunking and its fittings and accessories should be fitted and securely fastened in place.

Self-Check No. 5.1.3-5

1. What are the purposes of bare conductors are installed in buildings?
2. How many main types of conduits? Describe.

Answer Key No. 5.1.3-5

1. Bare conductors are installed in buildings for the following purposes:
 - Earthing connections
 - Protected rising-main and busbar systems
 - Collector wires for travelling cranes and trolleys
2. There are two main types of conduits:
 - PVC conduit
 - Steel conduit

Information Sheet No. 5.1.3-6: Earthing

1. Introduction

The general mass of earth is made up almost entirely of materials that are reasonably electrical conductors themselves or are made so by being moist. From this, it follows that a current will flow to earth through a live conductor to earth, provided that some other point of the system at a different potential is also connected to earth.

In practice, the neutral at the supply transformer (Fig 6-1) is always connected to the general mass of earth. This is done by connecting a conductor from the neutral at the supply origin to a rod driven into the ground. This is called earthing.

Thus, to prevent the potential of live conductors rising above the safe value, all exposed metal parts of an electrical installation must be connected to earth.

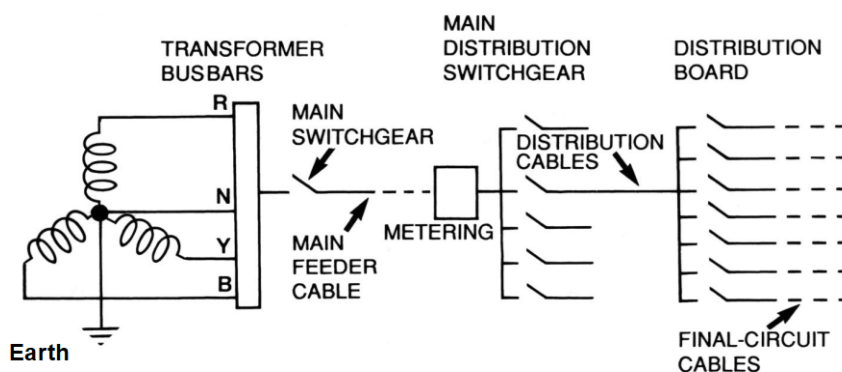


Fig 6-1 Typical Distribution System

GENERAL

The **earth** is considered as a large conductor at **zero potential**. Earthing, therefore, is to connect all exposed-conductive-parts of an installation to the main earthing terminal of that installation.

OBJECTIVE

- To provide an alternative path for the fault current to flow so that the protective devices can sense and operate to isolate the faulty circuit rapidly.
- To ensure that any exposed conductive part does not reach a dangerous potential with respect to earth
- To maintain the voltage at any part of an electrical system at a definite value with respect to earth, so as to prevent any dangerous overvoltage or excessive current on the equipment.

CRITERIA OF GOOD EARTH

Good earth must meet the following criteria:

- Low electrical resistance
- Good corrosion resistance
- Able to carry high fault current repeatedly
- Reliable

TYPES OF SYSTEM EARTHING

TT and **TN-S** systems (Fig 6-2) are adopted in **Singapore**.

FIRST LETTER	SECOND LETTER	SUBSEQUENT LETTERS
Earthing arrangement at energy source	Relationship of exposed conductive parts and earth	Arrangement of protective conductor and neutral
<i>T</i> One or more point of the supply is connected to earth	<i>T</i> Exposed conductive parts connected directly to earth which is independent of the supply earth	
<i>T</i> Supply system not earthed, or one point earthed through a fault limiting impedance	<i>N</i> Exposed conductive parts connected directly to the earth point of energy source	<i>S</i> Separate neutral and protective conductor

Table 6-1 Types of System Earthing

TT and TN-S Comparison

	TT	TN-S
Earth fault loop impedance	High	Low
RCD preferred?	Yes	Yes
Need earth electrode at site?	Yes	No
PE conductor cost	Low	Highest
Risk of broken neutral	No	High
Safety	Safe	Safest
Electromagnetic interference	Least	Low
Safety risks	High loop impedance (step voltages)	Broken neutral
Advantages	Safe and reliable	Safest

Table 6-2 TT and TN-S comparison

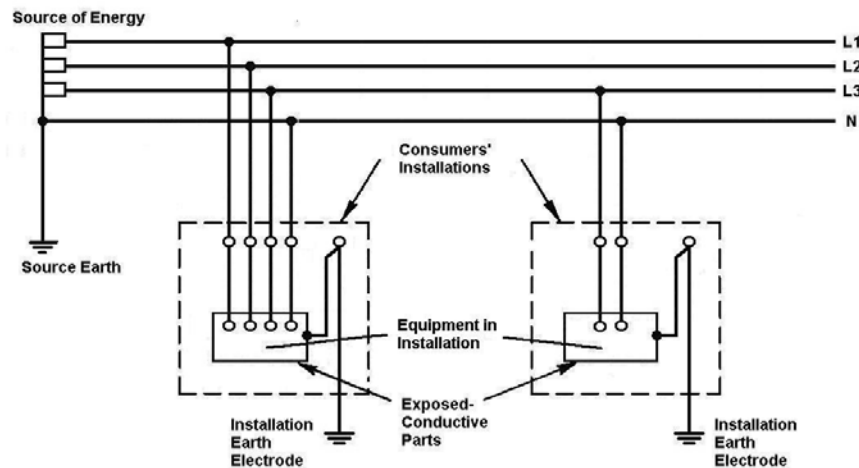


Figure 4. TT System

All exposed-conductive parts of an installation are connected to an earth electrode which is electrically independent of the source earth.

NOTE. ALL OTHER SYSTEMS SHALL NOT BE ALLOWED IN THE REPUBLIC OF SINGAPORE

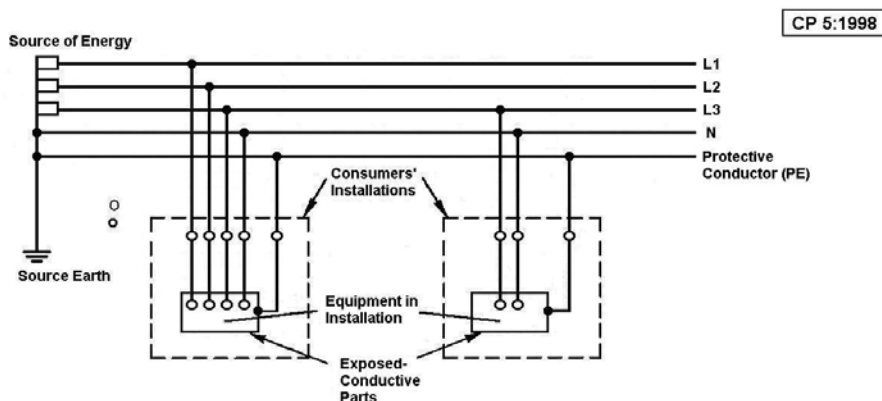


Figure 3. TN-S System

Separate Neutral and Protective Conductors Throughout the System

The protective conductor (PE) is the metallic covering of the cable supplying the installation or a separate conductor.

All exposed-conductive parts of an installation are connected to this protective conductor via the main earthing terminal of the installation.

Fig 6-2 Earthing Systems in Singapore

Earth fault loop impedance

An earth fault current is a fault current which flows to Earth.

Earth fault loop impedance is the impedance of the earth fault current loop starting and ending at the point of earth fault. This impedance is denoted by the symbol Z_s .

The earth fault loop comprises the following, starting at the point of fault:

- The circuit protective conductor, and
- The consumer's earthing terminal and earthing conductor, and
- For TN-S system, the metallic return path, and
- For TT system, the earth return path, and
- The path through the earthed neutral point of the transformer, and

- The transformer winding, and
- The phase conductor from the transformer to the point of fault.

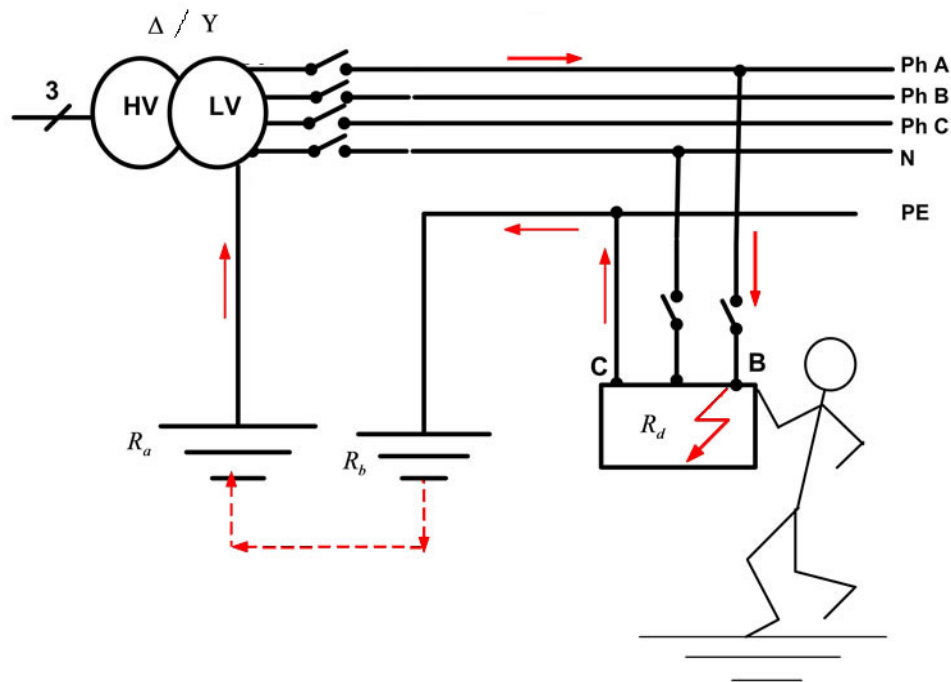


Fig 6-3 Path for earth fault current

TT SYSTEM

Used for consumers taking **LV** supply from Singapore Power as the energy source from Singapore Power and the consumer installation earth are separate.

In a TT earthing system, the **protective earth connection of the consumer** is provided by a **local connection to earth, independent of any earth connection at the generator**. Earth Path of TT System It is the path taken by earth fault current.

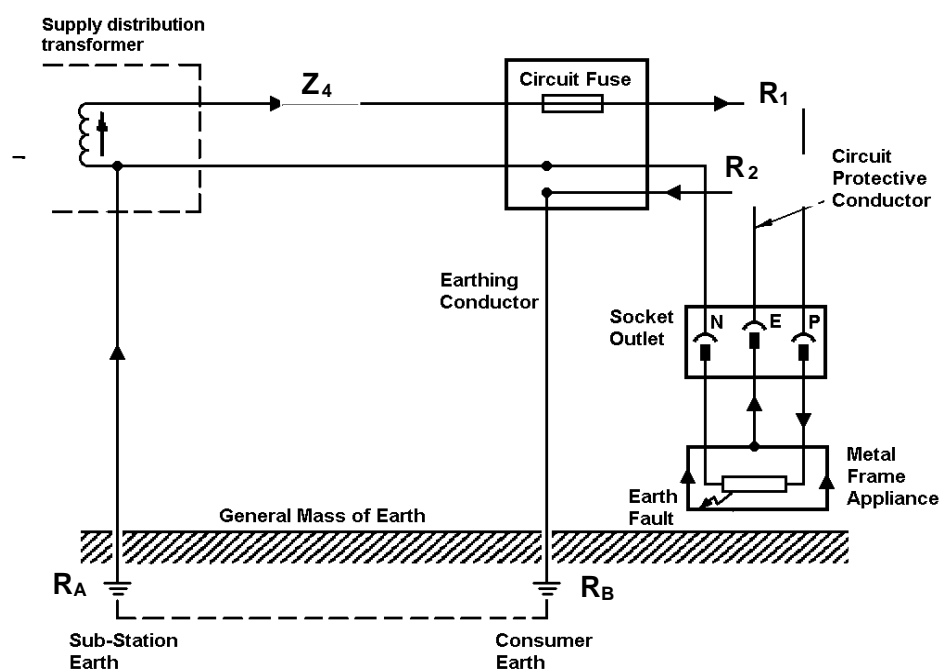


Fig 6-4 Earth Fault Loop of TT System

and the earth loop impedance, Z_s is

$$Z_s = Z_0 + Z_4 + R_1 + R_2 + R_A + R_B$$

- where
- Z_0 = Transformer impedance
 - Z_4 = Phase conductor impedance external to circuit
 - R_1 = Phase conductor circuit resistance
 - R_2 = Protective conductor circuit resistance
 - R_A = Source earth resistance
 - R_B = Installation earth resistance

For **TT** system, the earth loop impedance is generally higher; the protective device is preferably being **residual current type** than overcurrent type.

TN-S SYSTEM

Used for consumers taking **HV** supply (eg 22kV).

In a TN-S system, the protective earth (PE) and neutral (N) conductors are connected **only near the power source** as shown in Fig. 5-5.

Earth Path of TN-S System

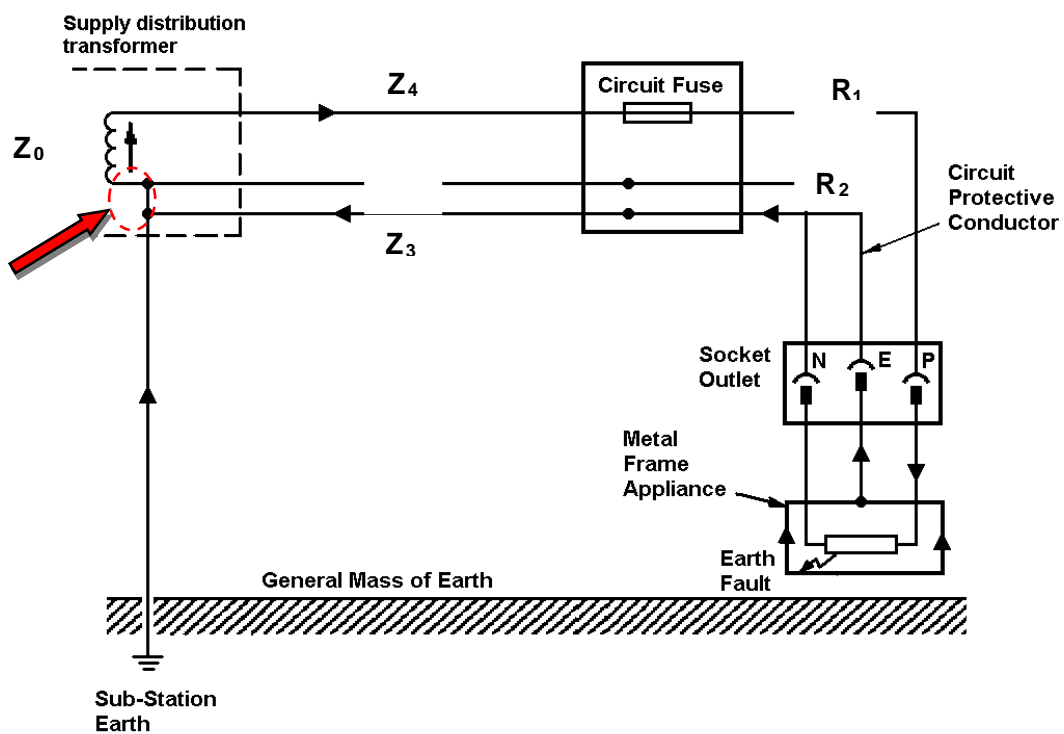


Fig 6-5 Earth Fault Loop of TN-S System

and the earth loop impedance, Z_s is

$$Z_s = Z_0 + Z_4 + R_1 + R_2 + Z_3$$

where Z_3 = Resistance of main earthing conductor

This system does not arrange earth fault current to flow through the general mass of earth. Thus the fault current could be very high. The protective device shall be overcurrent type and / or residual current type

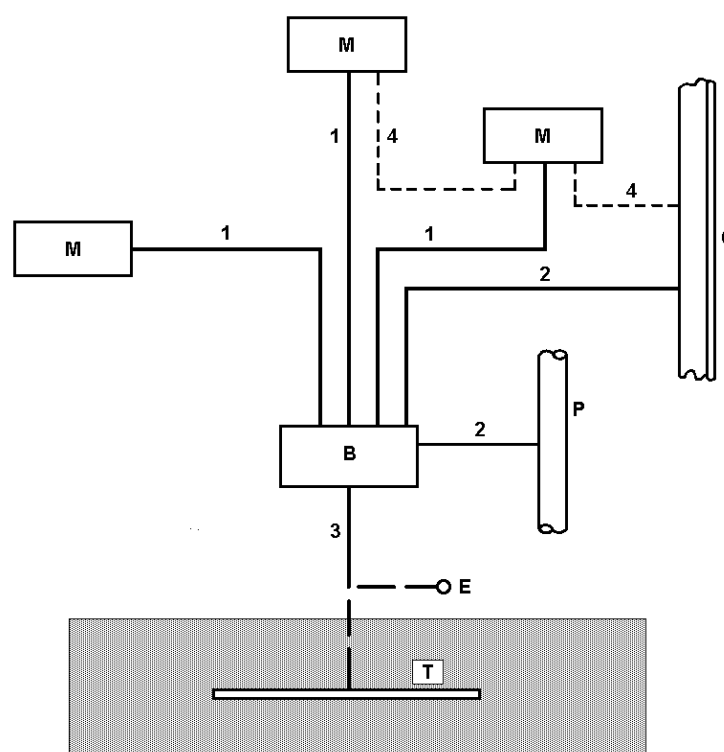
EARTHING INSTALLATION

An earthing installation consists of:

- Earth electrodes
- Earthing conductors
- Circuit protective conductors
- Main equipotential bonding conductors
- Supplementary equipotential bonding conductors.

The example of the earthing arrangement is as shown in Fig 6-6.

ILLUSTRATION OF EARTHING AND PROTECTIVE CONDUCTOR TERMS



Legend

Fig 6-6 Earthing and Protective Conductors

- 1, 2, 3, 4 = Protective conductors
- 1 = Circuit protective conductor
- 2 = Main equipotential bonding conductor
- 3 = Earthing conductor
- 4 = Supplementary equipotential bonding conductor (where required)
- B = Main earthing terminal
- M = Exposed-conductive part
- C = Extraneous-conductive part

TYPES OF EARTH ELECTRODE

Earth Electrode

A conductive part, which may be embedded in the soil or in a specific conductive medium, e.g. concrete in electrical contact with the earth.

Alternatively it can be explained as a conductor or group of conductors in intimate contact with, and providing an electrical connection to, Earth.

The recognised earth electrodes are:

- Earth rods or pipes
- Earth tapes or wires
- Earth plates
- Underground structural steelworks in foundations
- Welding metal reinforcement of concrete (except pre-stressed concrete) embedded in the ground
- Lead sheaths and other metal coverings of cables, where not precluded by SS 638 clause 542.2.5
- Other suitable underground metalwork

Earth electrode must be installed in such a way that their resistance does not increase due to climatic conditions such as soil drying and corrosion etc.

The metalwork of a gas, water or other service should not be used as a protective earth electrode.

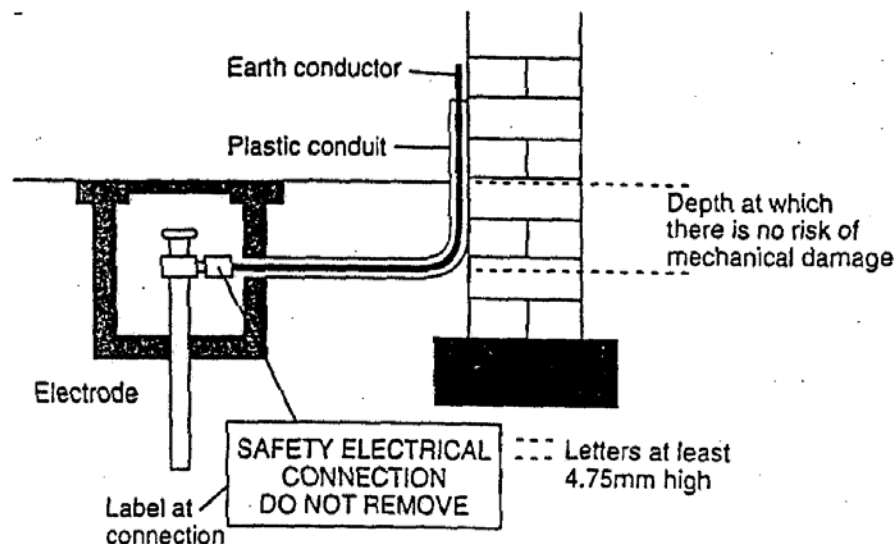


Fig 6-7 Installation of an Earth Electrode

PROTECTIVE CONDUCTORS

The conductors joined from the earth electrode to various parts of metalwork in the earthing installation. It includes:

- Earthing conductor
- Circuit protective conductor

- Main equipotential bonding conductor
- Supplementary equipotential bonding conductor

Earthing Conductor

It is a protective conductor connecting the main earthing terminal of an installation to an earth electrode or to other means of earthing.

A permanent label for earthing connection shall be fixed. This is to ensure that the earthing connection is not removed unintentionally.

Circuit Protective Conductor

It is a protective conductor connecting the exposed-conductive-parts of equipment to the main earthing terminal.

Main Equipotential Bonding Conductor

It is a protective conductor connecting extraneous-conductive-parts to the main earthing terminal to maintain equal potential. Its joint to gas and water services should be made as near as possible to the point of entry.

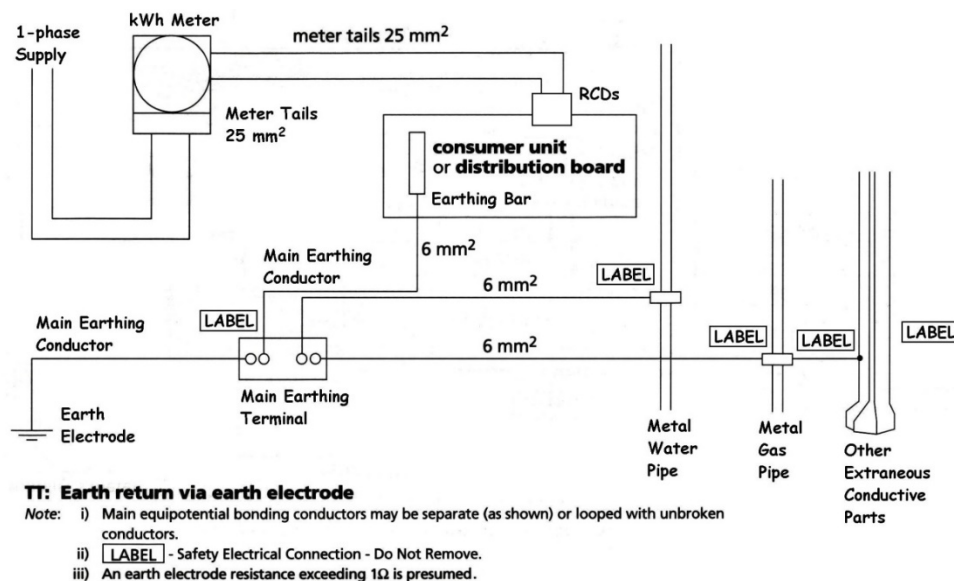


Fig 6-8 Main Equipotential Bonding Conductor

Supplementary Equipotential Bonding Conductor

It is a protective conductor connecting two exposed-conductive-parts, or an exposed-conductive-part to an extraneous-conductive-part or two extraneous-conductive-parts to maintain substantially equal potential.

