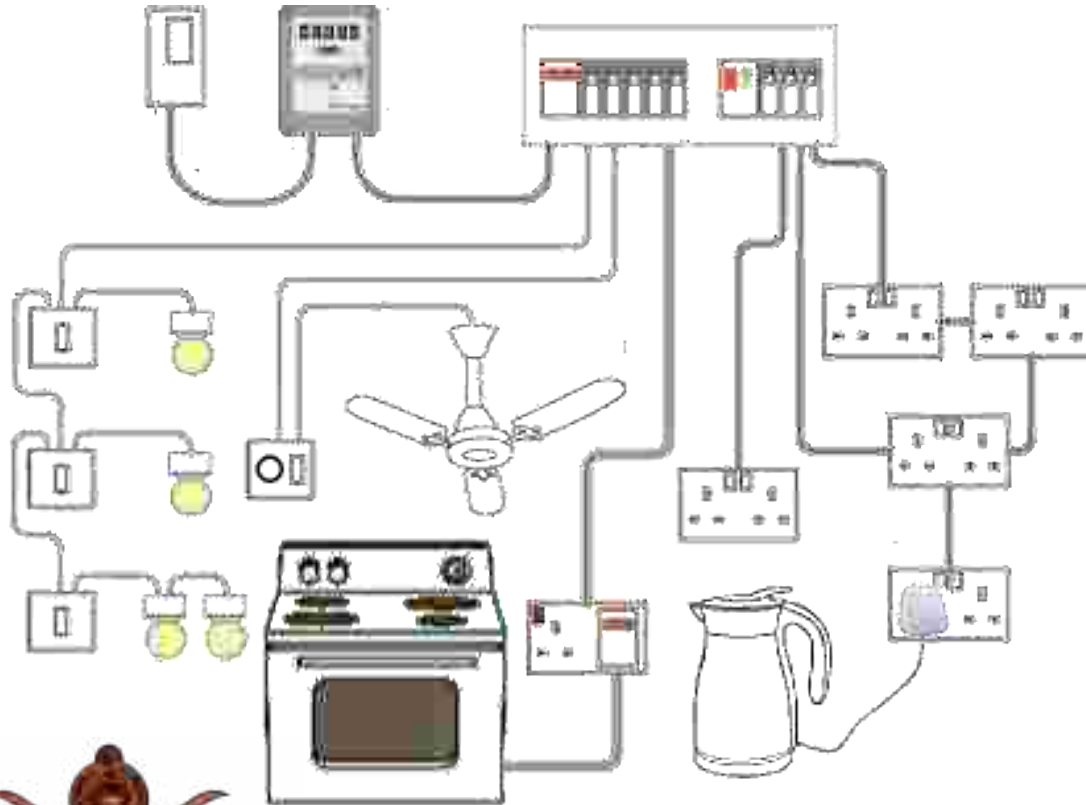




EE1102 – Fundamentals of Electrical Engineering

7.0 Electrical Installations

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Electrical Installations (4 hrs)

Learning Outcome:

Recognise the earthing systems used and be able to select the protection devices for a simple domestic electrical installation

Content:

- Domestic wiring systems
- Radial and Ring circuits
- Fuses and miniature circuit breakers
- Electrical safety, earthing and electric shock
- Earth leakage circuit breakers, residual current circuit breakers
- Wiring regulations
- Basic domestic installations





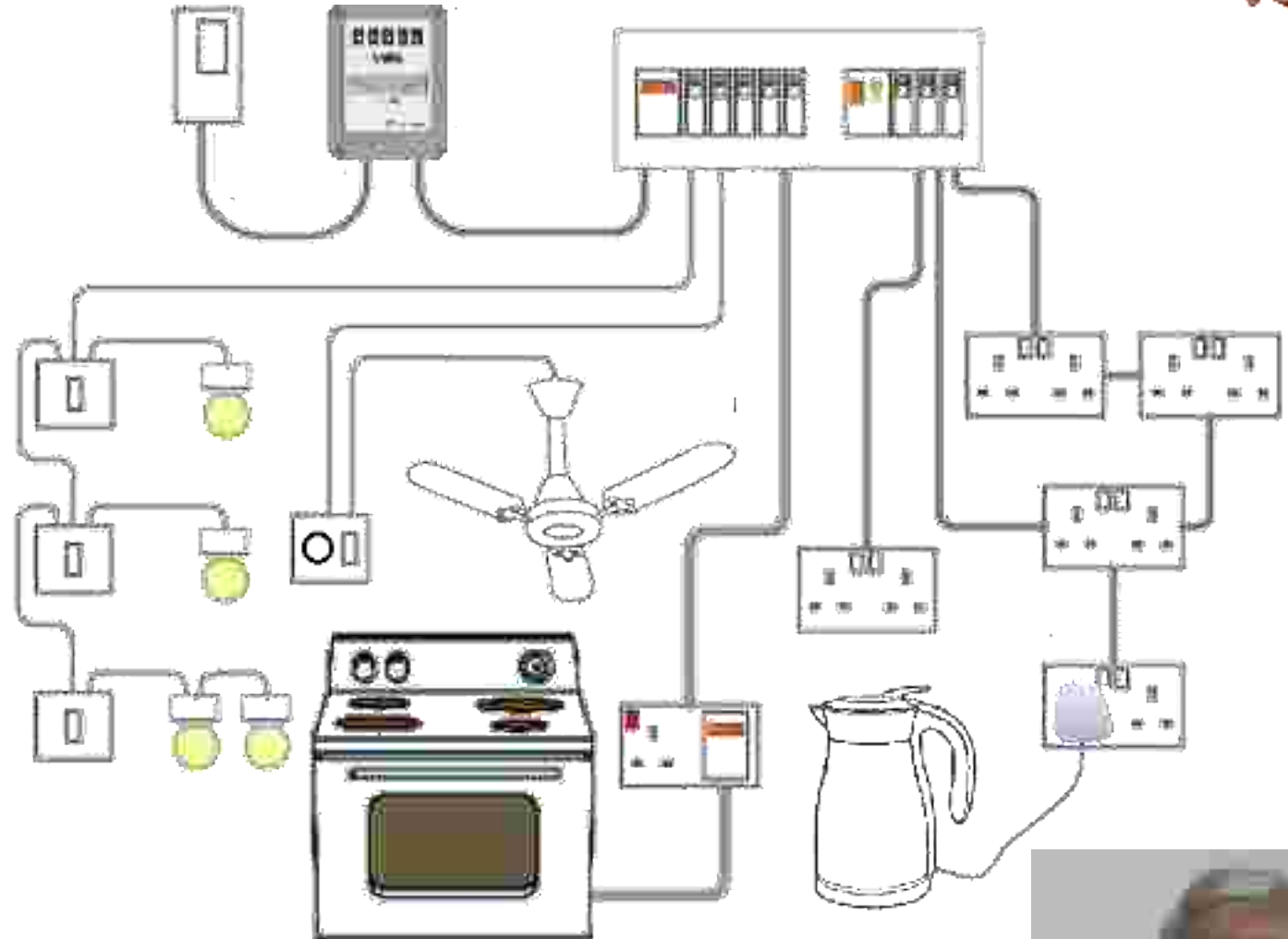
An Electrical Installation

A combination of electrical equipment installed

- to fulfill a specific purpose
- having coordinated characteristics.

Necessary to ensure the

- safety of personnel (including animals), and
- protection of equipment from electrical faults.





Faults in domestic systems

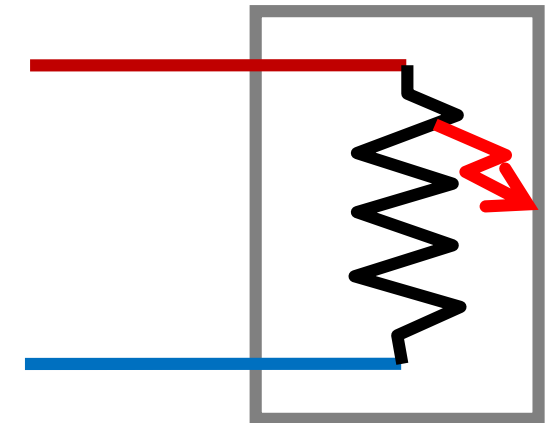
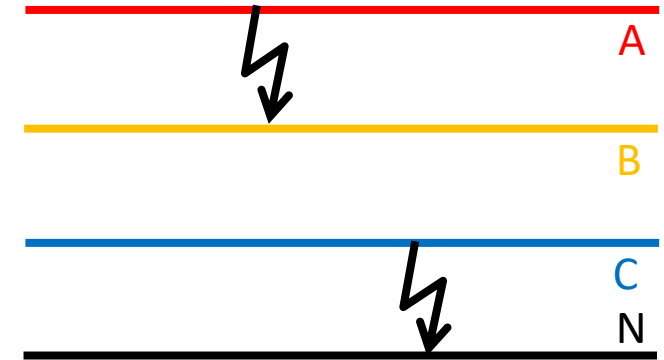
Most common types

➤ short circuit faults

- phase to neutral and line to line faults
- large currents will flow causing overheating
- damage may occur to wires, insulators, switches, etc.

➤ insulation failure faults

- fault between phase conductor and non-current carrying metallic parts
- high voltages may appear on frames of equipment
- may be dangerous to person coming in contact





Protective Devices

All electrical wiring systems and all associated electrical apparatus must be protected to:

- prevent damage by fire or electric shock
- maintain continuity of the supply
- disconnect faulty apparatus from remainder of system
- prevent damage to wiring and equipment
- minimize system interruptions under fault conditions

Protection must be provided against

- excess currents (MCB)
- earth leakage (RCD).



