ELECTRICITY
RESISTANCE

ELECTRICAL RESISTANCE:

(a) Ohm's Law:

It states that the current passing through a conductor is directly proportional to the potential difference across its ends, provided the temperature and other physical conditions (mechanical stain etc.), remain unchanged i.e.

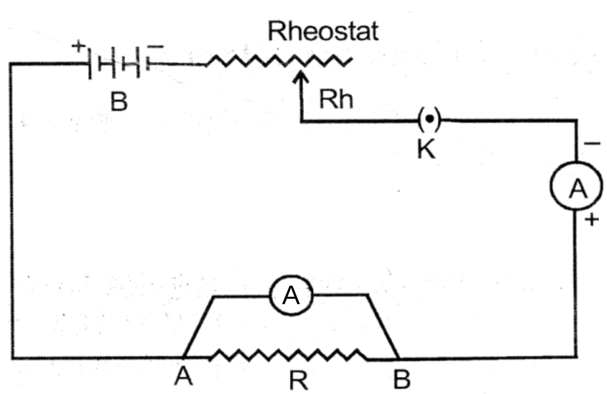
Where R is a content called resistance of the conductor.
The relation R = V/I is referred to an Ohm's law, after the German physicist George Simon Ohm (1789 -1854), who discovered it.
It is quite clear from the above equation that

(i) The current **I** is proportional to the potential difference **V** between the ends of the resistor.

(ii) Current **I** is inversely proportional to the resistance.

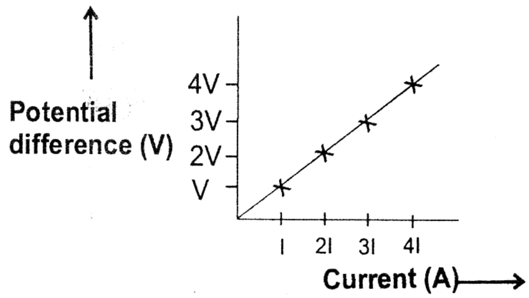
Experimental verification of ohm's law:

Set up a circuit as shown in the figure below consisting of a wire AB, a current measuring instrument called ammeter, an instrument measuring the potential difference called voltmeter and a number of cells, each of which provided some constant potential difference across the two point of a conductor. First, use one cell and note the current in the circuit and the potential difference across the wire AB. Suppose potential difference due to the cell produces a current **I** in the circuit and a potential difference (**V**) across the wire AB.
Repeat this experiment with two cells, three cells and four cells.



Note the successive readings in the ammeter and the voltmeter. WE will find that with two cells in the circuit, the current would be **2I** and the potential difference **2v.** Similarly, with three cells the current is **3I** and potential difference **3v** and so on. [The important precaution to observe here is not allow the current of flow in the wire continuously. This can be done by taking off the plug key and closing it only when the current is to be drawn.]

Now, plot a graph between the current and the potential difference. we will be a straight line graph.



(b) Resistance of a Conductor:

The electric current is a flow of electrons through a conductor. When the electrons move from one part of the conductor to the other part, they collide with other electrons and with the atoms and ions present in the body of the conductor. Due to these collisions, there is some obstruction or opposition to the flow of electrons through the conductor.

The property of a conductor due to which it opposes the flow of current through it, is called resistance. The resistance of conductor is numerically equal to the ratio of potential difference across its ends to the current following through it.

$$\Rightarrow \qquad \text{Resistance} = \frac{\text{Potential difference}}{\text{Current}}$$

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

(c) Unit of Resistance:

The S.I. unit of resistance is **ohm**, which is denoted by the symbol Ω.

When a potential difference of 1 volt is applied to its ends and a current of 1 ampere flows through it, then resistance f the conductor will be 1 ohm.

(d) Conductors, Resistors and Insulators:

On the basis of their electrical resistance, all the substances can be divided into three groups: conductors, resistors and insulators.

(i) Conductors:

Those substances which have very low electrical resistance are called conductors. A conductor allows the electricity to flow through it easily. Silver metal is the best conductor of electricity. Copper and aluminum metals are also conductors. Electric wires are made of copper or aluminum because they have very low electrical resistance.

