UNIT - 3
UTILIZATION OF ELECTRICAL POWER

RENEWABLE ENERGY SOURCES - SOLAR ENERGY

The electrical energy which is developed from the Solar radiation is known as Solar energy and it is Produced by the means of Solar Panel which Consists of Solar Cells.

The device which Converts light energy into electric energy by means of Photovoltaic effect is known as Solar Cell or PV Cell.

Photovoltaic effect is the generation of EMF by absorbing the ionizing Solar radiation.

CONSTRUCTION:

Solar Cell is made by diffusing the N type material into the P type material - forms the PN Junction.

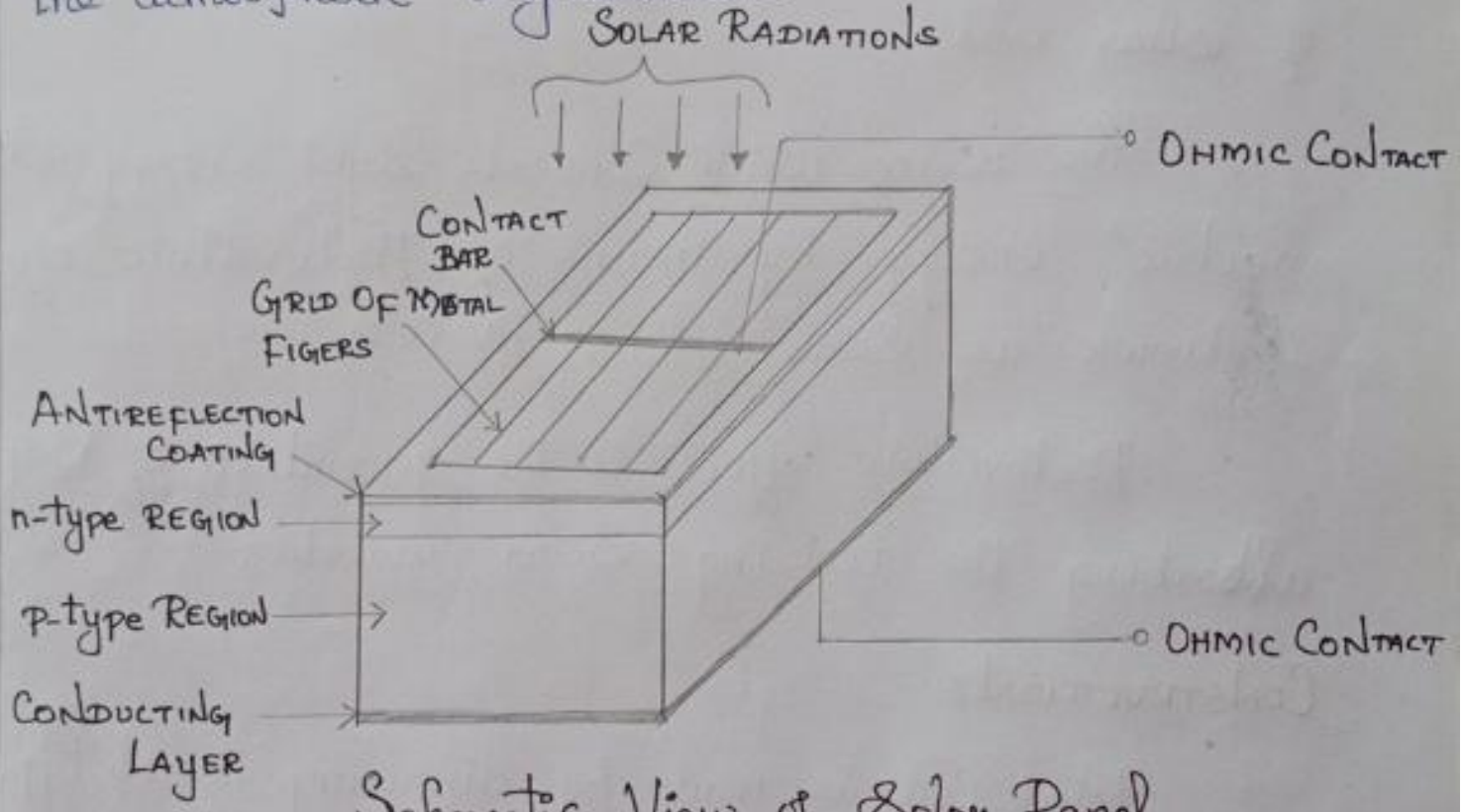
The metallic Contact is fixed at its top and bottom of the Cell.

A Single Solar Cell is Capable of Producing 0.5V.

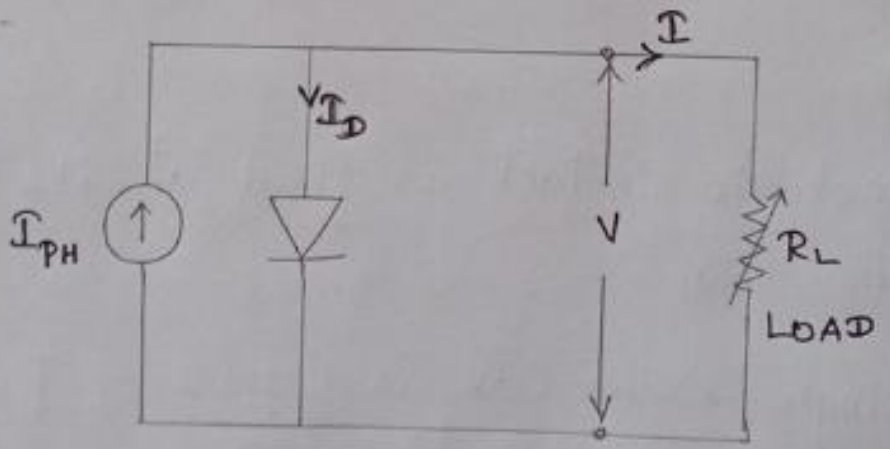
The Combination of Series and Parallel Connection of Cells increases the range of Voltage and Current.

(2) Solar Cells Connected in Series and Parallel forms Solar module.

Solar modules Connected in Series and Parallel forms Solar array and array forms the Solar Panel. Then the Panel is Shielded to Protect it from the atmospheric degradations.

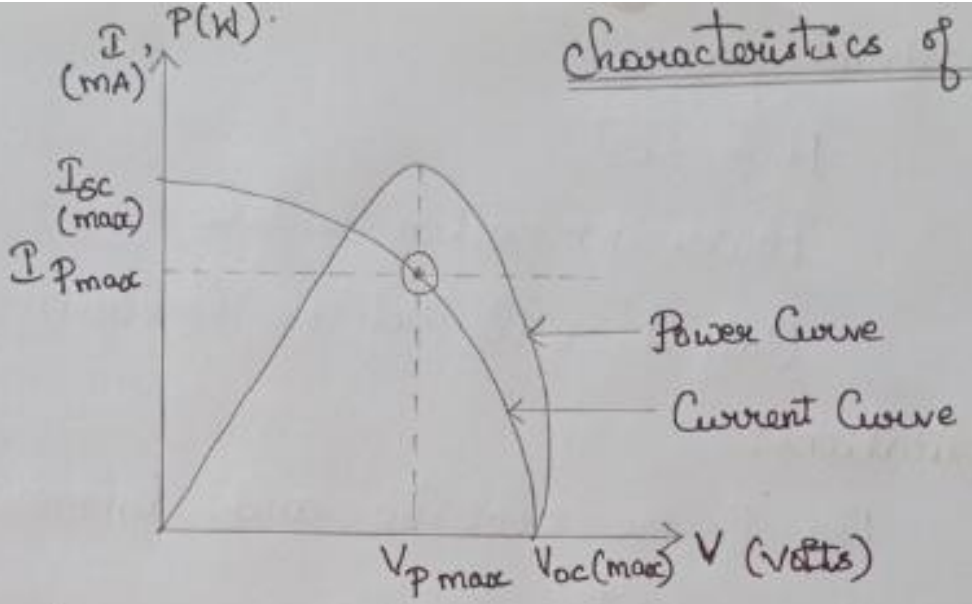


Schematic View of Solar Panel



Equivalent Circuit of Solar Cell

Characteristics of Solar Cell



OPERATION:

Bright Sunlight is made to fall on the Solar Cell.

The Photons in the Sunlight Produce holes and electrons in the PN Junction.

The holes Produced in the junction, moves to the P Layer and the electrons moves to the N Layer.

Concentration of holes and electrons in the P and N Layer increases.

The electrons in N Layer moves towards the holes in P Layer for recombination, if any Connection is made externally between the terminals.

The flow of electrons is known as electric Current and it is Collected.

Advantages:

No Pollution

Less Maintenance

Longer Life

Disadvantages:

High Cost

Power generation is less

Output will not be Constant.