Miniature Circuit Breaker



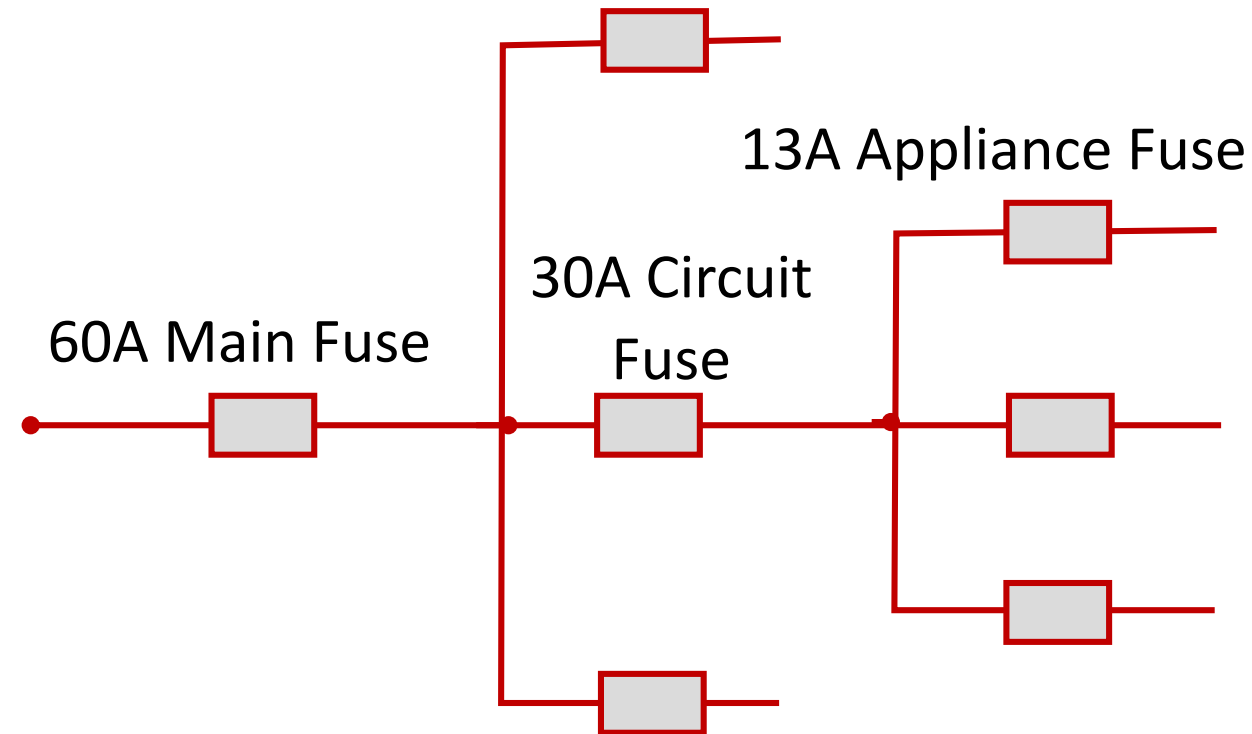
Residual Current Device





Features required of Protective equipment

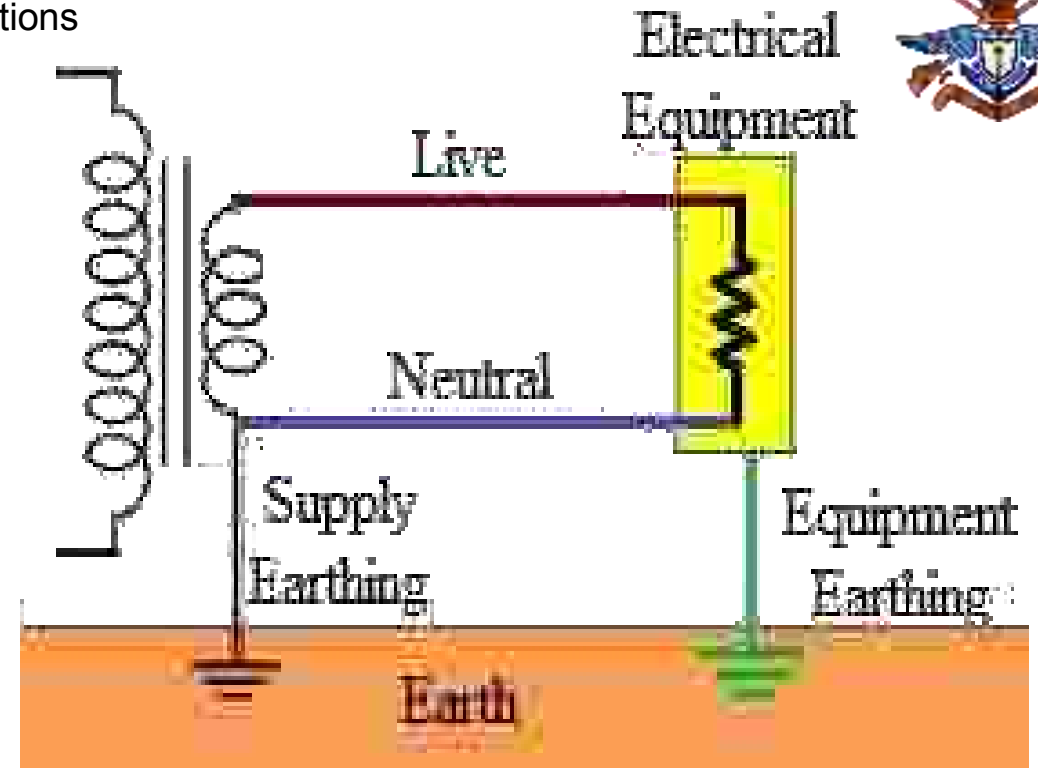
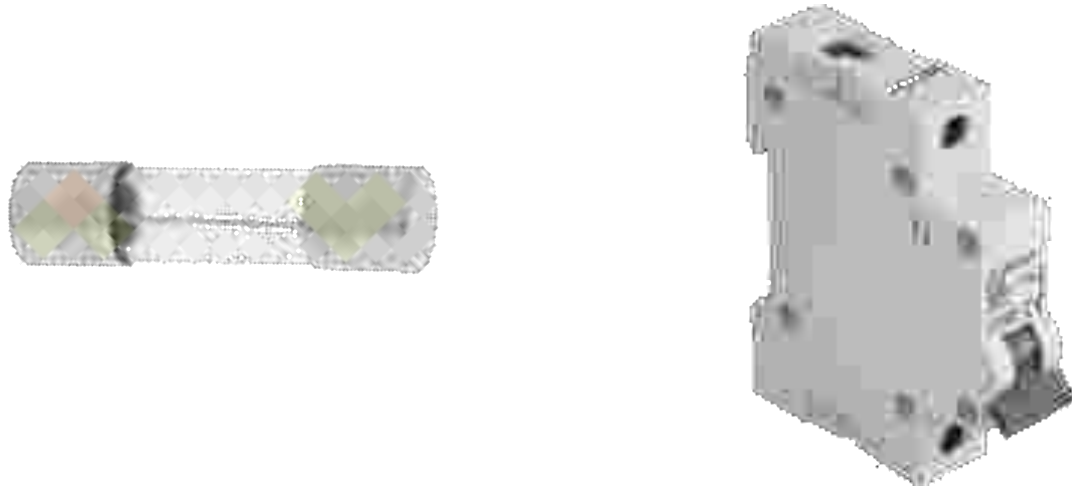
- Certainty and reliability
 - operation under fault conditions
 - non-operation normally
- Discrimination
- Rapidity of operation
- Simplicity
- Low initial and maintenance cost
- Ease of adjustment and testing.





Main methods of protection

- earthing or grounding of equipment



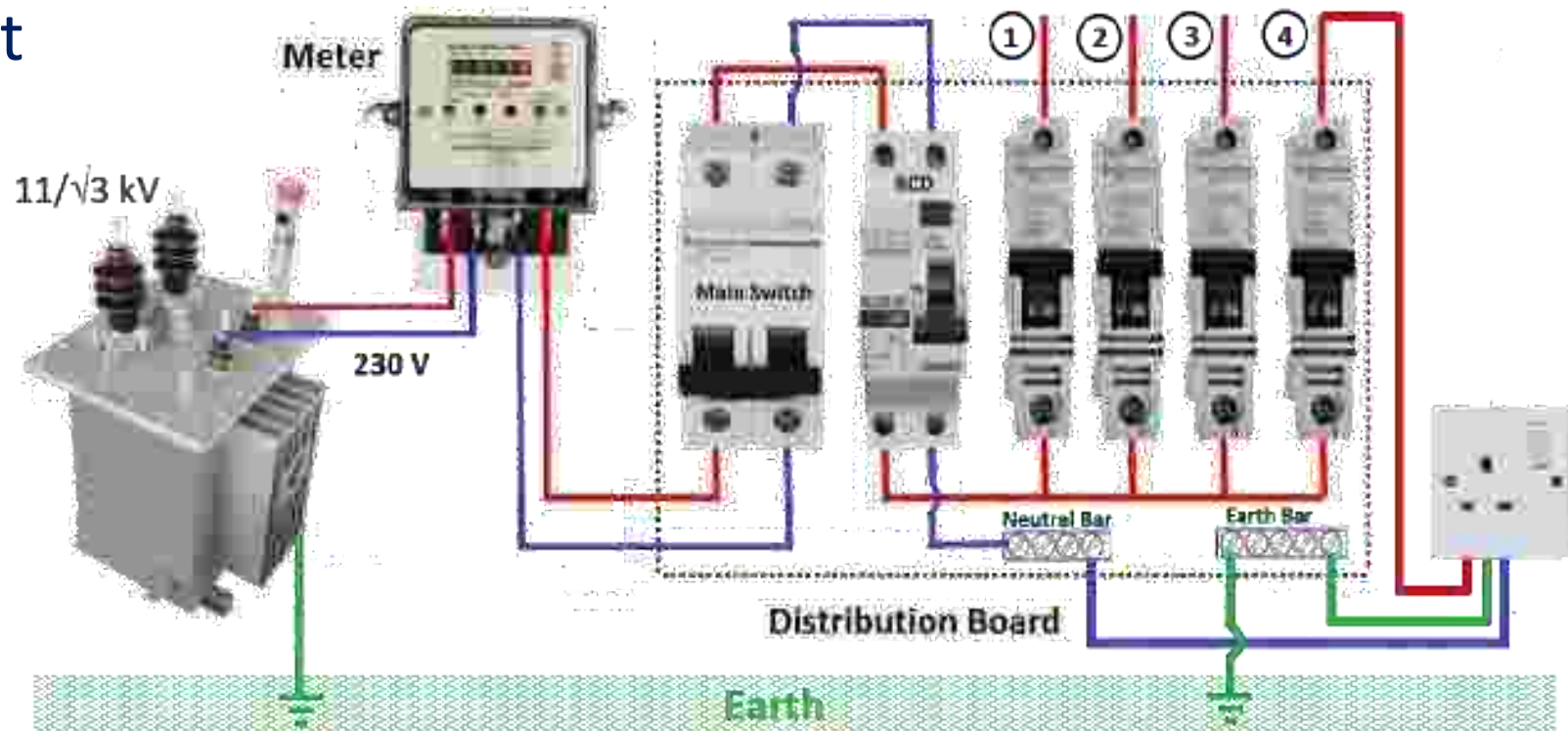
- use of fuses/circuit breakers (miniature circuit breaker – mcb)
- use of earth leakage and residual current devices.





Earthing

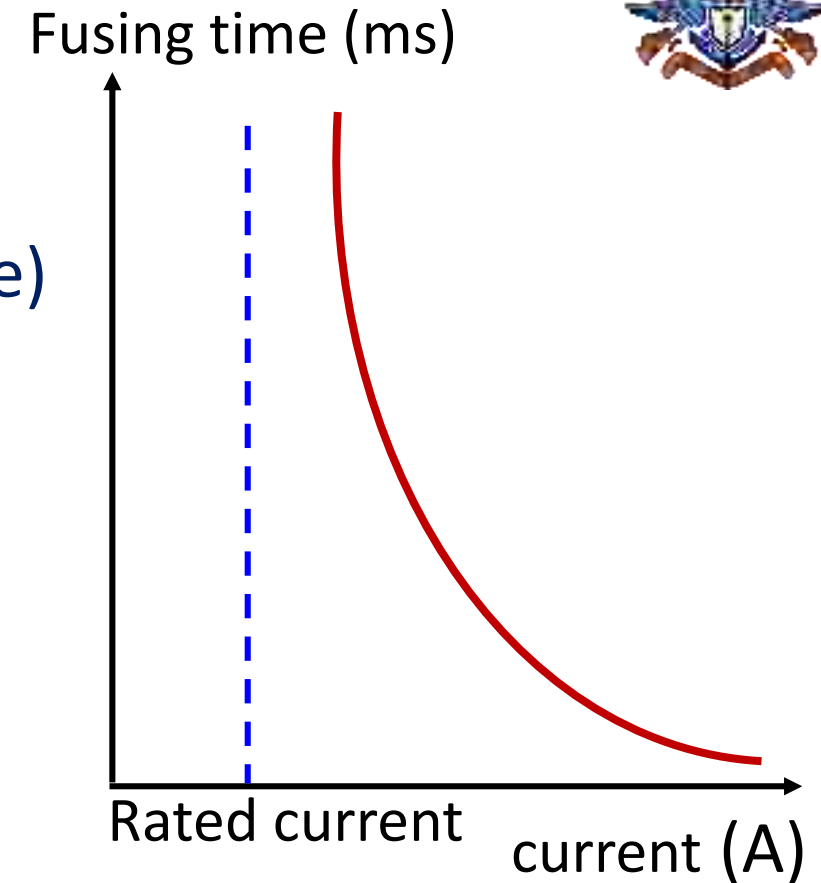
- Connection of non-current carrying conductive parts of electrical equipment to earth to maintain earth potential.
- Usually earthed by connecting to buried metallic pipes in ground.
- Effective earthing system
 - avoids having dangerous potentials on equipment even during electrical faults
 - ensures proper operation of electrical protection equipment during fault conditions.





