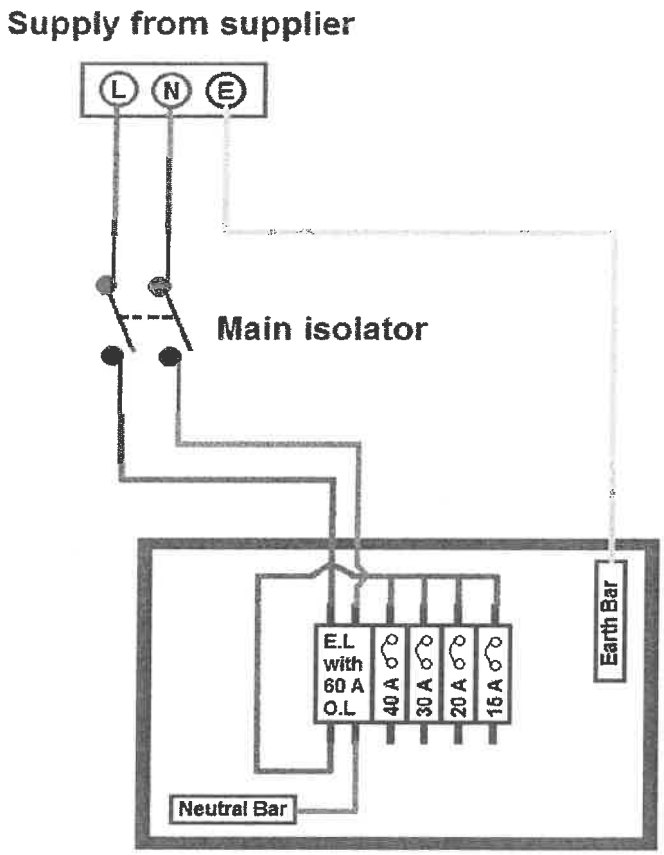
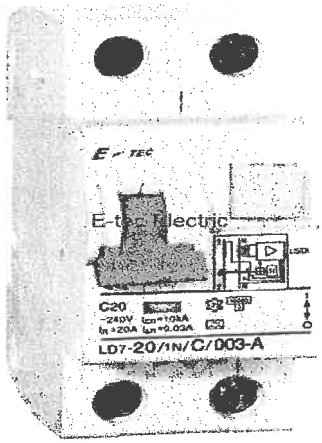


Figure 10: Practical wiring of a distribution board

Complete Learner Activity: 10

6.5. Protective Devices: Earth leakage



(DIYTrade)

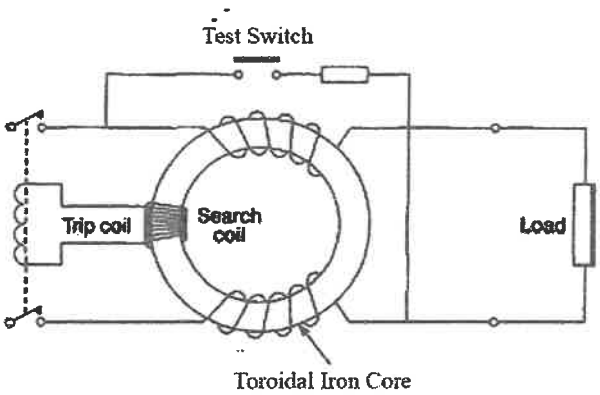
Figure 11: Earth Leakage unit

An Earth Leakage Circuit Breaker (ELCB) is a safety device used in electrical installations to prevent electric shock. The main purpose of earth leakage is to prevent injury to humans and animals due to electric shock.

It detects small stray voltages on the metal enclosures of electrical equipment, and interrupts the circuit if a dangerous voltage is detected.

6.5.1. Principle of Operation

If the different in current flowing between live and neutral wires exceeds 20 mA to 60 mA, the detector trips the power to prevent further electrical shock. The earth leakage will automatically disconnect an electrical installation from the supply when the leakage current exceeds 20 mA to 60 mA flowing to the earth.



(Cross, 2001)

Figure 12: Basic construction of earth leakage device

This leakage current is caused by a fault on electrical device or a person or an animal that by accident touches live and earth or neutral and earth.

6.5.2. Safety Considerations

To provide the user with protection against electric shock, the wiring of circuits must ensure that all live parts are insulated. If this basic insulation fails the live parts must be prevented from creating hazard to the user.

The most appropriate way of verifying Electrical Safety is to carry out a series of routine Safety Tests to provide protection against shock. These include:

- **Visual Inspection:** It is important when carrying out routine testing to first check for signs of undue wear and tear by a thorough visual inspection – a nick in the supply cable or a cracked casing etc. can easily lead to hazardous situations when the power tool or appliance is in use.
- **Electrical Safety:** the tests is to verify satisfactory earth bonding (class I, or earthed) and insulation (class II, or double insulation).
- **Earth Bond Continuity:** this requires that the earth bond resistance between all accessible conductive surfaces and the Earthing terminal within the item, does not exceed 0.1 Ohm.

In practice, the testing will always include the supply earth lead and exposed metal (conductive) surfaces of the tool e.g. metal conduits, metal switch boxes, plugs, metal roof, gutters, metal sinks, stoves, etc.

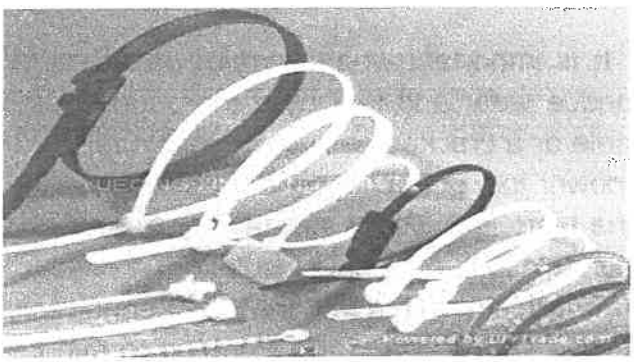
- **Electrical insulation:** check the insulation between conductors (live and neutral). The main supply and switch disconnector must be off, all switches and MCBs must be on. All appliances must be disconnected, and the reading must be at least 1MΩ.
- **Earth Leakage Current:** all tests must be carried out with the switches or earth leakage circuit breaker of the tool or appliance in ON position to ensure that all live parts are included when checking insulation. For equipment fitted with contactor, relay or low voltage electronic switching devices, it may be more appropriate to measure the earth leakage current when the equipment is powered up and running.

It is recommended that the outlet to be used is protected with an earth leakage circuit breaker.

6.5.3. Cabling and cable sizes

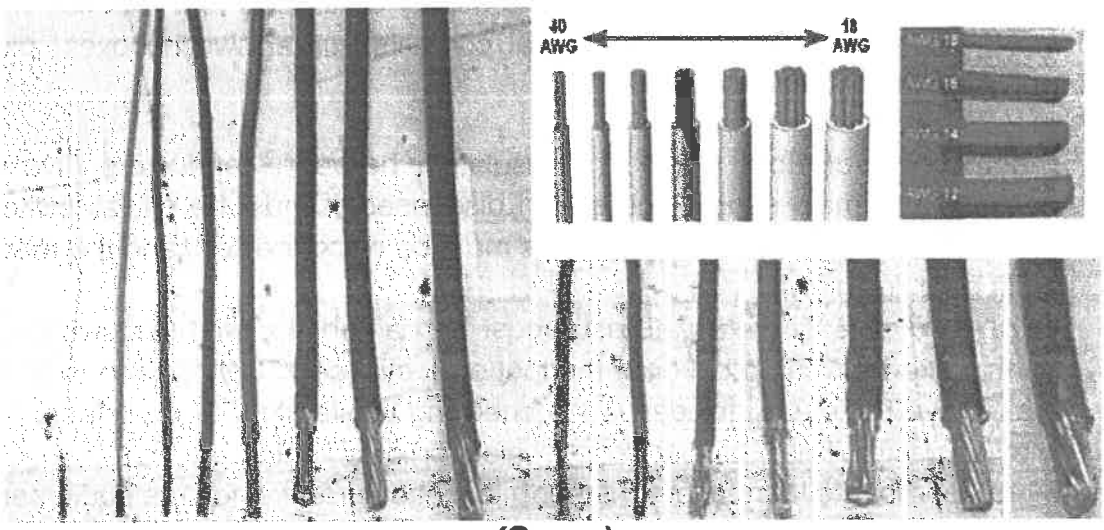
The requirement of conductor is determined by considering the required current – carrying capacity of the cable. The cable ties are used to tie the exposed wires. This will make the wiring look neat.

The cable should permit the voltage drop, overcurrent protection and short time overcurrent rating. The nominal cross-sectional area of the conductors of cable shall be such that the maximum estimated load to be carried by the conductor does not exceed their current-carrying capacity.



(DIYTrade)

Figure 13: Cable ties



(Gauge)

Figure 14: Different wire sizes

Sub-circuits	Sectional area	Rating current
Light	1,5 mm²	10 A
Socket outlet	2,5 mm²	20 A
Earth leakage	16 mm²	63 A
Stove	6 mm²	40 A
geyser	2,5 mm²	20 A

In the electrical system (or installation), conductors are identified with specific colour codes as outlined by SANS:

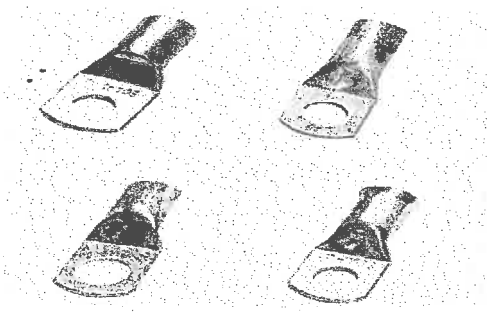
- Live: red , white or bleu
- Neutral: black
- Earth: green-yellow or bare copper wire

6.5.4. Correct identification and fitting of wiring for a domestic installation

Most of wiring in the electrical domestic installation is done through conduits (tubes or PVC pipes). The fitting of wires for domestic installation can consist of one or more separated wire way channels intended for different services such as installation wiring and telecommunication wiring. These conduits are incorporated in the foundation, walls and in the ceilings of a house.