(ii) Resistor:

Thos substances which have comparatively high electrical resistance, are called resistors. The alloys like nichrome, manganin and constantan (or ureka), all have quite high resistances, so they are used to make those electrical devices where high resistance is required. A resistor reduces the current in the circuit.

(iii) Insulators:

Those substances which have infinitely high electrical resistance are called insulators. An insulator does to allow electricity to flow through it. Rubber is an excellent insulator. Electrician wear rubber hundgloves while working with electricity because rubber in an insulator and protects them from electric shocks. Wood is also a good insulator.

(e) Factors affecting the Resistance of a Conductor:

Resistance depends upon the following factors:

(i) length of the conductor.

(ii) Area of cross - section of the conductor (or thickness of the conductor).

(iii) Nature of the material of the conductor.

(iv) Temperature of the conductor,

Mathematically : it has been found by experiments that :

(i) The resistance of a given conductor is directly proportional to its length i.e.

$$R \propto \ell \qquad \text{..........(i)}$$

(ii) The resistance of a given conductor is inversely proportional to its area of cross-section i.e.

$$R \propto \frac{\ell}{A} \qquad \text{........(ii)}$$

From (i) and (ii)

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

$$R = \frac{\rho \times \ell}{A} \qquad \text{...........(iii)}$$

Where ρ (rho) is a constant known as resistively of the material of the conductor. Resistivity is also known as specific resistance.

Dependency of resistance on temperature:

If R_0 is the resistance of the conductor at 0^0C and R_t is the resistance of the conductor at t^0C then the relation between R_0 and R_t is given by.

$R_t = T_0\,(1+\ \alpha\Delta T)$ [Here $\Delta t = t - 0 = t$]

or $$\alpha = \frac{R_t R_0}{R_0 t}$$

Here, α = Coefficient of Resistivity, t= temperature in ^{0}C

(r) Resistivity:

$$\text{Resistivity,}\quad \rho = \frac{R \times A}{\ell} \qquad \text{.........(iv)}$$

By using this formula, we will now obtain the definition of resistivity. Let us take a conductor having a unit area of cross - section of 1 m^2 and a unit length of 1 m. So, putting A = 1 and ℓ = 1 in equation (iv), we get:
Resistivity, ρ = R
The resistivity of a substance is numerically equal to the resistance of a rod of the substance which is 1 metre long and 1 metre square in cross - section.

$$'\rho' = \frac{\text{ohm} \times (\text{metre})^2}{\text{metre}} = \text{ohm - metre}$$

The S.I. unit of resistivity is ohm-metre which is written in symbols as Ω-m.
Resistivity of a substance does not depend on its length or thickness. It depends only on the nature of the substance. The resistivity of a substance is its characteristic property. So, we can use the resistivity values to compare the resistances of two or more substances.

(i) Importance of resistivity:

A good conductor of electricity should have a low resistivity and a poor conductor of electricity should have a high resistivity. The resistivities of alloys are much more higher than those of the pure metals. It is due to their high resistivities that manganin and constantan alloys are used to make resistance wires used in electronic appliances to reduced the current in an electrical circuit.
Nichrome alloy is used for making the heating elements of electrical appliances like electric irons, room-heaters, water-heaters and toasters etc. because it has very high resistivity and it does not undergo oxidation (or burn) even when red-hot.

(ii) Effect of temperature of resistivity:

The resistivity of conductors (like metals) is very low. The resistivity of most of the metals increases with temperature. On the other hand, the resistivity of insulators like ebonite, glass and diamond is very high and does to changes with temperature. The resistivity of semi-conductors like silicon and germanium is in between those of conductors and insulators and decreases on increasing the temperature. Semi-conductors are proving to be of great practical importance because of their marked change in conducting properties with temperature and impurity concentration.

Que.: Why alloys do not oxidize (burn) readily at high temperature?

Ans. Because with the change in temperature their resistivity changes less rapidly.

