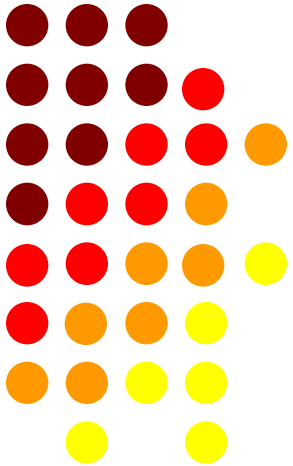
Fundamental of ELECTRICAL ENGINEERING

Electrical Installation

UNIT 5



LECTURE 37

CONTENTS

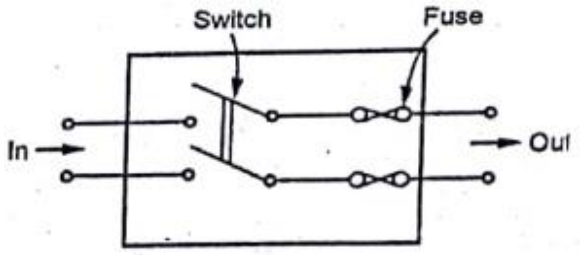
- Components of low tension (LT) switchgear
- Types of wires and cables
- Earthing Types and its importance
- Types of batteries
- Important characteristic of batteries
- Battery backup

COMPONENTS OF LT SWITCH GEAR

- Switch fuse unit (SFU)
- Miniature circuit breaker (MCB)
- Moulded case circuit breaker (MCCB)
- Earth leakage circuit breaker (ELCB)
- Air blast Circuit breaker(ABC)

SWITCH FUSE UNIT (SFU)

- Combination of switch and fuse together is called SFU.
- A switch isolate the circuit from supply for repair and maintenance. It is manually operated.
- Fuse is a protective device which acts quickly during abnormal condition to disconnect the circuit from the supply.



Advantages of SFU:

- Number of joints in the circuit get reduced.
- Less space is required due to compact construction.
- Easy to handle/operate.

Good Fuse

Blown Fuse

Switch fuse unit

Fuse

MINIATURE CIRCUIT BREAKER (MCB)

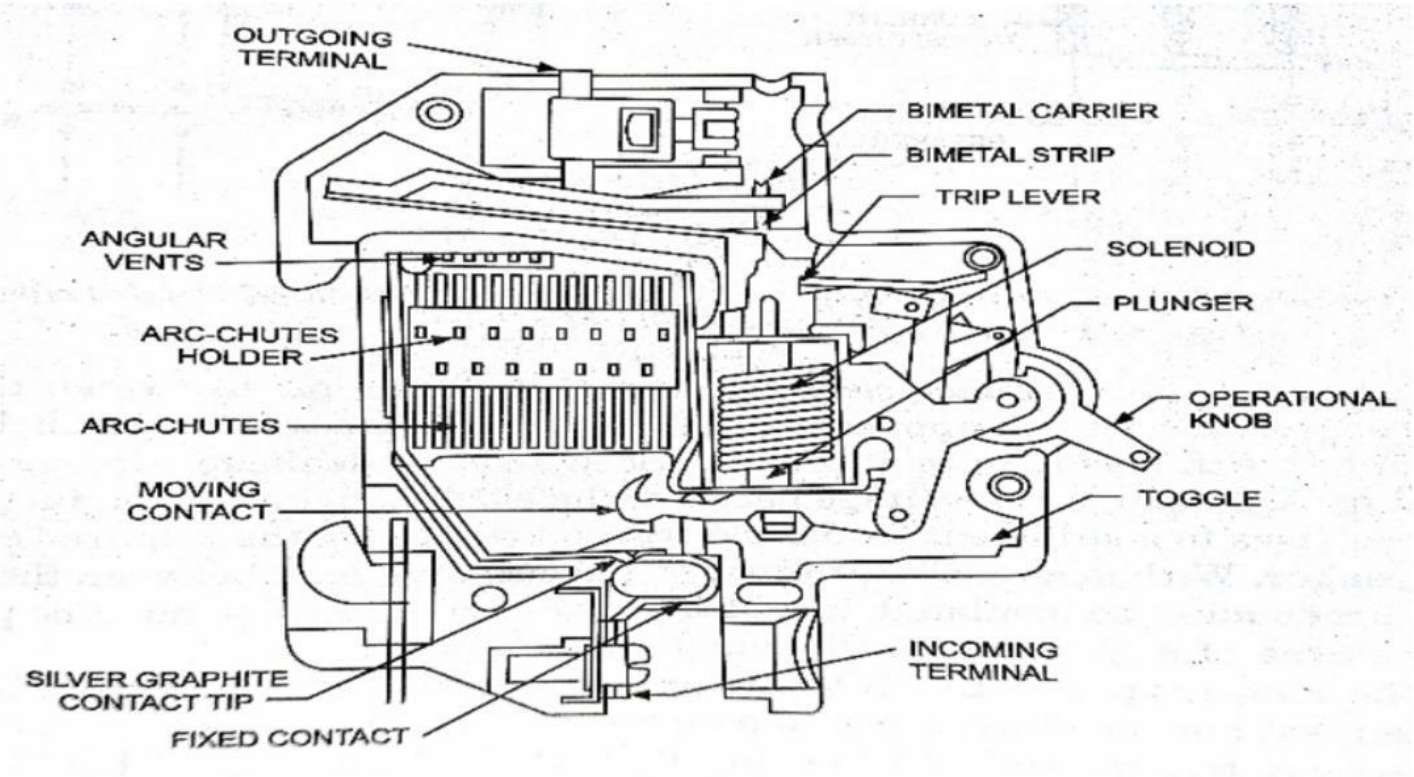
- An electromechanical device which makes and breaks the circuit in the normal operation.
- During fault/abnormal condition when current exceeds the preset value, MCB disconnects the circuit.
- MCB is high fault capacity current limiting, trip free, automatic switching with thermal and magnetic operation.
- MCB provides protection against overload and short circuit.
- MCBs are rated for 240V single phase, 415V three phase, and 220 V dc. The current rating is 0.5A to 63A.

MCBs are used because of following features:

- Its operation is very fast.
- No tripping circuit is required
- Automatic operation.
- Protection against overload and short circuit without noise, flames or smoke.
- Reset quickly after fault correction.
- No rewiring is required.
- Cannot be reclosed if fault exist.

3-pole MCB

2-pole MCB



Miniature Circuit Breaker

Comparison between Fuse and MCB

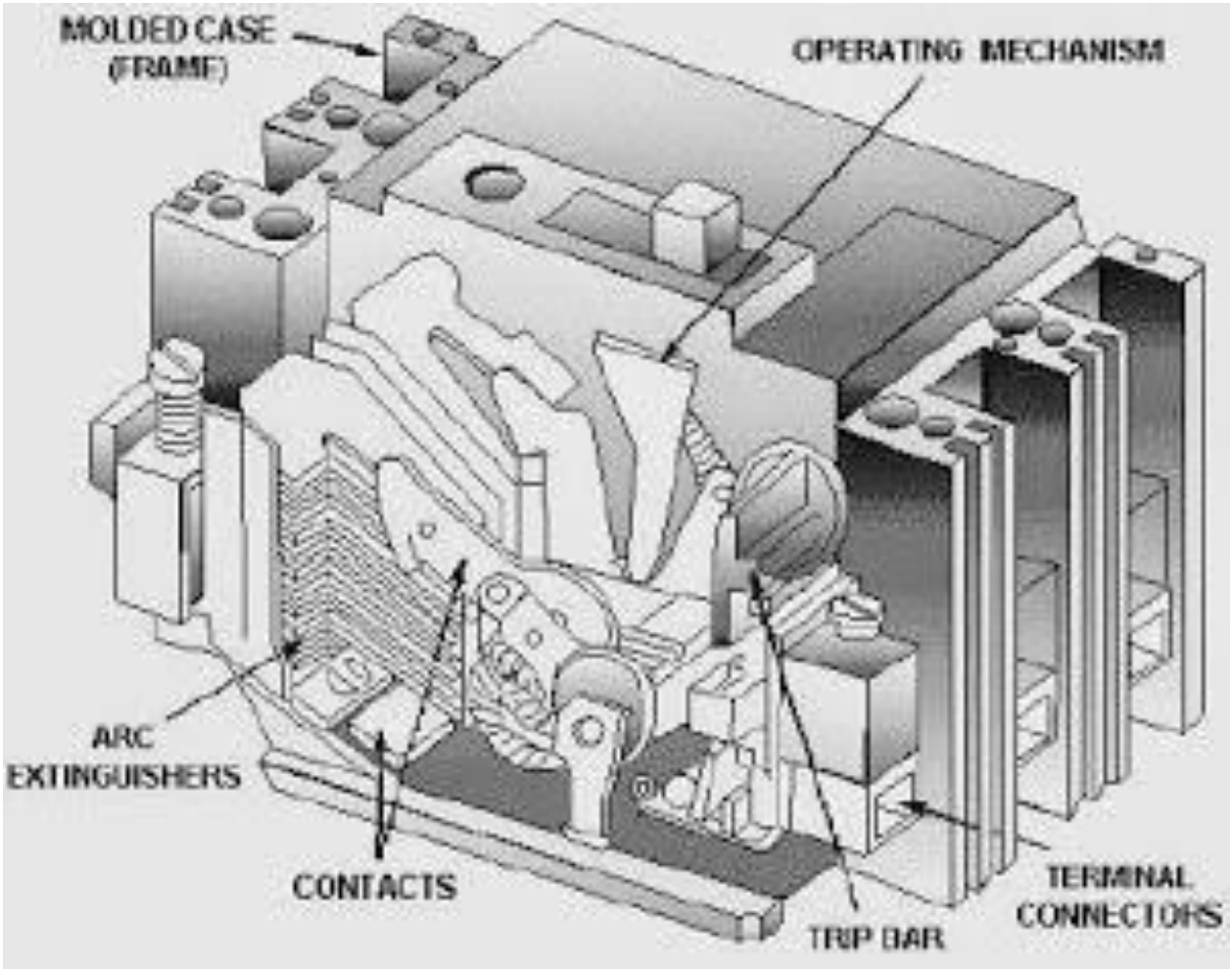
Sr. No.	Fuse	MCB
1	The operation of fuse is highly dependent on selection of its proper rating. If fuse wire is not selected properly ten it results in non operation of fuse even in case of short circuit.	MCB instantly disconnects the supply automatically in the event of short circuit or overload. It thus eliminates the risk of fire and prevents damage to wiring system.
2	If the fuse wire after operation is replaced with a newer one but go loose then it may be dangerous. Also to replace a blown use in between current carrying points is dangerous specially in dark.	Restarting the power supply after tripping due to overload or short circuit is easy.
3	During replacement of fuse wire, the exact size of fuse wire may not be available. Also for replacement a kit of hand tools has to be kept ready.	No maintenance and repairs is required for MCB. The distribution system employing MCB provides satisfactory operation and lasts for years.