6.5.5. Cable termination

In electrical wiring, the cable conductors (electric wires) are joined at the end with aluminium lugs used as cable termination. The lugs will allow proper joints (assembly) for example between the components terminals and the conductors. The lugs are used to ensure safety and proper (neat and accurate) joins are to be made.



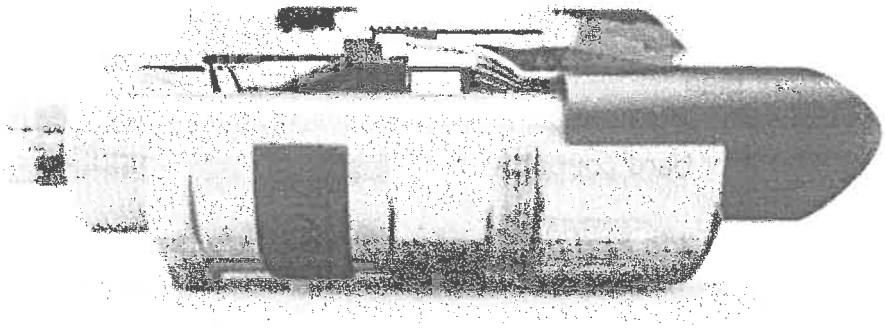
(Component)

Figure 15: Lugs

The cable terminals (lugs) come in different shapes and different diameter sizes. For example, there are flat, round, and y- shapes, insulated or naked (without insulation). Lugs may be found in diameters as 2mm, 4mm, 6mm, 16mm, depending to the size

of the cable. A crimping tool is used to join the lugs and the cables. Also the crimping tools may be found in different diameters depending to size of the lugs.

6.5.6. Glands (PVC Pressure Glands) Acknowledgement of Indigenous knowledge systems (PRATLEY Connector Boxes)



(ehawke)

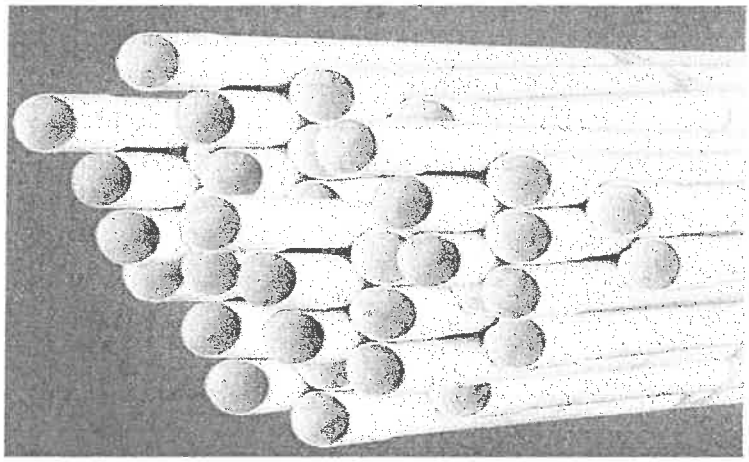
Figure 16: PVC Pressure Glands

The PVC glands are used to fasten (join or assemble) the cable to the box or Distribution Board cabinet (panel). A locknut should be placed on the outside and on the inside of the specific box to which the cable is fastened. The PVC glands can be found in different sizes, depending on the size of the conductor needs to be used.

Complete Learner Activity: 11 - 12

6.6. Pipe Sizes

The PCV conduits and accessories are mostly used in the new construction of houses as they are cheap and easier to work with than using metal conduits which are rigid. The metal conduits are mostly found in older houses and are also used in industries. An electrical conduit is a tube used for protection and routing electrical wiring in a domestic installation. Examples of PVC conduit pipes can be seen below.



(ALLWIN)

Figure 17: PVC Conduit Pipes

The PVC conduits can be found in different sizes, based on their internal and external diameters in which the accessories will be fitted into the conduits.

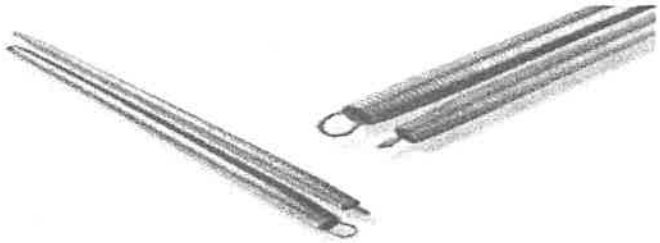
The table below shows the different PVC conduit pipes sizes:

Nominal size (in mm)	**Diameters**		**Coil Lengths in meters (m)**
	Internal diameter (ID), in (mm)	External diameter or Outside diameter (OD), in (mm)	
10	7,8	10,5	100
14	10,4	14	100
16	12,5	16	50
20	15	20	50
25	20	25	25
32	25	31,5	25
36	31	36	25
40	33,5	40	20
50	43	50	15

6.6.1. Bending, Fitting, Sawing

- A PVC conduit is bent with a spring bender. The spring bender of the correct diameter is placed inside the conduit, at the position where the bend should be made. A nylon or wire is tied onto the spring end to pull it out once the

bend has been made. The bend can be done to the required angles e.g. 30°, 45°, 60° or 90°. The bend is normally made over the knee or leg of a person. It is necessary to over-bend the PVC conduit as the conduit has some degree of elasticity, the bend will open slightly once the spring bender is removed



(ElectroTel)

Figure 18: PVC Pipe Bender

Once the bending is done, cut the conduit to the correct length and fit it to any necessary accessories. For example a male or female adapter bush is used to fit (terminate) the conduit in a box. PVC glue must be used to glue the accessories to the conduits.

- PVC conduit is fastened to the surface by mean of PVC saddles:
- PVC conduit is sawed with a hacksaw. When sawing conduit, it should be placed in a pipe vice. The desired length should be determined and marked. Ensure that the cut made by the hacksaw is perpendicular to the conduit.

6.6.2. PVC Conduit and Fittings

Below is a table which show PVC conduit and fittings.

Table 1: PVC Conduit and Fittings

Item	Description	Application
	Conduit box: 1way	Used at the end of conduit
	Conduit box: 2 ways	Used for junction, also wires changing different directions
	Conduit box: 3 ways	Used for junction, also when wires changing different directions
	Conduit box: 4 ways	Used for junction, also when wires changing different directions

	Conduit box lid (cover)	Used to cover the conduit box
	Conduit box: 4 knock out loops	Used for wire junctions (plugs)
	Female adaptor	Used to join the conduit box and the conduit pipe.
	Male adaptor	Used to join the conduit box and the conduit pipe.
	Coupling	Used to join two conduit pipes
	Saddle	Used to tie the conduit pipe
	Conduit inspection bend	Used for inspection of wiring
	Conduit inspection bend tee	Used for inspection of wiring
	Conduit bend with coupling at ends	Used were a certain angle is required and for joining two conduit pipes at both ends.

6.7. Practical: Install PVC Piping for the domestic circuit

Purpose: To install PVC for the domestic circuit

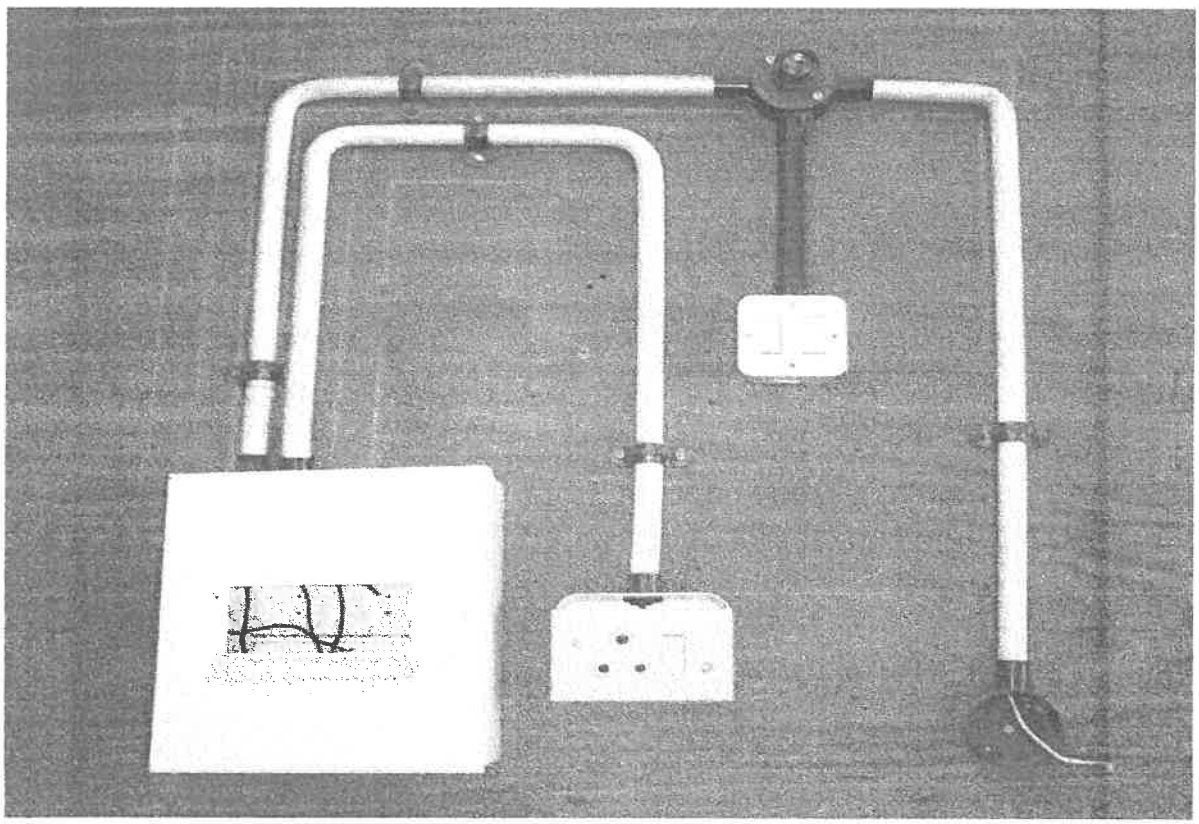
Duration: 2 hrs

Requirements:

- Distribution board
- 5m PVC conduit pipe
- 10 x PVC saddles
- Couple of screws
- 1 x Screw driver Phillips / flat
- 4 x Female adaptors
- 1 x conduit box 1way
- 1 x conduit box 3 way
- 1 x plug socket
- 1 x 2 lights switch
- 1 x 1,5 x 1,5 board

Procedure:

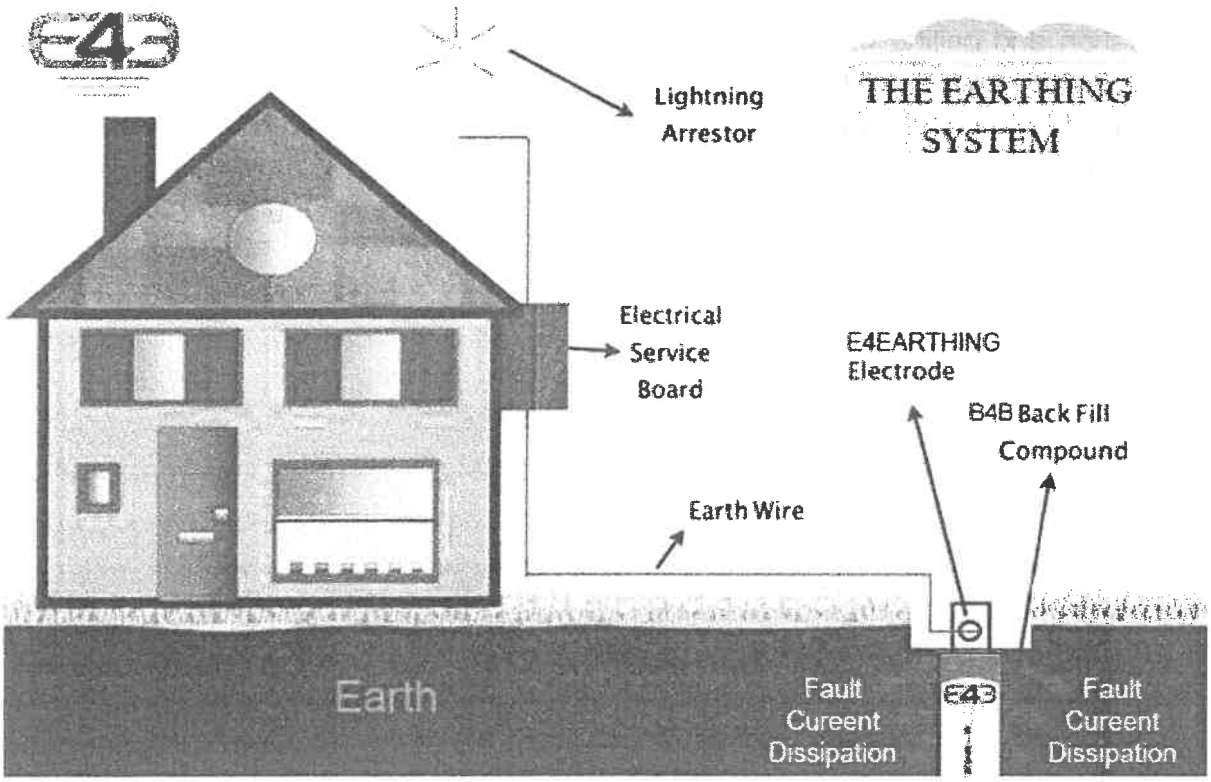
- Install the PVC conduit according to the picture below



Conclusion:

In practice, when a new house is built, the conduits are chased into the walls, foundation and ceiling boards from the distribution board to the allocated electrical points (lights, socket outlets, stove, geyser, washing machine, etc.). These conduits are intended to contain electric conductors or cables. In other words, in the process of wiring the electric wires will be run through the PCV conduits which are incorporated or hidden in the foundation, walls and ceiling. A long wire (about 20 m) is used to pull the conductors inside the PCV conduits, for example from the Distribution Board to the socket outlets.

6.8. Protective devices: Earthing



(ELECTRODE)

Figure 19: Earthing

Earthing may be described as a system of electrical connection to the general mass of earth (ground). The purposes of earthing an electrical installation are:

- To provide protection for persons or animals against the dangers of electric shock.
- To maintain the proper function of the electrical system.

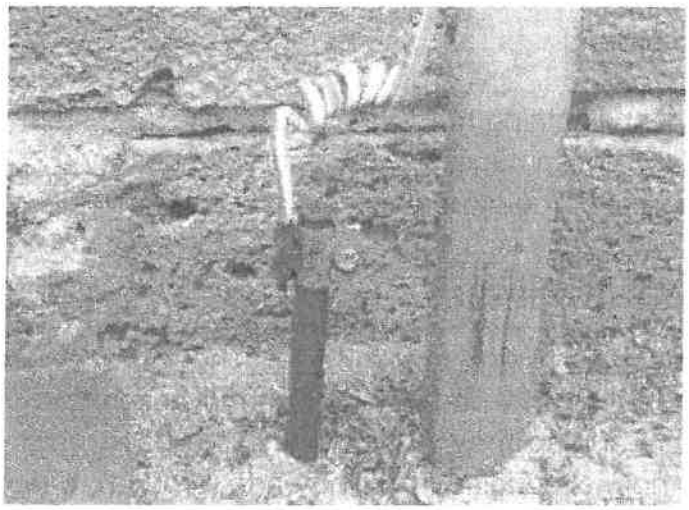
A fundamental principle of electrical safety is that no single fault condition should cause a hazardous situation. It is better to be safe than sorry.

The earth connection is supplied by the electricity supplier (Electricity Company) as shown in the picture above or through an earth electrode (usually a rod or plate is driven into the ground as shown the picture below).

This type of earthing (earth electrode) is more common in rural areas, where the electricity company cannot easily supply or guarantee an adequate earth conductor.

6.8.1. The earth spike, lightning arrestor, earth systems and bonding (Acknowledgement of Indigenous knowledge systems (Earth Leakage developed in SA)

a) The earth spike:

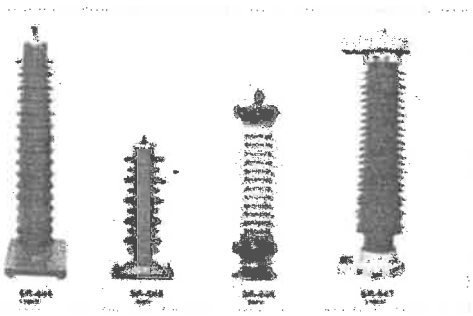


(Wikipedia, HomeEarthRodAustralia)

Figure 20: Earth Spike

The made spikes are approximately 1200mm long × 9mm diameter. A copper outer layer (or a nut) with a metal rod (steel core) sunk into the ground.

b) Lightning Arrestors



(Spikes)

Figure 21: Lightning Arrester

A lightning arrestor is a device used on electrical power systems and telecommunication systems to protect the insulation and conductors of the system from the damaging effects of lightning. The typical lightning arrestor has a high-voltage terminal and a ground terminal. When a lightning surge (or switching surge, which is very similar) travels along the power line to the arrester, the current from the surge is diverted through the arrestor, in most cases to earth.

In telegraphy and telephony, a lightning arrestors placed where wires enter a system to prevent damage to electronic instruments (electronic systems) within and ensure the safety of individuals near them. Smaller versions of lightning arrestors are also called surge protectors, which are connected between each electrical wire in power and communication systems and the earth. These prevent the flow of the normal power or signal current to ground.

If protection fails or is absent, lightning that strikes the electrical system will introduce thousands of kilovolts that may damage the transmission lines, and can also cause serious damage to transformers and other electrical and electronic devices.

c) Earth system and Bonding

Ground or earth in an electrical wiring system is a conductor that provides a low impedance (resistance) path to the earth and prevents hazardous voltages from appearing on equipment. Earthing means connecting the dead parts (parts which don't carry current under normal conditions) to the earth (ground). Examples frames, enclosures, supports etc.

Bonding is simply the act of joining two electrical conductors together. These may be two wires, a wire and a pipe, or so forth.

Electrical bonding is the practice of electrical connection of all exposed metallic parts not designed to carry electricity in the building to the earth as to protect from electrical shocks. It has to be done by connecting all the metal parts that are not supposed to be carrying current, bringing them to the same electrical potential.

In the domestic installations wiring, it is normal for safety reasons to connect all metal objects such as pipes together to the main earth to form an equipotential zone.

Equipotential bonding is to join together metalwork that is or may be earthed so that it is at the same potential (voltage) everywhere in installation. If a failure of electrical insulation occurs, all bonded metal objects in the room will have the same electrical potential, so that a person in the room cannot touch two objects with significantly different potentials. The person will be protected from different potential dangers.

d) Acknowledgement of Indigenous knowledge systems (Earth Leakage developed in SA)

The prime requirement of any rules for electrical installations is to ensure that people, animals and property are protected from hazards that can arise from the operation of an electrical installation under both normal and fault conditions.

Mandatory requirements for South Africa, a history of electrocutions led to a belief that earth leakage devices should be installed as a compulsory requirement.

Earth leakage device must be capable to detect a specified or predetermined current from a circuit to earth, and disconnect automatically and reliably the affected circuit within a specified time when a current exceeds the specified or predetermined value.

Earth leakage protection shall be provided for the circuit that supplies an electrode water heater, steam generator or boiler. This protection shall be set to operate in the event of a leakage current exceeding 10 % of the current consumed by the appliance under normal conditions of operation. The characteristics of the circuit and of the earth return path shall be such that the earth leakage device will operate before the potential between earth and the shell of the steam generator or boiler exceeds 50 V, including under short-circuit fault conditions (SANS 10142-1).

