UNIT-1

UNITS AND DIMENSIONS

The quantitative description of any object or material involves measurement and comparison of physical quantities. Any physical quantity can be measured using a standard unit of that quantity. The unit of a physical quantity is the reference standard used to measure it.

Dimension is a measurable physical quantity, while unit is a way to assign a number or measurement to that dimension. There is difference between dimension and unit. For example, length is a dimension, but it is measured in units of feet or meter. A particular quantity can be reported in many different kinds of units, but it will always have the same dimensions. Dimensions are represented using symbols by: length [L], mass [M] and time [T]. In order to maintain uniformity in the field of science and engineering the S.I. unit is used ("ysteme International d'Unites). The seven fundamental units in "I are - Meter, Kilogram, Second, Ampere, Kelvin, Mole and Candela.

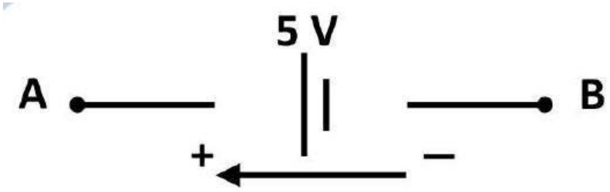
IMPORTANT LAWS:

a. Ohm's law : The current through a conductor between two points is directly proportional to the potential difference across it, provided the temperature of conductor and all other factors remain constant. The relations for ohms law are

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

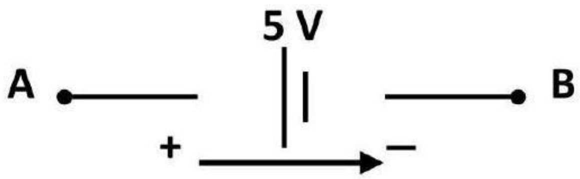
b. Kirchhoff's current law : The algebraic sum of the currents at a junction is equal to zero.
c. Kirchhoff's voltage law : The algebraic sum of the voltage sources in any closed circuit is always equal to the sum of the voltage drops as well as voltage rises in that closed circuit.
d. Assumption of polarity (sign) while applying Kirchhoff's voltage law (KVL) to electrical networks :

i) Voltage sources :



Rise in Potential
+ 5 V

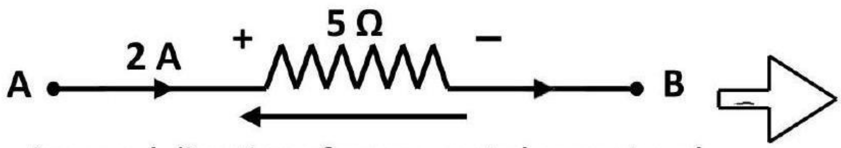
Assumed direction of movement along network



Fall in Potential
− 5 V

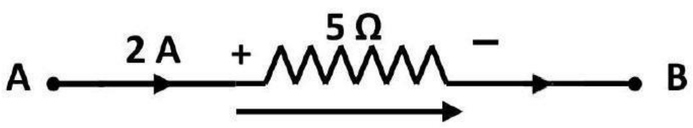
Assumed direction of movement along network

ii) Passive elements:



Assumed direction of movement along network

Rise in Potential
+10 V



Fall in Potential
− 10 V

Assumed direction of movement along network

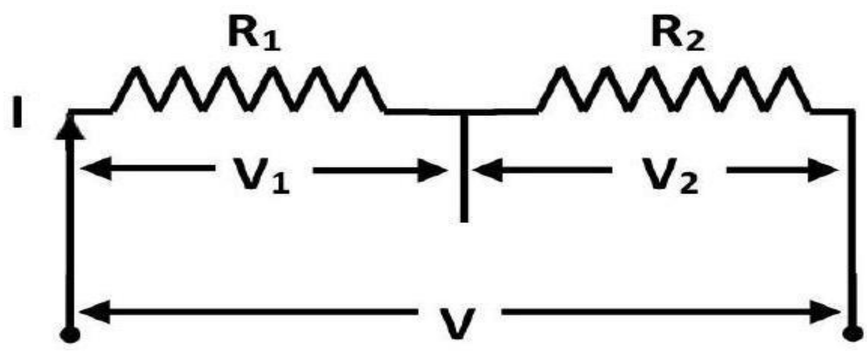
The analysis of DC circuits can be carried out if the below mentioned relations are known :

a. Resistors in series: $\boldsymbol{R}_{\text{eq}} = \boldsymbol{R_1} + \boldsymbol{R_2}$