MOULDED CASE CIRCUIT BREAKER (MCCB)

- MCCB is similar to MCB but used for circuit having current range from 63A to 3000A.
- Working is based on thermal mechanism. The bimetallic contact expands and contract when there are temperature changes.
- Under normal condition, the contacts are closed allowing current to pass. Under over-load or short circuit condition, current exceeds its safe value. Due to this, heat is generated, and the contacts are opened to interrupt the circuit.
- Due to the interruption of high current, there is arc formation. Hence in MCCB there are arc extinguishers which suppress the arc.

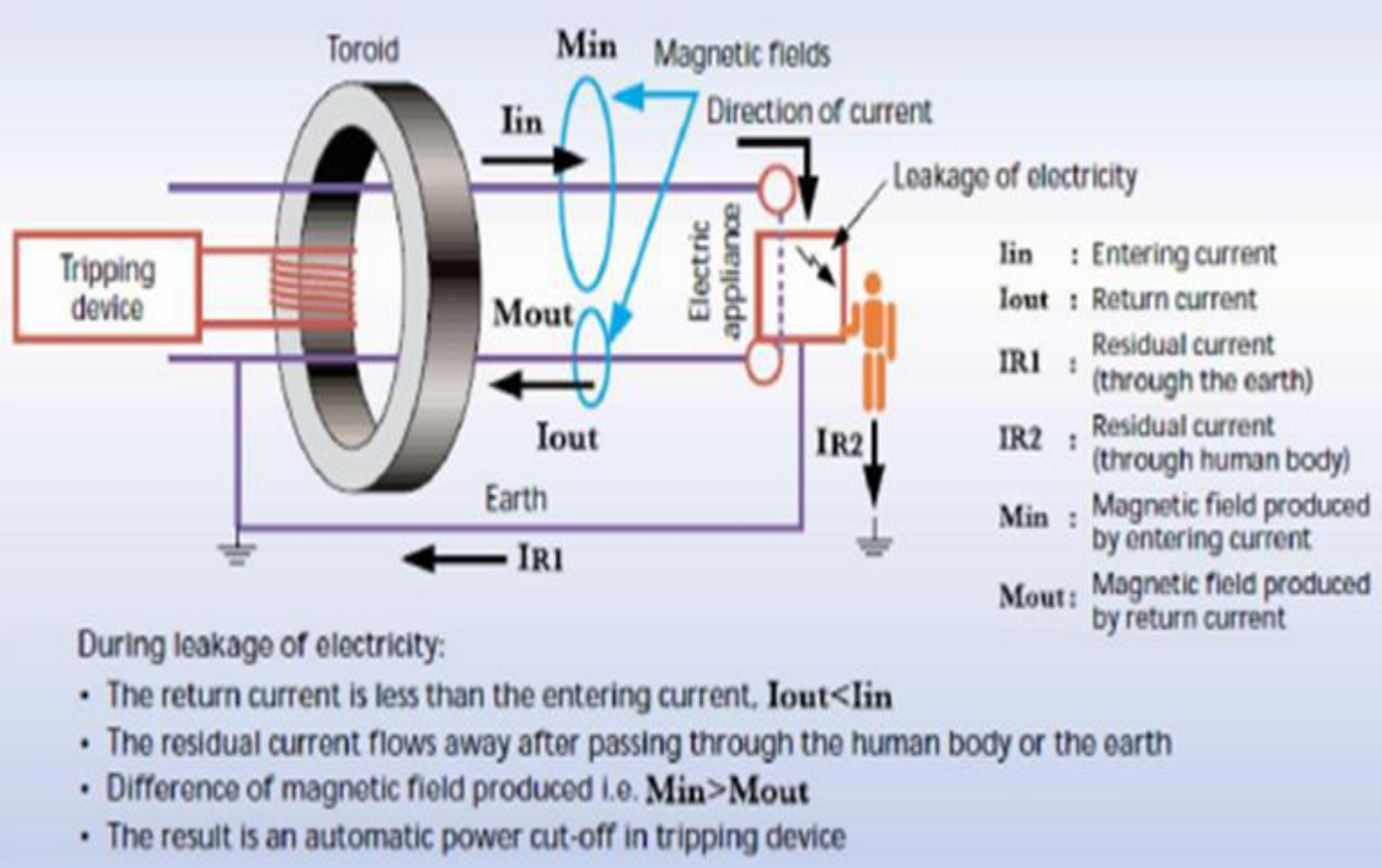
MCCB

- There is a disconnection switch, with the help of which, the MCCB can be operated manually.
- It has adjustable trip settings which can be used for high current applications.
- It can be easily reset after the fault rectification. Thus it provides operational safely and convenience.
- All the operating parts of MCCB are covered within a plastic moulded housing made in two halves. The two halves are joined together to form the whole structure.
- The basic difference between MCB and MCCB is the current rating.
- Hence MCCBs are used for industrial and commercial applications such as main feeder protection,, generator and motor protection, capacitor bank protection, welding applications and applications which require adjustable trip setting.


MOLDED CASE
(FRAME)
OPERATING MECHANISM
ARC
EXTINGUISHERS
CONTACTS
TRIP BAR
TERMINAL
CONNECTORS

EARTH LEAKAGE CIRCUIT BREAKER (ELCB)

- The ELCB is used to protect the circuit from the electrical leakage.
- When someone gets an electric shock, then this circuit breaker cuts off the power for protecting the personal safety and the circuit against short circuit and overload.
- ELCB is a security device used in electrical system with high Earth impedance to avoid shock.
- It notices difference in current between line and neutral wire, and interrupt the circuit if an unsafe current is detected.


Toroid
Min
Magnetic fields
Iin
Direction of current
Leakage of electricity
Tripping device
Electric appliance
Mout
Iout
IR2
Earth
IR1
Iin : Entering current
Iout : Return current
IR1 : Residual current (through the earth)
IR2 : Residual current (through human body)
Min : Magnetic field produced by entering current
Mout : Magnetic field produced by return current
During leakage of electricity:
• The return current is less than the entering current, Iout<Iin
• The residual current flows away after passing through the human body or the earth
• Difference of magnetic field produced i.e. Min>Mout
• The result is an automatic power cut-off in tripping device

ELCB

- ELCB consists of a small current transformer (C.T.) surrounding live/line/phase and neutral wire.
- The secondary winding of the C.T. is connected to relay circuit which can trip the circuit breaker (CB) which is connected in the circuit.
- Under normal conditions, the current in the line and the neutral is same. There will not be any production of flux in the core and no induced e.m.f.
- If there is a fault due to leakage, then the net current through the core will no longer remain as zero but equal to difference between line current and neutral current, which will set up flux and emf in C.T.

ELCB

- As per the preset value, the unbalance in the current is detected by C.T. and relay coil is energized which will give tripping signal for the circuit breaker.
- Thus ELCB provides protection against electric shock when a person comes in contact with live parts resulting in flow of current from body to earth.
- A properly connected ELCB detects such small currents in mA flowing to earth through human body or earth wire and breaks the circuit to reduce the risk of electrocution to humans.