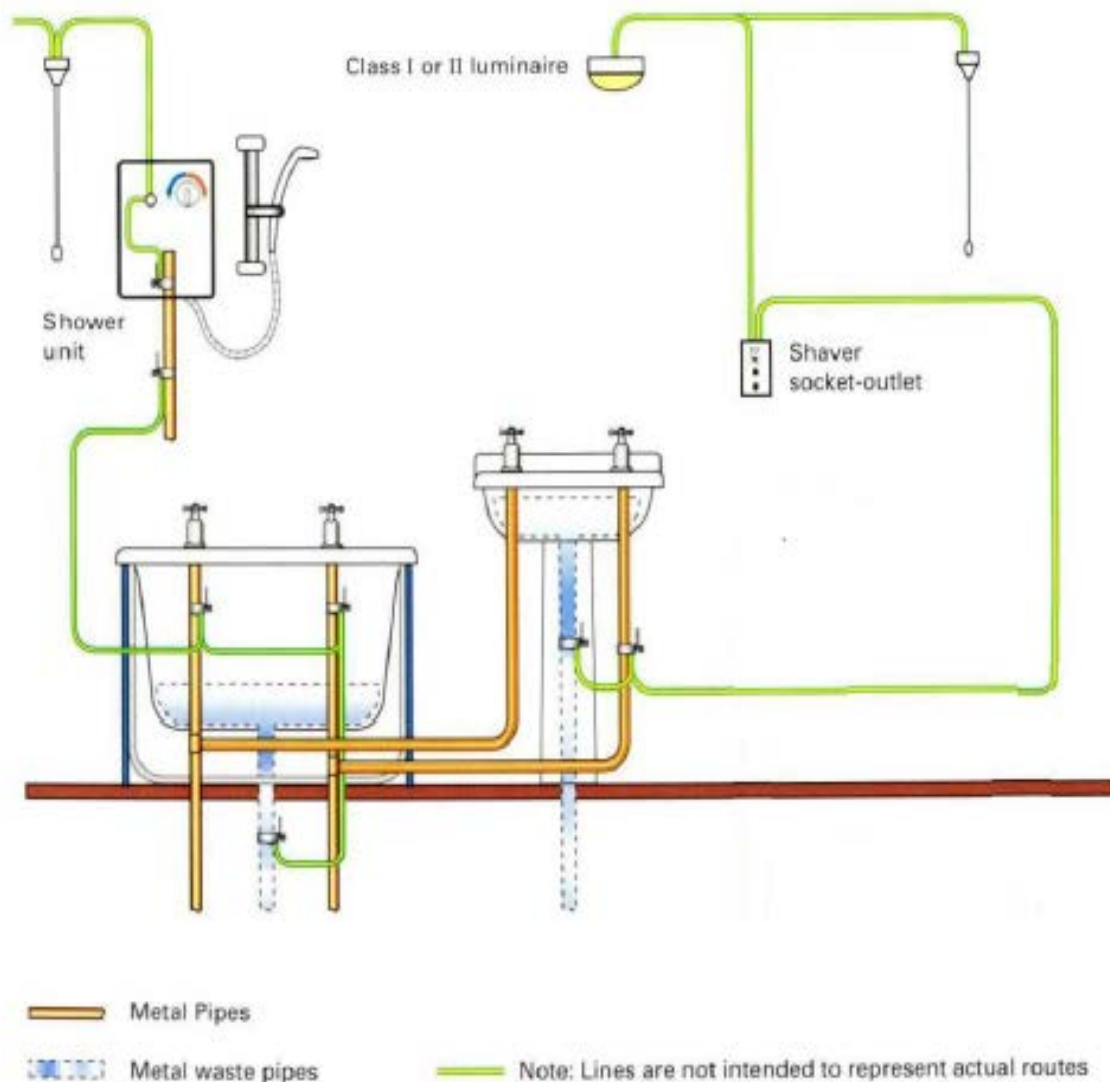


Fig 6-9 (17th Editions of IEE) - Supplementary Equipotential Bonding Conductor

Notes:

1. All simultaneously accessible metal (class 1) equipment (e.g. electric heaters and showers), central heating pipes hot and cold water and waste pipes require supplementary bonding in or close to, the bathroom.
2. Metal baths not connected to a metal building structure do not require supplementary bonding if all metal pipes connected to them has been bonded.
3. Connections to pipes to be made with BS 951 clamps (complete with “Safety Electrical Connection” label).

BONDING

It is a protective conductor connecting the exposed and extraneous-conductive -parts to the main earthing terminal.

Objective

To keep the fault voltage between exposed and extraneous conductive parts to a minimum.

Exposed Conductive Part

An exposed conductive part is a conductive part which **can readily be touched** and which is **not normally alive**, but which **may become alive under fault conditions**. It is also refers to conductive part of electrical equipment, which can be touched and which is not normally live, but which can become live when basic insulation fails. Typical exposed conductive parts are walls of enclosures, operating handles.

Extraneous Conductive Part

An extraneous-conductive-part is a conductive part liable to **introduce a potential**, generally **earth potential** and **does not form part of the electrical installation**. It can also be said to be metalwork which has nothing to do with an electrical appliance/installation and which **could become live (in-directly)** i.e. a radiator.

Example of extraneous-conductive-parts:

- Main water pipes
- Main gas pipes
- Main service pipes and ducting
- Risers of central heating and air conditioning systems
- Exposed metallic parts of the building structure

SIZE OF PROTECTIVE CONDUCTIVE CONDUCTOR

Protective Conductor	Size	Minimum Size		
		With Mechanical Protection	Without Mechanical Protection	Without Corrosion Protection
1. Earthing conductor	Calculation or Table 54.1	2.5mm ²	4mm ² 16mm ² (buried)	25mm ² (buried)
2. Circuit protective conductor	Calculation or Table 54.7	2.5mm ²	4mm ²	Not applicable
3. Main bonding conductor	(Earthing Conductor) ÷ 2	6mm ²		
4. Supplementary bonding conductor				
i) Exposed conductive part to exposed conductive part	Smaller CPC Connected	2.5mm ²	4mm ²	
ii) Extraneous conductive part to exposed conductive part	4 (i)	2.5mm ²	4mm ²	

iii) Extraneous conductive part to extraneous conductive part (No connection to exposed conductive part)	One of the minimums	2.5mm ²	4mm ²	
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Table 6-3 Sizes of Protective Conductors

TYPES OF CABLE USED AS PROTECTIVE CONDUCTORS

- A single core cables
- A conductor in a cable
- An insulated or bare conductor in a common enclosure with insulated live conductors
- A fixed bare or insulated conductor
- A metal covering, for example, the sheath, screen or armouring of a cable

Note:

A protective conductor of **6 mm² or less** must be **insulated** and of cross-sectional-area of **10 mm² or less** must be of copper.

RESIDUAL CURRENT DEVICES (RCDs)

When automatic disconnection of supply cannot be afforded by overcurrent device if the earth loop impedance cannot satisfy the requirements of Tables 41A, 41B1, 41B2, 41C and 41D. The RCD must be used.

RCD can also be used in conjunction with the overcurrent device for the protection against indirect contact as RCD is more sensitive at low residual / leakage current.

Types:

- Residual current circuit breaker without integral overcurrent protection (RCCB)
- Residual current circuit breaker with integral overcurrent protection (RCBO)
- Earth leakage relay (not to be covered).

RCCB comes with sensitivities of 10mA, 30mA, 100mA, 300mA, 500mA. The **30mA** RCCB is commonly used for **domestic installations**.

POINTS TO NOTE

- Main gas and water services must be bonded within **600mm** from the respective supply authority's meter on the consumer's side of the installation.
- Never use aluminium conductors to make final terminations to copper earthing rods or plates. Corrosion will set in and contaminate the mechanical bond.
- The metalwork of a gas, water or other service shall not be used as a protective earth electrode.
- The connection of an earthing conductor to an earth electrode must be electrically & mechanically sound and labeled permanently with the words "**Safety Electrical Connection – Do Not Remove**".
- Metallic flexible conduit, gas pipe, oil pipe and exposed-conductive-part of equipment shall not be used to form a protective conductor.

- f. No switching device shall be inserted in a protective conductor.

Self-Check No. 5.1.3-6

1. What is the good earth?

Answer Key No. 5.1.3-6

1. Good earth must meet the following criteria:
 - Low electrical resistance
 - Good corrosion resistance
 - Able to carry high fault current repeatedly
 - Reliable

Information Sheet No. 5.1.3-7: Lighting Circuits

Household electrical systems consist of a number of separate circuits. Some supply power socket outlets, other supply the fixed lighting, and there are separate circuits for individual high-power appliances such as cookers and air-conditioners. Each circuit, start at the consumer unit, and each has its own MCB or fuse and sized accordingly.

1. Final Circuits

Electrical apparatus is connected by cables to the electricity supply and to the associated protective and controlling devices (usually circuit breakers and switches). This arrangement of cables is known as a circuit. Such circuits connected to current-using equipment to the consumer unit or distribution board, are called final circuits.

Final circuits can be divided into the following types, all of which will need different treatment when planning the size of conductors and the rating of the overcurrent devices:

- Final circuit feeding lighting outlets
- Final circuit feeding fluorescent or other types of discharge lighting
- Final circuit feeding 13 A switched socket outlets to SS 145
- Final circuit feeding fixed equipment
- Final circuit feeding sockets to IEC 609-2
- Final circuit feeding cookers
- Final circuit feeding motors

LIGHTING CIRCUITS

All lighting circuits are primarily meant for on/off control. The current flow out from the consumer unit (CU) along the live (brown) cable, and back along the neutral (blue) cable. In between, it is intercepted by a switch which breaks the flow of current.

Understanding how house lighting circuits work makes it easier to track down faults and is essential if you plan to alter or extend your lighting in the future.

In domestic installations, it is **not a good practice** for a lighting circuit to feed a total load **exceeding 6 A**. This means up to 10 lights, assuming each rated at 100 W, can be connected to one lighting final circuit.

In normal installations, good planning usually limits the number of lights on each circuit to about 10, with more than one lighting circuit to each house. This ensures that the whole of a building is unlikely to be plunged into darkness by the operation of the MCB.

The simplest lighting circuit is one lamp controlled by one switch and is known as one-way circuit (Fig 2-1).

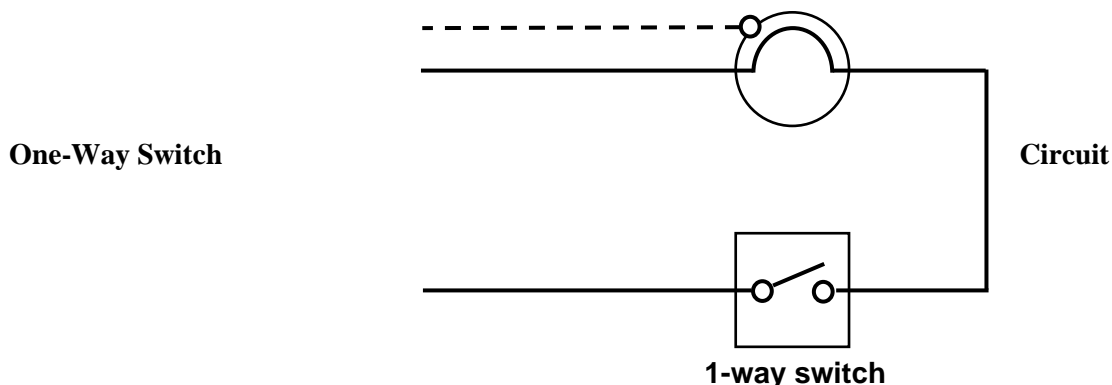


Fig 2-1 One-Way Switch Controls One Lamp

Where additional lighting points are required, the circuit is extended as shown in Fig 2-2. This circuit shows two lamps being controlled by one switch.

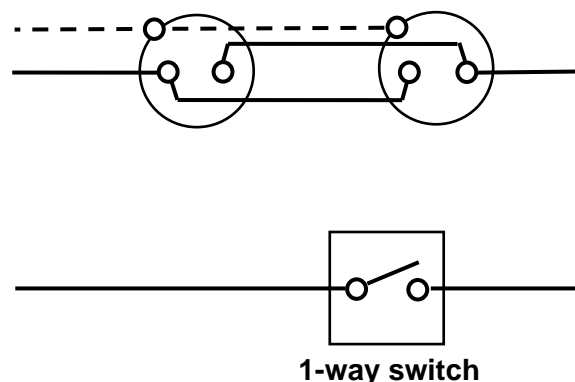


Fig 2-2 One-Way Switch Controls Two Lamps

If the lamps required to be switched on independently from each other, it would be necessary to extend the circuit as shown in Fig 2-3. This is known as the 'loop in' method of wiring.

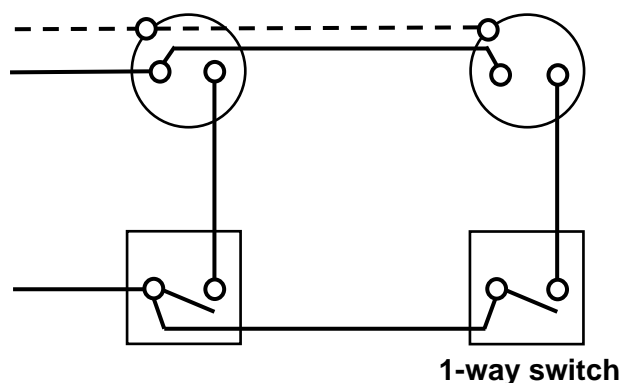


Fig 2-3 Two Lamps Controlled by Two
1-Way Switches

Another method of 'loop in' method of wiring is shown in Fig 2-4. This uses a 3-plate ceiling rose which the phase terminal must be shrouded so that it cannot be touched when the cover is removed for replacement of the flexible cord.

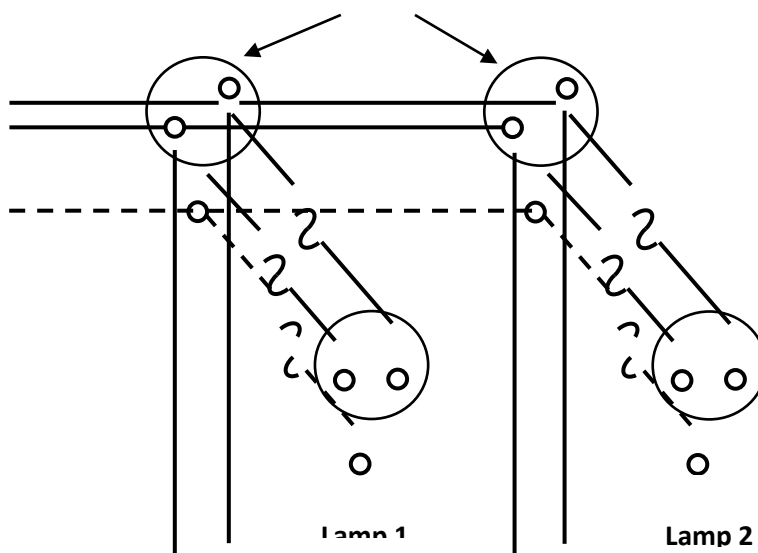




Fig 2-4 Two Lamps Controlled by Two 1-Way Switches Using the 3-Plate Ceiling Roses

Two-Way Switch Circuit

For independent control from two positions, for example on a staircase, two-way switches are required as shown in Fig 2-5. These switches have 3 terminals, one of which is called the common (C); the other two are called the strappers and are usually marked L1 and L2 respectively.

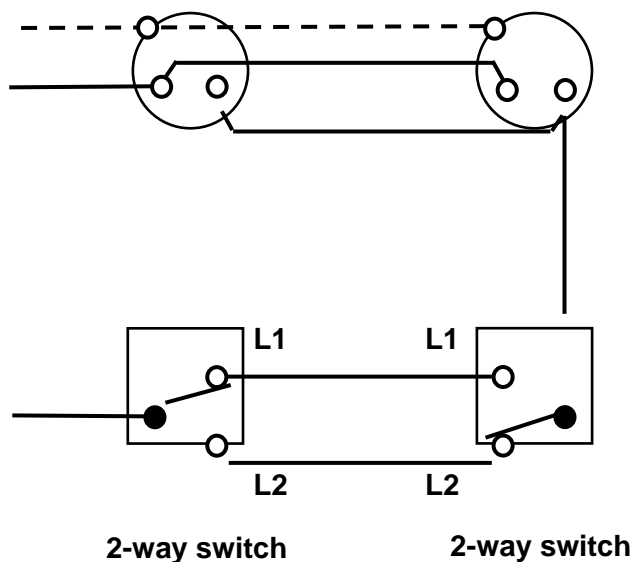


Fig 2-5 Two-Way Switch Circuit

Two-Way and Intermediate Switch Circuit

If it is desired to have control from three or more positions, intermediate type switches are necessary as well as the two 2-way switches. Intermediate switches have 4 terminals and although the switch action of different makes of switch end up with the same results, the connections vary. So, it is advisable to check the switch action before connecting up. The circuit is wired as shown in Fig 2-6.

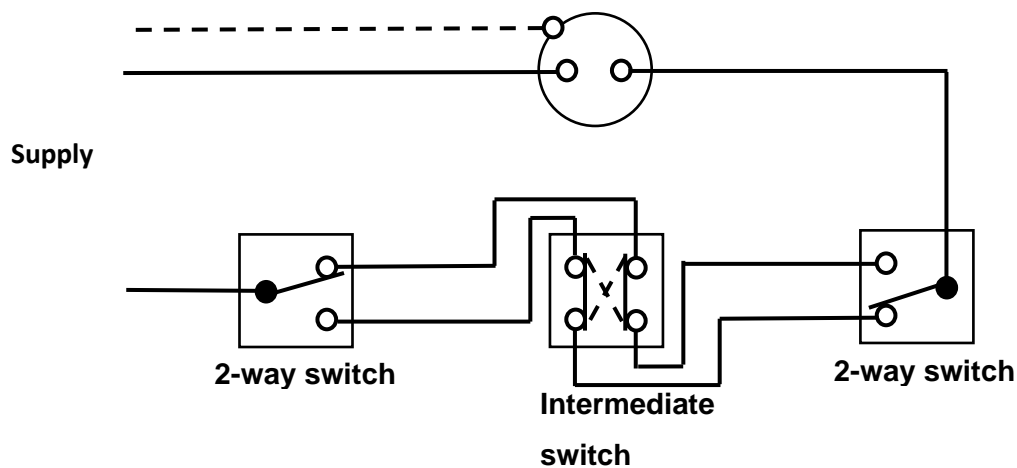


Fig 2-6 Two-Way and Intermediate Switch Circuit

CONVERSION OF 1-WAY CIRCUIT INTO A 2-WAY CIRCUIT

On occasion, an electrician is called upon to make alteration to existing circuits. One of the popular requests is to make a one-way circuit into a two-way. The conversion can be carried out quite simply by running three cables from the existing switch position into a new position. The connections are made as shown in Fig 2-7.

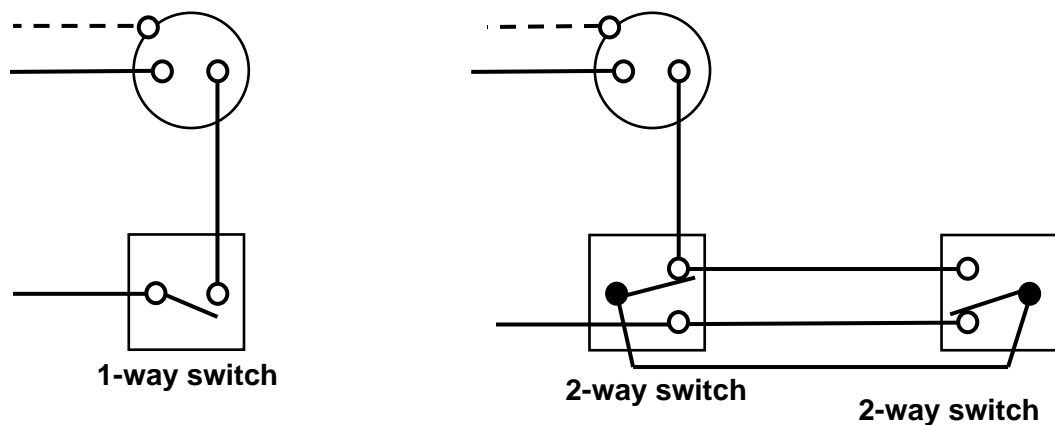


Fig 2-7 Conversion of a 1-Way Switch Circuit into a 2-Way Switch Circuit

Self-Check No. 5.1.3-7

1. What is two-way switch?
2. What is intermediate switch?

Answer Key No. 5.1.3-7

1. Two-way switches have 3 terminals, one of which is called the common (C); the other two are called the strappers and are usually marked L1 and L2 respectively.
2. Intermediate switches have 4 terminals and although the switch action of different makes of switch end up with the same results, the connections vary.

Information Sheet No. 5.1.3-8: Power Circuits

1. Power Circuit

Power circuits supply current to sockets into which you plug your electrical appliances and lamps. Some appliances in more or less constant use (i.e., washing machines, refrigerators) may not plug in, but instead connect directly to the power circuit. There are also special circuit for individual appliances which use a lot of electricity, such as cookers and water heaters.

Like lighting circuits, the power circuits start at the consumer unit, and each has its own MCB or fuse.

The fuse in the 13 A plug protects the flexible cord and the appliance, so the power circuit MCB or fuse now protects only the circuit cables and the socket outlets.

RECOMMENDED ARRANGEMENTS OF DOMESTIC CIRCUITS USING SOCKET-OUTLETS

The standard circuit arrangements, other than lighting final circuits, are:

- Final circuits using socket outlets complying with SS 145.
- Final circuits using socket outlets complying with BS 546.
- Final radial circuits using socket outlets complying with IEC 309-2 or BS 4343.
- Cooker final circuits in household premises.

Consideration should be given to the provision of a separate circuit in a kitchen.

A. FINAL CIRCUITS USING SOCKET OUTLETS COMPLYING WITH SS 145

Final circuit using socket outlets complying with SS 145 consists of:

- Radial final circuit using 13A switched socket outlets
- Ring final circuit using 13A switched socket outlets

(i) RADIAL FINAL CIRCUIT

Radial circuit wiring consists of a cable run from consumer unit to a number of socket outlets looped-in (ie. connected in-parallel) on one circuit. (Fig 3-1)

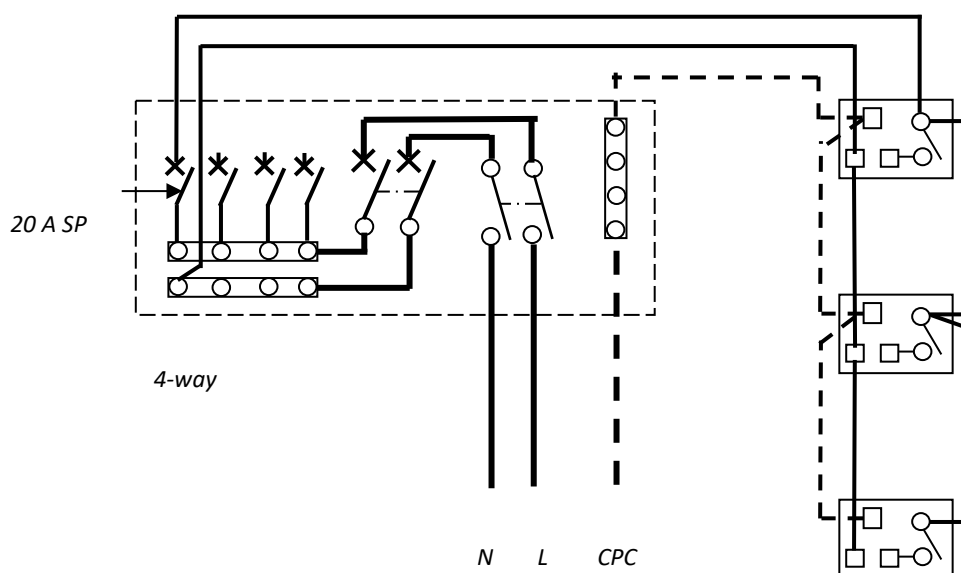


Fig 3-1 Wiring Diagram of a Radial Final Circuit Using 13A SSOs

General Requirements for Radial Final Circuits

- a. 20 A fuse or MCB protection with 2.5 mm² PVC or 1.5 mm² MI cables feeding a floor area of not more than 50 m². If the circuit feeds a kitchen or utility room, it must be remembered that high current using equipment such as a washing machine or a tumbler dryer leaves little capacity for the rest of the sockets. Consideration should be given to the provision of a separate circuit.
- b. 32 A fuse or MCB feeding through 4 mm² PVC or 2.5 mm² MI cables to supply a floor area no greater than 75 m².
- c. Permanently connected equipment and an unlimited number of socket outlets, inclusive of spurs if any, can be fed.
- d. The maximum demand of connected current-using equipment must not exceed the rating of the overcurrent protective device (OCD).
- e. Guidelines on the rating of protective device; type and minimum size of conductor; and maximum floor area to be served are given in Fig 3-2.

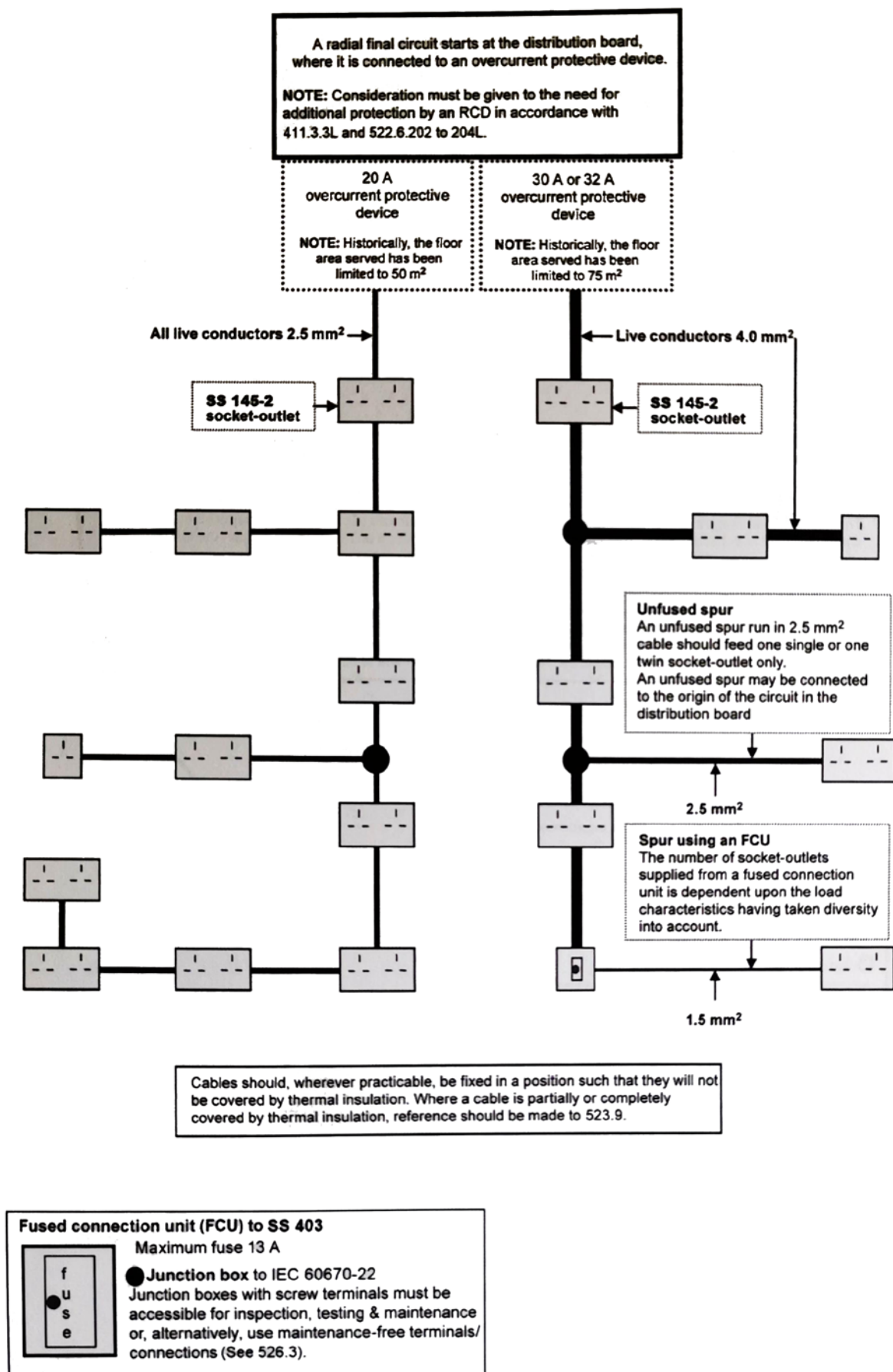


Fig 3-2 Radial Final Circuit arrangements for 13A Switched Socket Outlets

(ii) RING FINAL CIRCUIT

The cable in a ring circuit wiring runs from the consumer unit to each socket on the circuit and then back to the consumer unit again as shown in Fig 3-3.