R R

b. Resistors in parallel : $\boldsymbol{R}_{\text{eq}} = \frac{\boldsymbol{R_1 R_2}}{\boldsymbol{R_1+R_2}}$

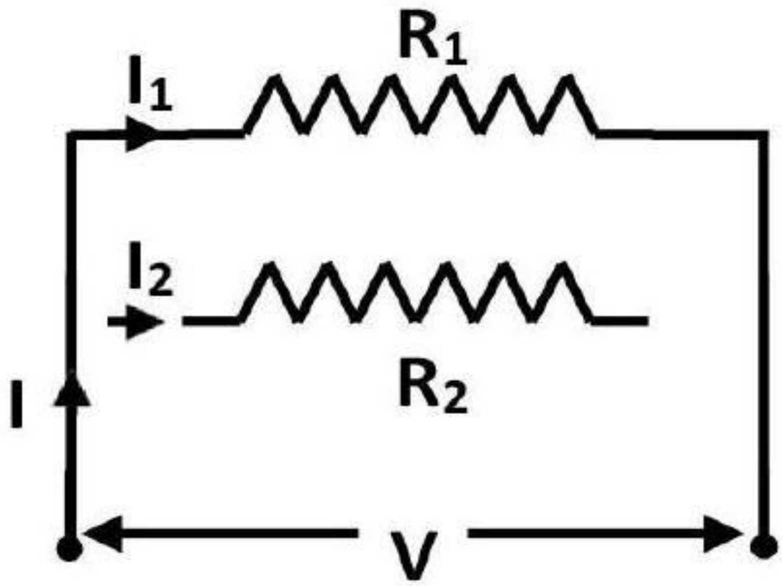
c. The voltage division for the circuit shown is :



$$V_1 = V\frac{R_1}{R_1 + R_2} \quad \text{and} \quad V_2 = V\frac{R_2}{R_1 + R_2}$$

d. The division of current for the circuit shown is:

$$I_1 = I\frac{R_1}{R_1 + R_2} \quad \text{and} \quad I_2 = I\frac{R_1}{R_1 + R_2}$$



In DC circuit analysis usually the circuits are reduced in steps to get their equivalent resistance and then obtain the required solution.

RELATIONS FOR POWER AND ENERGY:

We have electrical power, $\boldsymbol{P = VI}$
An electrical power of 1 watt is consumed in a circuit if a potential difference of 1 volt when applied across it, causes a current of 1 ampere to flow through it. Other relations for power are, $\boldsymbol{P = I^2R}$ and $\boldsymbol{P = V^2/R}$.

Unit for power is watts or $\boldsymbol{KW}$.
We have electrical energy, $\boldsymbol{E} =$ Power $\times$ Time.
An electrical energy of 1 watt-sec is consumed in a circuit when a power of 1 watt is utilized for one second OR An electrical energy of 1 kWh is consumed in a circuit when a power of 1 kW is utilized for one hour. Other relations for energy are, $\mathbf{E = I^2Rt}$ and $\mathbf{E = VIt}$; Unit for energy is Watt-sec or Watt-hr or kWh.

VOLTAGE AND CURRENT SOURCES:

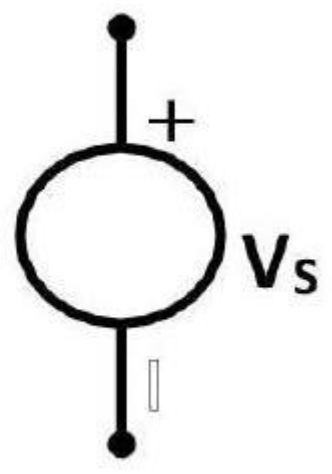
- Any device that produces electrical energy can be called a source.
- A source is usually expected to deliver power to a network and not to absorbit.
- A voltage source maintains the required difference in potential across the circuit it is connected.
- A current source supplies the required quantity of current to the circuit it is connected.
- An ideal constant voltage source is one whose output voltage remains absolutely constant irrespective of the change in load current. These voltage sources must possess zero internal resistance, so that the internal voltage drop in the source is zero. It is not practically possible to have an ideal constant voltage source.
- An ideal constant current source is one whose output current remains absolutely constant. These current sources have infinite internal resistance. Practically these sources possess a very high resistance when compared to its external load resistance.

DEPENDENT AND INDEPENDENT SOURCES:

The sources in which the voltage or current depends upon a current or voltage elsewhere in the circuit are known as Dependent sources or Controlled sources.

