BUILDING SERVICES

What is a Building and Building Services?

- A structure that has a roof and walls and stands permanently in one place. The primary function of buildings is to provide shelter to its occupants.
- Building function cannot be limited to provide shelter only. Basically "Building Services" is what that make the building comes to life. i.e. what makes the building work. Building should be designed in such a way to provide an environment where people can feel comfortable, work, live and achieve.
- **Building services** is therefore, everything inside a building which makes it safe, comfortable and livable.
- A building must do what it was designed to do-not just provide shelter but also provide a safe, comfortable and livable environment.
- Building services contribute largely to the sustainability and functioning of the building.
- Building services systems are essential provisions for a building, accounting for 20% to 40% of the total construction cost.

Main objectives of building services design engineering

- Hygiene (prevent disease & ensure health)
- Safety (protect against risks)
- Comfort (physio- & psycho- well-beings)
- Convenience (efficiency & productivity)

➢ Building should be design with features to provide better lighting, comfortable space, temperature and air quality, convenient power and communication capability, high quality sanitation and reliable systems for the protection of life and property.

➢ Building services are mainly divided into mechanical, electrical and building operation systems. They are all very important and should be put into consideration during planning, designing and construction of a building.

Mechanical systems include:

1. HVAC Systems: heating, ventilation and air conditioning.
2. Site drainage: water, drainage, sanitary disposal.
3. Plumbing: water distribution, water treatment, sanitary facilities.
4. Fire protection: water supply, stand pipe, fire and smoke detection, annunciation.
5. Gas supply

Electrical systems include:

1. Electrical power: normal, standby, emergency power supply and distribution.
2. Lighting: interior, exterior, emergency light.
3. Auxiliary: telephone, data, audio and video sound.

Building operation systems include:

1. Transportation: elevators, escalators, moving walkways.
2. Processing: product, food, services.
3. Automation: environmental control and management

STRUCTURAL BUILDING COMPONENTS

The building as a structure must fulfill the following conditions:

- Satisfy the need for which it was built (function).
- Must resist the loads coming to it i.e. (must be stable).
- Must continue to fulfill its function (durability).
- Must be achieved with the minimum use of resources. (economy).

Buildings are constructed to serve a range of purposes e.g. for shelter, to have a conducive place for work, for schools, industries, entertainment and all you can think of.

A building is broadly divided into two parts: **(1) substructure, (2) superstructure**. The portion of the building below the ground is the substructure and the portion above it is the superstructure. The components of a building can be broadly summarized as follows:

1. Foundations
2. Walls
3. Floors
4. Doors and windows
5. Stairs
6. Roof
7. Services etc.

Foundations

- It is the lowest part of a structure below the ground level and which is in direct contact with the ground, and transmits all dead, live and other loads to the soil beneath in a manner that these do not stress the soil beyond its safe allowable bearing capacity.
- The function of the foundation is, therefore, to spread the load from a building to the ground so that any movement that will occur do not cause damage to any part of the building.
- The foundation should be strong and this is influenced by the kind of materials used for its construction.
- It should be stable, and this is dependent on the way in which the foundation transmits the load to the soil, and the way in which the soil react.
- The pressure which the foundation exerts on the soil compresses the soil making the foundation to move downwards. This is called settlement. Causes of settlement include weak bearing soils, poor compaction, changes in moisture content, maturing trees and vegetation and soil consolidation.

WALLS.

➢ These are constructed with various types of material ranging from blocks, bricks, concrete, and stones. The external walls separate the outside from the inside, and enclose the space within. The internal walls help to divide the building into room spaces and are called partition walls.

FUNCTIONS OF WALLS

1. It should support upper floors and roofs together with their super imposed loads; this function is taken care of by the strength of the walling materials. Blocks are made to a specific strength. Below this strength, the blocks may not be able to withstand load.
2. Walls should resist damp penetration. Water may enter the building through the wall through a number of ways:
    - Water penetration from the driving force of rain
    - Rising damp i.e. water rising up from the ground through the walls.

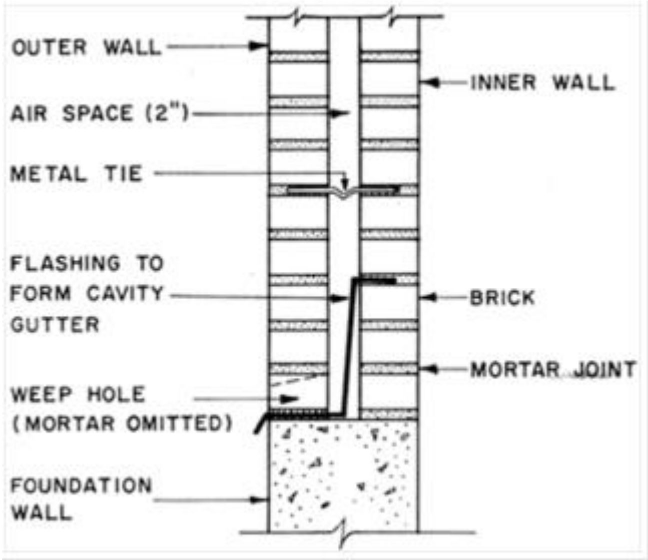
If water penetrate the building, the following are likely to happen:

- The growth of fungus will be favoured
- Furnitures in the building will be destroyed
- An uncomfortable temperature which injurious to human health will set in.

Walls can resist damp penetration by:

i. Using thick layer of material which allows water to pass through slowly, such that when favorable condition for evaporation comes, the water evaporates without reaching the inner face of the wall.

ii. Introducing cavity walls i.e. two leaves of block. This will help create a discontinuity in the passage of water to the other leaf. Cavity walls are constructed of two masonry (brick or block) walls, with a cavity (gap) of at least 50mm (2 inches) between. Originally, the main reason for the cavity was to prevent penetration from rain and damp.



3. Walls should provide adequate thermal insulation. Thermal insulation ensures that:
    - Excessive heat loss from the building is prevented
    - A large heat gain from outside in hot weather is also prevented.
    - Condensation is prevented.
    - Expansion and contraction of the structure is reduced.

In summary, thermal insulation ensures that a reasonable internal temperature is maintained. Materials used as walling material should have the features able to make them perform well.

4. Walls should provide sufficient sound insulation. Around us are sources from which noise enters the building making the occupants uncomfortable with its effect. The external wall acts as a barrier in the sense that when sound waves strike the surface of the wall, some of the sound is reflected,

some absorbed and some set the wall vibrating, thus setting up sound waves on the opposite face. The greater the mass of the walling material, the more it will absorb the sound and provide greater sound insulation. Any opening in the wall allows sound to pass through. For effective sound insulation, wall material must be thick and air tight. Sound insulation of walls is improved by rendering, lining with independent steel stud acoustic quilt.

5. Walls should offer adequate fire resistance. Fire is not only spread by combustible materials around the house, but it can adversely affect the wall that encloses the internal space (i.e. in the sense of conducting heat and igniting a closer materials. Walls, must, therefore, be constructed with materials that would reduce fire spread both from the inside and outside of the house. This means that walling materials must retain sufficient strength to stand up long enough for the people inside to leave the building. When walls have to constructed with different materials, it is necessary to consider how the materials react to fire in order to know how to combine them so that they can provide the necessary fire resistance. In choosing materials for walls, it is not only important to go for non combustible materials, but also to consider whether the material will not lose its strength very quickly.

FLOORS AND STAIRS

Floors are built to divide the space enclosed by the external walls and roof horizontally. By providing a number of floors at different levels, within a building, we create usable area. Floors must provide a level surface that is strong to support the users of the building including other furnitures and equipment that make up the imposed loading of that building. Floors are divided into two different groups in relation with their position in the structure.

TYPES OF FLOORS

- Floors next to the ground
- Upper floors.

Stairs, on the other hand are treated as floors and are meant to provide access between floors. Since stairs connect floors, they must fulfill the same functions as floors. These requirements are discussed below:

- ➢ Floors must withstand loads that will be imposed on them.
- ➢ Floors must prevent the growth of vegetable matter inside the building, this is achieved by the provision of an oversite concrete bed for the ground floor.
- ➢ Floors must prevent damp penetrating inside the building.
- ➢ Floors must provide thermal insulation.
- ➢ Floors must provide an acceptable surface finish which will meet the needs of users in terms of comfort, safety, cleanliness e.t.c.

Floors must provide adequate sound insulation. The reduction in sound transmission will depend on the mass of floor construction. Sound insulation is equally improved by:

- Providing a resilent covering to the floor.
- Providing some kind of discontinuity in the floor structure.

ROOFS.

- ➢ Roof is defined as a covering provided over the top of a building to keep out rain, snow, sun, wind and to protect the building from the adverse effect of these elements.
- ➢ A roof consist of a roof covering material supported on structural elements installed on the building top. The structural elements may be trusses, portal, flat slab, shell, dome etc. the roof covering materials may be thatch, tiles, slates, asbestos cement sheets, galvanized iron sheets etc.
- ➢ As it is important to provide safe foundation, so is it important to provide good roof above the house. As good foundation protects the building against damage from below the ground, so does good roof prevents deterioration of the building from the top.
- ➢ Roof, therefore should meet the following functional requirements:
  - i. It should be structurally sound and strong enough to carry the anticipated dead and live loads safely.
  - ii. It should be durable, able to withstand the adverse effects of sun, snow, rain wind etc.
  - iii. It should have efficient water proofing and drainage provisions.
  - iv. It should provide adequate thermal insulation.
  - v. It should also provide adequate sound insulation.

TYPES OF ROOFS

a) Lean to roof
b) Gable roof
c) Hip roof
d) Gambrel roof
e) Mansard roof
f) Deck roof

DOORS

The doors are a very important element of the house. After the roof, it serves the most important purpose of providing safety and security of the house. The main purposes of doors include:

1. Providing safe access into the house and inner partitions of the house.
2. Doors add to the aesthetic view of the house
3. Providing lighting and ventilation to various rooms in the house.
4. Doors also act as noise barrier when there are chances of too much noise outside of the house.
5. The doors are used to manage the physical atmosphere inside a room, so that heating or cooling of interiors may become more effective.

TYPES OF DOORS

Doors are classified based on the following criteria:

1. Location e.g. interior door or exterior door
2. Materials e.g. wood/timber door, glass door, steel door, pvc door, fiberglass door, aluminium glazed door
3. Operation of Door Shutter e.g. rolling shutter door, sliding door, swinging door, folding door, revolving door, collapsible door.
4. Method of Construction e.g. panel door, flush door, louvered door, wire gauzed door.
5. Arrangement of Door Components e.g. Battened and Ledged Door, Battened, Ledged and Braced Door, Battened, Ledged and Framed Door, Battened, Ledged, Framed and Braced Door

WINDOWS

A window is a vented barrier provided in a wall opening to admit light and air into the structure and also to give outside view. Windows also increases the beauty appearance of building. The main purposes of windows in buildings include:

1. Day-lighting- windows are designed and positioned to admit sun light into the building.
2. Ventilation- windows are designed to allow free circulation of air within the building.
3. Provision of outside view.
4. Beautification of the building- some window styles are designed to increase the beauty of the building.

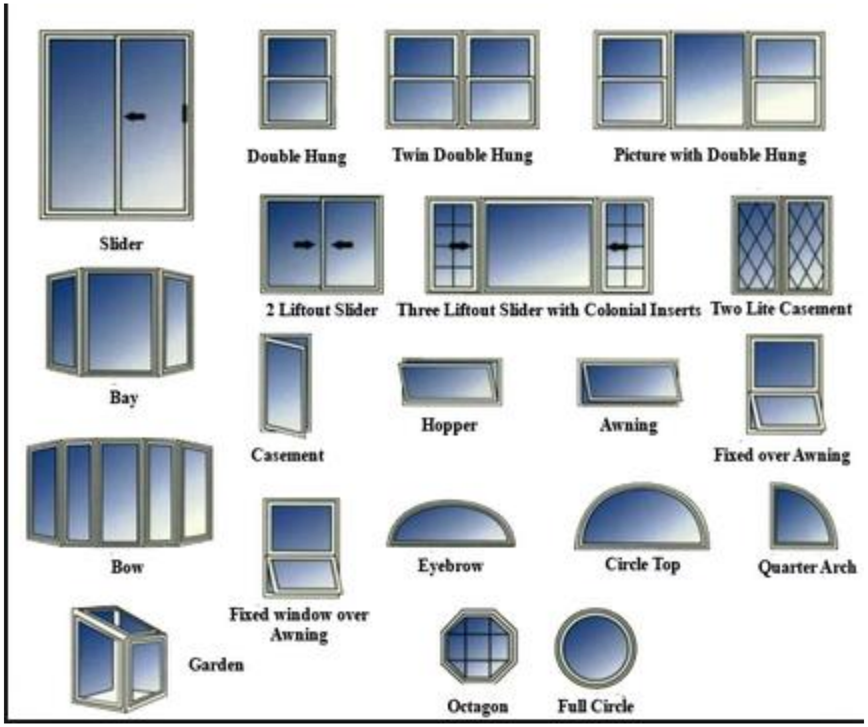
Types of windows:

There are different types of windows used in building construction to provide ventilation, and view. The selection of windows depends on many criteria such as:

- Location of room
- Size of room
- Direction of wind
- Climatic conditions
- Utility of room
- Architectural point of view

Examples of windows used in building include:

1. Fixed windows
2. Sliding windows
3. Pivoted windows
4. Double hung windows
5. Louvered windows
6. Casement windows
7. Metal windows
8. Sash windows
9. Corner windows
10. Bay windows
11. Dormer windows
12. Clerestory windows
13. Lantern windows
14. Gable windows
15. Ventilators
16. Skylights

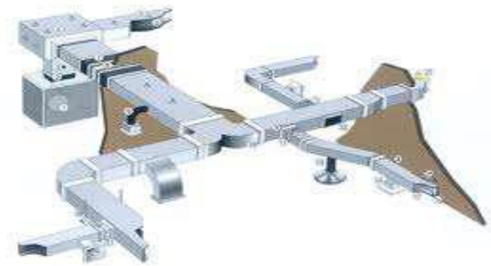


ACCOMMODATION OF ELECTRICAL SERVICES IN BUILDING

The building design and structure accommodate electrical services by incorporating physical features that allows for the installation of electrical services. The main features that allow for the installation of electrical services in building are discussed below:

DUCTS AND CHANNELS

Duct – space within a building specially enclosed for the accommodation of services and allowing facilities for working and inspection.



Duct

The main purposes of ducting include to:

1. Conceal the accommodated services and to facilitate inspection, repair and alterations/modifications of the housed services.
2. Help to reduce noise in the building
3. Protects the accommodated services from mechanical damage

Ducts for Small pipes or cables

- These may be formed in the floor or wall, or on the surface of the wall.
- The size of ducts depends upon the outside diameter of the pipe or cable and the number of services installed.
- Normally the outside diameter not exceeding 64mm

Plant space – area required for the accommodation of mechanical or electrical equipment or control gear required for the operation of services

Plant space

Subway – a horizontal passage for the conveyance of services underground or below the bottom floor of the building which allows walking headroom for access.


Subway

Crawlway – passage for services similar to a subway but where there is insufficient headroom to stand upright.


Crawlway

Trench – horizontal passage for services below floor level where the access is by removable covers in the floor.


Trench

Wells – vertical space used for the accommodation of stairs or lifts or to allow natural light or ventilation

Well

Casing – an enclosure formed over pipes or cables running on the surface of a wall or ceiling. Casing are usually for decoration but can also provide protection from impact or corrosion.


Casing

Chase – a recess cut in a wall or floor when building is over; it accommodates pipes or cables and is screed or plastered over.


Chase

Sump – pit for seepage, leakage and draining down of pipework that cannot be discharged by gravity to the drain and must be collected and pumped.


Sump

Flue – builders' work or metal passage to convey the products of combustion to an acceptable point for discharge to the atmosphere

Flue

Service core – zone extending vertically through high rise building containing vertical circulation, service ducts and other utility and sanitary provisions.

CONDUIT AND TRUNKING

Trunking – lightweight, usually sheet metal or PVC enclosure for the passage of air or cables


- Circular conduit systems are used to carry insulated cables and should last the service period of the building.
- The space occupied by the cable must not exceed 40% of the cross-sectional area of the inside of the conduit to allow for ventilation to remove the heat generated by cable resistance.
- Materials used are light- or heavy-gauge steel, depending upon exposure to damp or explosive fumes.
- The external conduit should be galvanized. Lug grip connections are used for light-gauge pipework and screwed joints for heavy-gauge pipework. Pipe sizes are 16, 20, 25 and 32 mm.
- PVC conduit, using solvent weld joints, is lighter and easier to handle and does not corrode but requires the cable to incorporate the protective conductor. Its upper temperature limit is 60°C.
- Rectangular galvanized sheet steel or PVC trunking is used where large-cable carrying capacity is needed. These must not be filled to greater than 45% of their cross-sectional area with cables.
- Surface-mounted trunking can be incorporated into the interior decoration and up to three separate cable compartments are used for different services, including telecommunications, computer, power and lighting cables.
- Trunking may be installed under raised timber flooring, within the concrete floor slab or screed, in a grid, branch duct or perimeter distribution arrangement. Outlets that are raised or flush with the floor are provided to suit either fixed or movable office layouts.

Important of Unified System of Services Distribution

- Most services can be run in common ducts except flammable liquids and gases
- The pattern of distribution of services is considered as a whole in relation to the building planning
- 3 different categories of services run having different requirements for patterns of distribution:
    - Wells and flues
    - Pipes and ventilation trunkings
    - Electrical cables
- Stair and lift wells run vertically through buildings. They do not required linkage with services at each floor level but prevent an obstacle to horizontal distribution of other services

Several factors to consider in deciding the size of ducts and recess:

- Number & size of pipes, cables & trunkings to be accommodated
- Any critical spacing or fixing position which must be followed for certain pipe types
- Clearance required for placing the pipes in position, which must also allow for ease of removal should it become necessary during maintenance
- Clearance to allow for position of fixings and to permit jointing
- Allowance for additional services which may be needed
- Space for access in the case of ducts
- Space of valve, dampers
- Space for expansion bands in long, straight horizontal or vertical ducts
- Space for branching and service junctions, and to carry these branches past adjoining services

Manholes: small covered opening in a paved area/building allowing access beneath, especially one leading to a sewer.


Manhole

- They are used to carry out inspection, cleaning and removing obstruction in the sewer line or ducted services.
- Manhole allows joining of sewers or changing the direction of sewer or alignment of sewer or both.
- They allow the escape of considerable gases through perforated cover and thus help in ventilation of sewage.
- They facilitate the laying of sewer line in convenient lengths.

UTILITY SERVICES IN BUILDINGS

Water supply system encompasses of a combination of pumps, pipes (of different dimensions and materials), valves and outlets that deliver water to building users**.**

Water supply is the act of Providing Water to the Individuals, Group of people, Institutions, Commercial organization or for irrigation by a system of pumps or pipes.

Water distribution system is the physical infrastructural works that deliver sufficient water quantity and quality water from the water source to the intended end point or user. Water distribution is achieved by way of pumps and motors, watermains, service pipes, storage tanks or reservoirs, and related equipment, in a closed system under pressure.

Water Distribution methods include **pumping** method, **Gravity** method.

Sources of water

1. Ground Water:
    i. Deep or artesian wells.
    ii. Springs.
2. Surface Water –
    i. Rainwater.
    ii. Rivers and lakes.
    iii. Surface wells.
    iv. Sea Water.
3. Other Resources –
    i. Snow
    ii. Artificial Rain

- Deep artesian wells furnish pure water as a rule, unless the piping is not tightly jointed, when impure water from a subsoil stream near the surface may enter the pipes.
- Springs are a source of pure water supply if they are not contaminated by passing through soil which is polluted.

- Rain water takes up the dust and gases from the air, and organic matter from the roofs over which it is collected- causing the water to be unsafe for drinking purposes.
- Rivers and lakes are a common source of water supply, but they may be made very unfit for drinking if the surface water and sewage from towns and cities is allowed to drain into them.
- Surface wells are a very unsafe source of drinking water supply, and the water should never be used when there are cesspools, drains, barnyards, or any other Sources of contamination within a radius of 200 feet of them.

Water treatment

- Purification or Treatment of water is a mandatory requirement of civic authority to supply potable water, safe water, free from all the impurities.
- There are Mainly three types of water impurities

  i. Physical Impurities: turbidity, colour, taste, odour
  ii. Chemical Impurity: hardness
  iii. Bacteriological impurities: pathogenic bacteria.

1. **Clarification**

Pre-treatment – (Screening, Storage, Preconditioning, Pre-chlorination)

- **Pumping and containment** - The majority of water must be pumped from its source to tanks.
- **Screening** - remove large debris such as sticks, leaves, trash and other large particles.
- **Storage** – water will be store for weeks or months to natural biological purification called aeration.
- **Pre-conditioning** - Water rich in hardness salts is treated with soda-ash.
- **Pre-chlorination** - incoming water was chlorinated to minimize the growth of fouling organisms on the pipe-work and tanks

pH adjustment

- Distilled water has a pH of 7 (neither alkaline nor acidic)
- If the water is acidic (lower than 7), lime, soda ash, or sodium hydroxide is added to raise the pH
- Making the water slightly alkaline ensures that coagulation and flocculation processes work effectively and also helps to minimize the risk of lead being dissolved from lead pipes and lead solder in pipe fittings

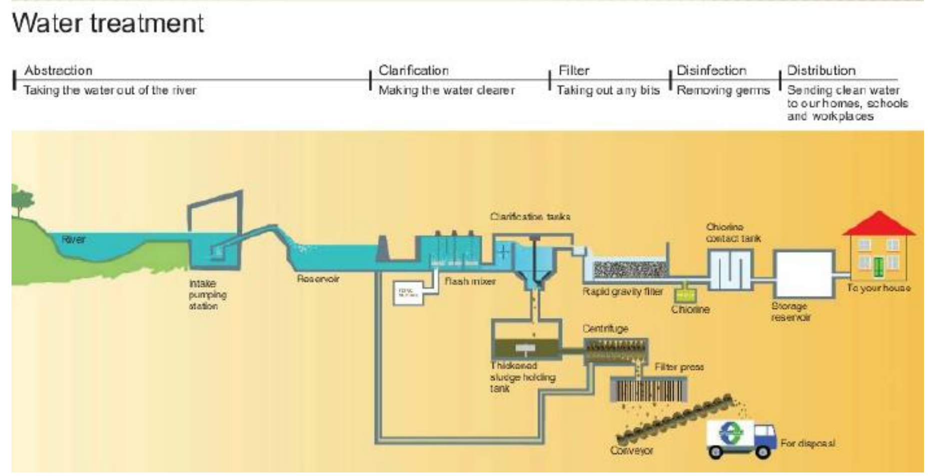
2. **Flocculation/Cogulation**

- **Flocculation** is a process which clarifies the water. Clarifying means removing any turbidity or colour so that the water is clear and colourless.
- **Sedimentation:** It is a large tank with slow flow, allowing flocculation to settle to the bottom. Sedimentation basins may be rectangular, where water flows from end to end, or circular where flow is from the centre outward.

