AUTOMOBILE ELECTRICAL AND ELECTRONIC SYSTEMS (3053)

FIRST MODULE

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Conductors:

A conductor is an object or type of material that allows the flow of charge (electric current) in one or more directions.

The property of conductors to “conduct” electricity is called conductivity.

Eg: Iron,copper, aluminium, gold, silver etc…

Insulators:

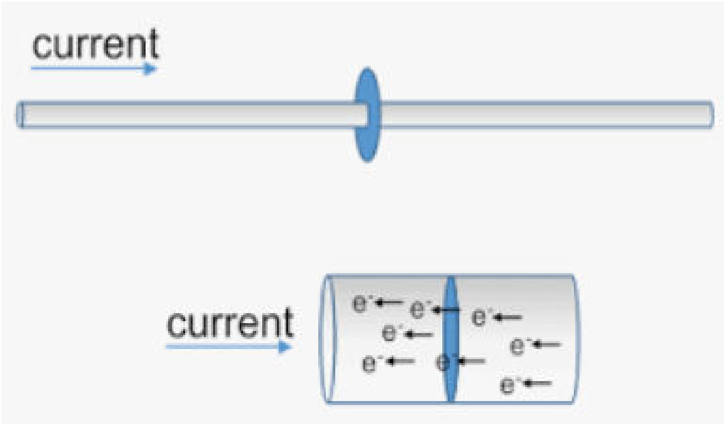
An electrical insulator is **a material in which electric current does not flow freely**. The atoms of the insulator have tightly bound electrons which cannot readily move.

Current (I)

- **The directed flow of free electrons is called *electric current.***
- **Unit of current is *ampere (A)***

Voltage (V)

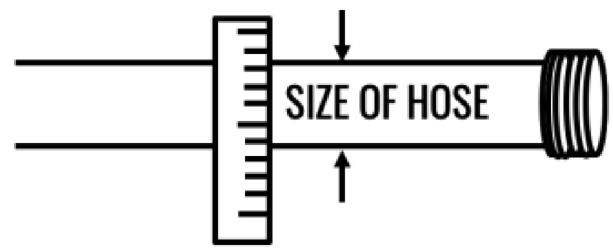
- **The potential difference in charge between two points in an electrical field is called voltage.**
- **Unit of voltage is ' *volt (V)*'**



Electricity is like a water hose

Voltage — Volts (V)

Current — Amps (A or I)

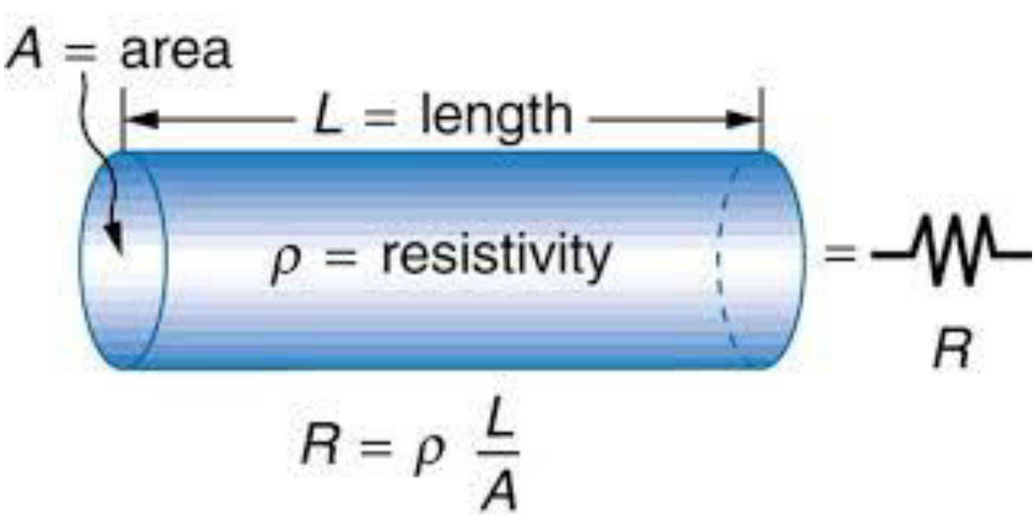


Resistance — Ohms (R or Ω)

FREEING ENERGY

Resistance (R)

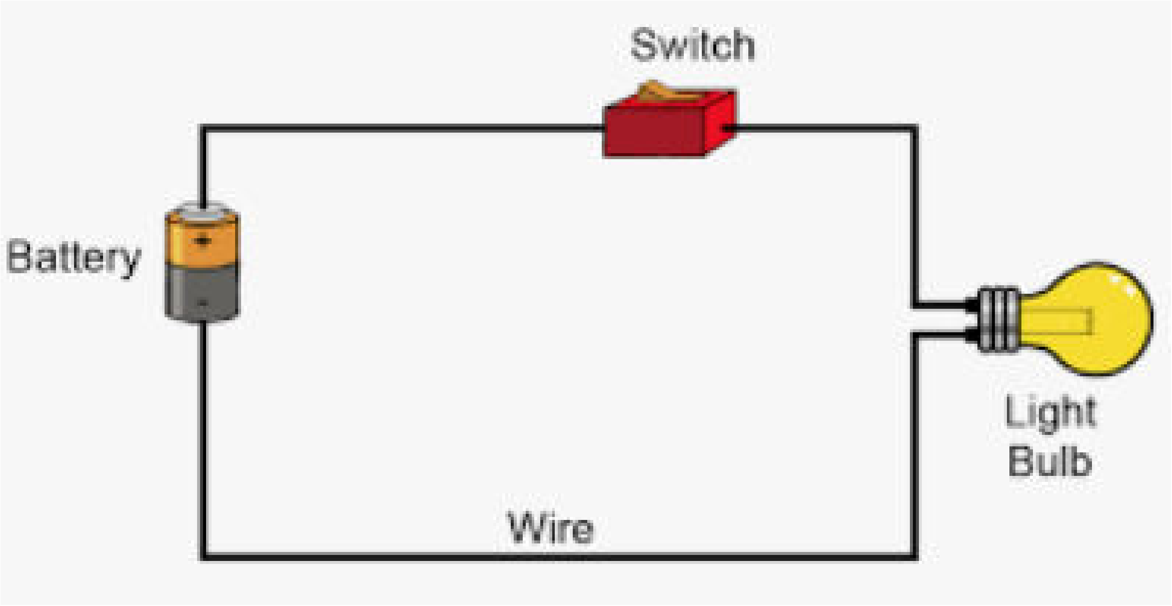
- **The opposition offered by a substance to the flow of electric current is called its *resistance*.**
- **Unit of resistance is *ohm (Ω)***
- ***Resistance is directly proportional to length of conductor and inversely proportional to area of cross section.***



$$\rho = R\,\frac{A}{\ell}$$

- **Electrical circuit:**

An electrical circuit is an interconnection of electrical elements linked together in a closed path so that current may flows continuously.

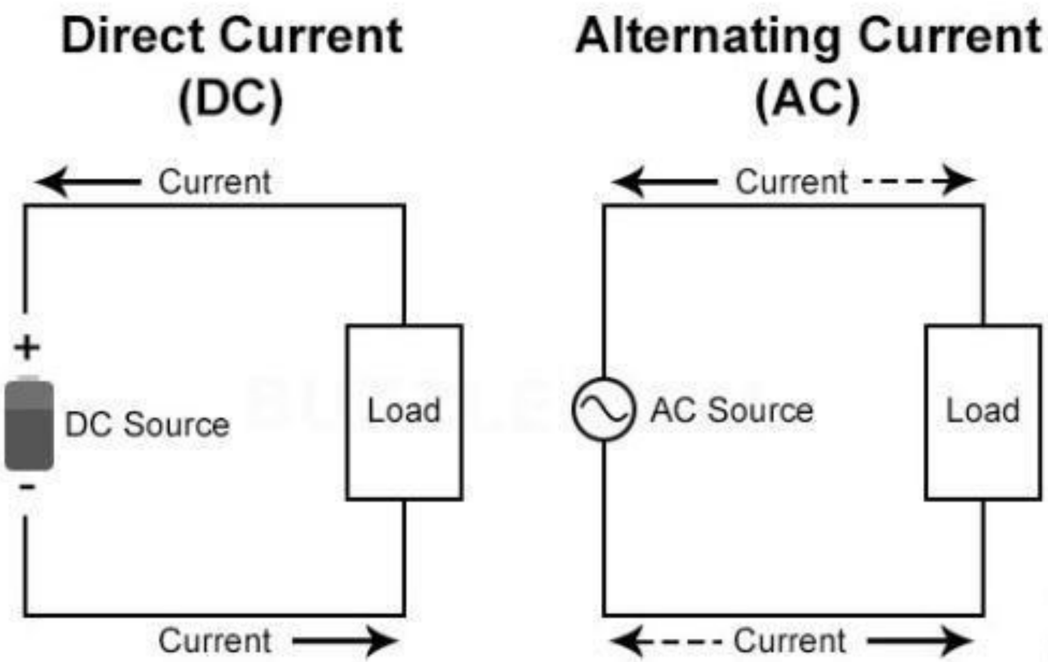


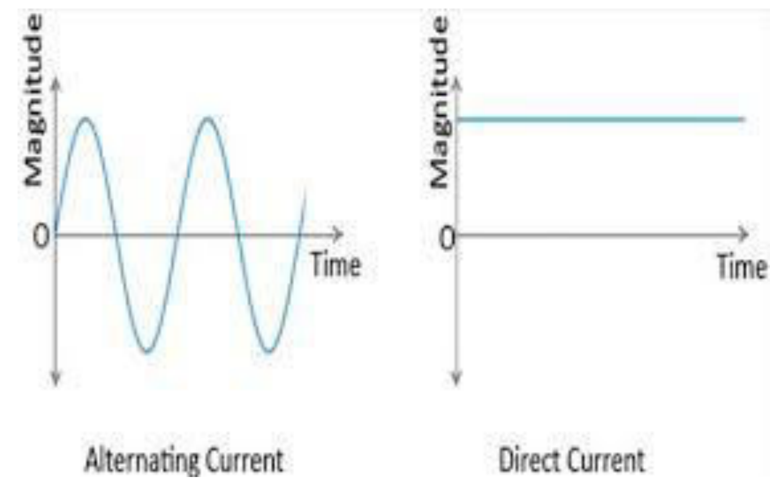
<u>Direct current or DC</u>

A direct current is a current of constant magnitude

<u>Alternating current or AC</u>

An alternating current is current of varying (changing) magnitude and direction





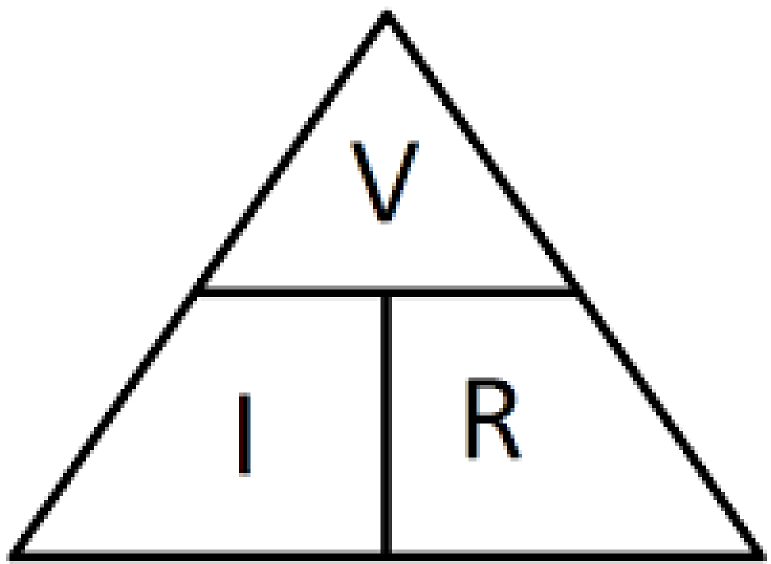
∝

Ohm's Law

- **At constant temperature, current through a conductor is directly proportional to the potential difference between two ends of the conductor.**