Fuses

- Earliest means of protection against over-currents
- Short length of suitable material (often a thin wire)
 - When current flow exceeds fusing current
 - fuse will get hot and melt
- Interrupts over current before causing damage
- Wire size designed to carry rated current indefinitely

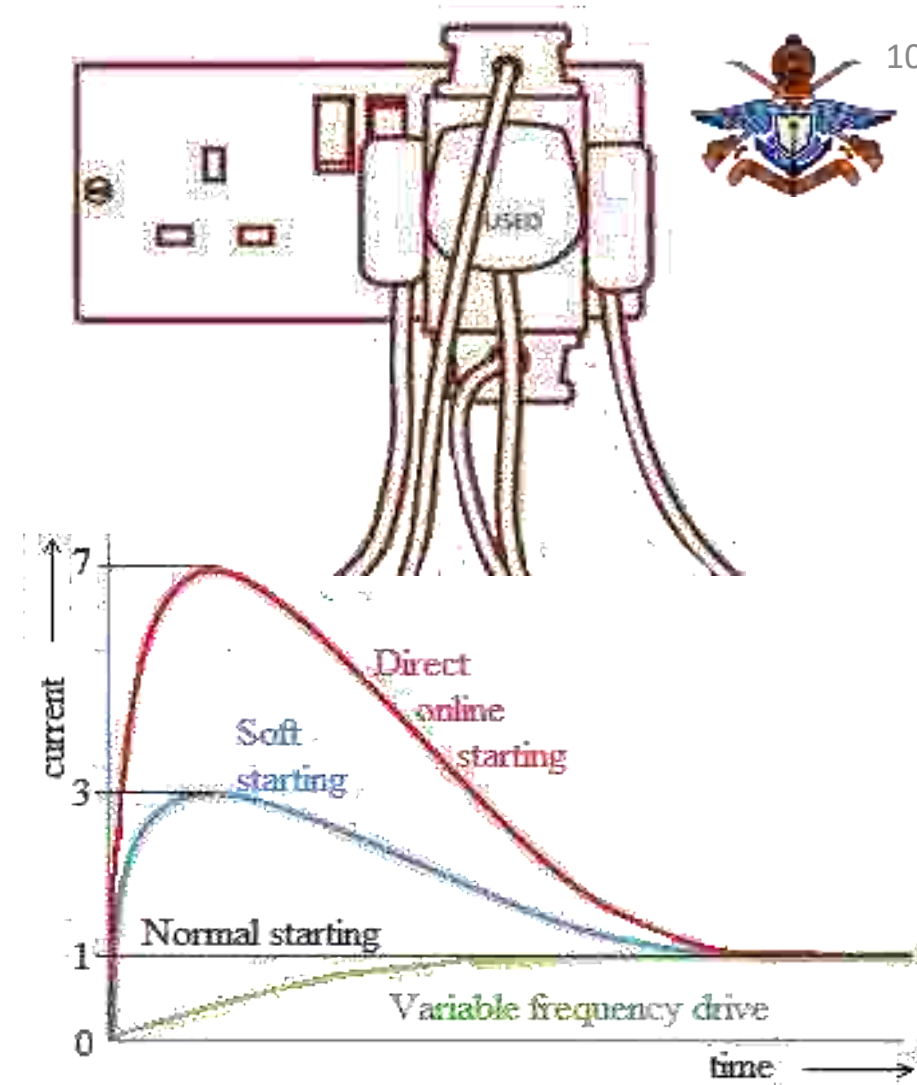


- Rewirable fuses fuse at 1.7 – 2 times rated current carrying capacity while cartridge fuses fuse at 1.25 to 1.75 times.
- Have inverse time characteristic
- Operation faster at faults as the current is larger



Fuses operate on Overcurrent

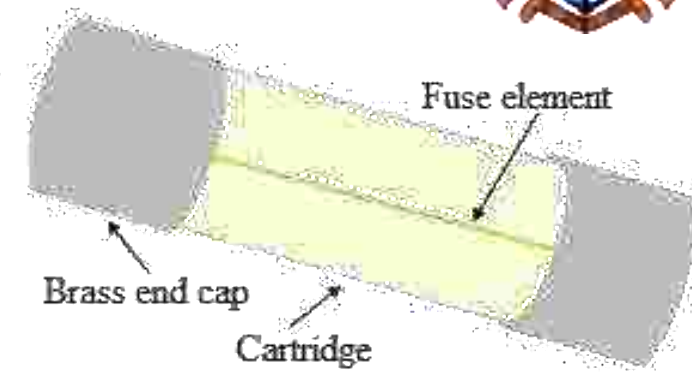
- In addition to operating for short circuits between live and neutral,
- fuses are expected to operate under over-load conditions.
- Over-loading occurs when extra power is taken.
- Increased currents will cause cables to heat up.
- Sustained over-loading will cause accelerated deterioration of cable insulation and its eventual breakdown to cause an insulation fault.
- A heavy-sudden over-load for a very short period (such as in motor starting) is not very serious since the over-load current flows for a short time and the rise in cable temperature is not very high.





Components of a Fuse

Fuse: Device for opening a circuit by means of a conductor designed to melt when an excessive current flows along it.



Fuse element: part of fuse designed to melt and thus open a circuit

Fuse link: part of fuse, comprising a fuse element and a cartridge (or other container) and capable of being attached to the fuse contacts

Current rating: Maximum current which the fuse will carry for an indefinite period without undue deterioration of the fuse element

Fusing current: Minimum current that will cause the fuse element to heat up, and melt or blow

Fusing factor: Ratio of the fusing current to current rating

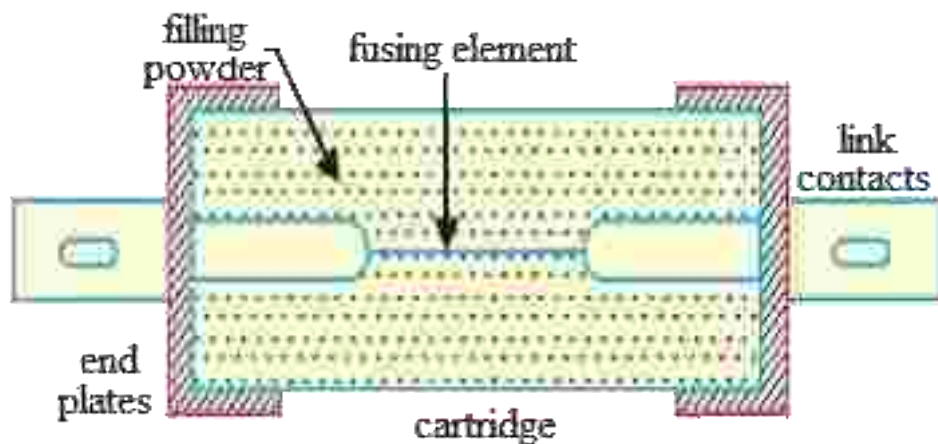
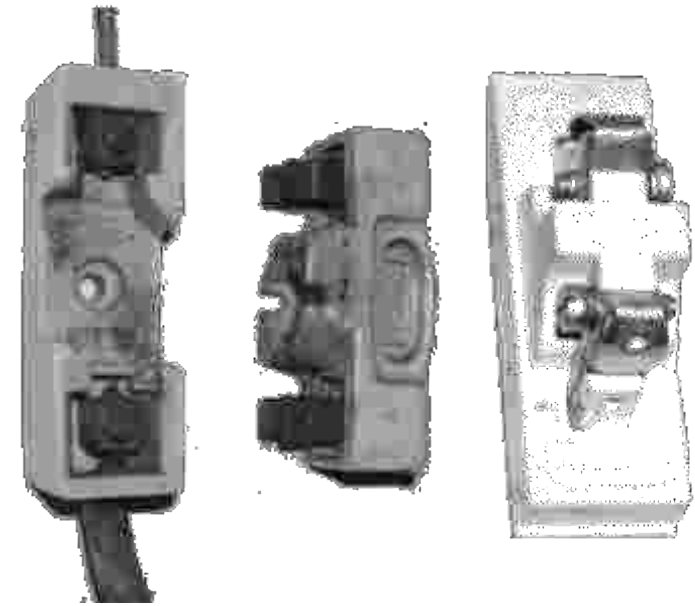


3 general types of fuses

➤ re-wirable (semi-enclosed) fuse

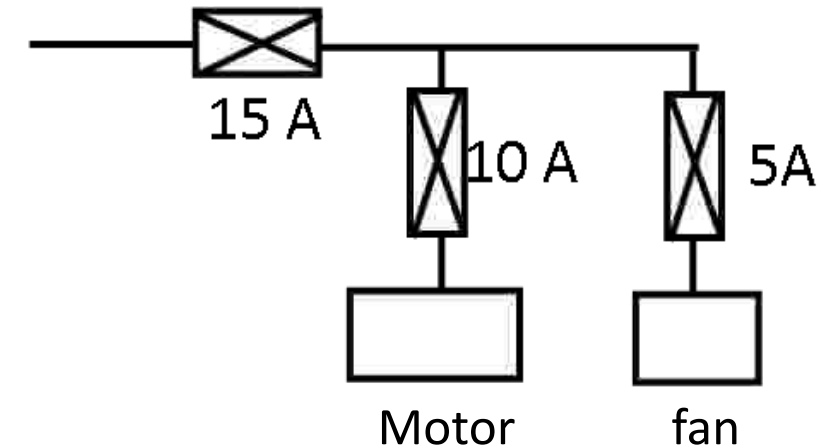
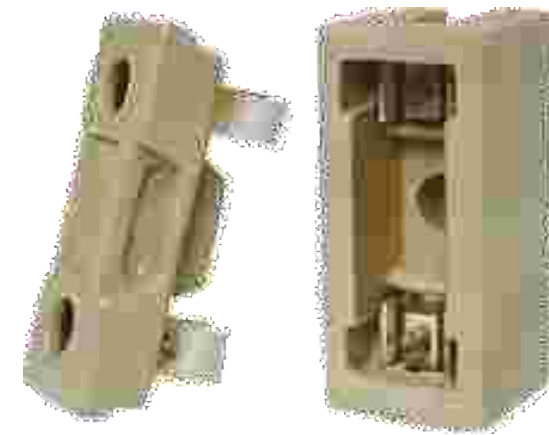
➤ cartridge fuse