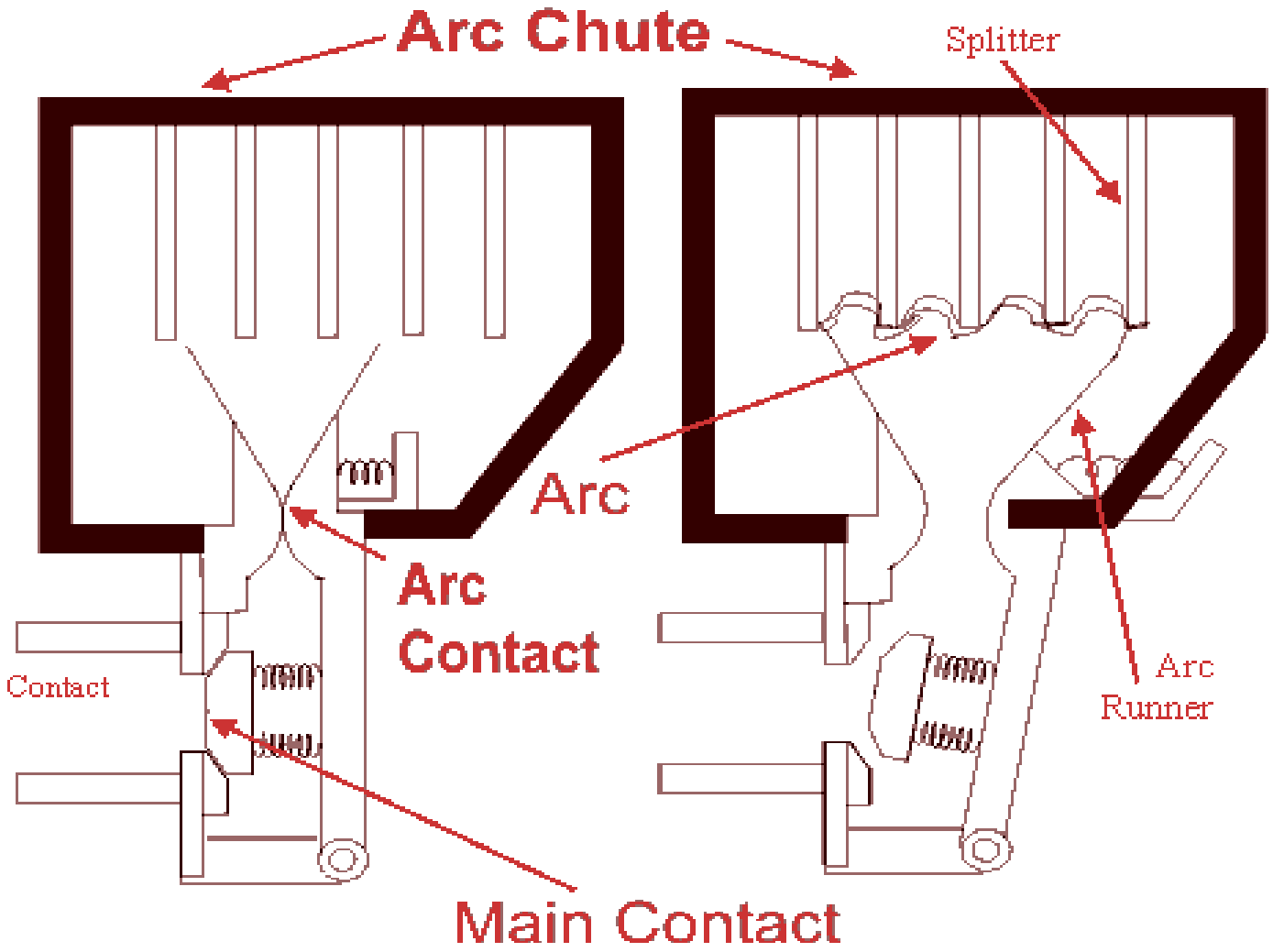
ACB

An **Air Circuit Breaker** (also known as an **Air Blast Circuit Breaker** or **ACB**) is an automatically operated electrical switch that uses air to protect an electrical circuit from damage caused by excess current from an overload or short circuit. Its primary function is to interrupt current flow after a fault is detected. When this happens, an arc will appear between the contacts that have broken the circuit. Air circuit breakers use compressed air to blow out the arc, or alternatively, the contacts are rapidly swung into a small sealed chamber, the escaping of the displaced air, thus blowing out the arc.

ACB

Air Circuit Breaker (ACB) is an electrical device used to provide Overcurrent and short-circuit protection for electric circuits over 800 Amps to 10K Amps. These are usually used in low voltage applications below 450V. We can find these systems in Distribution Panels (below 450V). Here in this article, we will discuss the working of Air Circuit Breaker.

ACB


Arc Chute
Splitter
Arc
Arc
Contact
Contact
Arc
Runner
Main Contact

LECTURE 38

WIRES

Metal drawn out into the form of thin flexible thread or rod is called a wire. For example, copper wire, aluminium wire, steel wire etc..

The various types of wires which are used for various wiring schemes are:-

1. Vulcanised India Rubber wires (V.I.R.)

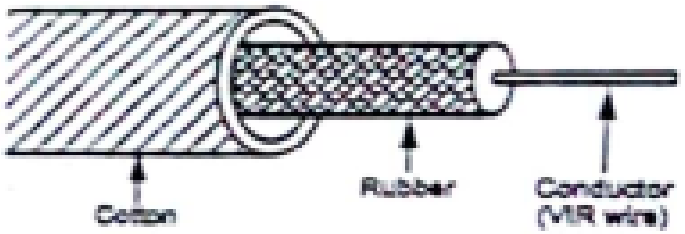
2. Cab Tyre Sheathed wires (C.T.S.)

3. Poly Vinyl Chloride wires (P.V.C.)

4. Flexible wires

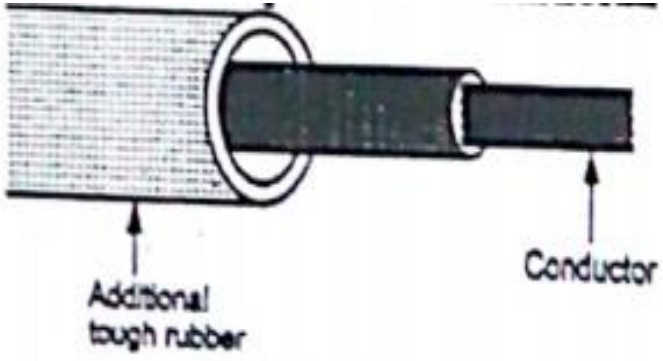
VULCANISED INDIA RUBBER WIRES (V.I.R.)

- This type of wire consists **tinned conductor coated with rubber insulation.**
- This is further covered with **protective cotton and bitumen compound and finally finished with wax**. This makes it moisture and heat resistant.
- These are always single core wires.
- Though are covered with a cotton layer **it has tendency to absorb moisture and hence rarely used, now a days.**



CAB TYRE SHEATHED WIRES (C.T.S.)

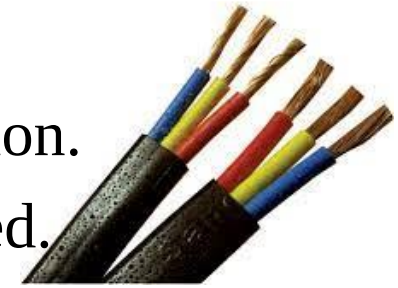
- In this type, ordinary rubber insulated conductors are provided with an additional tough rubber sheath.
- The wire is also known as tough Rubber Sheathed (T.R.S.) wire. It provides additional insulation and along with that a protection against moisture, chemical fumes and wear and tear.
- These are also available in single core, double core and three core varieties.



POLY VINYL CHLORIDE WIRES (P.V.C.)

These are most commonly used wires. These have conductors with P.V.C. insulation. P.V.C. has following characteristics:

- It is moisture proof.
- It is tough and hence durable.
- It is chemically inert, therefore resistant to corrosion.
- As it is tough so additional covering is not required.
- The only disadvantage is, it softens at high temperature and hence it avoided where extreme of temperature may occur e.g. in heating appliances.

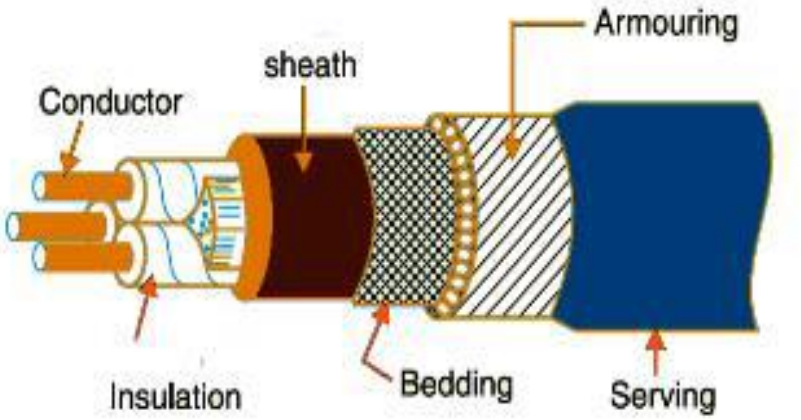


FLEXIBLE WIRES

- These are used very commonly in domestic wiring or for wiring of temporary nature.
- It consists of two separately insulated stranded conductors. The insulation is mostly rubber and more commonly available in parallel or twisted twins.
- Due to its flexible nature, the handling of these wires becomes very easy.

CABLES

- A cable is defined as the group of individually insulated one or more conductors which is put together and finally provided with number of layers of insulation to give proper mechanical support.



- **Conductor of Core:** This section consists of single conductor or more than one conductor. The conductors are also called cores. Cables with three conductors used are aluminium or annealed copper. The conductors are stranded conductors in order to provide flexibility to the cable.
- **Insulation:** Each conductor or core is covered by insulation of proper thickness. The commonly used insulating materials are varnished cambric, vulcanized bitumen and impregnated paper.
- **Metallic Sheath:** The insulated conductors are covered by lead sheath or aluminium sheath. This provides the mechanical protection but mainly restricts moisture and other gases to reach to the insulation.
- **Bedding:** The metallic sheath is covered by another layer called bedding. The bedding consists of paper type compounded with a fibrous material like jute strands or hessian tape. The purpose of bedding is to protect the metallic sheath from corrosion and from mechanical injury resulting due to armouring.
- **Armouring:** This layer consists of the layers of galvanized steel wires which provide protection to the cable from the mechanical injury.