6.8.2. SANS Chapter 6.11 – Consumers Earth Terminal

- Each installation shall have a consumer's earth terminal at or near the point where the supply cables to the installation enter the building or structure. All conductive parts that are to be earthed shall be connected to a main earthing terminal, which shall be connected to the consumer's earth terminal. The consumer's earth terminal shall be earthed by connecting it to the supply earth terminal or the protective conductor and, if installed, the earth electrode.
- In every installation where main equipotential bonding is used, the following shall be connected to the main earthing terminal in the distribution board:
    - main equipotential bonding
    - earthing conductors;
    - functional earthing conductors;
    - conductive screens, sheaths or armouring of telecommunication cables or telecommunication equipment;
    - earthing conductors for overvoltage protective devices (including conductors of lightning protection systems);
    - earthing conductors of radio communication antenna systems; and
    - the earthing conductor of an earthed DC power supply system for information technology equipment

NOTE: The main earthing terminal of the building can generally be used for functional earthing purposes

If, for practical reasons, the supply to the installation cannot be automatically disconnected by an earth fault current double the rated current (or higher) of the main protective device, as an alternative, an earth fault detection and disconnecting device may be installed at the supply of the installation. The earth fault detection and disconnecting device shall be so installed that it operates at a current related to the

earth loop impedance which will limit prospective touch voltages under short-circuit fault conditions to 25 V for a period not exceeding 5 s. This alternative does not relieve the supplier from the responsibility of providing a supplier's earth terminal (see SANS 10292).

- Each conductor connected to the main earthing terminal shall be able to be disconnected individually. This connection shall be disconnectable only by means of a tool, shall be mechanically strong, and shall ensure the maintenance of electrical continuity.
- A readily accessible earthing terminal shall be provided for the bonding of other services such as a telephone, an audio or a video system, and the like, to a building. Such an earthing terminal shall be bonded to the consumer's earth terminal by a conductor of at least 6 mm^2 copper or equivalent, and shall be identified by the earth symbol.

NOTE: Providers of services other than the electrical power services should not access the distribution board or other parts of the electrical installation.

- Labels shall be fitted to all distribution boards where the readily accessible earthing terminal for the bonding of other services is provided.

6.8.3. SANS Chapter 6.12 – Earthing

Many electrical devices e.g. washing machines, heaters, some light fitting and some socket outlets fittings have exposed metalwork which could become live if a fault occurred. Anyone touching it could then receive a shock or even be killed depending on the current flowing through them to earth.

To prevent this, an earthing conductor should be provided to all socket outlets, lighting circuits and any fixed appliances to which exposed metal parts are then connected.

The earth connection limits the voltage which can appear on the exposed metal parts under fault conditions to a safe value until the MCB trips.

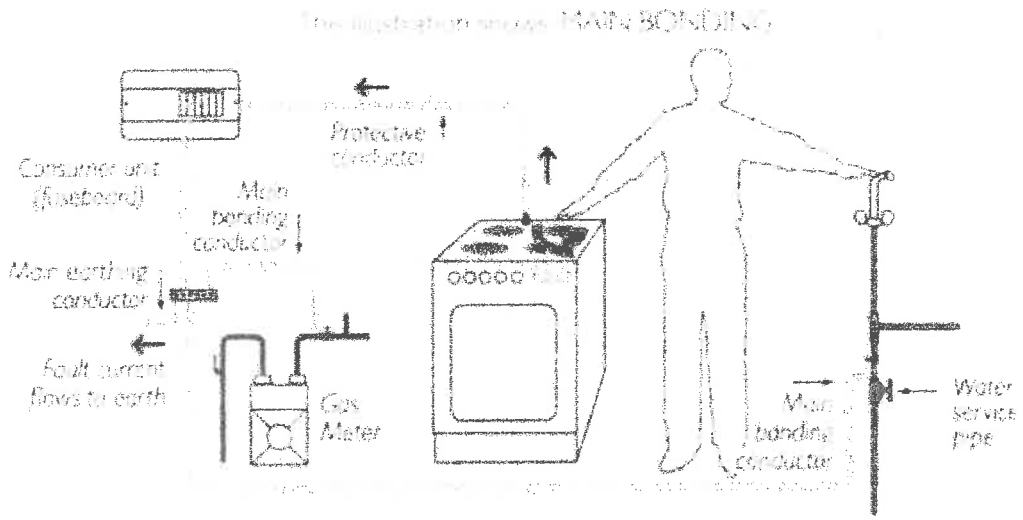
- **NOTE 1**: In line with SANS 10142-1, earth continuity conductors and equipotential bonding are to ensure the safety of the electrical installation. Earthing arrangements may be used jointly or separately for protective and functional purposes according to the requirements of the electrical installation. Requirements for protective purposes always take precedence.
- **NOTE 2:** The requirements for earthing arrangements are intended to provide a connection to earth that:
    - is reliable and suitable for the protective and functional requirements of the installation,

  - can carry earth fault currents, protective conductor currents and leakage currents to earth without danger from thermal, thermo-mechanical and electromechanical stresses and from electric shock that arise from these currents, and
  - where relevant, is also suitable for functional requirements
- Earth continuity conductors: An earth continuity conductor shall
  - consist of compatible conductors,
  - if it forms part of a cable other than a flexible cable, comply with the relevant requirements of the standard for the cable,
  - if it forms part of a flexible cable, be of the same material as, and have a nominal cross-sectional area at least equal to, that of the largest phase conductor,
  - if it does not form part of a cable or flexible cable, have a nominal cross-sectional area at least equal to the required cross-sectional area cable
- Earth continuity conductors shall be so arranged that they cannot be tampered with.
- A wire-way shall not be used as an earth continuity conductor.

Earthing of the neutral of combined sources

- When an installation that has a common neutral is supplied from a combination of transformers and generators located near one another, the neutral terminal of each of these items shall be connected to a single neutral bar. This neutral bar shall be the only point at which the neutral of the installation is connected to the consumer's earth terminal.

6.8.4. Bonding



(Hire)

Figure 22: Bonding

A fault current flowing in the earth conductor will cause the voltage on that wiring to rise to true earth potential. This could cause a shock to someone touching, for instance, the case of a faulty washing machine and water tap. To minimise this risk, an equipotential zone is created by connecting the services (for examples water pipes, gas pipes, oil pipes, heating, metallic ventilation, exposed parts of building structure, etc.) to the main earthing.

NOTE 1: The aim of bonding is to bring all the bonded parts to the same electrical potential.

NOTE 2 No external conductor is required if compliance with the requirements for continuity can be proved by the test. (8.7.2.SANS)

- Bonding conductors
  - A bonding conductor shall
    - have a nominal cross-sectional area of at least 2,5 mm² copper or equivalent, and
    - Be so arranged that it cannot be tampered with.
- Parts to be bonded
  - **Hot and cold water systems:** Hot and cold water systems shall be bonded together and also be bonded to the earth continuity conductor system.
  - **Antennas:** The conductive components of an antenna structure (including a satellite dish) shall be bonded to the installation earthing

system by means of a conductor of at least 2, 5 mm² copper or equivalent.

- **Roofs, gutters, down pipes and waste pipes:** If a building is connected to an electricity supply, the roof(s), gutter(s), down pipe(s) and waste pipe(s) shall be bonded and earthed and the resistance of the earth continuity path shall not exceed 0,2 Ω, unless:
  - the supply voltage does not exceed 50 V,
  - the supply uses an underground service connection,
  - the roof is made of, or covered with, non-conductive material,
  - the gutter(s), down pipe(s) and waste pipe(s) are of non-conductive material, or
  - The gutter(s) and down pipe(s) are attached to a metal roof that is covered with non-conductive material.
- **Water pumps:** All accessible extraneous conductive parts associated with a water pump motor shall be bonded to the earth continuity conductor. These parts include the suction pipe, delivery pipe and pump casing.

NOTE 1 Providers of services other than the electrical power services should not access the distribution board or other parts of the electrical installation.

NOTE 2 Extraneous conductive parts of other services should not be used as an earth conductor.

Complete Learner Activity: 15 - Learner Activity: 17

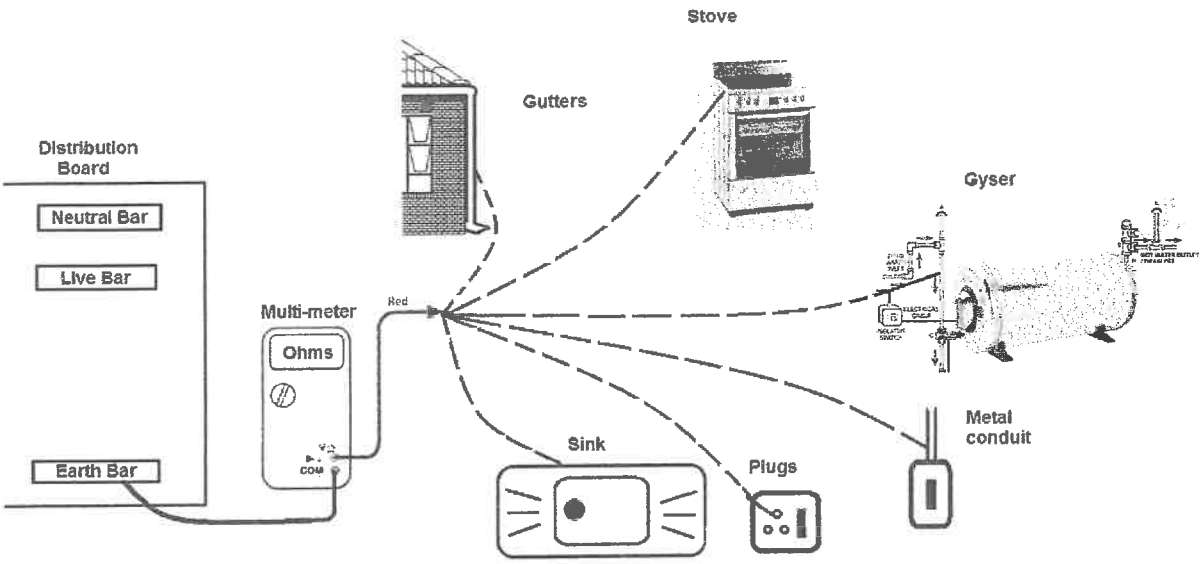
6.9. Testing and Troubleshooting (After Installation)

To ensure safety precautions, all electrical installations irrespective of new or alteration should satisfy the inspection and testing procedures as indicated by SANS 10142-1 installation regulations. If the installations are not installed correctly, by not referring to SANS 10142 wiring code, or referring to the manufacturer's specifications, terrible accidents could occur. Remember that electricity can kill and fire could be caused by electrical faults which could be prevented. You must work responsibly.