Applications:

For Power domestic and Commercial generation

Solar water heating

Solar Pumping

Solar drying etc.,

RENEWABLE ENERGY SOURCES - WIND ENERGY:

The main Components of Wind Power Plants are,

a). WIND TURBINE:

It Converts Kinetic energy of wind into mechanical energy.

Then the mechanical energy is Converted into electrical energy by using generator.

(i). Nacelle:

Includes gearbox, low and high Speed Shafts, generator Controller and brake.

It is located on top of the tower.

(ii) Rotor:

Combination of hub and the blades is known as rotor.

Mostly horizontal axis turbine uses 2 or 3 blades. Blades are made up of fiberglass - reinforced Polyester (FRP), aluminium etc.,

(iii) Hub and Shaft:

Rotor is attached with Shaft and hub.

Hub is in Conical in Shape and it is fixed in front Portion of the Shaft.

(iv). Anemometer:

This device is used for measuring the wind Speed.

Wind Speed is fed to Controller, where the Controller Varies the angle of blades etc., according to anemometer input for effective Operation.

b). TRANSMISSION SYSTEM:

The mechanical energy generated by the turbine is transmitted to electric generator by Transmission System which is in nacelle.

Transmission System Consists of gear box, clutch, braking System etc., in it.

Gear box is to increase the Speed and to maintain the Constant Speed of the rotor.

c). ELECTRIC GENERATOR:

It is used to Convert mechanical energy into electrical energy.

Generators used may be induction generator or Synchronous generator.

d). YAW CONTROL SYSTEM:

It changes the Position of nacelle according to the direction of wind.

Used mainly in horizontal axis wind turbine.

Wind Vane is mounted on top of the nacelle, it Senses the wind direction and wind turbine Controller Operates the yaw drives.

e). STORAGE:

Energy Storage is used to Store energy when there is excess Power developed and it is discharged when there is lack of energy.

Lead-Acid battery is most Commonly used.

f). ENERGY CONVERTERS:

Electric energy Produced from wind energy is direct Current (DC), it has to be Converted into alternating Current (AC) before transmitting into transmission grid.

So the Converters are used to Convert DC to AC.

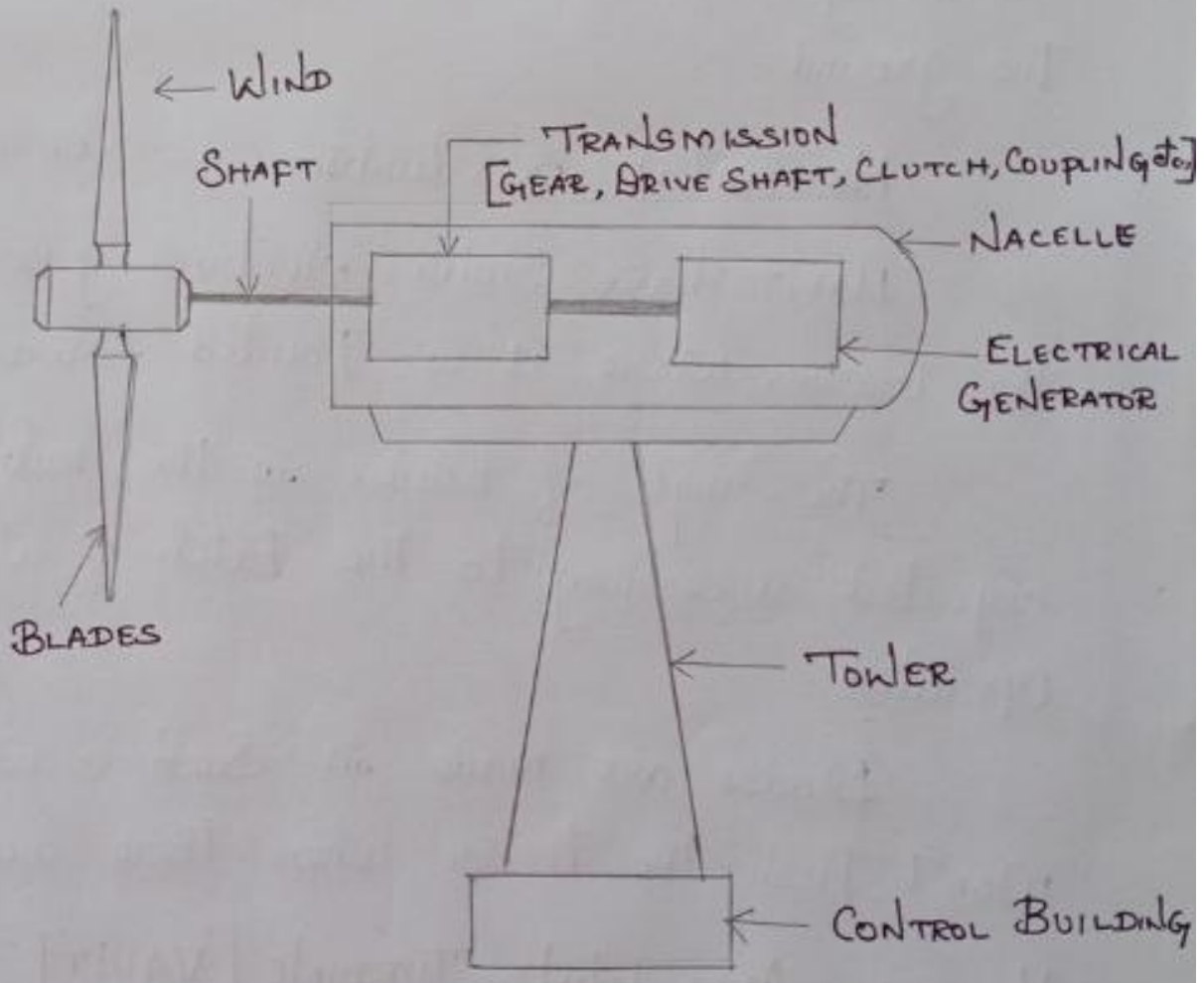
9). TOWERS:

Towers are used to place wind turbine over it.

It is made of tubular steel or steel lattice.

Towers are designed to withstand wind loads and gravity loads.

Tower height should be 12m to 37m for small turbines and 30m to 75m for moderate and high turbines.



ADVANTAGES:

Source is free of Cost

No Pollution

Renewable energy Source.

DISADVANTAGES:

High Capital Cost

Noisy

Seasonal energy.

(8) APPLICATIONS:

Power generation
Pumping
Rural applications

HORIZONTAL AXIS WIND TURBINE [HAWT]

In this turbine, the rotating shaft is Parallel to the ground and the blades are Perpendicular to the ground.

Horizontal axis turbine is Commonly used.

HAWT have rotor, electric generator at top of the tower, where it is Pointed towards wind.

The angle of blades in the hub is also adjusted according to the Pitch of wind for effective Operation.

Blades are made in Such a way that, it Won't Push the tower when there are high winds.

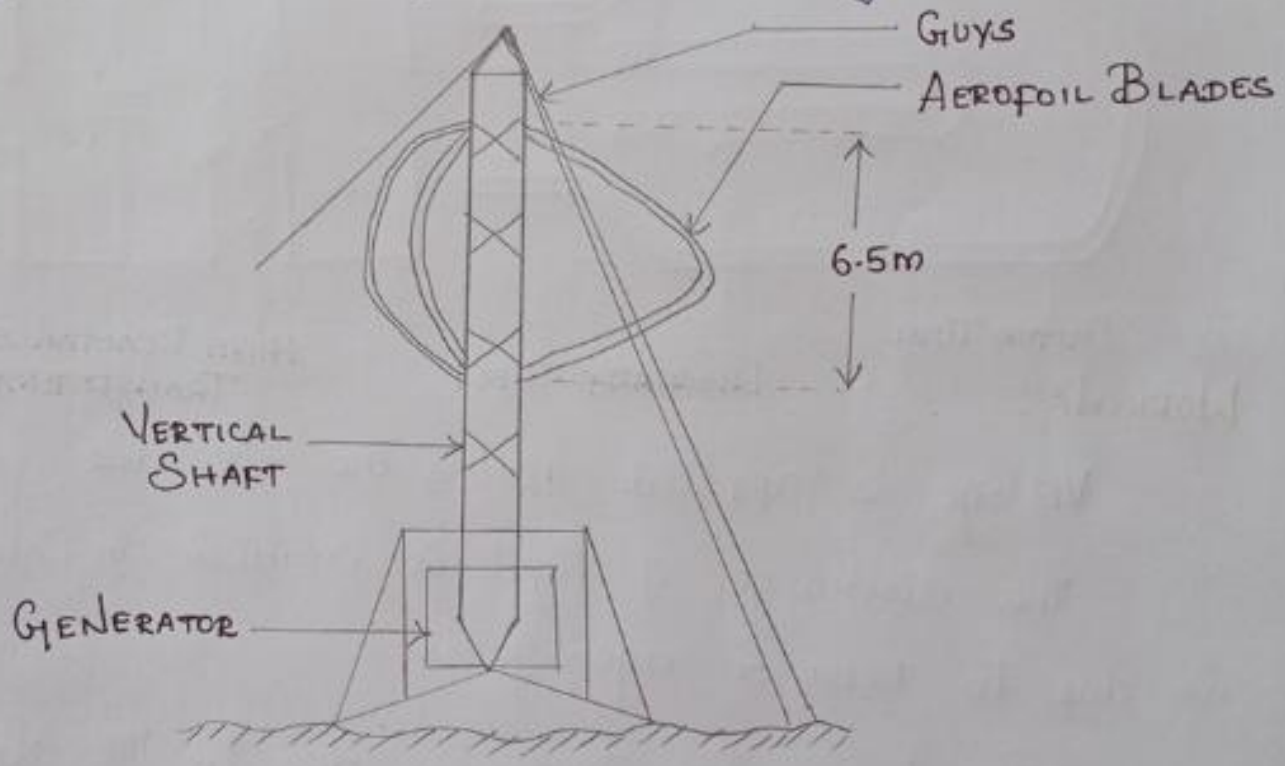
VERTICAL AXIS WIND TURBINE [VAWT]

In this turbine, the rotating shaft is Vertical to the ground.