➤ high-rupturing capacity (HRC) fuse



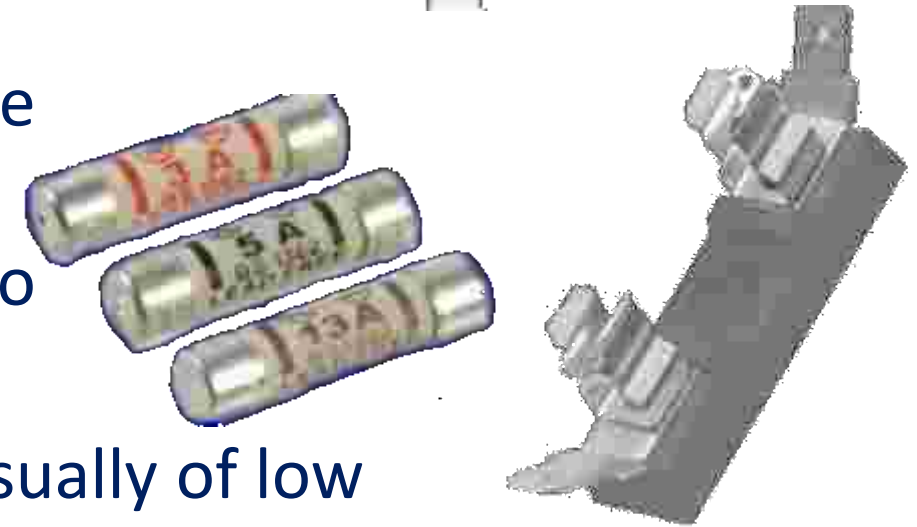
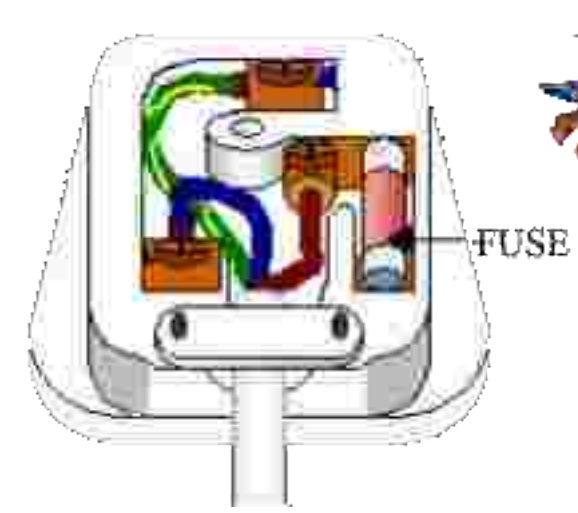
Semi-enclosed (re-wirable) fuse

- Short length of wire (generally tinned copper)
- Fusing current depends on cross sectional area
 - Affected by length of wire ($R = \rho l/A$)
- Although cheap, it has many limitations:
 - Deterioration with time due to oxidation
 - May operate at lower current due to deterioration
 - Very easy to replace blown element with incorrect size fuse
 - Time taken to blow may be long allowing considerable damage to occur
- Rating of re-wirable fuse can never be accurate
 - Unsuitable for circuits which require discrimination
 - 15A rated fuse may start melting before 10A element completes fusing
 - Not capable of discriminating between a transient high current (such as motor starting) and a continuous fault current.
- Has an associated fire risk
 - For particularly high fault current, even when fuse works, arc may be maintained through air and metallic vapour)
- Semi-enclosed or re-wirable fuses are now not recommended.



Fully enclosed (cartridge) fuse

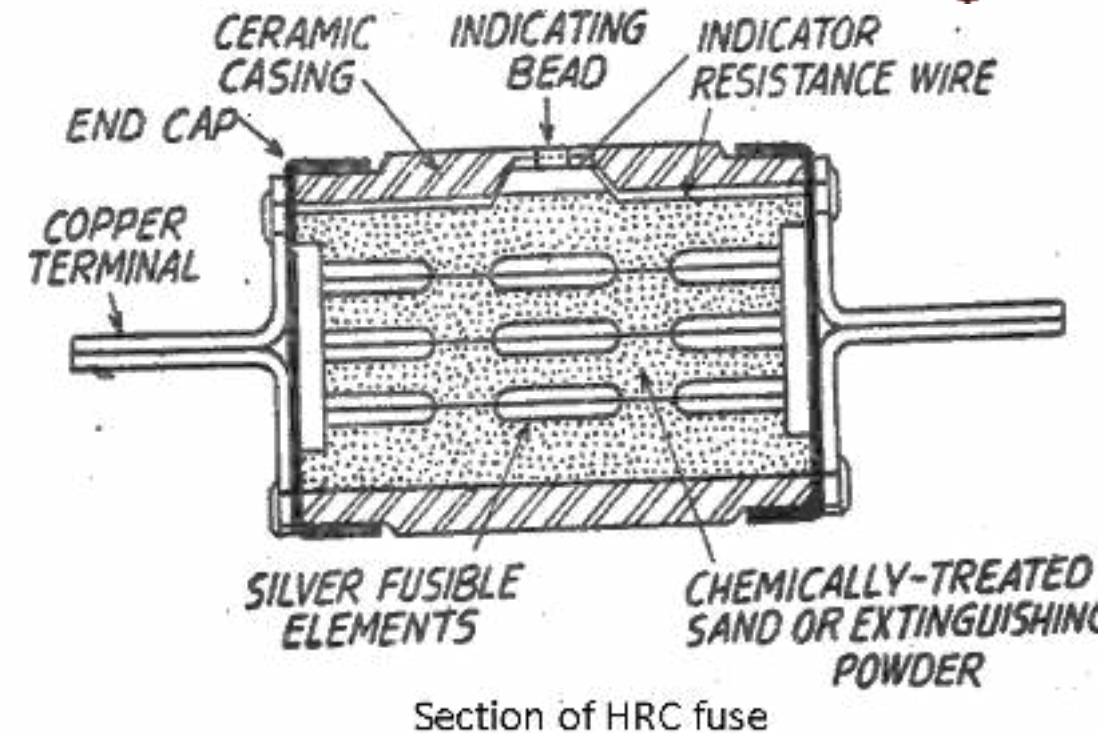
- Developed to overcome the disadvantages of the re-wirable type of fuse.
- In simplest form, fuse wire is enclosed in evacuated glass tube.
- Non-deterioration of fuse element is one of the most reliable features.
- However, cartridge fuses are more expensive to replace.
- Both re-wirable and cartridge type fuses are usually of low rupturing capacity (product of maximum current which fuse will interrupt, and supply voltage).
- Used in general house-hold, commercial and small scale industrial applications.





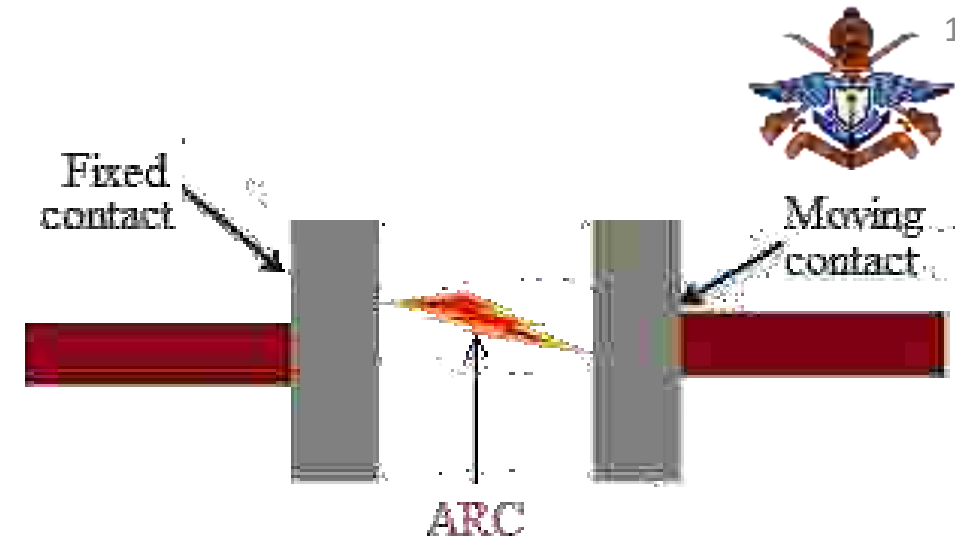
High rupturing capacity (HRC) fuses

- For high current applications
 - A high-grade ceramic barrel containing fuse element.
 - Barrel is filled with sand, which helps to quench resultant arc produced.
 - Able to withstand shock-conditions when interrupting high fault current.
- Fuse elements are in parts connected by bridges to have very precise melting point of 230°C .
 - With a specific current, temperature rises and bridge melts producing a break in the circuit.
 - Metal vapour diffuses with silica powder and product is of high resistance.
- HRC fuses are expensive to replace once blown.



Circuit breaker for over current protection

- Device for making and breaking a circuit
 - under normal and abnormal conditions
- Selected for a particular duty considering
 - normal current it will have to carry and
 - current fed by supply system into circuit under a fault (which circuit breaker will have to interrupt without damage)
- Able to provide a more accurate degree of over current protection than provided by either semi-enclosed or cartridge fuses.
- Has mechanism which in closed position, holds contacts together.
 - contacts are separated when release mechanism of the circuit breaker is operated by hand or automatically.





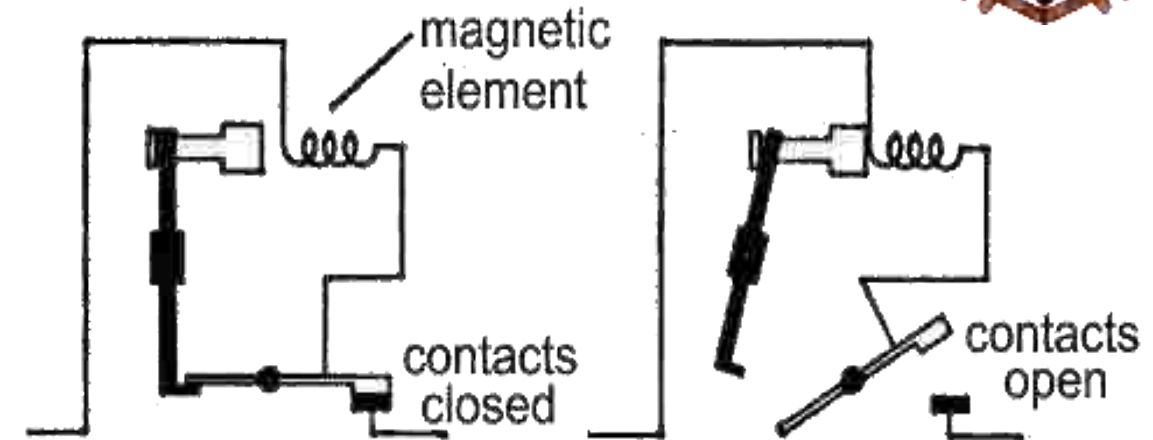
Miniature Circuit Breaker (mcb)

- Commonly used in domestic installations
 - Incorporates most features of circuit breaker in a compact form.
 - Fitted in place of fuses in consumer units in the home or office.
 - Eliminates necessity of fuse replacement.
 - May be used as a switch for isolating circuits.
- Automatic operation is by magnetic or thermal means.
 - Reason for two characteristics is to have proper operation during
 - short circuit conditions and
 - overload conditions.



