Unit 5: DC Circuit (Q No. 5 and Q. No. 6)

1. Explain following types of Electrical Networks.

1) Linear and Non Linear network (2Unilateral and Bilateral network) (3) Active and Passive network (4) Lumped and Distributed Network

Ans: **(1) Linear Network:** A network in which values of the circuit elements (resistance, inductance and capacitance) remain constant, irrespective of change in voltage or current, is known as *'linear network'*. Ohm's law is applicable to such network.

Non Linear Network: On the other hand, if values of the circuit elements change with change in voltage or current, such a network is called *'Non-linear network'*. Ohm's law is not applicable to such a network.

(2) Bilateral Network: If characteristics or behavior of the circuit is independent of direction of current through various elements, such a network is called *'bilateral'*. Network comprised of pure resistance is bilateral one.

Unilateral Network: If characteristic or behavior of the circuit depends on direction of current through one or more elements it is called '*Unilateral Network'*.

A diode allows flow of current only in one direction when it is forward biased, circuit consisting of diode is unilateral one.

(3) Active Network: If electric circuit contains at least single energy source, it is called *'Active network'*. It may be either voltage or current source.

Passive Network: A circuit in absence of an energy source containing only passive elements is called *'Passive network'*.

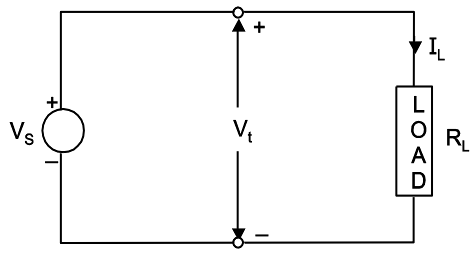
(4)Lumped Network: If all the network elements are physically separable, such a network is called *'lumpednetwork'*. Most of the electrical networks are lumped in nature.

Distributed Network: A network in which elements are not physically separable is known as *'distributednetwork'*.

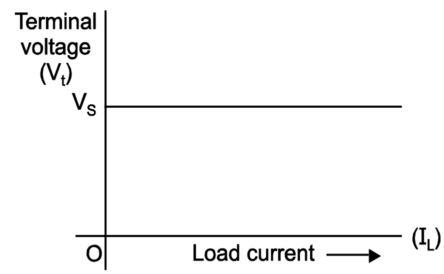
As resistance inductance and capacitance of a transmission line are uniformly distributed over its length, it is a 'distributed network'.

2. Explain concept of ideal and practical voltage and current sources.

Ans: **(1) Ideal Voltage Source:** An ideal voltage source is one which gives constant voltage across its terminals, irrespective of current drawn. Symbol for ideal voltage source and its V-I characteristic are shown in Fig. (a) and (b)



(a) Ideal Voltage Source



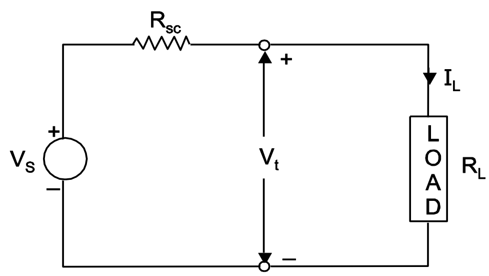
(b) V-I Characteristics

Where,

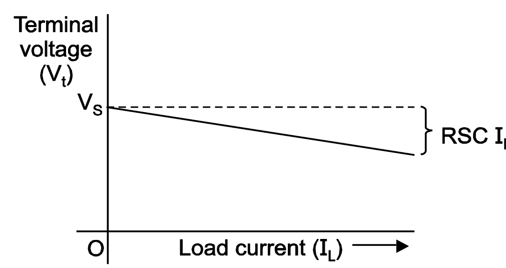
V_t=Terminal voltage, R_L= Load resistance, V_S=Source voltage and I_L=Load current

From V-I characteristic it can be seen that whatever is the value of load current terminal, voltage remains constant.

Practical Voltage Source: In practice, it is not possible because every voltage source has small internal resistance. Symbol of practical voltage source and it's V-I characteristic are shown in Fig. (c) and Fig. (d) respectively.



(C)Practical Voltage Source



(d) V-I Characteristics

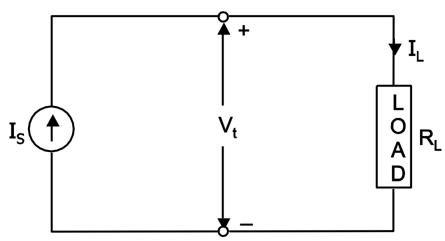
As load current increases ($R_{se} \times I_L$) drop increases and terminal voltage reduces.