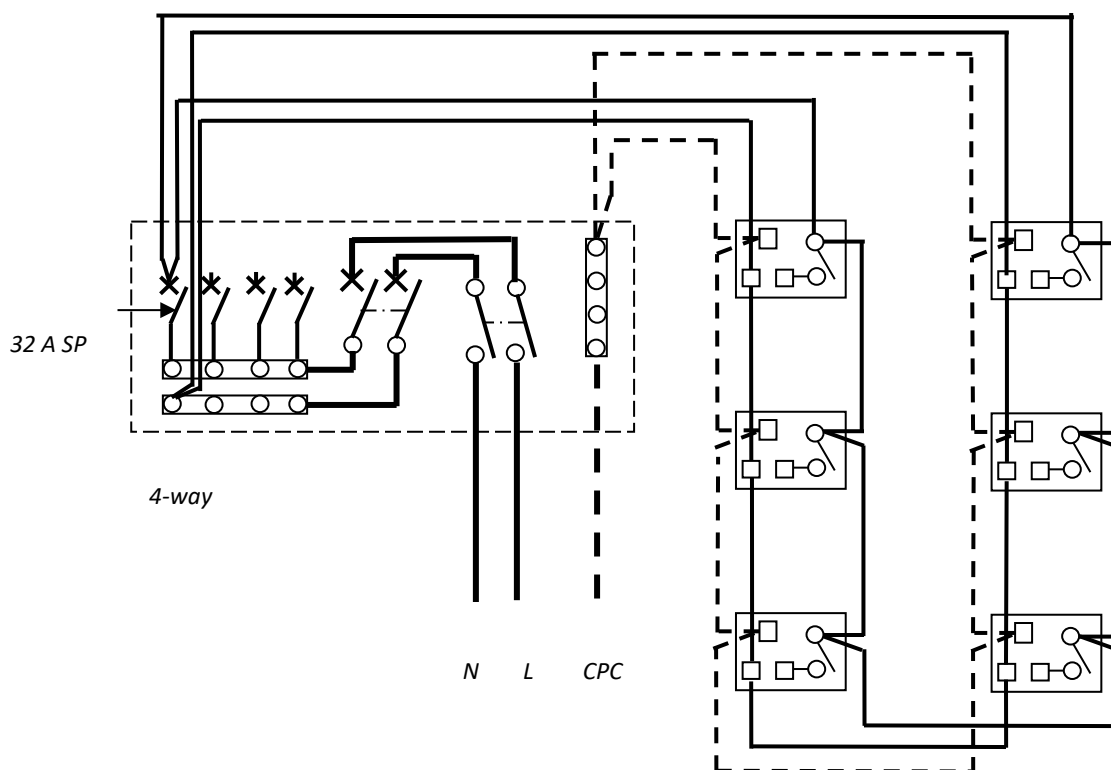


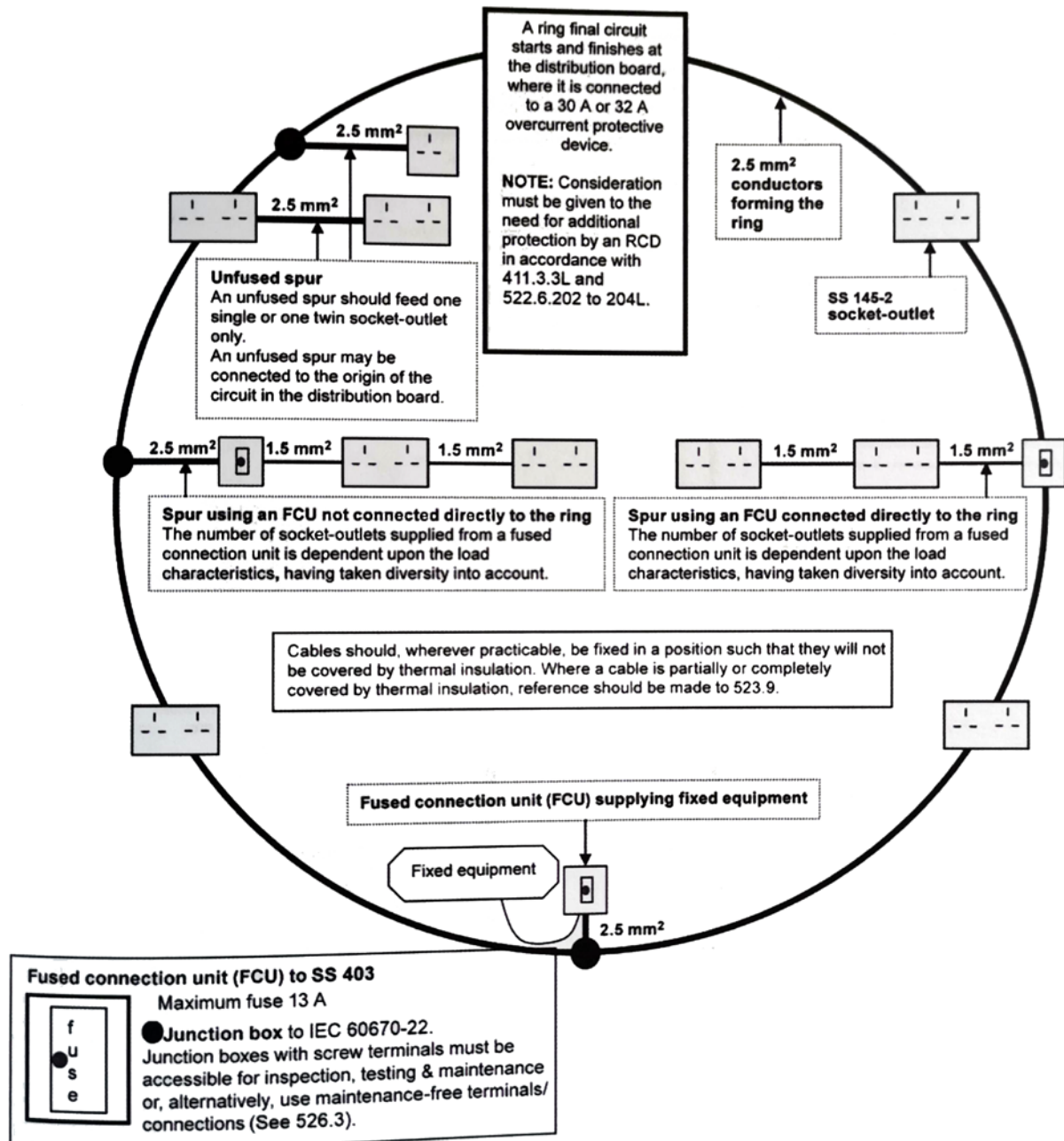
Fig 3-3 Wiring Diagram of a Ring Final Circuit

General Requirements for Ring Final Circuits

- The floor area served by each ring must not exceed 100 m² for domestic situations.
- Where ring circuits are used in commerce or industry, the diversity must be assessed to ensure that the maximum demand will not exceed the rating of the protective device.
- Consideration should be given to the provision of a separate ring (or radial) circuit in a kitchen.
- Where there is more than one ring circuit in the same building, the installed sockets should be shared approximately evenly between them.
- Cable sizes for ring circuits are 2.5mm² PVC or 1.5mm² mineral insulated (MI) cables.
- Permanently connected equipment and an unlimited number of socket outlets, inclusive of spurs if any, can be fed.
- The maximum demand of connected current-using equipment must not exceed the rating of the overcurrent protective device (OCD).
- Guidelines on the rating of OCD; type and minimum conductor size and maximum floor area served are given in Fig 3-4.

Note:

Each socket outlet of a twin or multiple sockets is regarded as one socket outlet.



Maximum floor area served 100 m².

Fig 3-4 Ring Final Circuit arrangements

SPURS

Spur is a branch circuit cable connected to a ring or radial final circuit. This is a result where most homes still do not have enough socket outlets to cope with the demands of modern living.

One answer is to use adaptors or extension leads, but these can be dangerous as well as inconvenient, and they are certainly no good for powering fixed appliances such as refrigerators.

The only satisfactory solution is to install extra sockets or fused connection units, exactly where you need them, so that flexible cords to appliances are kept short and outlets cannot be overload.

NON-FUSED SPURS

A spur is a branch cable connected to a 13 A circuit and **cannot** be used in kitchens.

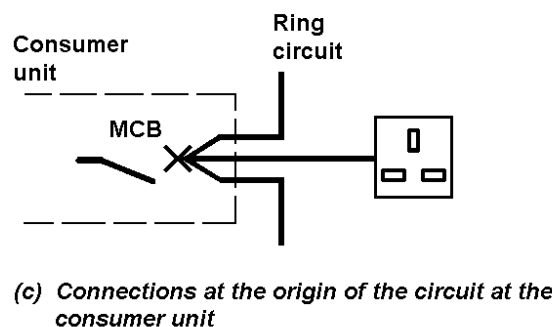
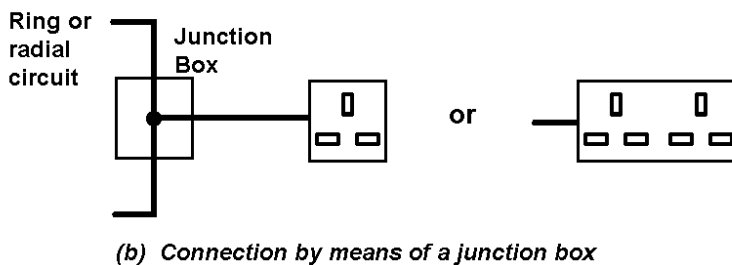
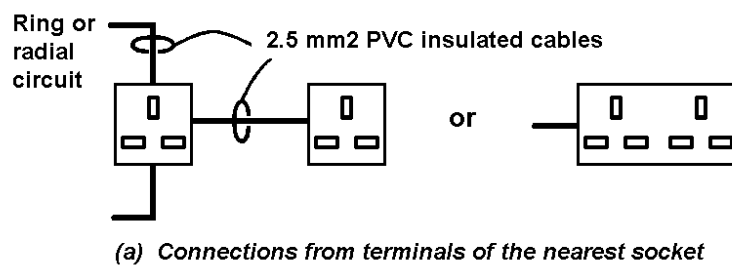


Fig 3-5 Non-Fused Spurs

The total number of non-fused spurs which may be connected to a 13A circuit must not exceed the total number of socket or fixed appliances connected direct in the ring.

Each non-fused spur may feed not more than one single or one twin socket outlet or one fixed appliance.

Non-fused spurs may be looped from the terminals of the nearest socket, or by means of a junction box in the circuit. For ring circuit, they can be connected at the origin of circuit at the consumer unit.

The size of the cable feeding non-fused spurs must be the same size as the circuit cable.

FUSED SPURS

The cable forming a fused spur must be connected to the ring circuit by means of a fused connection unit.

The rating of the fuse in this unit shall not exceed the rating of the cable forming the spur, and must not exceed 13A.

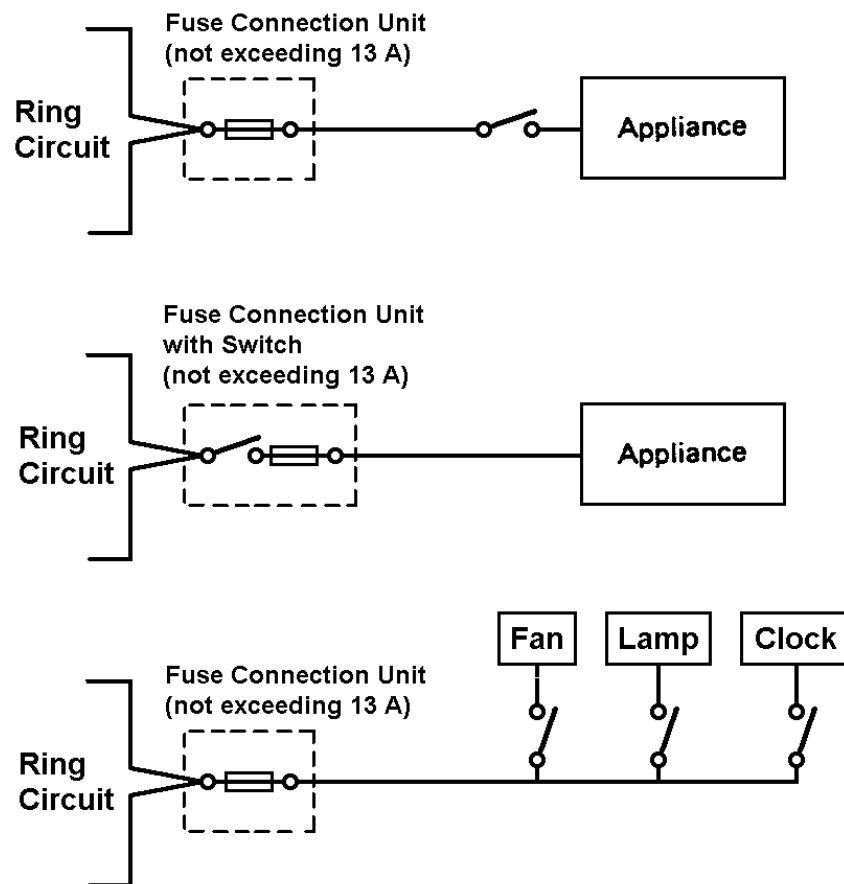


Fig 3-6 Fused Spurs

There is no limit to the number of fused spurs that may be connected to a ring.

The minimum size of cables forming a fused spur shall be 1.5mm² PVC with copper conductors, or 1.0mm² mineral insulated cables with copper conductors.

Fixed appliances permanently connected to 13A circuit (not connected through a plug and socket), must be protected by a fuse not exceeding 13A and a double-pole switch or a fused connection unit which must be separate from the appliances and in an accessible position.

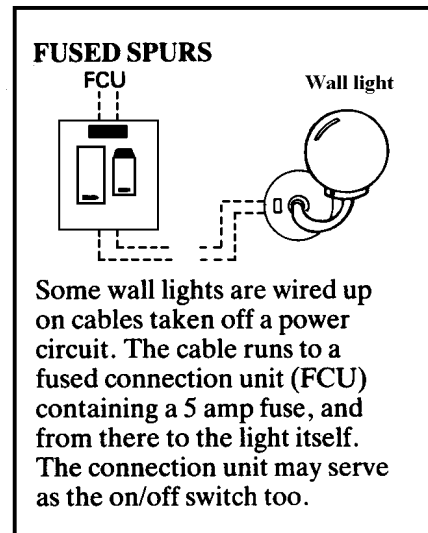


Fig 3-7 Example of a Fused Spur

PERMANENTLY CONNECTED EQUIPMENT

Permanently connected equipment or fixed loads should be locally protected by a fuse not exceeding 13A and be controlled by a switch or be protected by a circuit breaker not exceeding 16A.

Cable size for spur is dependent on the magnitude of the connected load.

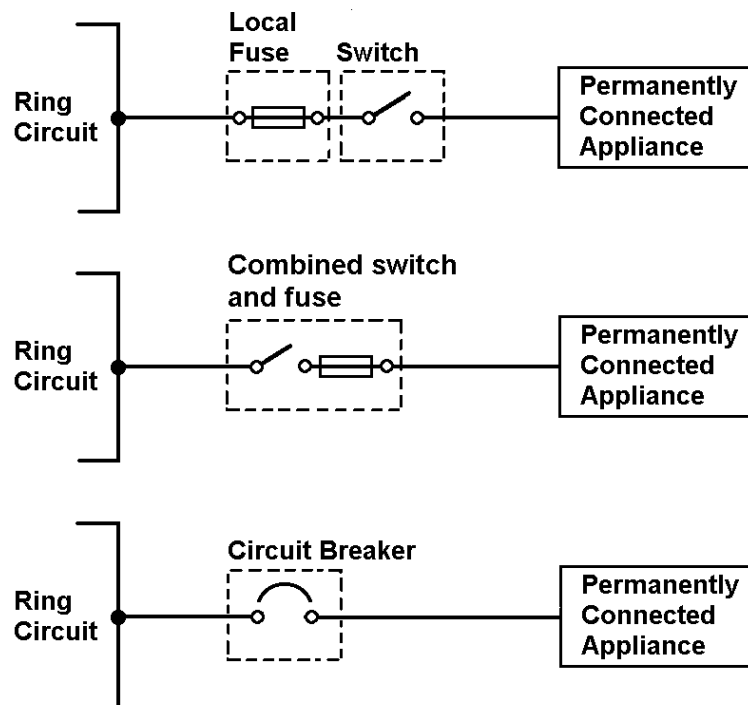


Fig 3-8 Permanently Connected Equipment

B. FINAL RADIAL CIRCUITS USING 16A SOCKET OUTLETS COMPLYING WITH IEC 309-2 OR BS 4343

There is no reason at all to prevent the installation of 13A socket outlets in industrial situations. Indeed, where light industries, such as electronics manufacture, are concerned, these sockets are most suitable.

Plugs and sockets to IEC 309-2 or BS 4343 (Fig 3-9) are available in 16A, 32A, 63A and 125A. They are for use in industrial circuits and construction site installations.

Fig 3-9 Industrial Plug and Socket to IEC 309-2 or BS 4343

Voltage Discrimination for IEC 309-2 Socket Outlets

This is achieved in two ways:

- By colour codes
- By the positioning of the earth contact in relation to a keyway.

The range of accessories consists of plugs, sockets, cable couplers and appliance inlets. They are available for single and three-phase supplies with a voltage between phases not exceeding 750V at a rated current of up to 125A.

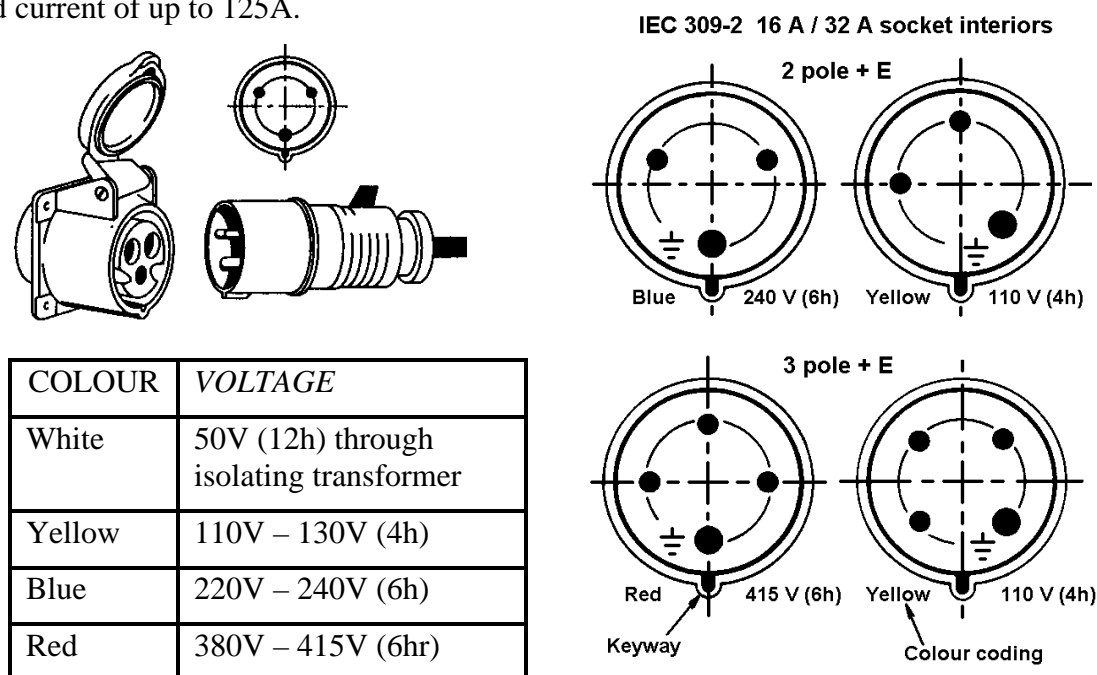


Fig 3-10 Colour Coding and Voltage Discrimination of IEC 309-2 Sockets

COOKER FINAL CIRCUITS IN HOUSEHOLD PREMISES

A cooker is regarded as a piece of fixed equipment unless it is a small table-mounted type fed from a plug by a flexible cord.

A cooking appliance circuit must include a control switch or cooker control unit which may incorporate a socket outlet.

The rating of the circuit should be properly calculated and determined by assessment of the current demand with allowances for diversity from Guidance notes or from the designer of the installation.

A circuit of rating exceeding 15 A but not exceeding 50 A may supply 2 or more cooking appliances where these are installed in one room.

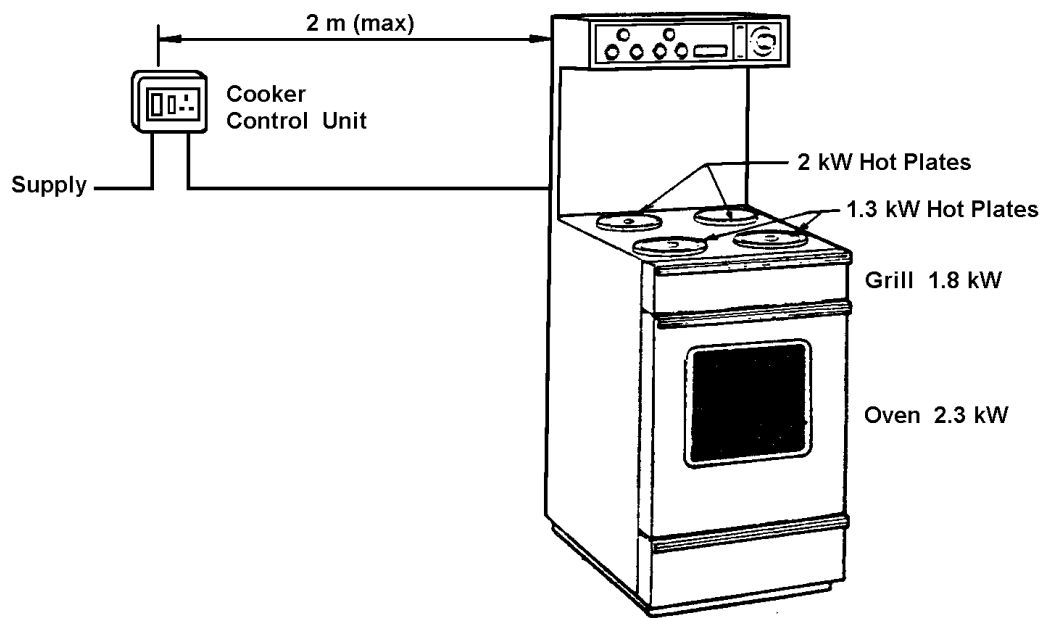


Fig 3-11 Electric Cooker Circuit

Example 1

A 230 V, 50 Hz domestic electric cooker has the following connected loads:

- (a) 2 nos 2.0 kW hot-plates;
- (b) 2 nos 1.3 kW hot-plates;
- (c) 1 no 1.8 kW grill; and
- (d) 1 no 2.3 kW oven

Determine the maximum demand of this cooker circuit if it is connected with a cooker control unit incorporating a 13A switched socket outlet.

