ALLEN®

ELECTRICITY

Electricity

(1)**Static electricity,** deals with charges at rest and phenomenon associated with them.

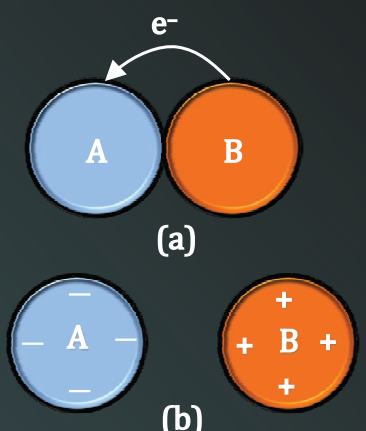
(2)**Current electricity,** deals with charges in motion and phenomenon associated with them.

Static electricity

The electricity developed on the surfaces of insulating bodies when rubbed against each other is called frictional electricity or static electricity.

Source of static electricity

When two substances are rubbed together, some electrons are removed from the atoms on the surface of one and transferred to the other. The substance which gains electrons becomes negatively charged and the one which loses electrons becomes positively charged.



Rubbing of two bodies makes one positive and another negative.

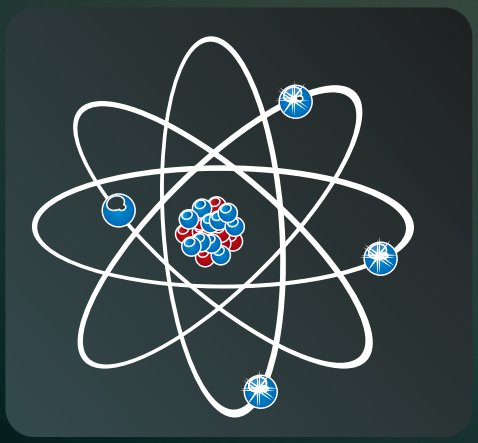
Electric Charge

Electrical charge is a property of matter.

Properties Of Electric Charge

- Electric charge is a scalar quantity.
- It can be of two types only : positive and negative
- Electric charge is measured in a unit 'Coulomb'.
- Like charges repel each other while unlike charges attract each other.

Matter consists of tiny particles called atoms. Atoms contain particles called protons, neutrons and electrons.



Neutrons ➡ No electric charge.
Protons ➡ Positive electric charge
Electrons ➡ Negative electric charge.

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Electric potential

Electric potential at a point A in an electric field is the work done per unit positive charge in transporting it from infinitely far away to the point A. (see figure)

$$V = \frac{W}{Q_0}$$

Electric potential is a scalar quantity.

Unit of electric potential
SI unit : Volt (V)

Definition of 1 volt in terms of electric potential 1 volt is the electric potential at any point A when 1 joule work is done in moving a charge of 1 coulomb from infinity to the point A.