3. **Disinfection**

- Finally bacteriological impurities to be removed before distribution either by adding chlorine or ozone or ultra violet radiation. Reverse Osmosis (RO) system may be used for purification, or water could be boiled or purified by water purifier.
- Reverse osmosis: Mechanical pressure is applied to an impure solution to force

STAGES OF WATER TREATMENT:



NOTE:

Desalination:

- Sea water is saline. Even if the salinity is variable for various oceans the water is unfit for drinking.
- **Desalination** is an artificial process by which saline water is converted to fresh water.

SANITATION

- **Sanitation** is the hygienic means of promoting health through prevention of human contact with the hazards of wastes as well as the treatment and proper disposal of sewage waste water.
- The **World Health Organization states that**: Sanitation refers to the provision of facilities and services for the safe management of human excreta from the toilet to containment and storage and treatment onsite or conveyance, treatment and eventual safe end use or disposal. More broadly sanitation also included the safe management of solid waste and animal waste. Inadequate sanitation is a major cause of infectious diseases such as cholera, typhoid and dysentery world-wide.
- For transporting sewage from houses & and commercial buildings, a separate underground carriage system, called **sanitary sewer**, to treatment or disposal, is used.
- Sanitary sewers serving industrial areas also carry industrial wastewater. The 'system of sewers' is called sewerage.
- A sewer system is a piped system to transport wastewater (and sometimes storm water) from the source (households, industry, runoff) to a treatment facility
- In rural areas or small residentials, where no sewer system is provided people use a tank sank into the ground, called Septic Tank. This tank has a storage limit, so time to time it should be drained and clean.

SANITARY APPLIANCES

Sanitary appliances are fittings used for collection and discharge of waste water, soil or waste matter in buildings.

Sanitary appliances are grouped into two categories:

1. Waste appliances - used for collection and discharge of water after use (e.g. wash basins, sinks, showers, baths tubs , drinking fountains)
2. Soil appliances- used for collection and discharge of excreta matter (e.g. water closet, urinal).

DESIGN REQUIREMENT for sanitary appliances

- A sanitary appliance should be designed so that its fouling area is reduced to the minimum and should have durable, easily cleaned and non-absorbent surface.
- All sanitary appliances are made of non-absorbent, non-corroding, smooth and easily cleaned material and usually made from ceramic ware, vitreous enameled cast iron, vitreous enameled pressed steel, stainless steel or plastics (thermosetting and thermoplastic).

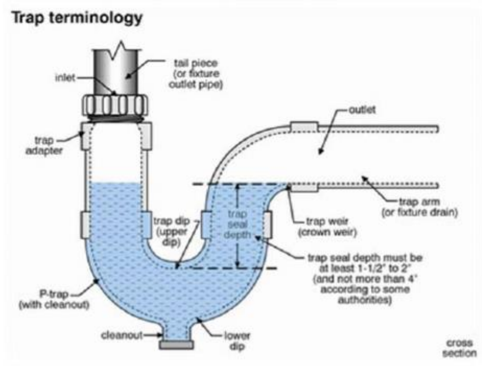
WATER CLOSET

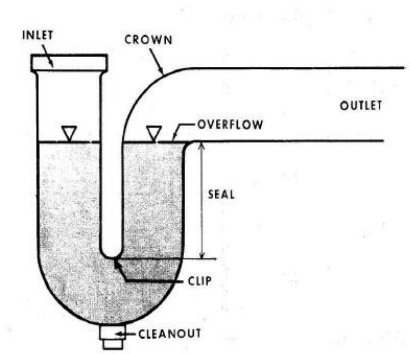
- This is the most common type of plumbing appliance and also known as a toilet.
- Water closet are usually subdivided according to where they are mounted (floor mounted and wall mounted) and how they are flushed (tank type and flush valve type).
- The most widely used pattern is the “wash-down”, in which the contents of the pan are removed by gravity water flush.

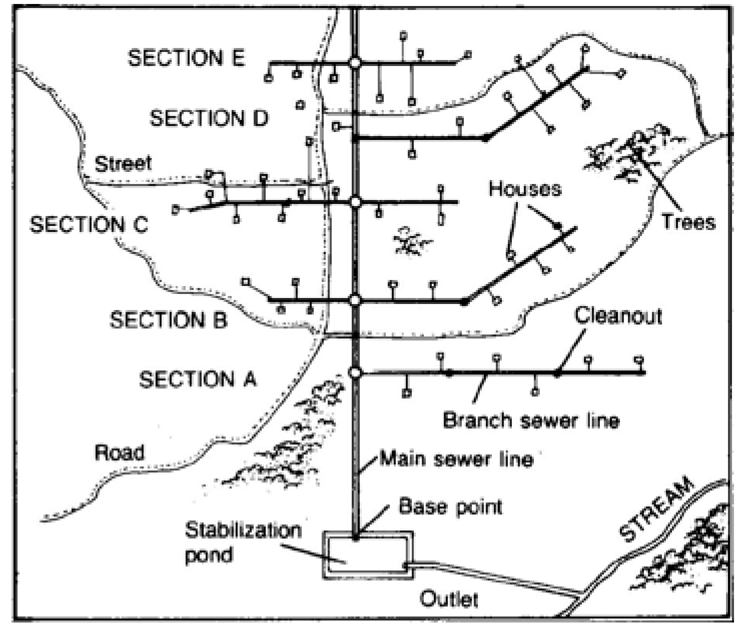
Fig: Types of water closets

WATER CLOSET TRAPS

- All plumbing fixtures have traps in their drains; these traps are either internal or external to the fixtures.
- Traps are pipes which curve down then back up; they 'trap' a small amount of water to create a water seal between the ambient air space and the inside of the drain system. This prevents sewer gas from entering buildings.







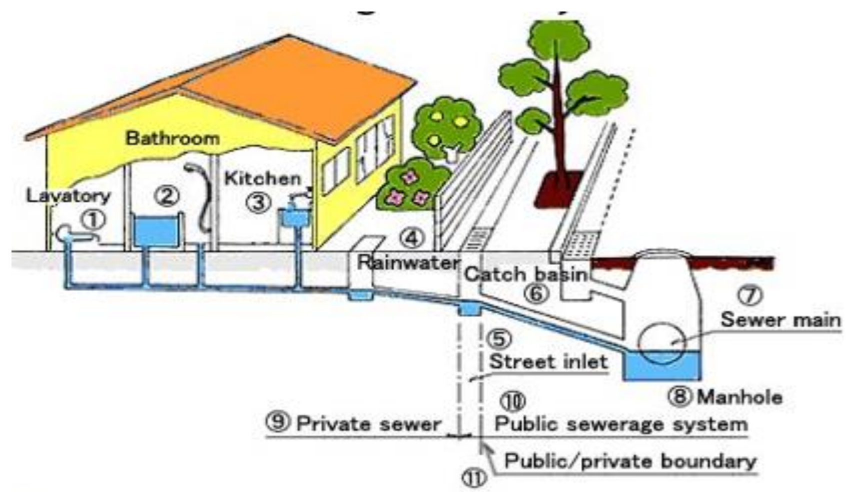
- Wastewater is transported to a centralised treatment facility by gravity.
- Depending on topography, sewer pumping stations are necessary.
- The lines are in a depth of 1.5 to 3 m and manholes proved access for maintenance.
- It must be designed to maintain “self-cleansing” velocity that no particles accumulate

DRAINAGE SYSTEM

Building drainage is the arrangement provided in a *building* for collecting or conveying waste water through *drain* pipes, by gravity, to join either a public *sewer* or a domestic septic tank.

Design Principle for Conventional Sewer

- Large networks of underground pipes, mostly in urban areas for Collection of blackwater, brownwater, greywater and stormwater.
- The system contains three types of sewer lines:
  - i. Main line (primary): the centre of the system, all other lines empty into it.
  - ii. Branch lines (secondary): extend from the main.
  - iii. House laterals (tertiary): bring wastwater from the houses to the branch lines.



Cross-section of a conventional sewer in a common urban set-up.

Layout of Building Drainage Sytem

Sanitary sewer systems should be sized and laid out to permit use of the smallest diameter pipes capable of rapidly carrying away the wastewater from fixtures without clogging the pipes, without creating annoying noises, and without producing excessive pressure fluctuations at points where fixture drains connect to soil or waste stacks. Such pressure changes may siphon off the liquid seals in traps and force sewer gases back through the fixtures into the building. Positive or negative air pressure at the trap seal of a fixture should never be permitted to exceed 1 in of water.

Basic Principles of Drainage system:

*House Drainage should be **preferable laid by side of the building** to facilitate easy repair and better maintenance.

*The sewage or sullage **should flow under the force of gravity.**

*The house sewer should **always be straight.**

The entire system should be **well ventilated** from start to the end.

*The house sewer should be connected to the manhole such that the invert level is sufficiently higher to avoid back flow of sewage in house sewer.

*Where ever there is change in direction of sewer line in the premises, provide **inspection chamber at the junction**.

*House sewer joints should be leek proof because leakage if any shall create an odour problem and leaked wastewater shall infiltrate in the ground and shall reduce bearing capacity of soil below foundation, which is not desirable.

***Rain water** from roofs or open courtyards **should not be allowed** to flow through the **house sewers**.

*Siphonage action can never be permitted and therefore adequate ventilation systems should be installed.

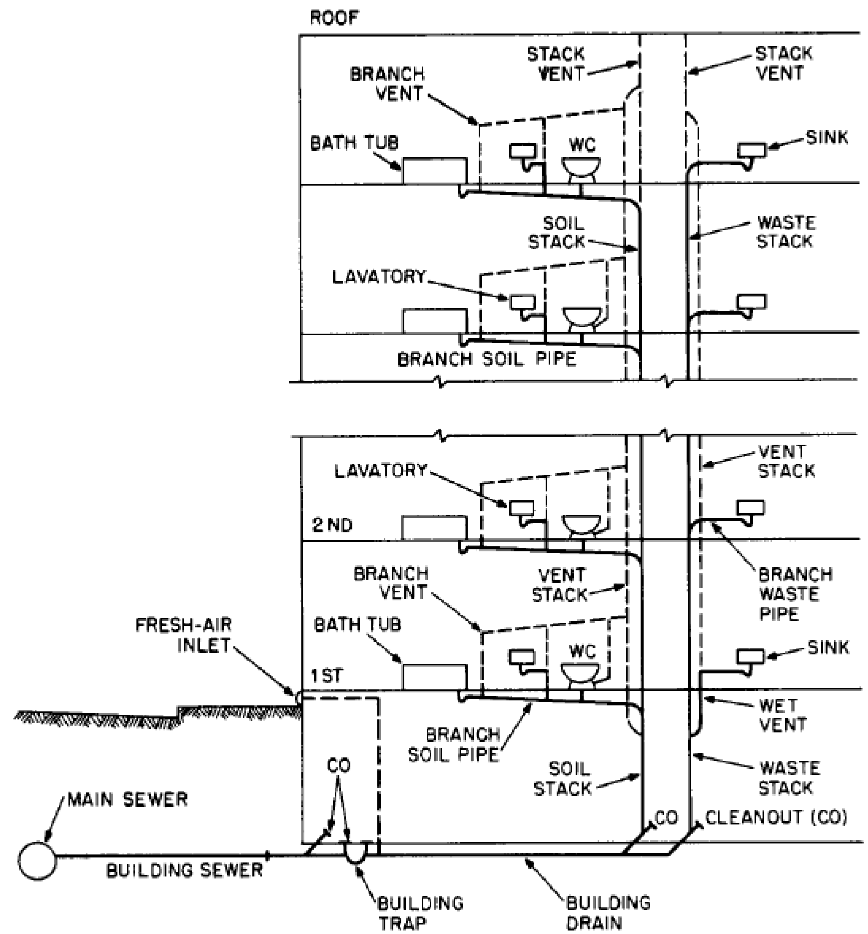


Fig.: Wastewater-removal system for a multistory building.

ILLUMINATION

When light falls on a surface, it becomes visible, the phenomenon is called illumination.

Illumination is defined as the luminous flux falling on a surface per unit area. It is denoted by E and measured in lumen per square meter or meter-candle.

$E = \Phi / A$ lm/m²

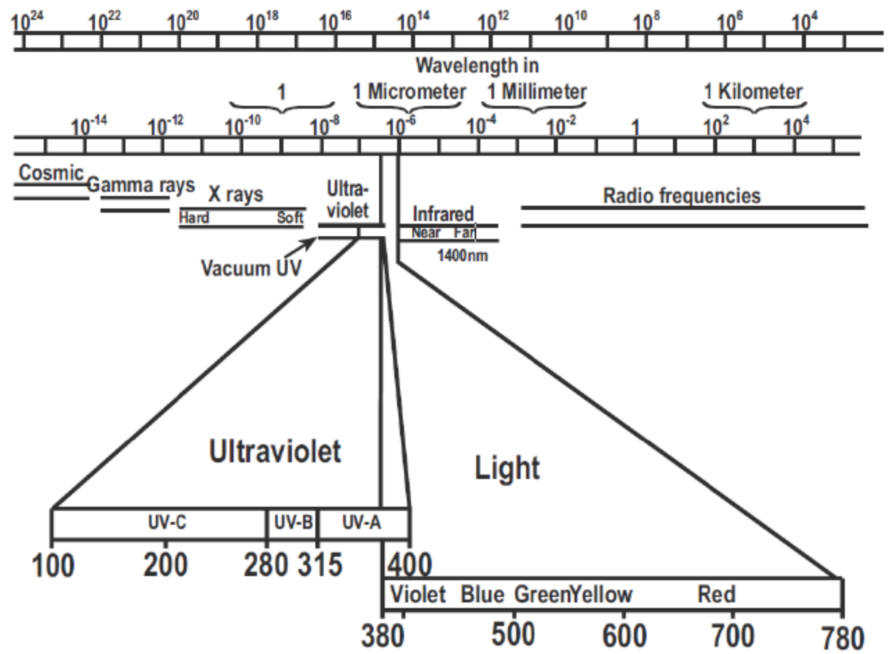
ILLUMINATION HISTORY

- Luminous efficacies were increased enormously through the centuries from 0.01 lm/W candle to above 100 lm/W for modern "white" light sources.
- Torch was probably the first lighting source and fixture as well around 400000 years BC.
- Simple lamps made of shell and fat around 13000 BC.
- Pottery lamps (with refined design) around 600 BC.
- Candle appeared around 400 AD and was the first light source that could be used either in interior or exterior with or without a transparent protective case.
- Around 1800 the carbon arc lamps were introduced
- Gas lamps in 1814.
- Incandescent lamp has appeared during 1879 by Thomas Edison with luminous efficacy ~1.4 lm/W.
- High Intensity Discharge lamps introduced in 1901.
- Low pressure sodium in 1932,
- Fluorescent in 1932.
- Quartz and metal halide in 1960.
- Then Sulfur lamp- exciting sulfur and quartz with microwaves.
- In recent years LED use have become widespread. There are two possible approaches to produce white light. The first is to use a blue LED coated with a white phosphor (1996). The second method of producing white light is to use additive mixing of the three primary colours red, green and blue.

Terminologies used in illumination

Light

Electromagnetic radiation that the unaided human eye can perceive, having a wavelength in the visible range from about 370 to 800 nanometres (nm) and propagating at the speed of $3x10^8$m/s.



Light is emitted from a body due to any of the following phenomenon:

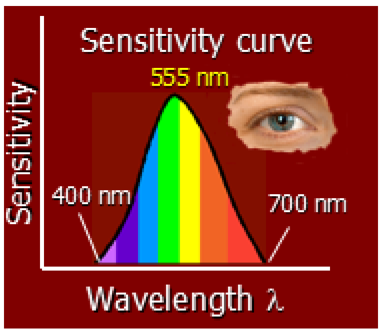
- **Incandescence:** Solids and liquids emit visible radiation when they are heated to temperatures about 1000K. The intensity increases and the appearance become whiter as the temperature increases.
- **Electric Discharge**: When an electric current is passed through a gas the atoms and molecules emit radiation whose spectrum is characteristic of the elements present.
- **Electro luminescence:** Light is generated when electric current is passed through certain solids such as semiconductor or phosphor materials.

- **Photoluminescence:** Radiation at one wavelength is absorbed, usually by a solid, and re-emitted at a different wavelength. When the re-emitted radiation is visible the phenomenon may be termed either fluorescence or phosphorescence.

Properties of Light

1. **Rectilinear propagation**: Light travels in straight lines.
2. **Reflection:** Light striking a smooth surface bounces/turns back into the original medium.
3. **Refraction:** Light bends when entering a transparent medium.

Human eyes are not equally sensitive to all colors. Eyes are most sensi- tive in the mid-range near λ = 555 nm. For example, Yellow light appears brighter to the eye than does red light.



NOTE:

White light refers to light with equal proportions of all visible wavelengths

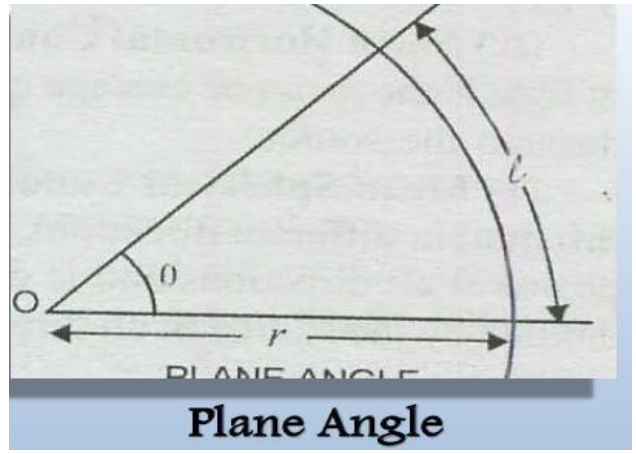
Photometry and Radiometry

Radiometry is the study of optical radiation,-light, ultraviolet radiation and infrared. Photometry, on the other hand is concerned with humans' visual response to light.

Radiometry is concerned with the total energy content of the radiation, while photometry examines only the radiation that humans can see.

Plane angle

The angle subtended at a point by two converging lines lying in the same plane is called plane angle. It is measured in radians and equal to the ratio of the length of the arc too its radius,

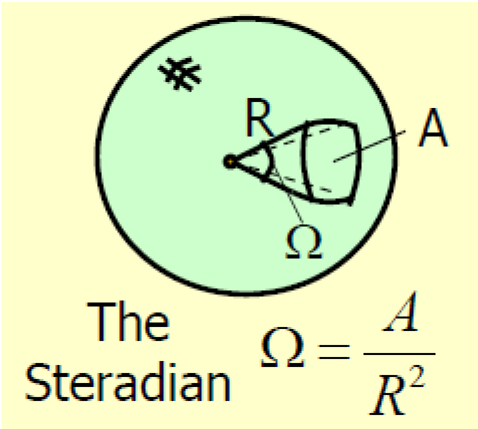


θ = arc/ radius = L/ r radians

Solid angle

The angle subtended by the partial surface area of a sphere at its centre is called as solid angle. A solid angle is the three-dimensional equivalent to a two-dimensional angle. It is measured in **steradians (sr).**

One **steradian (sr)** is defined as "the solid angle subtended at the centre of a sphere by an area on its surface numerically equal to the square of the radius."



From the definition, Steradian $\Omega = \frac{A}{r^2}$

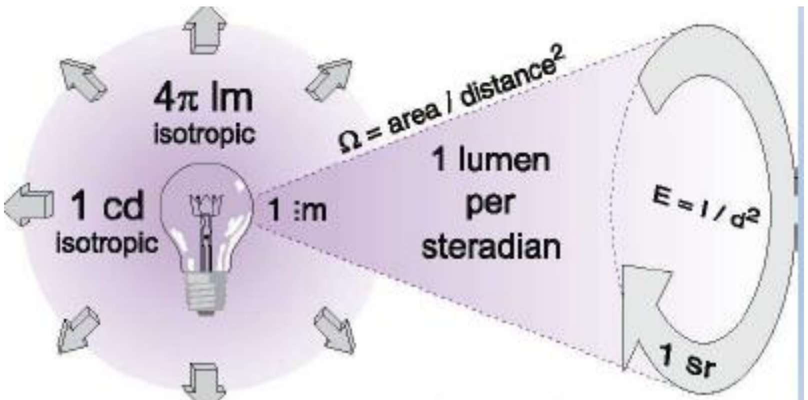


Fig. 7.7 Radiant Intensity.

Example: What solid angle is subtended at the center of a sphere by an area of 1.6 m m2? The radius of the sphere is 5 m m.

Luminous flux

Luminous flux' (F) is the rate of flow of light energy from a light source. Luminous flux is measured in Lumen (lm).

Luminous Intensity

Luminous intensity' (I) is the rate of flow of light energy per solid angle. The unit is lm/solid- angle or 1 candela (cd). (A solid angle is measured in steradians (sr) and there are 4 π sr in a sphere).

$$\textit{Luminous Intensity } I = \frac{\textit{Luminous Flux,F}}{\textit{Steradians,}\Omega}$$ **(Units in Candela cd)**

Simply put, Luminous intensity in any particular direction is the luminous flux emitted by the source per unit solid angle in that direction. It is denoted by I and its unit is Candela or candle power (CP).

Candle Power

- The light radiating capacity of a source is called its candle power.
- The number of lumens given out by a source per unit solid angle in a given direction is called its candle power. It is denoted by C.P.

Total flux emitted = CP X solid angle

= 1 X 4π = 4π lumens = 4π lumens.Lux

One meter candle or lux is defined as the illumination produced by a uniform source of one CP on the inner surface of a sphere of radius one meter.