Solution:

$$\begin{aligned}\text{Total cooker load control unit} &= (2 \times 2) + (2 \times 1.3) + 1.8 + 2.3 \\ &= 10.7 \text{ kW}\end{aligned}$$

$$\text{Total current} = \frac{P}{U} = \frac{10.7 \times 10^3}{230} = 46.52 \text{ A}$$

The demand is made up of:

$$\begin{aligned}\text{First 10 A} &= 10.0 \text{ A} \\ + 30 \% \text{ of remainder} &= \frac{30 \times (46.52 - 10)}{100} = \frac{30 \times 36.52}{100} = 10.96 \text{ A} \\ + \text{allowance for socket outlet} &= 5.0 \text{ A} \\ \text{Total} &= 25.96 \text{ A}\end{aligned}$$

A 30 A protective device is selected for use.

Self-Check No. 5.1.3-8

1. What is radial final circuit?
2. What is ring final circuit?

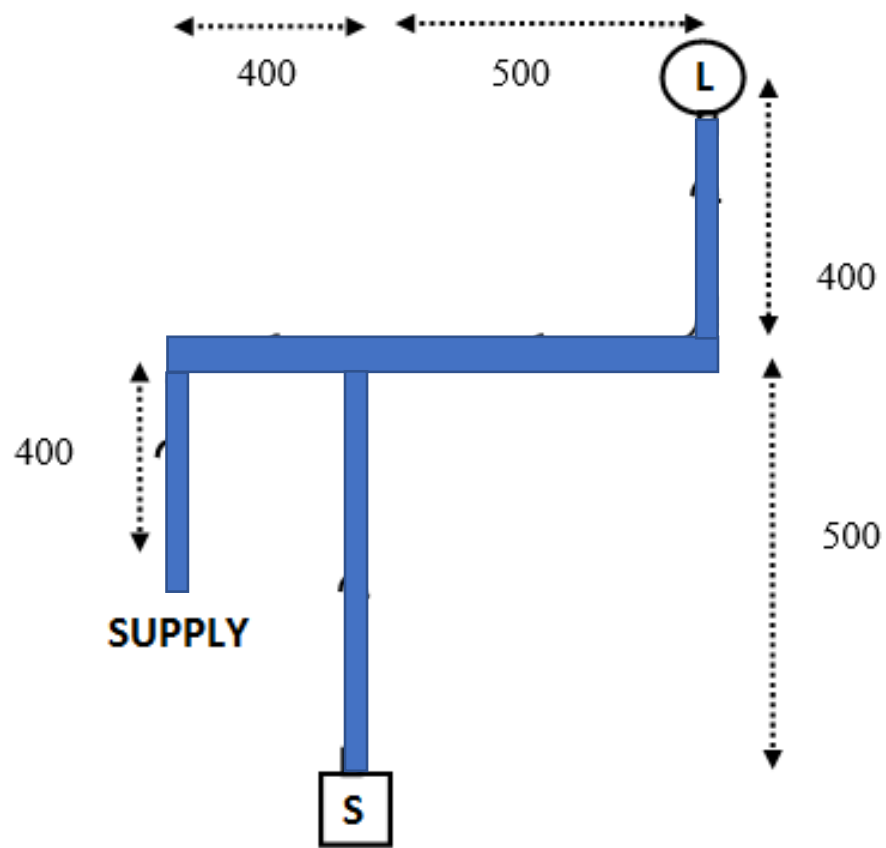
Answer Key No. 5.1.3-8

1. Radial circuit wiring consists of a cable run from consumer unit to a number of socket outlets looped-in (ie. connected in-parallel) on one circuit.
2. The cable in a ring circuit wiring runs from the consumer unit to each socket on the circuit and then back to the consumer unit again.

TASK SHEET 5.1.3-1	
Title: Install PVC trunking for electrical circuit	
Performance Objective/s: <ol style="list-style-type: none"> 1. Interpret layout diagram. 2. Estimate the material required 3. Cut & Install PVC trunking for a one-way switching control 4. Perform inspection and measurement 	
Supplies/Materials : <ul style="list-style-type: none"> 50 X 50 mm PVC Trunking 30 X 10 mm PVC trunking End Box Wood screws, wiring nails 	
Equipment :	
Steps/Procedure: <ol style="list-style-type: none"> 1. A shop owner engaged the service of your company to carrying out the following extension wiring project (installation) in his office showroom. 2. You are tasked by your supervisor to carry out installation of trunking together with your colleague. On completion of the installation, you are required to measure the layout and to check with leveler. 3. The layout of the installation is to be finalized as in Figure 1. 	
Assessment Method: Demonstration with oral questioning	

Performance Criteria Checklist	YES	NO
Did you....		

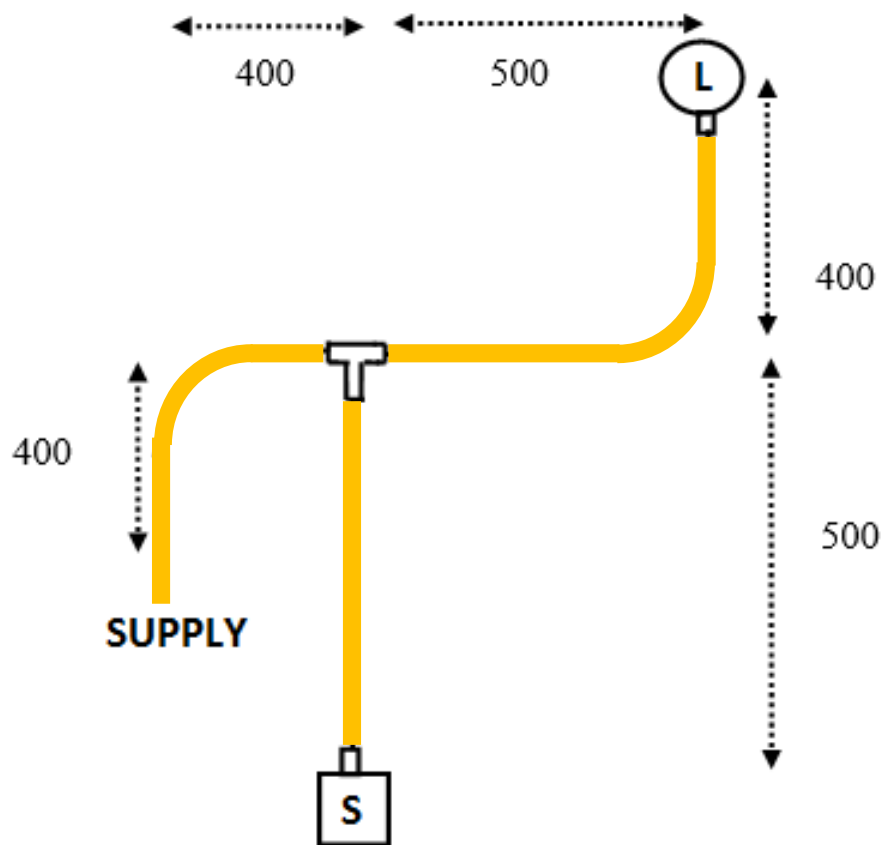
LAYOUT DIAGRAM:



TASK SHEET 5.1.3-2	
Title: Checking an installed PVC Conduit Bend	
Performance Objective/s: 1. To Cut, bend & Install PVC conduit for a one-way switching control 2. To interpret layout diagram.	
Supplies/Materials :	Diameter 20 mm PVC conduit End Box Saddler for 20mm PVC conduit Coupling for 20mm PVC conduit “T” Join for 20mm PVC conduit Wood screws, wiring nails
Equipment :	
Steps/Procedure: 1. A shop owner engaged the service of your company to carrying out the following extension wiring project (installation) in his office showroom. 2. You are tasked by your supervisor to carry out installation of conduit together with your colleague. On completion of the installation, you are required to measure the layout with leveler. 3. After some discussions with your colleague, the layout of the installation is finalized as in Figure 1.	
Assessment Method: Demonstration with oral questioning	

Performance Criteria Checklist	YES	NO
Did you....		

LAYOUT DIAGRAM:



TASK SHEET 5.1.3-3	
Title:	Lighting and Power Final circuits
Performance Objective/s:	<ol style="list-style-type: none"> 1. To Cut, Bend & Install PVC Trunking As shown In the Layout Diagram 2. To Install a Lighting & Ring Final Circuit Incorporating a Consumer's Control Unit 3. To draw The Wiring Diagram 4. To perform continuity and insulation test
Supplies/Materials :	25mm PVC Trunking PVC Square Base 13A Switch Socket-Outlet 1-Way Switch PVC Round Block Consumer Control Unit Batten Lamp holder 2.5mm ² PVC Insulated cable (brown Colour) 2.5mm ² PVC Insulated cable (blue Colour) 2.5mm ² PVC Insulated cable (green/yellow Colour) Wood screws, wiring nails
Equipment :	
Steps/Procedure:	<ol style="list-style-type: none"> 1. A shop owner engaged the service of your company to carrying out the following extension wiring project (installation) in his office showroom: <ol style="list-style-type: none"> a. A Lighting & Radial Final Circuit Incorporating a Consumer's Control Unit 2. You are tasked by your company to carry out this installation together with your colleague. On completion of the installation, you are required to test and commission the installation by conducting continuity test and insulation resistance measurement and testing the functionality of the final circuits. 3. After some discussions with the owner, the layout of the installation is finalised as in Annex A, Figure 1
Assessment Method:	Demonstration with oral questioning

Performance Criteria Checklist	YES	NO
Did you....		

Part 2 – Completing the wiring diagram

- Figure 1 is the layout drawing of the installation.
- Complete the wiring diagram in Figure 2 and submit to the invigilator.

Part 3 -Complete Continuity Test

Part 4 -Complete Insulation Test

Part 5 -Functionality Test of Final Circuits

Layout Diagram

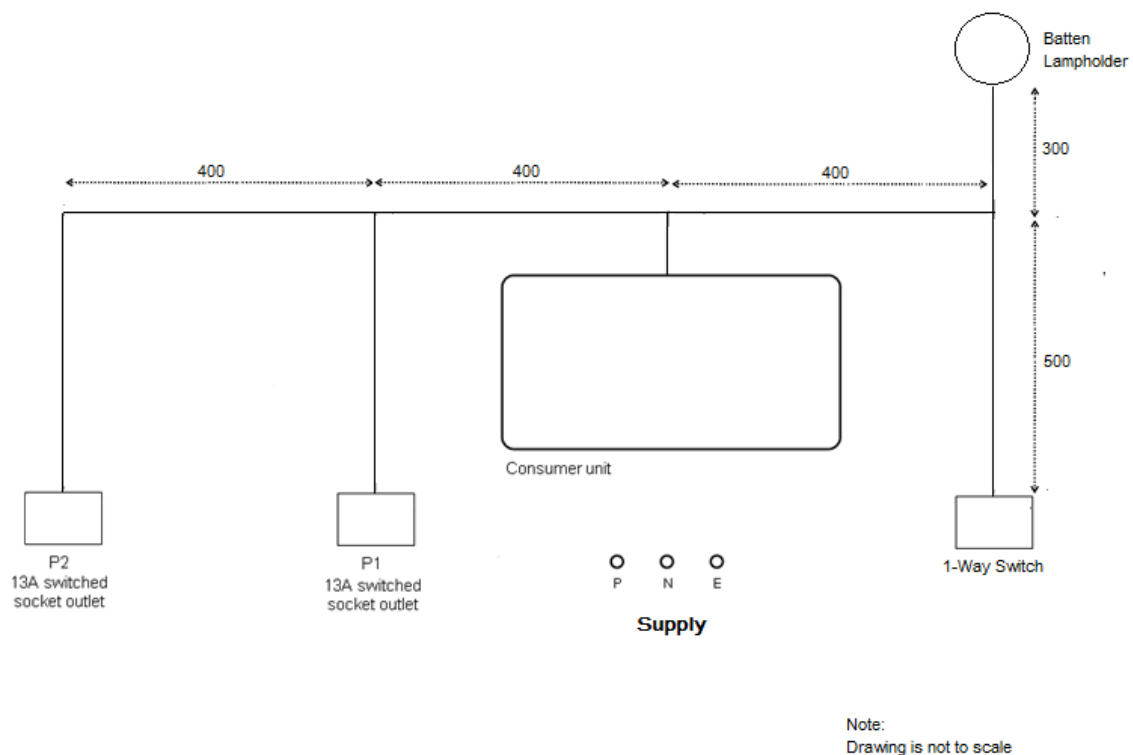


Figure 1

Wiring Diagram

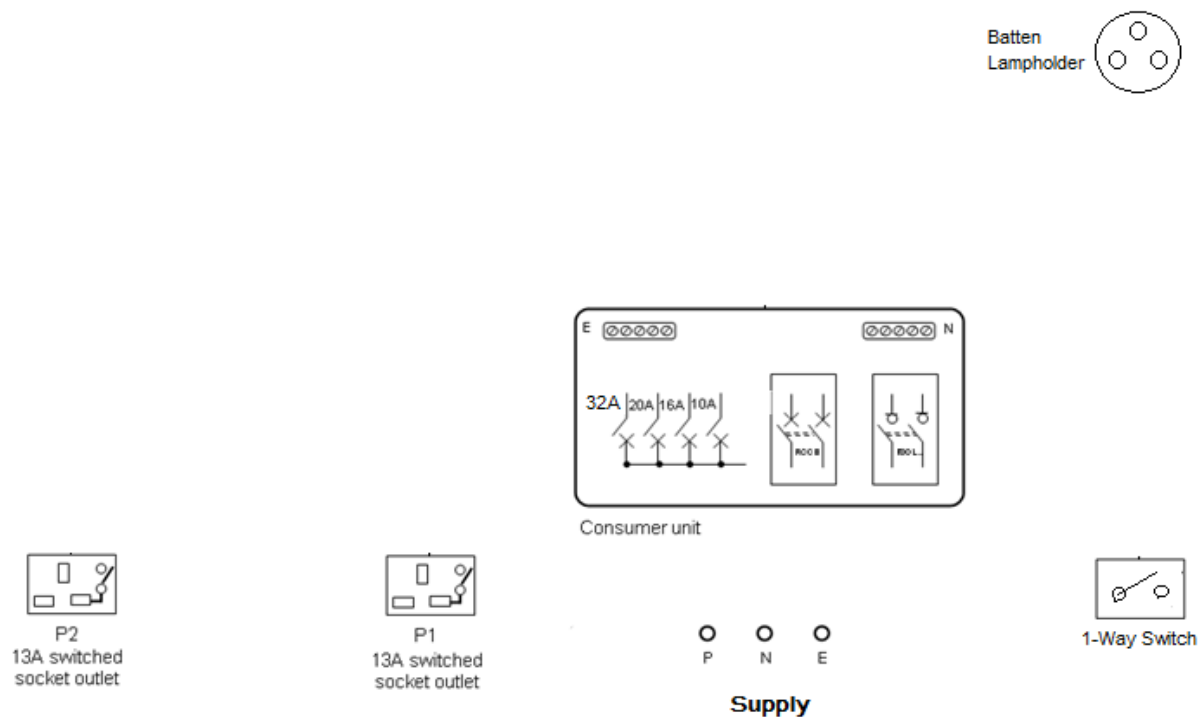


Figure 2

3. Continuity test

Measurement between Terminals (With Dead Circuit)	Measured Value (MΩ)
One Way Lighting circuit	
Phase at DB & Lighting point	
Neutral at DB & Lighting Neutral	
Earth at DB and at Lamp	
Phase & Neutral of lighting with lamp in circuit and switch turns on	
Radial Power circuit	
Phase at DB & Power circuit last point	
Neutral at DB & SSO neutral last point	
Earth at DB and SSO earth last point	

Phase & Neutral of power circuit with P&N at source temporary shorted with jumper link and resistance measured at SSO socket. (Remember to remove shorted link after measurement)	
Question 1: What is the continuity resistance of the Circuit Protective conductor for the power circuit for this installation? _____ Ohms Is this value met the minimum value required for the testing? Yes / No	
Question 2: What is the minimum acceptable continuity resistance for the lighting CPC? _____ Ohms	

4. Insulation Resistance test

Measurement between Terminals	Measured Value (MΩ)
Phase & Earth	
Phase & Neutral	
Phase to Phase	
Question 1: What is the test voltage value use for this installation? _____ Vdc	
Question 2: What is the minimum acceptable insulation resistance value of the installation? _____ MΩ	

L.O 04: Install and Maintain AC Incoming Supply System

Upon completion of this learning outcome, students or trainees will have the following competencies:

- Interpret electrical drawing from supply system to consumer installation.
- Draw wiring diagram for a single-phase incoming system correctly.
- Install AC incoming system including meter board and consumer unit according to requirements and regulations.
- Read energy meter correctly.
- Interpret energy bill correctly.
- Observe and adhere to safety rules and precautions during site visits, in workplaces and/or industry attachment.

Information Sheet No. 5.1.4-1: Electricity Supply Intake

To distribute electricity in a given area, sub-station is built at or near load centre of the area. Sub-station transformer changes electrical energy from one voltage level to another.

Consumers which require huge amounts of electricity, e.g. Shell Refinery are provided with 66 kV supply while many other consumers like hotels, flatted factories have 22 kV sub-stations installed in their premises.

1. THREE-PHASE, FOUR-WIRE DISTRIBUTION

The arrangement for obtaining 400V / 230V supply by means of delta-star transformer is generally used and is shown in Fig. 6-1 without the high-voltage and low-voltage protective switchgear:

- 3-phase, 3-wire high voltage source at sub-station is stepped-down by transformer to 3-phase, 400 V.
- 3-phase lines and a neutral (from transformer star point) are joined to busbars for distribution.
- Large consumers are supplied with 4-wire services, to give 230 V for 1-phase loads and 400 V for 3-phase loads.
- Domestic consumers requiring 1-phase supply, are taken from any one the 3 phases and neutral.
- In order to balance the three phases, consecutive services are connected to different phases and neutral in turn: Brown-N; Black-N and Grey-N. This helps to prevent any one phase being overloaded, thus
 - keeping the size of the cable used to a minimum;
 - reducing the current in the neutral; and
 - so keeping the distributing costs down.

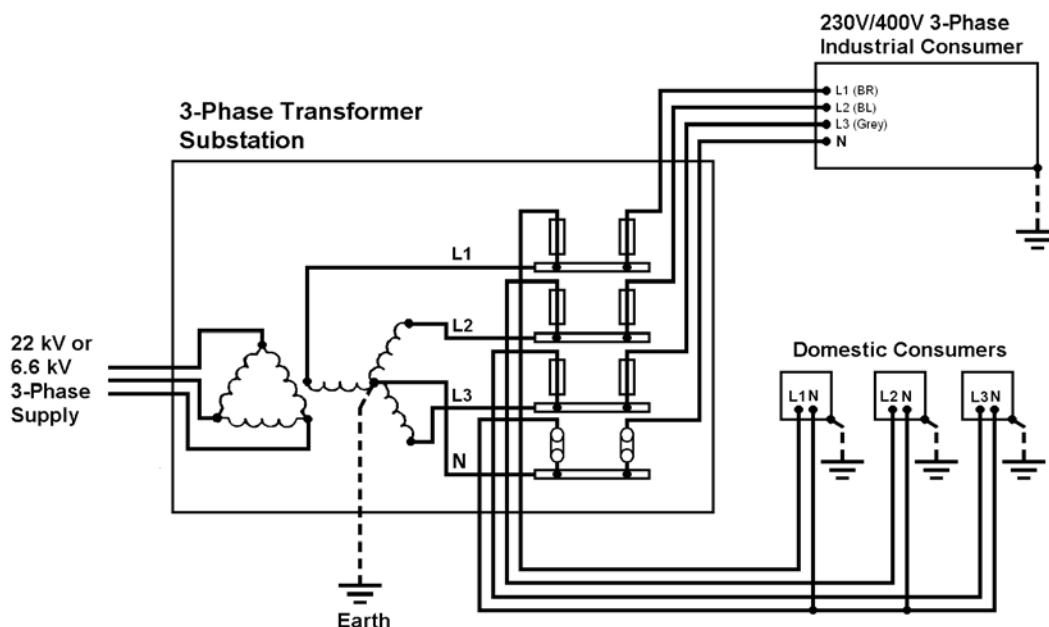


Fig 6-1 Three-Phase Four-Wire Distribution

SUPPLY INTAKE POSITION

The position in a building where electrical supply and main controls are situated is simply called intake. Intake normally forms the main distribution centre.

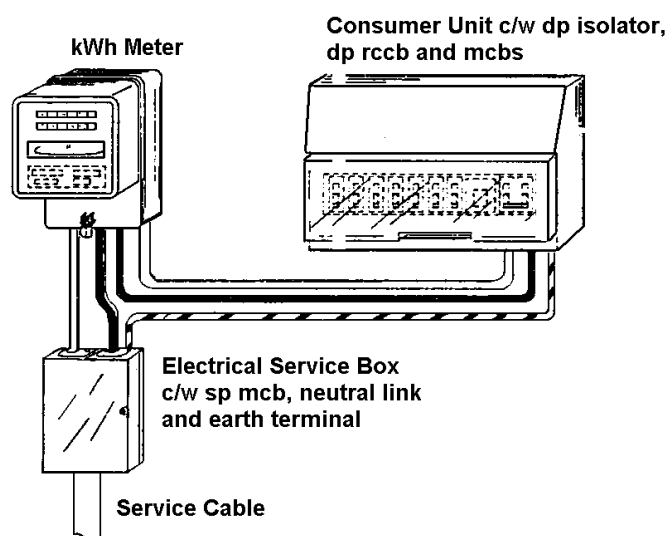
A Electrical Supply to Domestic Premises or Small Buildings

The supply intake to domestic premises (Fig 6-2) can be brought either through

- (a) an underground service cable and meter compartment located at the front-gate pillar or perimeter wall; or
- (b) cables in the vertical rising mains or horizontal mains to a meter board.

The height of the meter board shall be between 1 m and 1.8 m above ground level. The location of the meter is such that it is easily accessible to PSPL and Grid personal at all times for purposes of maintenance and reading of meters.

Fig 6-2 Typical Single-Phase Intake



SEQUENCE OF SUPPLY INTAKE EQUIPMENT

The sequence of control equipment (Fig 6-3) for all installation at the supply intake position is as follows:

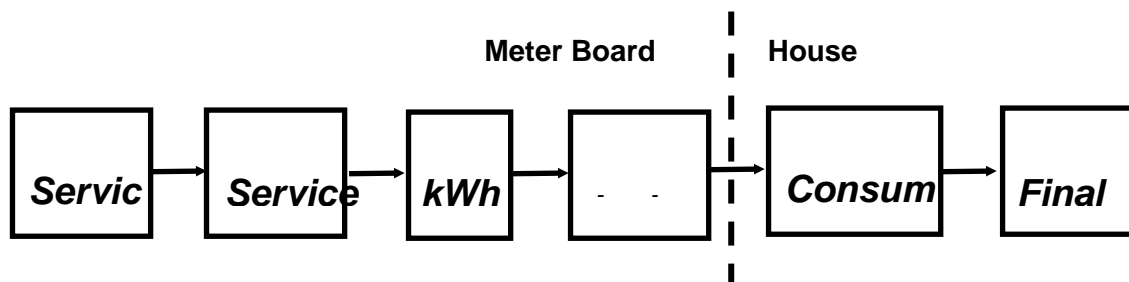


Fig 6-3 Sequence of Control

The above sequence must be followed accordingly. The consumer unit (CU) normally comprises the double-pole isolator, residual current circuit-breaker (RCCB) and a number of miniature circuit breakers (MCBs) or fuses of different ratings for protection of lighting and power circuits.

FUNCTION OF SUPPLY INTAKE EQUIPMENT

- Service circuit breaker or Cutout
 - For overcurrent protection
- kWh (Energy) meter
 - Used to register energy consumption
- Main switch / Miniature circuit breaker / Isolator

- As a means of isolation and switching
- Residual Current Circuit Breaker (RCCB) / Residual Current Device (RCD)
 - To disconnect the circuit when the current between the phase and neutral conductors are not balanced (equal). Such an imbalance is sometimes caused by current leakage through the body of a person who is grounded and accidentally touching the energized part of the circuit.
- Distribution board
 - For energy distribution to final circuits or other distribution boards.

B Electrical Supply to Large Buildings

Due to the higher electrical load, large buildings such as a hospital; factories; office blocks and shopping centers, will require a 3-phase supply.

The electrical installation is similar to a small building but is divided into sections. The intake and distribution units are normally made up of a standard factory-made cubicle switchboard.

Self-Check No. 5.1.4-1

1. What is the function of service circuit breaker or cutout?
2. What is the function of main switch/miniature circuit breaker/isolator?
3. What is the function of residual current circuit breaker/residual current device?
4. What is the function of distribution board?

Answer Key No. 5.1.4-1

1. Service circuit breaker or Cutout for overcurrent protection.
2. Main switch / Miniature circuit breaker / Isolator as a means of isolation and switching.
3. Residual Current Circuit Breaker (RCCB) / Residual Current Device (RCD) To disconnect the circuit when the current between the phase and neutral conductors are not balanced (equal). Such an imbalance is sometimes caused by current leakage through the body of a person who is grounded and accidentally touching the energized part of the circuit.
4. Distribution board for energy distribution to final circuits or other distribution boards.