Based on voltage level the various types of cables are:

- **Low tension cables:** Used for the voltage levels upto 6.6kV.
- **Medium tension cables:** Used for 11kV level and are called belted cable.
- **High tension cables:** Used for 22kV and 33kV levels. These are screened type cables and further classified as:

Extra high tension cables: Used for voltage levels more than 33kV. These are pressure cables which are further classified as:

i. Oil filled Cables.

ii. Gas pressure cables.

Based on the cores, the various types of cables are:

i. **Single core cable.**

ii. **Two core cable .**

iii. **Three core cable.**

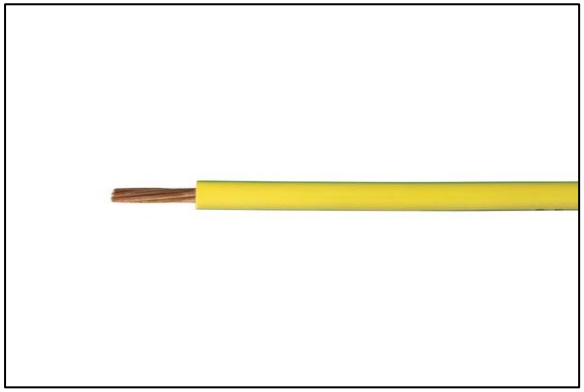
Single core cables are made up of a **single** conductor covered by

a PVC insulation. They are mainly used in power and lighting circuits, both domestic and commercial applications.

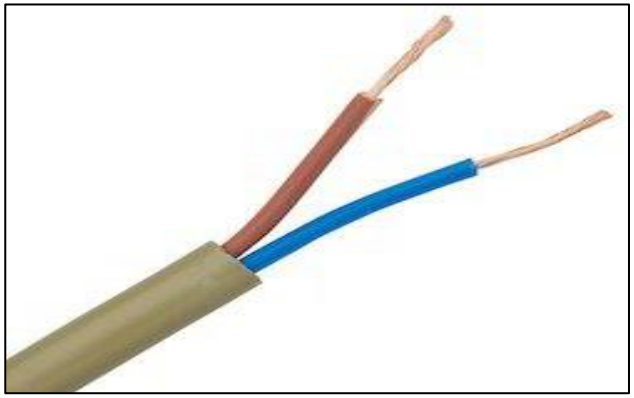
- They are also used in the internal wiring of appliances suitable for installation in conduits and trunks.

- **Two core cable** is used to connect small appliances which are double insulated and need no earth. The cable only has two cores being live and neutral. As this is flex cable it will be of circular shape with an outer sheath and two colour coded PVC insulated cores.

- **Three core cable** is made up of 3 solid cores, which are individually insulated and wrapped in an outer PVC sleeving. The colours of these cores are brown, black and grey, with a bare earth core (to be insulated with green and yellow sleeving).



Single core cable



Two core cable

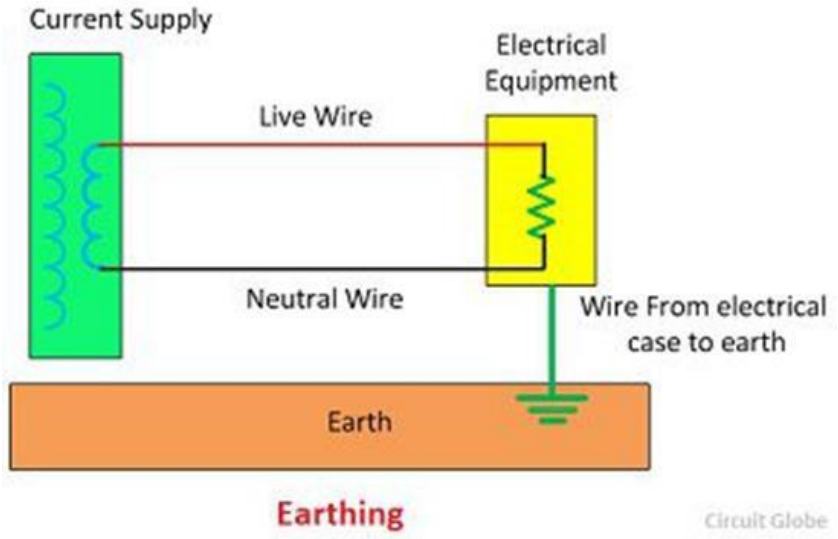
Three core cable

LECTURE 39

EARTHING

The connection of electrical machinery to the general mass of earth, with a conducting material of very low resistance is called earthing or grounding.

- The earthing of electrical equipment brings the equipments to zero potential and avoid the shock to the operator, under nay fault conditions.



IMPORTANCE OF EARTHING

Consider a machine which is not earthed. It is operated at supply voltage V.

- If a person touches to the outer part of the machine then as long as **insulation of the machine is perfect, person will not get a shock.** The insulation resistance of perfect insulation is infinite.
- But if there is some fault and insulation becomes weak or **if one of the winding is touching to the cover of the machine then insulation resistance becomes zero.**
- If person touches to such a machine, current flows through the body of the person towards the earth. **As body resistance is small, current through the body is high so that the person receives a shock.**
- To avoid such a situation, **the body of the machine is connected to the earth with a very low resistance.**
- If the machine is earthed and the person touches to a faulty machine then **body resistance and earthing resistance appears to be in parallel.**

- As **earthing resistance is very small than the resistance of the body**, hence almost entire leakage current flows through earthing connection.
- Thus current through the body of the person is almost zero and person does not receive any shock.
- Similarly due to earthing, **the tall buildings, structures and other machines are protected from high voltage in overhead lines** and the atmospheric lightening as high voltage and lightening gets discharged to earth through earthing connection.
- Due to earthing the **line voltage is maintained at constant value.**
- Hence earthing is necessary **for all domestic appliances, machines, buildings and structures, equipments power stations etc.**

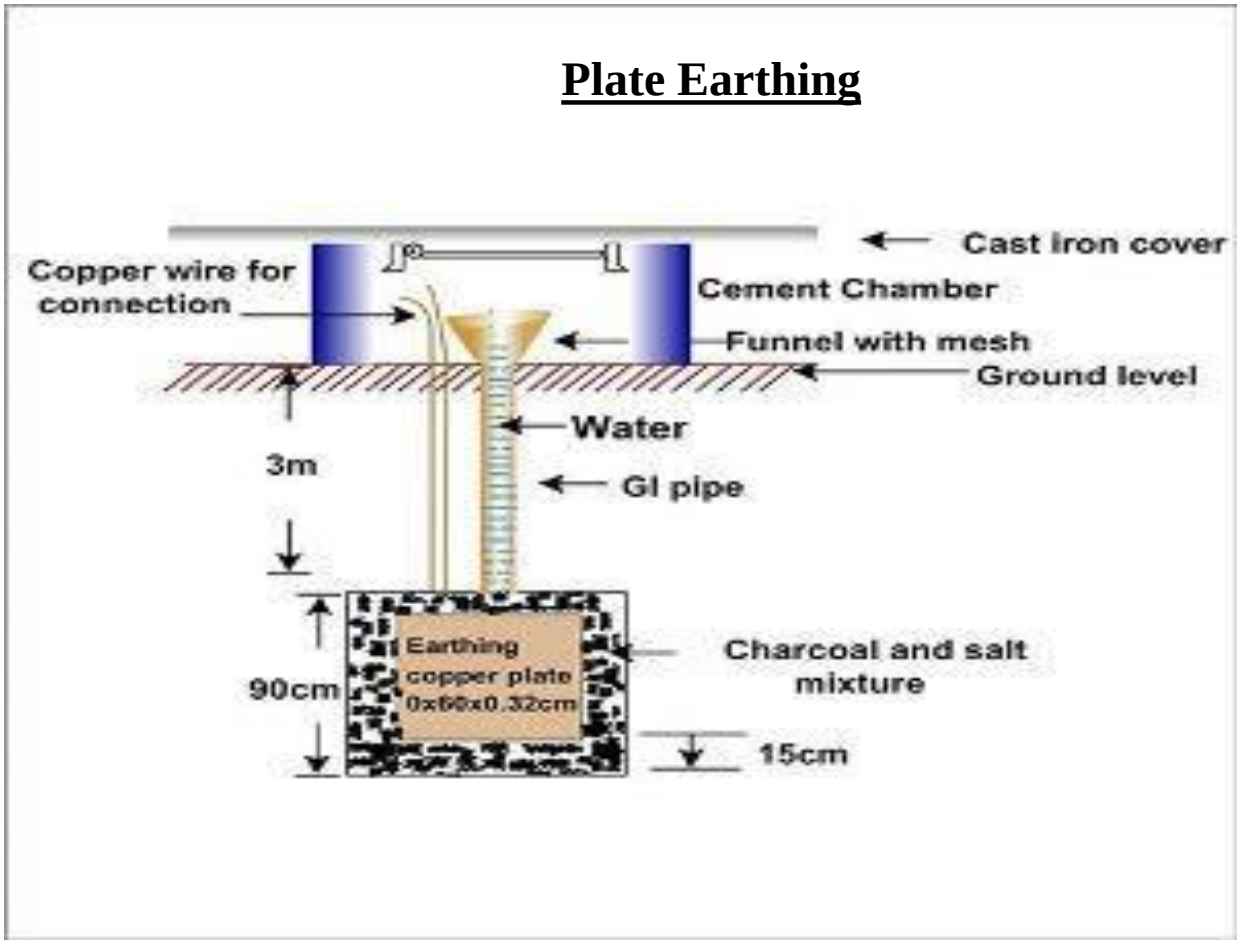
TYPES OF EARTHING

- **Plate earthing:** A copper plate or galvanized plate is buried in an earth pit below ground level. The plate electrode connects the electrical conductors to the earth.
- **Pipe earthing**: A galvanized steel perforated pipe inside the ground connects the electrical conductors to the earth.
- **Rod earthing:** Similar to the Pipe earthing. A copper rod replaces the pipe electrode.
- **Chemical earthing:** Similar to the pipe earthing. A chemical compound material replaces the charcoal and salt layers.