Glare

In the human eye, the opening of pupil is controlled by its iris which depends upon the intensity of light received by the eye. If the eye is exposed to a very bright source of light, the pupil of the eye contracts automatically in order to reduce the amount of light admitted and prevent damage to the retina. This effect is called glare.

Glare is defined as the brightness within the field of vision of such a character so as to cause discomfort and interference in vision.

Lamp efficiency

It is defined as the visible radiations emitted by a lamp in lumens per watt.

Usually, the light sources do not radiate energy only in the visible spectrum. The radiant energy is also accompanied with infrared and ultra violet radiations.

Sun light produces majority of radiations in the visible spectrum. The tungsten lamp produces small radiations so its efficiency is very poor.

The efficiency of fluorescent lamp is more than that of a tungsten lamp.

Reduction Factor

Reduction factor of a source of light is the ratio of its mean spherical candle power to its mean horizontal candle power.

Reduction factor = MSCP/ MHCP

Mean Horizontal Candle-Power

The average value of the candle-power of a light source in all directions in a horizontal plane through the source,

Mean Spherical Candle-Power

Mean Spherical Candle Power, a unit of measure that represents the average output of a light source measured in all directions (360°)

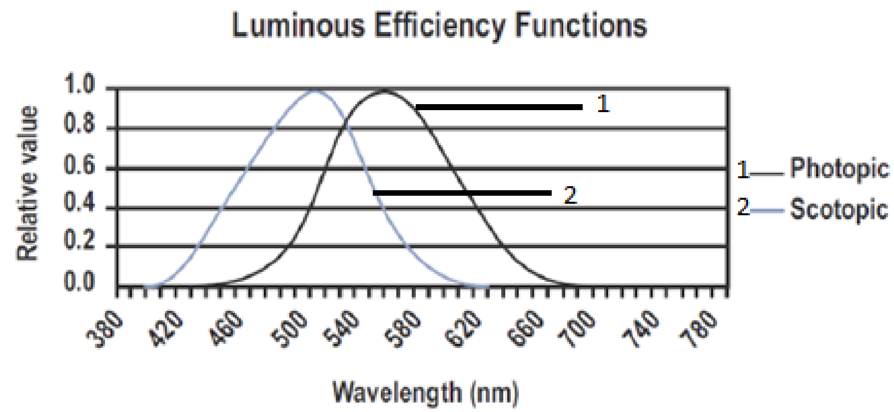
Reflection Factor

Whole of the light incident on a reflecting surface is not reflected. Some portion of it is absorbed by the surface.

The ratio of the reflected light to the incident light is called reflection factor.

Spectral Response

- Even within the narrow spectrum of visible light, the human eye is more sensitive to some wavelengths than to others.
- This sensitivity depends on whether the eye is adapted for bright light or darkness because the human eye contains two types of photoreceptors — cones and rods.
- When the eye is adapted for bright light, called **photopic vision** (luminance levels generally greater than about 3.0 cd/m^2), the cones dominate.
- At luminance levels below approximately 0.001 cd/m^2, the rods dominate in what is called **scotopic vision**.



- Between these two luminance levels, mesopic vision uses both rods and cones.
- The figure below shows the relative sensitivity to various wavelengths for cones (photopic) and rods (scotopic).
- Conventionally, the peak of the photopic luminous efficiency function (the wavelength 555 nm) is selected as the reference wavelength for the lumen, the standard photometric unit of light measurement.
- By definition, there are 683 lm/W at 555 nm and the lumens at all other wavelengths are scaled according to either the photopic or the scotopic luminous efficiency functions.
- For example, at 507 nm there are 1700 lm/W when the scotopic luminous efficiency function is used, but only 304 lm/W when the photopic luminous efficiency function is used.
- Nearly every light measurement uses the photopic luminous efficiency function.

Spectral Luminous Efficacy

•Spectral luminous efficacy, Kλ, is the ratio of luminous flux to radiant flux.

•In other words, spectral luminous efficacy describes the absolute eye response of the normalized efficiency function.

•The CIE defines Kλ for photopic vision as 683 lumens/watt at 555 nm.

•For other wavelengths, Kλ for photopic vision can be calculated using the following equation:

$$K'_{\lambda} = K'_{m} V'_{\lambda}$$

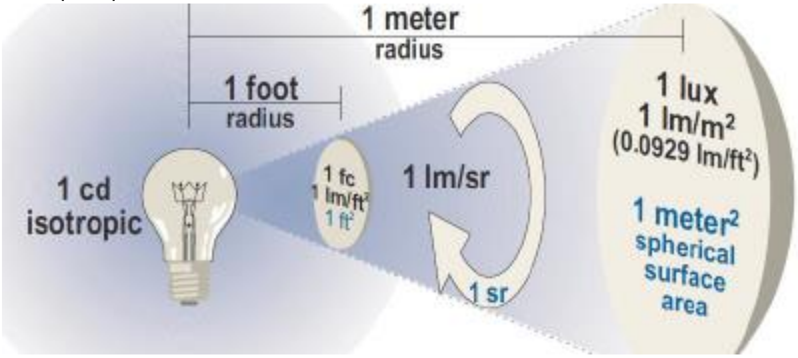
Where:

–K_m = 683 lm/W (the maximum sensitivity for photopic vision, which occurs at 555 nm)

–Vλ = the value of the photopic spectral luminous efficiency function for that wavelength

Radiant Exitance, Irradiance (Radiant Incidence), and Illuminance

- Radiant exitance, denoted by the letter M, is the radiant flux per unit area leaving the surface of a source of radiation.
- In other words, radiant exitance is the flux density.
- Irradiance or radiant incidence, denoted by the letter E, is the flux per unit area received by a surface. Irradiance and radiant exitance are both measured in W/cm^2 or W/m^2.
- **Illuminance (Ev)** is a measure of photometric flux per unit area, or visible flux density.
- Illuminance is measured in either lux (lm/m^2) or footcandles (lm/ft^2).
- One steradian has a projected area of 1 square foot at a distance of 1 foot, and an area of 1 square meter at a distance of 1 meter.
- Therefore, a 1-candela (1 lm/sr) light source produces 1 lumen per square foot at a distance of 1 foot, and 1 lumen per square meter at 1 meter.
- Note that as the luminous flux projects farther from the source, it becomes less dense**.**
- In the example below, the illuminance decreases from 1 lm/ft^2 at a distance of 1 foot to 0.0929 lm/ft^2 (1 lm/m^2) at a distance of 3.28 feet (1 m).



LAWS OF ILLUMINATION

The illumination on a surface depends upon the luminous intensity, distance between the source and surface and the direction of rays of light. It is governed by following laws:

1. Inverse square law

2. Lambert's cosine law

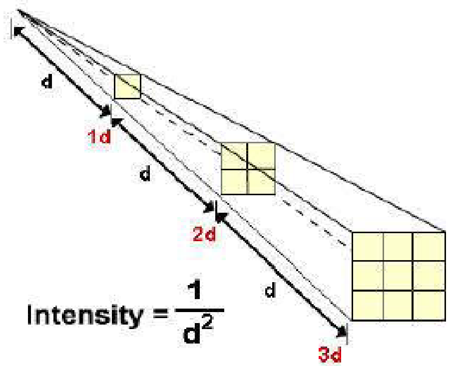
INVERSE SQUARE LAW

The Inverse Square Law states that the illumination of a surface is inversely proportional to the square of the distance of the surface from the point source.

The Inverse square law states that the Intensity of Illumination produced by a point source varies inversely as the square of the distance from the source.

$$E = \frac{I}{d^2}$$

- Where, I is intensity and
- d is Distance



As light radiates from a point source, the intensity of Light (I) is inversely proportional to the square of the distance (d) from the source, provided that the distance between the surface and the source is sufficiently large so that the source can be regarded as a point source.

$$E \alpha \frac{1}{d^2}$$

Example: A point light source has an intensity of 1000 cd and its light falls perpendicularly on a surface. Calculate the illuminance on a surface if the distance from the source is: 2m; 4m and 6m.

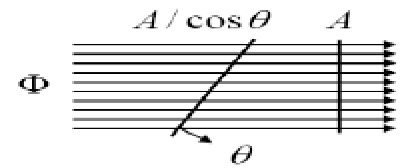
Question: Derive the inverse square law

LAMBERT'S COSINE LAW

This law states that the illumination on any surface is proportional to the cosine of angle between the direction of the incident flux and perpendicular to the surface, and inversely proportional to the distance d from the source.

Lambert's Cosine Law of Incidence –

$$E = \frac{I \times \cos\alpha}{D^2}$$



$$E = \frac{\Phi}{A / \cos\theta} = \frac{\Phi}{A}\cos\theta$$

Total flux for Isotropic Source

- An isotropic source emits in all directions; i.e., over a solid angle of 4π steradians.
- Thus, for such a source, the intensity is: $I = \frac{F}{\Omega} = \frac{F}{4\pi}$

$$\text{And Total flux: } F = 4\pi I$$

Electrical methods of producing Light

1. By developing arc between two electrodes
2. By passing a current through a filament
3. By electric discharge through vapors or gases

Example: A light source has an intensity of 2000 cd in all direction and is mounted 4m above the surface. Calculate the illuminance on the surface directly underneath and at a point 3m to the side.

Example: A 400-cd light is located 2.4 m from a tabletop of area 1.2 m^2. What is the illumination and what flux F falls on the table? Ans: E=69.4 lx and F=93.3 lm

Example:
A 30 cd spotlight is located 3m above a table. The beam is focused on a surface area of 0.4 m m2. Find the intensity of the beam.
Ans: I=8490.8 cd.

LIGHTING DESIGN

BZ Classification:

British Zonal Classification of 1–10 for the downward light emitted from a luminaire. The BZ class number relates to the flux that is directly incident upon the working plane in relation to the total flux emitted. BZ1 classification is for a downward directional luminaire. A BZ10 describes a luminaire that directs all its illumination upwards so that the room is illuminated by reflection from the ceiling**.**

Daylight Factor: the ratio of the natural illumination on a horizontal plane within the building to that present simultaneously from an unobstructed sky, discounting direct sunlight. A standard figure of 5000 lx is adopted for the external illuminance in the United Kingdom.

Efficacy: the luminous efficacy is the lamp light output in lumens per watt of electrical power consumption.

Glare: the discomfort or impairment of vision due to excessive brightness.

Illuminance: the luminous flux density at a surface in lumens per square metre, l/m^2, lux. The surface is normally the working plane. SI unit of illuminance; 1 lx = 1 lm/m^2.

Luminaire: the complete apparatus that contains the lamp, the light emitter and the electrical controls.

Light loss factor, LLF: the overall loss of light from the dirtiness of the lamp (0.8), luminaire (0.95) and the room surfaces (0.95). Clean conditions LLF may be 0.7 but 0.5 when equipment and room become soiled. Preferred to maintenance factor.

Maintenance factor, MF: The maintenance factor (M) is a ratio which takes into account the light lost due to an average expectation of dirtiness of light fittings and surfaces. It is an allowance for reduced light emission due to the build-up of dust on a lamp or within a luminaire. Normally 0.8 but 0.9 if the lamps are cleaned regularly or if a ventilated luminaire is used. Light loss factor is preferred.

UTILIZATION FACTOR, UF

Utilization factor, UF: the ratio of the luminous flux received at the working plane to the installed flux.
Alternatively, utilisation factor (U) is the ratio of the lumens received on the working plane to the total flux output of lamps in the lighting scheme.
The utilization factor is provided by the manufacturer and takes into account the pattern of light-distribution from the whole fitting, its light-distributing efficiency, the shape and size of the room for which it is being designed and the reflectivity of the ceiling and walls.
Values vary from 0.03, where purely indirect distribution is employed, the room has poorly reflecting surfaces and all the light is upwards onto the ceiling or walls, to 0.75 for the most energy-efficient designs.
Spot lighting can have a utilization factor of nearly unity.
The configuration of the room is found from the room index:

$$\text{room index} = \frac{lW}{H(l+W)}$$

Where *l* is the room length (m), W is the room width (m) and H is the height of the light fitting above the working plane (m).

Glare and reflections

Disability glare is when a bright light source prevents the subject from seeing the necessary detail of the task.
To maximize contrast on the working plane, luminaires should be placed in rows parallel to the direction of view. The rows should be widely spaced to form work areas between them.
Enclosing the fitting with a plastic diffuser to improve its appearance usually lowers the utilization factor.

LUMEN DESIGN METHOD

The number of light fittings to be installed is found from the total lumens needed at the working plane and the illumination provided by each fitting using the formula:

$$\text{number of fittings} = \frac{\text{lux} \times \text{working plane area m}^2}{\text{LDL} \times \text{UF} \times \text{MF}}$$

OR $N = \frac{E * A}{F * U * M}$ where:

N = number of lamps

E = average illuminance on the working plane (lux)

A = area of the working plane (m^2)

F = flux from one lamp (lumens)

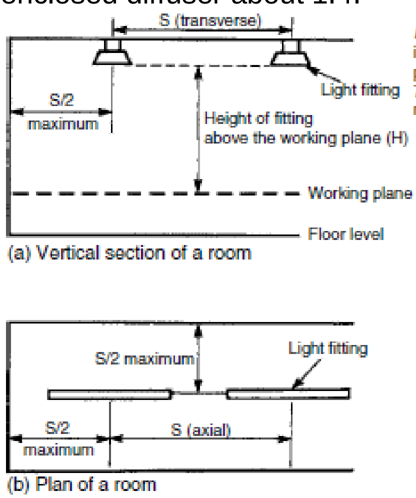
U = utilisation factor

M = maintenance factor.

Spacing-height ratio

Spacing-to-height ratio (SHR) is the centre-to-centre (S) distance between adjacent luminaires to their mounting vertical height (H) above the working plane.

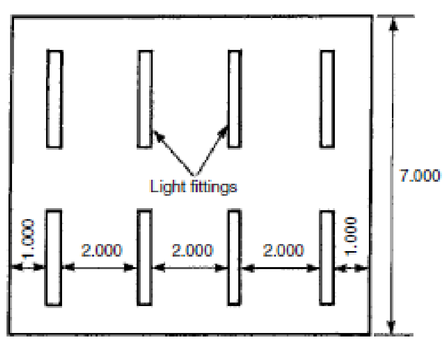
Manufacturers' catalogues can be consulted to determine maximum SHRs, e.g. a luminaire with trough reflector is about 1.65 and an enclosed diffuser about 1.4.



Method of spacing fluorescent tubes

Example. An office 8 m long by 7 m wide requires an illumination level of 400 lux on the working plane. It is proposed to use 80 W fluorescent fittings having a rated output of 7375 lumens each. Assuming a utilisation factor of 0.5 and a maintenance factor of 0.8 design the lighting scheme.

$N = \frac{E \times A}{F \times U \times M}$ $\therefore N = \frac{400 \times 8 \times 7}{7375 \times 0.5 \times 0.8}$ $N = 7.59$, use 8 fittings



Layout of fluorescent tubes for the office

EXAMPLE:

A drawing office 16 m × 11 m and 3 m high has a white ceiling and light-coloured walls. The working plane is 0.85m above the floor. 5100 lm double-lamp luminaires are to be used and their normal spacing-to-height ratio SHR is 1.75. The illuminance required is 600 lm/m^2.Calculate the number of luminaires needed and draw their layout arrangement. Find the electrical power consumption of the lighting system.

SOLUTION:

A high standard of maintenance will be assumed, giving a maintenance factor of 0.9. The lighting design lumens is taken as 5100 lm for the whole light fitting.

The height H of fittings above the working plane is:

$$H = (3 - 0.85) \text{ m}$$

$$= 2.15 \text{ m}$$

$$\text{room index} = \frac{lW}{H(l+W)} = \frac{16 \times 11}{2.15 \times (16 + 11)} = 3.03$$

From Table 11.3, for a room index of 3,

$$\text{utilization factor} = 79\% = 0.79$$

$$\text{number of fittings} = 600 \frac{\text{lm}}{\text{m}^2} \times \frac{16 \text{ m} \times 11 \text{ m}}{0.79 \times 0.9} \times \frac{\text{luminaire}}{500 \text{ lm}} = 29.12$$

The ratio of the spacing S between rows to the height H above the working plane is:

$$SHR = \frac{S}{H} = 1.75$$

Therefore,

$$S = 1.75\,H$$

$$= 1.75 \times 2.15 \text{ m}$$

$$= 3.76 \text{ m}$$

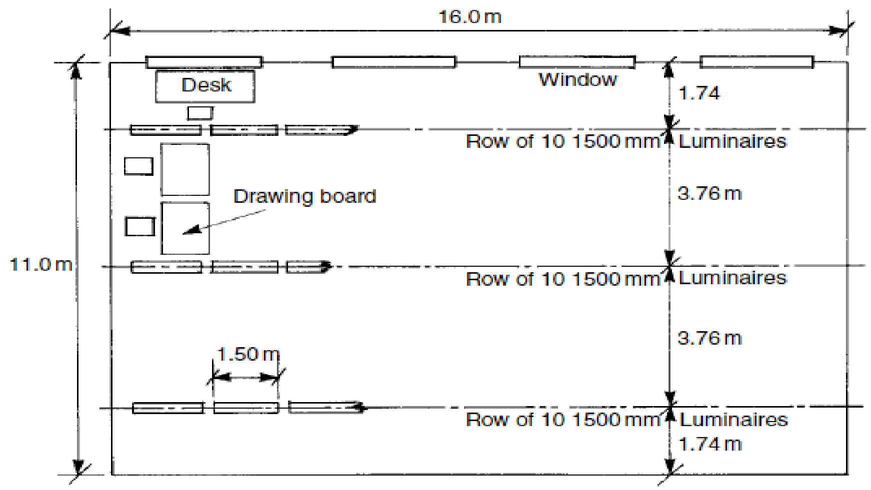
If it is assumed that windows are along one long side of the office and that rows of luminaires will be parallel to the windows, this will produce areas between rows where drawing boards and desks can be sited to gain maximum benefit from side day lighting without glare and reflection. The perimeter rows of luminaires are spaced at about half of S, 1.74 m, from the side walls.

Table 11.3 Utilization factors for a bare fluorescent tube fitting with two 58 W 1500 mm lamps (%).

Luminance factors		*Room index*								
Ceiling	*Walls*	*0.75*	*1*	*1.25*	*1.5*	*2*	*2.5*	*3*	*4*	*5*
70	50	48	53	59	64	71	75	79	83	86
70	30	40	46	51	57	64	69	73	78	82
70	10	35	40	46	51	59	64	68	74	78
50	50	43	48	52	57	63	67	70	74	76
50	30	37	41	46	51	57	62	65	70	73
50	10	33	37	42	46	53	58	61	67	70
30	50	39	42	46	50	55	59	61	65	67
30	30	34	37	42	46	51	55	58	62	65
30	10	30	33	38	42	48	52	55	59	62

Three rows of 10 luminaires are required, as shown in Fig. below, giving 30 luminaires and a slightly increased illuminance.
The electrical power consumption of each luminaire is 140 W. For the room the power consumption will be 30×140 W, that is, 4200 W, which is:

$$\frac{4200\ \text{W}}{16\ \text{m} \times 11\ \text{m}} = 23.86\ \text{W/m}^2\ \text{floor area}$$



LIGHTING SCHEMES

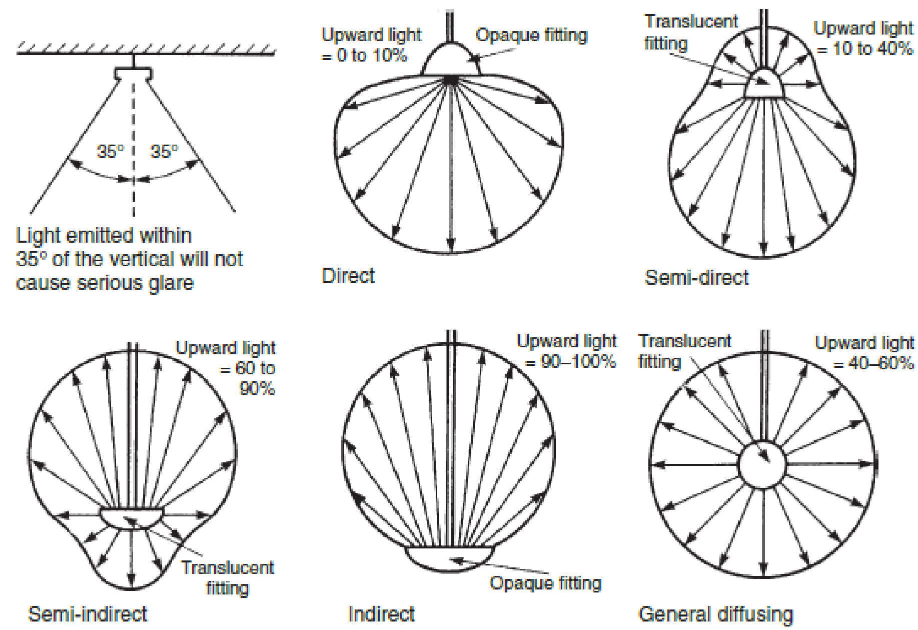
Fittings for lighting may be considered in three categories:

1. General utility -designed to be effective, functional and economic.
2. Special -usually provided with optical arrangements such as lenses or reflectors to give directional lighting.
3. Decorative -designed to be aesthetically pleasing or to provide a feature, rather than to be functional.

Lighting schemes are classified according to the location, requirement and purpose etc. as under:

1. Direct lighting
2. Indirect lighting
3. Semi direct lighting
4. Semi indirect lighting
5. General lighting

From an optical perspective, the fitting should obscure the lamp from the discomfort of direct vision to reduce the impact of glare. The various lighting schemes are illustrated in the figure below:



TYPES OF INCANDESCENT LAMPS

ARC LAMPS

The principle of an arc lamp is that when two electrodes carrying current are separated through a small distance, an arc is struck between them. The arc lamps were used in the past for street lighting purposes but now a day these are used when extreme brightness is required. Most commonly use arc lamp is the Carbon Arc Lamp

Carbon Arc Lamp

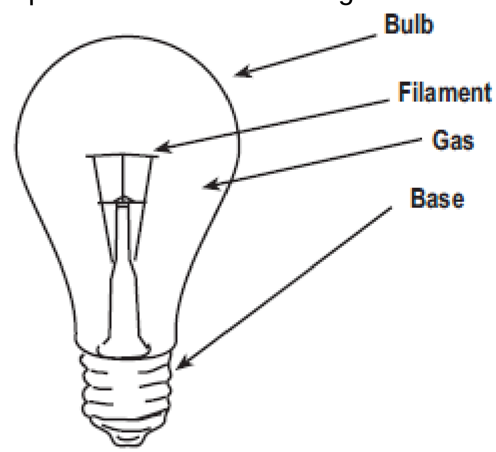
This is the oldest type of lamp and is still being employed in cinema projectors and search lights. It consists of two hard carbon rods (Electrodes). The diameter of +ve electrode is double to that of –ve electrode. The –ve electrode is generally fixed and +ve electrode is placed in adjustable holder and the process is manually or automatic. The arc consists of carbon vapors surrounded by orange red zone of burning carbon and pale green flames.