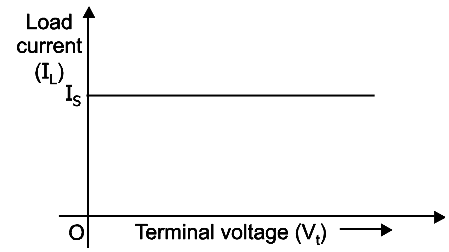
Terminal Voltage, $V_t = V_S - (R_{se} \cdot I_L)$

Thus, ideal voltage source has zero internal resistance, while practical voltage source has small internal resistance.

(2) Ideal Current Source: An ideal current source is one which delivers constant current irrespective of voltage across it's terminals.

Symbol for ideal current source and its V-I characteristics are shown in Fig. (a) andFig. (b) respectively.

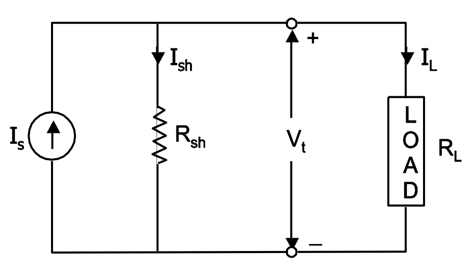


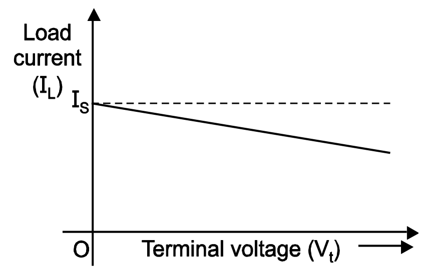


(a)IdealCurrent Source (b) V-I Characteristics

Internal resistance of ideal current source is infinity.

Practical Current Source: The practical current source has high (finite) internal resistance. Hence, with increase in terminal voltage, current delivered by such a source decreases. Symbol for Practical Current Source and it's V-I characteristics are shown in Fig. (c) and Fig. (d) respectively.

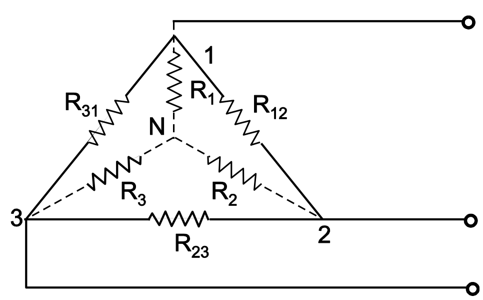




(a)Practical Current Source (b) V-I Characteristics

3. Derive the expression for conversion of a delta connected network into an equivalent star.

Ans: Let us convert this delta connection into an equivalent star connection. Let equivalent star resistances be R_1, R_2 and R_3.



To call these arrangements as equivalent of each other, resistance between two terminals must be same in both types of connections.

Resistance between terminals 1 and 2 will be

For delta connection $= \frac{R_{12}.(R_{23}+R_{31})}{R_{12}+R_{23}+R_{31}}$ … (1)

for star connection $= R_1+R_2$ … (2)

Equating (1) and (2)

$$\frac{R_{12}\,(R_{23}+R_{31})}{R_{12}+R_{23}+R_{31}} = R_1+R_2 \quad \ldots(3)$$

Similarly for resistances between terminal 3 and 1, we get

$$\frac{R_{31}.(R_{12}+R_{23})}{R_{12}+R_{23}+R_{31}} = R_1+R_3 \quad \ldots(4)$$

Also for resistances between terminals 2 and 3 we get,

$$\frac{R_{23}.(R_{31}+R_{12})}{R_{12}+R_{23}+R_{31}} = R_2+R_3 \quad \ldots(5)$$

Let's find R_1, R_2 and R_3 in terms of R_{12}, R_{23} and R_{31}

Subtracting Equation (4) from equation (5) we get,

$$\frac{R_{23}(R_{31}+R_{12})-R_{31}(R_{12}+R_{23})}{R_{12}+R_{23}+R_{31}} = R_2 - R_1 \quad \ldots(6)$$

Adding equations (3) and (6) we get,

$$\frac{R_{12}(R_{23}+R_{31})+R_{23}(R_{31}+R_{12})-R_{31}(R_{12}+R_{23})}{R_{12}+R_{23}+R_{31}} = 2.R_2$$

$$\therefore \quad \frac{2.R_{12}.R_{23}}{R_{12}+R_{23}+R_{31}} = 2.R_2$$

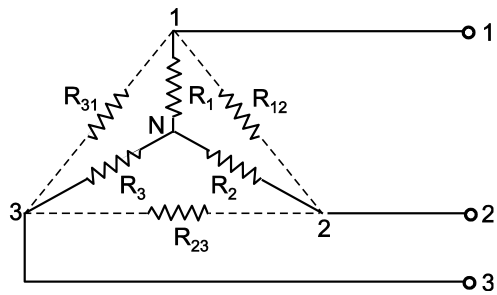
$$\therefore \quad R_2 = \frac{R_{12}.R_{23}}{R_{12}+R_{23}+R_{31}} \quad \ldots(7)$$

Similarly, $R_1 = \frac{R_{12}.R_{31}}{R_{12}+R_{23}+R_{31}}$ …(8)

and $R_3 = \frac{R_{23}.R_{31}}{R_{12}+R_{23}+R_{31}}$ … (9)

4. Derive the expression for conversion of a star connected network into an equivalent Delta.

Let 3 resistances R_1, R_2 and R_3 be connected in star as shown in Fig.



