

Introduction

Charge is a fundamental particle of matter. It may be positive and negative. S.I. unit of charge is Coulomb (C).

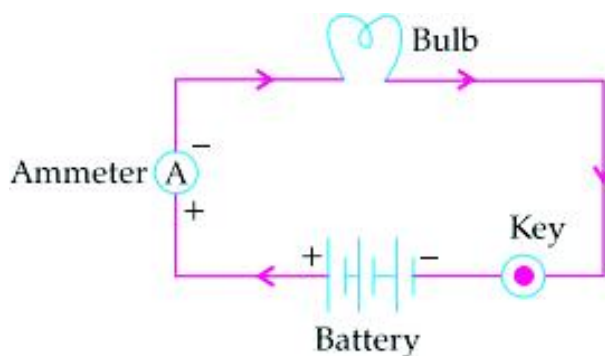
11.1 Electric Current: The net charge flows across any cross-section of a conductor in unit time is called electric current.

$$\text{Electric current (I)} = \frac{\text{Net Charge (Q)}}{\text{Time (t)}}$$

S.I. unit of electric current is ampere (A). Current is measured by Ammeter..

Conventional direction of current: Conventionally, the direction of motion of positive charges through the conductor is taken as the direction of current. The direction of conventional current is opposite to that of the negatively charged electrons.

11.2 Electric circuit: The closed path along which an electric current flows is called an 'electric circuit'. The schematic diagram of a typical electric circuit is

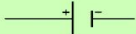
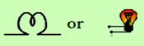
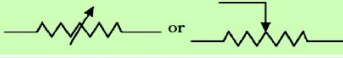
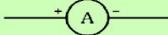
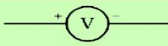


11.3 Electric potential: The amount of electric potential energy at a point.

Potential difference: The amount of work done in moving a unit positive charge from one point to another point in the field. It is known as voltage. S.I. unit of potential difference is volt (V). Potential difference is measured by Voltmeter .

$$\text{Potential difference (V)} = \frac{\text{Work done (W)}}{\text{Charge (Q)}}$$

11.4 Symbols of some commonly used components in circuit diagrams:

S1. No.	Components	Symbols
1	An electric cell	
2	A battery or a combination of cells	
3	Plug key or switch (open)	
4	Plug key or switch (closed)	
5	A wire joint	
6	Wires crossing without joining	
7	Electric bulb	
8	A resistor of resistance R	
9	Variable resistance or rheostat	
10	Ammeter	
11	Voltmeter	

11.5 Ohm's law: The potential difference across the ends of a given metallic wire in an electric circuit is directly proportional to the current flowing through it, provided its temperature remains the same.

Mathematical Form of Ohm's Law is $V = IR$

Where,

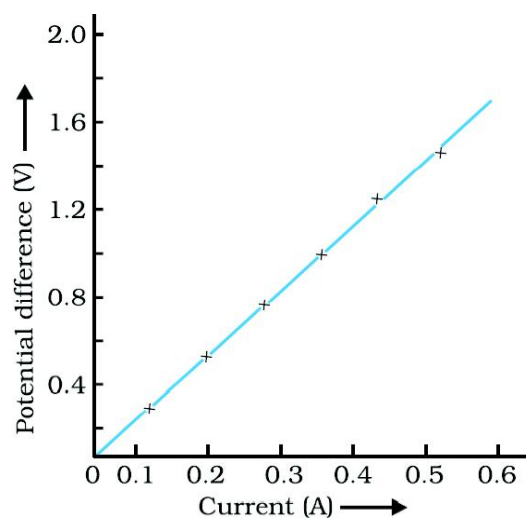
V = Potential difference (in volts, V)

I = Current (in amperes, A)

R = Resistance (in ohms, Ω)

Significance of Ohm's Law: It helps in understanding how current, voltage, and resistance are related and how to control the current in a circuit.

V-I graph for Ohm's law: The graph between V and I is straight line passes through the origin and V/I is a constant ratio.



11.6 Resistance: Resistance is the opposition to the flow of electric current in a conductor. S.I unit of resistance is ohm (Ω). It depends on the material, length, and cross-sectional area of the conductor, as well as the temperature.

$$\text{Resistance (R)} = V/I$$

Where, R = Resistance (in ohms, Ω),

V = Potential difference (in volts, V),

I = Current (in amperes, A).

Factors on which the Resistance of a Conductor depends:

- (i) Directly proportional to the length of the conductor.
- (ii) Inversely proportional to the area of cross-section.
- (iii) Directly proportional to the temperature.
- (iv) Depends on nature of the material.

11.7 Resistivity (ρ): The resistance of a uniform metallic conductor is directly proportional to its length (l) and inversely proportional to the area of cross-section (A).

$$R \propto l \text{ and } R \propto 1/A$$

Combining both equations

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

The resistance offered by a wire of unit length and unit cross-sectional area is called resistivity. Its S.I. unit is Ohm-metre ($\Omega\text{-m}$).

Resistivity does not change with change in length or area of cross-section but it changes with change in temperature.