When the lamp is OFF, the two electrodes are touching each other due to spring pressure on +ve electrode. When the supply is ON a large current is flow through electrodes. The temperature of carbon electrode is increased and thus the +ve electrode is pulled away against its spring pressure through a small distance by coil and thus an arc is struck between electrodes. This arc is maintained by transfer of carbon particles from one electrode to other electrode.
These particles travel from +ve electrode to –ve electrode, thus after sometime of operation +ve electrode become hollow and –ve become pointed. That's why +ve electrode is made double than –ve electrode.

In carbon arc lamp 85 % of light is given by +ve electrode which produces high intensity light and only 10 % by –ve electrode and 5 % by air. The temperature of +ve electrode is 4000 oC and that of –ve electrode is about 2500 oC. The luminous efficiency of such lamps is about 9 lumen/watt.

FILAMENT OR INCANDESCENT LAMP

When an electric current is passed through a fine metallic wire, it raises the temperature of wire. At low temperature only heat is produced but at higher temperature light radiations goes on increasing. As filament lamp consists of fine wire of high resistive material placed in an evacuated glass bulb.



Construction of a typical incandescent lamp.

A tungsten filament is enclosed in evacuated glass bulb but to improve its performance some inert gases like argon/exenon gas are filled.
This type of lamps are operated at the temperature of 2500 ^{o}C.

Properties of Metal for Filament

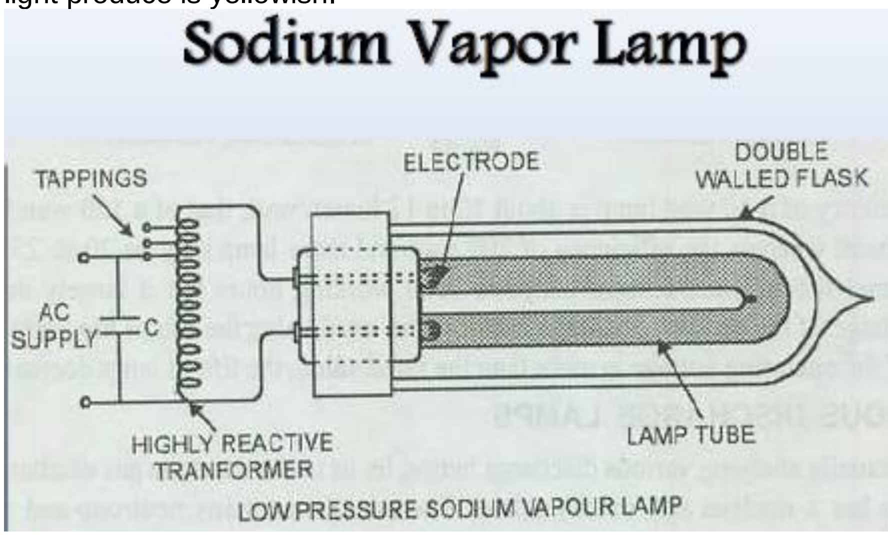
1. High melting point : so that it can be operated at high temperature.
2. High specific resistance : so that it produces more heat.
3. Low temperature coefficient : so that filament resistance may not change at operating temperature.
4. Low vapor pressure ; so that it may not vaporize
5. High ductile : so that it may withstand mechanical vibrations

SODIUM VAPOR LAMP

This lamp consists of discharge tube made from special heat resistance glass, containing a small amount of metallic sodium, neon gas and two electrodes. Neon gas is added to start the discharge and to develop enough heat to vaporised sodium. A long tube is required to get more light. To reduce overall dimensions of the lamp, the tube is generally bent into U-shape.

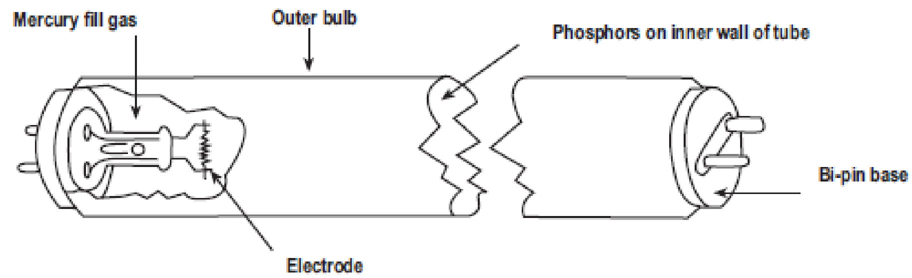
Working Principle:

An electric discharge lamps require a high voltage at staring and low voltage during operation. So at starting a voltage of 450 V is applied across the lamp to start the discharge. After 10 to 15 minutes, the voltage falls to 150 V because of low power factor. To improve the power factor a capacitor is connected across the supply. The color of light produce is yellowish.



FLUORESCENT LAMPS

It is a low pressure mercury vapor lamp. It consists of a glass tube 25 mm in diameter and 0.6 m, 1.2 m and 1.5 m in length. The tube contains argon gas at low pressure about 2.5 mm of mercury. At the two ends, two electrodes coated with some electron emissive material are placed.

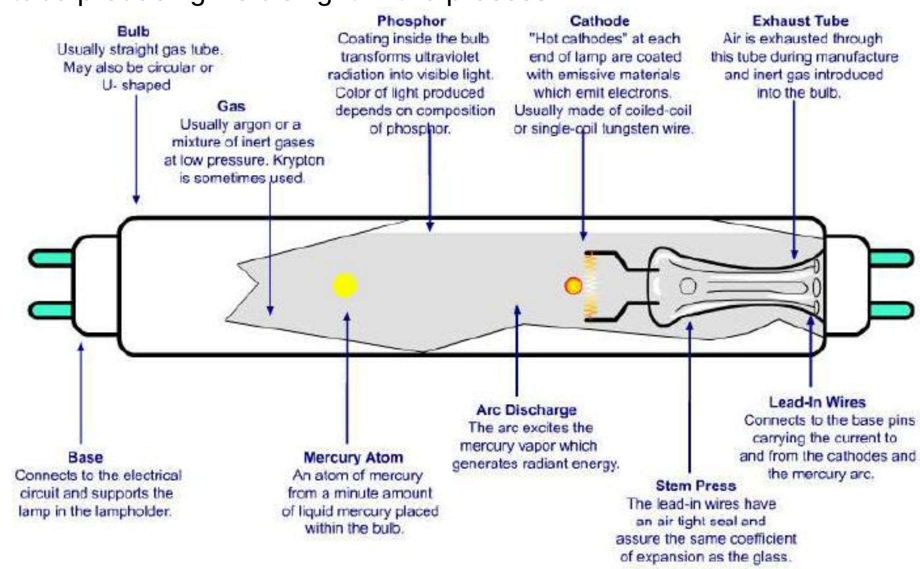


Construction of a linear fluorescent lamp.

Working :

A choke is connected in series with the tube which act as a blast and provide a high voltage at starting glow in the tube. During running condition the same choke absorbs some supply voltage and remain a voltage of 110 V across the tube. A capacitor is connected to improve the power factor.

The high voltage produce electrons which hit mercury atoms on their path through the discharge tube. Upon collision, the mercury atoms are shortly excited. The absorbed shock energy is immediately released in the form of invisible UV radiation. The UV radiations produced fall on the fluorescent phosphor-coated inner walls of the tube producing visible light in the process**.**



Advantages of Fluorescent Tube

1. Voltage fluctuation has very small effect on light output.
2. The luminous efficiency is more as length of rod is more.
3. It gives light close to natural light.
4. Heat radiations are negligible.

Disadvantages of Fluorescent Tube

1. Its brightness is less.
2. Initial cost is high
3. Overall maintenance cost is high.

NEON LAMP

These lamps are operated at a very low temperature of about 200 oC that's why these are called cold cathode discharge lamps.
Two electrodes are housed at the two ends of the tube which contain neon gas. The electrodes are made of iron or nickel cylinder without any coating and practically they do not emit electrons. It gives red light whereas with mixture of mercury and argon it gives bluish green color. Voltage require for starting and operation is
10000 V. This high voltage is obtained from transformer.

Working :

When the supply is switched ON at primary side of transformer, a voltage of 10000 V develops across secondary side which come across two electrodes. At this voltage a discharge occurs in neon gas. Different colors can be obtained by changing the constituents of gases and mercury filled in the tubes.

Applications the Neon Lamp:

Neon lamps are generally used for advertising. Most of letters having two ends at which electrodes are placed. In letter having more than two ends, the tube path is repeated for some portion.

HALOGEN LAMP

Halogen lamp is a special type of tungsten filament lamp which was developed in 1959, in this lams, a small amount of halogen vapor is added to the inert gas of the bulb. Its glass bulb is small in size and mechanically strong. It operates at high temperature of 3000 ^{o}C. When the supply is given to the lamp, a filament glows and produce light. The halogen in addition to inert gas causes the evaporated tungsten to resettle back on the filament during cooling, that's why lamp can be operated at high temperature. It provides high intensity light.

Advantages of Halogen Lamp

1. It is smaller in size.
2. It does not need any blast.
3. Good colors can be obtained.
4. Excellent optical control.
5. Gives same output throughout life
6. It has long life

Disadvantages of Halogen Lamp

1. During maintenance the handling of lamp is difficult.
2. Radiant heat is more which heats the surroundings.
3. Operating temperature is high which effects its life.

LIGHTNING PROTECTION

Lightning is defined *as an electric discharge between cloud and earth, between clouds or between the charge centers of the same cloud.*

How Does Lightning Occur?

(i) During the uprush of warm moist air from earth, the friction between the air and the tiny particles of water causes the building up of charges.

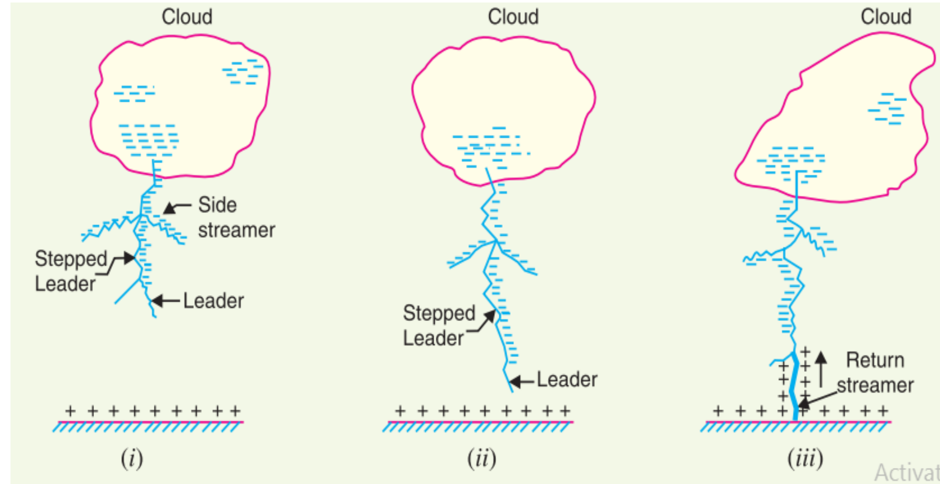
(ii) When drops of water are formed, the larger drops become positively charged and the smaller drops become negatively charged.

(iii) When the drops of water accumulate, they form clouds, and hence cloud may possess either a positive or a negative charge, depending upon the charge of drops of water they contain.

(iv) The charge on a cloud may become so great that it may discharge to another cloud or to earth and we call this discharge as lightning.

(v) The thunder which accompanies lightning is due to the fact that lightning suddenly heats up the air, thereby causing it to expand. The surrounding air pushes the expanded air back and forth causing the wave motion of air which we recognize as thunder.

Mechanism of Lightning Discharge



- 87% of all lightning strokes result from negatively and only 13% from positively charged clouds
- There occur about 100 lightning strokes per second.
- Lightning discharge may have currents in the range of 10 kA to 90 kA

Types of Lightning Strokes

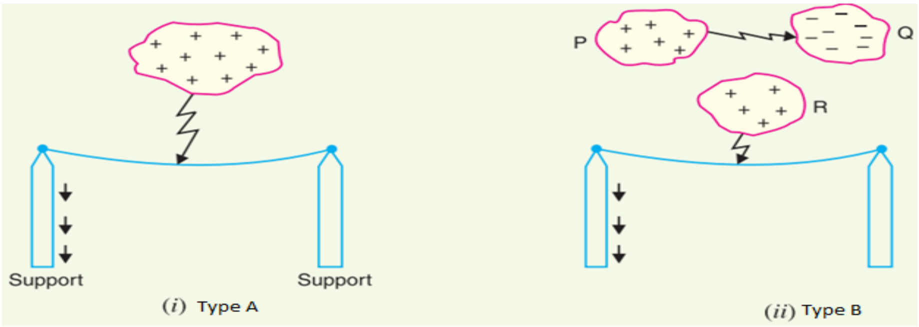
There are two main ways in which a lightning may strike the power system (e.g. overhead lines, towers, sub-stations etc.), namely;

- Direct stroke
- Indirect stroke

1. Direct stroke

Direct stroke lightning is subdivided into two types:

a. Direct stroke type A
b. direct stroke type B

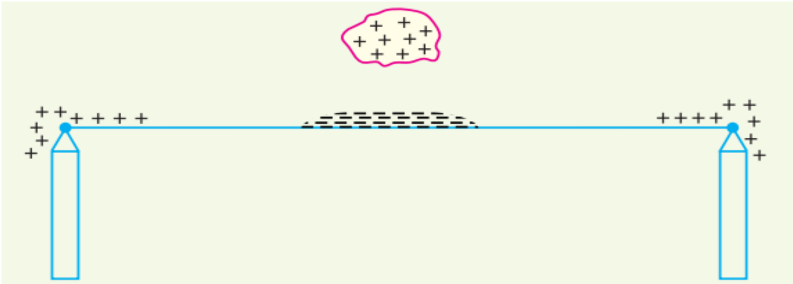


i. **Direct Stroke Type A:**
In the direct lightning strokes, the cloud attains a large amount of charge and induces an opposite charge on taller structures such as temple, churches or mosques. When the intensity of electrostatic field becomes sufficiently great to ionise the neighbouring air, the air break down and discharge takes place between the cloud and the structure, as shown in Fig (i). Such types of discharge take a long time to produce, and it strikes the highest and the most sharply pointed building in the neighbourhood.

ii. **Direct Strike Type B:**
Consider the three clouds, clouds P and R are positively charged, and cloud Q is negatively charged as shown in the figure (ii) above. The potential of cloud R is reduced due to the presence of the charged cloud Q. On the flash over from Cloud P to Cloud Q, both these clouds are discharged rapidly, and cloud R assumes a much potential and flashes to earth very rapidly. It is the most dangerous strokes because it can ignore taller structures and reach directly to the ground.

2. **Indirect Stroke:**
In the indirect stroke, charged clouds electrostatically induce opposite charges on the transmission below it as shown below. The positively charged cloud induces negative charges on the portion of the line directly below by electrostatic induction. The induced negative charges in turn induces positive charges on the far end portions of the line. These far end positive charges build up in potential and finally discharges to the earth.

Majority of the surges in a transmission line are caused by indirect lightning strokes



LIGHTNING PROTECTION SYSTEM (LPS)

- The high voltage currents from a lightning strike will always take the path of least resistance to ground. A lightning protection system (LPS) can protect a structure from damage caused by being struck by lightning by providing a low-resistance path to ground for the lightning to follow and disperse.
- An LPS does not attract lightning, and cannot dissipate lightning, it simply provides fire and structural damage protection by preventing lightning from passing through building materials themselves.
- Buildings most at risk are those at high altitudes, on hilltops or hillsides, in isolated positions and tall towers and chimneys.

HAZARDS OF A LIGHTNING STRIKE

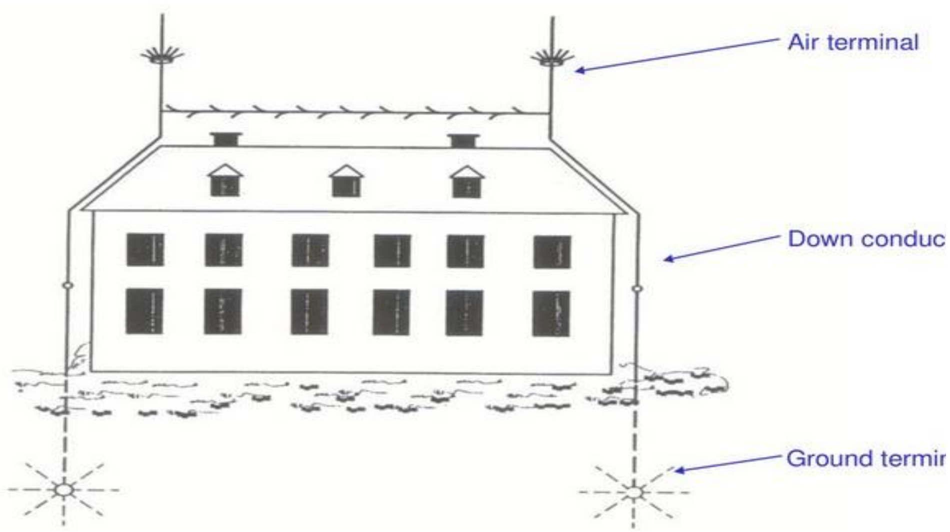
In the absence of an LPS, a lightning strike may use any conductor as a path to reach ground, which could include phone cables, power cables, utilities such as water or gas pipes, or the structure itself if it is a steel frame.

Some of the main hazards presented by a lightning strike to a building include:

- Destructive fires- Fire caused by lightning may igniting flammable materials or overheating electrical wiring.

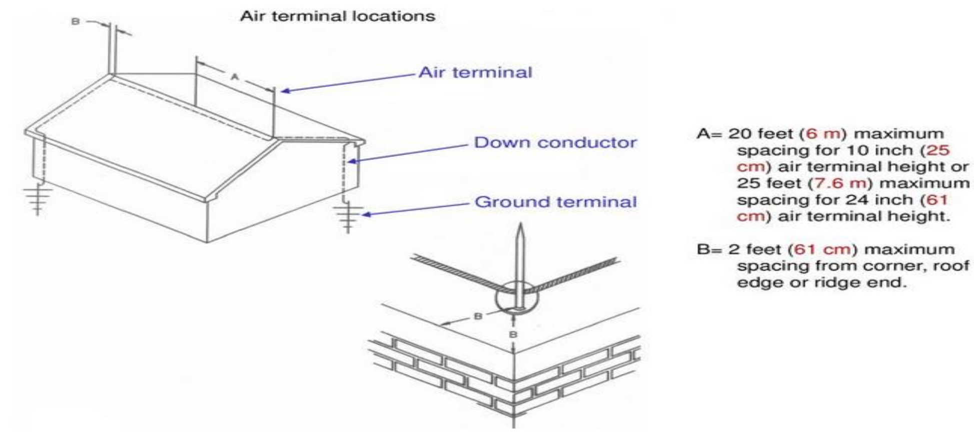
- Human/livestock injuries and/or fatalities- lightning strokes may cause fires or other accidents that may cause severe human injuries or even death.
- Side flashes- when lightning jumps through the air to reach a better-grounded conductor.
- Structural damage to buildings and properties- Building components can be damaged by explosive shock waves, glass shattered, concrete and plaster fragmented, and so on.
- Damage to electrical appliances- Any electrical appliance plugged into a circuit may be badly damaged.
- The air inside porous materials such as masonry may expand rapidly.
- Materials containing moisture from humidity or rain may flash to steam.
- Other materials can reach their plastic limit and melt or ignite.

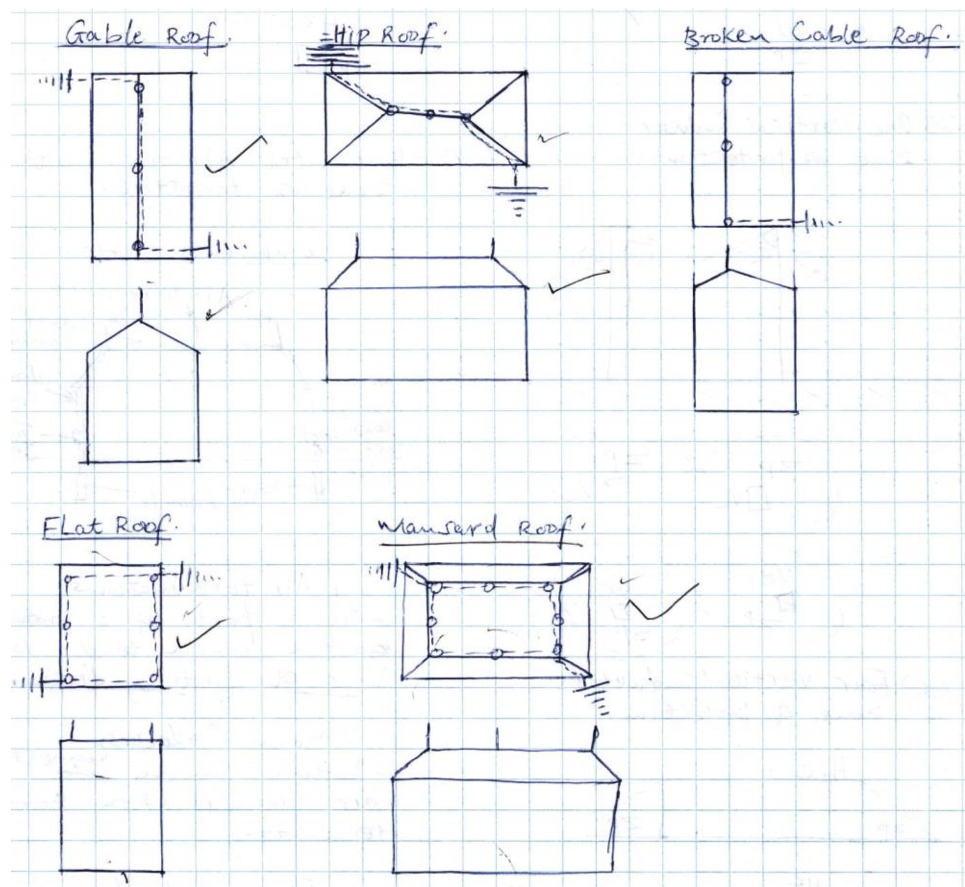
COMPONENTS OF A Lightning Protection System



1. **Air Terminations**

A lightning rod is a tall metallic tip, or pointed needle, placed at the top of a building. One or more conductors, often copper strips, are used to earth the rod. Rods are designed to act as the 'terminal' for a lightning discharge.