$$V \propto I$$

$$\frac{V}{I} = \text{Constant} = R$$



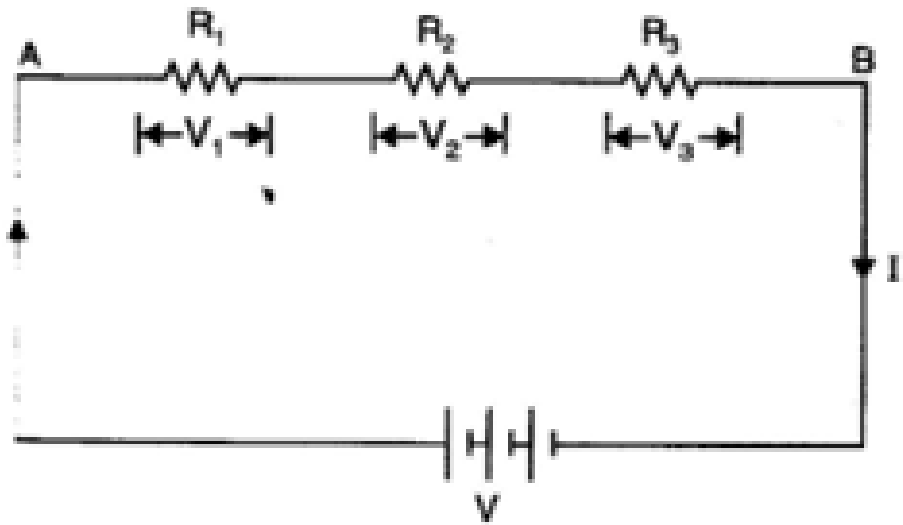
$I = V/R$

$V = IR$

$R = V/I$

Series and parallel combination of resistors

Series



$$V = V_1 + V_2 + V_3$$

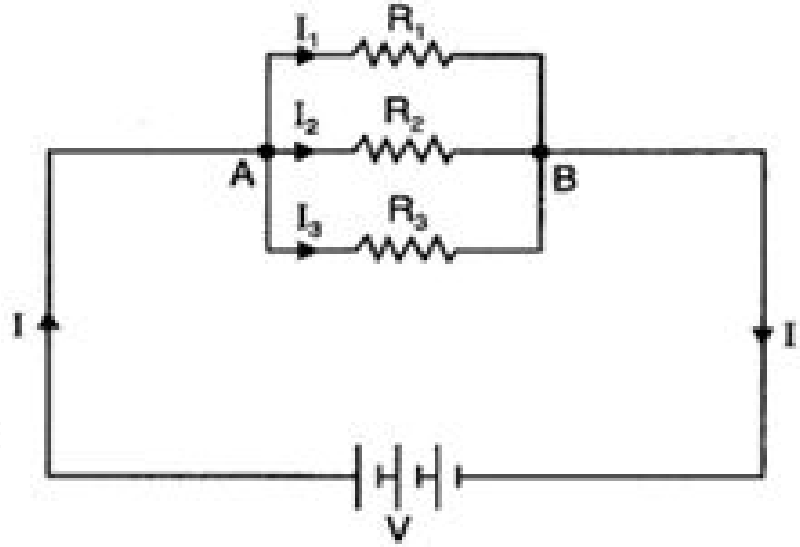
$$= IR_1 + IR_2 + IR_3$$

$$= I\,(R_1 + R_2 + R_3)$$

$$\frac{V}{I} = R_1 + R_2 + R_3$$

$$\boxed{R_S = R_1 + R_2 + R_3}$$

Parallel



$$I = I_1 + I_2 + I_3$$

$$= \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$= V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\frac{I}{V} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\boxed{\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

ELECTRICAL POWER

- The electrical energy consumed by a electrical device in unit time is called electrical power.
- Unit is watt (W)

Power (P) = I^2R

We have;

$I = V/R$

$P = (V/R)^2 \times R$

Power (P) = V^2/R

Also we have;

$R = V/I$

$P = I^2 \times V/I$

Power (P) = $I \times V$

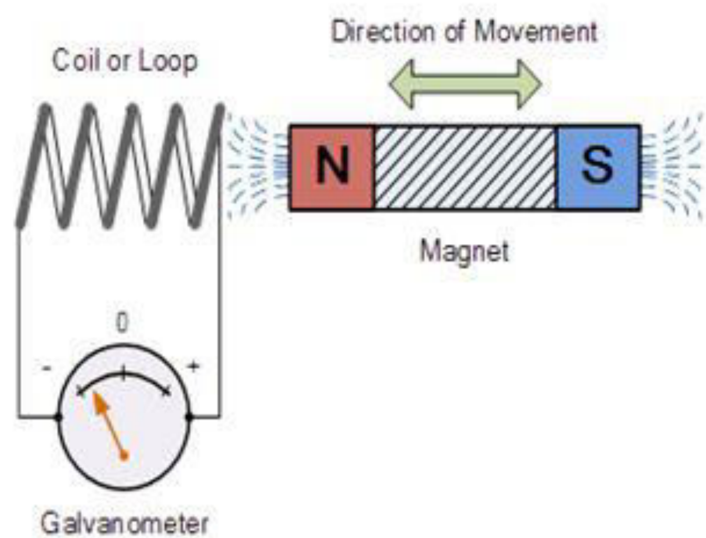
<u>ELECTROMAGNETIC INDUCTION</u>

Whenever there is a change in magnetic field (magnetic flux) linked with a conductor, there will be an induced emf in that conductor

Faraday's laws of electromagnetic induction

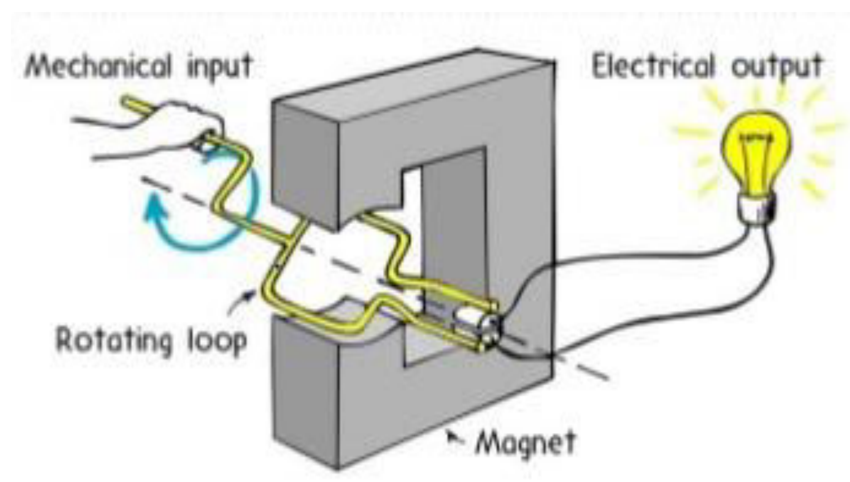
First law

- When the magnetic flux linking a conductor or coil changes, an e.m.f is induced in it.



OR

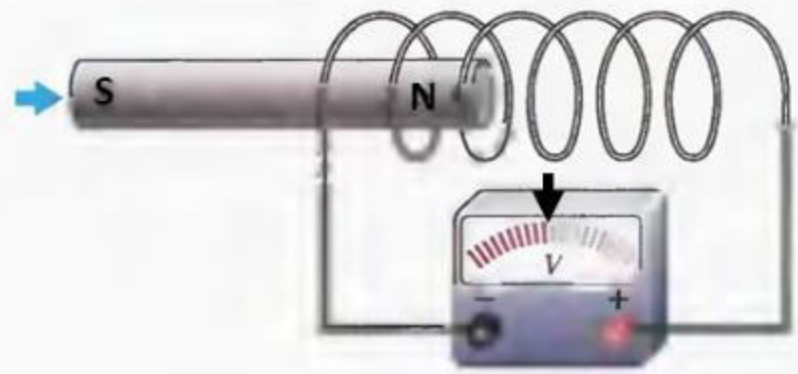
- Whenever a conductor cut the magnetic flux an e.m.f is induced in it.



Second law

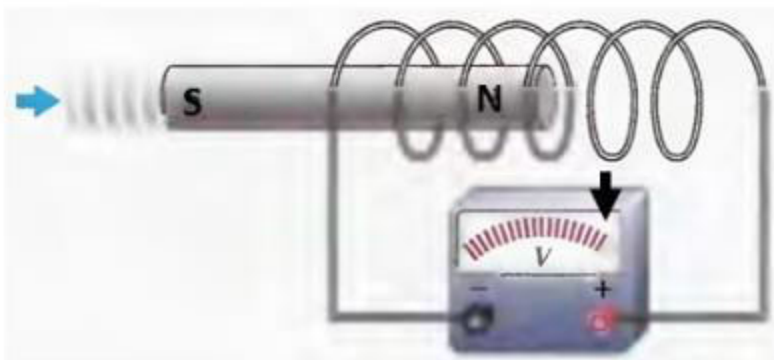
- The magnitude of the e.m.f induced in a conductor or coil is directly proportional to the rate of change of flux linkage.

  - Magnet is moved at certain rate and certain voltage is produced



(a) As the magnet moves slowly to the right, its magnetic field is changing with respect to coil, and a voltage is induced.

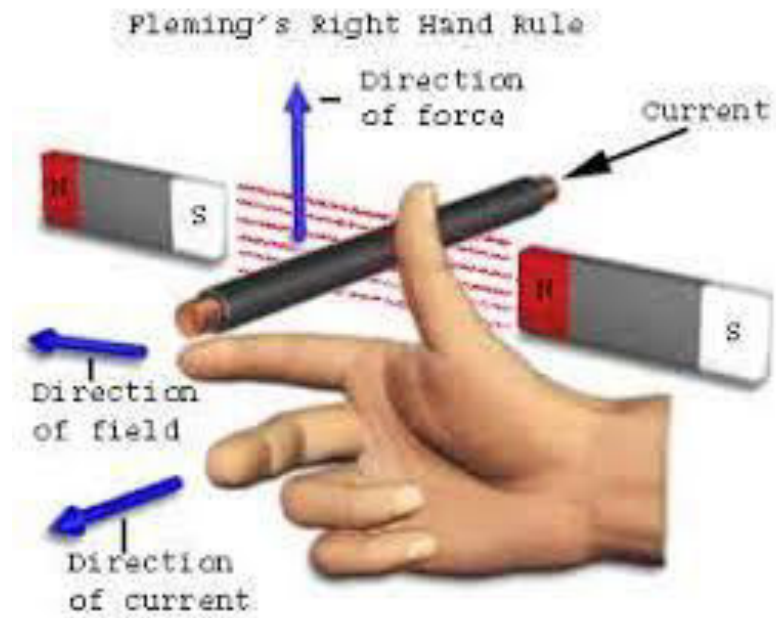
  - Magnet is moved at faster rate and creating a greater induced voltage.



(b) As the magnet moves more rapidly to the right, its magnetic field is changing more rapidly with respect to coil, and a greater voltage is induced.

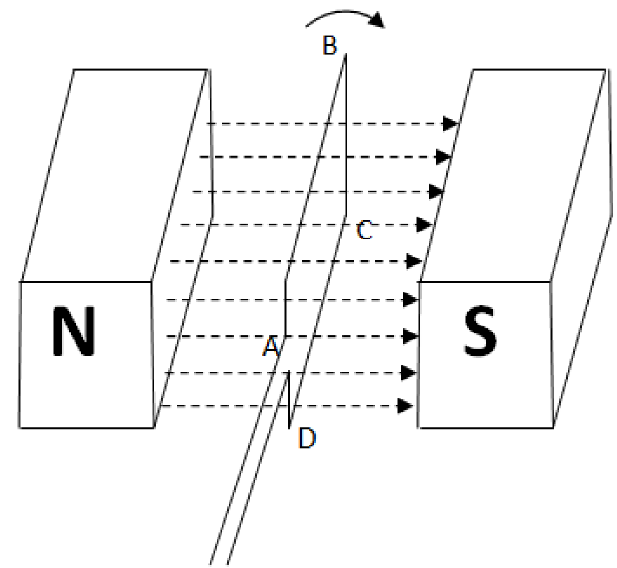
Fleming's Right-Hand Rule

- **Stretch out the forefinger, middle finger and thumb of your right hand so that they are at right angles to one another.**
- **If the forefinger points in the direction of magnetic field, thumb in the direction of motion of the conductor, then the middle finger will point in the direction of induced current.**

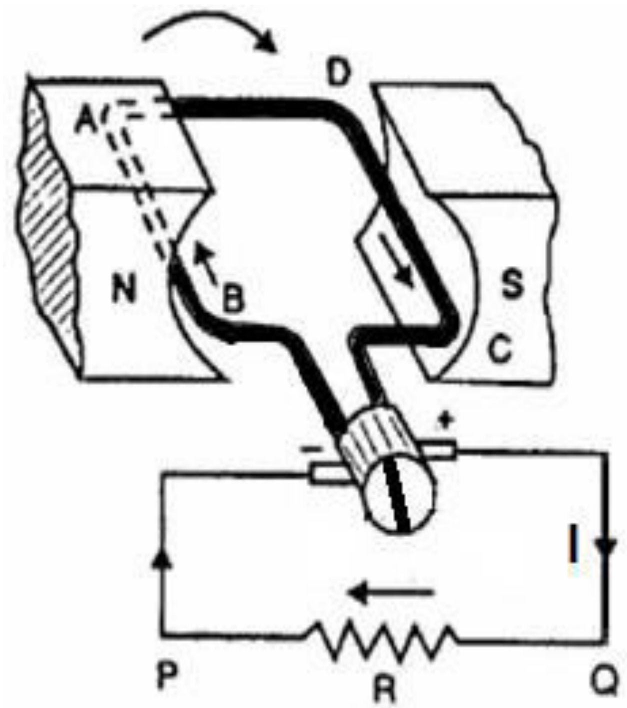


Single loop AC generator(Generation of AC)

- Consider a single turn rectangular coil ABCD rotating clockwise direction in a magnetic field.
- The e.m.f is induced in the coil is proportional to the rate of change of flux linkage.
- When the plane of the coil is at right angle to the lines of flux, rate of change of flux linkage is minimum , hence no e.m.f is induced in the coil
- When the plane of the coil is parallel to the lines of flux, rate of change of flux linkage is maximum hence e.m.f induced in the coil is maximum.