Information Sheet No. 5.1.4-2: Internal Distribution

1. INTERNAL DISTRIBUTION SYSTEM

Internal distribution system consists of loads connected in parallel in a final circuit and the connection of final circuits to distribution board. The types of internal distribution system depend on the incoming supply, namely

- 1-phase, 2-wire installation (Fig 1-1)
- 3-phase, 4-wire installation (Fig 1-2)

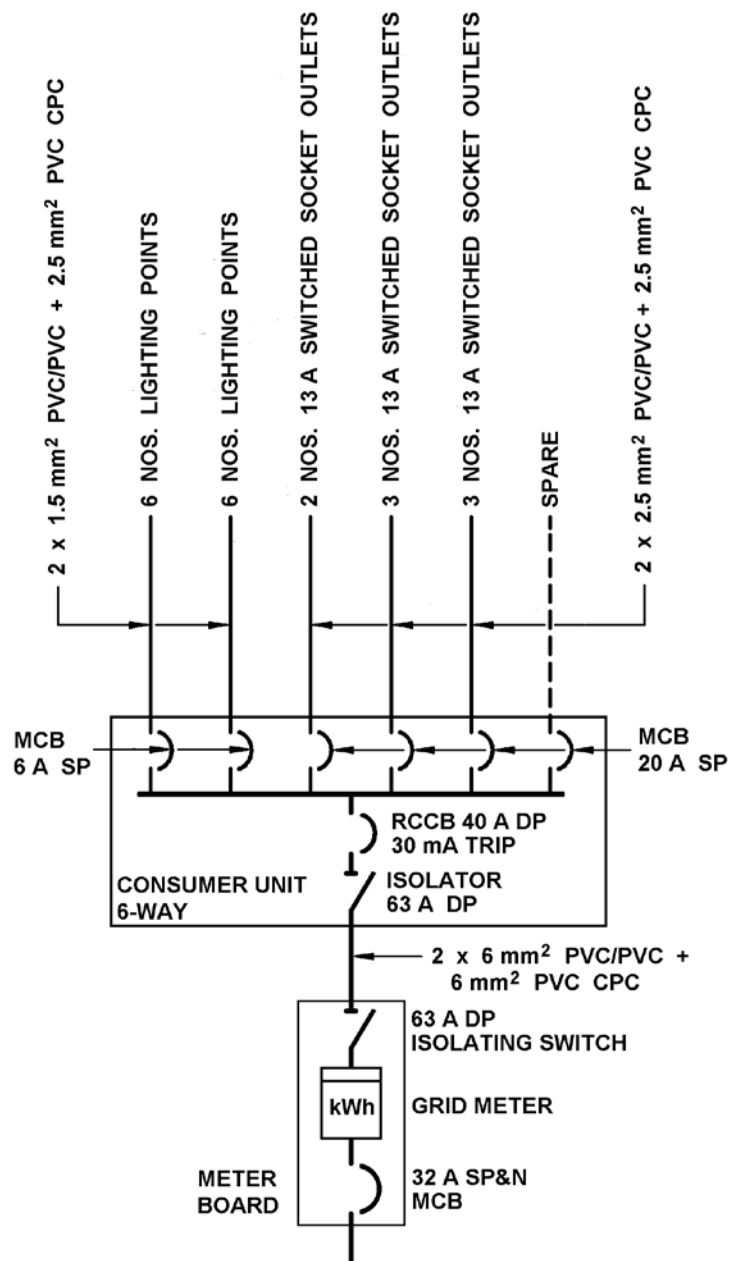


Fig 1-1 Typical Single-Line Diagram of Electrical Installation to 5-Room Apartment

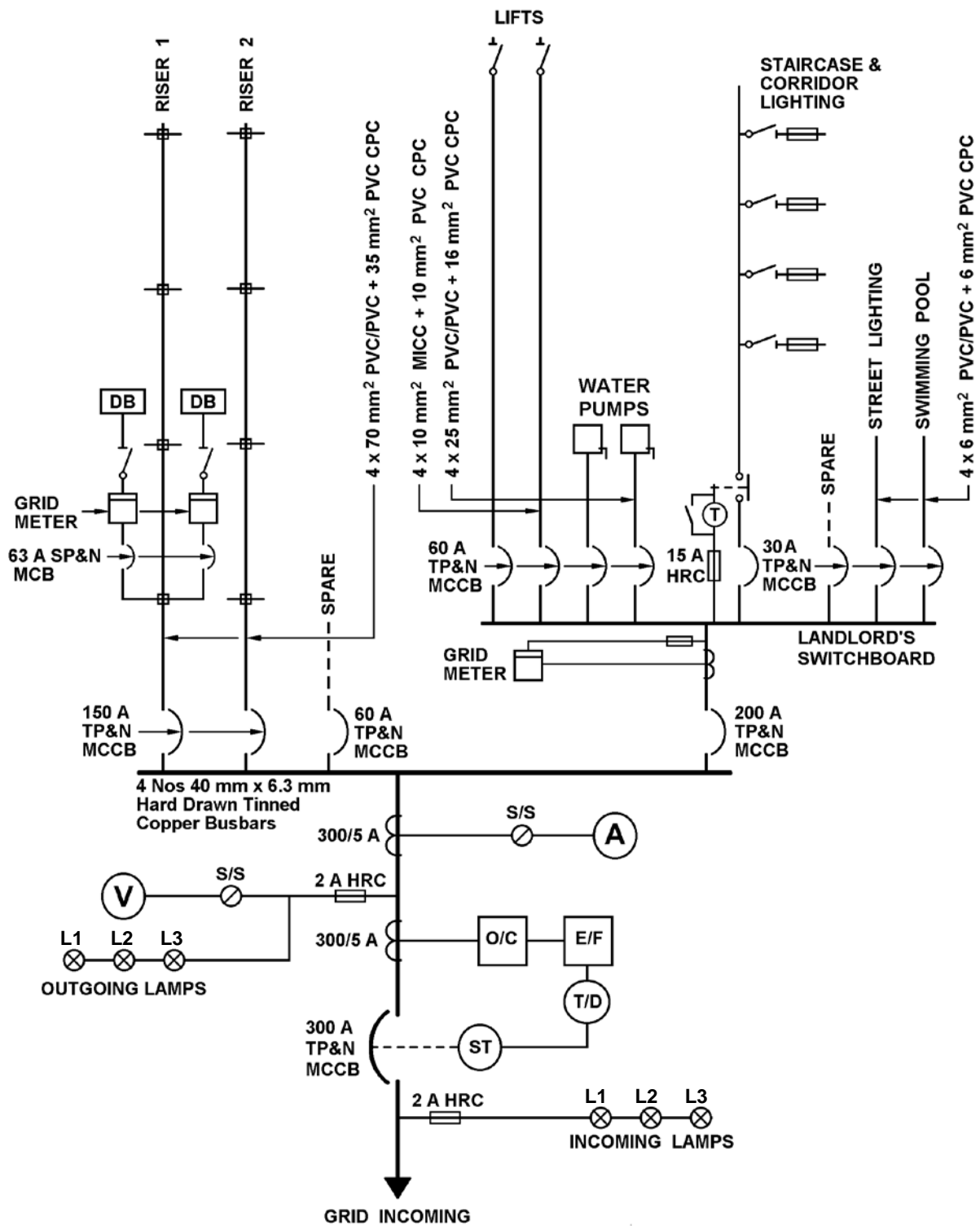


Fig 1 -2 Typical Single-Line Diagram of Electrical Installation to block of Flats (Condominium)

SUPPLY REQUIREMENTS

Depending upon the load requirements of a consumer, the electricity supply provided by Power Supply Ltd (PSL) are as follows:

- (a) 230 V, 50 Hz, single-phase, up to 23 kVA
- (b) 400 V, 50 Hz, 3-phase, 4-wire, up to a maximum of 2,000 kVA.
- (c) 22 kV, 50 Hz, 3-phase, 3-wire, up to a maximum of 30,000 kVA
- (d) 66 kV, 50 Hz, 3-phase 3-wire for supply requirements greater than 30,000kVA

When a consumer, especially with small loads, made an application for electricity supply service, PSL provides the following current ratings of standard service intake:

- (a) 30 A / 40 A 230 V single-phase
(Note: The 40 A is applicable for electricity supply via landlord's / HDB's installation only.)
- (b) 60 A / 100 A 230 V single-phase
- (c) 30 A / 60 A 400 V three-phase
- (d) 100 A 400 V three-phase

DISTRIBUTION IN A MULTI-STOREY BUILDING

When the power demand of an installation is in excess of above 100A single-phase, 230V, it becomes necessary for the incoming supply to be of 3-phase, 4-wire type in order to reduce the currents and hence, cable sizes, on both the supply and consumer side.

As in distribution system, it is important that the load currents are equally divided over the three phases, that is, they present a balanced demand to the incoming supply.

Another reason is that in a 3-phase supply, the neutral conductor only carries the out-of-balance current.

There are 2 commonly used methods of distribution for large buildings:

- radial; and
- rising mains.

Radial Distribution

The name comes from the fact that the electrical services to sub distribution boards radiate from the main switchboard (MSB).

The MSB normally consists of a main circuit breaker connected to various outgoing moulded case circuit breakers (MCCBs) through a busbar chamber. (Fig 6-3)

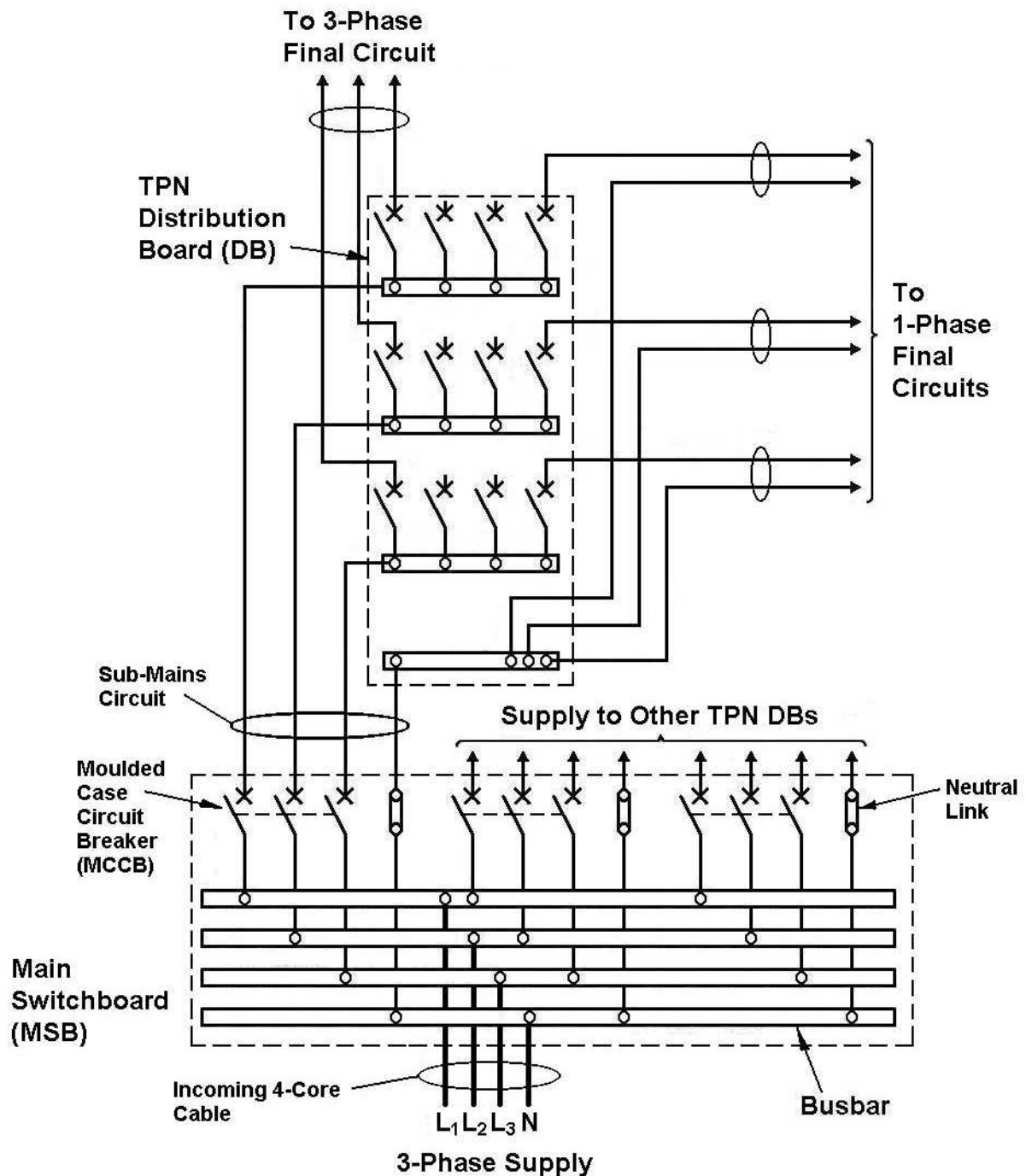


Fig 1-3 Detailed Diagram of a Radial Distribution System

Rising Mains Distribution

For buildings above 5 storeys in height, it is normally preferable to pass conductors vertically through the building. The supply to each floor is connected to the rising main by means of tap-off units. (Fig 1-4)

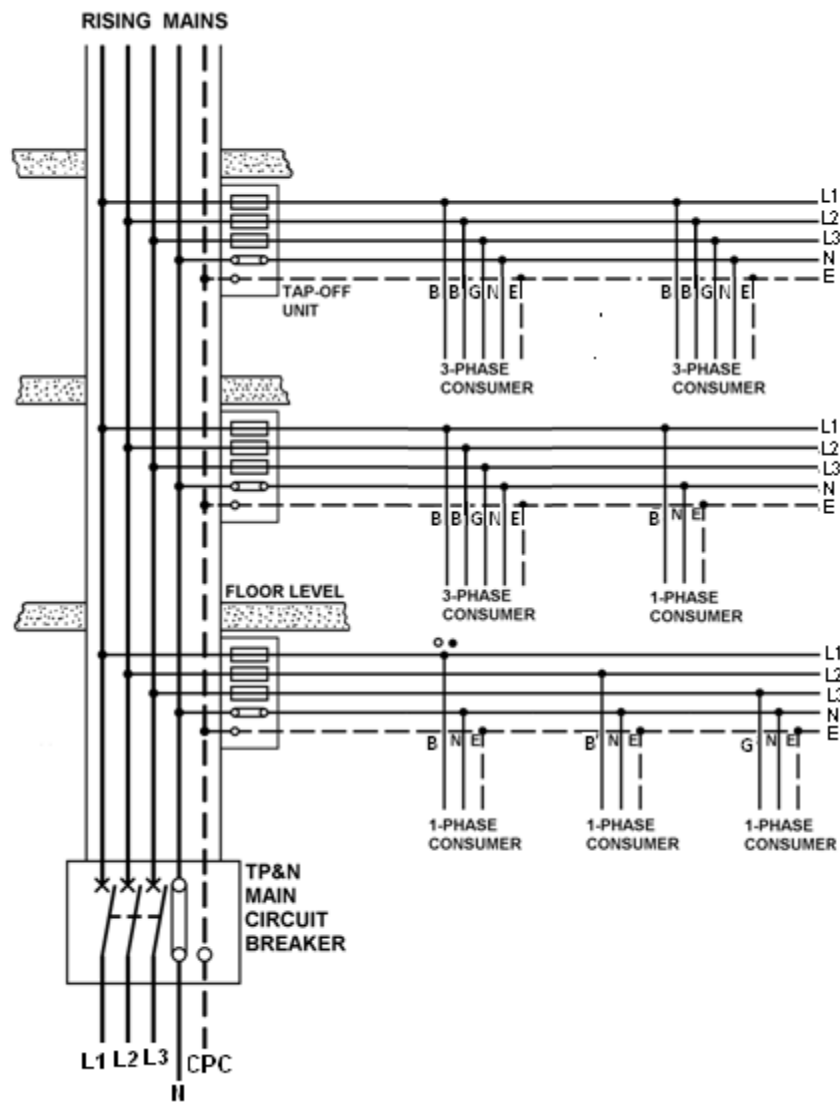


Fig 1-4 Detailed Diagram of a Rising Main Distribution System

Self-Check No. 5.1.4-2

1. What is internal distribution system?
2. How many methods of distribution for large buildings? Describe.

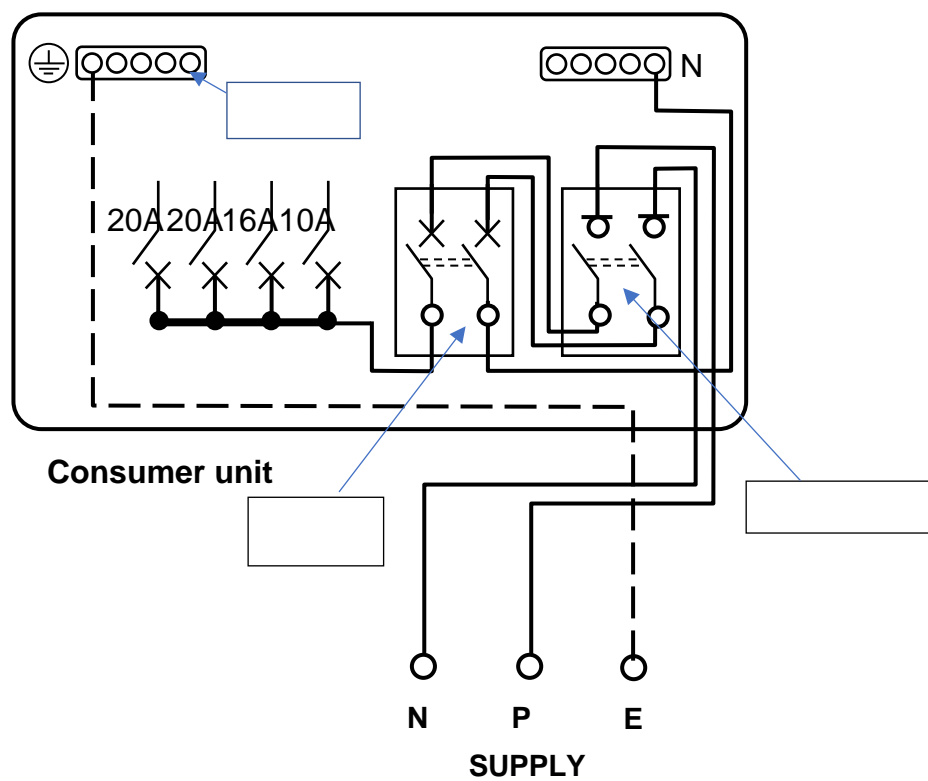
Answer Key No. 5.1.4-2

1. Internal distribution system consists of loads connected in parallel in a final circuit and the connection of final circuits to distribution board.
2. There are 2 commonly used methods of distribution for large buildings:
 - Radial
 - Rising mains

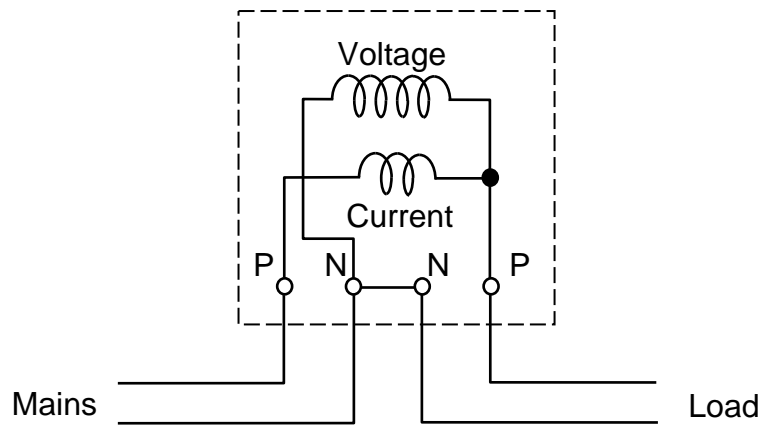
TASK SHEET 5.1.4-1	
Title: Installing a Single-Phase Meter Board in AC Incoming Supply	
Performance Objective/s:	<ol style="list-style-type: none"> 1. State the various components of the consumer unit. 2. Draw the circuit diagram of the domestic consumer switchgear arrangement. 3. State the reasons for the supply authority's use of lead seals on the energy meter. 4. State the size of the incoming cables. 5. Connect the following supply authority's equipment.
Supplies/Materials :	
Equipment :	
Steps/Procedure:	<ol style="list-style-type: none"> 1. A shop owner engaged the service of your company to carrying out the following extension wiring project (installation) in his office showroom. 2. You are tasked by your supervisor to carry out installation of trunking together with your colleague. On completion of the installation, you are required to measure the layout and to check with leveler. 3. The layout of the installation is to be finalized as in Figure 1.
Assessment Method: Demonstration with oral questioning	

Performance Criteria Checklist	YES	NO
Did you....		

1. Complete the labelling in the boxes indicated

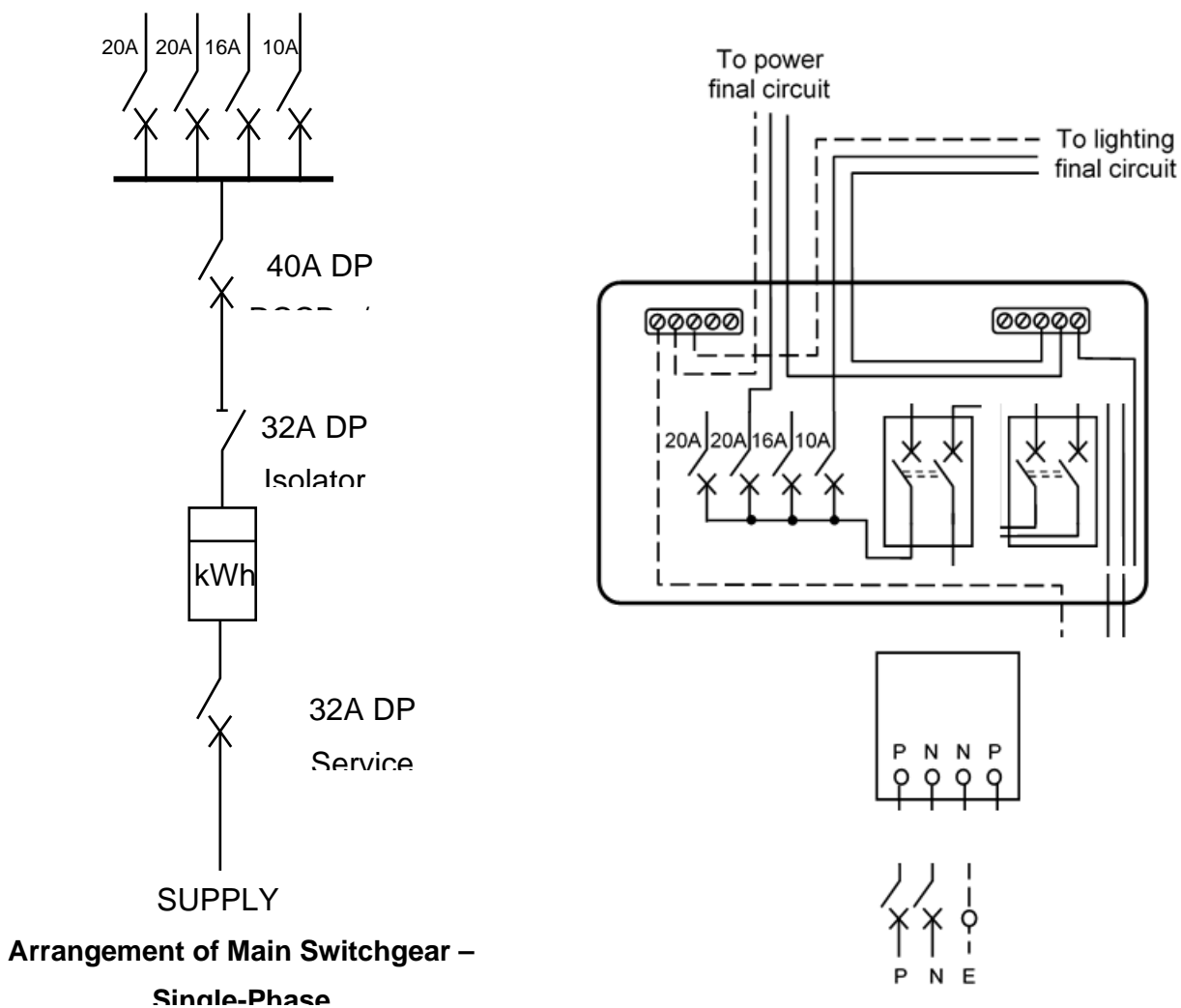


4-way Consumer Unit c/w RCCB, DP switch and MCBs



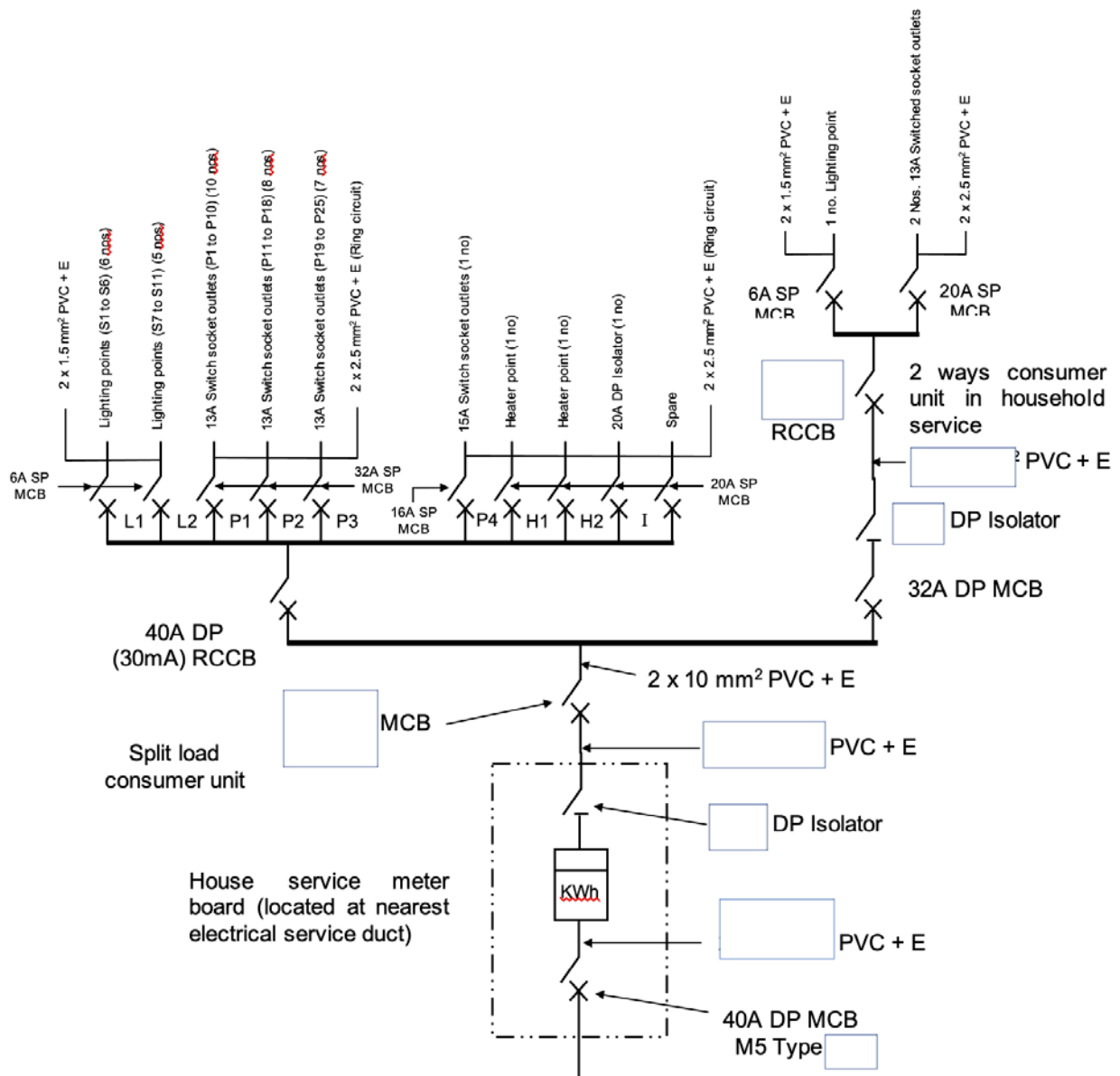
Internal connection of a single-phase Kilowatt-hour meter