2. **Down Conductors**

Numerous heavy cables placed around the building in a symmetrical arrangement. This is sometimes referred to as a 'Faraday cage'. These cables are run along the tops and around the edges of roofs, and down one or more corners of the building to the ground rod(s) which carry the current to the ground. This type of LPS may be used for buildings which are highly exposed or house sensitive installations such as computer rooms.

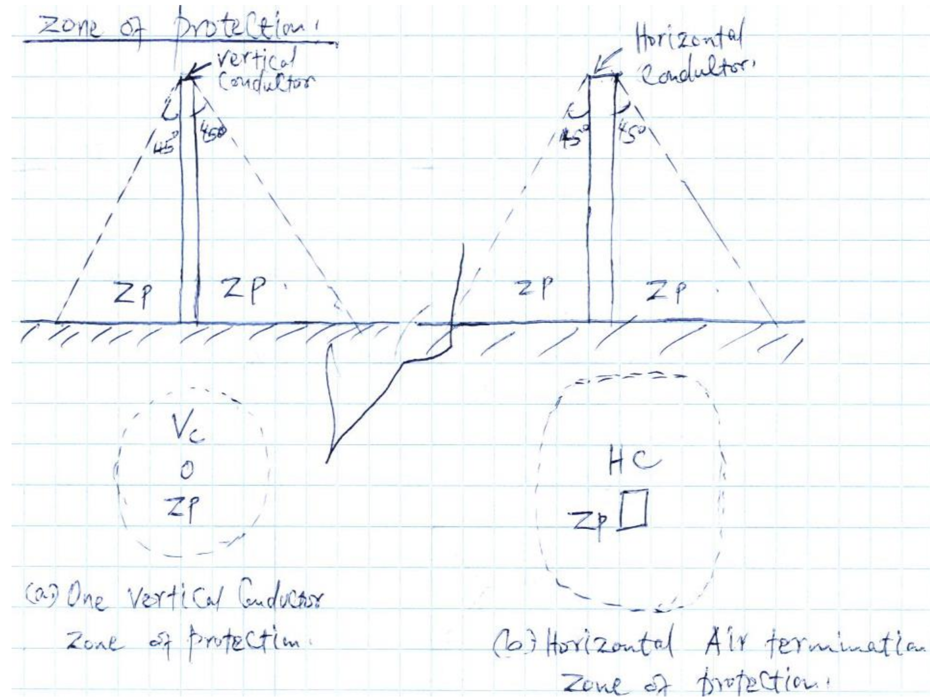
3. **Earth Electrodes (Ground terminals)**

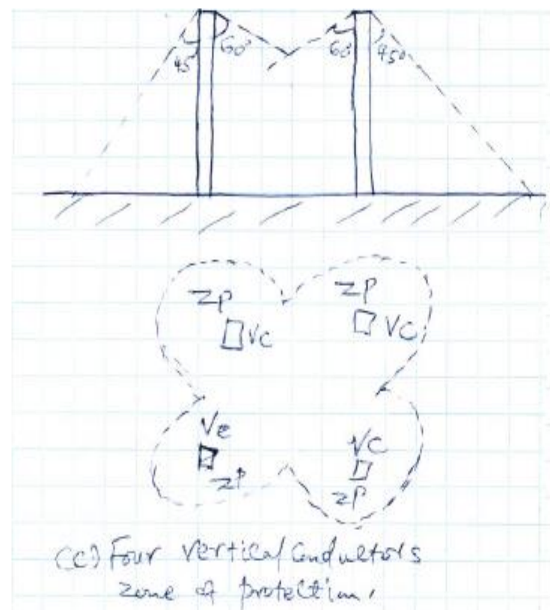
These are long, thick rods buried deep into the earth around a protected structure. They are normally made of copper or aluminium and are designed to emit positive streamers.

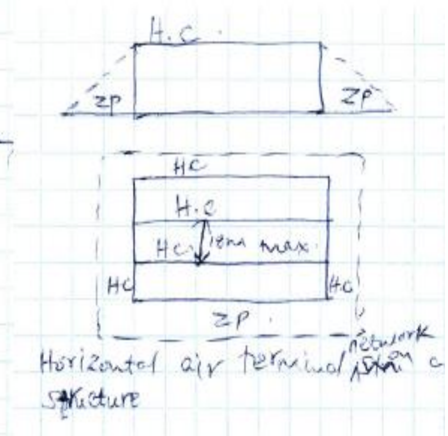
PROTECTION OF BUILDINGS AGAINST LIGHTNING STROKES

Factor to Consider When Designing a LPS

1. **Geographic location of the structure:** this pinpoints the average lightning flush density or the number of flushes to ground to km^2/year.
2. **The effective collection area of the structure:** this is the plan area projection in all directions taking account of the structure's height. This is significant because the larger the structure, the more likeliness of being struck.
3. **The intended use of the structure:** what is housed within the building/use of the building.
4. **Type of construction:** either built of brick, or concrete, or it has steel frame or reinforced frame.
5. **Location of the structure**: e.g. in large towns, forests or isolated hill side







TESTS CARRIED OUT ON LIGHTNING PROTECTION SYSTEMS

- A Lightning Protection Test (**LPT)** involves all lightning conductors and earth grounding installations being visually inspected and tested by a qualified Electrical Engineer.
- Each individual earth grounding point and its conductors are electronically tested for continuity and resistance to ground.
- The common test conducted on LPS are:

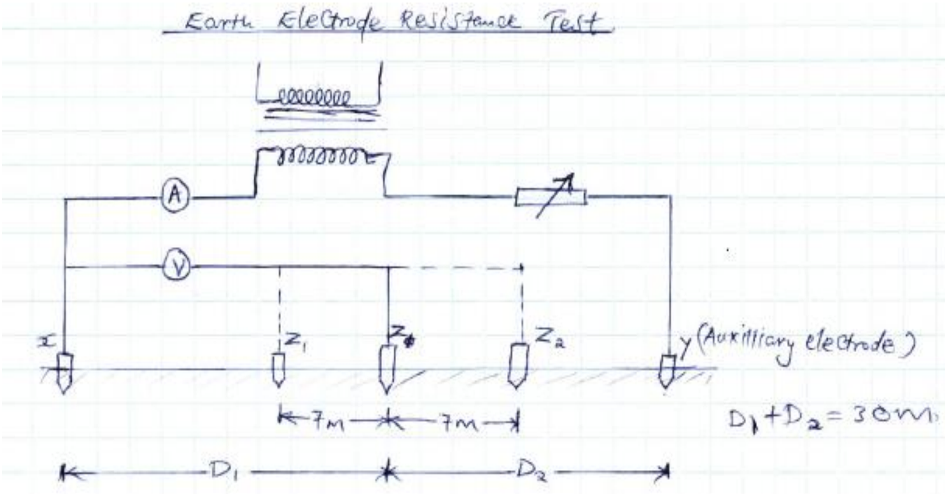
1) Continuity Test
2) Earth resistance test

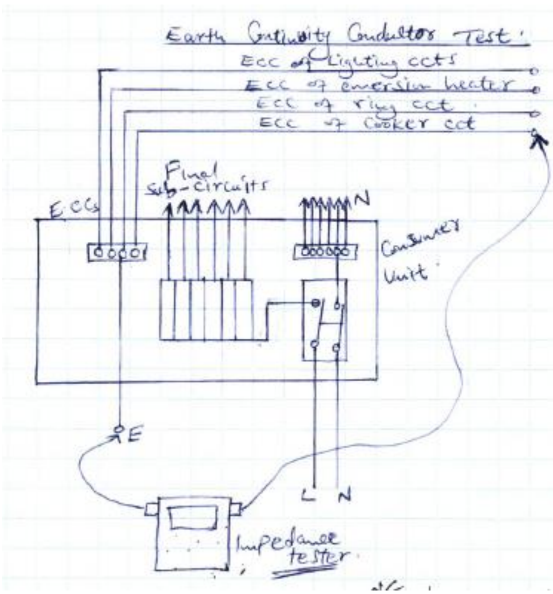
Continuity Test

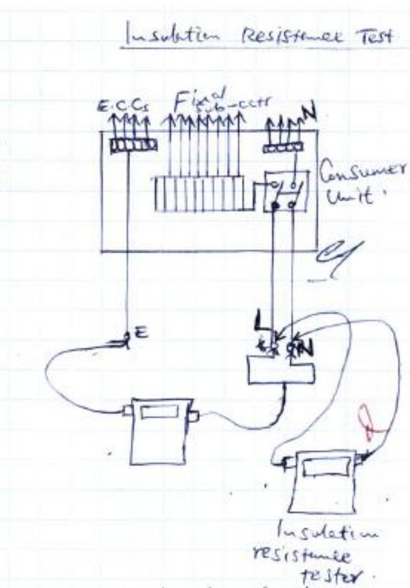
- IEE regulations require conduction of random continuity tests, especially continuity of those parts of the Lightning Protection System which were not visible for inspection during the initial installation and are not subsequently available for visual inspection.
- Tests can readily be made by connecting the phase or neutral conductor of the circuit under test to the main earthing terminal, with the supply disconnected, and then testing between the phase or neutral and protective conductor terminals at each outlet on the circuit

Earth Resistance Test

- Earth resistance test entails measuring the resistance to earth of each local earth electrode and, where practical, the resistance to earth of the complete earth termination system.
- Each local earth electrode should be measured in isolation with the test point between the down conductor and earth electrode in the disconnection position.
- If the resistance to earth of the earth termination system as a whole exceeds 10ohms, additional electrodes should be installed, where practicable, to obtain the requisite resistance value.
- If there is a significant increase in the value of the earth resistance from previously measured values, additional investigations should be made to determine the reason for the increase and measures taken to improve the situation







The IEE Regulations require routine inspections on all electrical installations, at least once every 12 months. The common electrical inspections include:

1) continuity of protective conductors and bonding
2) continuity of ring circuits
3) insulation resistance
4) electrical separation and barriers
5) polarity
6) earth fault loop impedance
7) earth electrode resistance
8) operation of earth-leakage circuit-breakers

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10) continuity of ring circuits
11) insulation resistance
12) electrical separation and barriers
13) polarity
14) earth fault loop impedance
15) earth electrode resistance
16) operation of earth-leakage circuit-breakers

EARTHING SYSTEMS/ARRANGEMENTS

- Factors affecting the earth impedance
  - Type of earth/soil (eg, clay, loam, sandstone, granite)
  - Stratification; layers of different types of soil (eg, loam backfill on a clay base)
  - Moisture content
  - Temperature
  - Chemical composition and concentration of dissolved salt
  - Electrode type and Electrode size
- BS 7671 lists five types of earthing system:

- TN System
- TNS System
- TN C S System
- TN C system
- TT System
- IT System

Where:

T = Earth (from the French word Terre

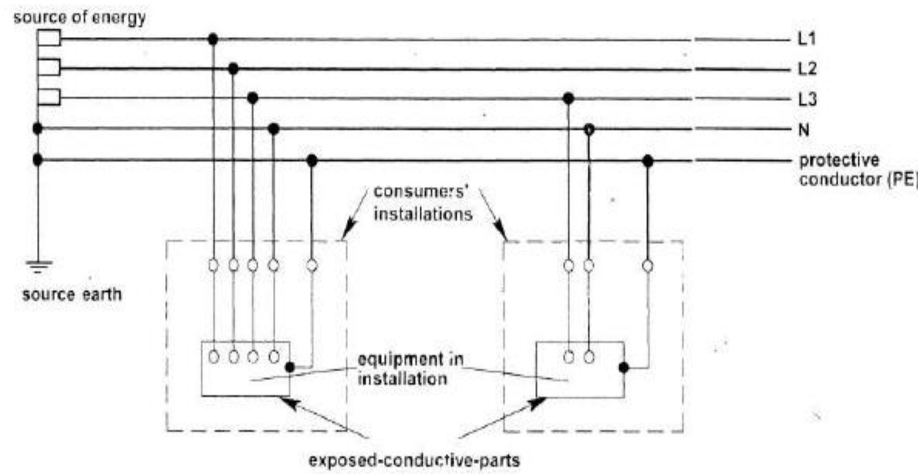
N = Neutral

S = Separate

C = Combined

I = Isolated

TN-S System



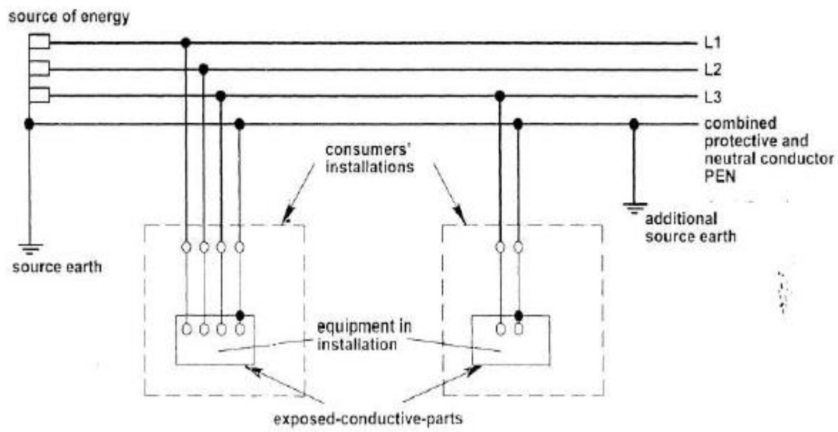
Separate neutral and protective conductors throughout the system.

The protective conductor (PE) is the metallic covering of the cable supplying the installations 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.

TN-C System

Fig 2.2 TN-C system



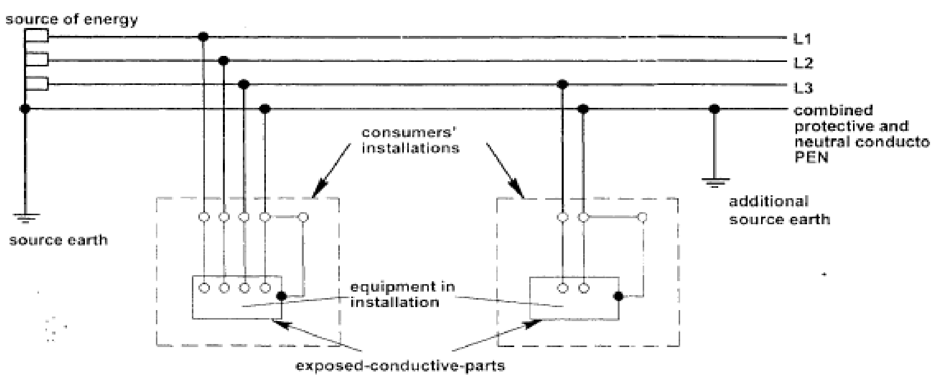
Neutral and protective functions combined in a single conductor throughout system.

All exposed-conductive-parts of an installation are connected to the PEN conductor.

Regulation 8(4) of the Electricity Safety, Quality and Continuity Regulations 2002 states that a consumer shall not combine the neutral and protective functions in a single conductor in his consumer's installation.

TN-C-S System

Fig 2.4 TN-C-S system



Neutral and protective functions combined in a single conductor in a part of the system.

The usual form of a TN-C-S system is as shown, where the supply is TN-C and the arrangement in the installations is TN-S.

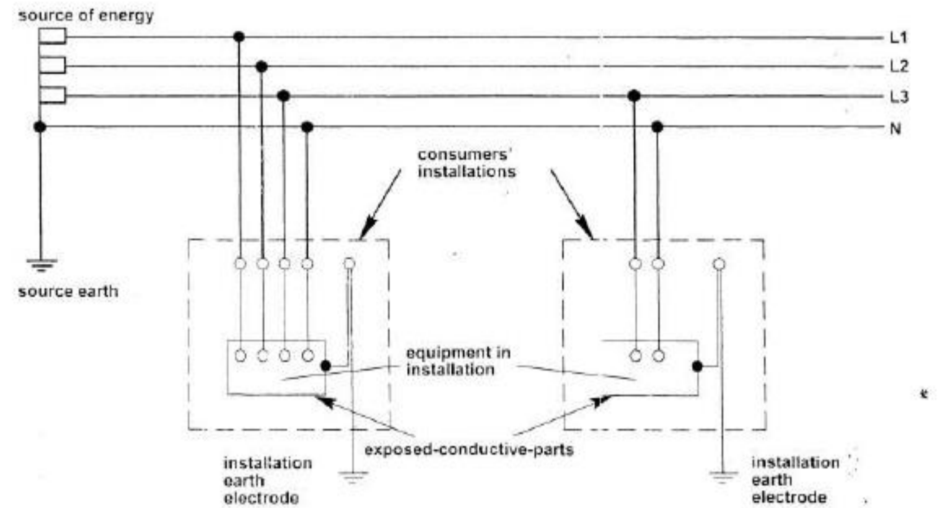
This type of distribution is known also as protective multiple earthing.

The supply system PEN conductor is earthed at two or more points and an earth electrode may be necessary at or near a consumer's installation.

All exposed-conductive-parts of an installation are connected to the PEN conductor via the main earthing terminal and the neu terminal, these terminals being linked together.

TT System

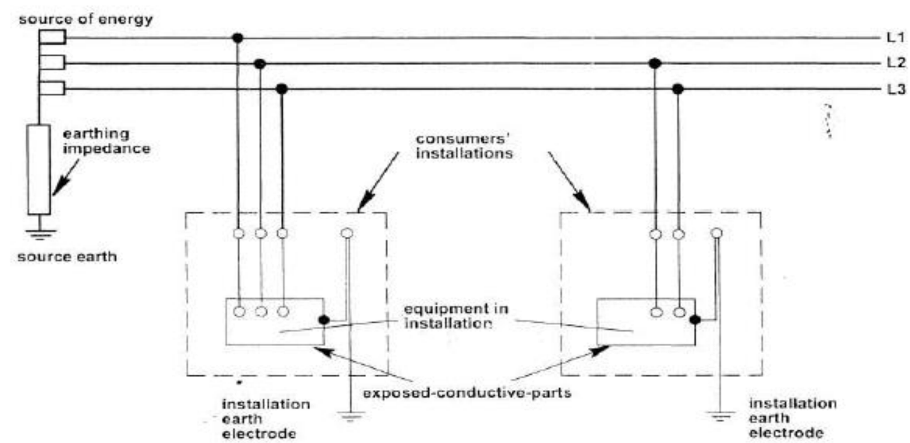
Fig 2.5 TT system



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

IT System

Fig 2.6 IT system



All exposed-conductive-parts of an installation are connected to an earth electrode.

The source is either connected to Earth through a deliberately introduced earthing impedance or is isolated from Earth.

SPECIAL TYPES OF INSTALLATION

THE FIRE TRIANGLE

The fire triangle is a tool to illustrate the three elements which must be present to have a fire or explosion: fuel, oxidizer, and energy. Fuel and oxidizer must be present in a concentration appropriate to form a combustible mixture. The ignition source must supply enough energy to initiate combustion. If any one of the elements of the triangle is not present in sufficient amount, then combustion cannot occur.

ELECTRICITY DISTRIBUTION WITHIN THE EXPLOSIVE AREAS

- The electrical distribution in an explosives area may be by means of underground cables or overhead lines. Underground cables are preferred and should be provided wherever practicable. Cables shall not be laid below buildings.
- Overhead lines shall be sited at greater than $D = \frac{S}{2} - H \; or \; D = 2H$ where the physical safe distance (D) is calculated by reference to the height (H) of the supporting structure (or the height of the highest conductor if greater) and the length of the span (S). The greater distance derived from either of the following expressions should be observed.

  NOTE:
  Note. This expression assumes that, if a break were to occur in the overhead line, natural recoiling of the broken line will restrict swing in a direction normal to the line axis to less than half the span distance.

- Surge protective devices shall be fitted between live conductors and earth and between live and neutral conductors at the junctions of overhead lines and underground cables.
- Lighting columns, shall be sited so as to ensure that in the event of failure no live conductor is able to fall onto an explosives building. Supports shall be installed a minimum distance of 1.5 times their height away from the building.
- Where possible the explosives area electrical distribution overhead power lines, should not cross roads and railways. Where such crossings are unavoidable, precautions shall be taken to reduce to a minimum the length of time vehicles loaded with explosives stand below the power lines. Power line crossings of roads and railways should be clearly marked (e.g. by painting yellow box markings on roads).
- Spans of overhead power lines at road and rail crossings and immediately adjacent spans should be inspected regularly and the results recorded.
- Explosives establishments shall hold and maintain plans showing the position and size of all underground cables, including the location of all joints in cables, cable pits, etc. within the explosives areas.

CLASSIFICATION OF HAZARDOUS AREA

Classified in 03 zones based upon the Frequency of the appearance and duration of an explosive gas atmosphere:

Class I (Zone 0) - An area where an explosive atmosphere is present continuously or for long periods or frequently. Examples: Vapour space above closed process vessels; Storage tanks; Closed containers; Areas containing open tanks of volatile, flammable liquid

Class II (Zone 1) - An area in which an explosive atmosphere is likely to occur in normal operation but, if it does occur, will persist for a short period only, i.e explosive atmosphere is likely to occur in normal operation occasionally.