Working of DC generator



- Consider a single turn rectangular coil ABCD rotating clock wise direction in a magnetic field.
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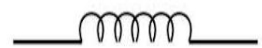
- When the plane of the coil is parallel to the lines of flux, rate of change of flux linkage is maximum hence e.m.f induced in the coil is maximum.
- Emf induced in the armature winding of dc generator is ac , for convertingthis AC into DC in the external circuit commutators are used

R

Resistor

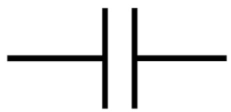
L

Inductor



C

Capacitor



Resistor oppose the flow of current

Inductor oppose change in current

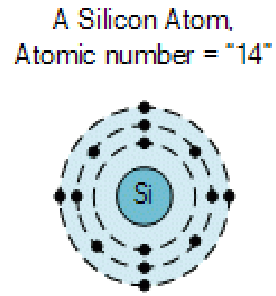
Capacitor oppose change in Voltage

Capacitance is the ability of a component or circuit to collect and store energy in the form of an electrical charge

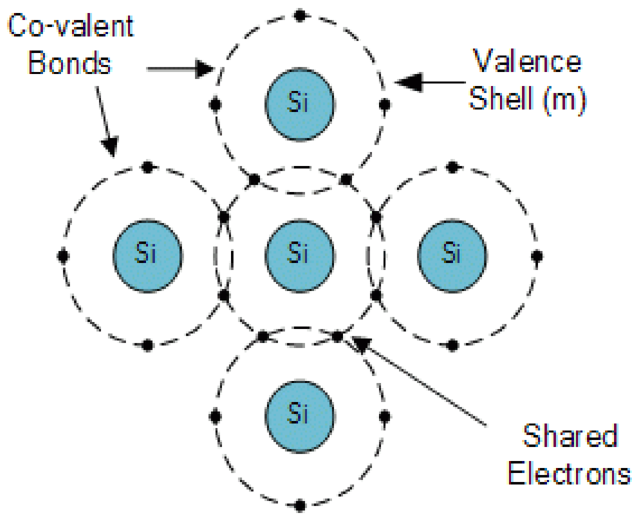
Inductance is the tendency of an electrical conductor to oppose a change in the electric current flowing through it.

Semiconductors

- Certain substance like germanium, silicon etc. are neither good conductors like copper nor insulators like glass. Such substances are called semiconductors.
- The resistivity of these materials lies in between conductors and insulators.
- A semiconductor is substance which has almost filled valence band and nearly empty conduction band with a very small energy gap separating the two.

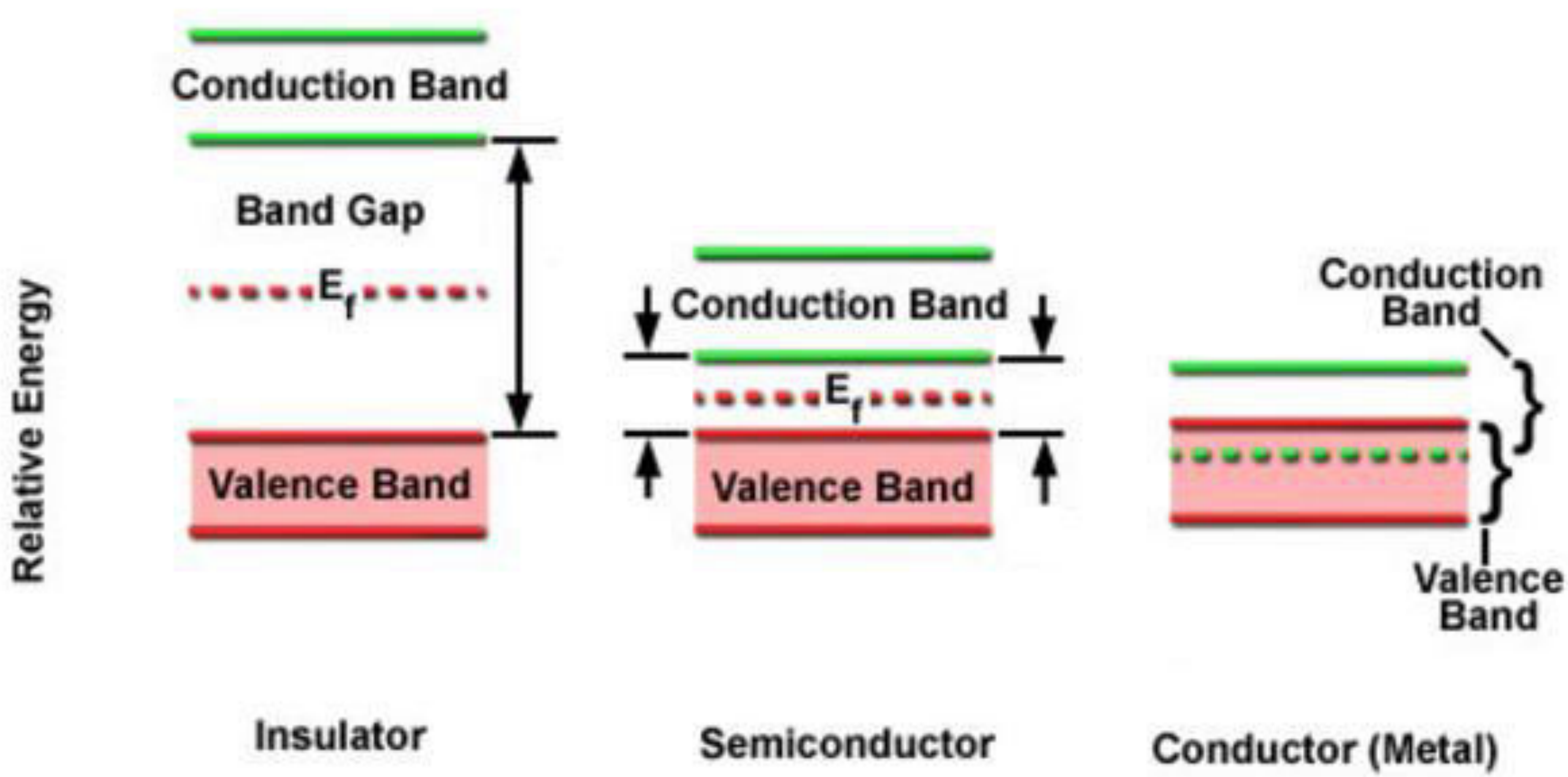


Silicon atom showing 4 electrons in its outer valence shell (m)



Silicon Crystal Lattice

Energy Band Gaps in Materials



Intrinsic semiconductor

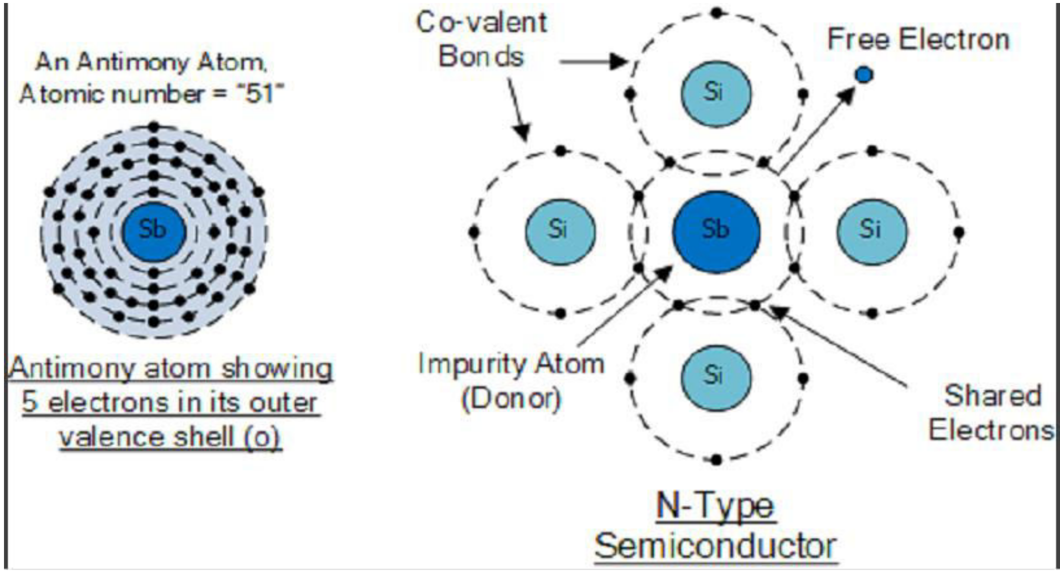
A semiconductor in an extremely pure form is known as an intrinsic semiconductor.

Extrinsic semiconductor

- **The intrinsic semiconductor has little current conduction capability at room temperature. To be useful in electronic devices, the pure semiconductor must be altered so as to increase its conducting property. This is achieved by adding a small amount of suitable impurity to a semiconductor. It is then called extrinsic semiconductor.**
- **The process of adding impurities to a semiconductor is known as doping.**
- **Depending upon the type of impurity added, extrinsic semiconductors are classified into :**
- **N- type semiconductor**
- **P-type semiconductor**

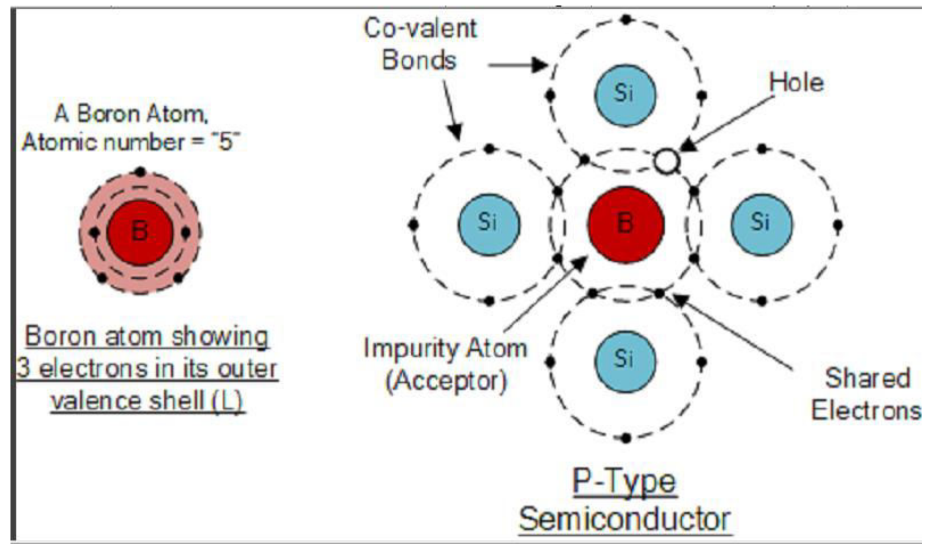
N- type semiconductor

- **When a small amount of pentavalent impurity is added to a pure semiconductor, it is known as n- type semiconductor.**
- **The addition of pentavalent impurity provides a large number of free electrons in the semiconductor crystal.**
- **Typical example of pentavalent impurities are *arsenic* and *antimony.***
- **Such impurities which produce n-type semiconductor are known as *donor impurities* because they donate free electrons to the crystal**