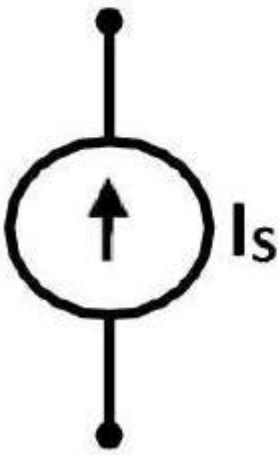
- The sources in which the voltage is completely independent of the current or the current is completely independent of the voltage are known as Independent sources.
- An ideal independent voltage source is one that maintains a specified voltage between its source terminals regardless of the current drawn from it. It is symbolised as shown: The positive and negative signs indicate the conventional direction of electric field when the source is applied to a load.

An ideal independent current source is one that maintains a specified current through its terminals regardless of the voltage across the terminals. It is symbolised as shown :



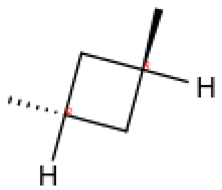
The arrow indicates the conventional direction of current when the source is connected to a load.

A dependent voltage source is one that produces a voltage as a function of voltages elsewhere in a given circuit. It is symbolised as shown :



The arrow indicates the conventional direction of current when the source is connected to a load.

- A dependent voltage source is one that produces a voltage as a function of voltages elsewhere in a given circuit. It is symbolised as shown:

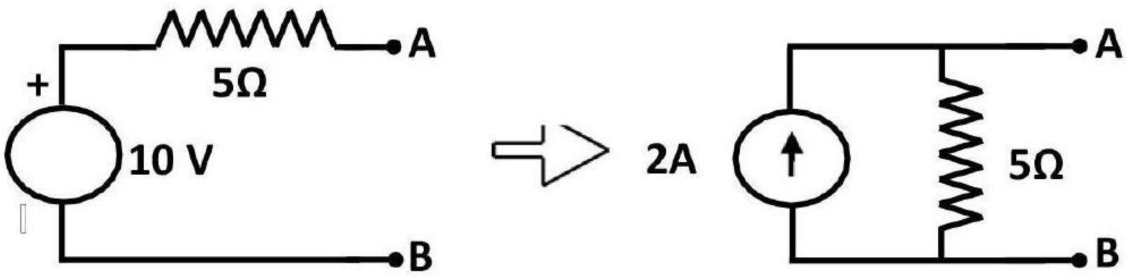


A dependent current source is one that produces a current as a function of currents elsewhere in a given circuit. It is symbolised as shown:

SOURCE CONVERSION:

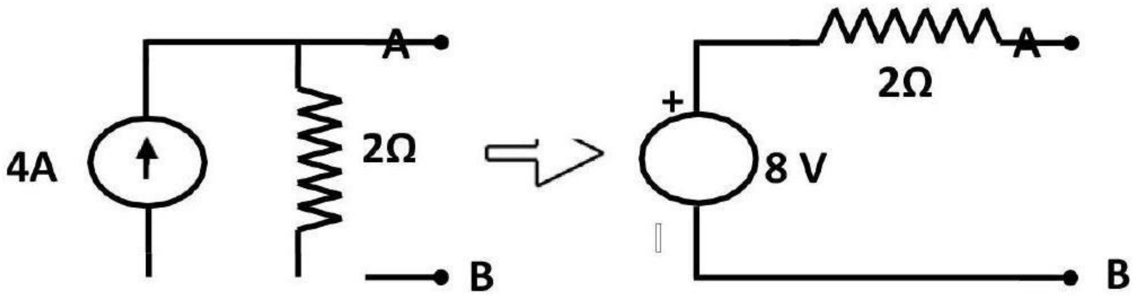
A voltage source with a series resistor can be converted into an equivalent current source with a resistor in parallel to it.

- A current source with a parallel resistor can be converted into an equivalent voltage source with a resistor in series with it.
- The conversions are possible only when their respective open circuit voltages are equal or their respective short circuit currents are equal.
- Example for voltage source to current source conversion :



Example for current source to voltage source conversion :