- Flammable gas or vapour concentration is likely to exist in the air under normal operating conditions
- explosive environment is likely to occur frequently because of maintenance, repairs or leakage
- Piping system (containing valves, meters, or screwed or flanged fittings) should be in an inadequately ventilated area

- The area below the surrounding elevation or grade is such vapours may accumulate therein
- Failure of equipment is likely to cause an electrical system failure simultaneously
- Examples:
    - Imperfectly fitting peripheral seals on floating roof tanks
    - Inadequately ventilated pump rooms for flammable gas /liquid
    - Oily waste water sewer / basins
    - Loading / unloading gantries
    - Interiors of Sample Retention Room
    - Areas in the immediate vicinity of vents and filling hatches

Class III (Zone 2) - explosive atmosphere is not likely to occur in normal operation but, if it does occur under abnormal operation, will persist for a short period only. Normally, the system handling flammable liquid /vapour is in an adequately ventilated area. Examples:

- Release of flammable liquid/gas in abnormal conditions such as accidental release of a gasket or packing
- The flammable vapours can be conducted to the location as through trenches, pipes or ducts
- Locations adjacent to Zone 1 areas
- Pressurized rooms where flammable gas / vapour can enter in the case of failure of positive mechanical ventilation

EXTENT OF HAZARD:

•**Division 1**: Hazardous media can exist under normal operating condition

•**Division 2:** Hazardous media can exist under abnormal operating condition

CLASS	MATERIALS:	DIVISION 1	DIVISION 2
I Gases, Vapors and Liquids	A: Acetylene B: Hydrogen, etc. C: Ether, etc. D: Hydrocarbons, fuels, solvents, etc.	Explosive or ignitable gases or vapors are present under normal operating conditions.	Explosive or ignitable gases or vapors are not normally present (but may accidentally exist).
II Dusts	E: Metal dusts F: Carbon dusts G: Flour, grain, wood or chemical dusts	Combustible dust is in the air under normal operating conditions.	Dust is not normally in the air in ignitable concentrations (but may accidentally exist).
III Fibers and Flyings	Textiles, wood chips, etc. (ignitable but not explosive)	Easily ignitable fibers or flyings are handled, manufactured or used.	Easily ignitable fibers are stored or handled.

IMPORTANCE OF HAZARDOUS AREA CLASSIFICATION/ZONING

1. Proper selection of electrical apparatus for installation
2. Enable electrical apparatus to be operated safely
3. Safety of personnel

Hazard: Risk of presence of flammable gas and air mixture.

-**Hazardous atmosphere:** An atmosphere/ environment containing any hazard in a concentration capable of ignition.

-**Hazardous area:** is an area in which an explosive gas/dust/fibres atmosphere is present, or likely to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus

-Ignition temperature: The lowest temp at which ignition occurs in vapour air mixture.

FLAMMABLE SUBSTANCES

Flammable substances may be gaseous, liquid or solid

- **Flammable gas:** Are often hydrocarbons & require very little energy to react with atmospheric oxygen. **Examples:** Methane, Ethane, Hydrogen

- **Flammable Liquids:** Which evaporates at room temperature in sufficient quantities to form flammable atmosphere. **Examples:** Lighter fuel (MS, Naphtha ….)

- **Flammable Solids:** Flammable Dust & fibers which react with atmospheric air to cause explosions in the presence of source of ignition. Ex: (Wood, Coal Dust, metals…..)

-**LEL Lower explosive limit:** Lower or Minimum level of concentration of flammable vapour/gas in atmosphere which can ignite by arc/spark

-**HEL/UEL:** Upper or maximum level of concentration of flammable vapour/gas in atmosphere which can ignite by arc/spark

-**Explosive/Flammability Range:** Range between LEL to HEL

TYPE OF PROTECTIONS

Various method of protection is prevalent & is suitable for use in hazardous location depending on the extent of hazard. They are:

a) Explosion proof or flame proof
b) Increased safety
c) Intrinsically safe
d) Purge protected
e) Non sparking
f) Oil filled/immersion
g) special installations

FLAME PROOF

Performance Requirements:

- ➢ It is a method of protection, where the equipment is enclosed in an enclosure, which will withstand the internal explosion of flammable gases that enter it, without damage and do not allow the internal explosion to permeate to the surroundings through any joints.
- ➢ Apparatus used will withstand an internal explosion of the inflammable gas which may enter it without causing damage and without communicating the internal inflammation to the external flammable gas. The escaping (hot) gases must sufficiently cool down along the escape path that by the time they reach the outside of the enclosure not to be a source of ignition of the outside, potentially ignitable surroundings.
- Lamps, circuits and sparking devices are contained within flameproof enclosure.
- Wiring enters enclosure via flameproof cable gland or flameproof barrier.
- Joints on covers or openings are protected by the 'flamepath'.
- Does not prevent explosion occurring but contains the explosion and prevents ignition of surrounding atmosphere.

Constructional Features:

•Flame path (length & clearances) is ensured as per code.

Suitability: For use in Zone-1 & Zone-2.

INCREASED SAFETY

Performance Requirements:

- ➢ Wherein additional precautions are taken to provide additional safety against excessive temperature, occurrence of arc & spark.
- ➢ These are not capable of withstanding explosion inside enclosure.

Constructional Features:

•No arcing devices such as fuse & switchgears are used.

•Ignition is prevented by use of non sparking components.

•Clearances & creep age distances are maintained as per code.

Suitability: For use in Zone-2.

INTRINSICALLY SAFE

Performance Requirements:

- A protection technique in which explosion is prevented by ensuring that sufficient energy for ignition of flammable gases is not available. It also ensure that the Surface temperature does not exceeds auto ignition temperature of surrounding flammable gases.
- The technique is based upon restriction of electrical energy within apparatus and in the interconnecting wiring, exposed to potentially explosive atmosphere, to a level below that which can cause ignition by either sparking or heating effects.
- Because of the method by which intrinsic safety is achieved it is necessary that not only the electrical apparatus exposed to the potentially explosive atmosphere but also other electrical apparatus with which it is interconnected is suitably constructed.
- The Surface temperature does not exceeds auto ignition temperature of surrounding flammable gases.

Constructional Features:

•These equipments are primarily low energy electronic device. Operates at lower voltage & amp.(28V,93mA,0.65W)

Suitability:

•For use in Zone-0 & Zone-1

PRESSURIZED/PURGE PROTECTED

Performance Requirements:

- Equipment is pressurized to a positive pressure relative to the surrounding atmosphere with air or an inert gas, thus the surrounding ignitable atmosphere cannot come in contact with energized parts of the apparatus. The overpressure is monitored, maintained and controlled.
- Explosion is prevented by purging flammable media & ensuring non-ingress of flammable media by keeping positive pressure.
- The Surface temperature does not exceeds auto ignition temperature of surrounding flammable gases.

Constructional Features:

•Components & devices are installed inside a purge panel. A positive pressure of uncontaminated air or other neutral gas is maintained inside the panel.

Suitability: For use in Zone-1.

NON SPARKING SAFE

Performance Requirements:

- It is a method of protection in which non arcing/non-sparking components are used such that in normal working condition, it is not capable of igniting the surrounding explosive atmosphere.
- Fault capable of causing the ignition is not likely to occur.

Constructional Features:

•Components selected are non arcing, non sparking

•Enclosed break-Incendive components.

•Restricted breathing by sealing & gasketing.

Suitability: For use in Zone-2.

OIL IMMERSION

- A method of protection where electrical apparatus is made safe by oil immersion in the sense that flammable gasses or vapors above the oil or outside the enclosure will not be ignited
- An electrical equipment capable of igniting explosive gas mixture is protected by immersion in mineral oil or other suitable protective liquid so that explosive gas mixture cannot come in contact with electrical equipment i.e. oil/liquid acts as a barrier between them.

SPECIAL TYPES OF INSTALLATION

Certain types of installation demand special consideration when designing and installing the electrical equipment. Part 7 of BS 7671 of the 17th edition of the IEE Wiring Regulations sets out the specific needs of some types of special installation and the IEE Regulations contained therein supplement or modify the other parts of the IEE Regulations. The term 'special' therefore means application of particular requirements in addition to the general rules of BS 7671 within Parts 1 to 6. In general, such 'Special Installations or Locations' listed in BS 7671 involve increased risks of danger and/or harsher conditions compared with those catered for by the general parts (Parts 1–6). These types of special installations include:

- Locations containing a bath or shower (701)
- Swimming pools and other basins (702)
- Rooms and cabins containing sauna heaters (703)
- Construction and demolition site installations (704)
- Agricultural and horticultural premises (705)
- Conducting locations with restricted movement (706)
- Electrical installations in caravan/camping parks and similar locations (708)
- Marinas and similar locations (709)
- Medical locations (710)
- Exhibitions, shows and stands (711)
- Solar photovoltaic (pv) power supply systems (712)
- Mobile or transportable units (717)
- Electrical installations in caravans and motor caravans (721)
- Temporary electrical installations for structures, amusement devices and booths at fairgrounds, amusement parks and circuses (740)
- Floor and ceiling heating systems (753)

Locations containing a bath or shower (701)

Introduction and risks

In a bathroom or shower room the increased risks are from:

- Exposed wet skin (with a lower contact resistance),
- The splashing and ingress of water,
- The usual close proximity of earthed metalwork.
- There may also be further risks due to disability or infirmity.

Table G 2.1 Bathroom electric shock requirements.

Requirement	Regulation
All circuits to have 30 mA RCD	701.411.3.3
Socket outlets to be 3 m from the outer limit of Zone 1 (except SELV)	701.512.3
Where main equipotential bonding is used in the installation, no local supplementary bonding is required	701.415.2
Obstacles and Out Of Reach are not permitted	701.410.3.5
Non-conducting location and earth-free local equipotential bonding are not permitted	701.410.3.6
Electrical separation can only be used for single items	701.413
For SELV and PELV basic protection must be used	701.414.4.5

NOTE: For a bathroom or shower, Zone 0 is the bath or shower tray. • Zone 1 can be considered to be the area where the individual is bathing or showering, or the area where shower water is likely to be directly sprayed. • Zone 2 is the area beyond Zone 1, extending by a further 600 mm.
SELV- Separate Extra-Low Voltage.
PELV- Protected Extra-Low Voltage.

Swimming pools and other basins (702)

Introduction and risks

Swimming pools and basins pose similar risks to bathrooms, in that people are generally unclothed and body contact resistance is low. One major difference to keep in mind, however, is that generally there are several people in the pool area and usually only one person in the bathroom.

Table G 3.1 Swimming pool and fountain electric shock requirements.

Swimming pool or fountain	Requirement	Regulation
Both	All extraneous-conductive-parts in Zones 0, 1 and 2 (except for fountains) to be supplementary bonded	702.411.3.3
Both	For SELV and PELV basic protection must be used	702.414.4.5
Swimming pools	Only SELV up to 12 V a.c. or 30 V d.c. can be used as a protective measure in Zone 0 in swimming pools	702.410.3.4.1
Swimming pools	Only SELV up to 25 V a.c. or 60 V d.c. can be used as a protective measure in Zone 1 in swimming pools	702.410.3.4.1
Swimming pools	Protective measure in Zone 2 in swimming pool can be SELV, RCD automatic disconnection or 'single item electrical separation'	702.410.3.4.3
Fountains	Protective measure in Zones 0 and 1 in fountains can be SELV, RCD automatic disconnection or 'single item' electrical separation	702.410.3.4.2

Agricultural and horticultural premises (705)

Introduction and risks

BS 7671, part 705 covers electrical installations inside and outside agricultural and horticultural buildings, including locations where animals are kept. These locations are characterized by arduous conditions, and people usually working in a wet or damp environment, both indoors and outdoors.
An increased risk of damage to the electrical installation and an increased risk of personal danger can come from a number of factors, including:

- The use, possibly widespread, of chemical cleaners and fertilizers;
- Unsettled behaviour and nature of animals (stock and vermin);
- Agricultural machinery;
- Frequent wet and damp conditions;
- Lower body resistance of livestock.

It should be noted that danger, including the risk from electric shock, particularly applies to livestock. In places where livestock is kept, there is a greater risk of electric shock to them due to their lower body resistance and more intimate contact with the general mass of earth. It can often be seen in milking parlours that cows will not pass from one place to another where they sense a small potential difference between their front and rear legs.
All electrical equipment should have physical protection to withstand wash down and the use of chemical cleaning agents, and will require special considerations against corrosion. High impact plastic materials may be better than metals, but these cannot be considered to be a Class II installation.

Generally, the best physical protection will be provided by careful placement of outlets and controls in areas where they are not likely to be subject to damage or impact.

Table G 4.1 Agricultural and horticultural installation requirements.

Requirement	Regulation
Final socket-outlet circuits with socket outlets up to 32 A require a 30 mA RCD	705.411.1
Final socket-outlet circuits with socket outlets above 32 A require a 100 mA RCD	705.411.1
All other circuits require an RCD not exceeding 300 mA	705.411.1
For SELV and PELV basic protection must be used	705.414.4
Where livestock is kept, supplementary bonding shall connect exposed and extraneous-conductive-parts; this includes floor reinforcing Copper conductors to be 4 mm^2 minimum, steel bonding to be galvanized and minimum of 8 mm diameter or 30 x 3 mm section	705.415.2.1 705.544.2
Where welfare of animals is affected by loss of supply (e.g. food, water, ventilation or lighting systems) a standby supply shall be installed and separate final circuits shall be used. Alternatively for ventilation systems, monitoring and alarms can be used	705.560.6
Ventilation supply circuits shall be designed to achieve discrimination	705.560.6
Electrical heaters for livestock shall be to BS EN 60335–2-71	705.422.6
All equipment to have IP minimum of IP44	705.512.2
Obstacles and Out Of Reach are not permitted	705.410.3.5
Non-conducting location and earth-free local equipotential bonding are not permitted	705.410.3.6

Caravan parks and camping parks (708)

Introduction, purpose and principles

Section 708 does not apply to installations for mobile homes and similar and its scope is for 'caravan parks/camping parks' as defined in the Standard, as follows:
Caravan: A trailer leisure accommodation vehicle, used for touring, designed to meet the requirements for the construction and use of road vehicles.
Caravan park/camping park: Area of land that contains two or more caravan pitches and/or tents.

Table G 5.1 Caravan and camping park requirements.

Requirement	Regulation
TN-C-S arrangements are not permitted	708.411.4
Equipment to be minimum of IP 44	708.512.2
Overhead cables to be minimum of 6 m where vehicles are used and 3.5 m elsewhere	708.521.1.2
Supply point at pitch is to be a maximum of 20 m from caravan inlet	708.530.3
Pitch socket outlets to be provided with at least one outlet, minimum 16 A, IP44, BS EN 60529 type and located between 0.5 and 1.5 m high	708.553.1.8 708.553.1.9 708.553.1.10 708.553.1.11
Each pitch socket outlet to be provided with overcurrent protection and 30 mA RCD	708.553.1.12 708.553.1.13
Obstacles and Out Of Reach are not permitted	708.410.3.5
Non-conducting location and earth-free local equipotential bonding are not permitted	708.410.3.6

- Electrical wiring is generally refers to insulated conductor used to carry current and associated device used to provide power in buildings and structures, commonly referred to as building wiring.

Types of wiring according to uses:

1. Domestic wiring.
2. Commercial wiring.
3. Industrial wiring.

FACTOR AFFECTING THE CHOICE OF WIRING:

1. **Durability:** Type of wiring selected should conform to standard specifications, so that it is durable i.e. without being affected by the weather conditions, fumes etc.
2. **Safety:** The wiring must provide safety against leakage, shock and fire hazards for the operating personnel.
3. **Appearance:** Electrical wiring should give an aesthetic appeal to the interiors.
4. **Cost:** It should not be prohibitively expensive.
5. **Accessibility & Flexibility:** The switches and plug points provided should be easily accessible. There must be provision for further extension of the wiring system, if necessary.
6. **Maintenance Cost**: The maintenance cost should be a minimum
7. **Mechanical safety:** The wiring must be protected against any mechanical damage.

Types of Wiring

- Commonly used types of wiring systems for residential buildings, commercial buildings etc are:
    1. Cleat wiring
    2. Wooden casing and capping wiring
    3. C. T. S or T. R. S. wiring
    4. Metal Sheathed or Lead Sheathed wiring
    5. Conduit wiring

Cleat Wiring

- Cleat wiring is normally used for temporary wiring purpose. E.g. functions, marriages…etc.
- In this type of wiring vulcanized india rubber(V.I.R) or polyvinyl chloride(PVC) insulated wires are used as conductors. Wires are held by the help of porcelain cleat which are placed 6mm off the walls or ceilings.
- As shown in dia. Grooves are provided in the base portion of the cleat for accommodating the wires. This System uses insulated Cables sub protected in porcelain cleats. Wiring is done as shown in figure:

Advantages:

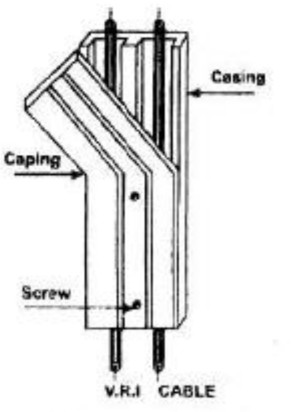
1. Cheapest system of internal wiring
2. Installation and dismantlement is easy and quick
3. Material is recoverable after the dismantlement
4. Inspection, alternations and additions can be easily made
5. Skill required is little.

Disadvantages:

1. It is not good looking
2. Quit temporary and perishes quickly
3. Wire are exposed to mechanical injury
4. Oil and smoke are injurious to V.I.R insulation
5. Not suitable for domestic premises.

Wooden casing and capping wiring

- In this cable is run through a wood casing having grooves.
- The wood casing is of required fixed length with parallel grooves that accommodates the cables.
- The wooden casing is fixed to the walls or ceiling with screws.
- After placing the cables inside the grooves of casing, a wooden cap with grooves is placed on it to cover the cables.
- This type of wiring is suitable for low voltage domestic installations in dry places and where there is no risk of fire hazards



Advantages:

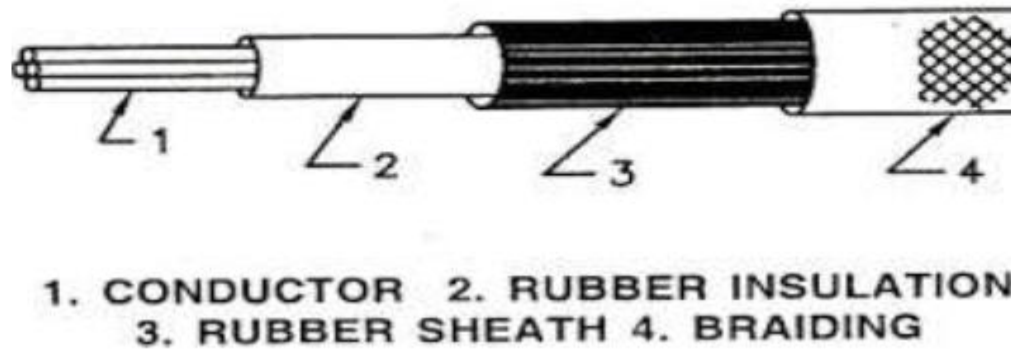
1. Better appearance than cleat wiring
2. Cheap in cost
3. Easy to install and rewire
4. Easy to inspect by opening the capping

Disadvantages:

1. Not suitable in damp places
2. Risk of fire
3. This type of wiring can only be used on surface and cannot be concealed in plaster.
4. Since it requires better workmanship , labour cost is more

C. T. S or T. R. S. wiring

- This type of wiring is also used for house wiring and is quite cheap.
- Cab tyre sheathed (C.T.S) wire or tough rubber sheathed (T.R.S) wire is normally used as conductor for this wiring.
- The wires are run on the teak wooden battens which are fixed on the wall or the ceiling by means of screws and wooden plugs.
- C.T.S OR T.R.S cables used are not much affected by chemicals , water, and steam.



Advantages:

1. It is easy to install and repair
2. It gives better appearance
3. Its life is long
4. It is fire proof up to a certain limit
5. It is cheaper than other types of wiring except cleat wiring
6. Conductors have strong insulations
7. Chemicals do not affect the conductor insulation

Disadvantages:

1. The conductors are open and liable to mechanical injury thus this type of wiring cannot be used in workshops etc.
2. Its use in places open to sun and rain is restricted
3. Good workmanship is suitable where acids and alkalis to be prescut

Metal Sheathed or Lead Sheathed wiring

- This type of wiring is adopted for low voltage installation.
- This system is similar to C.T.S wiring except that the cable used is different in this wiring system.
- In this type of system conductors are insulated with V.I.R and then covered with an outer sheath of lead aluminium alloy containing 95% lead and 5% aluminium.
- The metal sheath is provided over the insulated conductor in order to protect the system from mechanical injury, dampness and atmospheric action.
- Same as C.T.S wiring system cables are run on wooden batten and are fixed with the help of tinned link clips.
- Field of application:
    i. This wiring system is suitable for low voltage (up to 250V) installations.
    ii. It may be used in places exposed to sun and rain provided no joint is exposed.
    iii. It may be used in damp placed with a suitable protective covering.
    iv. This type of wiring is very common in use these days except for some small installations and distribution boards etc.

Advantages:

1. Conductors are protected againstmechanical injury
2. It is suitable employed under damp situations
3. It gives better appearance
4. It has longer life
5. Conductors are protected against chemicals
6. It can be installed in open space

Disadvantages:

1. Cables are costlier than C.T.S OR T.R.S wires
2. In case of leakage, there is risk of shock
3. Skilled labour and proper supervision is required
4. It is not suitable for places where chemical corrosion may occur

Conduit Wiring

- Conduit wiring system is best for domestic and commercial installations.
- It provide proper protection to the installation against fire hazards, shock, mechanical damage and dampness.
- The cable used in this system is either V.I.R or P.V.C insulated and is run in mild steel or P.V.C pipes called conduits.
- Conduits carrying the insulated wires can be installed on the surface of the walls or concealed in the walls and the ceiling.
- Modern practice is to conceal the conduit in the plaster of the wall, so that the appearance of the house remains unaffected.
- Field of application:
    i. Places where considerable dust of puff is present such as textile mills, saw mills, flour mills etc.
    ii. Damp situations
    iii. In workshops for lighting and motor wiring
    iv. Places where there is possibility of fire hazards such as in oil mills, varnish factories, etc.
    v. Placed where important documents are kept such as record room
    vi. Residential and public buildings where the appearance is of prime importance

Advantages:

1. Conduit provides protection against mechanical injury and fire & is shock proof
2. Conduit provides protection against chemicals
3. The whole system is water proof
4. Conductors are safety secured from moisture
5. This wiring has far better look
6. It has a longer life

Disadvantages:

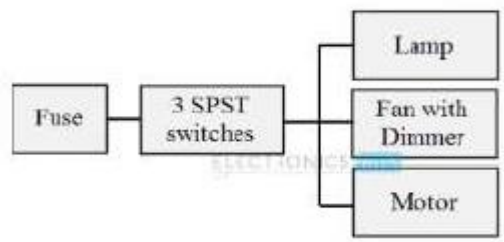
1. It is costly system of wiring
2. It requires more time for erection
3. It requires highly skilled labour
4. Internal condensation of moisture may cause damage to the insulation unless the system outlets are drained and ventilated

Condition for Domestic & Industrial Installation (EE Regulations- BS 7671**)**

- Height of switch board must be 1.3m to 1.75m from floor level
- Height of distribution board must be 1.5m to 1.75m from floor level
- The bottom of ceiling fan should have minimum clearance of 2.75m
- All lamp should be filled with a minimum clearance of 2.75m above floor level
- Load should be equally shared
- In any building light wiring and power wiring should be kept separate
- Power per circuit may take it as 800w or 1000w
- Weatherproof wire for service connection with sufficient current carrying capacity.
- All conductor/wire should be sage in all term of voltage rating with proper insulation.
- Ever line or phase should be protected by suitable ratings fuse.
- Each load point an appliances should be a independent control switch.
- In any light/fan and the number of load points connected in one sub circuit should be less than 10(ten).
- In the bath rooms, the 3 pin socket should be at a height of not less than 1.5 m.