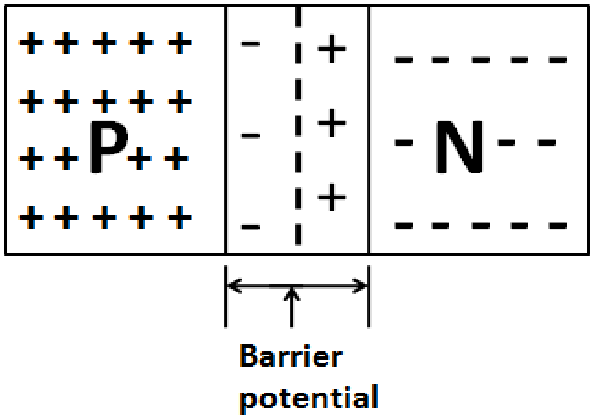
P - type semiconductor

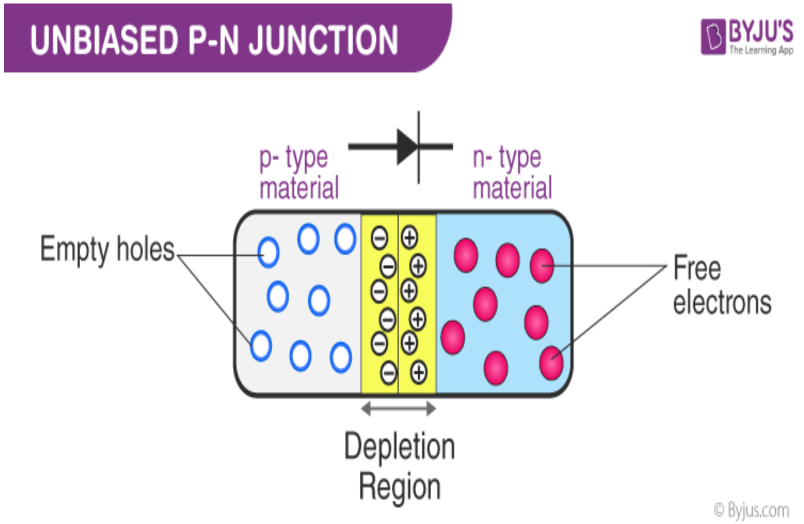
- **When a small amount of trivalent impurity is added to a pure semiconductor, it is known as p- type semiconductor.**
- **The addition of trivalent impurity provides a large number of holes in the semiconductor crystal.**
- **Typical example of pentavalent impurities are *gallium* and *indium.***
- **Such impurities which produce p-type semiconductor are known as *acceptor impurities* because they accept free electrons to the crystal.**



PN-Junction

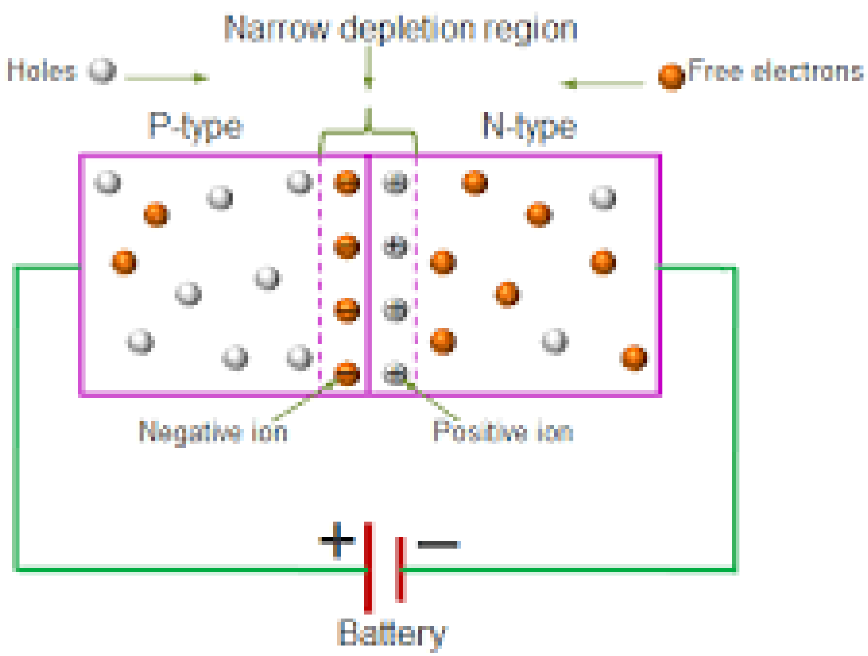
- When a p-type semiconductor is suitably joined to n-type semiconductor, the contact surface is called pn junction.
- When a pn junction is formed, the free electrons near the junction in the n-region begin to diffuse across the junction into the p- region
- As the free electrons diffuse across the junction, they combine with holes and leave a layer of positive charges in the n-region and a layer of negative charges in the p-region. This forms a barrier potential. This action continues until the voltage of the barrier stops further diffusion.
- For silicon the barrier potential is about 0.7V and for germanium, it is about 0.3V.



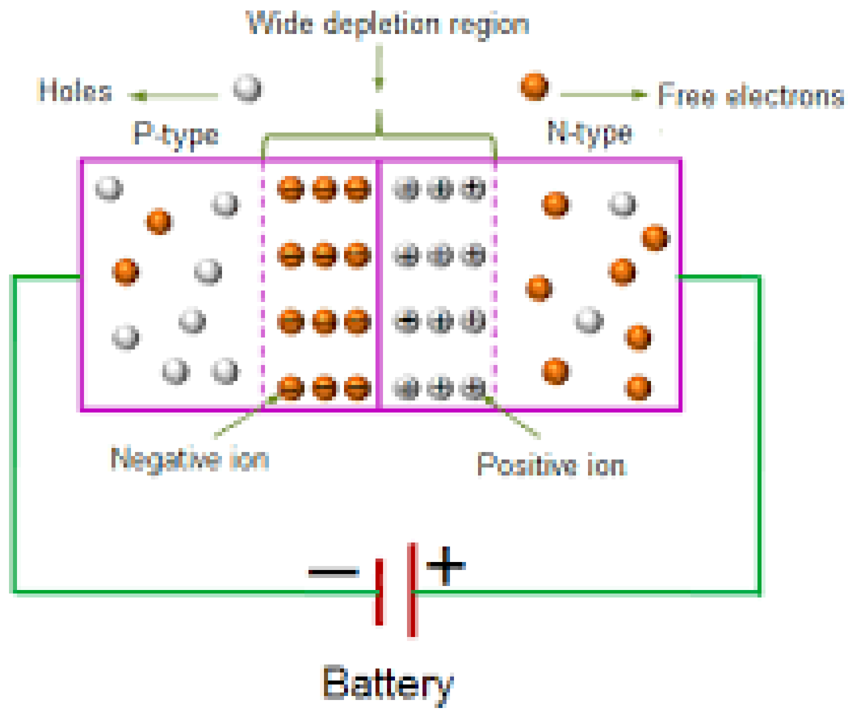


Working of PN junction diode
1) As forward Biased

- A P-N junction diode is said to be forward biased when the positive terminal of a cell or battery is connected to the p-side of the junction and the negative terminal to the n side.
- When diode is forward-biased the depletion region narrows and consequently, the potential barrier is lowered.
- This causes the majority charge carriers of each region to cross into the other region.
- The electrons travel from the n-side to the p-side and go to the positive terminal of the battery.
- The holes that travel from the p-side to the n-side combine with the electrons injected into the n-region from the negative terminal of the battery.
- This way the diode conducts when forward-biased.



Forward bias



Reverse bias

2)As reverse Biased

- **A PN-junction diode is said to be reverse biased when the positive terminal of a battery is connected to the n-side of the junction and the negative terminal to the p-side.**
- **When reverse biased, the depletion region widens and the potential barrier is increased.**
- **The polarity of the battery extracts the majority charge carriers of each region. The holes in the p-region from the electrons injected into the p-region from the negative terminal of the battery.**
- **The electrons in the n-region go to the positive terminal of the battery.**
- **This way, the majority charge carrier concentration in each region decreases against the equilibrium values and the reverse biased junction diode has a high resistance.**
- **Thus, the diffusion current across the junction becomes zero. Thus, the diode does not conduct when reverse biased and it acts as an open switch.**

DIODES

- The **diode** is the most used semiconductor device in electronics circuits.
- **It is a two-terminal electrical check valve that allows the flow of current in one direction**.
- They are mostly made up of silicon but germanium is also used.
- Usually, they are used for rectification. But there are different properties & characteristics of diodes which can be used for different application.
- These characteristics are modified to form different types of diodes.
- Nowadays, several different types of diodes having different properties are available

TYPES OF DIODES AND APPLICATIOIN

TYPE OF DIODE	APPLICATION
P-N Junction Diode	USED FOR RECTIFICATION
Small signal Diode	used in circuits with high frequencies.
Super Barrier Diodes	SBR uses MOSFET
Light Emitting Diode (LED)	Used for Lights LED converts electrical energy into light energy.
Photodiode	used in solar cells.
Laser Diode	Laser diodes are used in optical communication, laser pointer, CD drives and laser printer
Tunnel Diode	Used in oscillator and a microwave amplifier.


Photo Diode
Gunn Diode
PIN Diode
Tunnel Diode
LED Diode
Varactor Diode
Types of Diodes & Their Applications
Schottky Diode
PN Diode
Vacuum Diode
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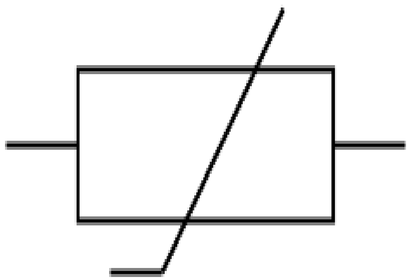
Thermistors

- The Thermistor or simply Thermally Sensitive Resistor is a temperature sensor that works on the principle of varying resistance with temperature.
- They are made of semiconducting materials. The circuit symbol of the thermistor is shown in the figure.



Construction of Thermistor

- A thermistor is made of oxides of metals such as Nickel, Manganese, Cobalt, Copper, Uranium etc. It is available in a variety of shapes and sizes. Commonly used for configurations are Disk type, Bead type and Rod type.

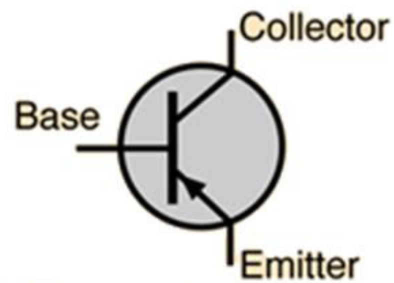
Working Principle of Thermistors

- The thermistor works on the simple principle of change in resistance due to a change in temperature. When the ambient temperature changes the thermistor starts self-heating its elements. its resistance value is changed with respect to this change in temperature. This change depends on the type of thermistor used.

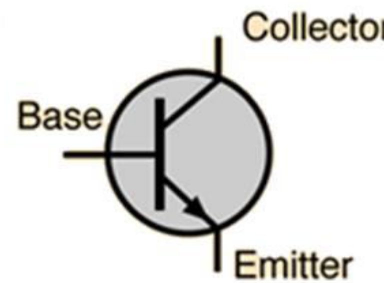
Bipolar junction transistor(BJT)

- **A transistor consists of two PN junctions formed by sandwiching either p-type or n-type semiconductor between a pair of opposite types.**
- **A transistor has three terminal *emitter* , *base* and *collector*.**
- **There are two types of transistors**
- **P-N-P transistor**
- **N-P-N transistor**