Here the generator with gear System is placed near the ground.

There is no need of turbine to Point towards the wind because it is independent of winds direction.

The Power generation will be low as, VAWT has no towers, it will be near the ground level and the wind Speed near the ground will be low.



ILLUMINATION OF LAMPS:

1. SODIUM VAPOUR LAMP:

Construction:

Consists of two glass tubes - Outer glass tube and inner glass tube.

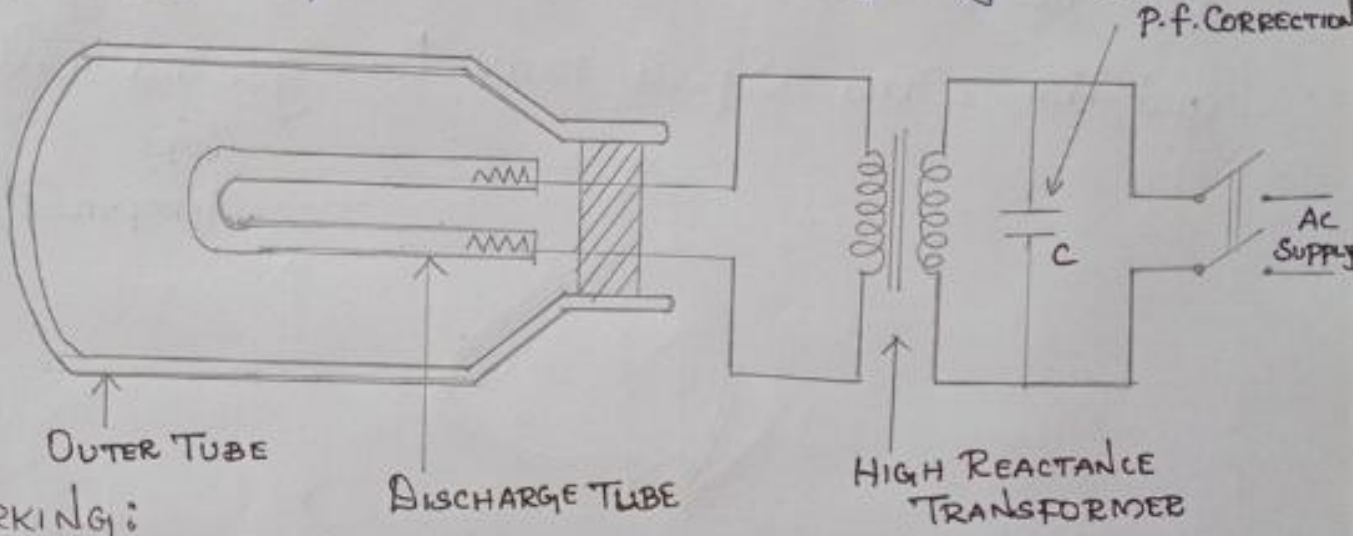
Inner glass tube Consists of electrodes.

Inner glass also Consists of Sodium and Small quantity of neon or argon gas for the Purpose of light

discharging.

The above setup is placed inside the outer tube. Outer tube reduces the heat loss.

The electrodes are connected with transformers which heats up to initiate the lighting.



WORKING:

Voltage is applied across the electrode.

The discharge of light is reddish in colour which is due to neon or argon gases.

The temperature increases, due to the above discharge and vaporizes the sodium, and it gives out the yellow discharge.

The yellow light discharge is the normal operation of lamp.

Operating temperature of the lamp is 300°c

ADVANTAGES:

→ Efficiency is high than filament lamp.

→ It lasts longer.

DISADVANTAGES:

Takes time to give full Output.

It is not applicable for indoor applications.

APPLICATIONS:

Street lighting

Industrial lighting etc.,

2. MERCURY VAPOUR LAMP:

CONSTRUCTION:

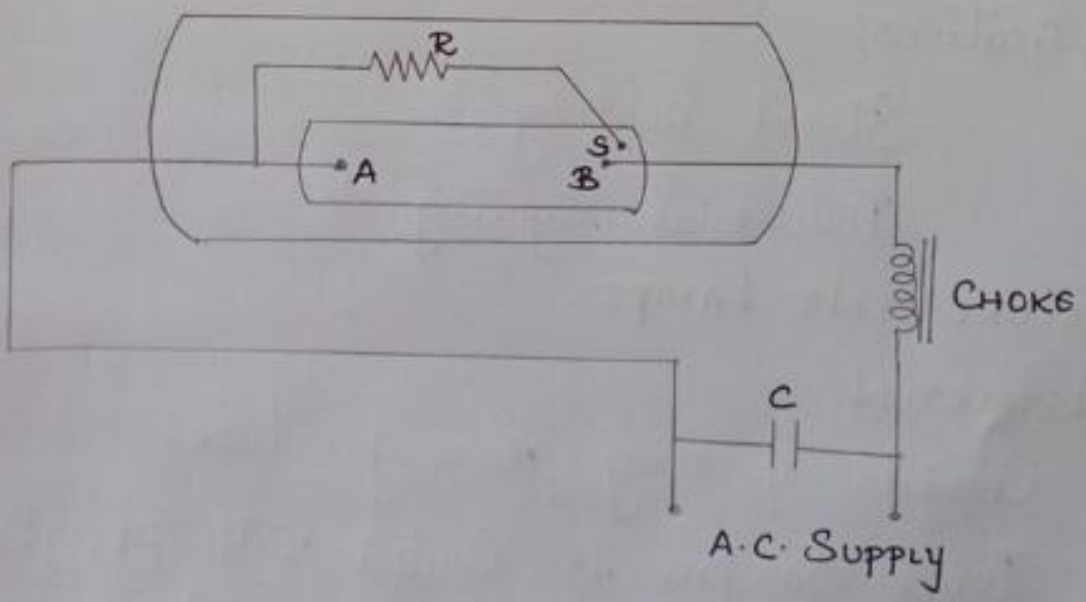
Consists of two bulbs - inner bulb and Outer bulb.

The inner bulb consists of electrodes A, B and S.

Electrode A and S are Connected by high resistance.

The inner tube also consists of mercury and argon gas in it.

The above Setup is placed in the Outer bulb. Outer bulb reduces the heat loss.



WORKING:

Voltage is applied across the electrode.

First the discharge of light occurs between electrode B & S and then between A & B.

Due to this discharge, the temperature gets increased and the mercury gets Vaporized and gives out whitish light as discharge and this is the normal Operation of lamp

Advantages:

High efficiency
Lasts Longer

Disadvantages:

Takes time to Start.
If the temperature is high, Lamp goes out of Service.