Table 11.2 Electrical resistivity* of some substances at 20°C

	Material	Resistivity ($\Omega\text{ m}$)
Conductors	Silver	1.60×10^{-8}
	Copper	1.62×10^{-8}
	Aluminium	2.63×10^{-8}
	Tungsten	5.20×10^{-8}
	Nickel	6.84×10^{-8}
	Iron	10.0×10^{-8}
	Chromium	12.9×10^{-8}
	Mercury	94.0×10^{-8}
	Manganese	1.84×10^{-6}
Alloys	Constantan (alloy of Cu and Ni)	49×10^{-6}
	Manganin (alloy of Cu, Mn and Ni)	44×10^{-6}
	Nichrome (alloy of Ni, Cr, Mn and Fe)	100×10^{-6}
Insulators	Glass	$10^{10} - 10^{14}$
	Hard rubber	$10^{13} - 10^{16}$
	Ebonite	$10^{15} - 10^{17}$
	Diamond	$10^{12} - 10^{13}$
	Paper (dry)	10^{12}

Range of resistivity of metals and alloys is 10^{-8} to $10^{-6} \Omega\text{m}$.

Range of resistivity of insulators is 10^{12} to $10^{17} \Omega\text{m}$.

Resistivity of alloy is generally higher than that of its constituent metals. Alloys do not oxidize (burn) readily at high temperature, so they are commonly used in electrical heating devices. Copper and aluminium are used for electrical transmission lines as they have low resistivity.

11.8 Combination of Resistors: Resistors can be connected in series or parallel to form different types of circuits.

(a) Resistances in series: When two or more resistances are connected end to end so that same current flows through each one of them in turn, they are said to be connected in series. Here, the total resistance is equal to the sum of the individual resistances.

$$R_s = R_1 + R_2 + R_3 + \dots$$

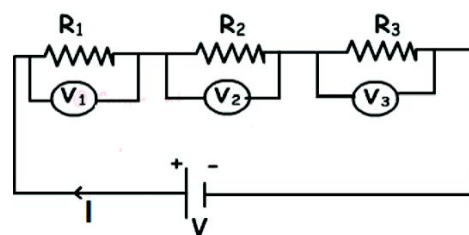
In series connection of resistors there is only one path for the flow of current in the circuit. Hence, the current in the circuit is equal to I

On applying Ohm's law to each resistor

$$V_1 = IR_1$$

$$V_2 = IR_2$$

$$V_3 = IR_3$$



Let R be the equivalent resistance of the combination of resistors in series.

$$\text{Also } V = IR_s$$

$$V = V_1 + V_2 + V_3$$

$$IR_s = IR_1 + IR_2 + IR_3$$

$$IR_s = I(R_1 + R_2 + R_3)$$

$$R_s = R_1 + R_2 + R_3$$

The resistance of the equivalent resistance in series combination is equal to the sum of their individual resistance.

(b) Resistances in parallel: When two or more resistances are connected across two points so that each one of them provides a separate path for current, they are said to be connected in parallel. Here, the reciprocal of their combined resistance is equal to the sum of the reciprocals of the individual resistances.

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

In parallel connection of resistors there is same potential difference at the ends of the resistors. Hence, the potential difference is equal to V .

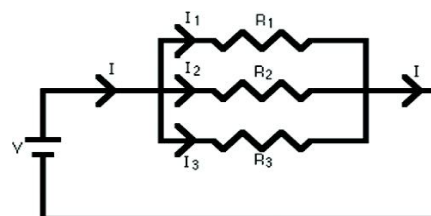
On applying Ohm's law to each resistor

$$I_1 = V/R_1$$

$$I_2 = V/R_2$$

$$I_3 = V/R_3$$

Let R be the equivalent resistance of the combination of resistors in series.



Also $I = V/R_p$

$$I = I_1 + I_2 + I_3$$

$$V/R_p = V(1/R_1 + 1/R_2 + 1/R_3)$$

$$1/R_p = 1/R_1 + 1/R_2 + 1/R_3$$

The reciprocal of the equivalent resistance of a parallel combination is equal to the sum of the reciprocals of the individual resistances.

11.9 Heating Effect of Electric Current: When an electric current flows through a conductor, it generates heat. This is known as the *heating effect of electric current*. The amount of heat produced depends on the current, the resistance of the conductor, and the time for which the current flows.

Formula for Heat Produced is $H = I^2 R t$

Where, H = Heat produced (in joules, J),

I = Current (in amperes, A),

R = Resistance (in ohms, Ω),

t = Time (in seconds, s).

Practical Applications of Heating Effect of Electric Current:

The electric laundry iron, electric toaster, electric oven, electric kettle and electric heater, electric bulb, Fuse are some of the familiar devices based on Joule's heating.

11.10 Electric Power: The rate at which electrical energy is consumed or produced in a circuit. It is measured in watts (W).

Formula for Electric Power is $P = VI$

Commercial Unit of Electric Energy: Electric energy is measured in kilowatt-hours (kWh) in commercial contexts. Formula for Electric Energy is $E = P \times t$