To prevent damage, ensure that voltage-sensitive electronic equipment such as dimmer switches, touch switches, timer delays, power controllers, electronic starter for fluorescent lamps, earth leakage units, surge arrestors and certain appliances are disconnected so that they are not subjected to the test voltage.

Before an installation may be connected permanently to the supply the following tests must be carried out:

6.9.1. Earth Continuity Testing



This test can be carried out with a tester that has an Ohm scale or an earth continuity tester. In this test we measure the resistance of the earth continuity conductors between the consumer's earth terminal and the earthing terminal of all points of consumption and switches. Items to be tested include:

- Metal conduits, Water pipes, Metal switch boxes, Plugs, Exposed metal of appliances, Metal roofs, Gutters, Down pipes, Metal sinks, Basins, Copper lintel, Outlet pipes on the geyser, Aerial conductors

The reading (values) must be in accordance with SANS regulations (table 8, sections 8.7.2), and must not exceed the values in the table that follows:

Maximum resistance of earth continuity conductor	
Rated current of protective device (A)	**Maximum resistance of earth continuity path (Ω)**
6,3	1,7
10	1,1
16	0.70
20	0.55
25	0.53
32	0.41
40	0.33
50	0.26
63	0.24
80	0,19
100	0.14

Maximum resistance of earth continuity conductor	
Rated current of protective device (A)	**Maximum resistance of earth continuity path (Ω)**
125	0.12
160	0,096
200	0.077
250	0.062
315	0.049

NOTE: In the case of metallic roofs, gutters, down pipes and waste pipes the resistance of the earth continuity path shall not exceed 0, 2 Ω.

6.9.2. Insulation Resistance Tests between conductors

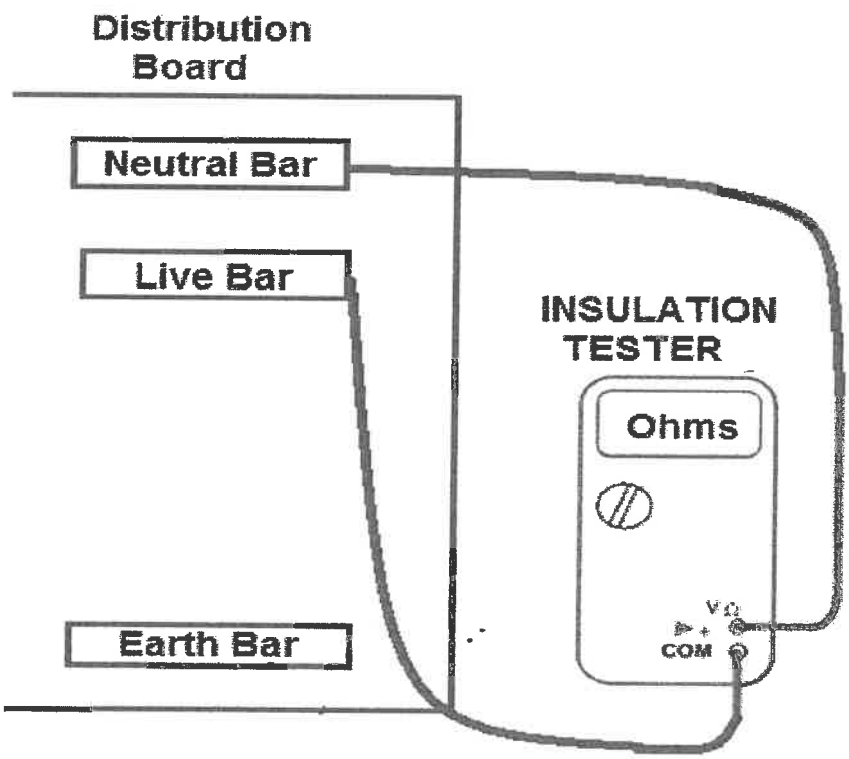


Figure 23: Insulation resistance between conductors

This test is carried out by connecting one lead of the megger or insulation tester to the live bar and the other to the neutral bar.

When testing the insulation resistance between conductors:

- The main supply and switch disconnector must be off,
- All switches and MCBs(miniature circuit breakers) must be on,

- All lamps must be out, and
- All appliances must be disconnected,
- Insulation reading should be at least 1 mega ohms

6.9.3. Insulation Resistance Tests between conductors and earth

This test is carried out by connecting one lead of the test instrument (insulation tester) to the earth terminal in the distribution board and the other lead to the live busbar or neutral bar. The live busbar must be bridged to the neutral bar. The minimum reading value must be at least 1 mega Ohm.

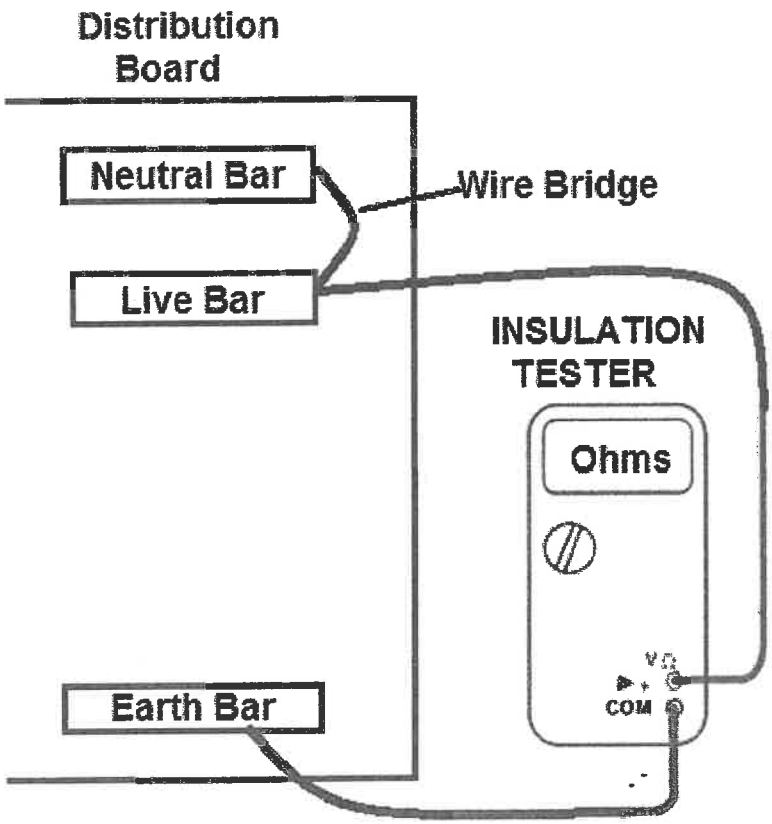


Figure 24: Insulation Resistance test between conductors and earth

When testing the insulation resistance to earth, always ensure that:

- The main supply and switch disconnector are off,
- All switches and MBCs are on,
- Live and neutral bars are bridged, and
- The resistance is at least 1 mega ohm.

6.9.4. Polarity tests (Plug Tester)

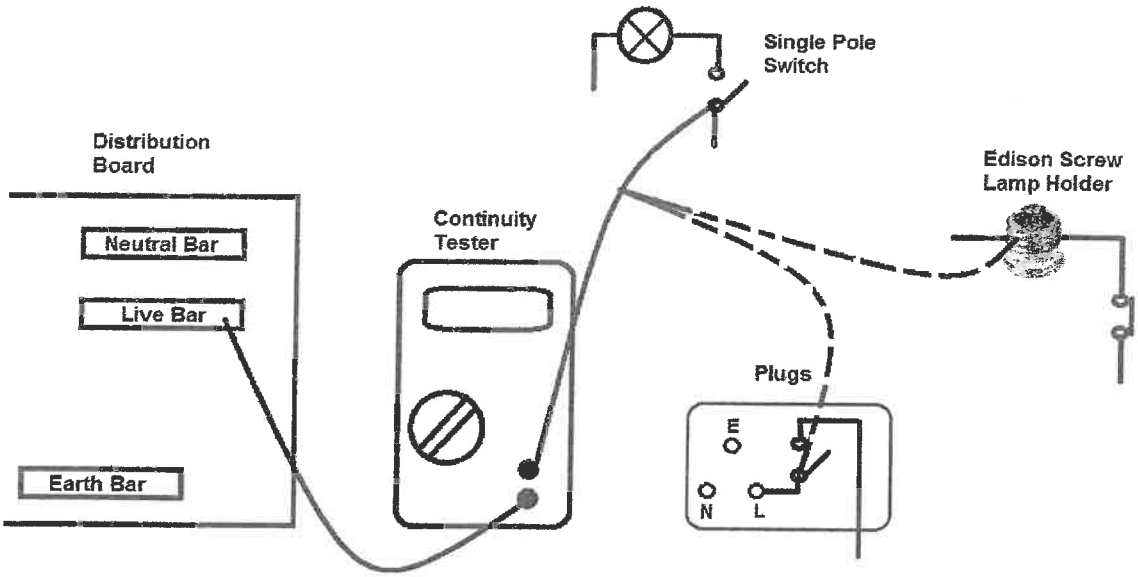


Figure 25: Polarity Testing

A polarity test should be carried out to ensure that:

- all single-pole switching devices, fuses and circuit-breakers have been connected in the phase conductor (live),
- the phase terminals in fixed appliances and in all single-phase socket outlets have been connected to the phase conductor,
- the centre contact of each Edison-screw lamp holder is connected to the phase conductor, and
- Phase rotation and identification is maintained for three-phase systems on the supply sides of all distribution boards.

When performing the polarity test, always ensure that:

- The main supply and switch disconnector are off, and
- The MCBs are on.