Applications:

Street lighting
Industrial lighting etc.,

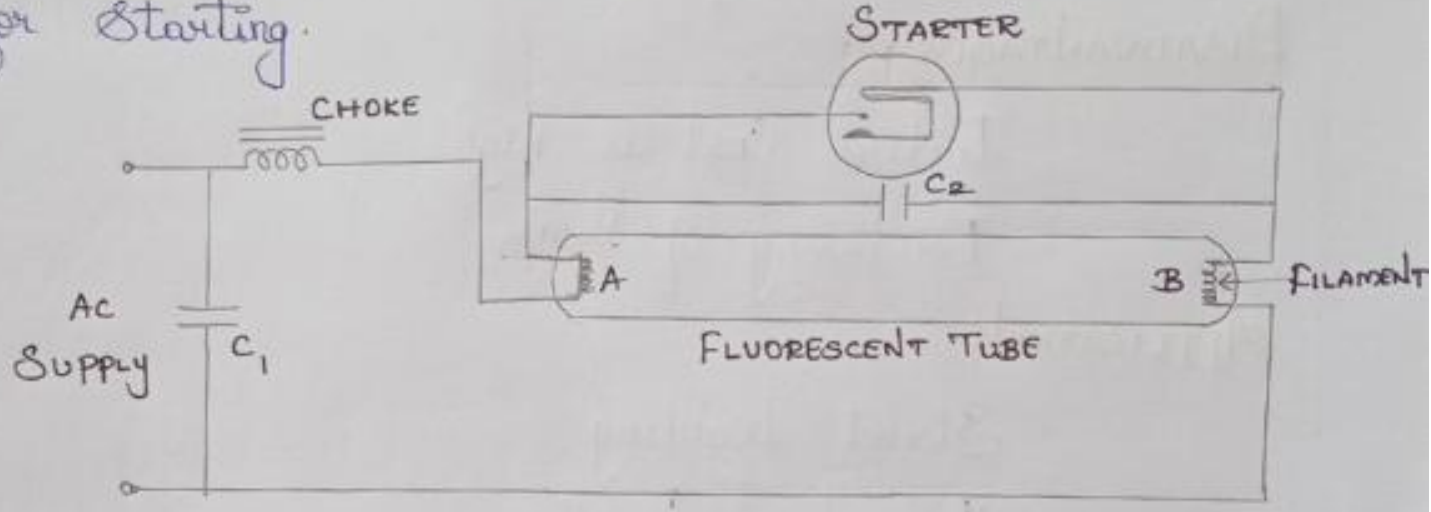
3. FLUORESCENT LAMP:

CONSTRUCTION:

Consists of long glass gas tube
Inner Surface is Coated with Phosphor and the tube is filled with argon gas with minimum mercury.

The glass tube is closed at its both ends by electrodes.

The fluorescent lamp requires choke and Starter for Starting.



OPERATION:

Voltage is applied across the electrodes through the choke and Starter.

Electrons from one electrode moves from to other electrode - arc.

For Starting the lamp, high Voltage is required to ionize the gas inside the tube.

So the choke is used to Produce high Voltage of 1100V.

Starters are used to Start the lamp.

After ionizing of gas the electrons Starts Passing from one electrode to other and Starts illuminating.

ADVANTAGES:

Energy efficient
Lasts Longer.

DISADVANTAGES:

Initial Cost is high
Flickering of lamp

APPLICATIONS:

Street Lighting
Industrial Lighting
Domestic Lighting, etc.,

AIR CONDITIONER:

Air Conditioner is used to maintain the room temperature at optimum level.

The general working of AC has three main Parts (evaporator, Condenser and Compressor).

It Consists of two Coils, (evaporator and Condenser) filled with refrigerant.

Evaporator - Colder than the room temperature
Condenser - hotter than the atmosphere temperature

Refrigerant flows in the Coils. The refrigerant absorbs from the room temperature and leaves out to the atmosphere.

First the hot air from the room is absorbed and blowed on to the evaporator.

When the hot air is blowed, the liquid refrigerant gets Converted into hot gases.

The evaporator Coil wrings out moisture from the incoming air, which helps to dehumidify the room.

This hot refrigerant gas is then passed on to the Compressor where the gas is Compressed and so its temperature gets increased.

The hot gas then enters the Condenser where the gas gets Converted into liquid (i.e., it loses its heat and gets Cooled).

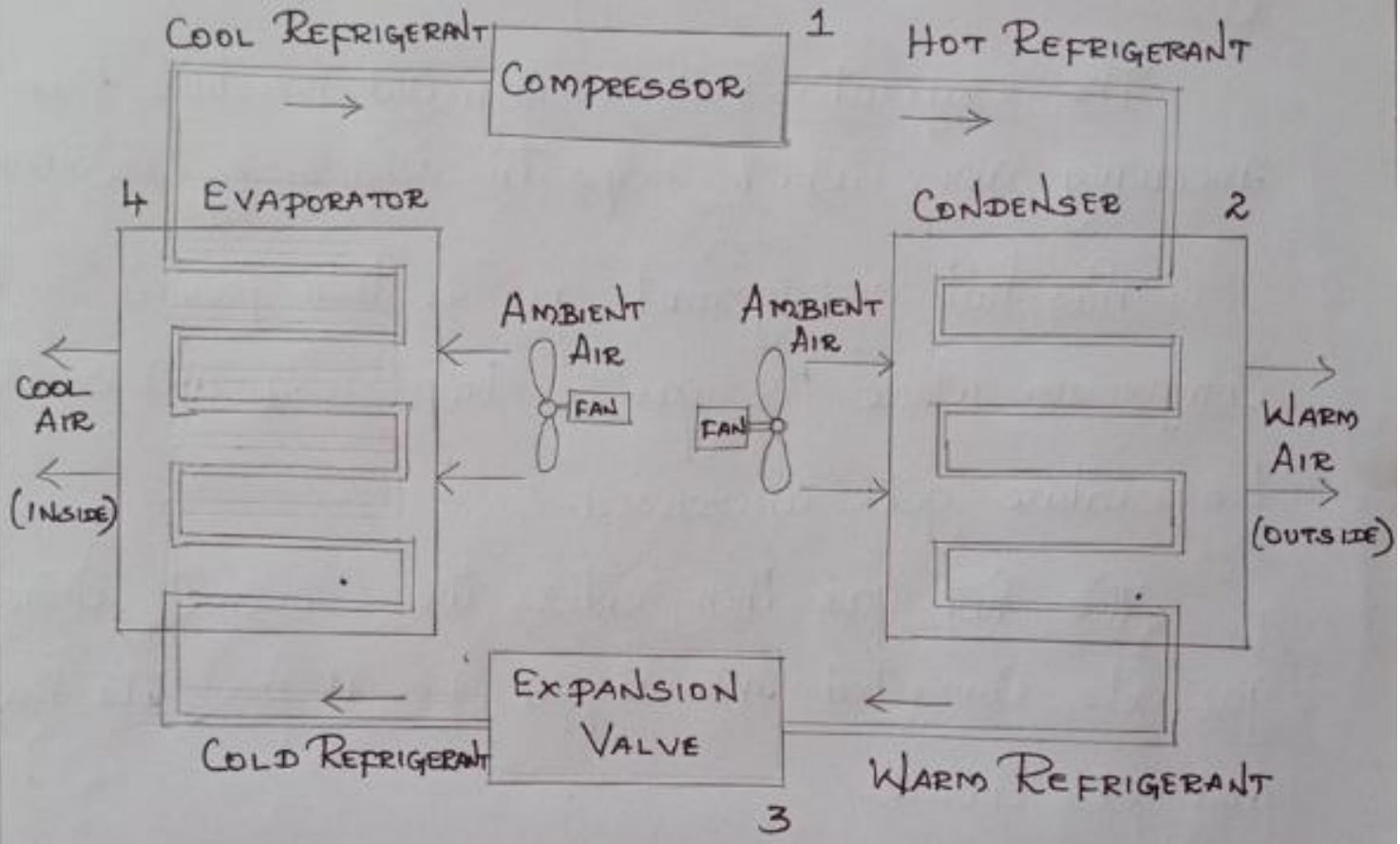
Than the refrigerant is given to the expansion Valve.

The expansion Valve reduces the Pressure and the temperature gets reduced further.

And then the liquid refrigerant is given to the evaporator and the Process is repeated.

If the evaporator and the Condenser are in the Same enclosure, it is known as window air Conditioning System.

If the evaporator (inner side) and the condenser (outer side) are in different enclosures, it is known as Split air Conditioning System.



Advantages:

Reduces dehydration

Improves Comfort level at work

Disadvantages:

Uses more energy.

May Cause Some health issues.

Applications:

Commercial and residential buildings.

Computer rooms, etc.,

Refrigeration:

Consists of Evaporator, Condenser, Compressor and Throttling Device (Capillary Tubes).

Diameter of Capillary tube - 0.6 mm and length is 2 mm

First the liquid refrigerant which is of high Pressure is Passed to Capillary tube.

Here the Pressure and temperature of liquid gets reduced and the liquid refrigerant is Partially Converted into gas. Then it is given to evaporator in the Cabin.

