ELECTRIC CURRENT, RESISTANCE AND E.M.F.

2.01. ELECTRIC CURRENT

The electric current is defined as the rate of flow of electric charge through any section of a wire. It is denoted by I. Thus,

$$I = \frac{\text{total charge flowing } (q)}{\text{time taken } (t)}$$

If charge dq flows through a wire in small time dt, then electric current through the wire is given by

$$I = \frac{dq}{dt} \quad \text{...(2.01)}$$

The direction in which the positive charge will flow gives the direction of *conventional current.* Since the flow of electric current is attributed to flow of electrons, the direction of *electronic current* is opposite to that of conventional current. Although a direction is associated with electric current, yet it is a scalar quantity. The reason is that laws of ordinary algebra are used to add electric currents or that the laws of vector algebra do not apply to the addition of electric currents.

Unit of electric current. S.I. unit of electric current is **ampere.** It is also the practical unit of current. It is denoted by **A.**

The electric current through a wire is called one ampere, if one coulomb of charge flows through the wire in one second. Thus,

$$\textbf{1 ampere (A)} = \frac{\textbf{1 coulomb (C)}}{\textbf{1 second (s)}} = \textbf{1 C s}^{-1}$$

Note. $6{\cdot}25 \times 10^{18}$ electrons constitute a current of 1 A.

2.02. OHM'S LAW

It is the most fundamental law of electricity and was given by George Simon Ohm in 1828.

It states that *the physical conditions (temperature, mechanical strain etc) remaining unchanged, the current flowing through a conductor is always directly proportional to the potential difference across its two ends.* Mathematically,

$$V \propto I$$

or

$$V = R\,I, \qquad ...(2.02)$$

where the constant of proportionality R is called the *ohmic electrical resistance or simply resistance* of the conductor. Its value depends upon the nature of conductor, its dimensions and the physical conditions. It is independent of the values of V and I.

2.03. RESISTANCE OF A CONDUCTOR

Resistance of a conductor is defined as the ratio of the potential difference applied to the current flowing through the conductor. Mathematically,

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

The resistance of a conductor implies the obstruction, which the conductor offers to the flow of charge through it. When a potential difference is applied across a conductor, an electric field is set up across its two ends. Due to this, the free electrons get accelerated. As the electrons move, they collide with the atoms and their motion is thus opposed. The opposition offered by the atoms as a result of which the electrons are slowed down is termed as the resistance of the conductor.

Unit of resistance. S.I. unit of resistance is **ohm**. It is denoted by Ω.

The resistance of a conductor is said to be one ohm, if one ampere of current flows through it, when a potential difference of one volt is applied across the conductor.

$$1 \text{ ohm } (\Omega) = \frac{1 \text{ volt (V)}}{1 \text{ ampere (A)}} = 1\text{ V A}^{-1}$$

1.6×10

2.04. RESISTIVITY AND CONDUCTIVITY

The resistance of a conductor depends upon the following factors :

(*i*) *It is directly proportional to the length of the conductor i.e.*

$$R \propto l \qquad ...(2.03)$$

(*ii*) *It is inversely proportional to the area of cross-section of the conductor i.e.*

$$R \propto \frac{1}{A} \qquad ...(2.04)$$

Combining equations (2.03) and (2.04), we have

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

or

$$R = \rho \frac{l}{A}, \qquad ...(2.05)$$

where the constant of proportionality ρ is called *electrical resistivity* or *specific resistance* of the conductor. Its value depends upon the nature of the material of the conductor and its temperature.

If $l = 1$, $A = 1$, then

$$R = \rho \frac{1}{1} \quad \text{or} \quad \rho = R$$

Hence, *resistivity or specific resistance of the material of a conductor is the resistance offered by a wire of this material of unit length and unit area of cross-section.*

Unit of resistivity. From equation (2.05), we have

$$\rho = R\frac{A}{l}$$

In S.I., unit of resistivity = ohm $\frac{\text{metre}^2}{\text{metre}}$ = ohm metre

i.e., S.I. unit of resistivity is **ohm metre (Ω m).**

The electrical resistivity of substances varies over a very wide range as can be seen from the following table :

Material	Resistivity at 0°C (Ω m)	Material	Resistivity at 0°C (Ω m)
(a) Conductors :		(c) Semiconductors :	
Silver	$1{\cdot}6 \times 10^{-8}$	Carbon	$3{\cdot}5 \times 10^{-5}$
Copper	$1{\cdot}7 \times 10^{-8}$	Germanium	0·46
Aluminium	$2{\cdot}7 \times 10^{-8}$	Silicon	2300
Tungsten	$5{\cdot}6 \times 10^{-8}$		
Iron	10×10^{-8}	(d) Insulators :	
Platinum	11×10^{-8}	Wood	10^8—10^{11}
Mercury	98×10^{-8}	Glass	10^{10}—10^{14}
(b) Alloys :		Amber	5—10^{14}
Manganin	44×10^{-8}	Mica	10^{11}—10^{15}
Constantan	49×10^{-8}	Hard Rubber	$10^{13} \times 10^{14}$
Nichrome	100×10^{-8}		

The first column lists the electrical resistivity of metals and alloys. It follows that metals have low resistivities and they are called *conductors* of electricity. In the second column, materials such as glass and hard rubber are about 10^{22} to 10^{24} times more resistive than silver and copper. These are called *insulators*. Materials like carbon, germanium and silicon having resistivity in between those of conductors and insulators are called *semi-conductors*.

Conductance. *The reciprocal of resistance of a conductor is called its conductance.* It is denoted by C. Thus, conductance of a conductor having resistance R is given by

$$C = \frac{1}{R} \qquad ...(2.06)$$

S.I. unit of conductance is **ohm**$^{-1}$ (Ω^{-1}), which is also called **mho**. Now a days, unit of conductance is termed as **simen** and is represented by the symbol **S**.

Conductivity. *The reciprocal of resistivity of the material of a conductor is called its conductivity.* It is denoted by σ. Thus,

$$\sigma = \frac{1}{\rho} \qquad ...(2.07)$$

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power cables.

2.05. COLOUR CODE FOR CARBON RESISTANCES

The value of resistances used in electrical and electronic circuits vary over a very wide range. These resistances are usually carbon resistances and a colour code is used to indicate the value of the resistance.

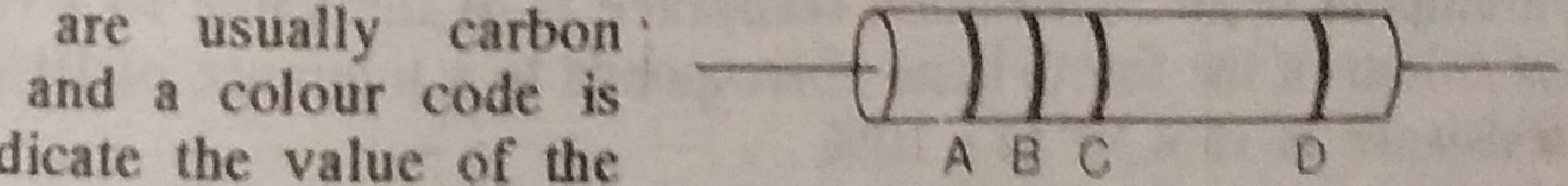

Fig. 2.01

A carbon resistance has usually four concentric rings or bands A, B, C and D of different colours [Fig. 2.01]. The colours of first two bands A and B indicate the first two significant figures of the resistance in ohm, while the colour of third band C indicates the decimal multiplier. The colour of fourth band D (which is either silver or gold) tells the *tolerance*. Sometimes, only three colour bands A, B and C are marked.