Complete Learner Activity: 18 – 20

6.10. Sub-circuits

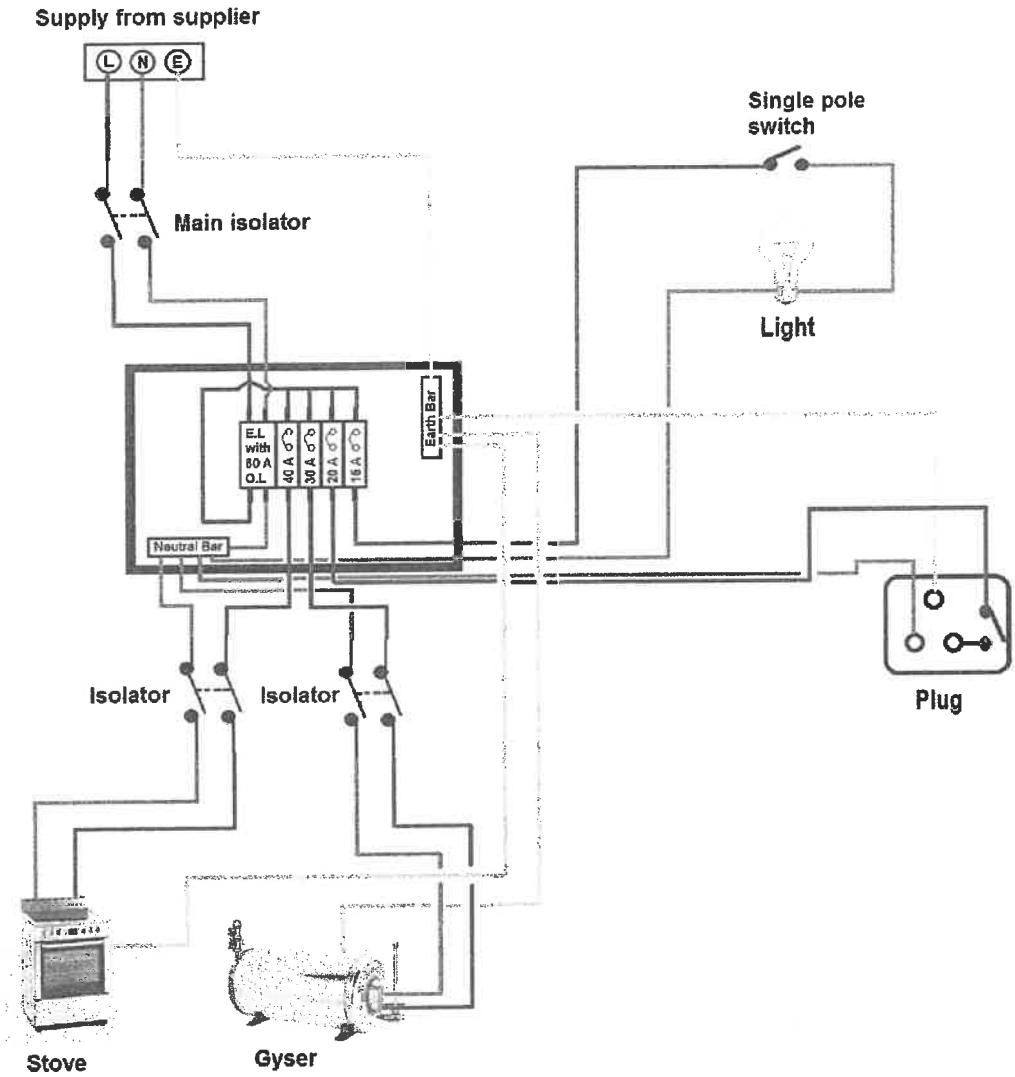


Figure 26: Sub - circuit wiring

The wiring of a domestic installation required that the distribution board receiving the power from the supplier should be fitted close to the point of entry and from here the power is divided into a number of sub-circuits such as light circuits, socket outlet circuits, stove circuit, geyser circuit, swimming pool circuit, washing machine circuit, etc.

It is normal in a domestic installation to separate socket outlet circuits, light circuits and other circuits so that if a fault occurs then not all socket outlets or all lights or all other circuits (equipment/ appliances) are isolated.

In a small house one light circuit can be used to power all the lights in the installation.

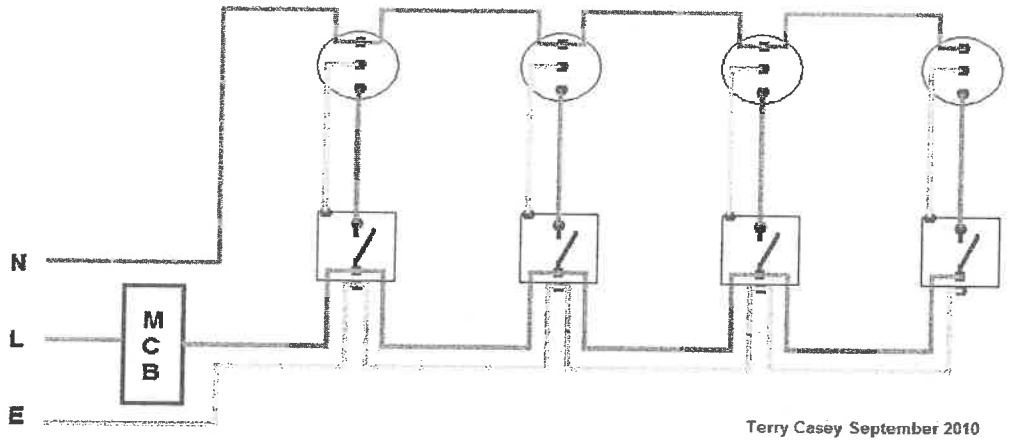


Figure 27: Small house lights wiring

In large houses two or more circuits can be used to power the lights. For example, in a two-storey house this would be one circuit for upstairs lights and one for downstairs lights. In a small house one socket outlet circuit can be used to power the entire socket outlets. In large houses two or more circuits can be used to power socket outlets. For example, in a two-storey house this would be one circuit for upstairs socket outlets and one for downstairs socket outlets.

In some larger houses a separate power circuit is also installed for the garage / utility area. In all domestic installations a separate power circuit (socket outlet circuit) is required for the cooker (stove) since the electrical demand is likely to be high. The geyser and some other services can also be supplied from separate circuits as the electrical demand for these is also likely to be high.

6.10.1. Lighting Circuits

In domestic installations, electrical circuits are used to operate for example the lights. These circuits used to operate the lights are referred to as light circuits

A typical example of light circuit is one way switching circuit as given below:

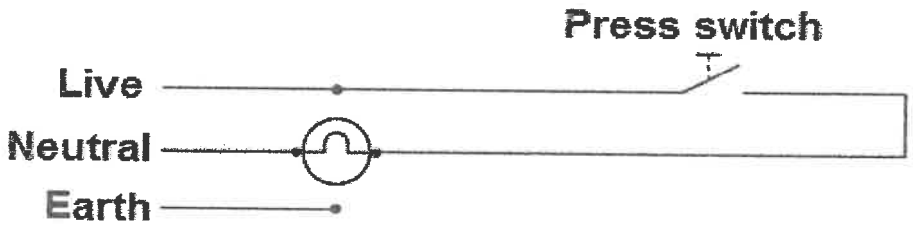


Figure 28: One way switch

Take note that the switch is always connected to the line (live or L) of the circuit and the Neutral (N) is always connected to the load (light) side of the circuit. The switch is used to control the operation of a light. This is a common application of connecting light switches in a room.

The cross-sectional area of the wire used in light circuits must be at least 1, 5 mm². The light circuit is normally connected through a 10 A circuit breaker to the supply.

a) ***Lights in Series (Voltage and Current measurement)***

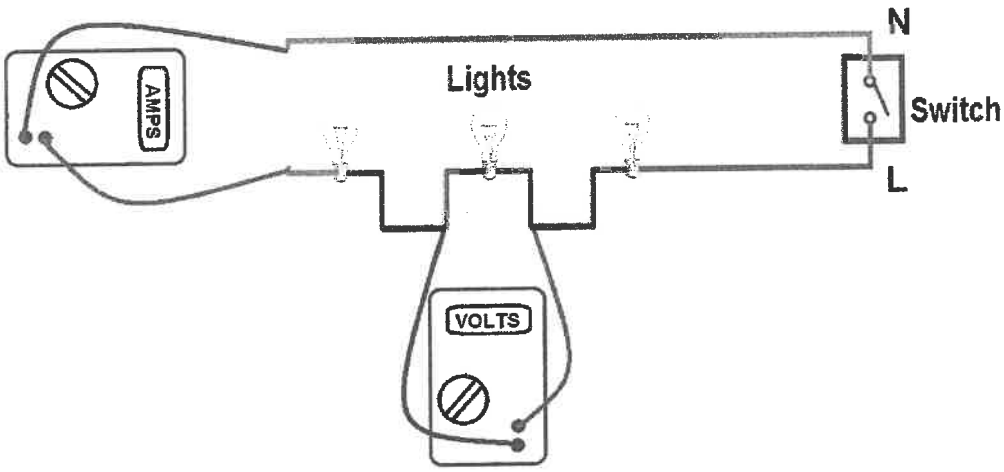


Figure 29: Three lights in series

Lights connected in series; if one light blows the other lights will also be off. The voltage is measured across each light. The current is measured in series with the live.

b) ***Lights in Parallel (Voltage and current measurement)***

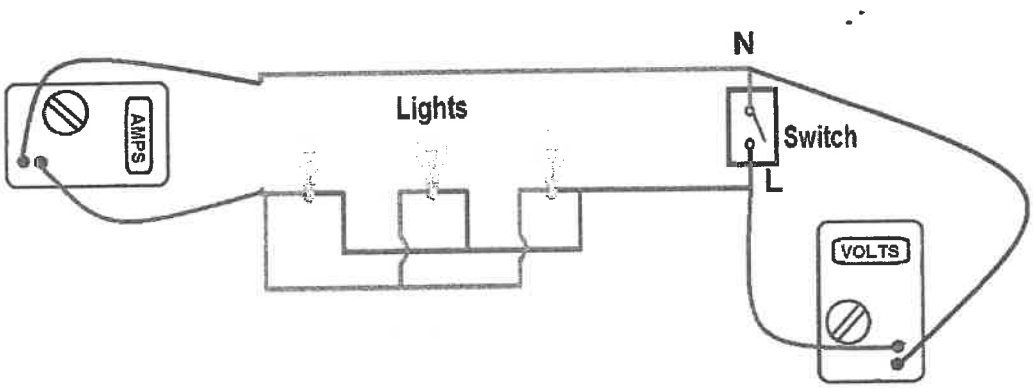


Figure 30: Three lights in parallel

When more than one light is used in domestic installation, they are normally wired in parallel. This is done so that if one light is not working, the others will still work. The voltage is measured across the live and neutral. The current is measured in series with the live.