The heat in the Cabin is absorbed by the evaporator and Converts the Partially Converted gas into Pure gas

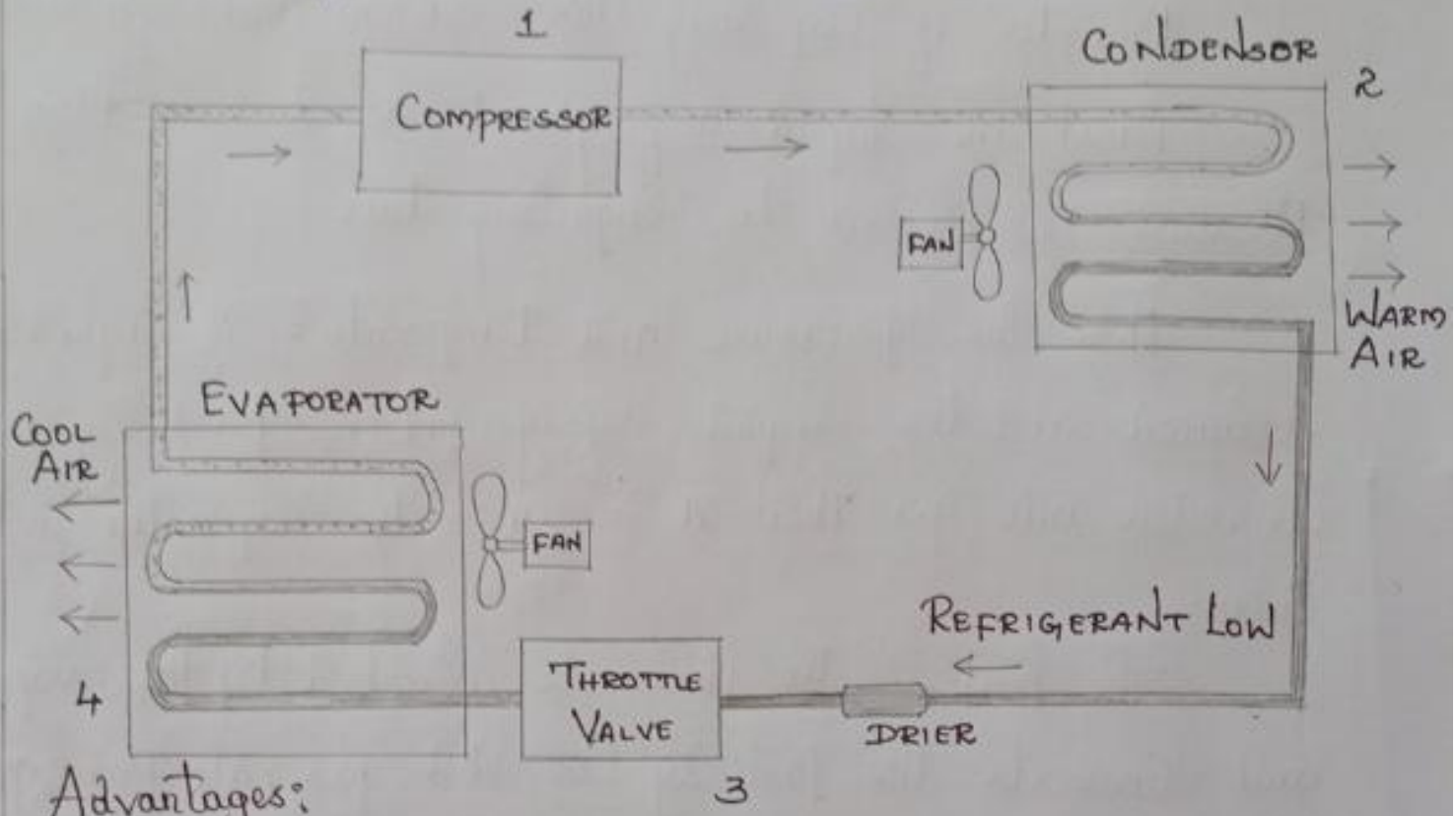
Now the hotness in the gas has to be exhausted Out, and the gas has to be Converted into liquid again.

So the gas is moved to the Compressor, whereas the temperature and Pressure of gas gets increased.

The Pressurized hot gas is now Passed to the Condenser.

The Condenser Condenses the gas refrigerant into liquid by exhausting the hotness in gas to the atmosphere.

Now again the Pressurized liquid refrigerant is Passed to Capillary tube and the Process is repeated for Continuous Cooling.



Advantages:

Simple Construction and no Complicated Parts.

Air Can be used as refrigerant.

Disadvantages:

High running Cost.

Bulky and requires larger Space.

BATTERIES:

1. Lead - Acid Battery:

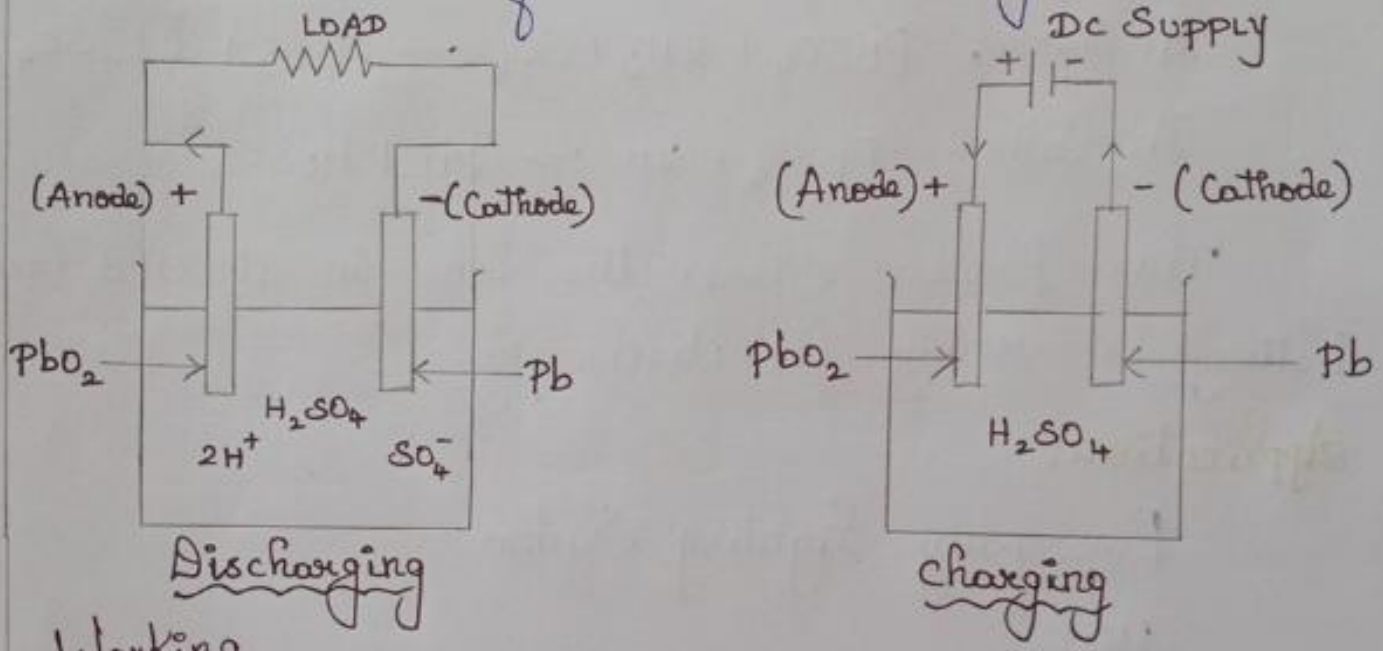
Battery which uses Sponge lead and lead Peroxide for the Conversion of Chemical energy into electrical Energy is Known as lead acid battery.

Lead-acid Cell gives Out 2.1V.

Construction:

Consists of two electrode., anode (i.e) +Ve terminal (Lead Peroxide) and Cathode (i.e) -Ve terminal (Sponge lead) and Sulphuric acid with distilled water as a electrolyte.

Two electrodes are dipped in the Container and the Container is filled with electrolyte.



Working

Discharging:

Load is Connected between the two electrodes

The molecules in dilute Sulphuric acid Split into +Ve hydrogen ions and -Ve Sulphate ions.

At Anode, $PbO_2 + 2H \longrightarrow PbO + H_2O$

$PbO + H_2SO_4 \longrightarrow PbSO_4 + H_2O$

At Cathode, $Pb + SO_4 \longrightarrow PbSO_4$

This forms Potentials at the electrode which is given out by external Circuit.

Charging:

DC Source is Connected with the electrode. +Ve terminal of DC Source is Connected with lead Peroxide and -Ve terminal is Connected with lead.

At Anode, $PbSO_4 + 2H_2 + SO_4 \rightarrow PbO_2 + 2H_2SO_4$

At Cathode, $PbSO_4 + 2H \rightarrow Pb + H_2SO_4$

This Process Stores the ions in it and now the battery is ready for discharging.

Applications:

Emergency lighting System

UPS

Automobiles.

