Unit 16
Current Electricity

Electric current:

The time rate of flow of electric charges through a cross-sectional area is called electric current.

The current I can be given as;

$$I = \frac{\Delta Q}{\Delta t}$$

The SI unit of current is Ampere denoted by (A)

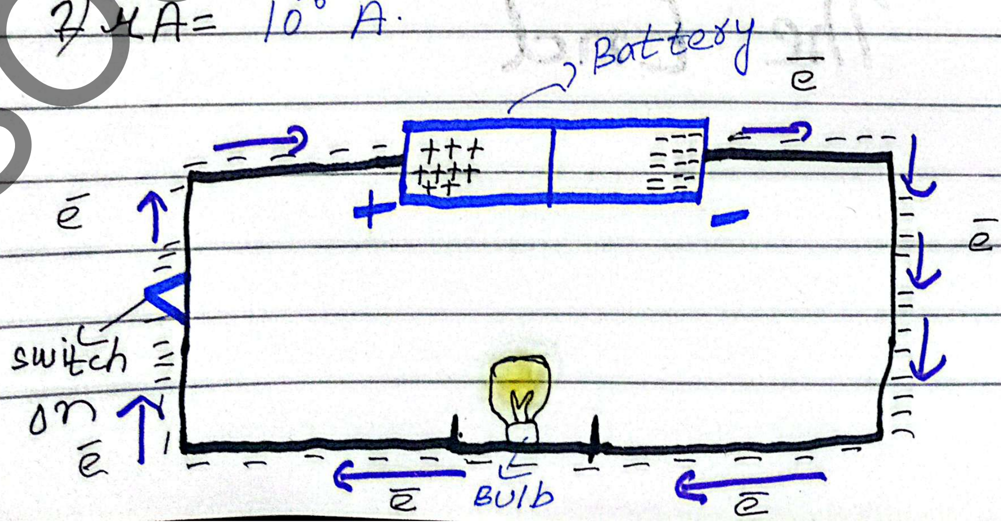
One ampere can be stated as; when on coulomb of charge flows through any cross sectional area in one second.