c) Two Way switching (SPDT)

Two-way switches are used to control the light(s) from two different points. One two-way switch has a normally opened (NO) and a normally closed (NC) connection. The common application is for switching a light on or off in a long passage or in a room which has two entrances / exits also at staircase, below is a two – way switching circuit

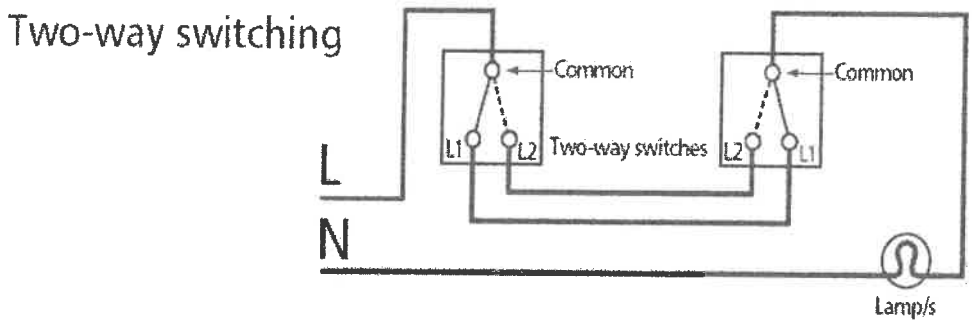


Figure 31: Two - way switching wiring

d) Intermediate Light Switching (DPDT)

The intermediate switch is always placed in between the two-way switches for operation. The intermediate switch is used to control the light(s) from three or more different points. The operation of this will allow the contact or breaking of current flow on the two-way switches when pressed. This type of switch is recommended for buildings with more than three storeys and T-junction passages. A typical example of wiring an intermediate switch is given as shown:

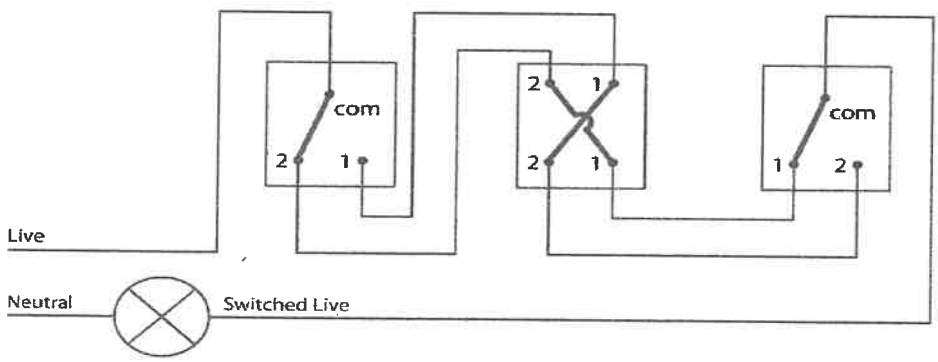
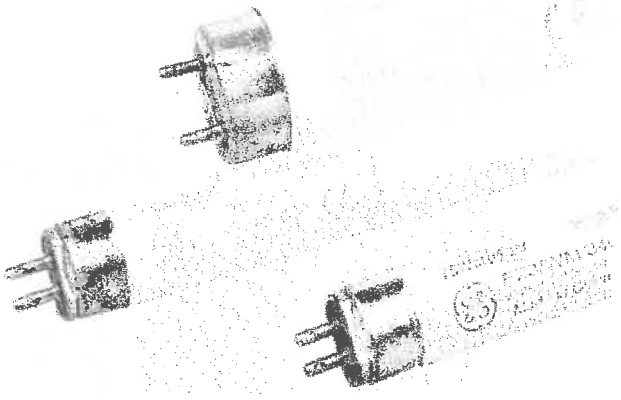


Figure 32: Intermediate switching

Complete Learner Activity: 21 – 22

6.11. Alternative Lighting Systems

6.11.1. Fluorescent Lights

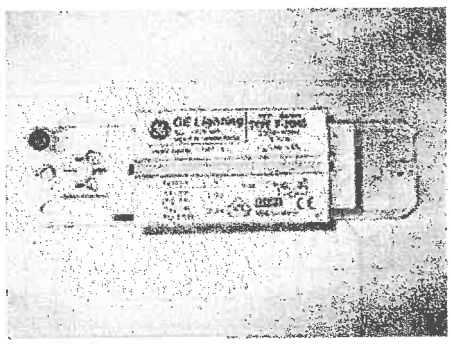


(Lighting)

Figure 33: Fluorescent Lights

A fluorescent lamp or fluorescent tube is a low pressure mercury-vapour discharge lamp that uses fluorescence to produce visible light. The lamp that consists of a long glass tube, fluorescence coated with cathodes at the end. A fluorescent lamp converts electrical energy into useful light much more efficiently than incandescent lamps. The luminous efficacy of a fluorescent light can exceed 100 lumens per watt, several times the efficacy of an incandescent bulb with comparable light output.

In the operation of fluorescent lamps, when the light is turned on, the electric power heats up the cathode enough for it to emit electrons. The lamps must use an auxiliary device, a ballast to regulate the current flow through the tube. The simplest ballast for alternative current is an inductor placed in series, consisting of a winding on a laminated magnetic core.



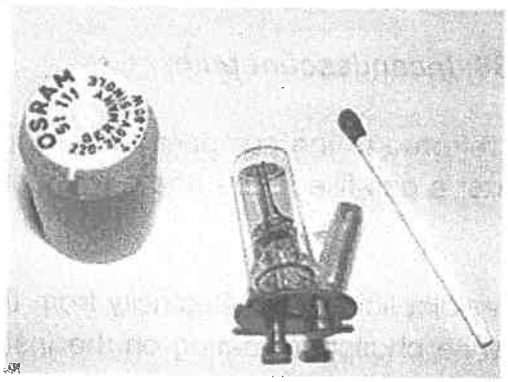
(Wikipedia, New_GE_Ballast)

Figure 34: Ballast

Ballasts are rated for the size of lamp and power frequency. Where the AC voltage is insufficient to start the long fluorescent lamps, the ballast is often a step-up autotransformer with substantial to limit the current flow.

The effects of temperature, each lamp contain a small amount of mercury, which must vaporize to support the lamp current and generate light. At low temperatures the mercury is in the form of dispersed liquid droplets. As the lamp warms, more of the mercury is in vapour form. At higher temperatures, self-absorption in the vapour reduces the yield of ultraviolet and visible light. Since mercury condenses at the coolest spot in the lamp, careful design is required to maintain temperature, around 40 °C.

Some fluorescent lamps require an automatic starting switch (starter) to start the lamp.



(Wikipedia, Starter)

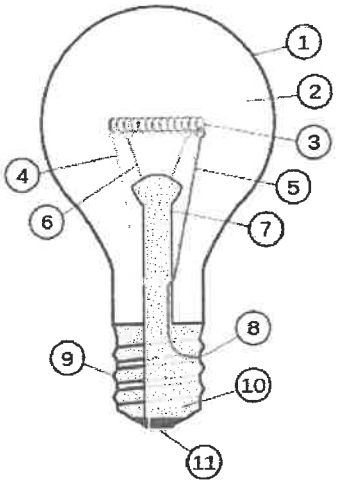
Figure 35: Automatic starting switch

Advantages: fluorescent lamps convert more of the input power to visible light than incandescent lamps

Disadvantage: If a fluorescent lamp is broken, a very small amount of mercury can contaminate the surrounding environment. This can be considered a hazard. Because mercury is poisonous, the mercury from lamps may be a contributor to air and water pollution.

6.11.2. Comparison between Incandescent Lamps and Energy Saving Lighting

An incandescent light bulb, incandescent lamp or incandescent light globe is an electric light which produces light with a filament wire heated to a high temperature by an electric current passing through it.



1. Outline of Glass bulb
2. Low pressure inert gas (argon, nitrogen, krypton, xenon)
3. Tungsten filament
4. Contact wire (goes out of stem)
5. Contact wire (goes into stem)
6. Support wires (one end embedded in stem; conduct no current)
7. Stem (glass mount)
8. Contact wire (goes out of stem)
9. Cap (sleeve)
10. Insulation
11. Electrical contact

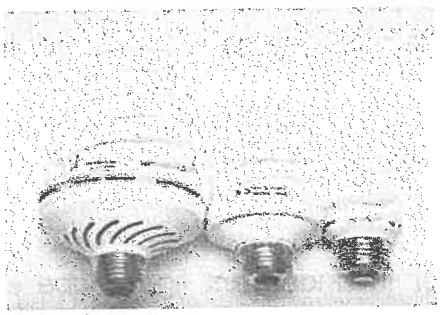
(Wikipedia, Incandescent_light_bulb)

Figure 36: Incandescent bulb

The energy saving lamp is mostly referred to the compact fluorescent lamps, learnt previously. They consist of two parts: a gas-filled tube and a magnetic or electronic ballast.

The gas in the tube glows with ultraviolet light when electricity from the ballast flows through it. This in turn excites a white phosphor coating on the inside of the tube, which emits visible light throughout the surface of the tube.

Compact fluorescent lamps are now available in the same popular sizes as incandescent and are used as an energy-saving alternative in homes. A compact fluorescent lamp can be installed in the sockets typically used on incandescent lamps. If an office or work area is equipped with small incandescent lamps, it is more efficient to replace the fixtures with compact fluorescent lamps.



(Wikipedia, Compact_flourescent_light_bulbs)

Figure 37: Compact fluorescent lamps

Many compact fluorescent lamps integrate it base to fit into a regular incandescent bulb socket. There are two types of compact fluorescent lamps: integrated and non-integrated lamps. Integrated lamps combine the tube and ballast in a single unit:

These lamps allow consumers to replace incandescent lamps easily with compact fluorescent lamps. Integrated compact fluorescent lamps work well in many standard incandescent light fixtures, reducing the cost of converting to fluorescent.