Magnetic mechanism

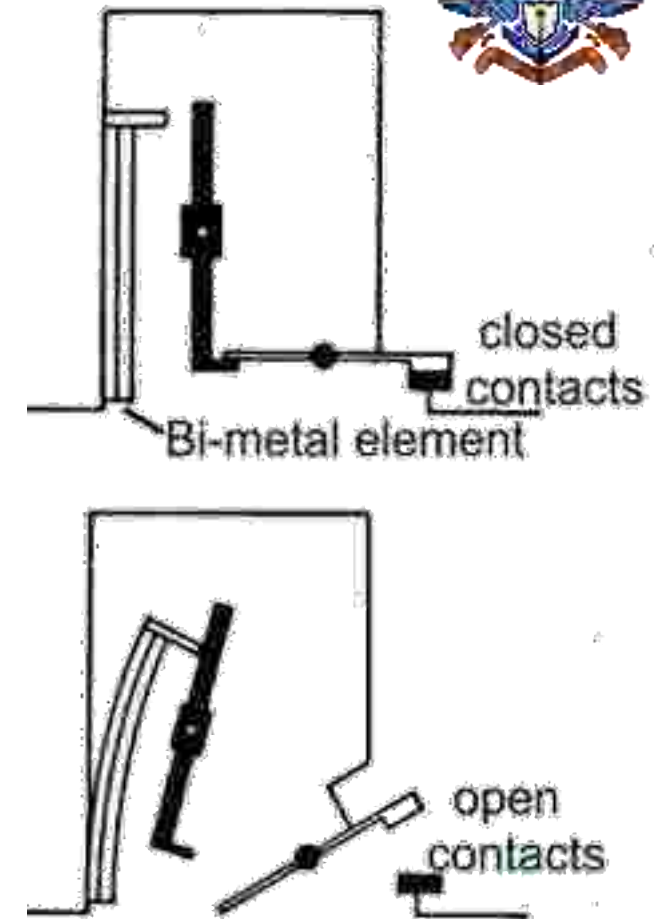
- For short circuit (fault) protection
 - Uses a solenoid
 - Has instantaneous operation
- High fault currents have to be isolated almost instantly.
 - when circuit current exceeds a certain level, magnetic field strength increases to cause the iron piece to move in the direction of solenoid.
 - operates tripping linkage to open contacts.
 - if mcb is closed again, contacts will not hold while fault is present.





Thermal mechanism

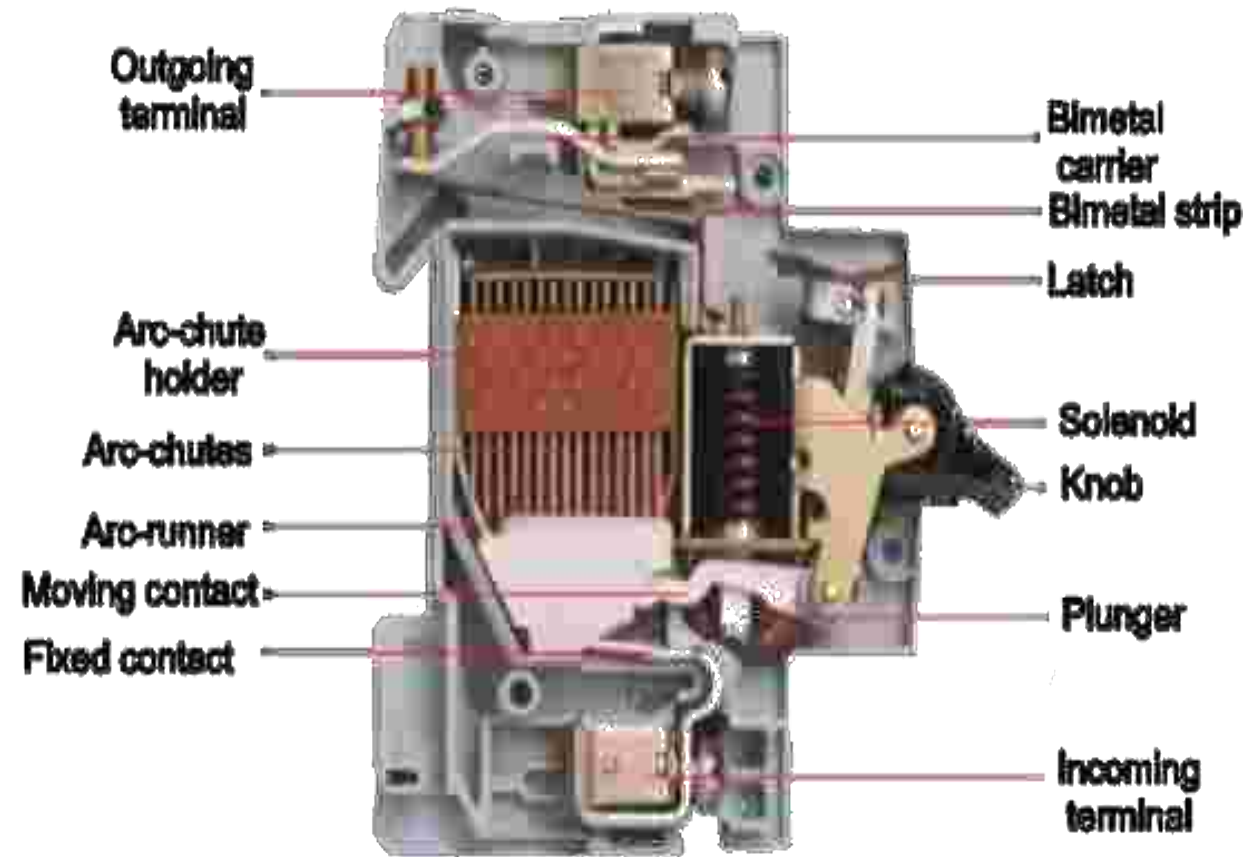
- uses heat sensitive bimetal element
 - at pre-determined temperature, resultant deflection trips circuit breaker.
 - heating depends on current magnitude and provides time delay required
- thermal tripping is not rapid as with magnetic tripping.
 - for small overload, thermal trip will take few seconds or minutes.
 - for a heavier over load, thermal trip disconnects circuit quicker.
- time delay characteristic avoids unwanted interruptions
 - during starting of motors and similar instances
 - With high initial current, but not an overload condition.





Advantages of the mcb

- Permits non-destructive determination of tripping characteristics
- Shorter tripping times under moderate over currents
- Immediate indication of faulty circuit
- Reclosing can be effected at once after fault has been cleared
 - No replacement stock required
- Can be easily used as a circuit control switch when needed





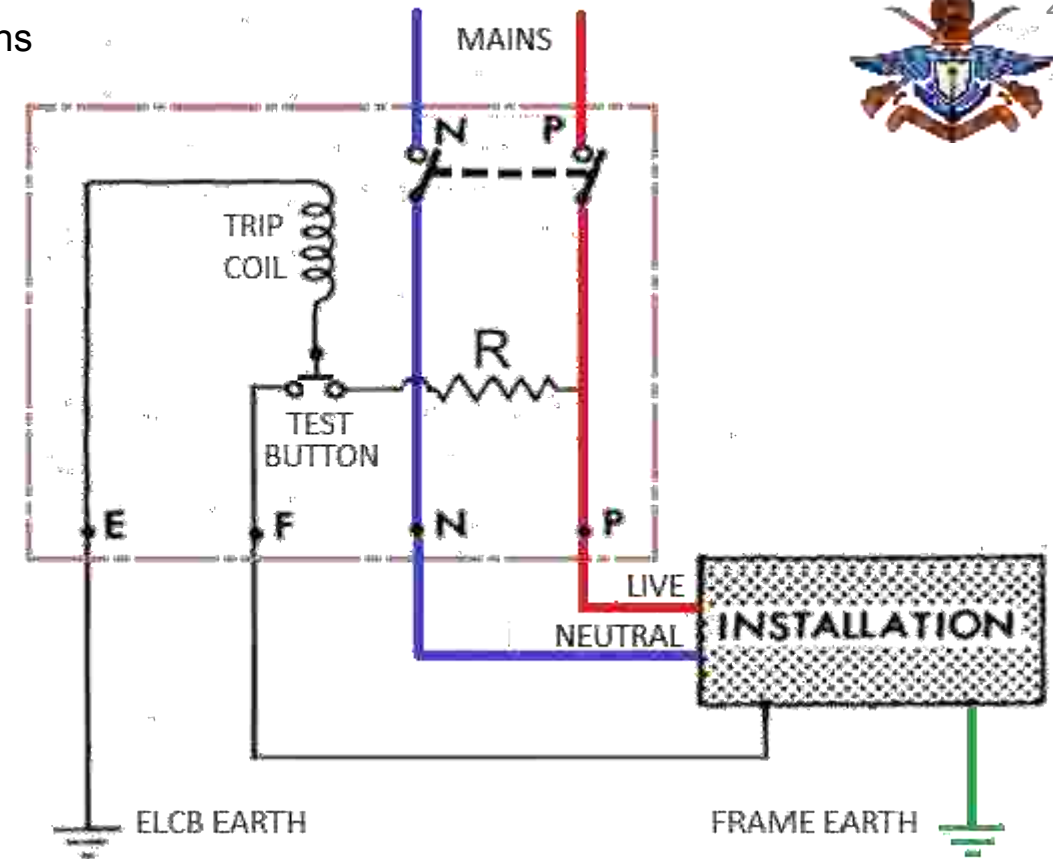
Circuit Breakers for earth leakage circuit protection

- Used to detect electrical faults to earth in equipment
 - Clears fault by tripping
- May be classified into two types:
 - Voltage operated : Earth Leakage Circuit Breaker (ELCB)
 - Current operated : Residual Current Device (RCD)
 - In both ELCB and RCD, a test switch is provided to create an artificial fault for test purposes.
- Commonly known as ***Trip Switch*** by electricians.



Earth Leakage Circuit Breaker (ELCB)

- For proper operation, two earth terminals required
 - frame earth to which all non-conducting metallic parts of equipment are connected,
 - and *ELCB* reference earth.
 - operates when voltage across coil (frame with respect to reference), exceeds 50V
 - 50V traditionally considered as maximum safe voltage
- However, what is important is the current that may pass through the human body rather than the voltage, and that too time dependent.
- *RCD* is now preferred to the *ELCB*.