$$1A = \frac{1C}{1s}.$$

$$1A = 1C\,s^{-1}.$$

$1\,mA = 10^{-3}A$

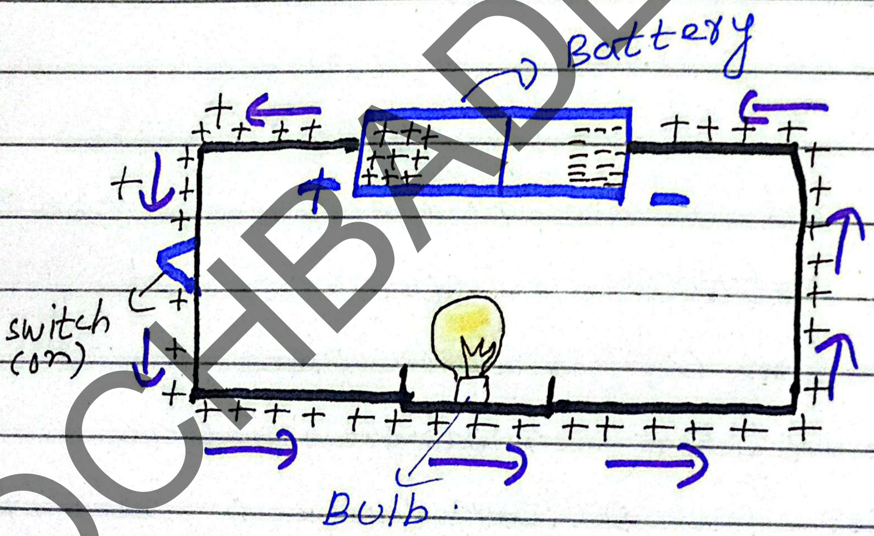
$2\,\mu A = 10^{-6}A.$



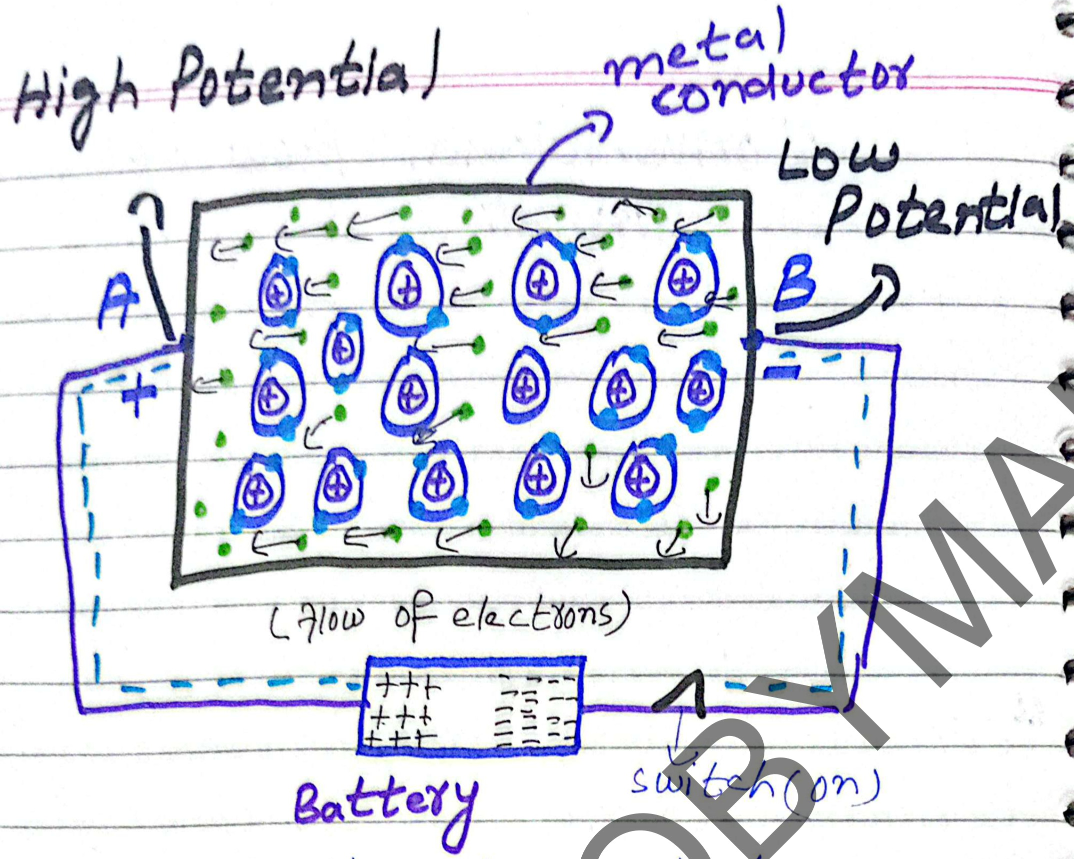
Conventional Flow of current

Before the discovery of electron, it was thought that electric current is due to flow of positive charge in conductor. This assumed direction of current flow is called conventional current. We can also describe it as;

"Current flowing from positive terminal to negative terminal of battery due to the flow of positive charges is called conventional current."



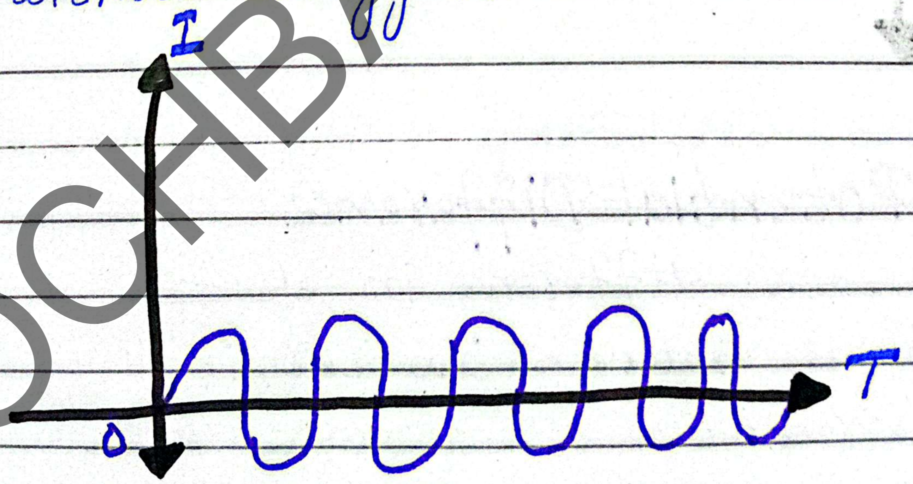
Electrical Conduction in Metals



In metals, the valence electrons are not tightly bound by nucleus and can move freely. When there is no battery or power supply connected. The net motion of free electron is zero and hence no electrical current. When a battery is connected to end of this copper wire piece, free electrons start motion in one direction. The positive plate of battery will attract free electrons while negative plate will push. The net movement of these electrons in one direction creates electric current. So, the electrical conduction in metals happens because of movement of free electrons when an electric field is applied across it generating electric current.