Symbol of a transistor



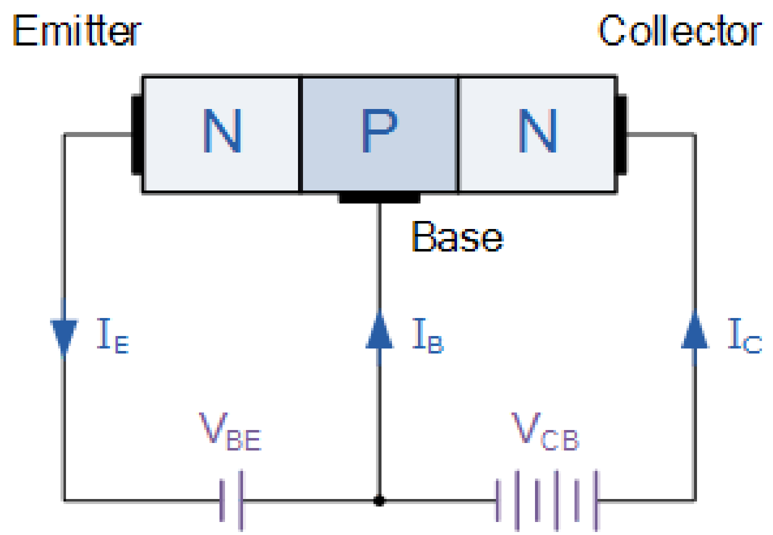
PNP transistor



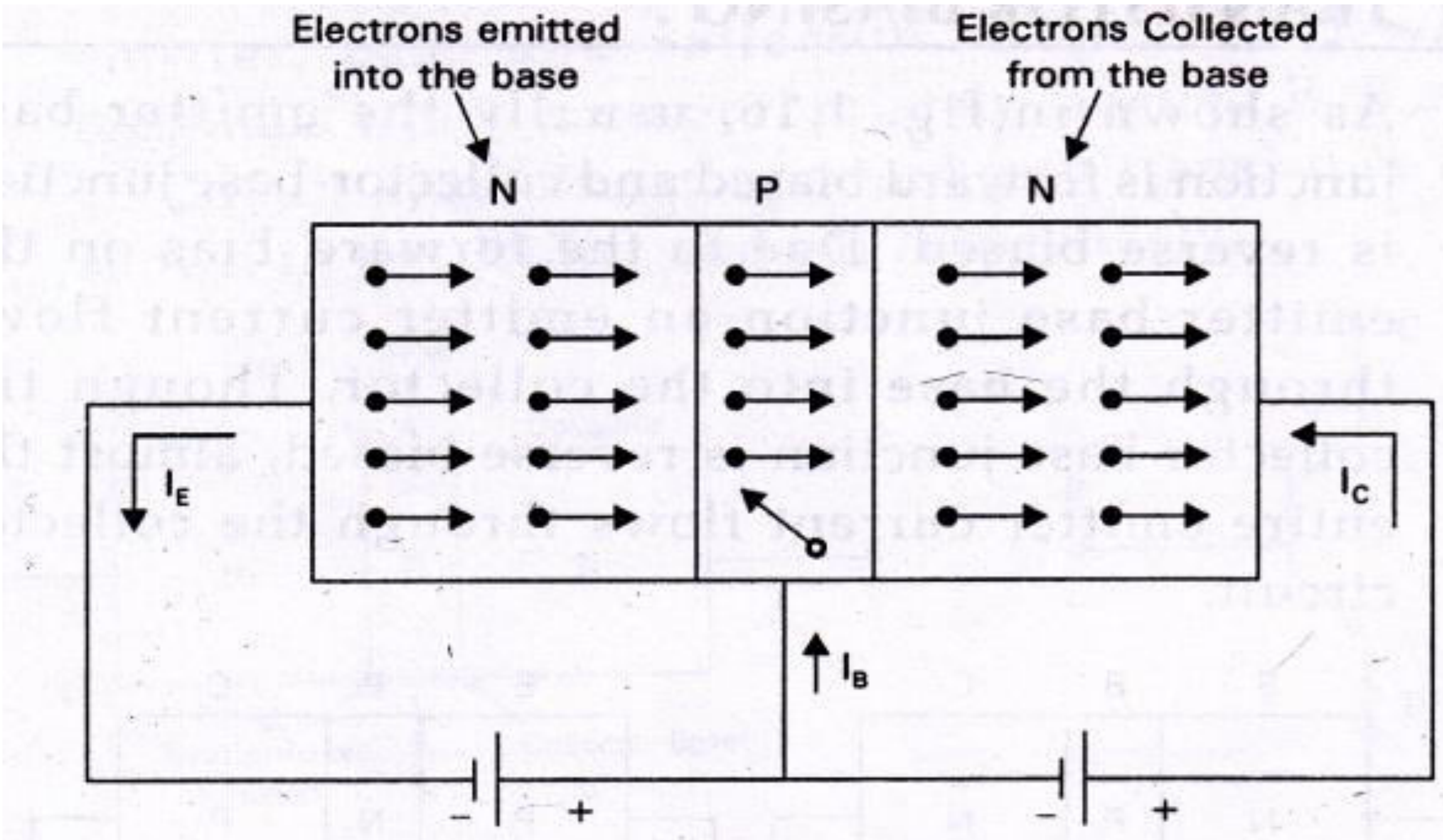
NPN transistor

Transistor biasing

- The process of applying dc voltages across the different terminals of a transistor is called biasing.
- For normal operation of a transistor emitter-base junction is always forward biased and collector-base junction is always reverse-biased.
- A battery V_{EB} is connected between emitter and base while a battery V_{CB} is connected between the collector and base.



Working of transistor

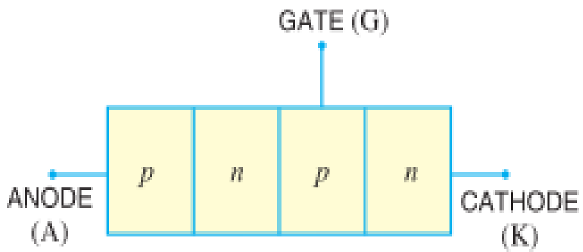


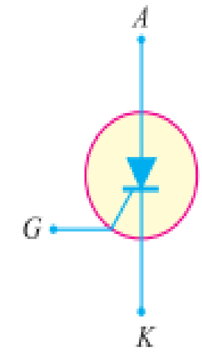
- For normal operation the emitter-base junction is always forward biased while the collector-base junction is always reverse biased.
- Electrons are injected into the emitter region by the emitter bias supply .
- The electrons injected to the emitter enter to the base and only few electrons recombine with the holes in the base region.
- Injected electrons diffuse into collector region due to extremely small thickness of base and most of the electrons cross into the collector region.
- Collector is reverse biased and creates a strong electrostatic field between base and collector. The field immediately collects the diffused electrons which enter the collector junction.

- The small current that we turn on at the base makes a big current flow between the emitter and the collector.
- By turning a small input current into a large output current, the transistor acts like an amplifier.
- But it also acts like a switch at the same time. When there is no current to the base, little or no current flows between the collector and the emitter. Turn on the base current and a big current flows.
- So the base current switches the whole transistor on and off.
- Technically, this type of transistor is called **bipolar** because two different kinds (or "polarities") of electrical charge (negative electrons and positive holes) are involved in making the current flow

Silicon Controlled Rectifier (SCR)

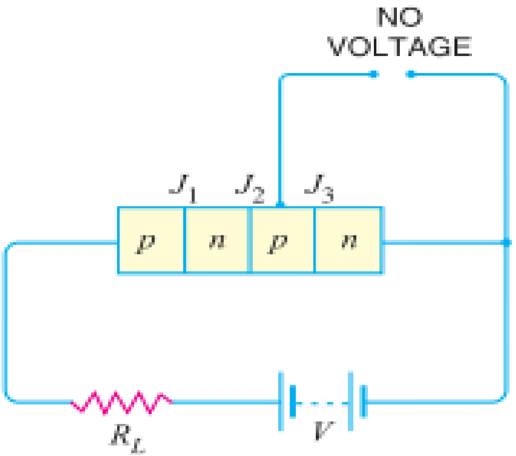
- **SCR is a four layer, three terminal semiconductor device which act as a electronic switch.**
- **Its terminals are *Anode* , *cathode* , *Gate***
- **In normal operating conditions of SCR anode is highly positive with respect to cathode and gate is small positive with respect to cathode.**

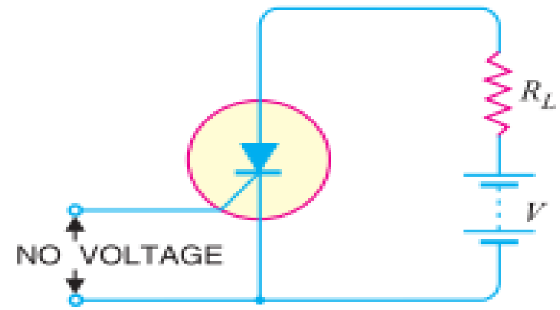




Working of SCR

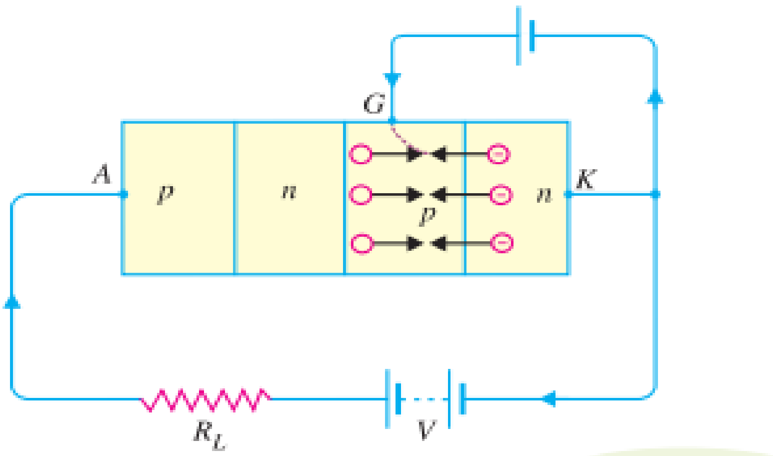
(i) When gate is open.

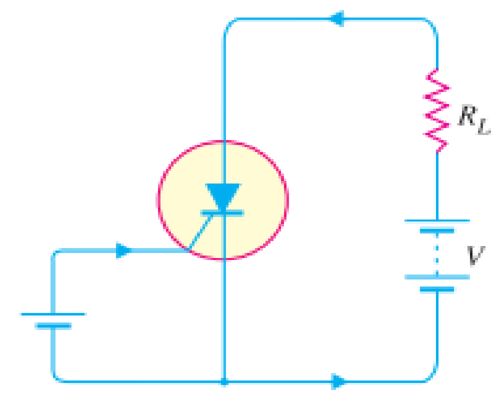




- Under this condition, junction J_2 is reverse biased while junctions J_1 and J_3 are forward biased. Hence, no current flows through the load RL and the SCR is cut off. However, if the applied voltage is gradually increased, a stage is reached when reverse biased junction J_2 breaks down.
- The SCR now conducts heavily and is said to be in the ON state. The applied voltage at which SCR conducts heavily without gate voltage is called Break over voltage.

(ii) When gate is positive w.r.t. cathode.





- The SCR can be made to conduct heavily at smaller applied voltage by applying a small positive potential to the gate as shown in Fig.
- Now junction J_1 J_2 and J_3 is forward biased. The electrons from n-type material start moving across junction J_3 towards left whereas holes from P-type towards the right.
- Consequently , the electrons from junction J_3 are attracted across junction J_2 and gate current starts flowing.

- **As soon as the gate current flows, anode current increases. The increased anode current in turn makes more electrons available at junction J_2. This process continues and in an extremely small time, junction J_2 breaks down and the SCR starts conducting heavily**
- **Once SCR starts conducting, the loses all control.**
- **Even if gate voltage is removed, the anode current does not decrease at all.**
- **The only way to stop conduction is to reduce the applied voltage to zero.**

Applications of SCR

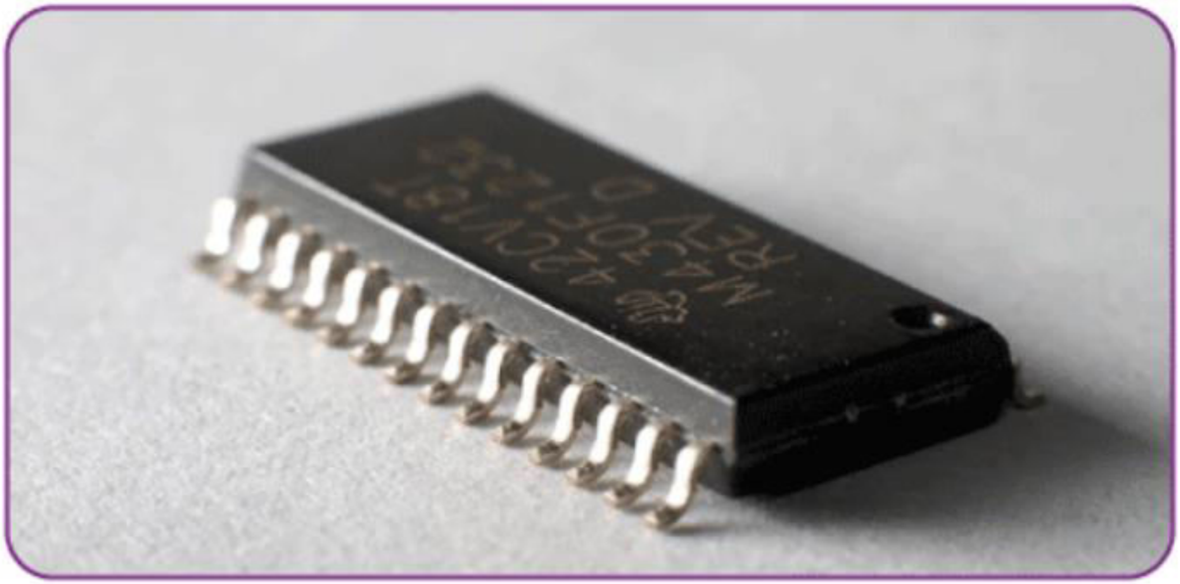
- **Speed control of DC and AC motors**
- **As rectifier for conversion of AC into DC**
- **As inverter for conversion of DC into AC**
- **As chopper for converting fixed DC into variable DC.**
- **As cycloconverter for converting AC of one frequency into AC of another frequency.**
- **Power switches.**
- **As static switches.**
- **Relay control.**

Integrated circuits (IC)

- Integrated circuits are made up of several components such as R, C, L, diodes and transistors. They are built on a small single block or chip of a semiconductor known as an integrated circuit (IC). All of them work together to perform a particular task.