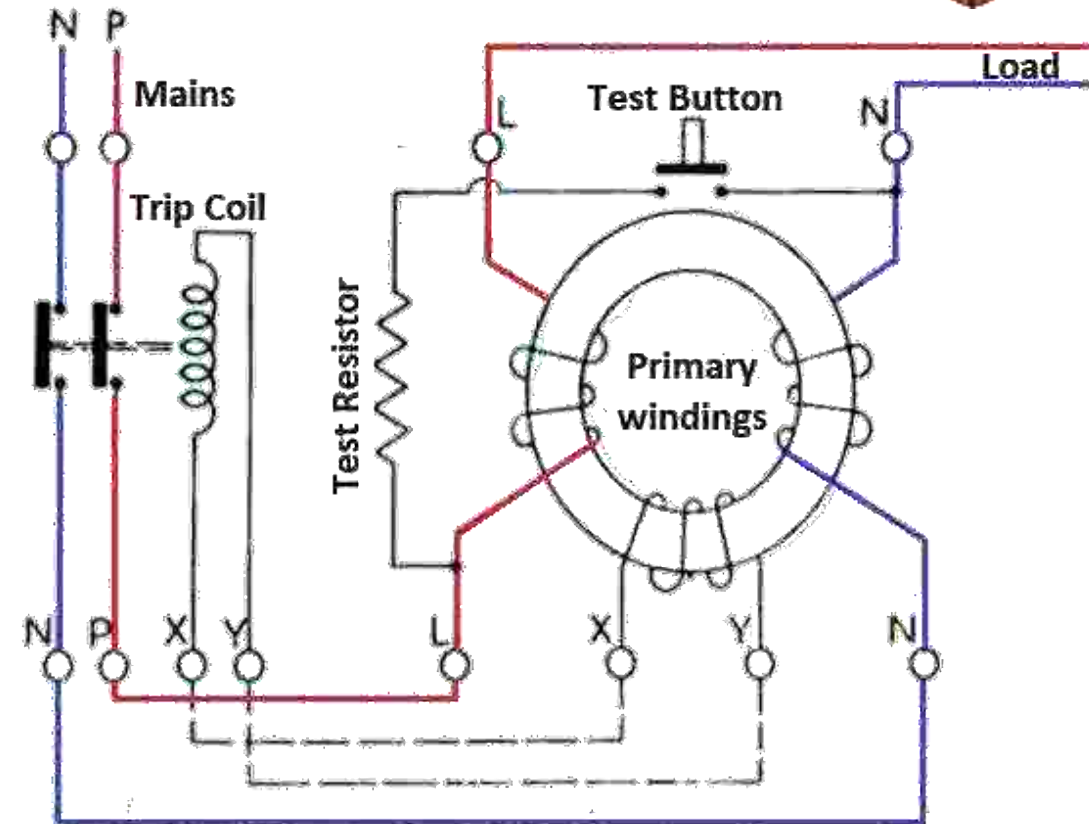


Residual Current Device (RCD)

- Operation based on a leakage, causing difference between line and neutral currents
- Difference used to energize solenoid.
 - normally, currents are equal and opposite
 - mmf balanced, no induced emf on detector
 - operating coil will not be energized.
- Under earth fault or other leakage conditions,
 - line and neutral currents will not be equal
 - trip coil energized by current in detector

Advantage of RCD

- If exposed live wire is touched and a current passes through, the RCD will detect it and operate, but not necessarily the ELCB.





Types of earthing arrangement

- TN - earthing of installation to that given by supply authority
- TT - supply authority earth and installation earth are independent
- IT - supply authority has isolated neutral and the installation has an independent earth

First letter denotes earthing arrangement at supply authority side.

T (short for terra) refers to a direct connection of one or more points of source to earth,

I (short for isolated) indicates that all live parts are isolated from earth

Second letter, denotes relationship of exposed conductive parts of installation to earth.

T denotes a direct electrical connection of exposed conductive parts of the consumers installation to earth, independent of earthing of any point of supply authority side,

N denotes a direct electrical connection of exposed conductive parts to earthed point of supply authority side, which is usually neutral point.

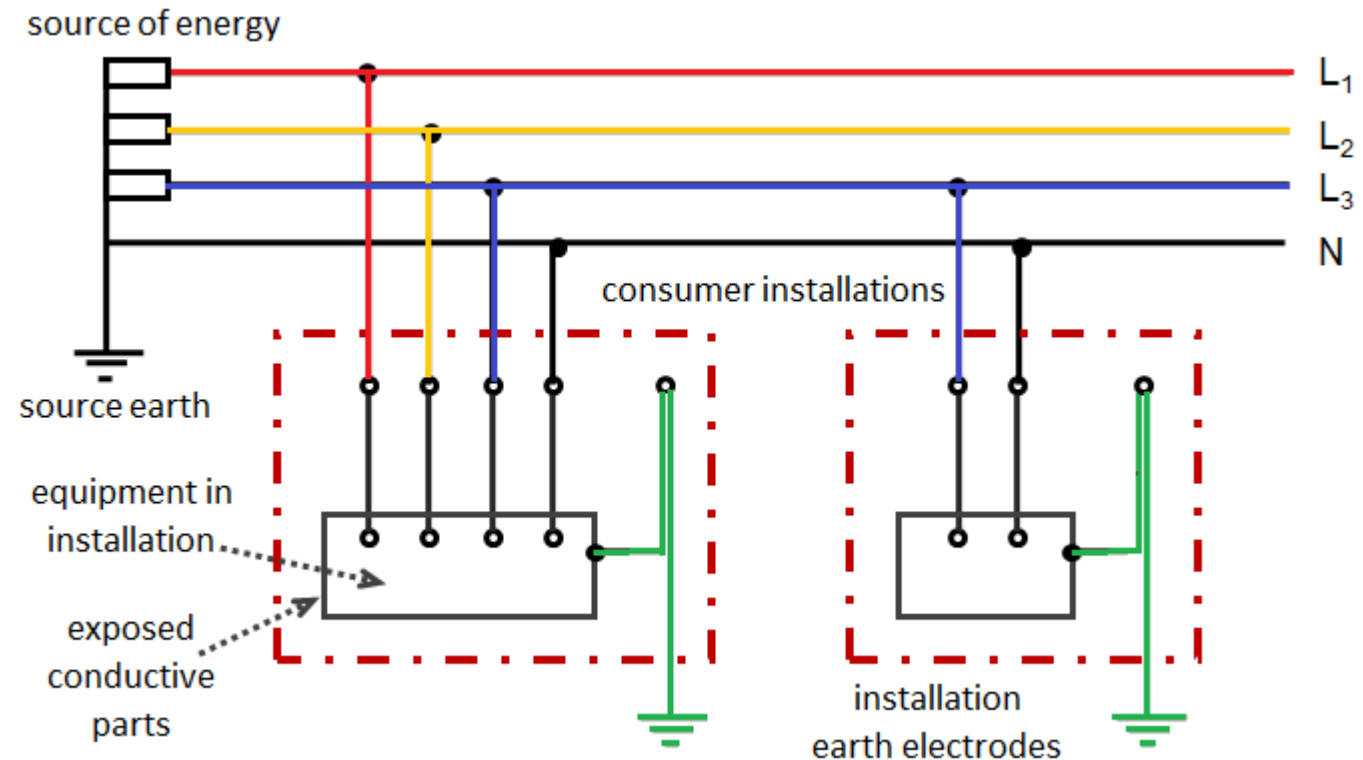
There are further sub-divisions of TN system, but are not considered here.





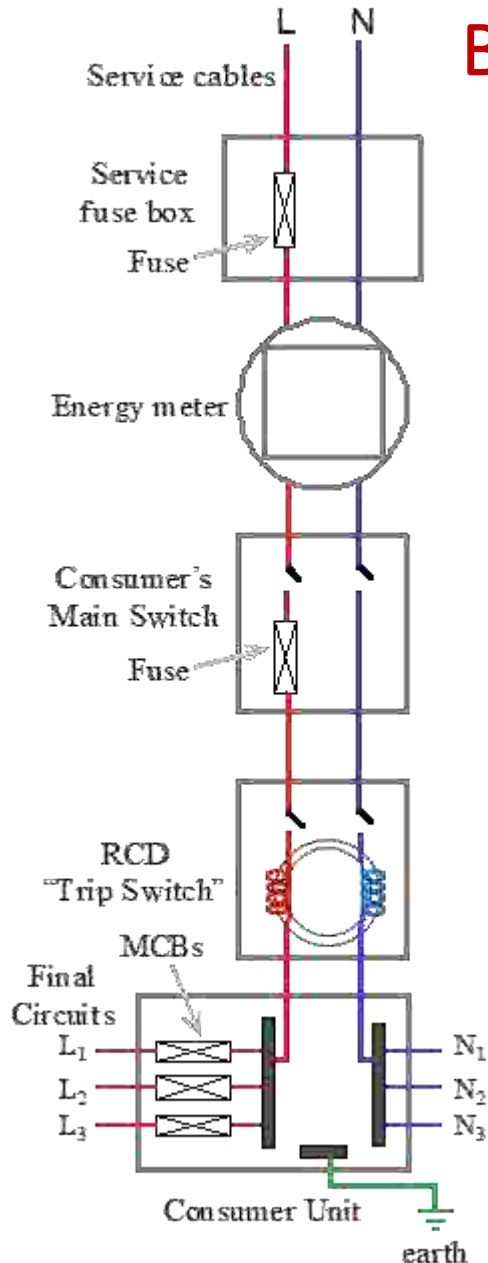
TT System

- System of Earthing generally used in Sri Lanka.
 - Supply is earthed at source end
 - all exposed-conductive parts are connected to electrically independent earth electrode at consumer end.
- Earth electrode resistance may be in excess of $100\ \Omega$.
- In TT earthing system, essential to use an RCD for protection.





Basic Domestic Installations in Sri Lanka



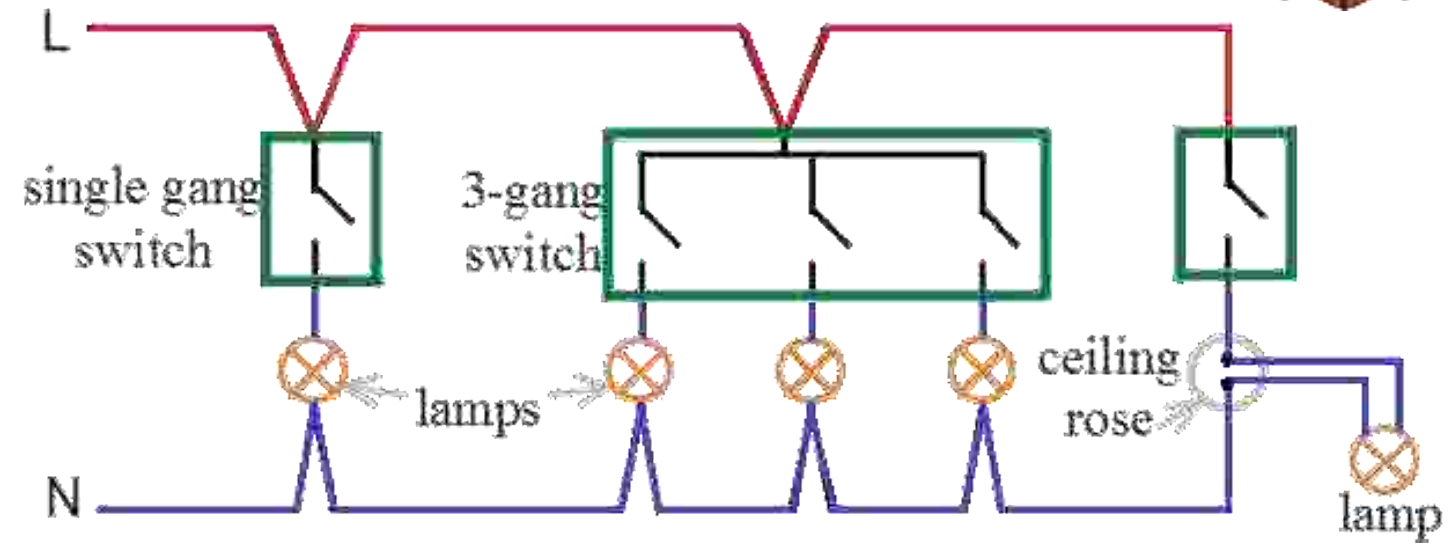
- 230V single phase supply (2 wire).
- **Service cable** from supply authority's distribution line
 - supplied from overhead distribution pole or underground cable
 - comes to **service fuse** box (or cut-out or service mcb)
 - then **energy meter**
- Up to Energy meter belongs to supply authority.
- Consumer installation starts from **Main switch**.
- Sri Lanka single phase supply limited to 30A.
- **Consumer Unit** (with **MCBs**) or in older installations a **Distribution Board** (with **fuses**) would follow RCD
- **Final circuits** taken from consumer unit (or distribution unit).