(g) Combination of Resistances (or Resistors):

Apart from potential difference, current in circuit depend or resistance of the circuit. So, in the electrical circuits of radio, television and other similar things, it is usually necessary to combine two or more resistances to get the required current in the circuit. We can combine the resistances lengthwise (called series) or we can put the resistances parallel to one another. Thus, the resistances can be combined in two ways : (i) series combination (ii) parallel combination

(i) Series combination of resistors:

Consider three resistors of resistances R_1, R_2 and R_3 connected in series to cell of potential difference V as shown in figure. Since the three resistors are connected in series therefore the current I through each of them is same.

Then by Ohm's law the potential drop across each resistor is given by $V_1 = IR_1$, V_2 and $V_3 = IR_3$.

Since V is the total potential in the circuit therefore by conservation of energy we have

$$V = V_1 + V_2 + V_3$$

Substituting for V_1, V_2 and V_3 in above equation we have,

$$V = IR_1 + IR_2 + IR_3 \qquad \text{........... (i)}$$

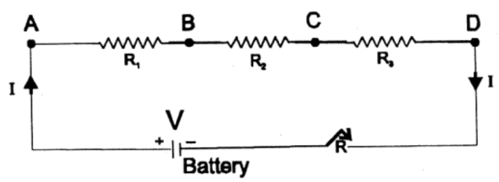
If R_S is the equivalent resistance of the series combination, then by Ohm's law we have

$$V = IR_s \qquad \text{........... (ii)}$$

Therefore from equations (i) and (ii) we have

$$IR_s = IR_1 + IR_2 + IR_3$$

Hence $$R_s = R_1 + R_2 + R_3$$



Series comination of resistances

Thus in series combination the equivalent resistance is the sum of the individual resistances. For more resistors, the above expression would have been-

$$\mathbf{R_s = R_1 + R_2 + R_3 + ...}$$

NOTE:

In a circuit, if the resistors are connected in series:

(A) The current is same in each resistor of the circuit:

(B) The resistance of the combination of resistors is equal to sum of the individual resistors.

(C) The total voltage across the combination is equal to the sum of the voltage drop across the individual resistors.

(D) The equivalent resistance is greater than that of any individual resistance in the series combination.

(ii) Parallel combination of resistors :

Consider two resistors R_1 and R_2 connected in parallel as shown in figure. When the current I reached point ‘a’, it splits into two parts I_1 going through R_1 and I_2 going through R_2. If R_1 is greater than R_2, then I_1 will be less than I_1 i.e. the current will tend to take the path of least resistance.

Since charge must be conserved, therefore the current I that enters point ‘a’ must be equal to the current that leaves that point. Therefore we have

$$I = I_1 + I_2 \qquad \text{.......(i)}$$

Since the resistors are connected in parallel therefore the potential across each must be same, hence by Ohm’s law we have

$I_1 = \frac{V}{R_1}$ and $I_2 = \frac{V}{R_2}$ substituting in equation (i) we have,

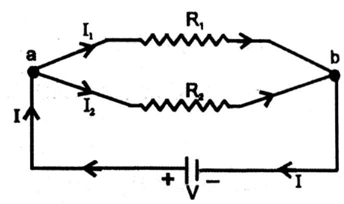
$$I = \frac{V}{R_1 + \frac{V}{R_2}} \qquad \text{........(ii)}$$

Let R_P be the equivalent resistance of the parallel combination, they by Ohm’s law we have,

$$I = \frac{V}{R_P} \qquad \text{........(iii)}$$

Hence from equations (ii) and (iii) we have,

$$\frac{V}{R_P} = \frac{V}{R_1} + \frac{V}{R_2} \quad \text{or} \quad \frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$$



An extension of this analysis to three or more resistors in parallel gives the following general expression

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \text{..........}$$

NOTE :

(A) The sum of the reciprocals of the individual resistance is equal to the reciprocal of equivalent resistance, R_P.

(B) The currents in various resistors are inversely proportional to the resistances, higher the resistance of a branch, the lower will be the current through it. The total current is the sum of the currents flowing in the different branches.

(C) The voltage across each resistor of a parallel combination is the same and is also equal to the voltage across the whole group considered as unit.

NOTE : For n equal residences $\frac{R_s}{R_p} = n^2$