INTEGRATED CIRCUIT

BYJU'S
The Learning App



Integrated circuits can function as an oscillator, amplifiers, microprocessors or even as computer memory.

Logic gates

- **Logic gates are the basic building blocks of any digital system.**
- **It is an electronic circuit having one or more than one input and only one output.**
- **The relationship between the input and the output is based on a certain logic.**
- **There are seven types logic gates namely**
- ***OR , AND , NOT, NOR, NAND, X-OR* and *X-NOR***
- **OR, AND, NOT gates are known as basic types of gates.**
- **An universal gate is a gate which can implement any Boolean function without need to use any other gate type.**
- **NAND and NOR gates are called the *universal gates***

OR gate

- The OR gate performs logical addition.
- An OR gate has two or more input signals with only one output signal.
- In OR gate ,output voltage is high if any or all of the input voltages are high.

Symbol

Truth table

INPUT		OUTPUT
A	B	A OR B
0	0	0
0	1	1
1	0	1
1	1	1

AND gate

- The AND gate performs logical multiplication.
- An AND gate has two or more input signals with only one output signal.
- In AND gate ,output voltage is high only when all the input voltages are high.

Symbol

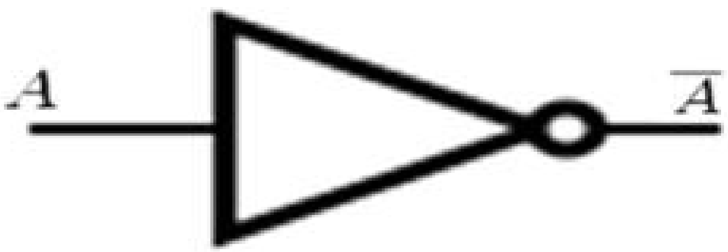
Truth table

INPUT		OUTPUT
A	B	A AND B
0	0	0
0	1	0
1	0	0
1	1	1

NOT gate

- The NOT gate performs a basic logical function called inversion or complementation.
- The purpose of NOT gate is to change one logical level to the opposite level.
- This gate has only one input and one output
- It changes a 1 to 0 and vice-versa.

Symbol



Truth table

INPUT	OUTPUT
A	NOT A
0	1
1	0

NAND gate

- NAND = AND + NOT
- The NAND gate performs AND function with inverted output.
- In NAND gate , output voltage is low only when all the input voltages are high.

Symbol

Truth table

INPUT		OUTPUT
A	B	A NAND B
0	0	1
0	1	1
1	0	1
1	1	0

NOR gate

- NOR = OR + NOT
- The NOR gate performs OR function with inverted output.
- In NOR gate ,output voltage is high only when all the input voltages are low.

Symbol

Truth table

INPUT		OUTPUT
A	B	A NOR B
0	0	1
0	1	0
1	0	0
1	1	0

X-OR gate

- In X-OR gate output is high when two inputs are different (one is high and another low), its output is low when the two inputs are the same (either low or high) .

Symbol

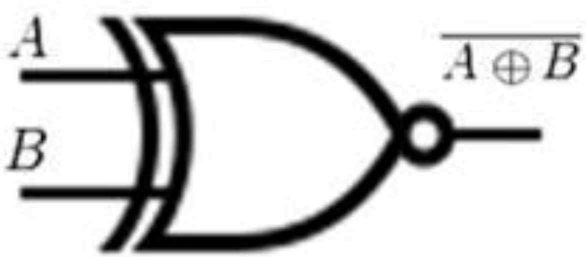
Truth table

INPUT		OUTPUT
A	B	A XOR B
0	0	0
0	1	1
1	0	1
1	1	0

X-NOR gate

- It operate just opposite to X-OR
- In X-NOR gate out is high when two inputs are same (either low or high), its output is low when the two inputs are the different (one is low and another is high)

Symbol



Truth table

INPUT		OUTPUT
A	B	AXNORB
0	0	1
0	1	0
1	0	0
1	1	1

BATTERY

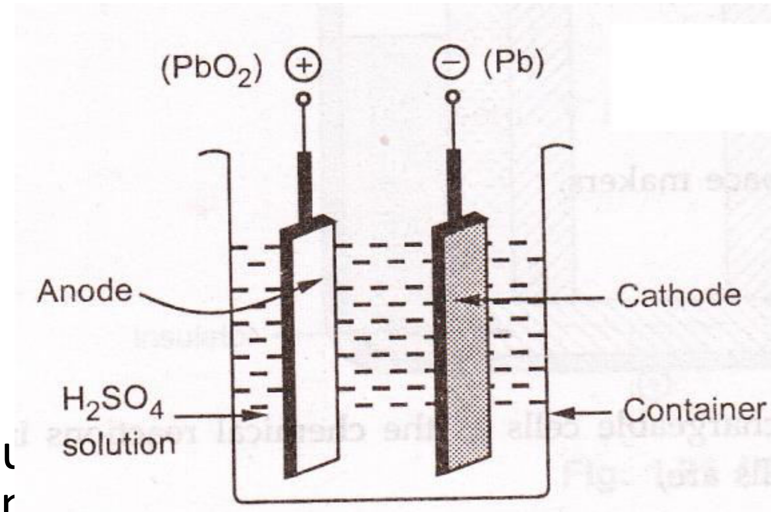
- It’s a device which convert chemical energy into electrical energy
- Important component of automobile electrical system
- The main purpose of battery are: to store electrical energy and to provide a supply of current for operating starting motor, to ignition system, lighting system and to other electrical units.

TYPES OF BATTERY

- Two principle type of batteries are used in automobiles:
- **lead acid type** and
- **alkaline type**
- Lithium –ion battery
- Zinc- air battery
- Nickel metal hydride battery
- Lithium –ion battery

- **Till recently lead acid batteries were being more extensively used.**
- **Today they are increasingly replaced by the alkaline type of battery in commercial vehicles and motor cycles**

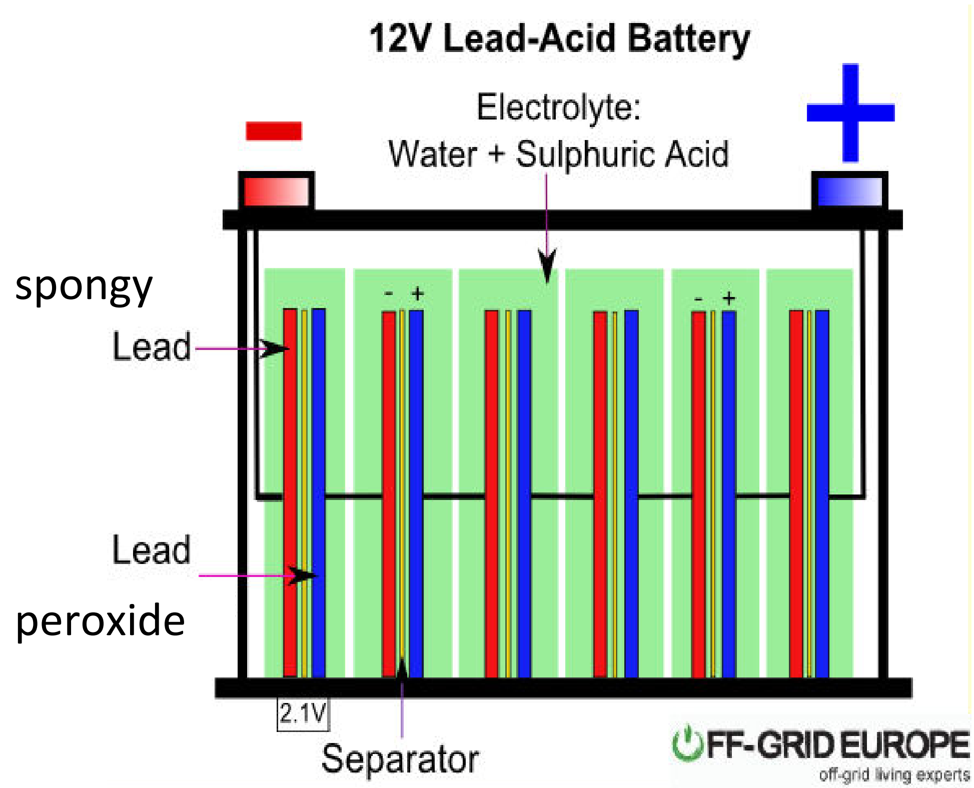
LEAD ACID BATTERY



- Its made u nd spongy lead on the negative p
- The positive and negative electrodes are immersed in dilute sulphuric acid .
- When the battery fully charged lead peroxide on positive plate and spongy lead on the negative plate as active materials
- During the process of discharge , the chemical reaction forms lead sulphate on the both plates ,thereby liberating water.
- So the specific gravity of the electrolyte is lowered
- During charging, there is reversal of this chemical reaction and specific gravity of electrolyte rises.
- So that the specific gravity is a good indication of the state of the battery.

Construction of Lead Acid Battery

- The following are the essential parts of a lead acid cell
- Container
- Positive Plate
- Negative Plate
- Separator
- Electrolyte
- Cell covers and vent plugs
- Cell connectors
- Battery terminals



Container:

- The container houses the plates and the electrolyte.
- It is made of acid resisting materials like glass or hard rubber depending upon service requirements.

Positive Plate

- Positive plate is made of lead peroxide (PbO_2) deposited on a grid frame.
- The grid frame is made of antimony-lead alloy.
- The color of the positive plate is dark brown.

Negative Plate:

- Negative plate is made spongy lead (Pb).
- It is also deposited on a grid frame for stiffness and strength.
- The color of the negative plate is grey.
- The number of negative plates in a battery is always one more than the positive plates to make use of both the sides of the positive plate most effectively.

Separator:

- It is made of thin sheet of porous insulating materials.
- Separators are placed between positive and negative plates.
- The positive and negative plates are separated electrically by the separators.
- The separators must allow free circulation of the electrolyte between the plates.
- these are made of specially treated wood, glass, non conducting ebonite, rubber etc.

Electrolyte:

- The electrolyte is dilute sulphuric acid (H_2SO_4).
- Battery grade sulphuric acid is used for the preparation of electrolyte.

Cell covers and Vent plugs:

- Each cell has a cover made of moulded hard rubber.
- Openings are provided in these covers for two terminal posts and vent plug.
- Vent plug has a vent hole for easy escape of gas formed inside the cell during charging.
- Vent plugs can be easily removed for adding electrolyte.

Cell connectors:

- Cell connectors are used to connect the individual cells in series to give the required voltage.
- Lead alloys are the material normally used as cell connector.
- Corrosion due to sulphuric acid is normally avoided by proper coating.

Battery terminals:

- A battery has two terminals, the +ve and the -ve.
- The polarities are marked on the terminals.
- The terminals are generally made of lead alloys

Working

- When the cell is supplies current to a load (Discharging), the chemical action takes place forms lead sulphate ($PbSO_4$) on both plates with water being formed in the electrolyte.
- To recharge the cell, direct current is passed through the cell in the reverse direction to that in which the cell provided current.
- This reverses the chemical process and again form lead peroxide (PbO_2) positive plates and pure lead (Pb) negative plates. At the same time H_2SO_4 is formed at the expense of water.

Charging and Discharging of Lead acid cell

❑ ***Discharging***

- When the cell is fully charged its positive plate or anode is PbO_2 and its negative plate or cathode is Pb.
- When the cell discharges i.e. it sends current through the external load, then H_2SO_4 is dissociated into positive H_2 and negative SO_4 ions.
- As the current within the cell is flowing from cathode to anode, H_2 ions move to anode and SO_4 ions move to the cathode
- At anode
- $PbO_2 + H_2 + H_2SO_4 \longrightarrow PbSO_4 + 2H_2O$
- At cathode
- $Pb + SO_4 \longrightarrow PbSO_4 + 2e-$

Charging

- In order to recharge the cell, direct current is passed through the cell in the reverse direction to that in which the cell provided current.
- During charging the H ions move to cathode and O ions go to anode, SO_4 goes back to electrolyte

At cathode

- $PbSO_4 + H_2 + 2e \longrightarrow Pb + H_2SO_4$
- At anode
- $PbSO_4 + 2H_2O \longrightarrow PbO_2 + 2\ H_2SO_4$

Dis advantages of lead acid cell

- Its relatively heavy for a given capacity
- It will start self discharging if allowed to stand long periods
- Its possible to damage if over charged
- Its possible to damage if discharged above a certain current rate
- It is unsuitable for use at lower temperatures due to its danger of freezing.
- It is possible to sulphate if left in fully discharged condition for long periods.