2. Complete the wiring on the Single-phase kWh meter at AC incoming



3. Question: Why does the supply authority's use of lead seals on the energy meter?

- 4 Complete the single line diagram for the metering and incoming AC supply
- 5 Includes all the rating of isolator, circuit breakers and cable sizes in the boxes



Single-line Diagram of electrical installation to domestic installation

L.O 05: Inspect and Test Electrical Installations

Upon completion of this learning outcome, students or trainees will have the following competencies:

- Select required tools and test equipment for testing of electrical installation.
- Carry out inspection of completed installation to ensure compliance with specifications and relevant regulations.
- Conduct tests on completed installation in accordance with relevant regulations.
- Interpret and analyze test results.
- Perform rectification of faults.
- Document test results and actions in accordance with regulations.
- Observe and adhere to safety rules and precautions.

Information Sheet No. 5.1.5-1: Rectify Faults in Lighting Circuits

1. Electrical Circuit Faults

There are many types of faults that can occur in electrical circuits. These include not only failure of some physical component but also errors in the original design of the circuit.

The following focuses on hard wiring faults in lighting circuits that can occur either during normal use or can be a result of poor workmanship during installation.

1.1 High resistance connections

A high resistance connection can occur in a circuit anywhere a cable or wire is joined. This will usually be at an accessory such as a socket-outlet, switch, light fitting, or junction box.

1.1.1 Causes

The most common cause is simply a loose screw terminal connection. This may be because it was not made sufficiently well in the first place, it could be that dirt or other debris is present in the connection (remnants of insulation for example), or it might be that it has become loose over time. Connections that work loose can result from the normal thermal cycling of a circuit. If it routinely carries a significant proportion of its maximum design current, the cable will be subject to repeated heating and cooling cycles. This in turn results in expansion and contraction which can loosen the terminal's grip on its conductor(s). Environmental issues like vibration can also play a big part here. Good cable support and fixing can help mitigate these problems.

1.1.2 Effects

The most common effect of a high resistance connection will be localised heating around the connection. On a high current circuit even a small unwanted resistance (of the order of an ohm) can result in the dissipation of hundreds of watts of power at the joint. This will quickly damage the insulation of cable. The follow-on risks are that of fire, or circuit failure, or unexpected operation of the circuit protective device due to short circuit resulting from insulation failure.

A secondary effect can be that of excessive voltage drop experienced in other parts of the circuit. This can result in equipment damage, failure of protective devices to operate correctly, and flickering or variation in brightness of lamps etc.

1.2 Broken and disconnected conductors

Less common than high resistance connections are completely open-circuit connections.

1.2.1 Causes

These can occur because a wire is no longer (or never was) making contact with the terminal or has broken or been damaged. The most common wire in a circuit to suffer this problem is the small size conductor. They are usually unsheathed and hence requires protection by a slip-on sleeve. They are easier to break by over-tightening of terminals and are more likely to not ever be connected in the first place as the presence of the loose sleeving can obstruct visibility of the actual conductor which can make it more difficult to position and hold the wire in place in the terminal when tightening.

1.2.2 Effects

On live and neutral connections, a broken conductor will either stop a circuit working correctly or may result in a risk of overload in a part of it.

In the case of a broken CPC the risks can be much greater, since it could impair or prevent operation of the protective devices in the circuit and could expose someone to a serious shock hazard.

1.3 Worn and defective accessories

Accessories have a limited life span. This in particular applies to sockets. Over time the terminals will get dirty and can lose some of their spring tension. This will cause high resistance connections. The knock-on effect of local heating can further damage the socket. Switches may also get dirty and develop resistance, or simply break and fail to switch any more leaving the accessory permanently stuck in one position or the other.

2 Fault and overload currents

The terms "Fault current" and "Overload Current" have specific meanings in the context of the wiring regulations.

2.1 Fault Current (Short circuit current)

This is the current that flows when a short circuit fault occurs in a circuit between either the live and neutral conductors, or the live and earth conductors.

A common short circuit fault was on the bulb holder which can get damaged by heat. which also makes the cable brittle and then the insulation fails.

The magnitude of fault currents can be huge (100s or 1000s of Amps) since they are limited only by the resistance of the wires in the circuit between the consumer unit and the fault, and the impedance of your power supply and earth connection as delivered to the property.

2.2 Overload Current

This occurs when the total current demand made by the appliances connected to the circuit exceed its design capacity. This significance of an overload will depend on its magnitude and its duration. Small overloads may be tolerable for long durations, while big ones can only be tolerated for short durations, before any damage to the circuit wiring occurs.

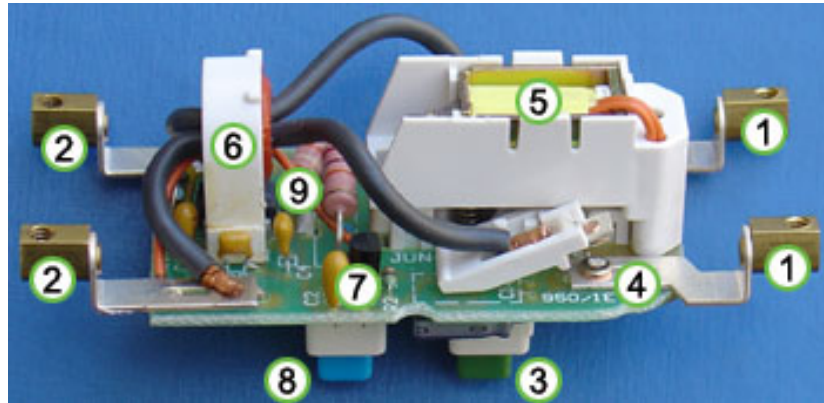
3 Earth fault and its protective device - RCCB

3.1 Earth Fault

Earth Fault is an inadvertent fault between the live conductor and the earth. When earth fault occurs, the electrical system gets short-circuited and the short-circuited current flows through the system. The fault current returns through the earth or any electrical equipment, which damages the equipment. It also interrupts the continuity of the supply and may shock the user. To protect the equipment and for the safety of people, fault protection devices are used in the installation.

3.2 Earth Fault Protection Devices

The devices give the tripping command to break the circuit when earth fault occurs. The fault current is restricted, and the fault is dispersed by the Restricted Earth Fault Protection (REFP) scheme. Normally earth fault relay (EFR), earth leakage relay (ELR) Residue current circuit breaker (RCCB) or earth leakage circuit breaker (ELCB, old name) are used to restrict the fault current.



3.2.1 RCCB construction and working principle

Terminal 1: For incoming supply and the neutral conductors

Terminal 2: For outgoing load conductors Reset button

(3): When it is pressed, the contacts (4) and (5) close, allowing current to pass.

Solenoid (5): It keeps the contacts closed when the reset button is released.

Sense coil (6): It is a differential current transformer which surrounds (but is not electrically connected to) the live and neutral conductors.

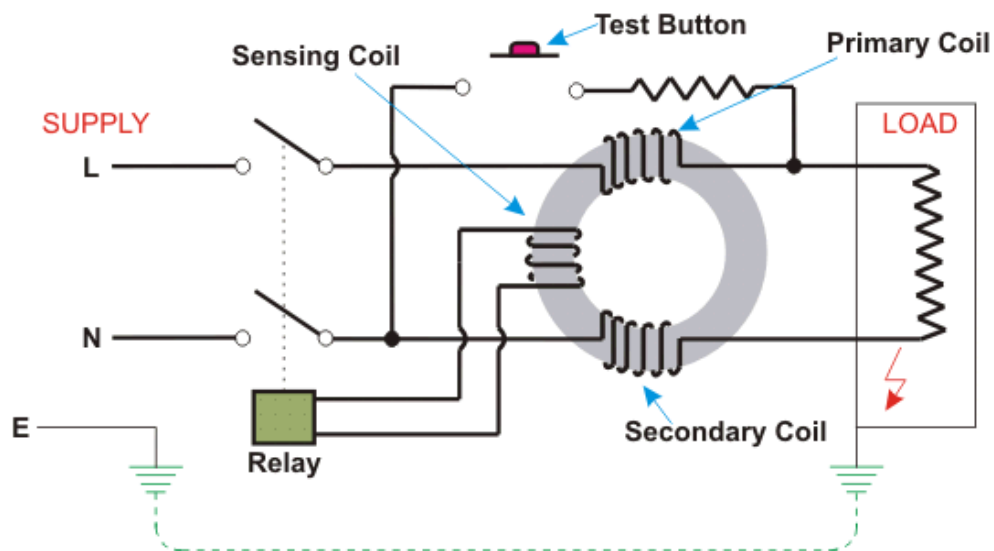
In normal operation, all the current down the live conductor returns up the neutral conductor. The currents in the two conductors are therefore equal and opposite and cancel each other out.

Any fault to earth (for example caused by a person touching a live component in the attached appliance) causes some of the current to take a different return path, which means that there is an imbalance (difference) in the current in the two conductors (single-phase case), or, more generally, a nonzero sum of currents from among various conductors (for example, three phase conductors and one neutral conductor).

This difference causes a current in the sense coil (6), which is picked up by the sense circuitry (7). The sense circuitry then removes power from the solenoid (5), and the contacts (4) are forced apart by a spring, cutting off the electricity supply to the appliance.

The test button (8) allows the correct operation of the device to be verified by passing a small current through the orange test wire (9). This simulates a fault by creating an imbalance in the sense coil. If the RCD does not trip when this button is pressed, then the device must be replaced.

3.2.2 Schematic diagram of a RCCB



Working Principle of Residual Current Circuit Breaker

3.3 RCCB test

3.3.1 Check Your RCCB Regularly

Formerly known as Earth Leakage Circuit Breaker, the Residual Current Circuit Breaker (RCCB) is a safety device available in all households and buildings. The RCCB helps prevent electric shocks by cutting off electricity supply immediately upon detecting any current leakage in an electrical circuit.

You should ensure that an RCCB is installed in your premises and check it once a month to see that it is in good working condition, by pressing the test button.

3.3.2 Testing

RCDs must be tested; the requirements are stated in the following Regulations:

- The effectiveness of the RCD must be verified by a test simulating an appropriate fault condition and independent of any test facility, or test button, incorporated in the device.
- Where an RCD with a rated residual operating current, $I_{\Delta n}$, not exceeding 30 mA is used to provide additional protection, the operating time must not exceed 40 ms at a residual current of 5 $I_{\Delta n}$

Tests are made on the load side of the RCD between the line conductor of the protected circuit and the associated cpc. Any load or appliances should be disconnected prior to testing.

3.3.3 Range of tests

Whilst the following tests are not a specific requirement of BS 7671:2008(2013), it is recommended that they are carried out:

Device	Instrument test current setting	Satisfactory result
General purpose RCDs to BS 4293 and RCD	50% of operating current	Device should not operate

protected socket-outlets to BS 7288	100% of operating current	Device should operate in less than 200 ms Where the RCD incorporates an intentional time delay it should trip within a time range from 50 % of the rated time delay plus 200 ms' to 100 % of the rated time delay plus 200 ms.
General purpose RCCBs to BS EN 61008 or RCBOs to BS EN 61009	50% of operating current	Device should not operate
	100% of operating current	Device should operate in less than 300 ms unless it is of 'Type S' (or selective) which incorporates an intentional time delay. In this case, it should trip within a time range from 130 ms to 500 ms.
Devices providing additional protection $I\Delta n \leq 30 \text{ mA}$	Test current at $5 I\Delta n$ The maximum test time must not exceed 40 ms, unless the protective conductor potential does not exceed 50 V. (The instrument supplier will advise on compliance).	Device should operate in less than 40 ms.





Quality and reliability is our tradition

KYORITSU

RCD(ELCB) Tester KEW 5410

NEW



CE

- **Measurement of RCD trip time**
Conducting testing of rated residual non-operating currents at x 1/2 Range, measuring RCD trip time at x1 and x5 Ranges..
- **Measurement of trip out current**
Measuring trip out current by varying current automatically.
- **Remote Test**
Enabling a user to hold the Test Leads with his both hands by locking the Test Button. Measurement will automatically start when the main voltage is detected



Self-Check No. 5.1.5-1

1. What is the earth fault?
2. What is the working principle of RCCB?

Answer Key No. 5.1.5-1

1. Earth Fault is an inadvertent fault between the live conductor and the earth.
2. In normal operation, all the current down the live conductor returns up the neutral conductor.

Information Sheet No. 5.1.5-2: Rectify Faults in Electrical Circuits

1. Calculation of Voltage, Current and Resistance of an Electrical Circuit

1.1 Ohm's Law

The three basic electrical elements of an electrical circuit are, voltage, current and resistance. Ohm's Law are used to calculate these three basic elements of an installation.

Ohm's Law states that under constant conditions, the current through a conductor is proportional to the potential difference across the conductor and inversely proportional to the resistance.

V = Voltage supply (Volts, V)

I = Current (Ampere, A)

R = Resistance (Ohms, Ω)

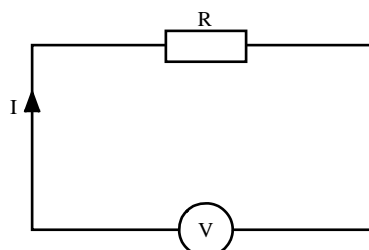


Figure 8-1

The current is directly proportional to the voltage across the resistor.

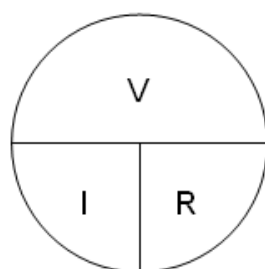
$$I \propto V$$

The current is inversely proportional to the resistance.

$$I \propto 1/R$$

Therefore,

Ohm's Law can be expressed by the equations:



$$V = I \times R$$

$$I = V / R$$

$$R = V / I$$

Figure 8-2

EXAMPLES

1. A heater takes a current of 2.77A from a 220V supply. What is the resistance?

Solution: $V = 220V$, $I = 2.77A$

$$\begin{aligned} R &= V / I = (220/2.77) \Omega \\ &= 79.42\Omega \end{aligned}$$

2. How much current does a 50Ω electric iron takes if the applied voltage is 250V?

Solution: $V = 250V$, $R = 50\Omega$

$$\begin{aligned} I &= V / R = (250/50) A \\ &= 5A \end{aligned}$$

1.2 SERIES CIRCUIT

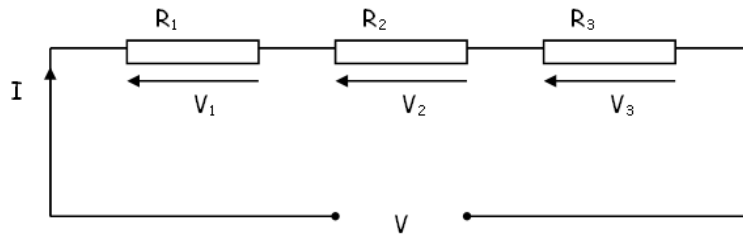


Figure 8-3

Characteristics of Series Circuit:

1. Current is the same throughout the circuit.
2. Total supply voltage is the sum of all branch voltages.

$$V = V_1 + V_2 + V_3$$

$$V_1 = \frac{1}{R_1}; V_2 = \frac{1}{R_2}; V_3 = \frac{1}{R_3}$$

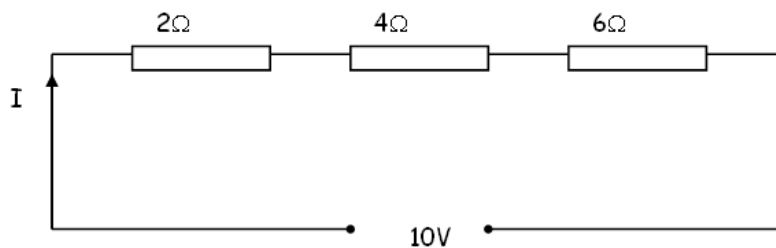
3. Total resistance is the sum of all individual resistance.

$$R_T = R_1 + R_2 + R_3$$

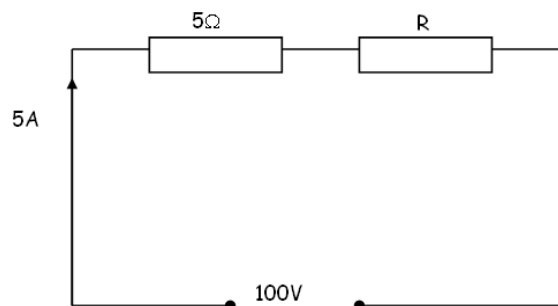
4. Total resistance is greater than the largest individual resistance.

EXAMPLES

1. Three resistors of 2Ω , 4Ω and 6Ω respectively are connected in series. Calculate the total resistance of the circuit. If a potential difference of 10V is applied, calculate the current and the voltage drop along each resistor.



2. Find the resistor R in the series circuit as shown in the figure below.



1.3 PARALLEL CIRCUIT

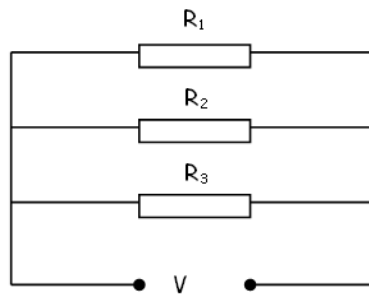


Figure 8-4

Characteristics of Parallel Circuit:

1. Supply voltage is equal to all branch voltages.
2. Supply current (Total current) is equal to the sum of all individual branch currents.

$$I_T = I_1 + I_2 + I_3$$

$$I_1 = \frac{V}{R_1}; I_2 = \frac{V}{R_2}; I_3 = \frac{V}{R_3}$$

3. The reciprocal of the total resistance is equal to the sum of the reciprocal of Individual resistance.

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \dots \frac{1}{R_N}$$

EXERCISES

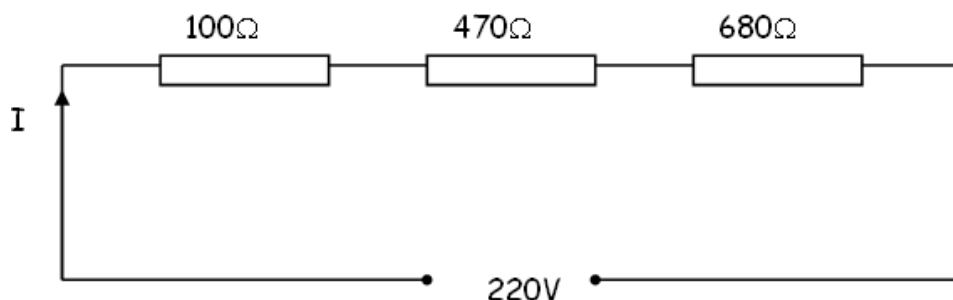
1. Two resistors of 330Ω and 560Ω respectively are connected in parallel. Calculate the circuit resistance.
2. Three resistors of 100Ω , 220Ω , 470Ω respectively are connected in parallel. Calculate the circuit resistance.
3. Three resistors of $1k\Omega$, $3.3k\Omega$ and $2.7k\Omega$ respectively are connected in parallel. Calculate its equivalent resistance.

1.4 SERIES - PARALLEL CIRCUIT

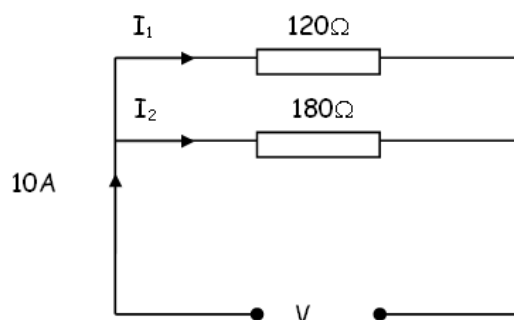
In series-parallel circuit, Ohm's Law still apply to each resistance, the characteristics of the series circuit will apply on the series connection and the characteristics of the parallel circuit will apply on the parallel connection.

EXAMPLES

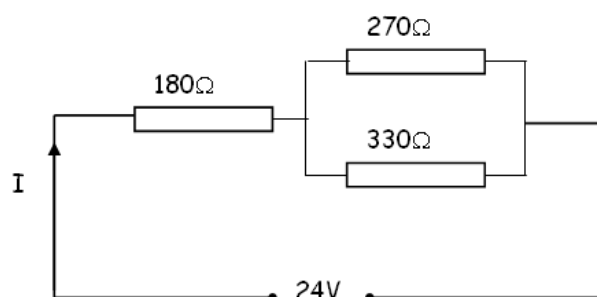
- 1 Find the voltage across each resistor.



2. Find the branch currents of the following circuit.



3. Calculate the equivalent resistance and the branch currents.



(2) Electrical Power

Power is the rate of doing work. The faster the work is done; the more power is required.

Symbol: P

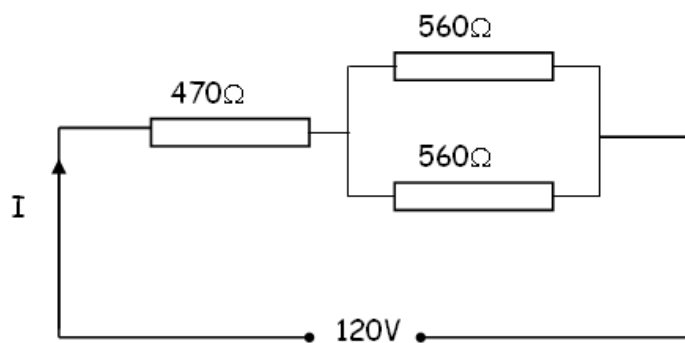
Unit: Watts (W) or Joules second (J/s)

One watt of power is obtained when a current of one ampere passes through a potential difference of one volt.

Power	=	$V \times I$
	=	$I^2 R$
	=	V^2 / R

EXAMPLES

1. Calculate the supply voltage when a resistance of 100Ω is dissipating 1kW of power.
2. Calculate the power consumed by each resistor and the total power as shown in the figure below.



3. A 240V, 100W bulb is mistakenly used on 100V supply. Calculate the power dissipated under this condition.

2.1 ENERGY

It is important to make a distinction between power and energy as frequently the terms are incorrectly used interchangeably. Energy is the ability to do work. In terms of power, energy is the product of power and time:

$$\text{Energy} = \text{Power} \times \text{Time}$$

Unit: Joules (J) or Kilowatt-hours (kWh)

Since energy = power x time, the amount of energy used is directly proportional to the power of the system and to the length of time it is in operation.