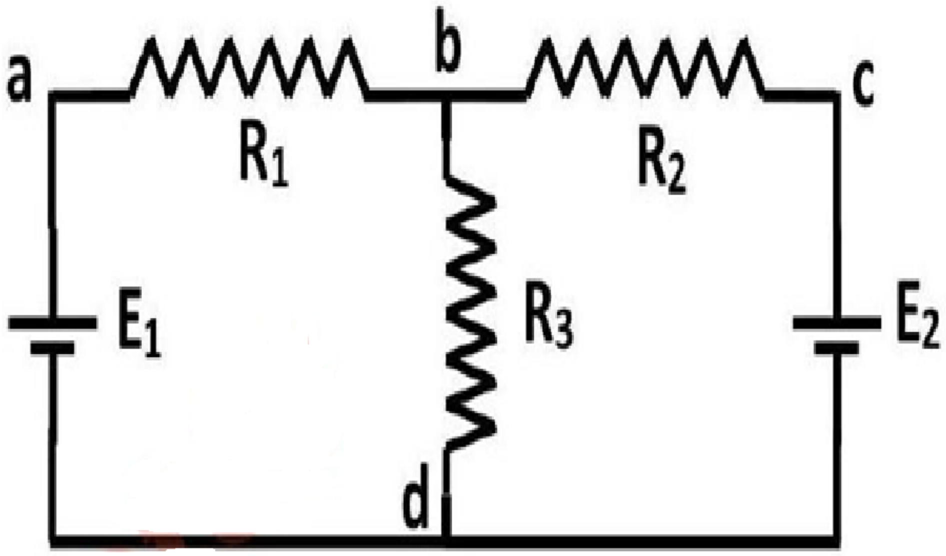
Conversion of sources helps in simplifying the analysis of circuits.



NETWORK TERMINOLOGIES:

- A network or circuit is an arrangement of active and passive elements that form closed paths.
- Consider the circuit shown :
- It has two active elements E_1 and E_2.
- It has three passive elements R_1, R_2 and R_3.

- A node of a network is an equi-potential surface at which two or more circuit elements are joined.
- In the circuit shown above a, b, c and d are nodes.
- A junction is that point in a network where three or more circuit elements are joined.
- In the circuit there are two junctions b and d.
- A branch is that part of a network which lies between junction points.
- There are three branches dab, dcb and db.
- The branch dab has two elements E_1 and R_1.
- The branch dcb has two elements E_2 and R_2.
- The third branch db has only one element R_3.
- A loop is any closed path of a network.



- The loops in the circuit are $abda, dbcd$ and $abcda$.
- A mesh is the most elementary form of a loop.
- The meshes in the circuit are abda and dbcd.
- A mesh is also a loop that cannot have another loop within it.
- A mesh current is that current which flows around the perimeter of the mesh.
- The mesh currents are always assumed to flow in the clockwise direction.

- Branch currents have physical identity but mesh currents are fictitious quantities introduced so that they allow us to solve problems with minimum number of unknowns.

MESH AND LOOP ANALYSIS:

- When the number of branches in a network increase, the earlier methods used will lead to complications. In order to simplify the solution of such networks one of the methods is the Loop analysis or the Mesh analysis.
- The step by step procedure adopted to use the method of mesh analysis is:
  a. Observe the circuit for finding the possible number of meshes, if there are any current sources, convert them into their equivalent voltage sources.
  b. Assign mesh currents to each mesh assuming the current to flow in clockwise direction.
  c. Apply KVL to each mesh and write the equations.
  d. The number of equations will be equal to the number of unknown mesh currents.
  e. The equations are solved to determine the mesh currents.
  f. The required branch currents are determined from the mesh currents determined.
  g. In case the branch current determined is negative, then the branch current is flowing opposite to the assumed direction.
  h. In case the branch current determined is positive, then the branch current is flowing in the assumed direction.

NODE VOLTAGE ANALYSIS:

A node is a point in a network that is common to two or more circuit elements. If three or more elements are joined at a point, that point can be called a junction. It is also called as an independent node or principle node.

- Usually the negative terminal of an active element is selected as the reference node or datum node and its potential is assumed to be zero.
- The node voltage is the voltage of a given node with respect to the reference node or datum node.
- The node analysis method helps us to find the voltages at all the principle nodes with respect to the reference node.

- Usually all the branch currents are assumed to be positive when the direction of the currents are not known or not given in the circuit.
- At all the principle nodes, the currents flowing towards the node are considered negative and the currents flowing away from the node are considered positive.
- The step by step procedure adopted to use the method of nodal analysis is:
  a. Observe the circuit to find the number of principle nodes and identify the reference node.
  b. Number the principle nodes serially and assume the node voltages.
  c. Assume the currents to flow outward from the nodes in each branch.
  d. Apply KCL to all the nodes and write the equations in terms of voltages and resistances.
  e. The number of equations will be equal to the number of principle nodes.
  f. The equations are solved to find the values of the assumed node voltages.
  g. With the determined values of the node voltages all the branch currents are calculated.