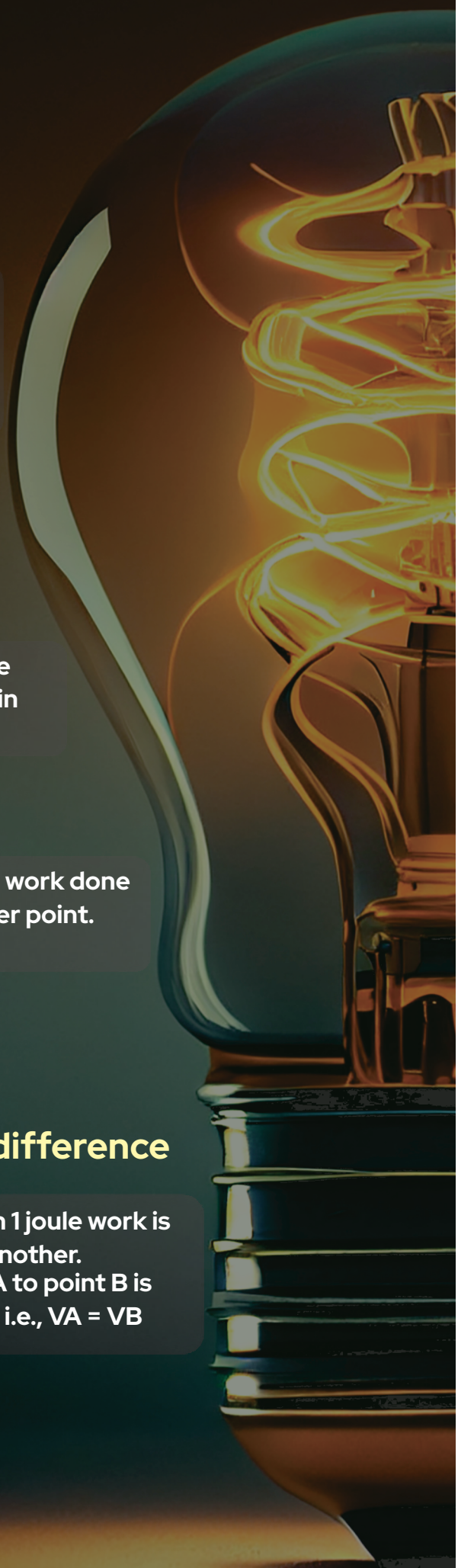
Potential difference

Potential difference between two points is defined as the work done in carrying a unit positive charge from one point to another point.

$$V = \frac{W}{Q_0}$$

Definition of 1 volt in terms of potential difference

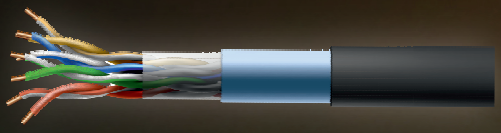
1 volt is the potential difference between two points when 1 joule work is done in moving a charge of 1 coulomb from one point to another.
If work done in moving a unit positive charge from point A to point B is zero, it means, potentials of point A and point B are same, i.e., VA = VB



Conductors

Conductors are 'materials which allow electric current to pass through them are conductors of electricity'.

e.g.



Insulators

The substances which do not allow the electric current to flow through them are called insulators.

e.g.



Current Electricity

Electric current

Electric current is a scalar quantity. Though, a direction is associated with electric current, still it is not considered as vector quantity because it does not obey the vector laws but obeys scalar laws of addition.

Unit of electric current

The electric current is expressed by a unit called ampere (A), named after the French scientist, Andre-Marie Ampere (1775–1836). Small quantities of current are expressed in milliampere (1mA = 10–3 A) or in microampere (1 μ A = 10–6 A).

SI unit : Ampere

1 Ampere = 1 coulomb/sec = 1 Cs–1

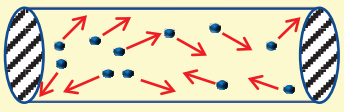
Definition of 1 ampere

1 ampere is the electric current flowing through a conducting wire when 1 coulomb charge flows through it in 1 second.

Current carriers

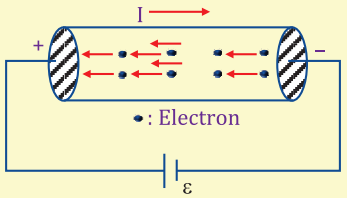
The charged particles which flow in a particular direction to produce electric current are called 'current carriers'.

Flow of charge through a conductor



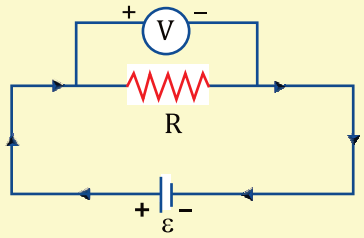
• : Electron

(a) Random motion of electrons in the absence of any potential difference.



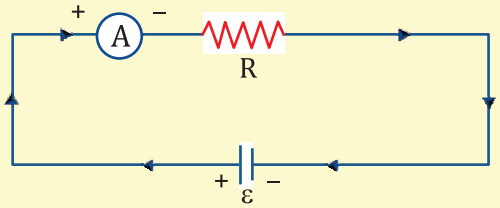
(b) Motion of electrons in a particular direction resulting an electric current on applying potential difference.