Power is expressed in watts or kilowatts and time usually in hours (as seconds and minutes are too small for our use), we have for units of energy watt-hours (Wh) or kilowatt-hours(kWh). That is, one watt-hour equals one watt of power in use for one-hour, and one kilowatt-hour equals one kilowatt in use for one hour.

EXAMPLES

1. A single-phase motor rated at 1.8kW runs continuously for 18 hours a day, 7 days a week.
 - a) What is the total energy that will be consumed by the motor in a month? Assume 1 month = 30days.
 - b) If the cost of 1kWh = \$0.27, how much is the cost of the electrical energy usage by the motor? Assume 1 month = 30days.
2. Find the daily energy consumption of the appliances listed if they are used daily for the amount of time shown.

Appliance	Rated Power	Duration
Iron	(1000W)	30mins
Television	(200W)	4hours
Refrigerator	(500W)	24hours
Toaster	(1200W)	15mins
Water heater	(3000W)	20mins

If the cost of 1kWh = \$0.27, find the daily operating cost.

- 3 Faults related to Power circuit of an electrical installation

3.1 No protection against indirect contact –

The socket outlet and lighting circuits fails to provide with the residual current device having a rated residual operating current of not exceeding 30mA.

3.2 Fails to comply with the following Standard Circuit Arrangements

- for radial final circuit under SS 145 or equivalent:

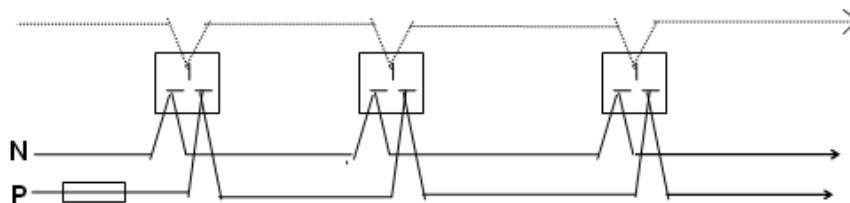


Figure 8-1

- 20A fuse or MCB protection with 2.5 mm² PVC or 1.5 mm² MI cables feeding a floor area of not more than 50 m².
- 32 A fuse or MCB feeding through 4.0 mm² PVC or 2.5 mm² MI cables to supply a floor area no greater than 75 mm².
- The maximum demand of connected current-using equipment must not exceed the rating of the overcurrent protective device, i.e. 20A or 32A.
The floor area served by the circuit should not exceed the above stated values. for ring final circuit under SS145 or equivalent
- Is the floor area served exceeded 100m²?
- Is the maximum demand after assessing the diversity had exceeded the rating of the protective device?
- Are the installed sockets of the ring circuits in the same building shared approximately evenly between them?
- Correct Cable sizes for ring circuits, ie 2.5mm² PVC or 1.5mm² mineral insulated (MI) cables.

3.3 Spur

- The rating of the fuse used in the fuse spur should not exceed that of the cable forming the spur and should not exceed 13A.
- The minimum size of the conductor used for a fused spur is:
 - 1.5mm² for rubber or PVC insulated copper cables.
 - 1.0mm² for mineral insulated copper cables.
- The Non-fused spur may supply only one single or one twin socket outlet or one permanently connected equipment.

3.4 Permanently connected equipment

Is the Permanently connected equipment be locally protected by a 13A fuse or less or a 16A circuit breaker or less?

3.5 Circuit for immersion heaters

Is the immersion heaters exceeding 15 litres capacity or a heater with comprehensive space heating installation, eg. electric fire installed in separate circuits?

3.6 Circuit Arrangement of an installation

Is the single-pole fuse, switch or circuit breaker inserted in the phase conductor only?

3.7 Radial circuits faults

3.7.1 High resistance connection faults

Generally radial circuits do not perform well with this type of fault.

The severity of the problem caused by a high resistance connection in a radial will depend on where it is. The worst case is a fault near the supply end of the circuit where the conductors are liable to be carrying the greatest current, supplying all outlets on the radial. A fault in the live or neutral connection will result in heating. A fault in the CPC will result in a reduction in safety of the circuit since operation times of protective devices in the event of a fault can extend, or they may fail to operate altogether, and the potential for dangerous voltages to be present on metal casework of appliances increases (i.e. a shock hazard caused by "indirect contact").

3.7.2 Broken and disconnected conductor faults (Opened circuit fault)

A break in the live or neutral will stop outlets downstream from working, giving a good indication that a fault is present (and making the fault relatively easy to locate and correct).

The more common event of a break in the CPC however will cause a particularly **dangerous failure mode**. The circuit will continue to supply power and appliances will appear to function as normal, but much of the circuit's fault protection has been lost and the shock risk from indirect contact during a fault is severe. There are not usually any obvious indications of this fault condition to a normal user.

3.8 Ring final circuits

3.8.1 High resistance connection faults

Since there is an alternative conduction path (the "other way" round the ring) the risks from a high resistance connection in the live or neutral wire are dramatically reduced. Typically (but not always) this failure can result in an increased chance of a low-level overload occurring elsewhere in the ring since the cable used is typically rated to carry a bit less than the full circuit load.

The ring circuit of course makes no difference to a bad connection outside of the ring, such as damage inside a socket. Such a fault poses the same risk regardless of the wiring feeding it.

The same high resistance fault in the CPC is handled very well by a ring circuit of a modern design. There is generally no immediate reduction in safety and the impairment of the operation of protective devices should be minimal. Ring circuits of old design that are not protected by MCB or RCD and often with a thinner CPC in the circuit cable are a little different: the risk is considerably reduced by the ring configuration, but some risk of failure to clear a fault remains, due to the possibility of the remaining CPC melting.

Voltage drop related problems are also likely to be less severe (but hence also less noticeable).

3.8.2 Broken and disconnected conductor faults

In the case of a break in the live or neutral conductor a ring circuit will continue working but with a risk of (usually) low level overload in some parts of the circuit (although fault protection is usually adequately maintained in this circumstance).

A broken CPC has little effect on a ring circuit of a modern design, and it will usually continue to operate normally in most cases without having much effect on the performance of the

protective devices, or the risk of shock from indirect contact. Again, on older circuit designs, using rewirable fuses, and a thinner CPC the risks are greater.

4 Low voltage cable

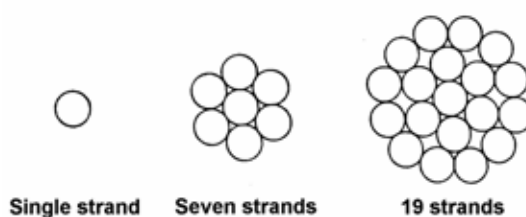
4.1 Stranding

Conductors are often stranded to ensure: -

- Flexibility.
- Ease of handling.
- Reduce the build up of magnetic field around cables.

Stranding refers to the conductor being divided into a number of smaller wires which are twisted together spirally forming a core equivalent to a single wire of the required size.

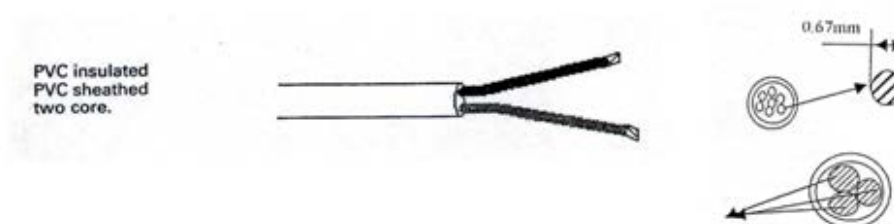
Eg. a 2.5mm^2 insulated cable.



Figure

4.2 Cable core

It refers to the conductor or group of stranded conductors which were insulated to form one current path.



Figure

4.3 Cable size

The size of a cable can be specified in 2 ways:

Number of strands and the diameter of each strand, e.g. 7/0.67 i.e. 7 strands of wires, the diameter of each strand is 0.67mm.

- Nominal cross-sectional area of the conductor, e.g. 1.5 mm^2 , 2.5 mm^2 , 4 mm^2 and 6 mm^2 and 10 mm^2 .

4.4 Description of a Cable

To describe a cable, the following information is needed:

- size of conductor
- type of conductor
- type of cable

- number of cores and
- type of insulation and sheath or mechanical protection.

4.5 Voltage Rating of Cable

Every cable must have a higher voltage rating than the actual voltage of the circuit in which it is used. The voltage rating of the cable is marked on its insulation as E_0/E , where

E_0 = the voltage to earth the cable is designed for, and

E = the voltage between conductors in the cable.

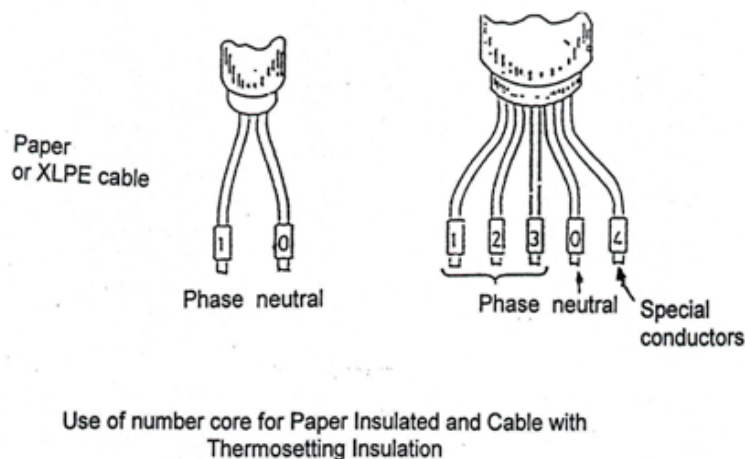
4.6 Identification of conductors CP5:1998 Amendment No1

To ensure ease of connections, every conductor should be identifiable at its terminations and preferably throughout its length.

One of the ways of identifying conductors is by means of colour. The standard colours used for identifying conductor are given in The CP.

The colour combination green and yellow is reserved exclusively for identification of protective conductors and should not be used for any other purpose.

The other way of identifying conductors is by means of numbers where the numbers 1, 2 and 3 are meant for phase conductors, the number 0 is for neutral, and the number 4 is for the fifth or 'special purpose' conductor. This method of identification is normally used on armoured PVC cables, paper-insulated cables and XLPE cables.



Figure

For mineral-insulated and bare conductors, the application of tapes, sleeves or discs of the appropriate colours as stated in Table below is used. Painting with these colours is also being used for identifying bare conductors.

Old colour code Table for reference

Colour identification of cores of non-flexible cables and bare conductors for fixed wiring

Function	Colour identification
Earthing conductor	green-and-yellow
Phase of AC single-phase circuit	red or yellow or blue
Neutral of AC single- or three-phase circuit	black

Phase R of 3-phase a.c. circuit	red
Phase Y of 3-phase a.c. circuit	yellow
Phase B of 3-phase a.c. circuit	blue
Positive of d.c. 2-wire circuit	red
Negative of dc. 2-wire circuit	black

New Colour code in the CP

Function	Colour identification
Earthing conductor	green-and-yellow
Phase of a.c. single-phase circuit	Brown (L)
Neutral of a.c. single- or three-phase circuit	Blue (N)
Phase 1 of 3-phase a.c. circuit	Brown (L1)
Phase 2 of 3-phase a.c. circuit	Black (L2)
Phase 3 of 3-phase a.c. circuit	Grey (L3)
Positive of d.c. 2-wire circuit	Brown (L+)
Negative of dc. 2-wire circuit	Grey (L-)

5 Flexible cables and flexible cords

5.1 Flexible cables

5.1.1 Flexible cables and cords are made of fine gauge wires so that they are much more flexible than ordinary wiring cables.

5.1.2 They are used for such purposes as from ceiling rose to lamp-holder or from socket outlet to portable apparatus.

5.1.3 In general they must not be used for fixed wiring.

5.1.4 The difference between the two types of flexible wires is:

9.1.4.1 Flexible cords - wires varying in size from 0.5mm^2 (16/0.20) to 4mm^2 (56/0.30)

9.1.4.2. Flexible cables - wires of larger sizes from 6mm^2 (84/0.30) to 630mm^2 (2257/0.60).

5.1.5 Some common uses of cords include:

Size	Amps	Watts	Typical Use
0.5 mm^2	3 A	690 W	Lights and appliances up to 480 W
0.75 mm^2	6 A	1,380 W	Lights and appliances up to 986 W
1 mm^2	10 A	2,300 W	Kettles and other appliances up to 1.9 kW
1.25 mm^2	13 A	2,990 W	Heavy duty extension leads, kettles and other appliances up to 2.4 kW
1.5 mm^2	16 A	3,680 W	Air-conditioners and water machines with heaters

5.2 Flexible cords

Where a flexible cord supports or partly supports a luminaire, the maximum mass supported by the cord should not exceed the appropriate value indicated as shown:

Nominal cross section area of conductor (mm ²)	Maximum mass (kg)
0.5	2
0.75	3
1.0	5

Flexible cords, where they are exposed to risk of mechanical damage, shall be of a type sheathed with rubber or PVC. Where necessary shall also be armoured; provided that for domestic and similar applications where flexible cords are subject only to moderate bending and/or wear, uninkable flexible cords complying with SS 236 or equivalent may be used.

Braided circular twin and three core flexible cords insulated with glass fibre shall be used only for luminaire or for other applications where the cord is not subjected to abrasion or undue flexing.

Flexible cords shall not be used as fixed wiring, unless contained in an enclosure affording mechanical protection.

Flexible cables or flexible cords shall be used for connections to portable equipment. For the purpose of this code an electric cooker of rated input exceeding 3 kW is considered not to be portable. Such flexible cables or flexible cords shall be of suitable length to avoid undue risk of mechanical damage.

Exposed lengths of flexible cord used for connections to fixed equipment shall be as short as possible and connected to the fixed wiring by a suitable accessory or an enclosure and require a suitable device or devices for overcurrent protection, isolation, and switching.

5.3 Colour codes for flexible Cable

Flexible cords or flexible cables having the following core colours should not be used, green alone, yellow alone or any bicolour other than the colour combination of green and yellow that is reserved exclusively for protective conductors.

Every core of a flexible cord or flexible cable should be identifiable through its length as appropriate to its function as indicated in Table 51B.

Table 51B

Colour identification of cores of flexible cables and flexible cords

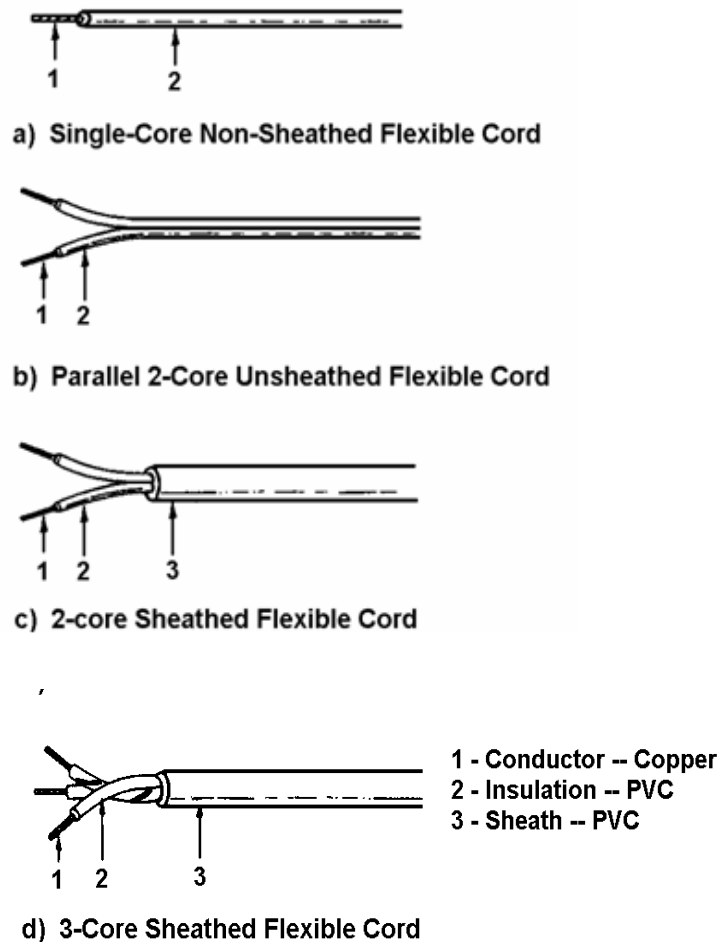
Number of core	Function of core	Colour(s) of core
1	Phase Neutral Protective	Brown Blue Green-and-yellow
2	Phase Neutral	Brown Blue
3	Phase Neutral Protective	Brown Blue Green-and-yellow
4 or 5	Phase Neutral Protective	Brown, or black Blue Green-and-yellow

Flexible cables or cords should be identified throughout their length using the colours specified in Table 52B of regulations for the particular function of the core.

Note: The colour combination of green and yellow is to be used exclusively for the identification of protective conductors.

5.4 Types and applications

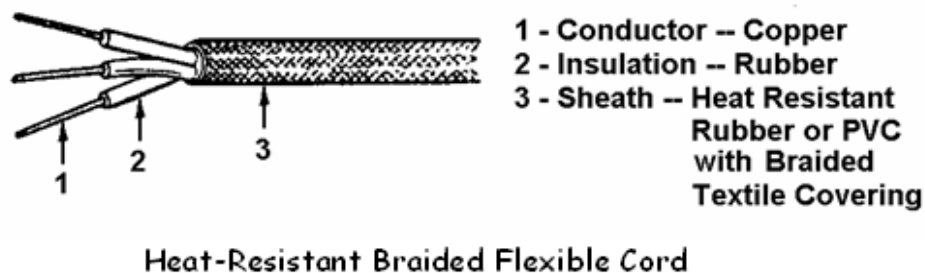
5.4.1 PVC Insulated and Sheathed Flexible Cords



Figure

5.4.2 Heat-Resistant Braided Flexible Cord

Heat-resistant braided flex is used on irons, luminaire with filament lamps, and any other appliances that might become hot and burn or melt normal PVC sheathed flexible cord.



Figure

5.4.3 Tough-Rubber Sheath Flexible Cord

This has a thick black rubber outer sheath and rubber insulated cores. It is a standard flexible cord for power tools, and extension leads, where there is a risk of the lead becoming damaged.

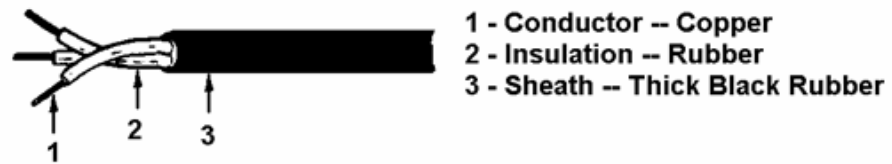


Figure: Tough-Rubber Sheath flexible Cord

Self-Check No. 5.1.5-2

1. What are the three basic electrical elements of an electrical circuit?
2. What is the color of earthing conductor?
3. What is the color of phase of AC single-phase circuit?
4. What is the color of neutral of AC single- or three-phase circuit?

Answer Key No. 5.1.5-2

1. The three basic electrical elements of an electrical circuit are, voltage, current and resistance.
2. green-and-yellow
3. red or yellow or blue
4. black

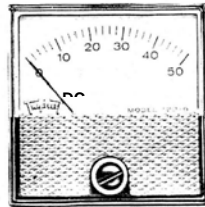
Information Sheet No. 5.1.5-3: Conduct Electrical Tests

1. Types and Functions of Electrical Measuring Instrument

Electrical indicating instrument are used to measure accurately electrical quantities such as volts, ampere, ohms, watts etc associated with electrical circuit. They indicate the value of the electrical quantity being measured at that time. The measured quantities are given by pointers moving over calibrated scales.

1.2 The followings are some of the common measuring instruments that can be used:

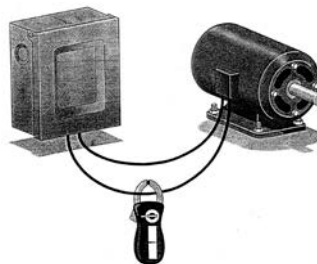
1.2.1 DC ammeter - for measuring direct current.



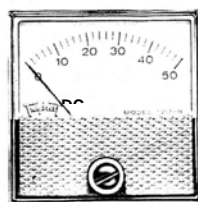
1.2.2 AC ammeter - for measuring alternating current.



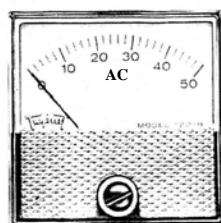
1.2.3 Clip-on ammeter - for measuring alternating current.



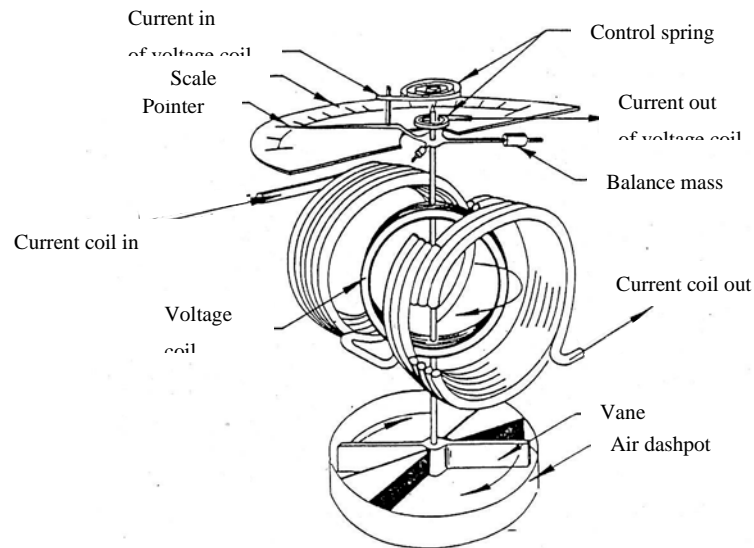
1.2.4 DC voltmeter - for measuring DC voltage.



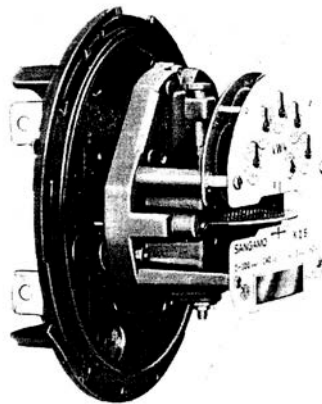
1.2.5 AC voltmeter - for measuring AC voltage.



1.2.6 Wattmeter - for measuring power.



1.2.7 kWh meter - for measuring electrical energy in kWh.



2 Insulation tester and continuity tester

Portable insulation resistance testers and megohmmeters are designed to help prevent hazards such as electric shock and short-circuits caused when the insulation in electrical devices, parts, and equipment used in industrial plants, buildings, and other settings degrades over long periods of use.



A continuity tester is an item of electrical test equipment used to determine if an electrical path can be established between two points; that is if an electrical circuit can be made. The circuit under test is completely de-energized prior to connecting the apparatus.



A voltage and continuity tester



An electrical continuity tester

3 Inspection of electrical installation

3.1 Introduction

Every completed installation must be inspected and tested before being connected to the supply and energized. The purpose is to verify that the installation is safe and comply with the requirements of relevant Code of Practices. The methods of tests shall be such that no danger to persons or property or damage to equipment can occur even if the circuit tested is defective.

3.2 Identification and notices

The following information shall be made available to the person carrying out the inspection and testing of an installation. The installation tester, as well as the user, must be clear as to how the installation is arranged to carry out its functions. The installation must be provided with:

- Labels to indicate the purpose of switch gear and control gear.
- Correct identification of conductors and protective conductors.
- Warning notices to indicate the presence of voltages.
- Labeling on distribution boards, arranged so that the circuits protected may be quickly and easily identified.

- (e) Diagrams, charts or tables to show arrangement of circuits, as well as the identification and location of fuses, circuit breakers, switch, fuses, isolators, etc.

3.3. Visual Inspection

Visual inspection has three main purposes, that is to

- (i) make sure that the equipment installed complies with the applicable Code of Practices or requirements of relevant authorities.
- (ii) check that the installation itself has been carried out to comply with the Regulations.
- (ii) ensure that there is no visible damage to the installation, or to equipment connected to it.

3.4. Testing Sequence

The tests required are listed in the recommended sequence:

- (a) Ring circuit continuity
- (b) Protective conductor continuity
- (c) Measurement of insulation resistance
- (d) Verification of polarity
- (e) Test of operation of earth leakage circuit breakers or RCCB

Testing can be dangerous, to the tester and to others who are within the area of the installation during the test therefore the list of tests is arranged in the order in which they must be carried out, it is important that these tests are made in the correct sequence.

4 Continuity of Ring Final Circuits

The ring final circuit is widely used. Therefore, it is important that each ring circuit (phase, neutral and protective conductors) should be continuous and not broken. If this happens, current capacity will not be properly shared by the circuit conductors.

A test must be made to verify the continuity of all conductors (including the protective conductor) of every ring final circuit. Two methods of measurement are suggested:

Method 1

This test confirms that complete rings exist and that there are no breaks. To conduct the test, the two ends of the ring cable are disconnected at the distribution board. The phase conductor P1 and the neutral N2 are connected together. An ohmmeter used to measure the resistance between the remaining phase and the neutral (P2 and N1). To check the continuity of the circuit protective conductor, connect the phase and CPC of different sides together (P1 and E2) and measure the resistance between phase and CPC of the other side (P2 and E1).