PLATE EARTHING

- The earth connection is provided with the help of **copper plate or Galvanized Iron (G.I.)** plate. The copper plate size is 60 cm × 60 cm × 3.18 mm, while G.I. plate size is not less than 60 cm × 60 cm × 6.3 mm. The plate is embedded 3 m (10 ft.) into the ground. The plate is kept with its face vertical.
- The plate is surrounded by **the alternate layer of coke and salt for minimum thickness** of about 15 cm. The earth wire is drawn through G.I. pipe and is perfectly bolted to the earth plate. The nut and bolts must be copper plate and must be of galvanized iron for G.I. plate.
- The earth lead used must be G.I. wire or strip of sufficient cross sectional area to carry the fault current safely. The earth wire is drawn through G.I. pipe of 19 mm diameter, at about 60 cm below the ground.
- The G.I. pipe is fitted with a funnel on the top. In order to have an effective earthing, **salt water is poured periodically through the funnel.**
- The earthing efficiency, increases with the increases of the plate area and depth of embedding. If the resistivity of the soil is high, then it is necessary to embed the plate vertically at a greater depth into ground.
- **The only disadvantage of this method is that the discontinuity of the earth wire from the earthing plate below the earth can not be observed physically. This may cause misleading and may result into heavy losses under fault condition.**

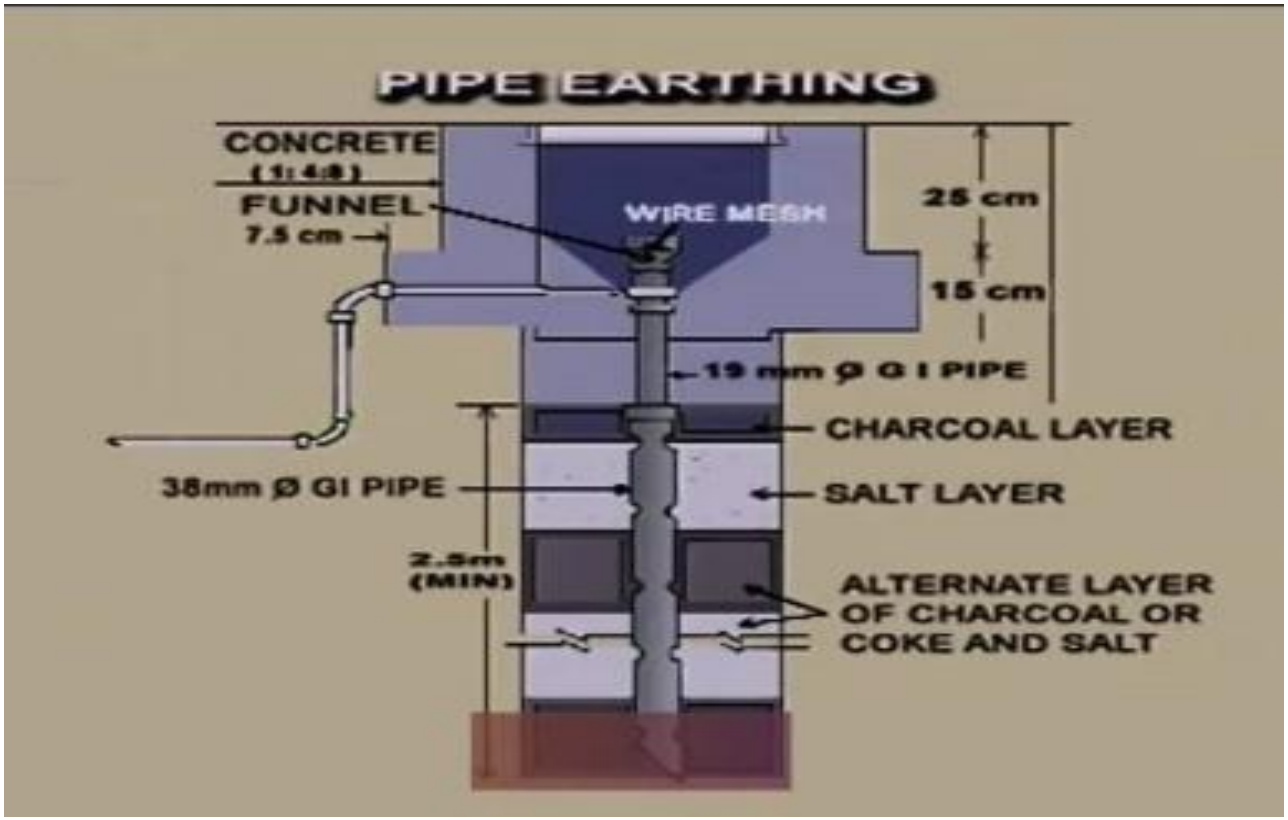
Plate Earthing



PIPE EARTHING

- A G.I. pipe of 38 mm diameter and 2-meter (7 feet) length is **embedded vertically into the ground.** This pipe acts as an earth electrode. The depth depends on the condition of the soil.
- The **earth wires are fastened to the top section of the pipe** above the ground level with nut and bolts.
- The pit area around the pipe is **filled with salt and coal mixture** for improving the condition of the soil and earthing efficiency.
- The contact surface of G.I. pipe with the soil is more as compare to the plate due to its circular section and hence can handle heavier leakage current for the same electrode size.
- **In summer season, soil becomes dry. In such case salt water is poured through the funnel connected to the main G.I. pipe through 19 mm diameter pipe. This keeps the soil wet.**
- **The earth wires are connected to the G.I. pipe above the ground level and can be physically inspected from time to time.** These connections can be checked for performing continuity tests. The earth lead used must be G.I. wire of sufficient cross-sectional area to carry fault current safely.
- **The only disadvantage of pipe earthing is that the embedded pipe length has to be increased sufficiently in case the soil specific resistivity is of high order. This increases excavation work and hence increased cost.**

Pipe Earthing



LECTURE 40

Battery

- A device that converts the stored **chemical energy into electrical energy using chemical action** is called battery.
- The chemical action that takes place in the battery is the **movement of electrons from one terminal to another.** Due to this chemical action, there exists a difference in charge between two terminals that creates an electrical energy between them.
- A cell is a device that consists of **two electrodes and an electrolyte.** But battery is a Single unit which **comprises of two or more cells** which are connected together electrically.

CONSTRUCTION

The component of a battery that participates actively in a chemical reaction to generate electrical energy is called the active component. The three main active components of a battery are:

- **Anode:-**The electrode that oxidises and release electrons when an electrochemical reaction occurs is called anode. It is also called negative electrode or reducing electrode. For example zinc and lithium.
- **Cathode:-**The electrode that acquires electrons during electrochemical reaction is called cathode. It is also called positive electrode or oxidising electrode. For example metallic oxides.
- **Electrolyte:-** The medium through which electrons get transferred from anode to cathode is called electrolyte. In general, electrolytes are in liquid from like water or other solvents in which the material required for ionic conduction, i.e., salt, acid, or alkalis are dissolved.

WORKING

When a load is connected **between the cathode and anode**, due to electrochemical action, the electrons get transferred from anode to cathode. Due to this movement of electrons, the current starts flowing from cathode to anode through the connected load.

The advantages of using batteries as energy sources are:

- Energy can be stored for a long duration of time.
- Delivers the energy effectively when compared to fossil fuels.
- Response time is less when compared to other fossil fuels.
- Efficiency of the battery is high.
- Battery can be operated at any place as it offers good tolerance to shock and vibrations.
- Operating cost of the battery is cheap.
- Low- maintenance cost is required for the battery.

CLASSIFICATION OF BATTERIES

The two main categories of batteries are:

- Primary batteries and Secondary batteries.

Primary Batteries

- It is also called single-use or throw-away batteries as it cannot be recharged to reuse. It is discarded after complete depletion of charge in it. Examples of primary batteries are alkaline batteries, mercury batteries. silver-oxide batteries, and zinc carbon batteries.

Secondary Batteries

- The batteries that can be electrically recharged again are called secondary batteries. By allowing the current in the opposite direction, these batteries can be recharged. Nickel Cadmium, Lead-Acid batteries and Lithium batteries fall into the secondary battery category.