2. NICKEL CADMIUM BATTERY:

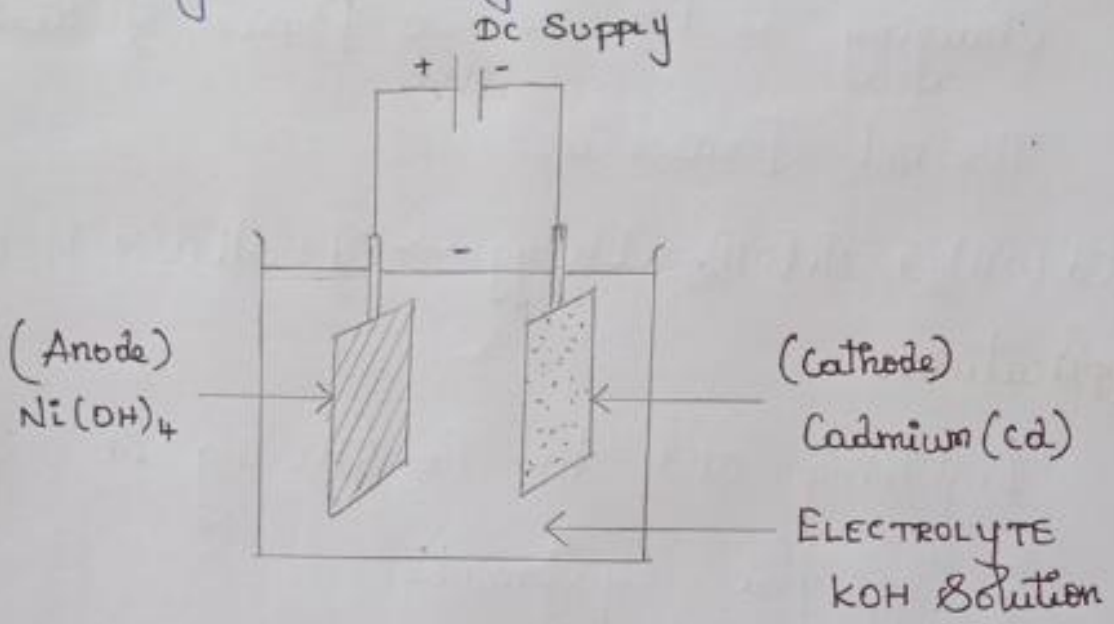
Battery which uses nickel hydroxide and Cadmium for the Conversion of chemical energy into electrical energy is known as nickel Cadmium battery.

Construction:

Consists of two electrode - Cathode (Nickel hydroxide), anode (Cadmium) and electrolyte (Potassium hydroxide).

Two electrodes are diped in the Container and the Container is filled with electrolyte.

This battery Supply high Currents and it Can be recharged rapidly.



Working:

Discharging:

Load is Connected between the two electrodes

At Anode, Cadmium reacts with hydroxide to give Cadmium hydroxide and electrons.

$$Cd + 2OH^- \longrightarrow Cd(OH)_2 + 2e^-$$

At Cathode, nickel Oxide reacts with above formed two electrons to form nickel hydroxide and hydroxide.

$$NiO_2 + 2e^- \longrightarrow Ni(OH)_2 + 2OH^-$$

Now the net Process is,

$$Cd + NiO_2 \longrightarrow Cd(OH)_2 + Ni(OH)_2 + Energy.$$

Charging:

DC Source is Connected with the electrode. +Ve terminal of DC Source is Connected with nickel hydroxide and -Ve terminal is Connected with Cadmium

Charging is the reverse Process of discharging.

The net Process is,

$$Cd(OH)_2 + Ni(OH)_2 + Energy \rightarrow Cd + NiO_2 + H_2O$$

Applications:

Lightning and Air Conditioning in railways.

Photographic equipments

Cordless electronic devices.

LITHIUM ION BATTERY:

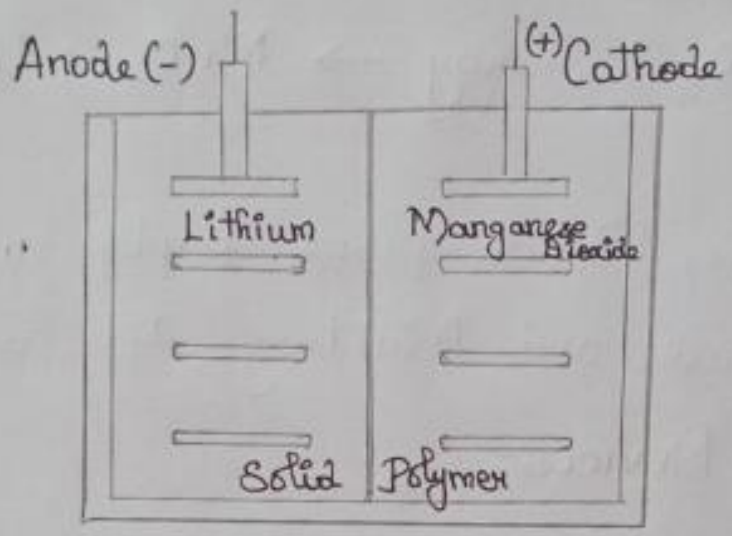
Battery which uses lithium and manganese dioxide for the Conversion of chemical energy into electrical energy is known as lithium ion battery.

Construction:

It is the Solid State battery. No liquid electrolyte is used.

Consists of two electrode - Cathode (Manganese Dioxide) anode (Lithium) and electrolyte (Solid polymer).

The Solid Polymer is Capable of allowing only the lithium ions to Pass through it.



WORKING:

Discharging:

Load is Connected between the two electrodes.

At anode, lithium forms lithium ions and electrons.

$$Li \rightarrow Li^+ + e^-$$

At Cathode, this lithium ions moves to manganese dioxide and forms lithium manganese oxide.

$$MnO_2 + Li^+ + e^- \rightarrow LiMnO_2$$

The net reaction takes place is,

$$MnO_2 + Li^+ \rightarrow LiMnO_2 + \text{Electrical energy}$$

Charging:

Dc Source is Connected with the electrode. +Ve terminal of Dc Source is Connected with Lithium and -Ve terminal is Connected with Manganese dioxide.

Charging is the reverse Process of discharging.

The net Process is,

$LiMnO_2 + Energy \rightarrow MnO_2 + Li^+$

Applications:

Cameras, Mobile phone, Laptop and Bluetooth.

Aerospace and Military applications.

PROTECTIVE DEVICES:

1. FUSE

It is Protective device which Protects the electrical equipments from high Currents.

Fuse is a Small Piece of metal Connected in between the two terminals in an insulating base.

The metal Connected between the terminals is known as fusing element.

Usually, fuse will be Connected in Series with the electrical equipments.

When the high Current due to over load (or) any Short Circuit, the fusing elements melts due to high heat developed by high Current and breaks the Circuit.

The fusing elements may be made of Copper, aluminium, lead, Zinc Silver, etc.,

There are different types of fuses, they are:

a). Rewirable fuse - Consists of fusing element placed in a Carrier. Fusing element melts when there is high Current. If the fusing element is blown off, it Can be replaced.

b). Cartridge type fuse - Here the fuse is enclosed in a Container because there may a chance of generation of arc during blow off. Used in HV and LV applications This fuse is of two types and they are D-type and Link type Cartridge fuse.

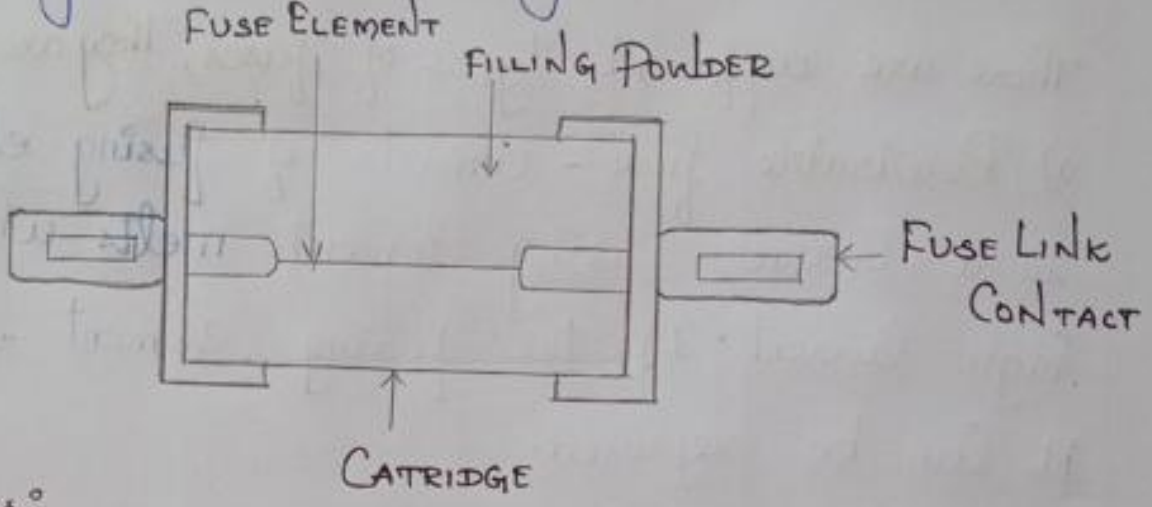
c). High Voltage Fuse - Used in Power Systems to Protect high rating transformers.

d). Expulsion type fuse - Used in Power Systems to Protect feeders, transformers etc.,

e). Liquid fuse - It has fuse and a liquid (oil) in it. During blown off Operation, there will be generation of arc. The oil used will extinguish the arc generated.

f). HRC fuse - High Rupturing Capacity fuse. Consists of quartz Sand Powder. During blow off Operation,

there will be generation of arc. The Sand used will extinguish the arc generated.