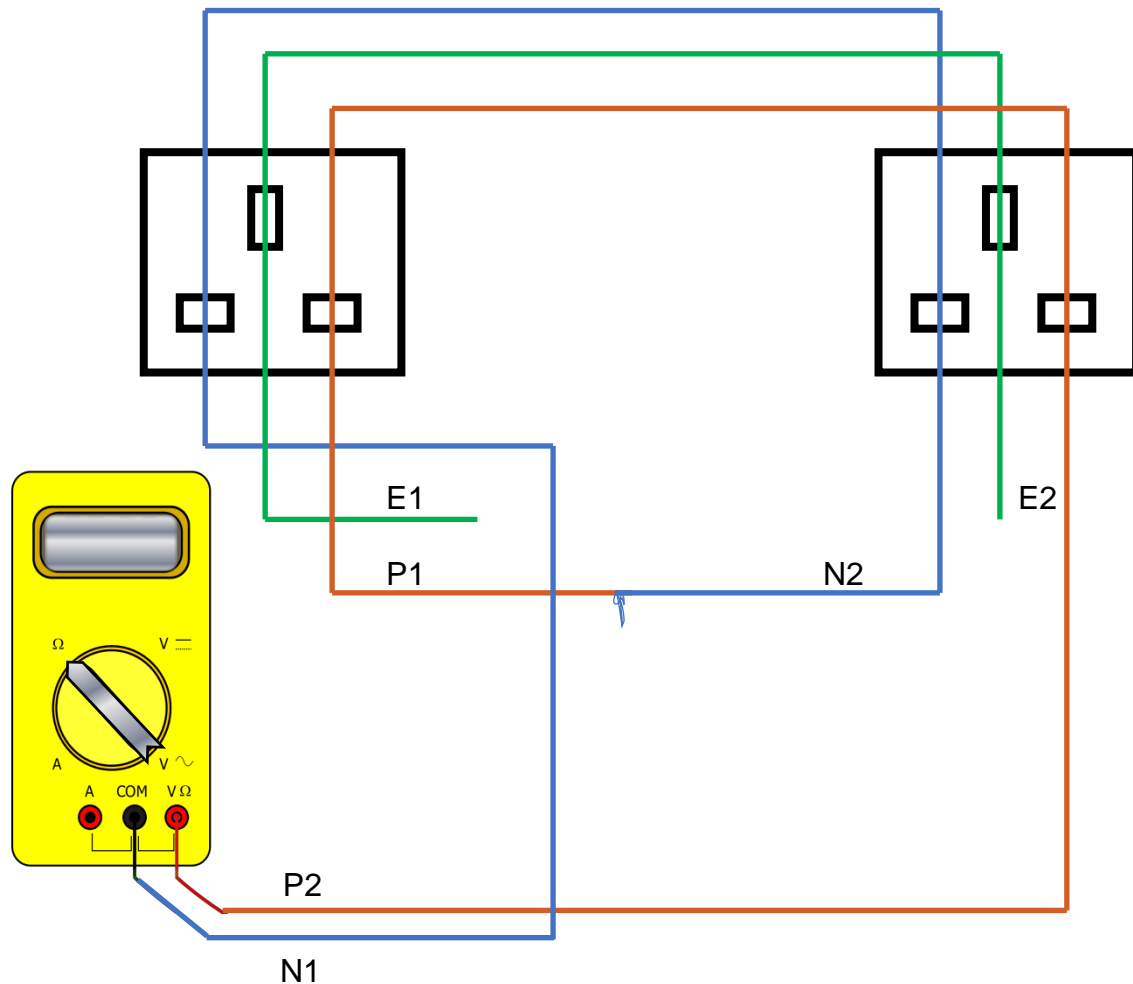


Figure 9-1

Method 2:

This test will confirm the absence of bridges in the ring circuit. To conduct the test, the phase conductor of one side of the ring is connected to the neutral of the other (P1 and N2) and the remaining phase and neutral are also connected together (P2 -and N1). The resistance is then measured between phase and neutral contacts of each socket on the ring. If the results of these measurements are all substantially the same, the absence of a bridge is confirmed. If the readings are different, this will indicate the presence of a bridge or may be due to incorrect connection of the ends of the ring.

Figure 9-2

4 Continuity of Protective Conductors

Measurement of resistance of protective conductors as well as a continuity test to ensure that the conductor is sound and is correctly connected.

Continuity may be checked before connection of the supply by connecting together the neutral and protective conductors at the mains position and checking between earth and the neutral at every outlet.

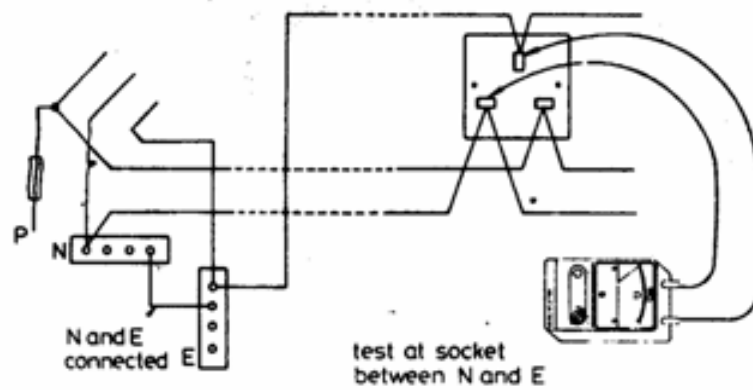


Figure 9-3

5 Polarity test

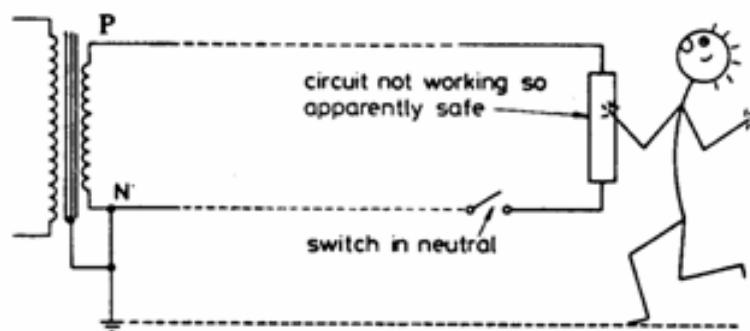


Figure 9-4

Fig. 9-4 shows the danger that may arise if a circuit is broken in the neutral, rather than in the phase conductor.

It is important that single poles switches, fuses and circuit breakers are connected in the phase and not the neutral. The outer contacts of single-contact bayonet cap or edison screw lampholders must be connected to the neutral and not the phase conductor.

If portable appliances are to be safe, their polarity also must be correct, which involve testing each socket outlet for correct connection. The polarity test may be carried out with a continuity tester connected to the phase conductor at the mains position with its other contact taken in turn to phase conductors throughout the installation as shown in Fig. 24-5.

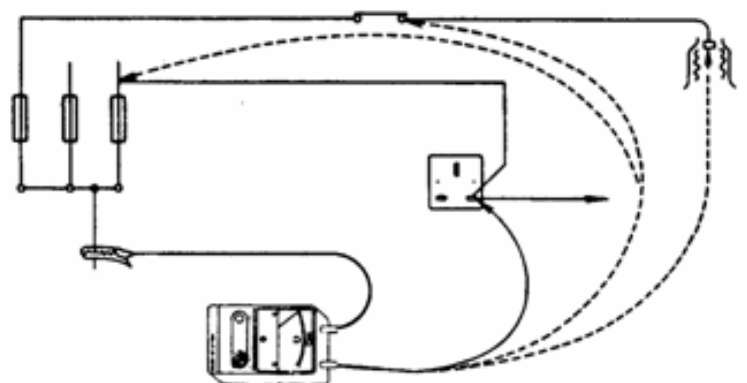


Figure 9-5

6 Insulation Tests

If the resistance between poles of the supply, or from either pole to earth is low, then a significant leakage current will flow. Not only is such a current likely to result in deterioration of the insulation, but it also involves wasted energy which will increase the running costs of the installation. Thus, insulation must have a resistance of not less than 0.5 mega-ohm ($0.5\text{M}\Omega$) between poles or to earth.

The test to earth must be carried out with all poles connected together, fuses in, switches and circuit breakers closed (Fig 9-6).

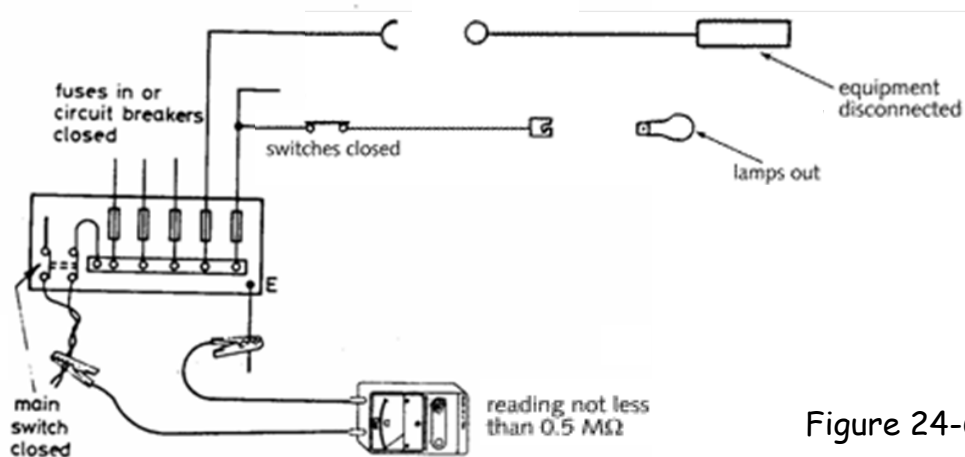


Figure 24-6

Where equipment is disconnected to allow the tests to be carried out, the equipment must itself be insulation tested to earth with a result complying with the relevant regulation, or at least $0.5\text{M}\Omega$.

The test between poles must be carried out with the same requirements for fuses, switches and circuit breakers, lamps must be out, and equipment disconnected. For a single-phase system, the test is from phase to neutral. For a three-phase and neutral system, six tests are needed, as in Fig. 9-7.

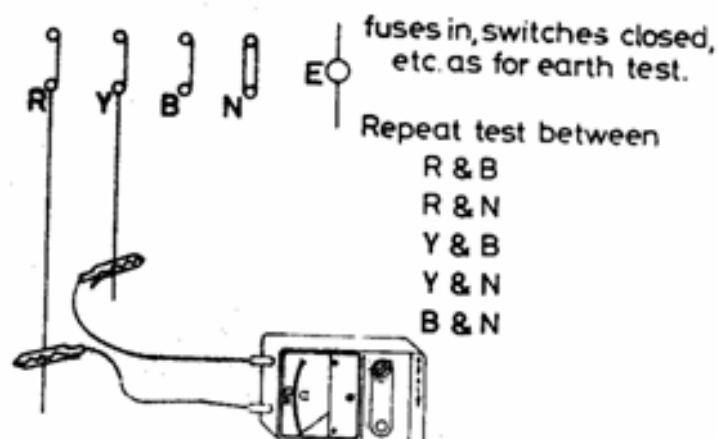


Figure 9-7

Self-Check No. 5.1.5-3

1. What are insulation resistance testers and megohmmeters?
2. What is continuity tester?

Answer Key No. 5.1.5-3

1. Insulation resistance testers and megohmmeters are designed to help prevent hazards such as electric shock and short-circuits caused when the insulation in electrical devices, parts, and equipment used in industrial plants, buildings, and other settings degrades over long periods of use.
2. A continuity tester is an item of electrical test equipment used to determine if an electrical path can be established between two points; that is if an electrical circuit can be made.

Information Sheet No. 5.1.5-4: Inspect Lightning System

1. Lightning

Lightning is one of nature's most powerful and destructive phenomena. They contain enormous amount of energy ranging from several thousand amps to over hundred thousand of amps.

Lightning strokes are visible discharge of electrical static caused by unbalanced electric charges accumulated in storm clouds. Strokes can occur within the cloud, between the clouds or from the cloud to ground.

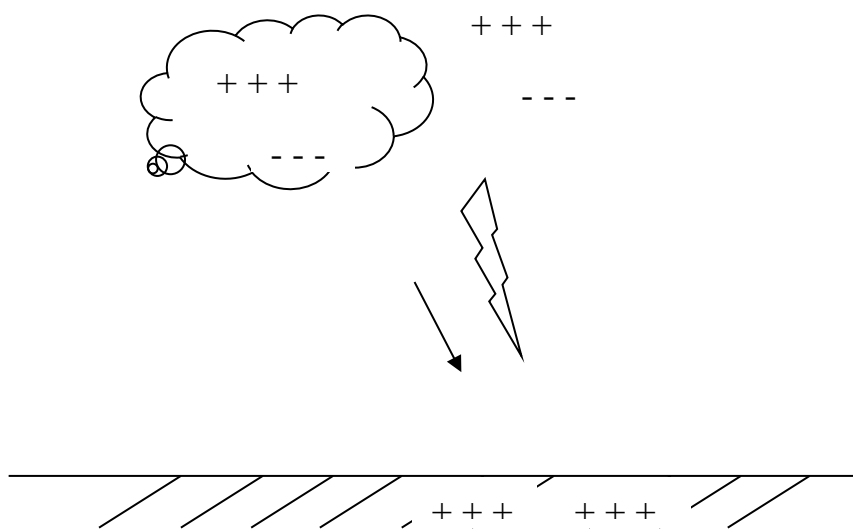


Figure 28-1 Typical Charge Distribution in the Storm Clouds

2. Lightning protection system

Lightning can result in damage to the building itself, to its occupants and failure of internal systems, especially electrical and electronic systems.

Lightning protection is governed by SS 555. In SS 555, lightning protection requirement is divided into 4 protection levels I, II, III, & IV. Lightning protection system I, II, III & IV requirements relate to protection level I, II, III, & IV respectively.

For example, if the risk assessment determines that a lightning protection system with lightning protection class II is required to reduce the risk to below the tolerable level, then the design of the lightning protection system will need to be in accordance with the requirements of lightning protection level II (or higher). The greater the level of lightning protection (LPL I being the greatest), the larger the resulting material requirement for the lightning protection system.

In many cases, it is usually necessary to provide some form of lightning protection. In high-risk buildings such as oil refineries, armouries will require the highest possible class of lightning protection.

In India, IEC 62305 provides general principles to be followed for protection of structures against lightning, including their installations and contents, as well as persons. ...

This standard supersedes IS 2309: 1989 Code of practice for the protection of buildings and allied structures against lightning'.

3. Components of lightning protection systems

The main components of a lightning protection system are:

1. Air Termination Network

2. Down Conductors
3. Earth Terminations
 - 3.1. Air Termination Network

The air termination network is the point of connection for a lightning strike. It typically consists of several connected air terminals arranged, on the roof of the building.

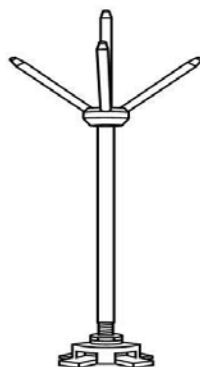


Figure 28-2 Multipoint Air Terminal

- 3.2. Down conductors

Down conductors are installed on the side of the buildings and run vertically from the roof to the ground. It connects the air terminals to the earth electrode on the ground. Its purpose is to provide a path of low impedance for the lightning current to be conducted safely and quickly to earth.



Figure 28-3 Down conductor

The spacing between down conductors is at a maximum distance of 20m apart.

Lightning Protection System	Down conductor Spacing
Class I	10m
Class II	10m
Class III	15m
Class IV	20m

- 3.3. Earth Termination Network

Earth Termination Networks are means of discharging the lightning current to the general mass of earth.

An earth termination network typically consists of:

- a) Type A arrangement - Earth rods are installed at the base of each down-conductor and driven into the ground. A minimum of two electrodes must be used.
- b) Type B arrangement - A ring arrangement of earth rods around the perimeter of the structure connected to one another by conductors

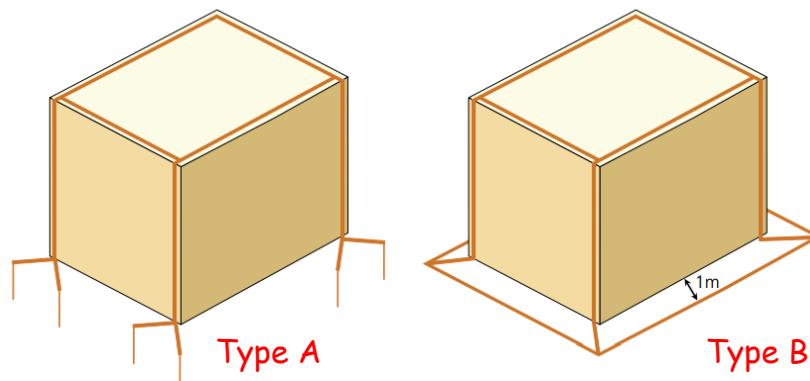


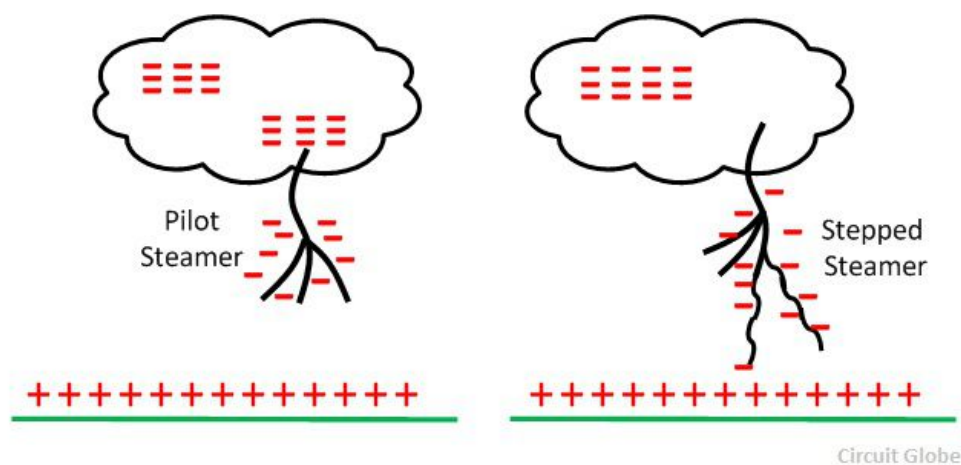
Figure 28-3 Type A & B earthing systems

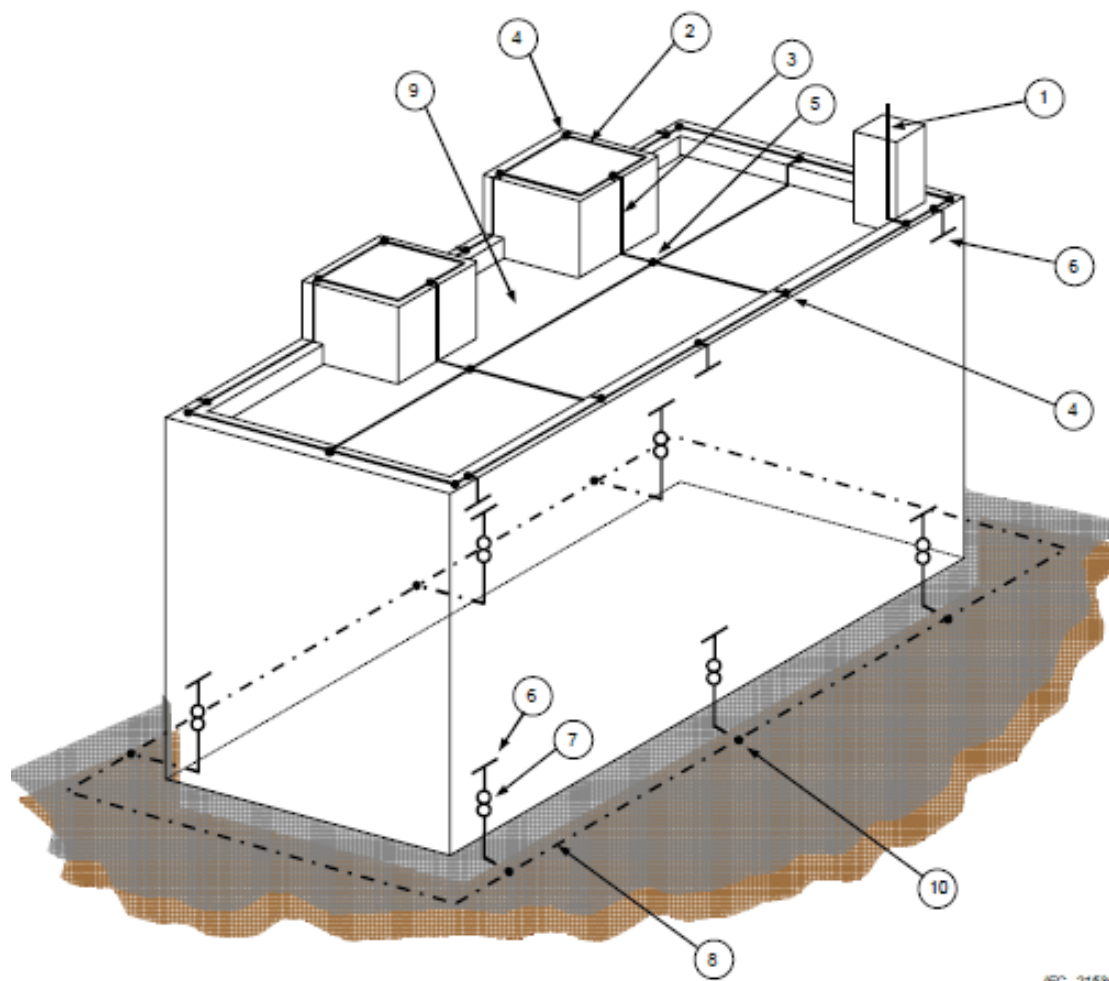
4. inspection and Testing

Lightning conductors and system components are to be checked and inspected in accordance to SS 555 requirement and procedures. Periodic inspection should be performed at least once a year. The following checks shall be carried out:

- a) No corrosion of parts
- b) Verification of continuity of all conductors, bonds and joints
- c) Down conductors and ground terminals are intact and securely fastened to their mounting surfaces
- d) No visual damage is found
- e) Measurement of resistance to ground of the each earth termination and the whole installation

1) How lightning was occurred:





IEC 2153H

Self-Check No. 5.1.5-4

1. How many lightning protection requirement?
2. What is air termination network?
3. What are down conductors?
4. What are earth termination networks?

Answer Key No. 5.1.5-4

1. Lightning protection requirement is divided into 4 protection levels I, II, III, & IV.
2. The air termination network is the point of connection for a lightning strike.
3. Down conductors are installed on the side of the buildings and run vertically from the roof to the ground.
4. Earth Termination Networks are means of discharging the lightning current to the general mass of earth.

TASK SHEET 5.1.5-1
Title: Inspection and Testing on a completed installation
Performance Objective/s: <ol style="list-style-type: none"> 1. To carry out inspection on completed installation 2. To list the correct order of electrical testing on an installation 3. To list down all the equipment and PPEs that are required. 4. To perform the testing.
Supplies/Materials :
Equipment :
Steps/Procedure: <ol style="list-style-type: none"> 1. You have been engaged by your company to conduct inspection and testing on a completed installation. 2. You are tasked by your company to carry out these tasks together with your colleague. On the completed installation, you are required to inspect, test and commission the installation.
Assessment Method: Demonstration with oral questioning

Performance Criteria Checklist Did you....	YES	NO

Part 1 – Inspection of completed installation

		INSPECTION ASPECTS	Remarks in compliance with requirements.
1		Inspection on trunking and conduit works -any damaged trunking bends -any damaged conduits bend -any dimension out by more than 5mm -any levelling where bubble is outside the limit -Any openings which violate the regulation	
2		Secureness of control panels, trunking and conduit works and accessories	
3		Cable Management -Any loose wiring -Wire looming is well formed -No jointing of cable in adjacent cables -All terminations are not exposed (within 2mm)	
4		Wiring and Testing the Lighting and Ring Final Circuit	
	4.1	Wire-up the Ring Final Circuit <ul style="list-style-type: none">• Circuit wiring correctness• MCB rating• Cable sizes• Cable colour	
	4.2	Wire-up the Lighting Final Circuit <ul style="list-style-type: none">• Circuit wiring correctness• MCB rating• Cable sizes• Cable colour	

	4.3	Perform Continuity Test <ul style="list-style-type: none"> • Select the correct meter • Select the correct range • Perform the test • Explain and show the result to the trainer 	
	4.4	Perform Insulation Test <ul style="list-style-type: none"> • Select the correct meter • Select the correct range • Perform the test • Explain and show the result to the trainer 	
	4.5	Perform Polarity Test <ul style="list-style-type: none"> • Select the correct meter • Select the correct range • Perform the test • Explain and show the result to the trainer 	
	4.6	Perform Earth Effectiveness Test <ul style="list-style-type: none"> • Ensure supply is ON • Test the RCCB's Test Earth button • Explain and show the result to the trainer 	