COMPARISON BETWEEN PRIMARY AND SECONDARY BATTERIES

Primary Battery	Secondary Battery
Initial cost is less.	Initial cost is high.
Cost per kWh is high.	Cost per kWh is less.
As these batteries are disposable, there is no requirement of maintenance.	As these batteries are rechargeable, regular maintenance is required.
Most suitable for portable application since it is smaller and light weight in nature.	Less suited for portable applications.
Has good charge maintenance	Has poor charge maintenance
Not suitable for heavy load applications since the discharge rate is poor.	Suitable for heavy load applications due to its superior discharge rate.
In general, these batteries are limited to specific applications.	Due to inherent versatility, these batteries are used in most of the applications.
Examples:- Alkaline batteries, Mercury batteries, Silver-oxide batteries, zinc carbon batteries etc.	Example:- Nickel Cadmium, Lead-acid Batteries, Lithium batteries etc.

TYPES OF BATTERIES AND APPLICATIONS

Sr. No.	Types of battery	Applications
1.	Lead acid battery	In automobiles for starting and lighting, battery electric vehicles, backup operations like rail road signals, air traffic controls and critical systems in submarines, for lights and fans in trains etc.
2.	Nickel-Cadmium battery	In railways for lighting and air conditioning systems, for starting engines and provide emergency power supply in military aero-planes and helicopters, in movie cameras and photoflash, in electric shower, variety of cordless electronic devices etc.
3.	NiMH battery (Nickel metal hydride)	Cellular phones, portable computers and laptops, digital cameras, electronic toys, providing emergency supply to various electronic instruments etc.
4.	Lithium battery (Lithium Ion)	Consumer products such as camcorders, calculators, electric razors, medical equipments, portable radios, in traction applications in electric and hybrid vehicles as standby power.
5.	SMF battery (Sealed Maintenance free)	UPS systems, telecommunications equipments, fire alarms and security systems, office automation equipments, EPABX, solar lantern, emergency lights, electronic weighing scale etc.

IMPORTANT CHARACTERISTICS

The various important characteristics for batteries are

- **Nominal voltage:** It is indicated on a battery depending on the number of cells connected in series. It is open circuit voltage of a battery.
- **Battery capacity or battery life:** It is specified in ampere-hours (Ah). It indicates the amount of electricity which a battery can supply at the specified discharge rate till its voltage falls to a specified value. Mathematically product of discharge current (I_D) in amperes and the time for discharge (T_D) in hours till voltage falls to a specified value.

$$\text{Battery capacity} = I_D * T_D \text{ (Ah)}$$

- **Specific gravity of electrolyte:** More the specific gravity of electrolyte, more is the battery capacity. It decides internal resistance of a battery.

- **Specific energy:** The battery capacity expressed in watt-hour per kg weight is called specific energy. It is also called gravimetric energy density of a battery.
- **Electrical characteristics:** These characteristics include the charging and discharging curves for a battery. It is the graph of terminal voltage against charging or discharging time in hours at normal rate.
- **Battery efficiency** :It is defined as the ratio of the output during discharging to the input required during charging, to regain the original state of the battery.

It is commonly called ampere-hour efficiency and denoted as η_{Ah}.

$$\eta_{Ah} = \frac{Ampere - hourondisch\arg e}{Ampere - houronch\arg e}$$

$$\%\eta_{Ah} = \frac{Current \times Timeondisch\arg e}{Current \times Timeonch\arg e} \times 100$$

Q1. An alkaline cell is discharged at a steady current of 4 ampere for 12 hours, the average terminal voltage being 1.2 V. To restore it to original state of voltage , a steady current of 3 A for 20 hours is required, the average terminal voltage being 1.44 V. Calculate the ampere-hour and watt-hour efficiencies in this particular case.

Sol. I_d = 4 A, T_d = 12 hrs, V_d = 1.2 V, I_c= 3 A, T_c = 20hrs, V_c= 1.44 V.

Ampere hour efficiency:

$\%\eta_{AH}$ $= \{(\mathbf{I_d \times T_d})/(\mathbf{I_c \times T_c})\} \times 100$

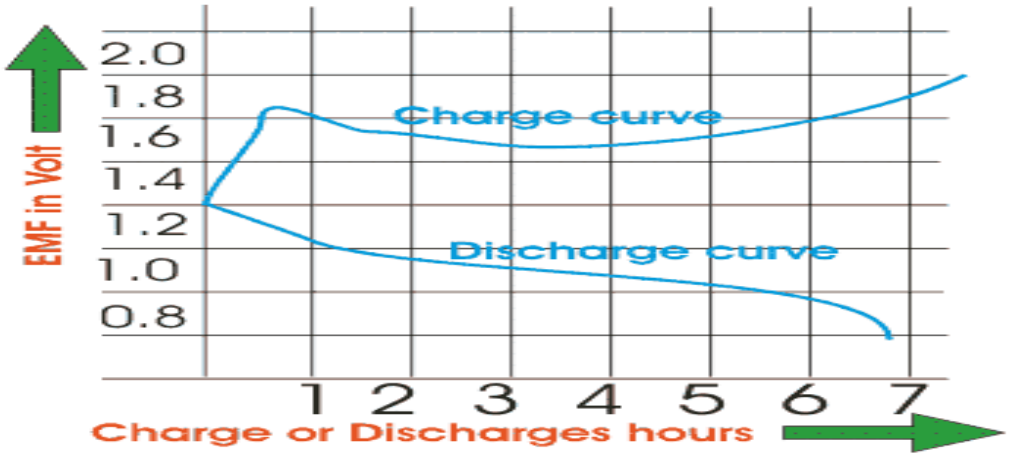
$\%\eta_{AH}$ $= \{\mathbf{(4\times12)/(3\times20)}\} \times 100 = 80\%$ **Ans.**

Watt-hour efficiency:

- $\%\eta_{WH}$ $= \{(\mathbf{I_d \times T_d \times V_d})/(\mathbf{I_c \times T_c \times V_c})\} \times 100$
- $\%\eta_{WH}$ $= \{\mathbf{(4\times12\times1.2)/ (3\times20\times1.44)}\} \times 100 = 66.66\%$ **Ans.**

BATTERY CHARACTERISTICS

- The emf of a fully charged Nickel-Iron battery is 1.4 V. The average discharge voltage is about 1.2 V and the average charging voltage is about 1.7 V per cell. The characteristics of this type of battery are shown below in the figure.



Characteristics of Edison Battery

- The voltage characteristics of the Nickel Iron battery are similar to that of the lead-acid cell. As the fully charged EMF 1.4 V and it slowly decreases to 1.3 V and then very slowly to 1.1 or 1.0 V during discharge.
- From the graph, we can see that there is no lower limit for discharging EMF beyond which the output of the battery will be zero. That's why after a certain period the battery stop to any output.
- The EMF of a battery is directly proportional to the temperature, which means the EMF of the battery increases with increase in temperature.
- The average time of charging of a battery is 7 hours and discharging time is 5 hours.

- Another **characteristic of Edison battery** is that continuous operation at higher temperature decreases the life of the battery, the same thing happens if the battery is charged for more than the average time of charging.

- The ampere-hour and watt-hour efficiency of this nickel-iron battery is 85 % and 60 % respectively.

- At $4^{o}C$ temperature, the capacity of Edison battery falls to zero, that's why the battery should be heated up before operation though during operation the I^2R losses keeps the battery hot and running.

LEAD ACID BATTERY

Lead acid battery is the most commonly used secondary battery. It uses sponge lead and lead peroxide for the generation of electrical energy from chemical reaction. It is also denoted as Pb-Acid battery. In general, a single Pb-acid battery can consist of 3, 6, or 12 lead acid cells.

The active components of lead acid battery are:

- **Cathode:** Lead peroxide (PbO_2) and it is dark chocolate brown in color when fully charged.
- **Anode:** Sponge lead and is grey in color when it is charged.
- **Electrode**: Dilute Sulphuric acid (H_2SO_4) contains 31% of concentrated H_2SO_4.

CHEMICAL ACTION IN Pb-ACID BATTERY

Electrical Energy is supplied to the load when it is connected to Pb-acid battery and the battery gets charged when it is connected to DC Supply. The chemical action taking place in battery during charging and discharging are given below:

During Charging

Here, a DC supply voltage higher than battery voltage is connected to the electrodes of the battery such that positive electrode gets connected to positive terminal.

- At anode:

$$PbSO_4 + 2H \longrightarrow Pb + H_2SO_4 \qquad (1)$$

- At cathode:

$$PbSO_4 + SO_4 + 2H_2O \longrightarrow PbO_2 + 2H_2SO_4 \qquad (2)$$

The changes that take place during charging of battery are:

- Cathode gets converted into PbO_2 and makes is dark chocolate brown color.
- Similarly, anode changes into grey color sponge lead.
- Concentration of electrolyte increases.
- Output voltage of a cell rises to 2.1V at no load condition.
- Chemical energy is produced from electrical energy.

During Discharging

When Pb-acid battery supplies current, the electrolyte, i.e., H_2SO_4gets splits into Hydrogen ions ($2H^+$) and Sulphate ions (SO_4)

- At anode:

$$Pb + SO_4 \longrightarrow PbSO_4 \qquad (3)$$

- At cathode:

$$PbO_2 + 2H + H_2SO_4 \longrightarrow PbSO_4 + 2H_2 \qquad (4)$$

The changes that takes place during discharging of energy are:

- Cathode is covered with white colour $PbSO_4$
- Similarly, anode is covered with $PbSO_4$and converts grey colour plate to white colour.
- Concentration of electrolyte decreases due to formation of water.
- Output voltage of a cell falls to 1.8V at no load condition.
- Electrical Energy is produced from chemical energy.