Block Diagram for Electrical installations

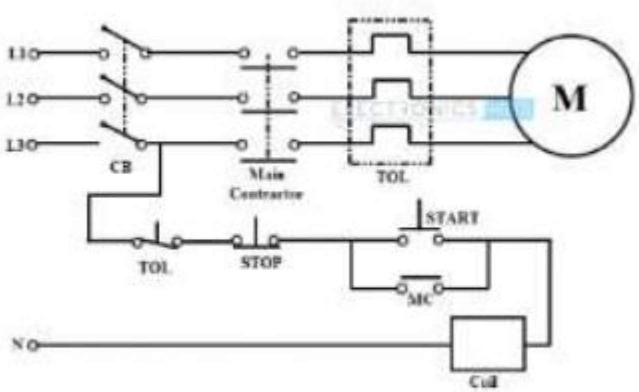
- It is a functional drawing which shows and describes the main operating principles of the equipments or devices.
- It consists of :--principle functions (represented by blocks) - line connections (shows relationship between them).
- The diagram is usually drawn before implementing a circuit diagram.
- Not give any detailed information.
- Leaves the information about smaller components.



Line Diagram

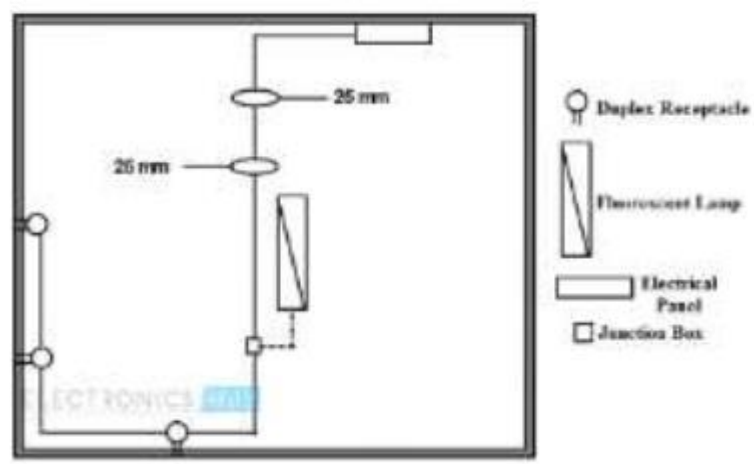
- Is a simplified notation of an electrical system.
- Called as one-line diagram or single line diagram.
- Similar to the block diagram
- It consists of symbols to represent the components.

- Lines to represent the wires or conductors which connects the components together.
- The line diagram is derived from the block diagram.



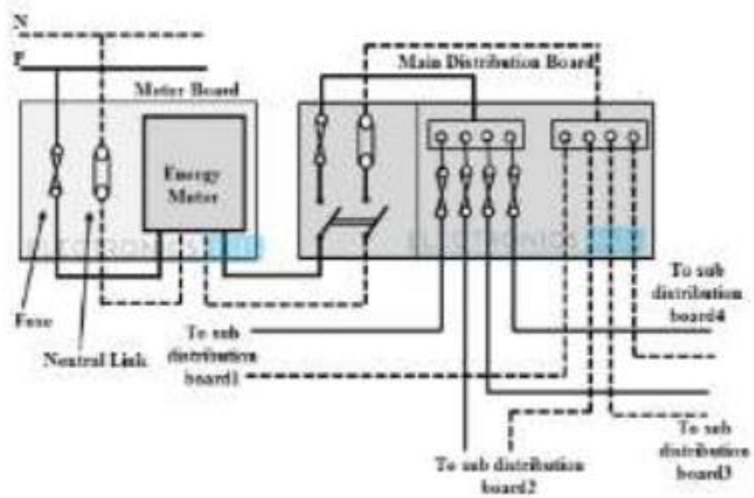
Circuit Diagram

- Electrical circuit is graphically represented in a simplified manner.
- It gives the position information of various elements (in cm or m or mm)
- Doesn’t give any layout of the parts and their detail wiring information of the components.
- One can do wiring by following the information given in this diagram
- These diagram illustrate the working of an electric circuit.



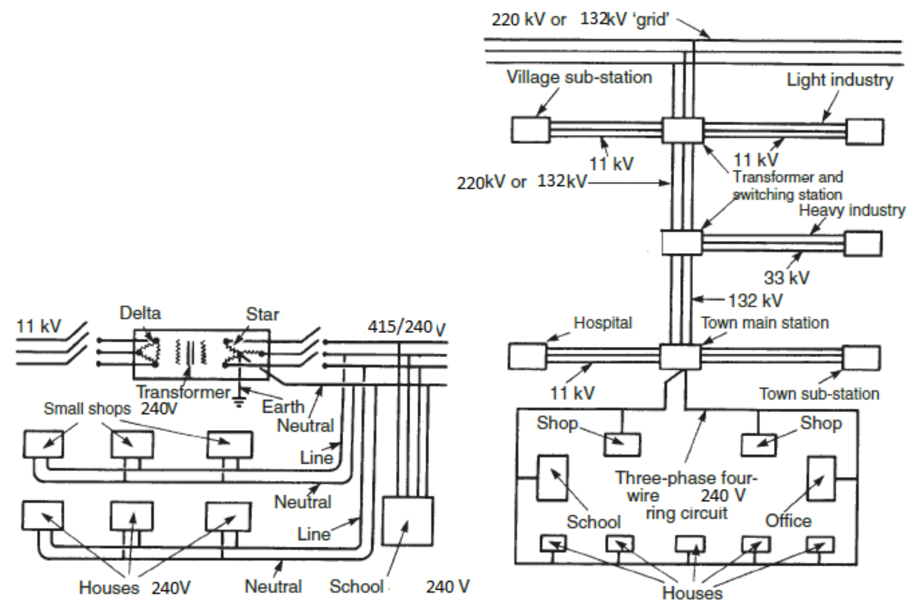
Wiring Diagram

- Wiring diagram is a representation of the circuit, shows the wiring between parts or elements.
- Gives detailed information about wiring.
- It includes:- -relative position -arrangement of devices -terminals on the devices
- It shows power supplies and earth connections.



Electricity distribution to Buildings

- In the Kenya electricity is produced at power generating stations at 11kV, in three-phase supply at 50 cycles per second or hertz (Hz). Thereafter it is transformed by step-up transformers to 132, 220 or 400 kV for transmission before connecting to the national grid. This very high voltage is used to minimize the current carried by the cables over long distances, hence reducing transmission losses.
- Power to large towns and cities is by overhead lines at 66 kV or 33 kV where it is transformed to 11 kV underground/overhead supply at sub-stations.
- From these sub-stations the supply is again transformed to the lower potential of 415 volts, three-phase supply and 240 volts, single-phase supply for general distribution.
- The supply to houses and other small buildings is by an underground/overhead ring circuit from local sub-stations. Supplies to factories and other large buildings or complexes are taken from the 33 or 11 kV mains supply. Larger buildings and developments will require their own transformer, which normally features a delta-star connection to provide a four-wire, three-phase supply to the building (see figure below).



Supply from town or village sub-station

Supply to the buildings

Note:

- A balanced load, such as a three-phase electrical motor driving an air-conditioning fan, water pump or lift motor, does not produce a current in the neutral wire. This is because an alternating current flows alternately in the forward and backward directions along the line wire. The overall effect of three driving coils in the motor is a balance in the quantity and direction of the current taken from the line conductors. There is no net return current in the neutral wire from such a balanced load. Single-phase electrical loads, which are not in balance, produce a net current in the neutral conductor.

- The casings of all electrical appliances must be connected to earth by a protective conductor, the earth wire, connected to the earthed incoming service cable of the electricity supply authorities or an earth electrode in the ground outside the building. Gas and water service pipes are bonded to the earth by a protective conductor.

- Equal amounts of power are fed into each phase, and so it is important that power consumption within a building is equally shared by each line. The neutral wire is a live conductor in that it is the return path to the alternator for the current which has been distributed.

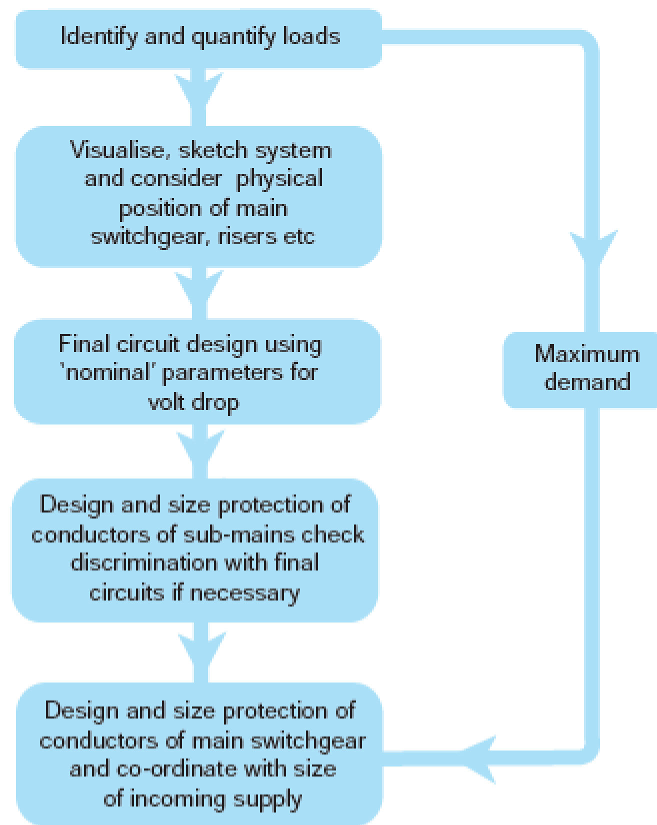
- For easy identification, each live phase cable has colour coded plastic insulation of red, yellow or blue. The neutral is colour coded black.

- A sub-station is required for the conversion, transformation and control of electrical power. It is used where large buildings or complexes of buildings require greater power than the standard low or medium potential of 240 and 415 volts. A sub-station must be constructed on the customer's premises. It is supplied by high voltage cables from the electricity authority's nearest switching station. The requirements for a sub-station depend upon the number and size of transformers and switchgear.

- The termination and metering of services cables to buildings is determined by the electricity authority's supply arrangements. Most domestic supplies are underground with the service cable terminating at the meter cupboard, as shown. Depth of cover to underground cables should be at least 750 mm below roads and 450 mm below open ground. In remote areas the supply may be overhead.

Circuit Design Procedure Overview

The procedure of carrying out an electrical system design of an installation can be quite involved and often a number of drafts and subsequent adjustments are necessary. The following flow diagram shows the logical order of steps in the design process:



Cable Capacity and Voltage Drop

- The maximum current-carrying capacities and actual voltage drops according to the IEE Regulations for Electrical Installations (17th edn, 2008) for unenclosed copper cables which are twin-sheathed in PVC, clipped to the surface of the building, are given in Table below. Flexible connections to appliances may use 0.5 mm^2 conductors for 3 A and 0.75 mm^2 conductors for 6 A loads.
- The maximum voltage drop allowed is 4% of the 240 V nominal supply.

Electrical cable capacities.

Nominal cross-sectional area of conductor (mm^2)	*Maximum current rating (A)*	*Voltage drop in cable (mV/Am)*
1	15	44
1.5	19.5	29
2.5	27	18
4	36	11
6	46	7.3
10	63	4.4
16	85	2.8

Standard applications	Cable specification (mm^2 c.s.a.)
Lighting	1 or 1·5
Immersion heater	1·5 or 2·5
Sockets (ring)	2·5
Sockets (radial)	2·5 or 4
Cooker	6 or 10
Shower	4, 6 or 10

EXAMPLE 13.6

Find the maximum lengths of 1, 1.5 and 2.5 mm^2 copper cable which can be used on a 240 V circuit to a 3 kW immersion heater.

$$\text{current} = \frac{3000\text{ W}}{240\text{ V}} = 12.5\text{ A}$$

$$\text{allowed voltage drop} = \frac{4}{100} \times 240 = 9.6\text{ V}$$

$$\text{maximum length or run} = \frac{\text{maximum voltage drop allowed mV}}{\text{load current A} \times \text{voltage drop mV/A m}}$$

For 1 mm^2 cable:

$$l = \frac{9.6 \times 10^3}{12.5 \times 44}\text{ m} = 17.5\text{ m}$$

For 1.5 mm^2 cable:

$$l = \frac{9.6 \times 10^3}{12.5 \times 29}\text{ m} = 26.5\text{ m}$$

For 2.5 mm^2 cable:

$$l = \frac{9.6 \times 10^3}{12.8 \times 18}\text{ m} = 42.7\text{ m}$$

E.g. a 7.2kW shower with a clipped cable length of 10m:

Amps = Watts ÷ Volts = 7200 ÷ 230 = 31·3

From table, select 4mm² c.s.a. (36 amps)

Voltage drop = (mV × Current flowing × Cable length) ÷ 1000
= (11 × 31.3 × 10) ÷ 1000 = 3.44 volts

Maximum voltage drop = 230 × 4% = 9.2 volts.

Diversity

- Diversity in electrical installations permits specification of cables and overload protection devices with regard to a sensible assessment of the maximum likely demand on a circuit. For instance, a ring circuit is protected by a 30 amp fuse or 32 amp mcb, although every socket is rated at 13 amps. Therefore if only three sockets were used at full rating, the fuse/mcb would be overloaded. In practice this does not occur, so some diversity can be incorporated into calculations.
- Guidance for diversity in domestic installations:

Circuit	Diversity factor
Lighting	66% of the total current demand.
Power sockets	100% of the largest circuit full load current + 40% of the remainder.
Cooker	10 amps + 30% full load + 5 amps if a socket outlet is provided.
Immersion heater	100%.
Shower	100% of highest rated + 100% of second highest + 25% of any remaining.
Storage radiators	100%.

Consumer Unit

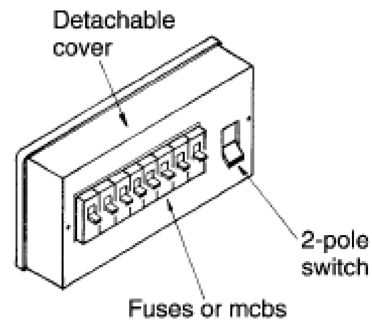
- Traditionally, Electrical installations required a separate fuse and isolator for each circuit. Modern practice is to rationalize this into one ` fuse box ', known as a consumer's power supply control unit or consumer unit.

- The consumer unit contains a two-pole switch isolator for the phase/line and neutral supply cables and three bars for the live line, neutral and earth terminals. The line bar is provided with several fuse ways or miniature circuit breakers, (up to 16 in number for domestic use) to protect individual circuits from overload. Each fuse or mcb is selected with a rating in accordance with its circuit function.
- Traditional fuses are rated at 5, 15, 20, 30 and 45 amps whilst the more modern mcbs are rated in accordance with BS EN 7671: Circuit breakers for over current protection for household and similar installations.

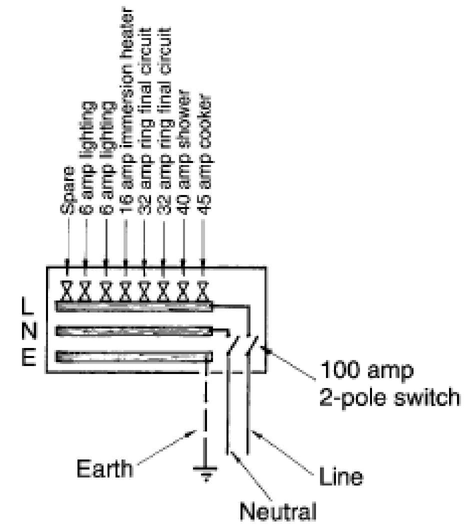
Circuit	Mcb rating (amps)
Lighting	6
Immersion heater	16 or 20*
Socket ring	32
Cooker	40 or 45*
Shower	40 or 45*

*Depends on the power rating of appliance. A suitable mcb can be calculated from: Amps = Watts ÷ Voltage.

E.g. A 3kW immersion heater: Amps = 3000 ÷ 230 = 13.
Therefore a 16 amp rated mcb is adequate.



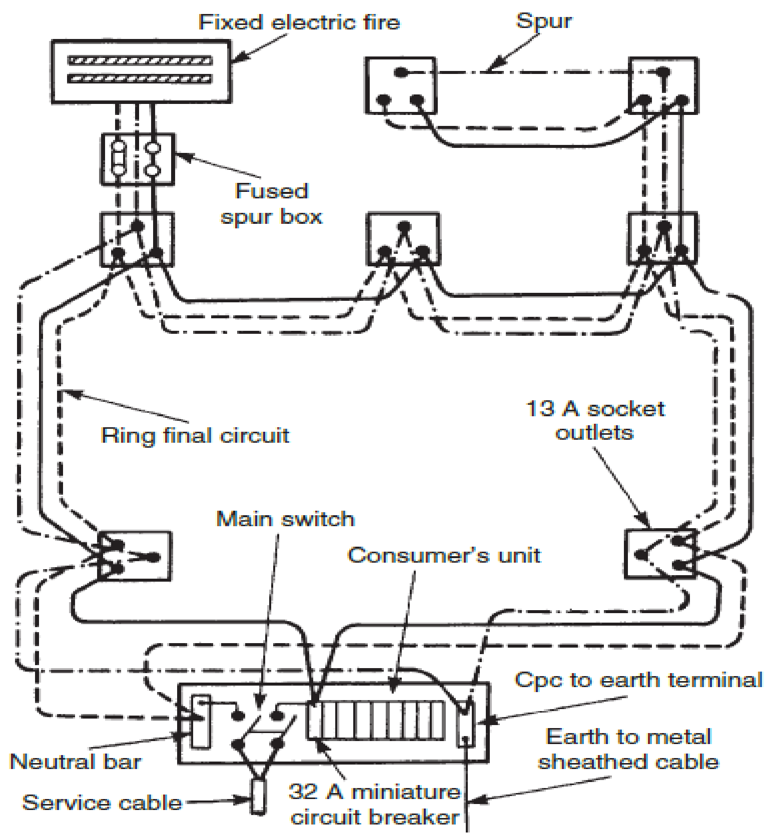
Eight-way consumer unit



Typical contents of consumer unit

Ring Final Circuit

- A ring final circuit is used for single-phase power supply to three-pin sockets.
- It consists of PVC sheathed cable containing a live line and neutral conductors in PVC insulation and an exposed circuit protective conductor to earth looped into each socket outlet.
- In a domestic building a ring final circuit may serve an unlimited number of sockets up to a maximum floor area of 100 m^2.
- A separate circuit is also provided solely for the kitchen, as this contains relatively high rated appliances.
- Plug connections to the ring have small cartridge fuses up to 13 amp rating to suit the appliance wired to the plug.
- The number of socket outlets from a spur should not exceed the number of socket outlets and fixed appliances on the ring.



Ring circuit

NOTE:

1. Fixed appliances such as fires, heating controls and low powered water heaters can be connected to a fused spur from a ring socket.
2. Appliances and installations with a load factor above 3 kW, e.g. immersion heater, cooker, extension to an outbuilding, etc. must not be connected to any part of a ring final circuit. These are supplied from a separate radial circuit from the consumer unit.
3. Power sockets should be positioned between 150 mm and 250 mm above work surfaces and between 450 mm and 1200 mm above floor levels. An exception is in buildings designed for the elderly or infirm, where socket heights should be between 750 and 900 mm above the floor.
4. Every socket terminal should be fitted with a double outlet to reduce the need for adaptors.