AC (Alternating current)

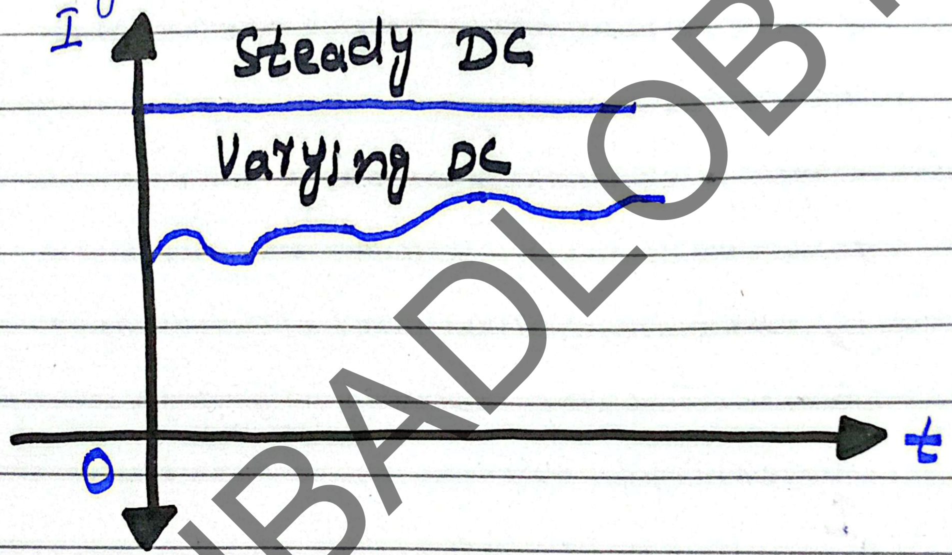
- This current changes its direction continuously.
- AC is produced by power stations or generators.
- Its frequency is 50Hz.
- The AC graph is wave.
- AC is used in home and industries.
- This current can travel long distance without energy loss.



DC (Direct current)

- This current flows in one direction only.

- DC comes from batteries or solar cells.
- Its frequency is zero Hertz.
- DC graph is straight line.
- DC is used in electronic devices.
- This current cannot travel over long distance.



Potential Difference

It is the difference in electric potential between two terminals in a circuit.

It is effect.

It converts electrical energy to non-electrical energy.

Its unit is volt.

It is outside the battery and across on any electrical components.

$$P.D = \Delta V = \frac{\Delta U}{\Delta q} = \frac{\Delta W}{\Delta q}$$

EMF

It is the energy provided by cell.
It is cause.
It converts non electrical to electrical energy.
It is inside the source/battery.
Its unit is volt.

$$EMF = \mathcal{E} = \frac{W}{q}$$

Additional Questions

Q. What type of current - AC or DC - flows in only one direction?

Q. What does EMF stand for and what does it represent in an electrical circuit?

Ohm's law

This law tells the relationship between electric current flowing through a conductor and potential difference applied across. It can be stated as;

If temperature remains constant, the current (I) flowing through a conductor is directly proportional to the voltage (V) applied across it.

If V is voltage (Potential Difference) across the two ends of conductor then current "I" will flow through it:

Mathematically:

Potential difference $\propto$ current

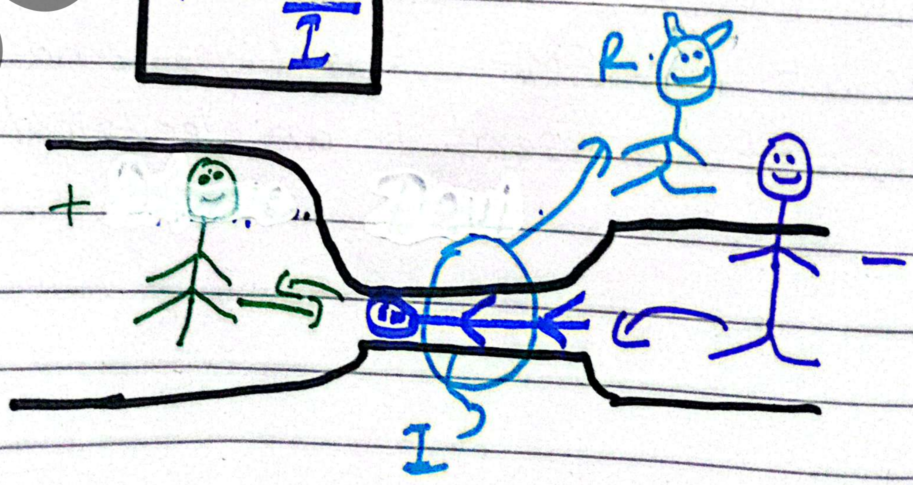
$$V \propto I$$

$$V = \text{constant} \times I$$

$$\boxed{V = IR}$$ ∴ where constant is Resistance

or

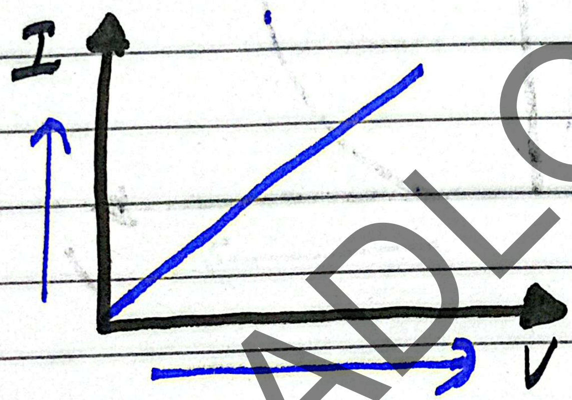
$$\boxed{R = \frac{V}{I}}$$



Ohmic Devices

- The materials which obey ohm's law are called ohmic devices.
- Their resistance does not change with increase or decrease in voltage.
- The V versus I graph will be a straight line.

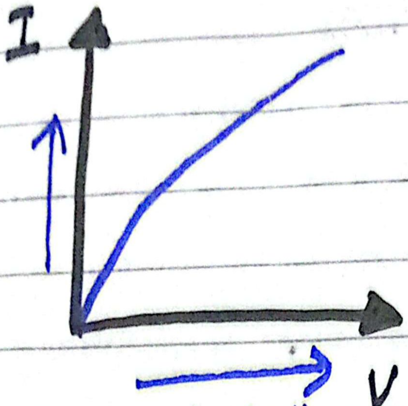
Example: metal like copper or Aluminium.



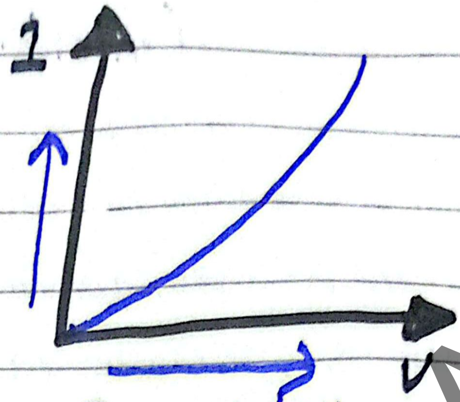
Non Ohmic Devices

- The materials which do not obey ohm's law are called non-ohmic devices.
- Their resistance changes when voltage changes.
- The V versus I graph is a curved line instead of straight line.

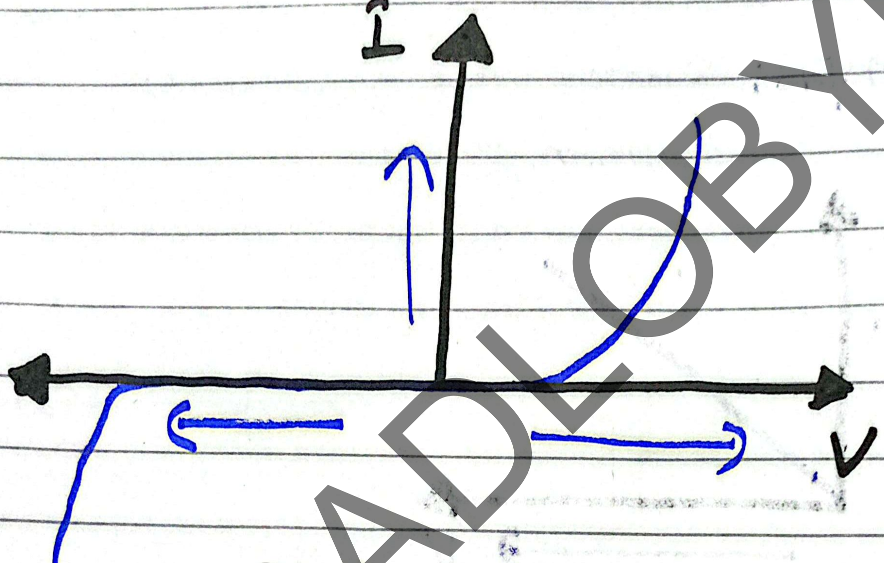
Example: Diode, filament bulb, transistor.