Advantages:

- Simple and cheap
- No Maintenance
- Protects from high Current

Disadvantages:

- Requires replacement
- No Secondary Protection

2. CIRCUIT BREAKERS:

Circuit breaker is one in which used to Protect the electrical equipments from high Currents.

CB's makes or breaks the Circuit either manually or automatically in Case of any faulty Conditions.

CB's Consists of two Contacts - fixed and moving Contact, Current transformer and the trip Coil.

The trip Coil is Connected at the Secondary Side of the Current transformer.

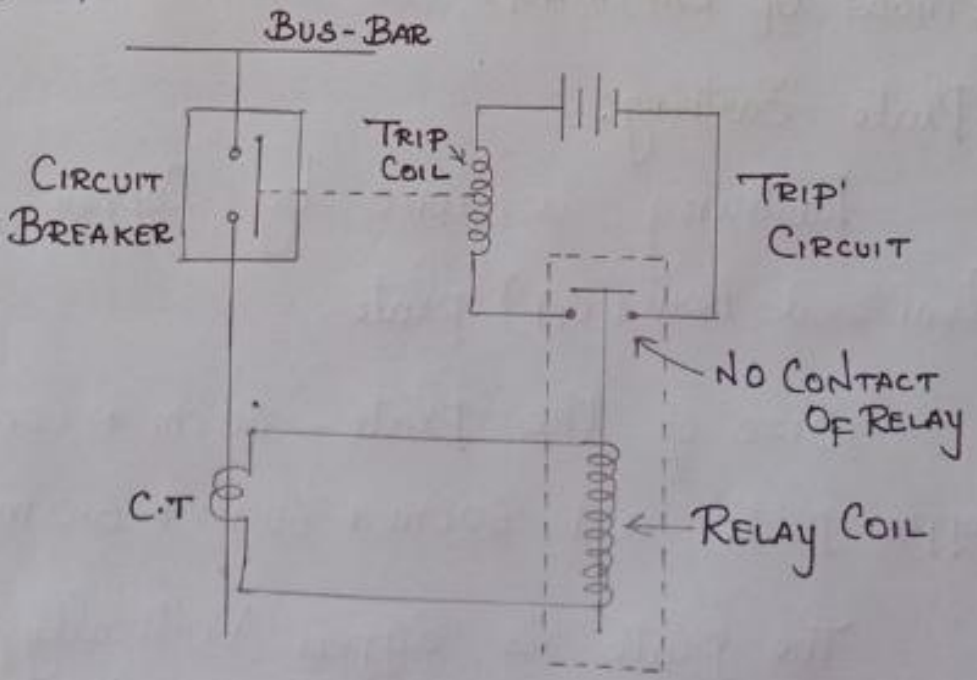
In normal Condition, both the Contacts are physically Connected and the Voltage is not Sufficient to energize the trip Coil.

In abnormal or faulty Condition, the Voltage will be Sufficient to energize the trip Coil.

This trip Coil will move the moving Contact from fixed Contact, thus Contact is Opened.

The time interval between energization of trip Coil and the Contact Separation is Called Opening time.

There are different types of Circuit breaker- air CB's, SF6 CB's, Oil CB's and Air CB's.



Advantages:

Simple and cheap
No Maintenance
Protects from high Current.

Disadvantages:

Aging issues
Rewiring or replacement takes time
No Secondary Protection for fuse.

3. EARTHING:

Earthing is done for electrical equipment to avoid electrical shock which occurs due to faulty condition or leakage Current.

The resistance of earthing material should be Very low.

METHODS OF EARTHING:

a). Plate Earthing:

Earthing is done by Copper plate or galvanized iorn (GI) plate.

Size of the plate - 60cm * 60cm * 3-18mm (Copper plate) and 60cm * 60cm * 6-3mm (GI plate)

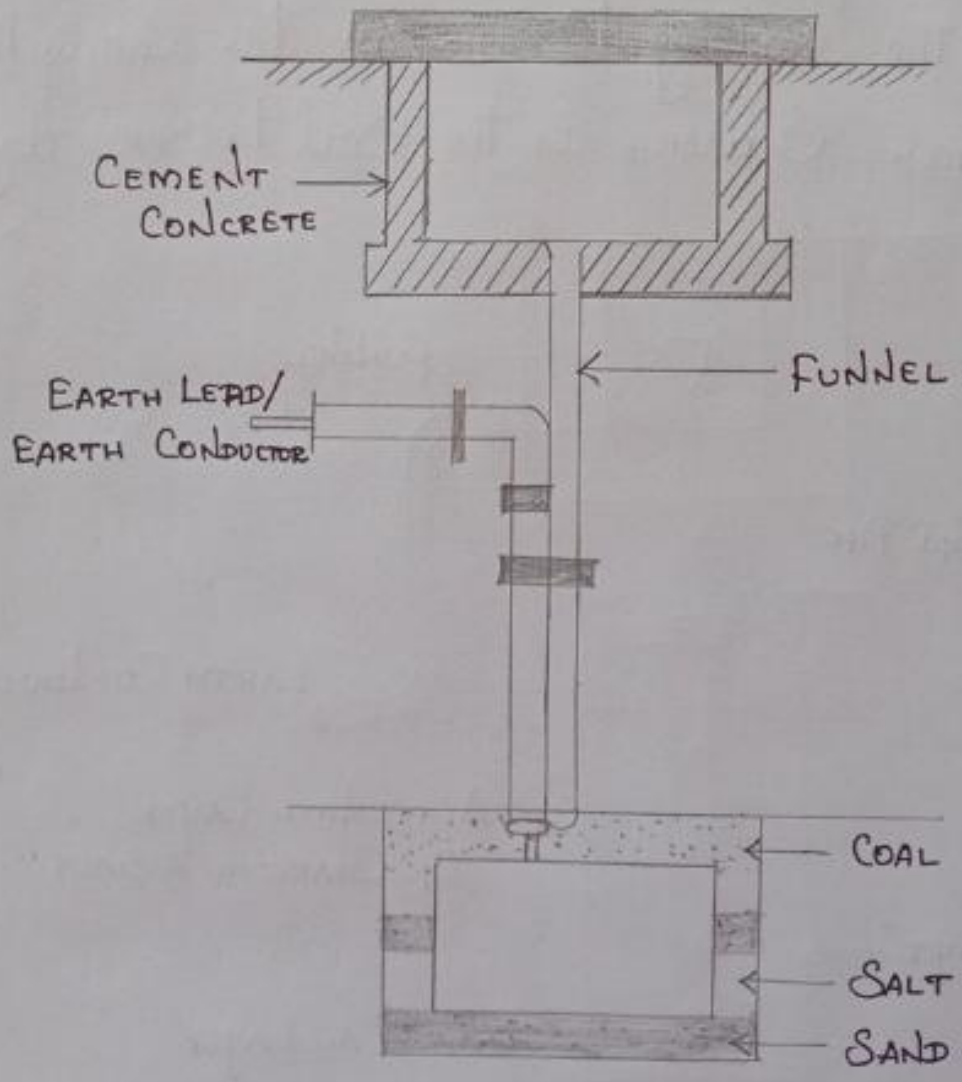
The plate is dipped Vertically into the ground and it is Surrounded by alternate

layer of Salt and Coke to increase the earthing efficiency.

The wire is Connected between the plate and the electrical equipment.

To increase the efficiency of earthing, depth of dipping the plate should be increased.

Funnel is fixed at the top. Salt water is Powred at the earthing to increase the Conductivity during Summer Season, as the Soil becomes dry.



b). Pipe Earthing:

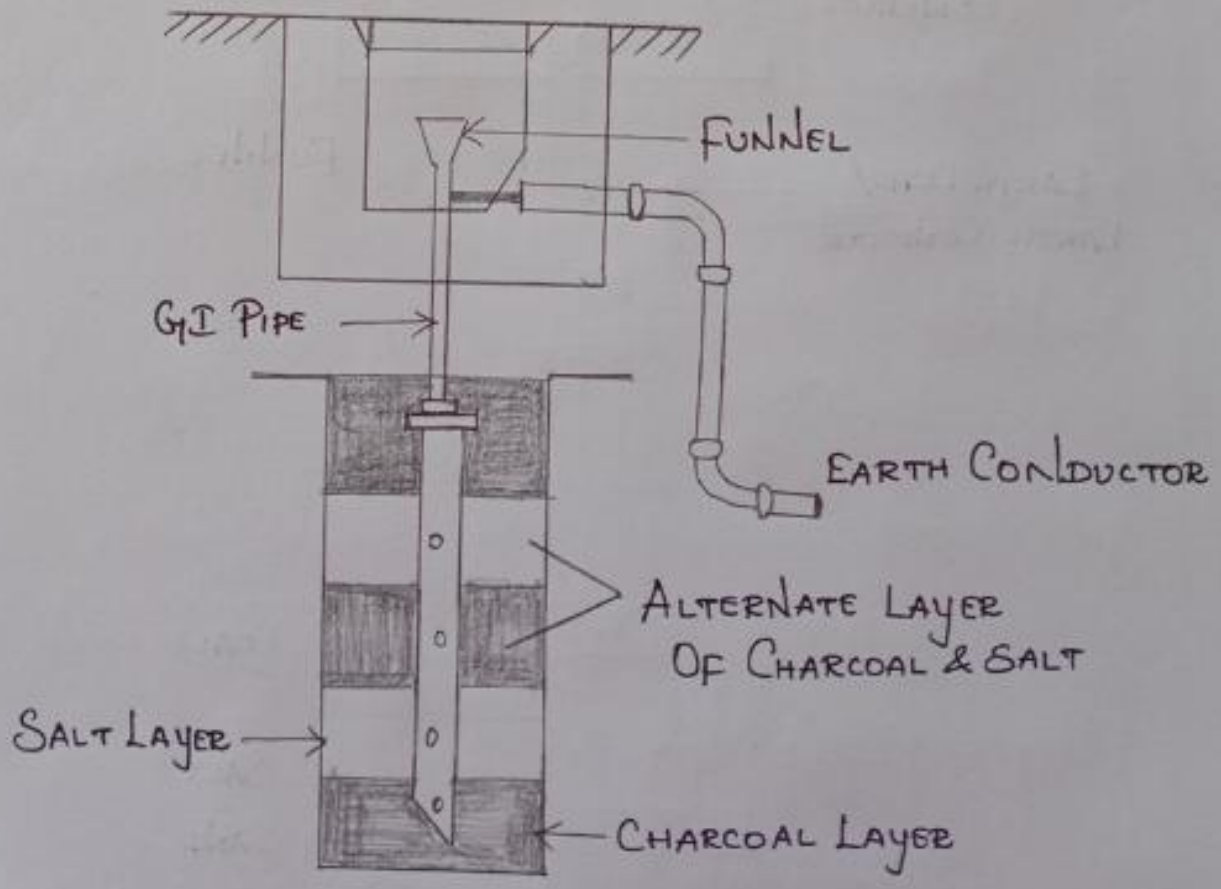
Earthing is done by using galvanized iorn (GI) Pipe.

Size of the Pipe - 38mm diameter and 2m length.

The Pipe is dipped Vertically to the ground and it is Surrounded by the alternative layer of Salt and Coal mixture to increase the earthing efficiency.

It also earths the heavier leakage Current.

Funnel is fixed at the top. Salt water is Powred at the earthing to increase the Conductivity during Summer Season, as the Soil becomes dry.



TARIFF CALCULATIONS FOR ELECTRICAL LOADS:

It is the method of charging the Consumers for the Consumption of electricity, Capital Cost of the Power plant, running Cost and with the minimum Profit.

The tariff is given by, $E = Ax + By + C$

where,

E = total amount of bill for Period Considered

A = rate Per KW of maximum demand.

X = maximum demand (KW)

B = energy rate Per KWh.

Y = energy Consumed in KWh during Period Considered.

C = Constant amount charged to Consumer during each bill Period.

Requirement of Tariff:

Should be easier to understand.

Should Provide low rates for high Consumptions.

Should encourage the Consumers having high load factors.

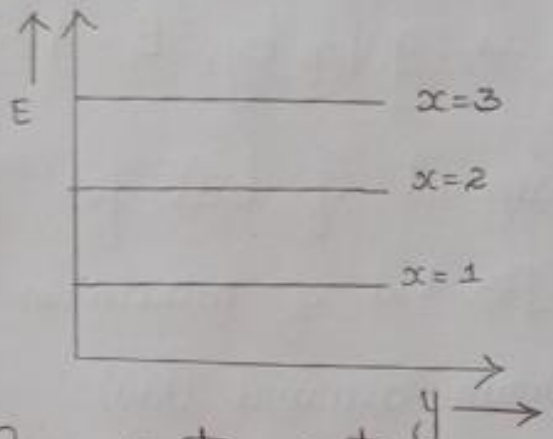
Should Provide less charge for Power Connections than for lighting.

(30) Types Of Tariff:

(i) Flat demand rate:

Charging depends on the Connected load and number of hours of use per month or year.

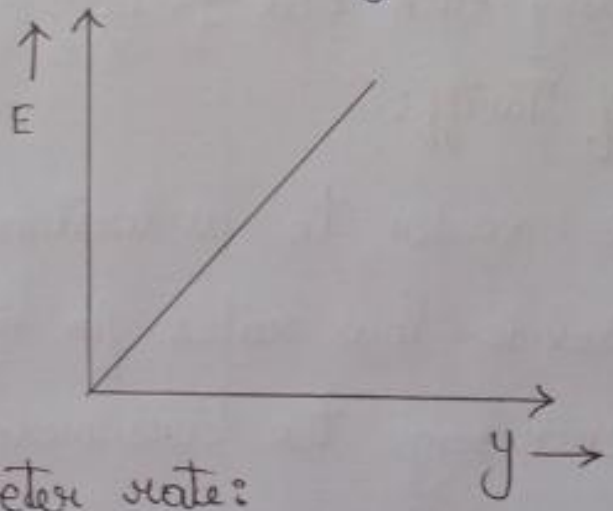
Equation is, $E = Ax$



(ii) Straight line meter rate:

Charging depends on the amount of total energy Consumed by the Consumer.

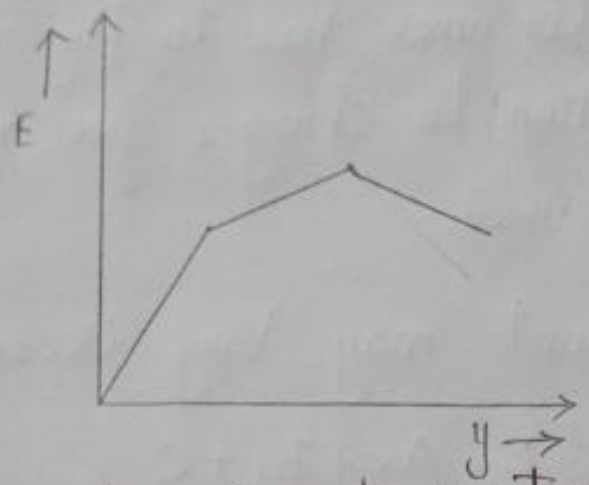
Equation is, $E = By$



(iii). Block Meter rate:

Charging price per units (kWh) is charged for all or any block of each unit and for Succeeding blocks of energy.

Equation, $E = B_1 y_1 + B_2 y_2 + B_3 y_3 + \cdots$



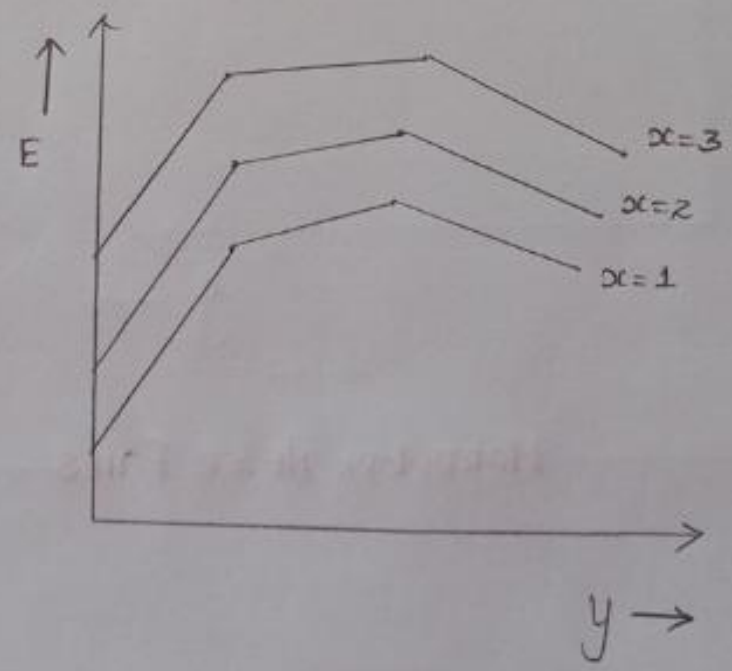
(iv) Hopkinson demand rate (or) Two Part Tariff:

Charging depends on maximum demand and energy Consumptions.

Equation is, $E = A + By$

Here, a meters is used to record maximum demand and energy Consumptions of the Consumer.

Used for industrial Consumers.



(v). Doherty rate (or) Three Part Tariff:

Here the Consumer has to Pay Some fixed amount in addition to charges for maximum demand and energy Consumed.

Fixed amount may Vary Occasionally.

Equation is, $E = Ax + By + C$

Commonly used in India and this method is used to discourage the Consumer in using more Power.

Used for large Consumers.