Alkaline type battery

- There are 2 distinct alkaline type of batteries

1.Nickel iron battery

2.Nickel cadmium battery

- The basic construction of both is similar to that of lead acid cell
- In each type the active material on positive plate is nickel peroxide or nickel hydroxide and electrolyte is potassium hydroxide and water
- On negative plate it is metallic iron in Nickel Iron cell and cadmium oxide in Nickel cadmium cell
- The material for both positive and negative plates is contained in the Steel tubes which combines together a plate
- The electrolyte does not take part in chemical reaction on charging and discharging, unlike in the in the lead acid cell. so that small quantity of electrolyte is required
- The specific gravity is unaffected during charging and discharging processes. its no indication the state of charge

ADVANTAGES OF ALKALINE CELL

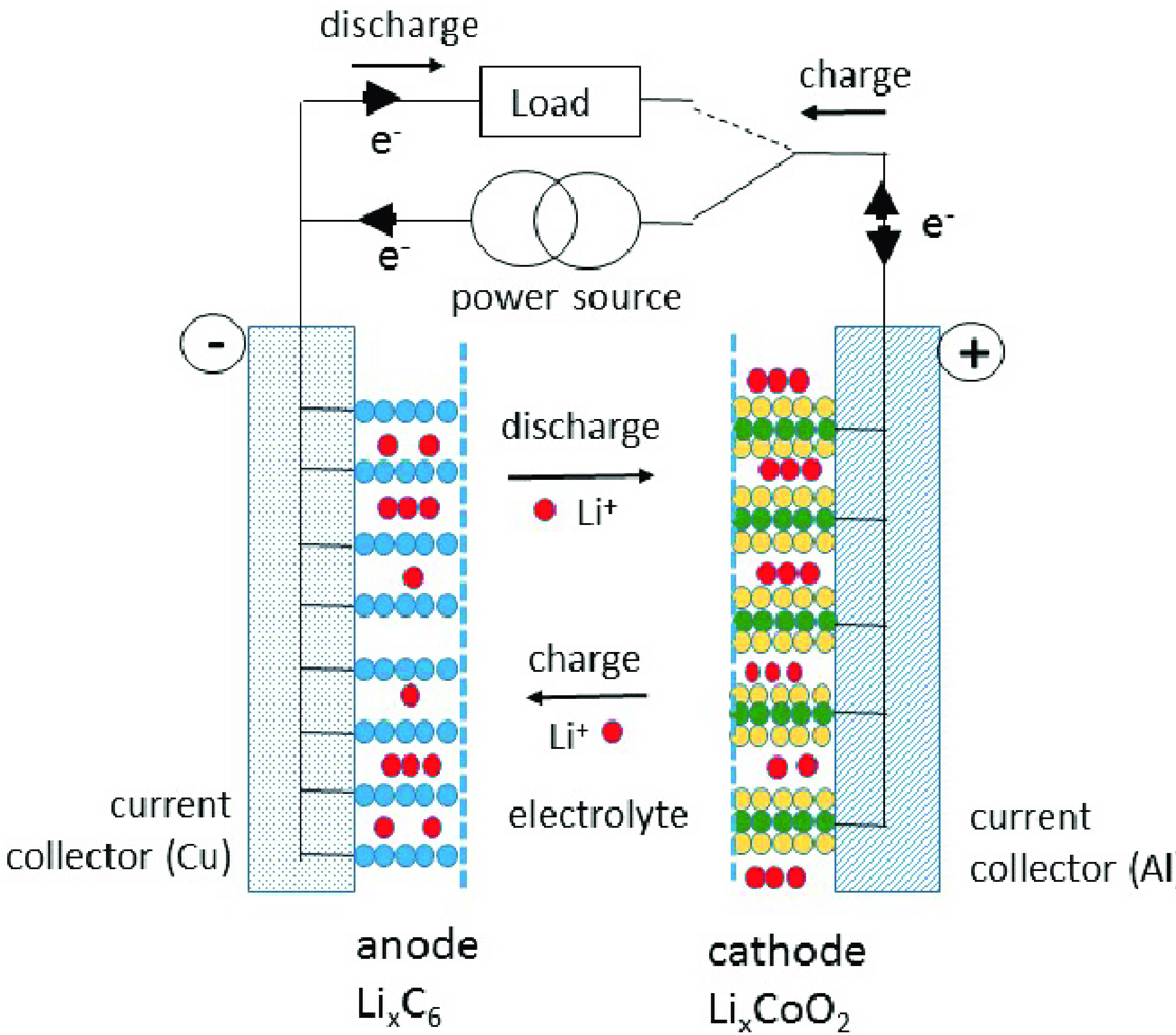
- It has much longer life then lead acid cell
- It has lighter than lead acid cell
- it is mechanically very strong, and can stand for very tough use
- the Rate of charging is much higher than the lead acid cell
- the discharging rate is very low as compared to lead acid cell
- it has ability to withstand low atmospheric temperature without damage
- it can be discharged for long period with out damage

Disadvantages

- Voltage of one cell is only 1.2 V
- High internal resistance so less efficiency
- Initial cost is high

Lithium – ion Battery

- The positive electrode is typically made from a chemical compound called lithium-cobalt oxide (LiCoO2) or lithium iron phosphate (LiFePO4).
- The negative electrode is generally made from carbon (graphite).
- The electrolyte varies from one type of battery to another. Most of the electrolytes used in commercial lithium-ion batteries are non-aqueous solutions, in which Lithium hexafluorophosphate ($LiPF_6$) salt dissolved in organic carbonates
- The electrolyte carries positively charged lithium ions from the anode to the cathode.
- The movement of the lithium ions creates free electrons in the anode which creates a charge at the positive current collector.
- The electrical current then flows from the current collector through a device being powered (cell phone, computer, etc.) to the negative current collector. The separator blocks the flow of electrons inside the battery
- Cell voltage of Lithium Ion battery is 3.7 volts



discharge
Load
e⁻
charge
e⁻
e⁻
power source
-
+
discharge
Li⁺
charge
Li⁺
electrolyte
current
collector (Cu)
current
collector (Al)
anode
Li_xC_6
cathode
Li_xCoO_2

Capacity of a battery

It is the quantity if electricity which can give out during single discharge.

It is usually measured in Ampere – hour, also there is Reserve Capacity

- **Ampere-hour Capacity**

A battery with a capacity of **1 amp**-hour should be able to continuously supply a current of **1 amp** to a load for exactly 1 hour, or **2 amps** for 1/2 hour, or 1/**3 amp** for 3 hours, etc., before becoming completely discharged

- **Reserve Capacity** (RC) is a very important rating. This is the number of minutes a fully charged battery at 80°F will discharge 25 amps until the battery drops below 10.5 volts

Ratings of Battery

(i) **20-hour Rate**

It represents the capacity of the battery in terms of the amount of current it can deliver in a period of 20 hours, holding the cell voltage above l.75 V and starting with an electrolyte temperature of 27°c.

(ii) **25-A Rate**

lt is the measure of battery performance at moderate constant current output at 27°C temperature to a final limiting voltage of 1.75 V per cell. 1.5 6

(iii) **Cold Rate-**

- lt is also termed as short time rate. This rating is the number of minutes that a battery will deliver 300 A of current at a starting temperature of -18° C before the cell voltage falls below 1.0 V. It indicates the ability of battery during cold weather starting

(iv) **4-hour Rate**

- This rating is often used for heavy vehicles. It represents the ampere-hour rating of a battery discharged in 4 hour

Testing of battery

1.Polarity test

2.Specific gravity test using hydrometer

3.High discharge test

4.Cadmium test

1.Polarity Test

(identification of battery terminals)

a)By voltmeter

- Connect a DC voltmeter to the terminals of battery if it shows a positive reading then terminal connected to the positive point of voltmeter will be positive ,and remaining terminal will be negative
- If a voltmeter pointer tries to move in a backward direction then the polarities of terminal are reverse direction

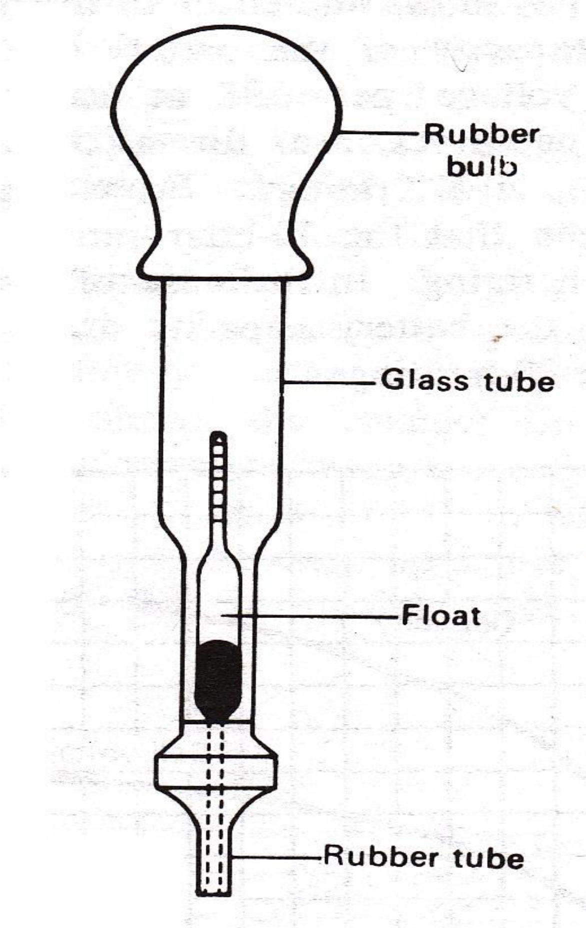
b)By acidic water

- A few drops of sulphuric acid are brought to both terminals of battery by means of wire, then the wire at which gas bubbles are formed will be negative terminal

C) By potato

If both terminals of a battery are brought to a freshly cut raw potato by means of wire .then the conductor around which a green circle is formed is connected to the positive terminal of battery

Specific gravity test using hydrometer



Battery hydrometer.

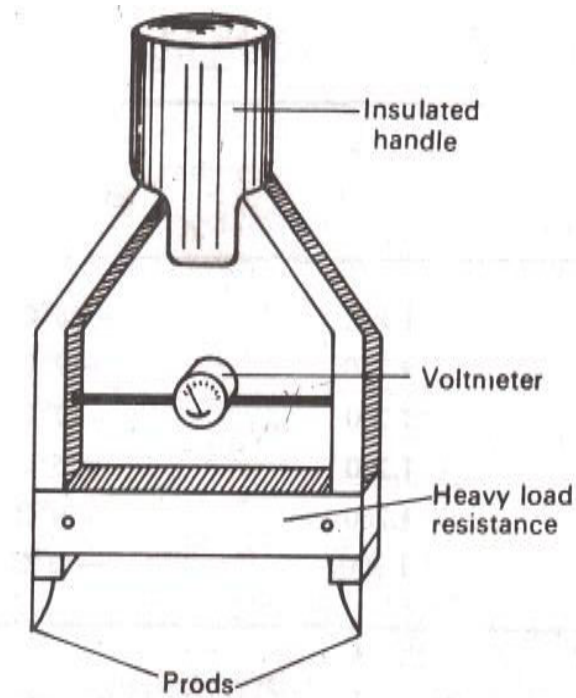
- State of charge battery is find by checking the amount of sulphuric acid left in the electrolyte.
- This can be found out with the help of hydrometer
- In case fully charged battery .there is 39 % acid and 61% water.
- When its discharged it becomes 85 % water and 15% acid.
- The hydrometer does not measure the percentage ,but instead it directly measures the specific gravity of electrolytes.
- Its made up of a glass tube containing a weighted Float with markings on the stem.