Advantages of Pb-acid Battery:

- Efficiency of the battery is high, i.e., nearly 80 percent.
- Number of times the battery can be recharged is 300 to 1500
- It is environmental friendly.
- Cost of the battery is less.

Disadvantages of Pb-acid battery are:

- Effectiveness if the battery gets reduced at low temperature
- Due to overcharging, corrosion of battery occurs.
- It is not possible to keep it in ideal position for long duration.

Applications of Pb-acid Battery

The Pb-acid batteries are:

- Used in automobile applications for starting of internal combustion engines.
- Used in emergency lighting and security alarm systems.
- Used in heavy duty loads like trains, lift, truck, etc.
- Used as an energy source in submarines.

Nickel Cadmium Battery

A secondary battery made of nickel and cadmium is called Nickel Cadmium battery and is denoted as Ni-Cd Battery. The active components of Ni-Cd Battery are:

- **Anode:** Cadmium , Cd
- **Cathode:** Nickel hydroxide, $NiOH_2$ and
- **Electrolyte:** Alkaline Potassium hydroxide, KOH.

The chemical action taking place in Ni-Cd Battery during discharging and charging process is given as follows:

During Discharging

During the battery operation, the electrolyte KOH breaks into K and OH ions. Hence, the following action takes place at anode and cathode when the battery is connected to the load.

- **At Anode:**

$$Cd + 2OH \longrightarrow Cd(OH)_2 \quad (5)$$

- **At Cathode:**

$$NiO(OH) + H_2O \longrightarrow Ni(OH)_2 + OH \quad (6)$$

During Charging

When the battery is connected to DC supply for charging purpose, the following action takes place at anode and cathode:

- **At Anode:**

$$Cd(OH)_2 + 2K \longrightarrow Cd + 2KOH \quad (7)$$

- **At Cathode:**

$$Ni(OH)_2 + OH \longrightarrow NiO(OH) + H_2O \quad (8)$$

Advantages, Disadvantages and Applications of Ni-Cd Battery

The advantages of Ni-Cd Battery are:

- It can be recharged many times.
- During discharging, it maintains voltage at a constant level.
- At low temperature, the performance of the battery is good.
- It is available in different configurations like button, cylindrical and rectangular.

The disadvantages of Ni-Cd Battery are:

- Due to high toxicity level of cadmium, it creates environmental pollution.
- Since cadmium is a heavy metal, the weight of the batteries is high.
- The electrolyte used is in this battery is a corrosive hazardous chemical.

The major applications of Ni-Cd Battery are:

- Used in flash lights, photoflash units and portable electronic equipment.
- Used in emergency lighting and alarm systems.
- Used in air-crafts, space satellite systems.
- Used to start large diesel engines, gas turbine, etc.

LITHIUM ION BATTERY

The secondary battery that plays a major role in electric vehicles is Lithium Ion Battery or Li-ion battery. The active components of Li-ion battery are:

- **Anode:** Lithium carbon
- **Cathode:** Lithium metal oxide, $LiMO_x$ where M is any metal, and
- **Electrolyte:** Non-aqueous electrolyte like Ethylene carbonate or Diethyl carbonate.

Based on metal, the Li-ion battery is classified as:

1. Lithium cobalt oxide battery
2. Lithium Manganese oxide battery
3. Lithium Nickel Manganese battery
4. Lithium Ion Phosphate battery
5. Lithium Nickel Cobalt Aluminium Oxide battery
6. Lithium Titanate battery

Advantages, Disadvantages and Applications of Li-ion Battery

The advantages of Li-ion Battery are:

- Weight of the battery is less when compared to other batteries.
- Li-ion Battery is available in different shapes.
- It posses very low self-discharging rate, i.e., 5-10 % per month.
- This battery does not pollute the environment, i.e. it is eco friendly.

The disadvantages of Li-ion Battery are:

- Flow of charge inside the battery gets affected due to deposition of ions.
- The internal resistance of the battery gets increases gradually and hence, the output decreases.
- It cannot be used to charge the normal charges.

The major applications of Li-ion Battery are:

- Used in the laptop, computers and advanced cellular phones.
- Used in military equipments like mine detectors, satellite, military radios etc..

Lead Acid	Nickel Cadmium	Lithium Ion
It has very low internal resistance.	It has very low internal resistance.	It has medium internal resistance.
Nominal battery voltage is 2V	Nominal battery voltage is 1.2V	Nominal battery voltage is 3.2-3.7V
Charge and discharge cutoff voltage are 2V and 2.4V respectively	Charge and discharge cutoff voltage are 1.2V and 1V respectively	Charge and discharge cutoff voltage are 4.2V and 2.5V respectively
Less maintenance is required.	Moderate maintenance is required.	Free from maintenance
Its efficiency is approximately 90 percent	Its efficiency is approxi. 70-90 percent	Its efficiency is 99 percent
Very high toxicity level	Very high toxicity level	Low toxicity level
It is thermally stable	It is thermally stable	Requires protection circuit for stability
Time taken to charge the battery is 8 to 16 hours.	Time taken to charge the battery is 1 to 2 hours.	Time taken to charge the battery is 1 to 4 hours.
Self-discharge per month is 5 percent of its total capacity	Self-discharge per month is 20 percent of its total capacity	Self-discharge per month is less than 3 percent of its total capacity

ENERGY CONSUMPTION AND SAVINGS

The total electrical energy consumption is the addition of electrical energy consumption of various domestic appliances or industrial machinery.

- To calculate the consumption of an electrical appliance, following factors are required:
  1. Capacity of electrical appliances in watts.
  2. Number of hours for which appliance is in use in one day.
  3. Number of days per month or year as per the required energy calculation.

Mathematically energy consumption of an appliance is given by-

- **kWh** per month = {(Capacity of appliance in Watt)*(Number of hours/day)*(Number of days/month)}/1000
- The division of 1000 is to express energy consumption in kWh i.e. units.

[1Unit = 1 kWh]

- Addition of energy consumptions of all appliances, total energy consumption per month can be obtained.
- But practically an energy meter is installed which directly measures the total energy consumption of a house or industry.
- Thus for practical energy consumption calculation we need,
  1. Energy meter reading at the start of counting period.
  2. Energy meter reading at the end of counting period.
  3. Number of days in a counting period which is generally a month.

Total energy consumption per month = Final reading in kWh after a month – Initial reading in kWh.

- To find the consumption for one year, the energy consumption per day is multiplied by 365 days.
- For calculating energy savings use:

Energy saving (kWh/year) = [365×Energy Consumption per day in previous year] – [Energy consumption per current year].

- By knowing energy consumption of each appliance and replacing bulbs by lower wattage bulbs, saving in energy can be achieved.

Q2. Calculate the energy consumption per day in a house using 5 CFLs of 20 W each, 3 fans of 60 W each for 3 hrs a day.

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Sol. KWh = $\dfrac{(5 \times 20 \times 3) + (3 \times 60 \times 3)}{1000}$ **= 0.84 kWh.**

BATTERY BACKUP

A battery backup device is an electronic device that supplies secondary power in the absence of the main power. It can also protect electronic hardware from power spikes and fluctuations.

The main battery backup device which is commonly used is called **uninterruptible power supply [UPS].**

Need of UPS:

1. Most of the systems operate on A.C. supply. Thus A.C. supply failure causes periodical stoppage of the various systems.