Measuring potential difference



Measuring potential difference across a resistor using a voltmeter.

Measuring current

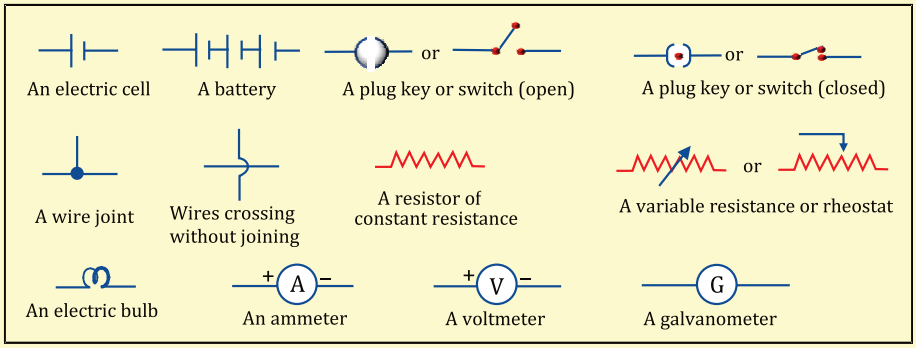


Measuring electric current through a resistor using an ammeter.

Electric circuits

A continuous path which consists of various electric devices like bulb, tube light, resistors, etc.

Circuit elements



Symbols of some commonly used components in circuit diagrams

Electric resistance

The property of a material which offers opposition to the electric current and dissipates energy is called its 'electric resistance'.

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

SI unit : ohm (Ω)

1 ohm = 1 volt/ampere or $1\,\Omega = 1\,V\,A^{-1}$

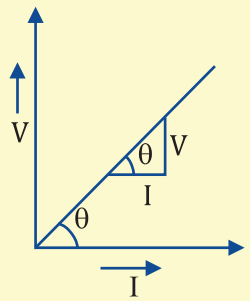
Ohm's law

According to Ohm's law, 'the current through certain conductors is directly proportional to the potential difference between its ends at a constant temperature'.

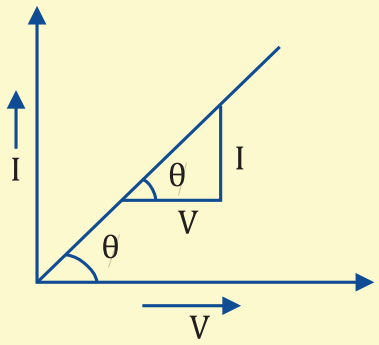
$I \propto V$ or $V \propto I$

or $V = IR$

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

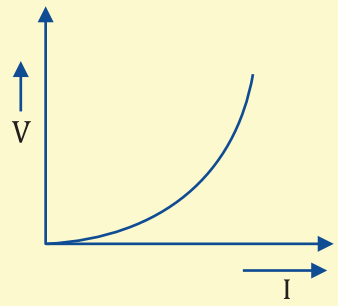


(a) Resistance, =tan θ V-I graph for a conductor obeying



(b)I-V graph for a conductor obeying Ohm's law.

Ohm's law is not a fundamental law, it is only an empirical law that holds approximately good for many substances particularly metals



V-I graph for a conductor not obeying Ohm's law.

Resistors

A physical device which has the principal characteristic of offering electric resistance is called 'resistor'.

Materials used for resistors

(1) Alloys like manganin, constantan, nichrome, etc.; used in wire wound resistors.

(2) Carbon resistors; compact and low cost.

(3) Aluminium or copper wires; low resistance conductors used to make connecting wires/electrical transmission lines.

$R \propto \ell$

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

$R \propto \frac{\ell}{A}$ or $\boxed{R = \rho \frac{\ell}{A}}$

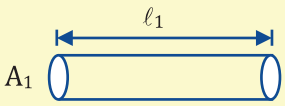
Resistivity (specific resistance)

It is a characteristic property of a material rather than that of a particular specimen of a material. It depends on physical conditions such as temperature and pressure.