Loop-in Method of Wiring

Enables all terminations and joints in a single final circuit to be made at switches, ceiling roses, or other accessories.



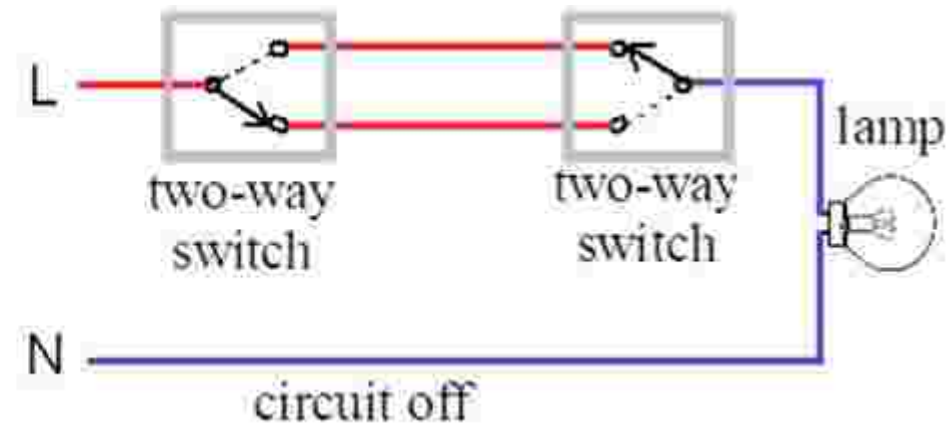
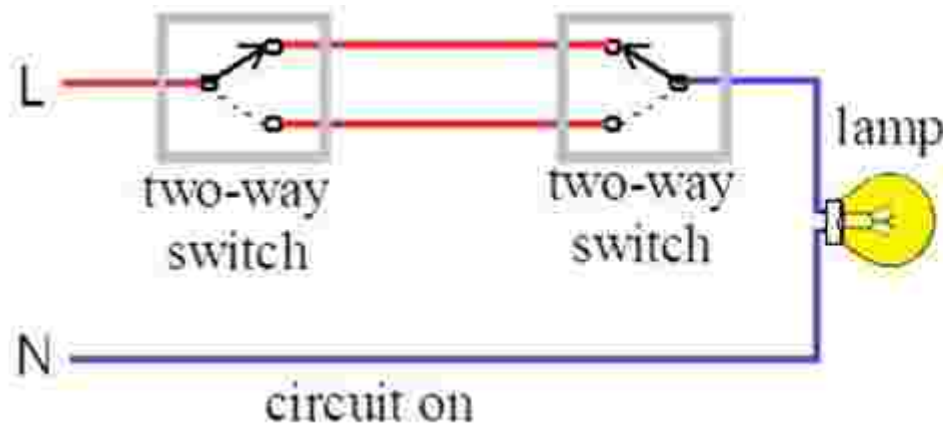
- all joints are accessible for purpose of alterations and for testing.
- each final circuit has live and neutral terminating at consumer unit.
- wires usually laid in PVC conduits.
- Lamp circuits do not normally need an earth wire unless there is a metallic fitting which needs to be earthed for safety.





Two way switches

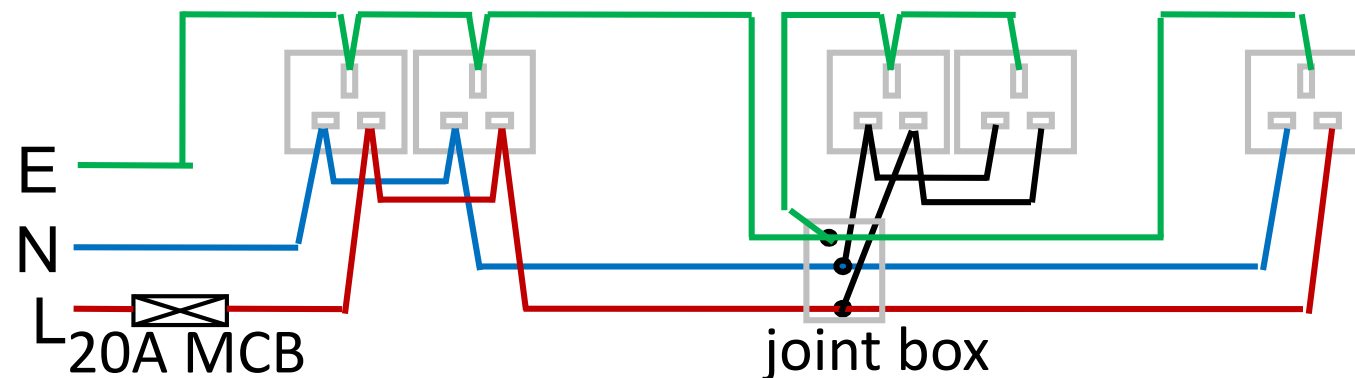
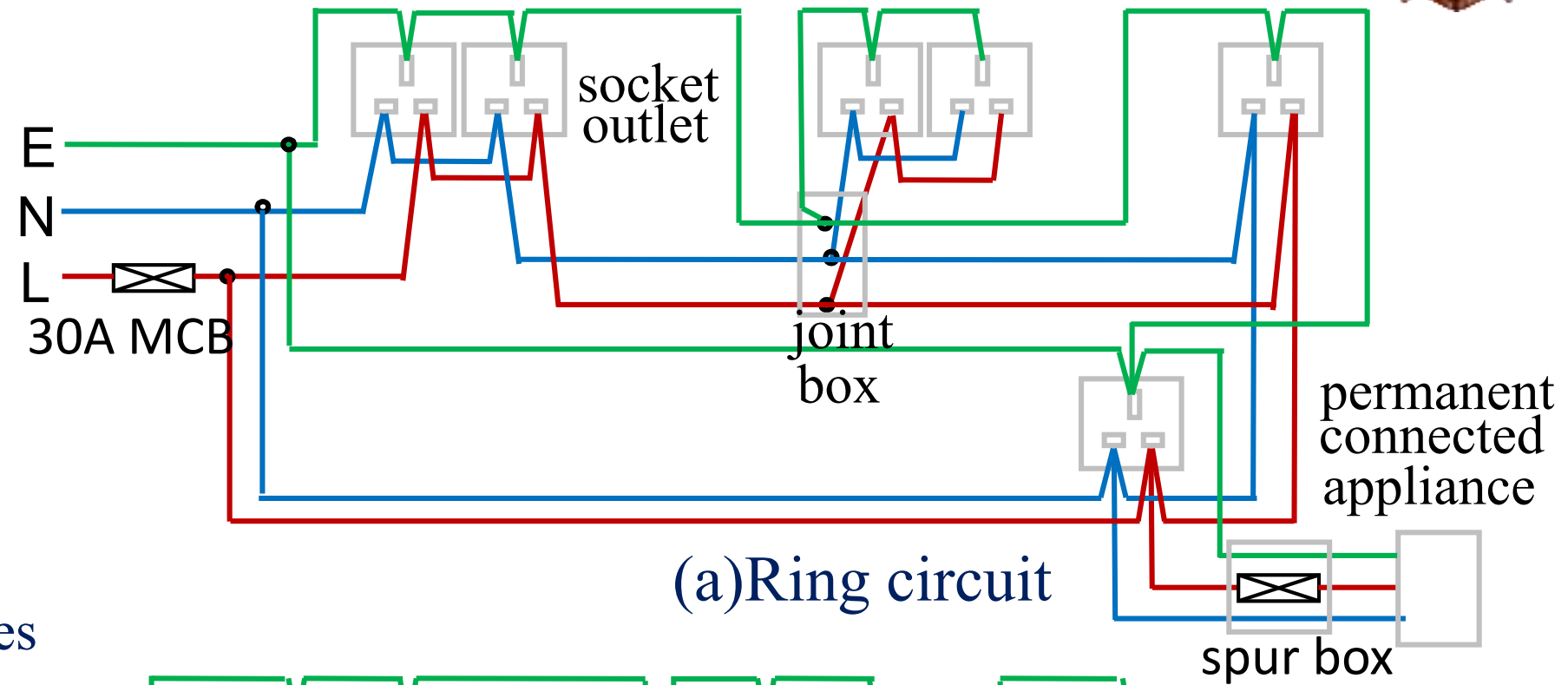
- Two-way switch is used
 - to operate a lamp from two positions
 - at top and bottom of a staircase
 - at ends of a long corridor.





