1.3 OHM'S LAW

Ohm's law states that in a linear network, at constant temperature the voltage across the conducting material is directly proportional to the current flowing through the material,

i.e.,

$$V \propto I$$

or,

$$V = RI$$

where the constant of proportionality, R, is called *resistance*; its unit is ohm.

When the temperature changes, the resistivity (ρ) and the physical dimension (length l or area A) of the resistance material also vary. As $R = \rho \dfrac{L}{A}$, any change in the value of resistivity or physical dimension would affect the value of the resistance, R. Therefore, Ohm's law is only valid at constant temperatures.

For illustration purpose, let us assume that a resistor, R, is connected between the nodes 1 and 2, with potentials V_1 and V_2 as shown in Fig. 1.8.

If $V_1 > V_2$, then the potential difference between these nodes 1 and 2 is given by

$$V_1 - V_2$$

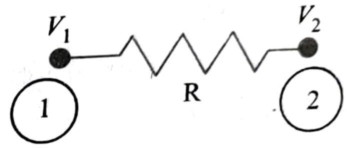

FIG. 1.8 An illustration for Ohm's law

If the current I flows because of this potential difference, then according to Ohm's law

$$V_1 - V_2 = IR$$

or simply, $V = IR$, where $V = V_1 - V_2$.

The V–I relationship for a linear resistor is shown in Fig. 1.9.

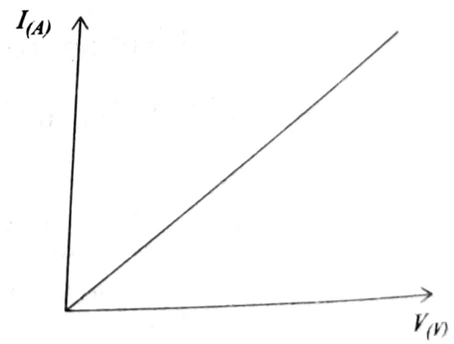

FIG. 1.9 V–I relationship for a linear resistor

From this relationship, the unknown voltage across a resistor can be calculated by the known current and resistance values. Similarly, if the values of R and V are known, the value of I can be calculated using the relationship,

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

If the values of I and V are known, R can be calculated by using the relationship,

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

Limitations of Ohm's Law

1. Ohm's law is applicable only for metallic conductors maintained at a constant temperature. The law is not applicable if the temperature changes.
2. Ohm's law is not applicable to all non-metallic conductors.

3. It is also not applicable to non-linear devices such as diodes, transistors, and other semiconductor devices.

Example 1.1 Find the voltage drop across a 10 kΩ resistor if the current flowing through it is 1 mA.

Solution

Given: $R = 10\ \text{k}\Omega$ and $I = 1\ \text{mA}$
According to Ohm's law, the voltage across the resistor is

$$V = IR = 1\times10^{-3}\times10\times10^{3} = 10\,\text{V}$$

Example 1.2 Find the current in the circuit shown in Fig. E1.2.

Solution

Given: $V = 20\,\text{V}$ and $R = 20\,\text{k}\Omega$
According to Ohm's law, the current flowing through a 20 kΩ resistor is

$$I = \frac{V}{R} = \frac{20}{20\times10^{3}} = 1\,\text{mA}$$

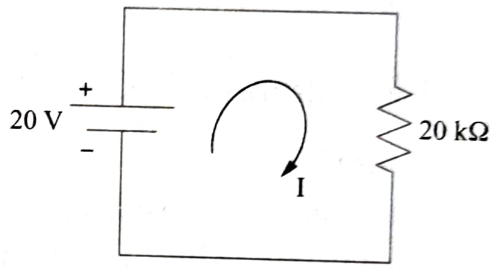

FIG. E1.2

Example 1.3 Find the value of resistance, R, in the circuit shown in Fig. E1.3, if the ammeter measures 1 mA and voltmeter measures 2 V.

Solution

Given the ammeter measures $I = 1$ mA and the voltmeter measures $V_R = 2$ V.
Applying Ohm's law, the unknown resistance R is calculated as

$$R = \frac{V_R}{I} = \frac{2}{1\times10^{-3}} = 2\,\text{k}\Omega$$

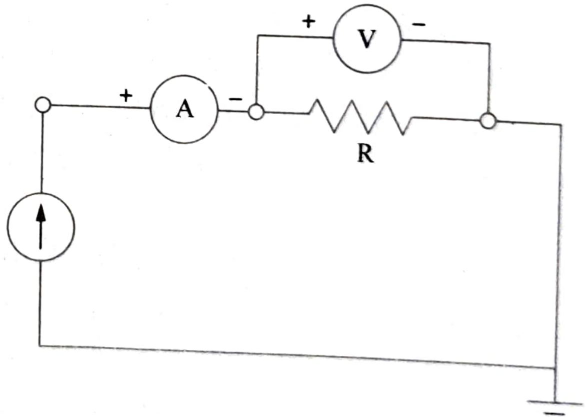

FIG. E1.3

Example 1.4 A conductivity meter measures the conductance of a material as 5℧. If the current flowing through that material is determined as 2 mA, find the applied voltage.

Solution

Given the conductance, $G = 5℧$

As resistance is the inverse of conductance, $R = \frac{1}{G} = \frac{1}{5} = 0.2\,\Omega$

The ammeter measures $I = 2\,\text{mA}$
Therefore, the applied voltage, $V = IR = 2\times10^{-3}\times0.2 = 0.4\,\text{mV}$