Dr. Kumar Balwant Singh.

1) State and explain Kirchhoff's Laws and discuss their physical significance with the help of a suitable example, explain their use in circuit analysis.

Ans:- **Kirchhoff's Law:-**

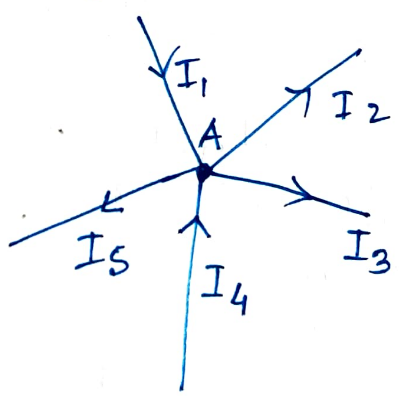
Gustav R. Kirchhoff present a rule of series and parallel circuits to solve the circuit problems known as Kirchhoff's law which are two types written and explain as follows:-

i) Kirchhoff's current Law (KCL)
ii) Kirchhoff's Voltage Law (KVL)

Kirchhoff's Current Law (KCL):-

Statement:- In any network of conductors, the algebraic sum of current meeting at a point (or junction) is zero.

In other words, it simply means that the total current leaving a junction is equal to the total current entering that junction.



Explanation:- Let us consider the case of five currents meeting at point A of the network shown in fig - 1 (a). Let us adopt positive sign for all currents entering the point and negative for leaving the point A.

According to this convention, I_1 and I_4 be positive and I_2, I_3 and I_5 be negative. Using KCL, we have.

$$I_1 + (-I_2) + (-I_3) + I_4 + (-I_5) = 0$$

or, $$I_1 - I_2 - I_3 + I_4 - I_5 = 0$$

$\therefore$ $$\sum I = 0$$ — at a junction or point.

Also, transposing the negative sign terms to the right hand side, we get.

$$I_1 + I_4 = I_2 + I_3 + I_5$$

i.e., incoming currents = outgoing currents

or, $I_{in} = I_{out}$ — at a junction

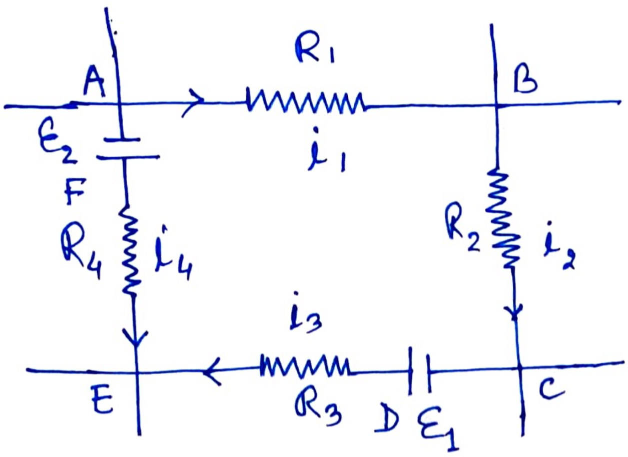
Kirchhoff's Voltage Law (KVL) :-

Statement :- The algebraic sum of all the potential differences along a closed loop in a circuit is zero.

or

The algebraic sum of all IR drops and EMFs in any closed loop (or mesh) of a network is zero.

or, $\sum IR = \sum EMF = 0$ — round a loop



Explanation:- Fig - 2.

While using this rule, one starts from a point on the loop and goes along the loop, either clockwise or anticlockwise to reach the same point again. Any potential drop encountered is ~~taken~~ to be negative. The net sum of all these potential differences should be zero.

In fig. 2, we show a loop ABCDEFA of a circuit. As we start from A and go along the loop clockwise to reach the same point A, we get the following potentials differences.

$$V_A - V_B = i_1 R_1$$

$$V_B - V_C = i_2 R_2$$

$$V_C - V_D = -\mathcal{E}_1$$

$$V_D - V_E = i_3 R_3$$

$$V_E - V_F = -i_4 R_4$$

$$V_F - V_A = \mathcal{E}_2$$

Adding all these;

$$0 = i_1 R_1 + i_2 R_2 - \mathcal{E}_1 + i_3 R_3 - i_4 R_4 + \mathcal{E}_2 .$$

The KVL or Loop law follows directly

from the fact that electrostatic force is a conservative force and the work done by it in any closed path is zero.

Circuit Analysis :-

~~We~~ use ~~of~~ the Kirchhoff's Laws to solve the circuit problem by nodal analysis and mesh analysis.

In the nodal method the numbers of independent node-pair equations needed is one less than the number of junctions in the network. That is, if 'n' denotes the number of independent node eqn. and 'j' the number of junctions,

$$n = j - 1.$$

In mesh method where KVL eqns are frequently used to solve the network, the ~~total~~ nodal method is advantageous when the network has many parallel circuits; otherwise, both the nodal and mesh methods offer almost equal advantages. In this method, the number of independent mesh eqn. needed is

$m = b - (j-1)$, where b is the number of branches.

If $m < n$, the mesh method offers advantages while for $m > n$ i.e., when the number of parallel paths in the network is more, nodal method is preferred.

K.Bisoi
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