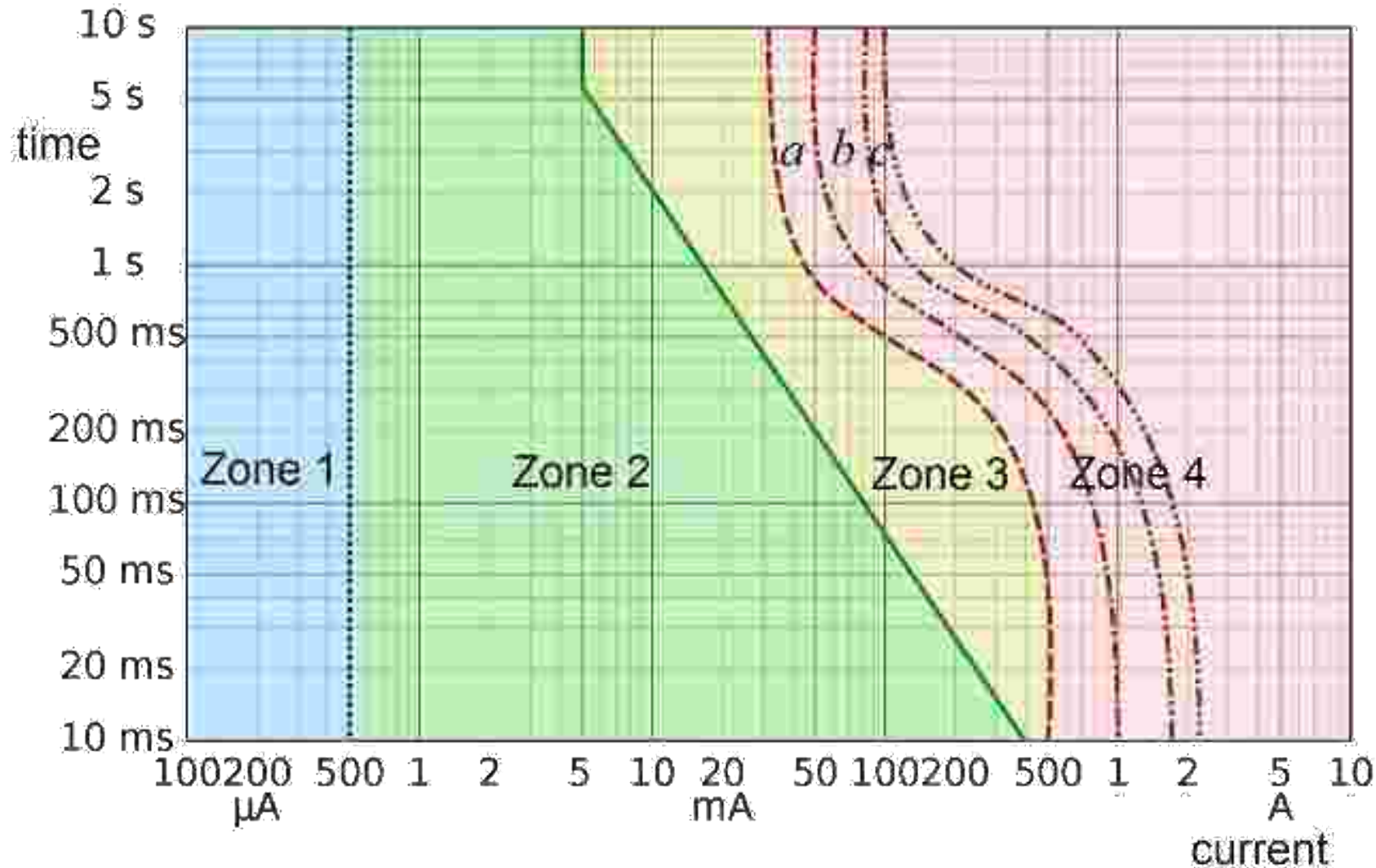
Final circuits for 13A socket outlets

- Individual 13A plugs are separately fused (at 13A, 5A or 3A dependent on load).
- Ring connection method is for 13 A socket outlets only and does a complete loop
- Radial circuit commences at consumer unit, loops into each socket outlet but does not return to original mcb).





Electric Shock - effects of 50 Hz current on human body



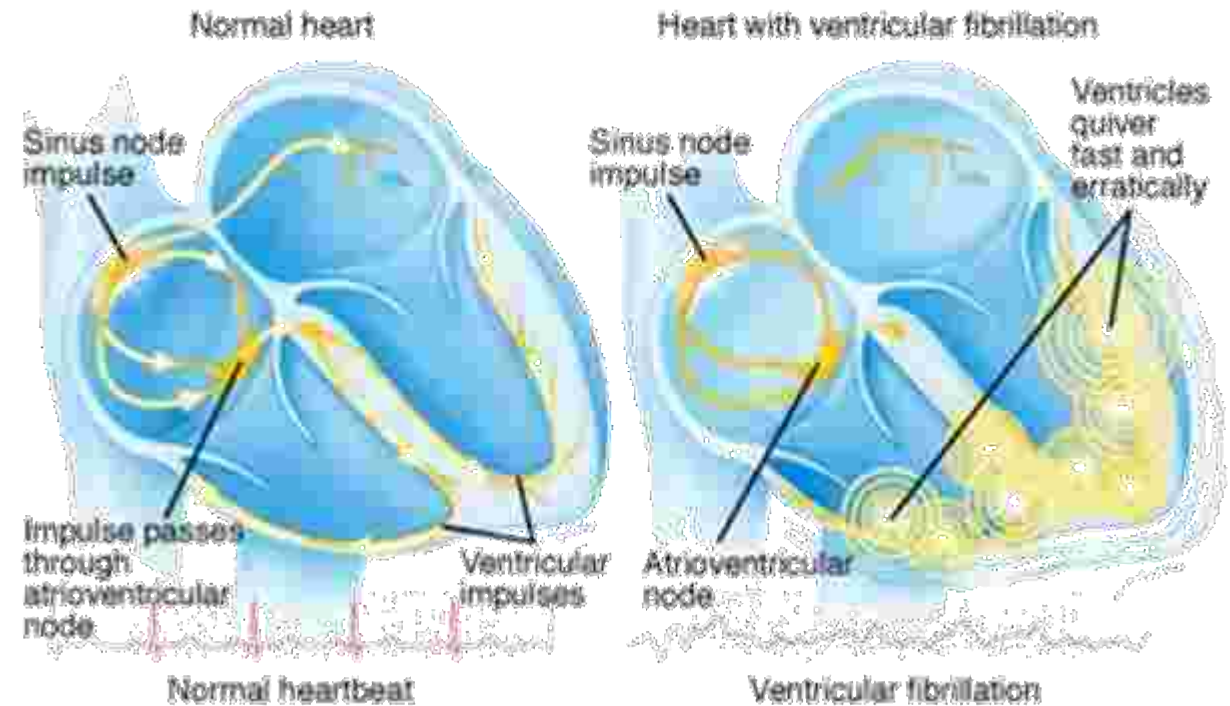
Zone 1 - No sensation
Zone 2 - Perceptibility of current, no harmful effect (let-go: 10 mA)
Zone 3 - Muscular contractions, difficulty in breathing.
0.5% probability of ventricular fibrillation
30 mA never goes into zone 4
Zone 4 - Probability of ventricular fibrillation increases
(a - up to 5%, b - up to 50%, c - greater than 50%)





Ventricular fibrillation of the heart

- Prevention of the heart acting as an effective pump
- Causing a stoppage of blood circulation to all parts of the body
- Resulting in death in a very short time.
- Probability of ventricular fibrillation
 - Zone 3 - 0.5%
 - Zone 4 - Probability increases
 - a - up to 5%, b - up to 50% , c - greater than 50%)





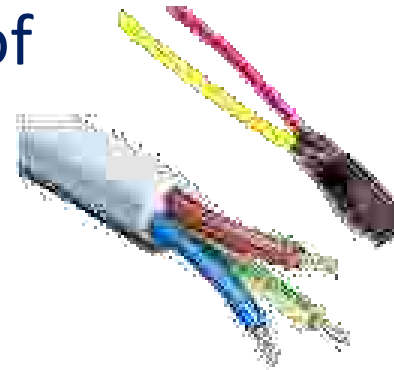
Wiring Regulations

- Electricity can, if uncontrolled, present a serious threat of
 - injury to persons or livestock, or
 - damage to property by fire.
- Regulations have been framed to govern the practice to ensure
 - that all electrical installations provide adequate degree of safety from fire and shock risks,
 - to operators of installations and associated apparatus and equipment.
- Every person who designs and constructs electrical installations must be familiar with the principal set of regulations issued by the Institution of Engineering and Technology for Electrical Installations, commonly known as the **IET Wiring Regulations**.
- A legal requirement in Sri Lanka for electrical installations to satisfy IEE Wiring Regulations
- He must be familiar with other regulations as well, some statutory, such as Electricity Act of Sri Lanka.



Purpose of Wiring Regulations

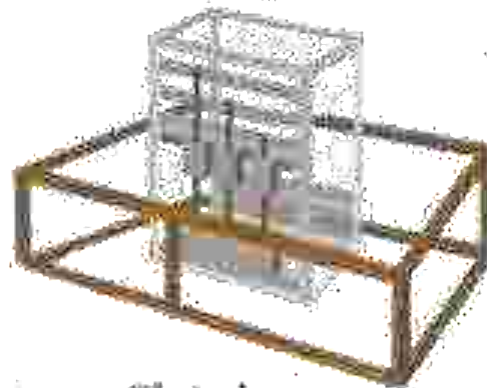
- **Protection of persons, property and livestock** from
 - electric shock, fire, burns
 - injury from mechanical movement of electrically actuated equipment.
- **Prevention of electric shock** is carried out by such actions as
 - insulation of live parts,
 - barriers or enclosures,
 - placing obstacles
 - keeping out of reach



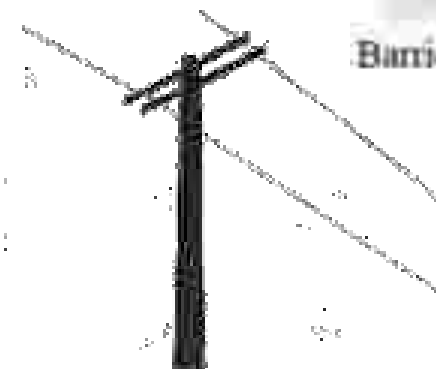
Insulation of Live Parts



Barriers and Enclosures



Obstacles



Keeping out of reach





Fundamental requirements for safety

- Good workmanship, approved materials and equipment
 - Choose correct type, size and current-carrying capacity of cables
- Regulations ensure choosing equipment for the maximum demand
- Ensure that conductors are insulated, and sheathed or protected
 - Place cables in a position to prevent danger.
 - Use properly constructed joints and connections
 - to be mechanically and electrically sound.
- Provide over-current protection s for every circuit in an installation
 - Supply authority provides protection for installation at supply point
 - However, an effective means of isolation must be provided to cut off all voltage from an installation or any of its circuits.
 - Choose suitable protective devices for location and the duty.
- Metalwork that can become live due to fault, should be earthed
 - circuit should be protected by an RCD in TT system.
- All single-pole switches are wired in the phase conductor only.
 - Fuse, switch or MCB should not be placed in an earthed neutral.





Additional safety requirements

➤ Motors

- Must have a readily means of disconnection to ensure that the protection device is accessible and easily operated.

➤ Equipment in adverse conditions

- To be installed in a situation exposed to weather or corrosion, or in explosive or volatile environments.

➤ Additions and alterations to installation

- Ensured that such work will not damage/weaken any part of existing installation, and are compatible with it.

➤ Inspection and testing

- To ensure, as far as reasonably practicable, that fundamental requirements for safety have been met .
- Done after completion of an installation or an alteration to an installation



Inspection and Testing

Inspection

- Identification of conductors
- Checking for connection of conductors, single-pole devices, equipment
- Checking for selection of conductors, routing of cables, presence of fire barriers
- Methods of protection against electric shock, prevention of detrimental influences
- Presence of devices for isolating and switching, under-voltage protection
- Choice of setting and labelling of protective devices, switches and terminals
- Selection of equipment for external influences, access to switchgear and equipment
- Presence of warning signs, danger notices, diagrams, instructions and erection methods.

Testing

- Continuity of live, neutral and protective conductors,
- Measure resistance of earth electrodes,
- Measure insulation resistance of live conductors to earth, between live conductors
- Check polarity to ensure all switches are connected in phase conductors and not neutral;
- Earth loop impedance tests,
- Operation of residual current devices.





Recap of Electrical Installations

- Domestic wiring systems – TN, TT and IT
- Radial and Ring circuits
- Overcurrent protection devices – fuse and MCB
- Safety, electric shock and earthing
- Earth leakage and residual current circuit breakers
- Wiring regulations
- Basic domestic installations





END OF PRESENTATION