Making use of following equations (Delta to star conversion),

$$R_1=\frac{R_{12}.R_{31}}{R_{12}+R_{23}+R_{31}} \quad \ldots(1)$$

$$R_2=\frac{R_{12}.R_{23}}{R_{12}+R_{23}+R_{31}} \quad \ldots(2)$$

$$R_3=\frac{R_{23}.R_{31}}{R_{12}+R_{23}+R_{31}} \quad \ldots(3)$$

Taking product of equations (1) & (2), (2) & (3) and (3) & (1)

$$R_1.R_2=\frac{R_{12}^2.R_{31}.R_{23}}{(R_{12}+R_{23}+R_{31})^2} \quad \ldots(4)$$

$$R_2.R_3=\frac{R_{23}^2.R_{12}.R_{31}}{(R_{12}+R_{23}+R_{31})^2} \quad \ldots(5)$$

$$R_3.R_1=\frac{R_{31}^2.R_{12}.R_{23}}{(R_{12}+R_{23}+R_{31})^2} \quad \ldots(6)$$

Adding equations (4),(5) and (6) we get,

$$R_1.R_2+R_2R_3+R_3R_1=\frac{R_{12}^2R_{31}R_{23}+R_{23}^2R_{12}R_{31}+R_{31}^2R_{12}R_{23}}{(R_{12}+R_{23}+R_{31})^2}$$

$$\therefore \quad R_1R_2+R_2R_3+R_3R_1=\frac{R_{12}.R_{23}.R_{31}(R_{12}+R_{23}+R_{31})}{(R_{12}+R_{23}+R_{31})^2}$$

$$\therefore \quad R_1R_2+R_2R_3+R_3R_1=R_{12}.\left(\frac{R_{23}.R_{31}}{R_{12}+R_{23}+R_{31}}\right) \quad \ldots(7)$$

Put $\frac{R_{23}.R_{31}}{R_{12}+R_{23}+R_{31}} = R_3$ in equation (7)

$$\therefore \quad R_1R_2+R_2R_3+R_3R_1 = R_{12}.R_3$$

$$\therefore \quad R_{12}=R_1+R_2+\frac{R_1.R_2}{R_3} \quad \ldots(8)$$

Similarly,

$$R_{23}=R_2+R_3+\frac{R_2.R_3}{R_1} \quad \ldots(9)$$

and

$$R_{31} = R_3 + R_1 + \frac{R_3 . R_1}{R_2} \quad \ldots (10)$$

5. State & explain Kirchhoff's Laws.

Kirchhoff's Current Law (KCL)

Statement: Algebraic sum of currents meeting at any junction point in an electric circuit is always zero. i.e. $\sum I=0$

In other words, at any junction or node in an electric circuit, sum of incoming currents is equal to sum of outgoing currents.

i.e. at any node, $\sum$ Incoming Currents= $\sum$ Outgoing Currents

Explanation : Consider a node as shown in Fig.

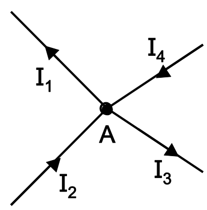


Fig.

Four branches meet at junction or node A. By KCL,

$$I_2 + I_4 = I_1 + I_3$$

where I_2 and I_4 are incoming currents while I_1 and I_3 are outgoing currents.

Kirchhoff's Voltage Law (KVL)

Statement : In any electrical network, algebraic sum of voltage drops across various elements around any closed loop or mesh is equal to algebraic sum of e.m.f.s in that loop.

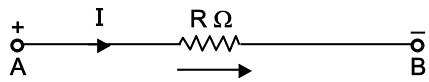
$$\sum IR=\sum E$$

In other words, if we trace any closed path or loop in an electrical network an algebraic sum of branch voltages is always zero.

$$\sum V=0$$

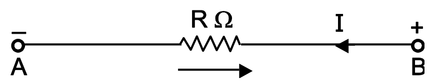
Sign Convention: Direction of current through a circuit element decides polarity of voltage. Current always flows from higher potential to lower potential.

While tracing a closed path, from positively marked terminal of resistor to negatively marked terminal then it indicates potential drop. This is shown in Fig. (a).