Maximum appliance load (watts) and plug cartridge fuse (BS 7671) selection for 230 volt supply:

Maximum load (W)	Plug fuse rating (amp)
230	1
460	2
690	3
1150	5
1610	7
2300	10
2900	13

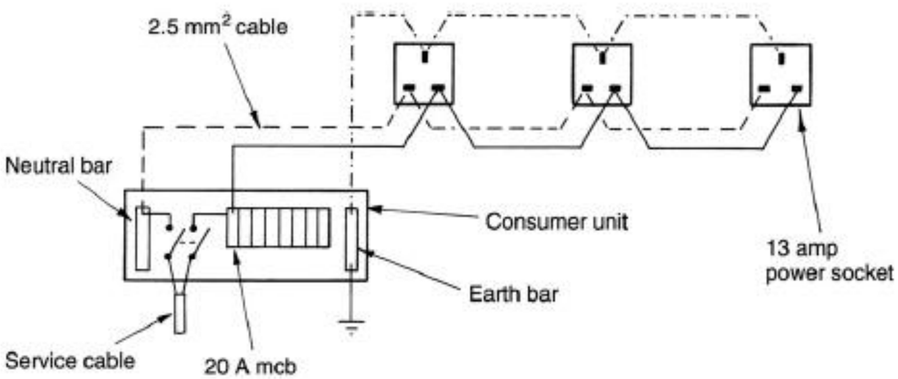
Radial Circuit

A radial circuit may be used as an alternative to a ring final circuit to supply any number of power sockets, provided the following limitations are effected:

Cable c.s.a. (mm^2)	Minimum overload protection (amps)	Remarks
2.5	20	Max. 20 m^2 floor area, 17 m cable
4.0	30	Max. 50 m^2 floor area, 21 m cable

With 2.5 mm^2 cable length limitation of 17 m over 20 m^2 floor area for a radial supply to sockets, a ring main with a maximum cable length of 54 m over 100 m 2 will usually prove to be more effective. Therefore radial circuits are more suited to the following:

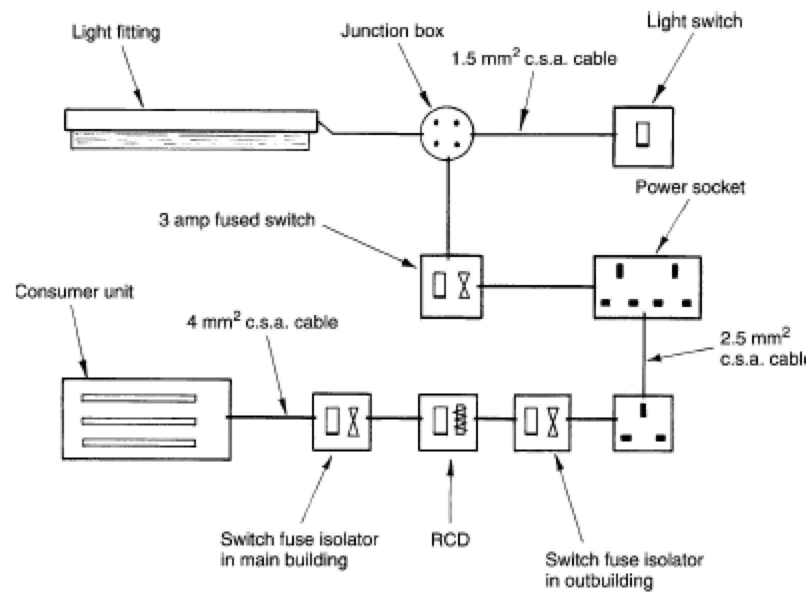
Application	Cable c.s.a. (mm²)	Minimum overload protection (amps)	Remarks
Lighting	1.5	5	Max. 10 light fittings
Immersion heater	2.5	15	Butyl rubber flex from 2-pole control switch
Cooker	6 10	30 45	Cable and fuse ratings to suit cooker rating
Shower	4, 6 or 10	30 to 45	See page 372
Storage radiator	2.5	20	See page 510
Outside extension	2.5	20	Nominal light and power
	4	30	Max. five sockets and 3 amp light circuit



Radial circuit to power sockets

Radial Extension to an Outbuilding

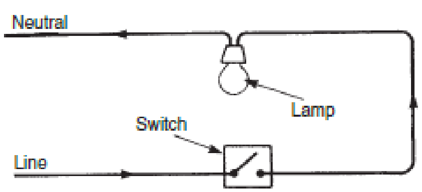
- An electricity supply to an outside building may be by overhead cable at a height not less than 3.5 m; supported in a conduit or from a catenary suspension wire.
- An underground supply is less obtrusive and should be at least 500 mm below the surface. The underground cable should be armoured PVC sheathed or copper sheathed mineral insulated (MICC). Standard PVC insulated cable may be used, provided it is enclosed in a protective conduit. Fused isolators are required in the supply building and the outside building, and a residual current device (RCD) ` trip switch' should also be installed after the fused switch control from the consumer unit.
- 2.5 mm² c.s.a. cable is adequate for limited installations containing no more than a power socket and lighting. In excess of this, a 4 mm 2 c.s.a. cable is preferred particularly if the outbuilding is some distance to overcome the voltage drop.



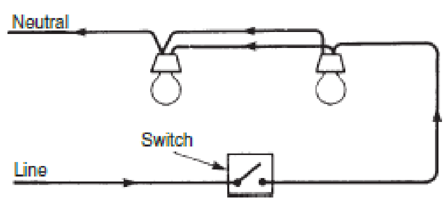
Schematic diagram of electricity supply to an outbuilding

Lighting Circuits – 1

- Lighting circuits can incorporate various switching arrangements.
- In a one-way switch circuit, the single-pole switch must be connected to the live line conductor.
- To ensure that both live line and neutral conductors are isolated from the supply, a double-pole switch may be used, although these are generally limited to installations in larger buildings where the number and type of light fittings demand a relatively high current flow.
- Provided the voltage drop (4% max.) is not exceeded, two or more lamps may be controlled by a one-way single-pole switch.
- In principle, the two-way switch is a single-pole changeover switch interconnected in pairs. Two switches provide control of one or more lamps from two positions, such as that found in stair/landing, bedroom and corridor situations.
- In large buildings, every access point should have its own lighting control switch. Any number of these may be incorporated into a two-way switch circuit. These additional controls are known as intermediate switches. (see illustration diagrams below).

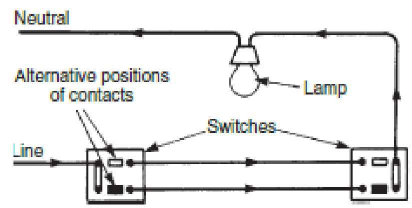


One-way single-pole switch circuit controlling one lamp.

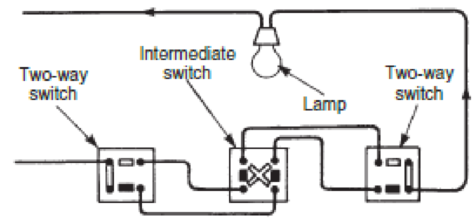


One-way single-pole switch circuit controlling two or more lamps

NOTE: *Earth connection also required between switch and lamp fitments, but omitted here for clarity*.



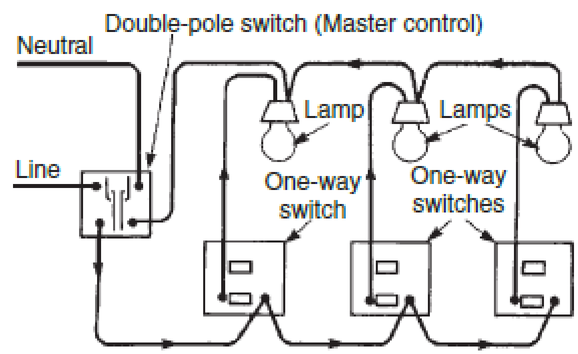
Two-way switching



Two-way switching with one intermediate switch

Lighting Circuits – 2

The purpose of a `master' switch is to limit or vary the scope of control afforded by other switches in the same circuit. If a `master' switch (possibly one with a detachable key option) is fixed near the main door of a house or flat, the householder is provided with a means of controlling all the lights from one position.

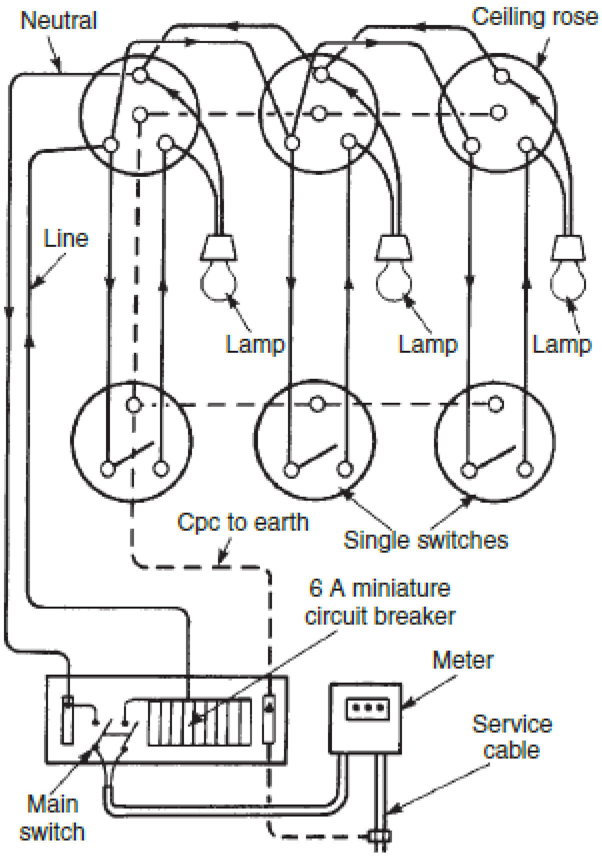


'Master' control wiring circuit

- A sub-circuit for lighting is generally limited to a total load of 10, 100 watt light fittings. It requires a 5 amp fuse or 6 amp mcb overload protection at the consumer unit. The importance of not exceeding these ratings can be seen from the simple relationship between current (amps), power (watts) and potential (voltage), i.e. Amps= Watts /Volts.
- To avoid overloading the fuse or mcb, the limit of 10 lamps @ 100 watts becomes:

Amps = (10 x 100) ÷ 230 = 4.3 i.e. 5 < amps fuse protection.

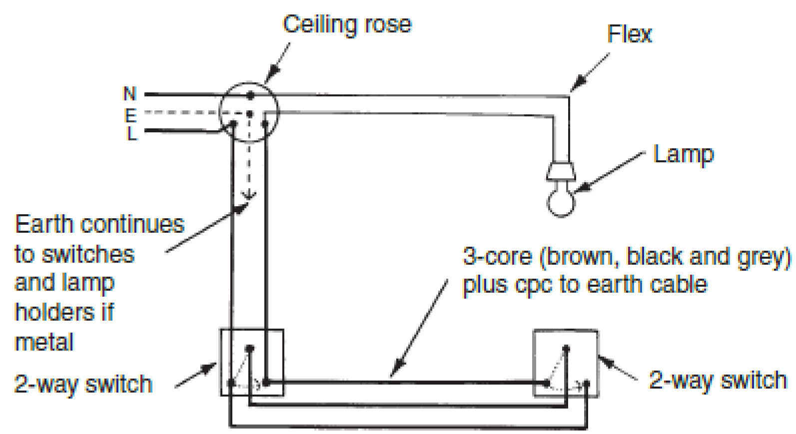
- In large buildings higher rated overload protection is often used due to the greater load.
- Wiring for lighting is usually undertaken using the `looping-in' system, although it is possible to use junction boxes instead of ceiling roses for connections to switches and light fittings.



Looping-in system of wiring

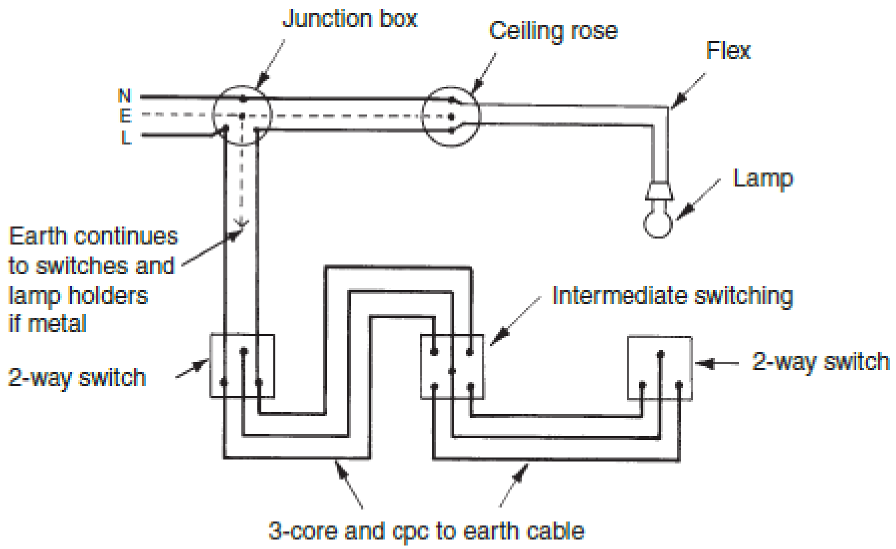
Two-way switching

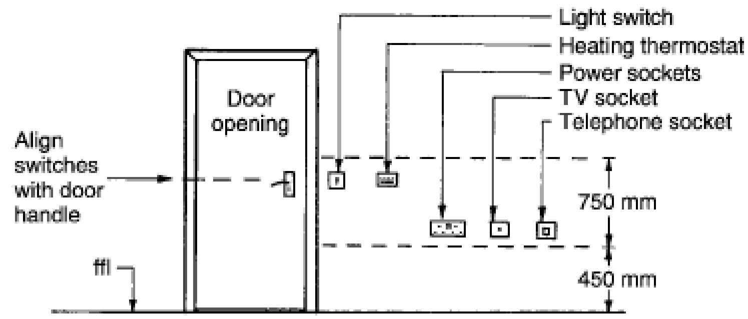
- Two-way switching is convenient for hall/landing lighting control and for bedroom door/bedside control.



Intermediate switching

- Intermediate switching has application to long corridors and multi-flight stairways.





Location of switches and sockets in a dwelling

Accessible Switches and Sockets

- The Building Regulations require reasonable provision for people, whether ambulant or confined to a wheelchair, to be able to use a building and its facilities. Facilities include wall-mounted switches and sockets located within easy reach, to be easily operated, visible and free of obstruction.
- Dwellings- switches and sockets between 450 and 1200 mm from finished floor level (ffl).

Non-domestic buildings: basic requirements for switches, outlets and controls:

- Conventional and familiar.
- Contrasting in colour to their surroundings.
- Large push pad preferred or extra wide rocker switches.
- Pictogram to clarify use and purpose where multiple switches occur.
- Separation or gap between individual switches where multiples exist.

Recommendations for location of wall-mounted switches and sockets in non-domestic buildings:

- Sockets for TV, power and telephone: 400 to 1000 mm above ffl and 350 mm from corners. Power socket switches to indicate whether they are `ON' .
- Switches to permanently wired appliances: 400 to 1200 mm above ffl.
- Controls requiring precise hand movement: 750 to 1200 mm above ffl.
- Push buttons, e.g. lift controls; 1200 mm above ffl.
- Pull cords for emergencies, coloured red and located close to a wall and to have 2, 50 mm diameter bangles set 100 mm and 800-900 mm above ffl.
- Controls that require close visual perception, e.g. thermostat, located 1200-1400 mm above ffl for convenience of people sitting or standing.

- Light switches for general use of the push pad type and located at 900-1100 mm height. Alternatively, a pull cord with 50 mm diameter bangle set at the same height. The pull cord should be distinguishable from any emergency pull.
- Main and circuit isolators to clearly indicate that they are ` ON' or `OFF'.
- Pattress or front plate to visually contrast with background.
- Operation of switches and controls to be from one hand, unless both hands are required for safety reasons.

Overload Protection

- Electrical installations must be protected from current overload, otherwise appliances, cables and people using the equipment could be damaged. Protection devices can be considered in three categories:

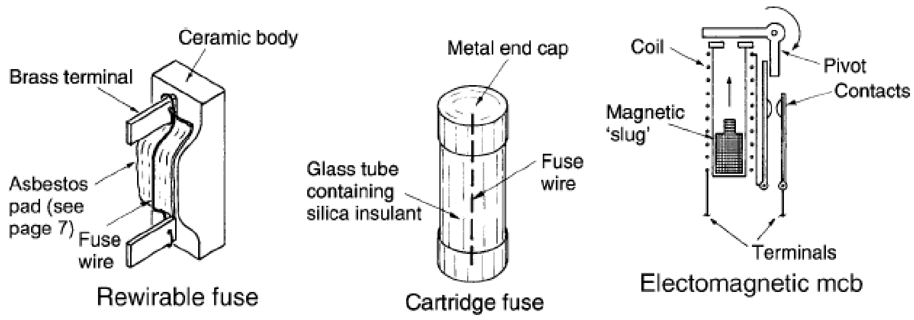
1. Semi-enclosed (rewirable) fuses.
2. High breaking or rupturing capacity (HBC or HRC) cartridge fuses.
3. Miniature circuit breakers (mcb).

- None of these devices necessarily operate instantly. Their efficiency depends on the degree of overload. Rewirable fuses can have a fusing factor of up to twice their current rating and cartridge fuses up to about 1. Times. Mcbs can carry some overload, but will be instantaneous (0.01 seconds) at very high currents.**Characteristics:**

Semi-enclosed rewirable fuse:	**Cartridge fuse:**
Inexpensive. Simple, i.e. no moving parts. Prone to abuse (wrong wire could be used). Age deterioration. Unreliable with temperature variations. Cannot be tested.	Compact. Fairly inexpensive, but cost more than rewirable. No moving parts. Not repairable. Could be abused.

Miniature circuit breaker:

- Relatively expensive.
- Factory tested.
- Instantaneous in high current flow.
- Unlikely to be misused.



Residual Current Device

Residual Current Devices (RCD) are required where a fault to earth may not produce sufficient current to operate an overload protection device (fuse or mcb), e.g. an overhead supply. If the impedance of the earth fault is too high to enable enough current to effect the overload protection, it is possible that current flowing to earth may generate enough heat to start a fire. Also, the metalwork affected may have a high potential relative to earth and if touched could produce a severe shock.

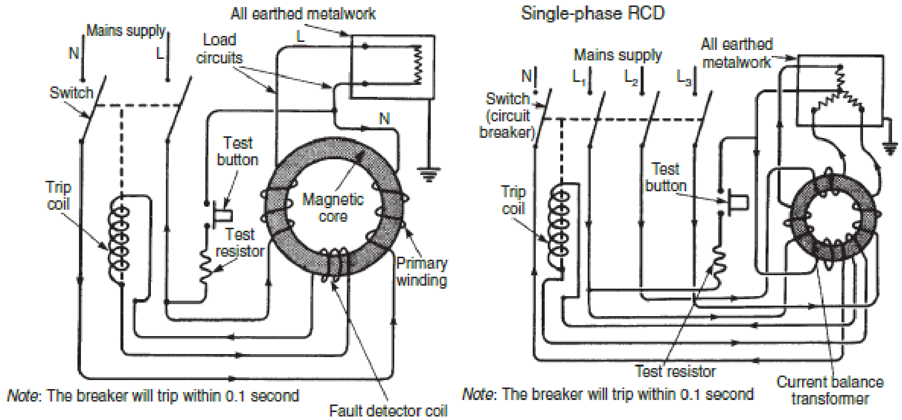
Operation of RCDs

An RCD has the load current supplied through two equal and opposing coils, wound on a common transformer core. When the line and neutral currents are balanced (as they should be in a normal circuit), they produce equal and opposing fluxes in the transformer or magnetic coil. This means that no electromotive force is generated in the fault detector coil. If an earth fault occurs, more current flows in the line coil than the neutral and an alternating magnetic flux is produced to induce an electromotive force in the fault detector coil. The current generated in this coil activates a circuit breaker. The test resistor provides extra current to effect the circuit breaker.

A three-phase device operates on the same principle as a single-phase RCD, but with three equal and opposing coils.

RCDs are used primarily in the following situations:

- Where the electricity supply company do not provide an earth terminal.
- In bedrooms containing a shower cubicle.
- For socket outlets supplying outdoor portable equipment.



Single-phase RCD

Three-phase RCD

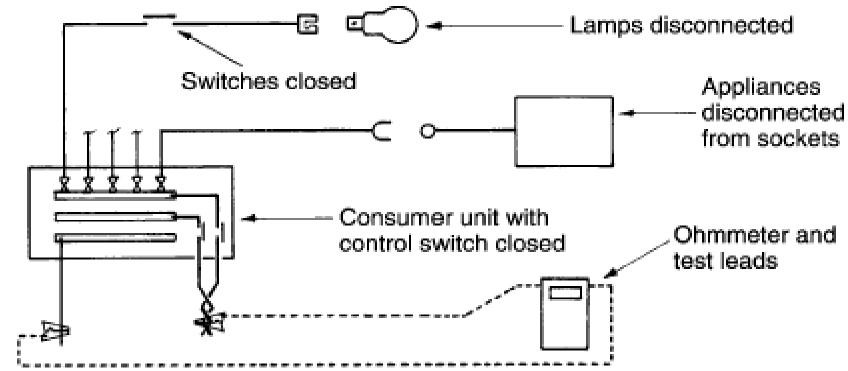
Testing Completed Installation

- ➢ Electrical installations must be tested on completion to verify that the system will operate efficiently and safely.
- ➢ The tests are extensive, as defined in the Institution of Electrical Engineers Regulations. They can only be carried out by a competent person, i.e. a qualified electrician or electrical engineer.
- ➢ Testing is undertaken by visual inspection and the use of a multipurpose meter (multimeter) or an instrument specifically for recording resistance, i.e. an ohmmeter.
- ➢ The following tests are an essential part of the proceedings:

1. Continuity.
2. Insulation.
3. Polarity.

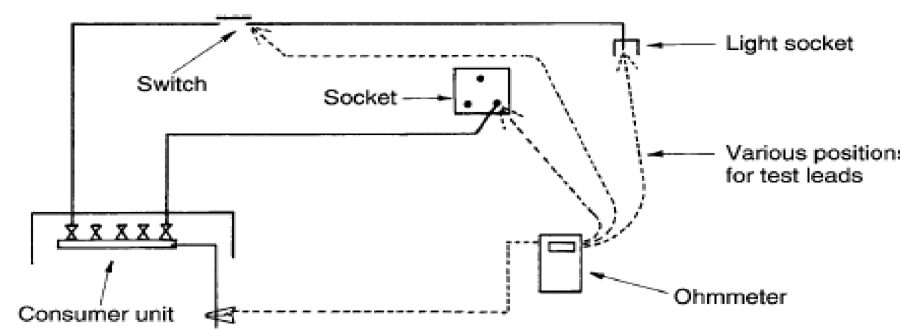
Continuity Test -there are several types of continuity test for ring final circuits. Each is to ensure integrity of the line, neutral and circuit protective (earth) conductors without bridging (shorting out) of connections. The following is one established test to be applied to each conductor:

Insulation Test- this test is to ensure that there is a high resistance between the live line and neutral conductors and these conductors and earth. A low resistance will result in current leakage and energy waste which could deteriorate the insulation and be a potential fire hazard. The test to earth requires all lamps and other equipment to be disconnected, all switches and circuit breakers closed and fuses left in. Ohmmeter readings should be at least 1 M Ω.



Insulation test

Polarity Test- this is to ensure that all switches and circuit breakers are connected in the phase or line conductor. An inadvertant connection of switchgear to a neutral conductor would lead to a very dangerous situation where apparent isolation of equipment would still leave it live! The test leads connect the line bar in the disconnected consumer unit to line terminals at switches. A very low resistance reading indicates the polarity is correct and operation of the switches will give a fluctuation on the ohmmeter.



Polarity test