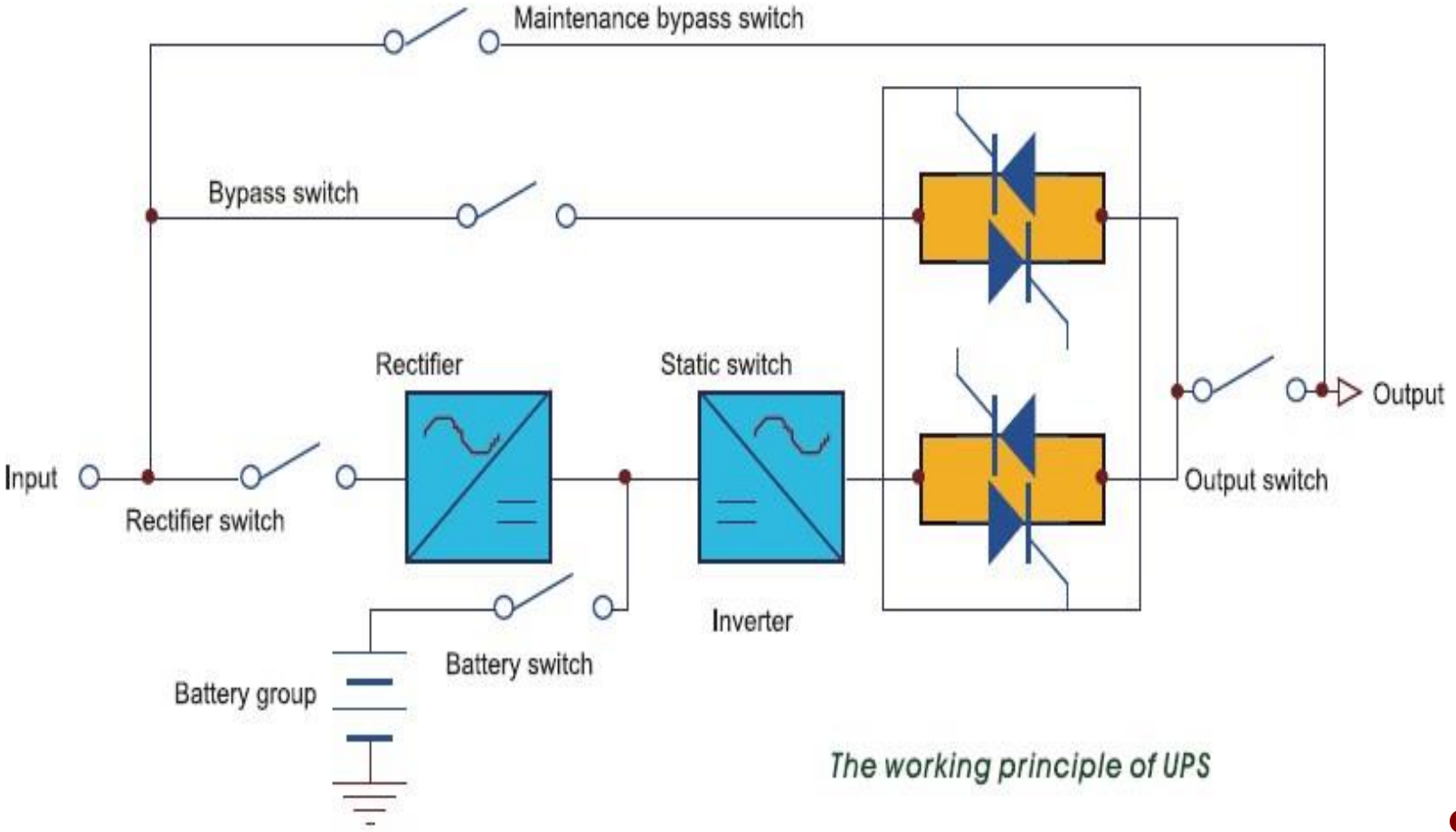
2. Most of the modern systems are computers and microprocessors. Any interruption in the power supply may results into the loss of the work and may make system ineffective.

3. Many important places like hospitals, temples, playing grounds, banks etc. require continuous supply for their efficient operation.

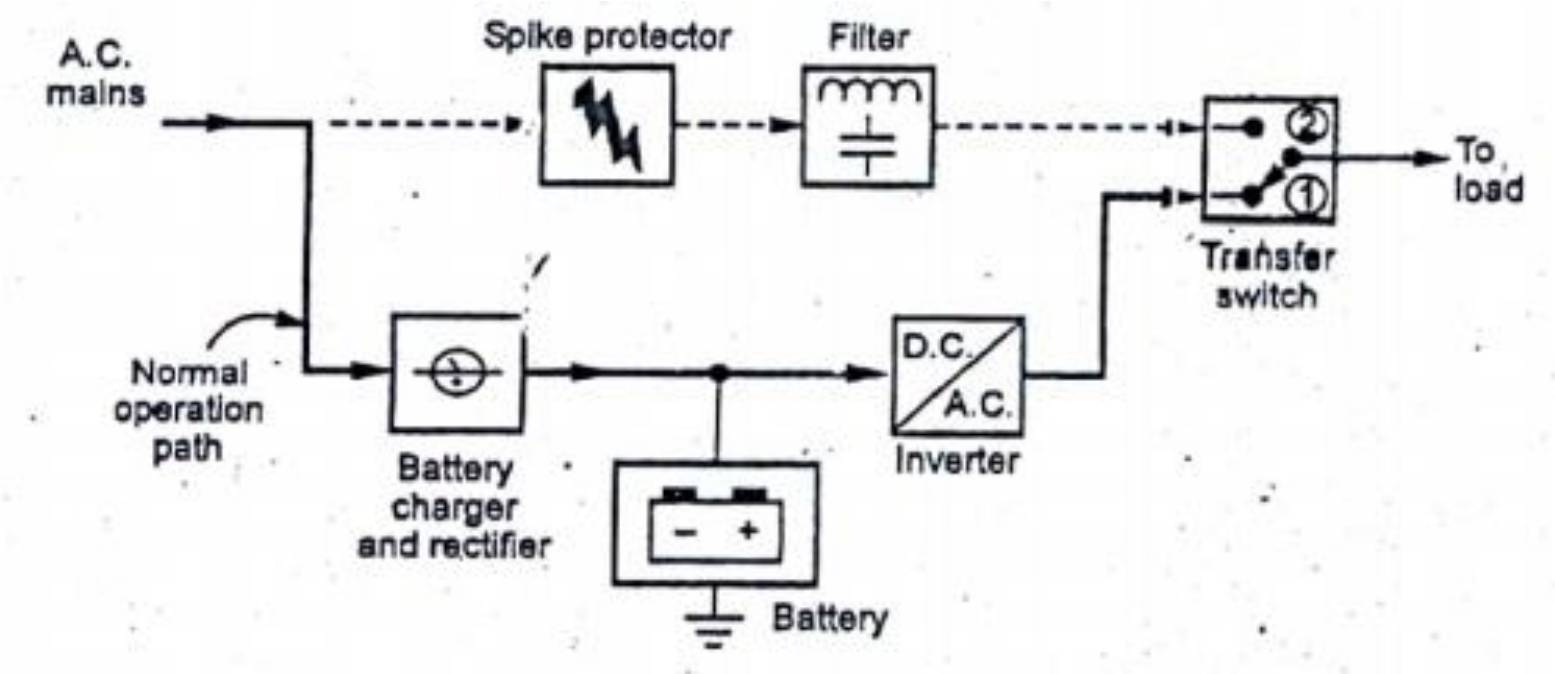
UNINTERRUPTIBLE POWER SUPPLY (UPS)

The basic block diagram of an UPS which is using two power sources, controlled by a switch.

- The UPS is designed so that there is one source of power, used under normal conditions, known as primary power source (a.c. mains) and other source called the secondary power source that comes in to action if the primary source is disrupted.
- A switch is used as a controlling device. It changes from primary source to secondary source when it detects that the primary source has failed. It automatically switches back from the secondary power source to the primary when it is detected that the primary source has returned to normal.
- The power available from mains is a.c. All batteries provided d.c. Hence in UPS there is circuitry to convert a.c. to d.c. for battery charging called a converter. Similarly there is a device converting d.c. from battery to a.c. as required by the load. This is called an inverter. These are important components of any UPS.
- The two types of UPS are:- 1. On line UPS. 2. Off line UPS.



The working principle of UPS


A.C.
mains
Spike protector
Filter
To
load
Transfer
switch
Normal
operation
path
Battery
charger
and rectifier
D.C.
A.C.
Inverter
Battery

Online
UPS

COMPARISON BETWEEN ON-LINE AND OFF -LINE UPS

Sr. No.	Parameter	ON line UPS	OFF Line UPS
1.	Operation	Battery is the primary source and a.c. mains is secondary power source.	A.C. is the primary source and battery is the secondary power source.
2.	Isolation	Complete isolation between load and a.c. mains.	No isolation between load and a.c. mains.
3.	Reliability	Highest and transfer time is zero	Lower and transfer time is few msec
4.	Economy	High cost	Low cost
5.	Size	Large size	Small size
6.	Efficiency	Less due to power dissipation	High efficiency

Q1. Explain the necessity of ELCB.

- There are certain situations where leakage current can flow through the metal bodies of appliances, when person touches to such appliances. Thus person gets a shock.
- Similarly there is risk of fire due to such earth leakage currents.
- Thus a protective device is necessary which can sense small leakage current and disconnects the circuit from supply. Such a device is called earth leakage circuit breakers (ELCB).

Q2. State the advantages of ELCB.

- Provide protection to a human against the electric shock.
- Detects very small leakage currents.
- Reduces the risk of fire due to hot spots.
- Saves electrical energy due to leakage.
- Energy conservation can be achieved.

Q3. States the application area of MCCB.

MCCB are used for high current protection such as,

- Generator protection
- Main feeder protection
- Motor protection
- Capacitor bank protection
- Welding applications
- Applications which needs adjustable current trip settings.

Q4. Names the various types of wires used in electrical installations. AKTU (2018-19)

- Vulcanized India Rubber Wires (V.I.R.)
- Cab Type Sheathed Wires (C.T.S.)
- PolyVinyl Chloride Wires (P.V.C.)
- Flexible Wires

Questions asked in AKTU Even Sem 2018-19

- Describe the electrical characteristics of lead-acid battery.
- Explain the construction, rating,specific applications of at least two types of wires and cables used in electrical engineering.
- Explain (i).MCB (ii).MCCB (iii).ELCB
- Define The purpose of earthing the electrical appliances.
- What is the difference between primary and secondary batteries?

Questions asked in AKTU OddSem 2018-19

- Why Earth pin is made thicker and bigger than line and neutral?
- Calculate the energy consumption per day in a house using 5 CFLs of 20 W each, 3
- fans of 60 W each for 3 hrs a day.
- Draw the characteristics of battery.
- Calculate the backup of battery of 100AH connected to load of 100 watts and supply voltageis 12V.
- (a)Write short notes on the following:
  - MCB (ii) MCCB (c) Fuse (d) Types of wires
- Explain following:
  - Need of Earthing
  - Battery backup