Filament bulb



Thermistor.



Diode

Additional Questions

Q. What does Ohm law state in simple words?

Q. What are limitations of ohm's law?

Q. How are current and voltage related in ohmic conductor.

Q. What happens to current if voltage is doubled while resistance remains constant?

Q. Why does current stop flowing when voltage becomes zero?

Q. What is meant by an ohmic conductor.

Q. Give two examples of ohmic & non-ohmic conductors.

Q. Why does a filament bulb not obey ohm's law?

Q. How can we tell from a graph if a material obeys ohm's law?

Q. What would the I-V graph look like for a non-ohmic conductor?

Resistance

Resistance is defined as 'the opposition to the flow of charges. or

When electrons move through a wire, they collide with atoms of the material. These collisions slow down the flow of current. This slowing effect is called resistance. It can be given as;

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

Its unit is volt per ampere

called ohm (Ω). "The resistance of a wire will be one ohm if a voltage or one volt causes a current of one ampere to flow through it".

Point to note:

Value of resistance is independent of the voltage and current as increase in voltage will increase current and ratio V/I will remain constant.

Type of resistor: 1) Metal film resistor. 2) Trimmer 3) Rheostat. 4) Thermistor.

Factors affecting Resistance.

1) Length of wire:

Greater the length of conductor (wire), greater will be its resistance i.e resistance is directly proportional to length.

Mathematically;

$$R \propto L$$

2) Cross-sectional area of wire

Greater the cross-sectional area of conductor (wire) smaller will be its resistance. i.e resistance is inversely proportional

RKMZ

Mota pipe me pani jldi flow kara ga then patla pipe me. Pani se murad current Mota pipe me kam rukawat then patla pipe.

to cross-sectional area i.e

$$R \propto \frac{1}{A}$$

Derivation:

$R \propto L \longrightarrow (i)$

$R \propto \frac{1}{A} \longrightarrow (ii)$

By combining eq (i) and (ii) then

$$R \propto \frac{L}{A} \Rightarrow R = \text{constant} \times \frac{L}{A}$$

constant = Resistivity = ρ

$$\boxed{R = \rho \frac{L}{A}}$$

3) Effect of Temperature on Resistance

The resistance of a material changes as the temperature changes, depending upon nature of material.

In Conductors, As the temperature rises, its resistance increases because when free electrons in a conductor get heated, the chances of collision with each other increases. This increases resistance.

In **insulators** & **semiconductors**, the resistance decreases as the temperature increases because the heat energy cause the bound electrons to transfer as charge.

Therefore, the temperature changes, the resistance of material changes.

Mathematically;

$$\Delta R \propto \Delta T$$

Resistivity

It tells how much a particular piece of wire or conductor opposes the flow of current. It tells how strongly a material resists current.

Since; $R = \rho \frac{L}{A} \Rightarrow \frac{R \times A}{L} = \rho$

$$\rho = \frac{R \times A}{L}$$

$$\rho = \frac{1\Omega + 1m^2}{1m}$$

$$\boxed{\rho = 1\Omega m}$$

"We can also define it as; Specific resistance or resistivity ρ of a material is the resistance offered by a wire of length having a cross-sectional area $1m^2$."

The unit of resistivity is ohm meter. (Ωm)

The resistivity of metal and alloys is very small therefore they are very good conductor of electricity. On the other hand, resistivity of insulator is very high. That is why, they difficulty conduct electricity.

Temperature Dependence of Resistivity

Consider a conductor having;

① ρ_0 = Resistivity at $0°C$.

② ρ_T = Resistivity at $T°C$.