Sl. No.	Approximate sp. gravity	State of charge of battery
1.	1.260-1.280	Fully charged
2.	1.230-1.260	3/4 charged
3.	1.200-1.230	Half charged
4.	1.170-1.200	1/4 charged
5.	1.140-1.170	About run down
6.	1.110-1.140	Discharged

- So that the specific gravity readings may be taken as directly
- At one end of the glass tube is fitted a rubber bulb and on the other a flexible suction tube.
- When the electrolyte is drawn inside the tube ,the float rises, depending upon the gravity of electrolyte.
- By using following table we can understand the state of charge of battery

HIGH DISCHARGE TEST

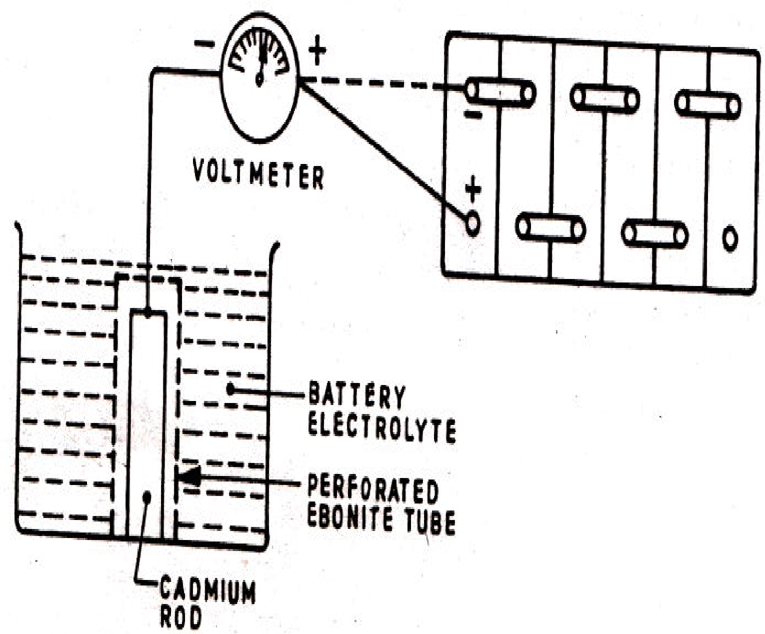
- The state of charge of a battery can be measured with an instrument which insert a resistance across the cell terminals and the cell voltage is obtained by the voltmeter
- The prods are placed on the cell terminal, the resistance are placed under high discharge at the same time the voltmeter indicates cell voltage
- Each cell should show a voltage greater than the 1.5 V.
- A cell show a voltage below the 1.5V may be defective
- The duration of test should be low, because the current flow across the cell is very high, other wise the battery may be damaged.



A cell tester.

Cadmium test

- This test is conducted to know the chemical condition of positive and negative plate
- A cadmium rod is enclosed in a perforated ebonite tube and its immersed in battery electrolyte
- The rod is then connected to the negative terminal of the voltmeter ,whose positive terminal is connected alternately to the positive and negative terminals of battery
- In case of positive terminal voltage should not be less than 2.5 volts. A lower reading indicates defectives to positive plate
- On the other hand, reading in case connection in negative terminal of battery not be more than the .2 volt. A higher reading will indicate defective to negative plate



❑ Charging methods

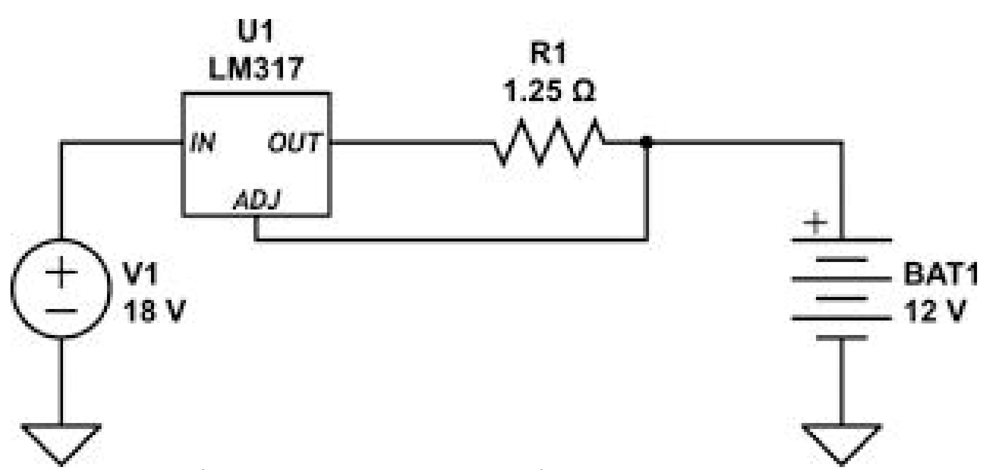
Battery is always charged with dc supply

- The battery requires more amount of charging current when in low state of charge.
- There are 3 methods of charging

1.constant current method

- In this method charging current kept constant by varying the supply voltage to over come the increased back emf of battery
- The chargers of this type generally employs a rectifier.
- The rectifier may be of a gas-filled bulb type or a series of copper oxide or other chemical disks.
- The rectifier also incorporates some form of rheostat to adjust the amount of charging current value.

- If batteries of different ratings are being charged in series, the charging rate should be decided by the battery with the lowest rating.
- If somehow the rating cannot be determined, the battery may be charged at the 5-A rate.
- Battery charging may be continued till all the cells of the battery are gassing freely and no further rise in the specific gravity of the electrolyte takes place for another two hours as per the battery manufacturer's recommended



2.constant voltage method

- In this method charging voltage is kept constant.
- The constant voltage chargers are operated on the principle that as the battery nears its charge, the terminal voltage increases.
- The battery is usually charged with dynamo, whose voltage is kept equal or more than that of the battery voltage.
- The generator gives 7.5 V for 6 V batteries and it shall be rated at 15 V for 12 V batteries.
- When a battery in a discharged condition is connected to the generator, a high rate of charging current will flow into the battery.
- As the battery nears, its charge, its terminal voltage will increase with increase in opposition to charging current.
- This means that the charging current tapers off as the battery approaches the charged condition.
- Batteries of automobiles are generally charged by this method
- An automatic cut out is also needed to stop the dynamo voltage given when the battery attains fully charged

3)Booster or High-rate charging—

- Boosters are devices which supply high charging currents of the order of 40-100 A, depending upon the size of the battery.
- it is a more recent developed process with the help of which the charging process can be boosted up.
- It is possible to recharge a battery to almost the full charge condition in one hour with this process.

DEFECTS/ Troubles OF BATTERY

1.Effects of over charging

If a battery subjected long period off charging excessive heat will produced which will cause to extend the plates of battery and its push upward cause raising the cell cover ,also cause damage to separator

2. Self discharge

A battery if left standing gets discharge by itself , this phenomenon is called self discharge. The cause of self discharge contamination of electrolyte , damaged separators and long term storage

3.Sulphation

If a battery left discharged for a long time ,then the lead sulphate become hard which shall resist reconversion .

In addition the plates will tends to expand and break the grid, this causes battery useless

4.internal short circuit

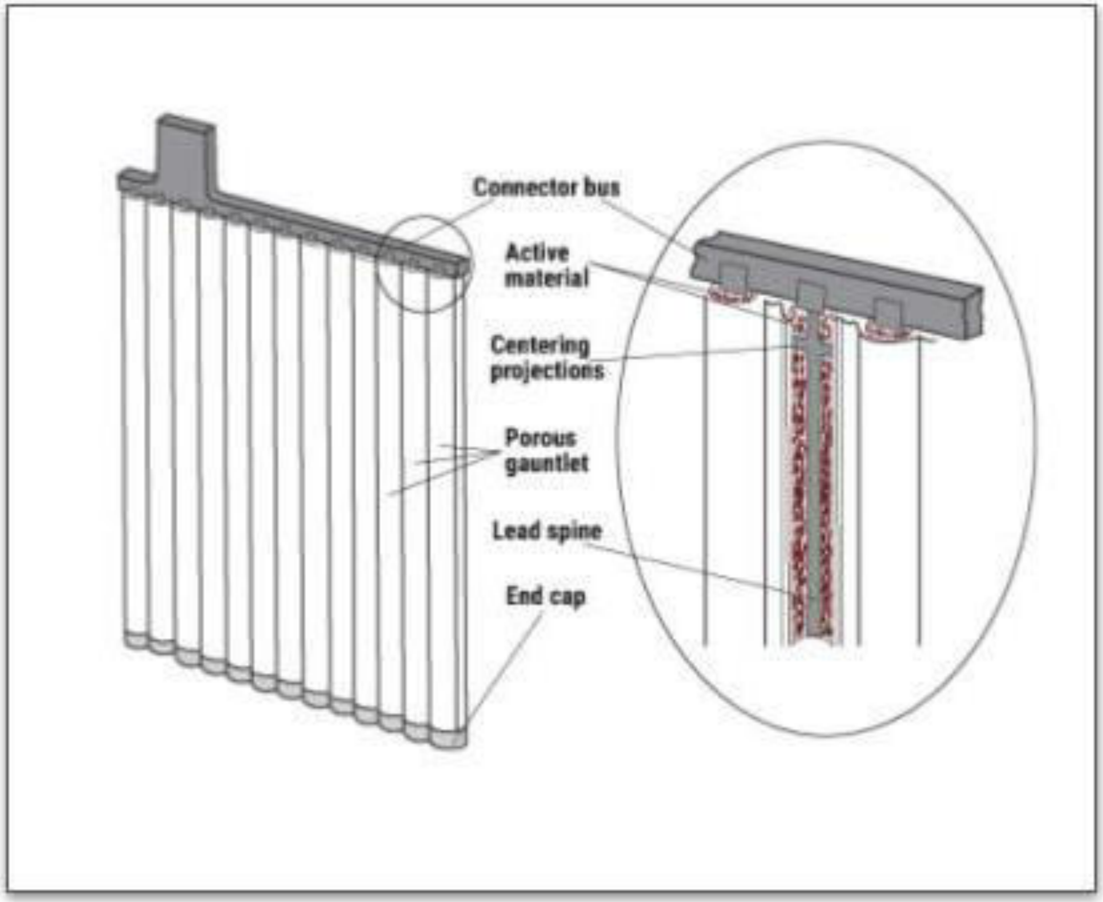
The internal Short circuit is caused either damaged separators or each charging and discharging some sulphate powder leaves the plates and it's gets deposited in the bottom of battery container and it will cause short circuit between the plates

5. Corrosion/ sulphation of terminals

- Corrosion of the external metal parts of the lead–acid battery results from a chemical reaction of the battery terminals, lugs and connectors.
- Corrosion on the positive terminal is caused by electrolysis, due to a mismatch of metal alloys used in the manufacture of the battery terminal and cable connector. White corrosion is usually lead or zinc sulfate crystals. Aluminum connectors corrode to aluminum sulfate
- If the battery is over-filled with water and electrolyte, thermal expansion can force some of the liquid out of the battery vents onto the top of the battery. This solution can then react with the lead and other metals in the battery connector and cause corrosion

Tubular battery

- A **tubular battery** uses technology that seals the active material in polyester tubes called gauntlets, instead of pasting it on the surface of the plate.
- As a result, there's no shedding or corrosion, ensuring long **battery** life.
- Owing to their toughness and durability, tubular batteries can operate at extreme temperatures.
- They are used in high cyclic applications involving frequent and prolonged power outages
- Tubular battery is a type of lead acid battery in which the positive electrode is not a grid, but a comb like lead skeleton that holds the positive material with the help of tubular bags. The structure looks like a series of tubes kept side by side along the length of the electrode, hence the name “tubular”.
- Tubular batteries are used in applications like home power backup, electric propulsion of vehicles, solar equipment etc.
- Tubular batteries are “deep discharge” kind of batteries i.e. You will get a small amount of current(5–10Amps) for a very long period of time (12–24 hours). Tubular batteries cannot produce burst of current because the electrodes are thicker than the ones in a flat plate model and hence produce a low surface area. That’s why they cannot be used in applications where a huge amount of current is needed for a very short length of time(like starting your car in the morning)



Tubular Electrode

Maintenance free battery

- They are also called VRLA, or “Valve Regulated Lead Acid” batteries.
- Maintenance-free batteries should **never be topped up**, therefore there are no filler caps on top.
- The filler cap is replaced by an over-pressure valve that is normally closed.
- Any gas that forms ends up being recombined in the cell as water. This way there is always sufficient electrolyte in the battery.
- Good quality maintenance-free batteries have the advantage of being **guaranteed for life**

- A **valve-regulated lead-acid battery** (**VRLA battery**) sometimes called **sealed lead-acid** (**SLA**), **gel cell**, or **maintenance free battery**[**.**
- They are widely used in large portable electrical devices, off-grid power systems and similar roles.
- **In AGM and gel type VRLA's**, the electrolyte is immobilized. In AGM this is accomplished with a fiberglass mat; in gel batteries or "gel cells", the electrolyte is in the form of a paste-like gel created by adding silica and other gelling agents to the electrolyte.
- If the charging current is too great, electrolysis will occur, decomposing water into hydrogen and oxygen, in addition to the intended conversion of lead sulfate and water into lead dioxide, lead, and sulfuric acid.

- If these gases are allowed to escape, as in a conventional flooded cell, the battery will need to have water added from time to time.
- In contrast, VRLA batteries retain generated gases within the battery as long as the pressure remains within safe levels.
- Under normal operating conditions the gases can then recombine within the battery itself, sometimes with the help of a catalyst, and no additional electrolyte is needed.
- However, if the pressure exceeds safety limits, safety valves open to allow the excess gases to escape, and in doing so regulate the pressure back to safe levels.