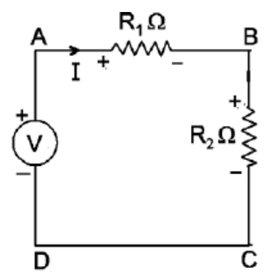
(a) Potential drop

If circuit path is traced from negatively marked terminal to positively marked terminal, then it indicates potential rise. This is shown in Fig. (b)



(b) Potential rise

Consider a network shown below.



Using KVL, $\sum V=0$

$-I R_1 - I R_2 + V=0, \quad V=I(R_1+R_2)$

$I= (V/(R_1+R_2))$

6. State & explain Superposition theorem.

Statement: In any linear, bilateral network containing atleast two energy sources, the current flowing through a particular branch is the algebraic sum of the currents flowing through that branch when each source is considered separately and remaining sources are replaced by their respective internal resistances.

Explanation: Consider a network shown in Fig. (a). The current (I) through R_2 is to be estimated using Superposition theorem

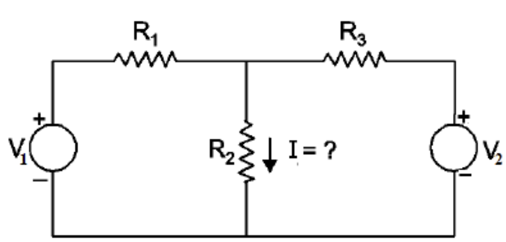


Fig (a)

Consider voltage source V_1 acting alone. Make other voltage source inactive i.e. replace it by it's internal resistance. As internal resistance of an ideal voltage source is zero, it is replaced by short circuit. Circuit will be as shown in Fig. (b).The current through R_2 is I'.

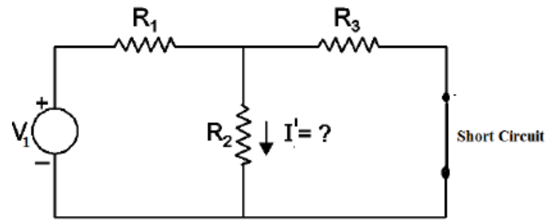


Fig. (b)

Now consider second voltage source V_2 is acting alone. Replace first voltage source V_1 by short circuit. Circuit will be as shown in Fig. (c).The current through R_2 is I''

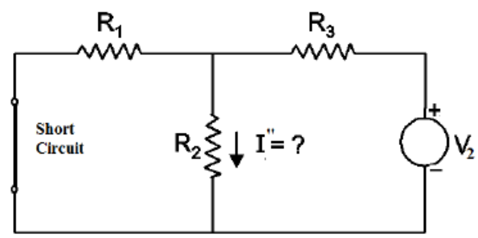


Fig. (c)

I' and I'' can be calculated by using KVL or branch current method.

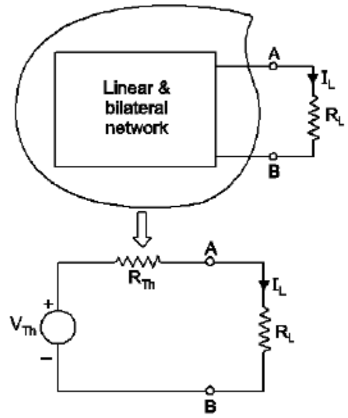
Hence the current flowing through R_2 when both the sources are acting is… **I=I'+I"**

7. **State & explain Thevenin's Theorem.**

Statement: Any linear, bilateral network containing energy sources and circuit elements can be replaced by an equivalent circuit containing a voltage source $V_{Th}$and a series resistance R_{Th} or R_{eq} across the terminals under consideration. Value of voltage source $V_{Th}$is equal to the open-circuit voltage across the terminals under consideration while R_{Th} or R_{eq} is the equivalent resistance measured between the same terminals replacing all the energy sources by their internal resistances.

Explanation:By using this theorem current flowing through any particular circuit element can be calculated.

Consider linear bilateral network as shown in figure. The current (I_L) through branch AB carrying resistance R_L is to be determined using Thevenin's Theorem.



Thevenins Equivalent Circuit

How to apply Thevenin's theorem to calculate I_L?

(i) Remove the circuit element (R_L) under consideration from the network.

(ii) Find the value of open-circuit voltage across those terminals. This is nothing but Thevenin's voltage source (V_{TH}).

(iii) Find the equivalent resistance between the same terminals replacing all energy sources by their internal resistances. Ideal voltage sources are replaced by short circuit, while ideal current sources are replaced by open circuit. This resistance is R_{Th}or R_{eq}.

(iv) Replace the given network across terminals under consideration by Thevenin's equivalent circuit, which is Thevenin's voltage source in series with an equivalent resistance.

(v) Reconnect original element across Thevenin's equivalent circuit and find current through it.