Non-integrated compact fluorescent lamps have the ballast permanently installed in the luminary, and only the lamp bulb is usually changed at its end of life:

Fluorescent lamps: Energy saving lamps	**Incandescent lamps**
- Turn on within a second, but many still take time to achieve full brightness. - Have no noticeable warm-up period, but others can take up to a minute to reach full brightness or even longer in very cold temperatures. - The average life is between 8 and 15 times that of incandescent lamp (typically have a rated lifespan of between 6,000 and 15,000 hours) - fluorescent lamps convert about 22% of the power input to visible light - Save electricity and reduce CO2. - They use up to 80% less energy than conventional light bulbs.	- reach full brightness within a second after being switched on - the light colour may be slightly different immediately after being turned on - don't last as much as energy saving lamps (are usually manufactured to have a lifespan of 750 hours to 1,000 hours) - convert less than 5% of the energy they use into visible light, with the remaining energy being converted into heat - consume more energy and CO2

6.11.3. LED Lighting

(Wikipedia, 60_LED_3W_Spot_Light)

Figure 38: LED Spot Light

Light Emitting Diodes (LEDs) can save on electricity by reducing electricity consumption, on lighting, by up to 90% and this saving on electricity can equate to thousands of Rand. LED light bulbs last 50 times longer than incandescent bulbs and five times longer than compact fluorescent lamps (CFLs). With their low consumption of electricity, LED lights contribute greatly to the reduction in the emission of greenhouse gases

LED lamps have a lifespan and electrical efficiency that is several times better than incandescent lamps and significantly better than most fluorescent lamps (can emit more than 100 lumens per watt).

The applications of the LED lamps, for example they are used for both general and special-purpose lighting. They are used where coloured light is needed:

The LED lamps are also used where high efficiency is important at low power levels. Some of these applications include flashlights, solar-powered garden or walkway lights, and bicycle lights. Monochromatic (coloured) LED lamps are now commercially used for traffic signal lamps, where the ability to emit bright monochromatic light is a desired feature.

The LEDs are also used for electronic functions, e.g. in some electronic systems or appliances, the type below is commonly used:

The LED lights have some advantages such as:

- Reduces energy costs (uses at least 75% less energy than incandescent lighting, saving on operating expenses).
- Reduces maintenance costs (lasts 35 to 50 times longer than incandescent lighting and about 2 to 5 times longer than fluorescent lighting).
- Reduces cooling costs (LEDs produce very little heat).
- Offers convenient features (available with dimming on some indoor models and automatic daylight shut-off and motion sensors on some outdoor models).
- Is durable (won't break like a bulb).

LED lighting displays the following characteristics:

- Brightness is equal to or greater than existing lighting technologies (incandescent or fluorescent) and light is well distributed over the area lighted by the fixture.
- Light output remains constant over time, only decreasing towards the end of the rated lifetime (at least 35,000 hours or 12 years based on use of 8 hours per day).
- Excellent colour quality. The shade of white light appears clear and consistent over time.

- Efficiency is as good as or better than fluorescent lighting.
- Light comes on instantly when turned on.
- No flicker when dimmed

6.11.4. Day Night Light Circuits

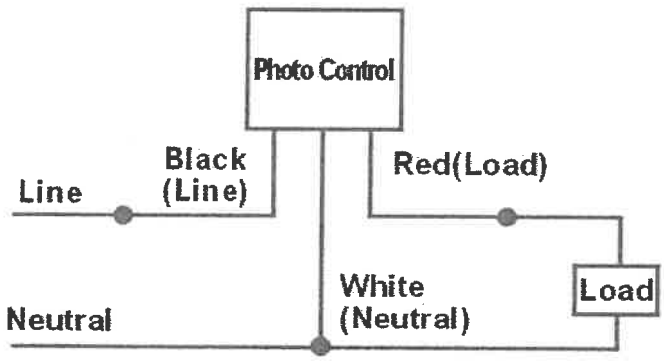
(Matelec)

Figure 39: Day Night switch

The day night switch is an electrical device that turns a light on or off depending on the amount of light shining on it. In electrical circuit the day night switch will turn the light on at night (in darkness). Also it will turn the light off early in the morning (daytime, or sun light).

The day night switching systems have benefits; these can reduce lighting operating hours up to 50 % and save energy.

Wiring circuit design:



(Photo control)

Figure 40: Photo control

Applications: day night switching circuits are used for lighting circuits, for example street lights, exterior walkways, and building facade lighting.

6.11.5. SANS Chapter 6.14 – Lighting

- A single-phase circuit that supplies luminaries only can supply any number of luminaries.
- Each identified group of single-phase luminaries supplied from a multiphase supply that also feeds other luminaries, shall be controlled by a local multiphase disconnecting device.

NOTE the disconnecting device should disconnect all live conductors that feed the group of luminaries, including the neutral, in order that maintenance work can be carried out without switching off all the lights.

- A circuit that has two phase conductors and that supplies only luminaries that are connected between the phase conductors, may supply any number of points if
    - the circuit is controlled by a multiple switch-disconnector, and
    - Any additional switches in the circuit are multiple switches.
- In a lighting circuit, a luminary that is in a false ceiling or in a roof space 4 m above the floor where there is no ceiling, or in a floor cavity, or in a wall cavity, or in a similar position, may be fed from a socket-outlet which may be unswitched and not protected by earth leakage protection, provided that the socket-outlet complies with SANS 164-3 or, except in the case of residential installations, with BS 1363-2 (for 13 A fused plugs),
- In a lighting circuit, a luminary may be fed from a socket-outlet on a wall (that may be unswitched), provided that the socket-outlet
    - Complies with SANS 164-3,
    - is protected by earth leakage protection,
    - supplies one luminary only, not exceeding the rating of the socket outlet, and
    - Is within 3 m of the luminary that it supplies.
- At least one 16 A socket-outlet that complies with SANS 164-1 or SANS 164-2 shall be installed in the same room.
- If more than one phase in a lighting circuit is brought into one enclosure for switching purposes,
    - labels, stating that the voltage between phase conductors could exceed 250 V shall be fixed in a visible position inside the enclosure (not on the cover plate);
    - The phase terminals in the enclosure shall be separated by suitable barriers.

NOTE To avoid nuisance tripping where earth leakage protection is used, it is advisable to restrict the number of discharge luminaries on a circuit.

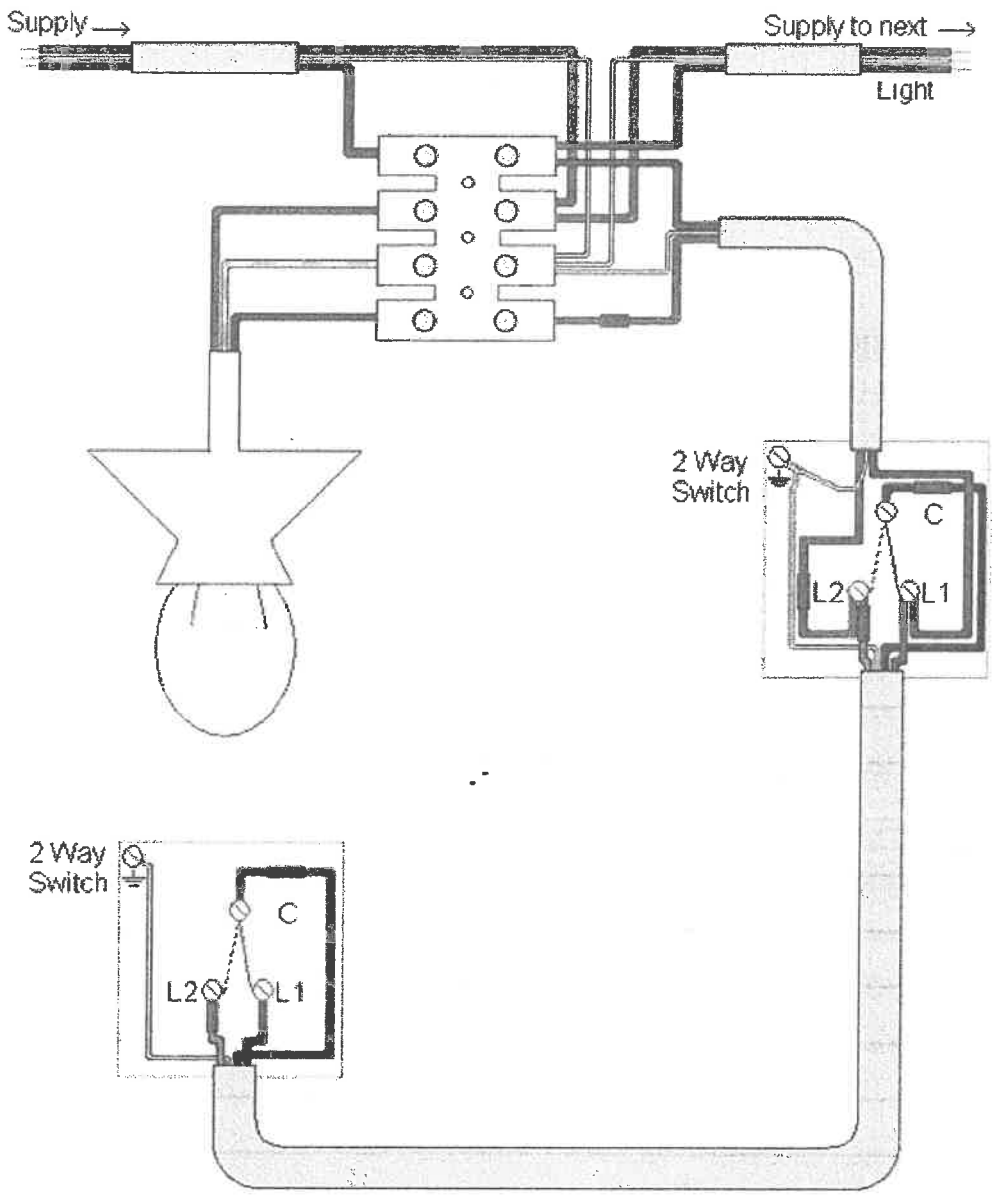
- If more than one circuit is brought into an enclosure, a warning label must be provided.

6.12. Practical: Wire a Lighting Sub-circuit with two way and intermediate switching

6.12.1. Wiring of two way switch light circuit

Purpose: To practically wire a two way switch light circuit

Duration: **1½ hrs**



Procedure:

1. Draw in freehand the two way switch lighting circuit

2. List components, materials and tools needed to wire up the two way switch light circuit.

3. Do the practical wiring of the circuit on your panels.