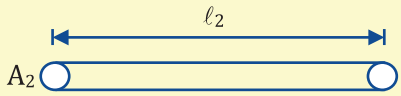
If l is 1 unit length and A is 1 square unit area, then, R = r

SI unit : ohm-meter (Ωm)

Effect of stretching of a wire on resistance



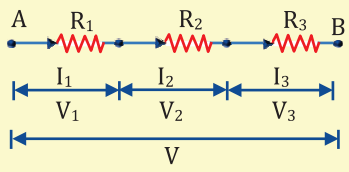
(a) A wire before stretching

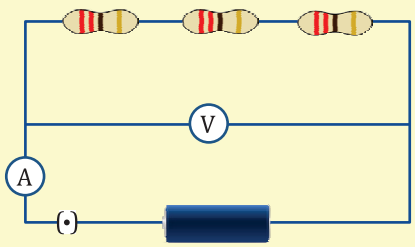


(b) A wire after stretching

$$R_2 = n^2 R_1$$

Resistors in series

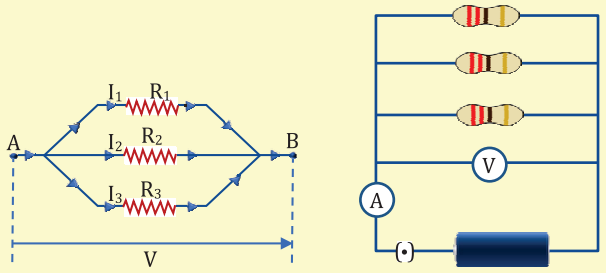




A series combination of resistors

$$R_s = R_1 + R_2 + R_3 + ... + R_n$$

Resistors in parallel



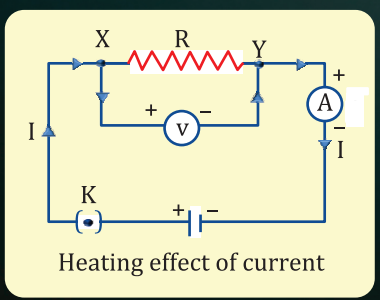
A parallel combination of resistors.

$$\frac{1}{R_p}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\text{---}+\frac{1}{R_n}$$

Heating effect of electric current

If an electric circuit is purely resistive, that is, it consists of resistors only connected to a battery, the source energy gets dissipated entirely in the form of heat. This heating effect is utilised in devices such as electric geysers, electric heater, electric iron, etc

Electric power : The work done per unit time by a source of emf (like a battery) in order to maintain electric current in a circuit is called 'electric power'.



Heating effect of current

$$W = Q \times V \quad \ldots (1) \left(\because V=\frac{W}{Q}\right)$$

Thus, the power input to the circuit by the source is

$$P=\frac{W}{t}=\frac{Q\times V}{t}=\left(\frac{Q}{t}\right)\times V = I\times V \text{ or } \boxed{P=VI}$$

Joule's law of heating

$H = I^2Rt$

According to Joule's law of heating, the heat produced in a resistor is directly proportional to the square of current for a given resistance, directly proportional to resistance for a given current, and directly proportional to the time for which the current flows through the resistor.

Applications of thermal effects of current

Electric bulb : The electric heating or joules heating is used in producing light in 'electric bulb'.

An electric bulb consists of a filament of a strong metal with high melting point such as 'tungsten' (melting point 3380 °C) sealed in a glass bulb. Most of the power consumed by the filament appears as heat, and a small part of it is converted into the form of light.

Electric fuse and its action : It is a safety device used to prevent the electric appliances against excessive electric currents.

It consists of a piece of wire made of a metal or an alloy of appropriate melting point, for example aluminium, copper, iron, lead etc. Usually, a metallic conducting wire (fuse wire) made of Tin (25%) and Lead (75%) having low melting point is used. The fuse wire is usually encased in a cartridge of porcelain or similar material with metal ends.