As $\Delta \rho = \rho_T - \rho_0$ is directly proportional to;

$$\Rightarrow \rho_T - \rho_0 \propto \rho_0 \longrightarrow (i)$$

$$\rho_T - \rho_0 \propto \Delta T \longrightarrow (ii)$$

By combining eq (i) & eq (ii)

$$\rho_T - \rho_0 \propto \rho_0 \Delta T$$

$$\rho_T - \rho_0 = \text{constant } \rho_0 \Delta T$$

$$\rho_T - \rho_0 = \alpha \rho_0 \Delta T$$

$$\frac{\rho_T - \rho_0}{\rho_0 \Delta T} = \alpha$$

$$\boxed{\alpha = \frac{\rho_T - \rho_0}{\rho_0 \Delta T}}$$

$$\alpha = \frac{\cancel{\Omega m} \cdot K}{\cancel{\Omega m}}$$

$$\alpha = \frac{1}{K} = \boxed{\alpha = K^{-1}}$$

The unit of temperature coefficients of resistance or resistivity are $^{\circ}C^{-1}$ or K^{-1}.

The temperature coefficients is positive for metals.

The temperature coefficient is negative for semiconducting materials.

Electrical Measuring Instruments.

2) Galvanometer:

A galvanometer is a device which is used to detect electrical current.

2) Ammeter:

An ammeter is a device used to measure current. To create ammeter. A shunt resistance must be connected to galvanometer parallel. To measure the current, an ammeter must be connected in a circuit in series as it finds current flowing through component of circuit.

Range

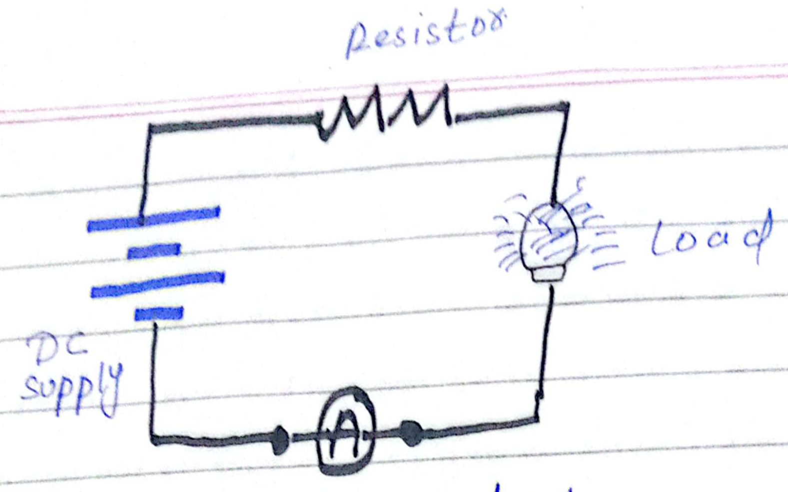
measures ampere values of ranging 1A to 100A. For small currents we use milli-ammeter (mA) or micro-ammeter (μA).

Voltmeter

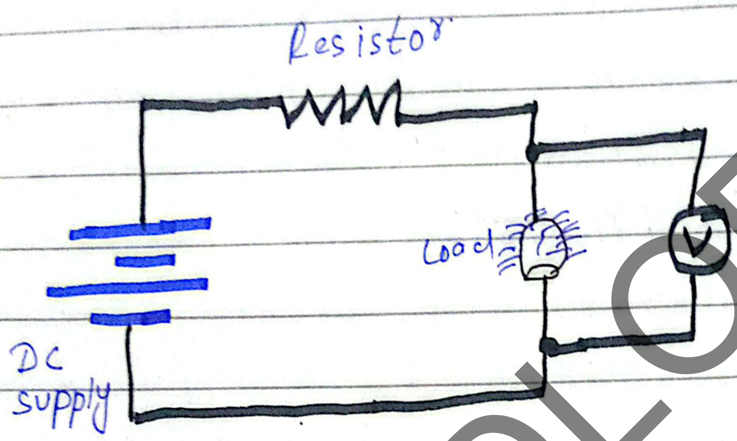
It is a device used to measure potential Difference. To create voltmeter, Add a high resistance in series with the galvanometer. To measure potential Difference, voltmeter must be connected in parallel with the component across which the potential difference is to be measured.

Range

It can measure values ranging from 1V to 500V. Millivoltmeter (mV) is used for small voltage measurements.



Ammeter



Voltmeter

Additional Question:

Q. How can we convert galvanometer to ammeter?

Q. How can we convert galvanometer to voltmeter?

Q. Why the resistance in conductor increases with temperature?

Q. Why the resistance/resistivity of insulators or semiconductor decreases with temperature?

Q. Explain the relation of resistivity

with temperature.

The End