SUPERPOSITION THEOREM :

This theorem is very useful as it extends the use of Ohm's law to circuits that have more than one source. It is possible to calculate the effect of each source at a time and then superimpose results of all the other sources.

Statement: "In a network with two or more sources, the current or voltage for any component is the algebraic sum of the effects produced by each source acting separately".

Step by step procedure to analyse a network using superposition theorem:

Let us consider the circuit shown in figure- A, I_1, I_2 and I_3 are the currents flowing in the circuit due to the twovoltage sources of 8 V and 12 V .

To solve the circuit by using superposition theorem, only one voltage source has to be considered to be acting at a time in the circuit.

So the 8 V source is retained and the 12 V source is removed, as it has no internal resistance the circuit is drawn as shown in figure-B.
$\mathbf{I_1}'$, $\mathbf{I_2}'$ and $\mathbf{I_3}'$ are the currents flowing in the circuit as shown due to the 8 V source only. The equivalent resistance of the circuit is calculated, the total current and the branch currents are found using Ohm's law. Next considering the 12 V source only

in the circuit the 8 V source is removed, as it has no internal resistance the circuit is drawn as shown in figure-C.

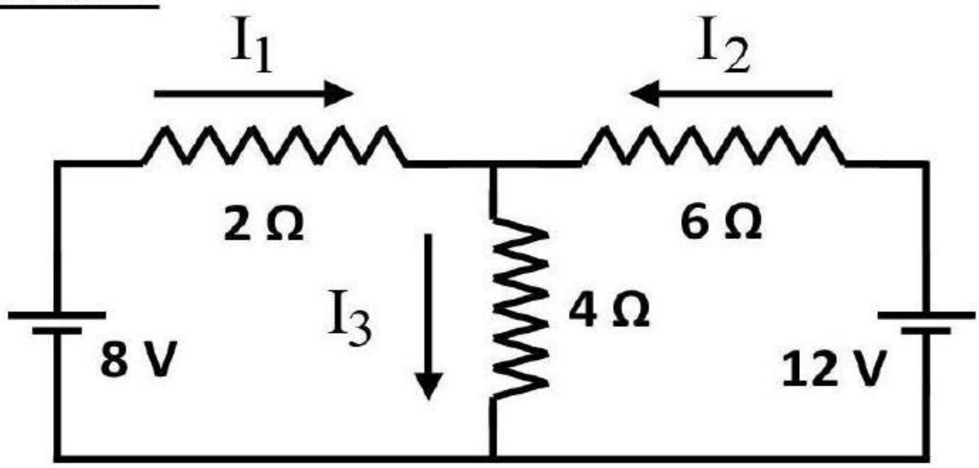


FIGURE - A

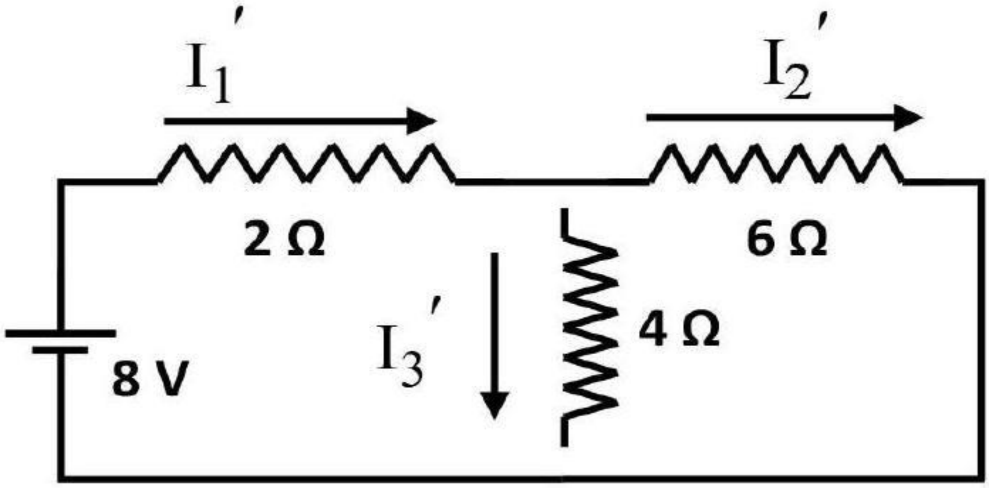


FIGURE - B

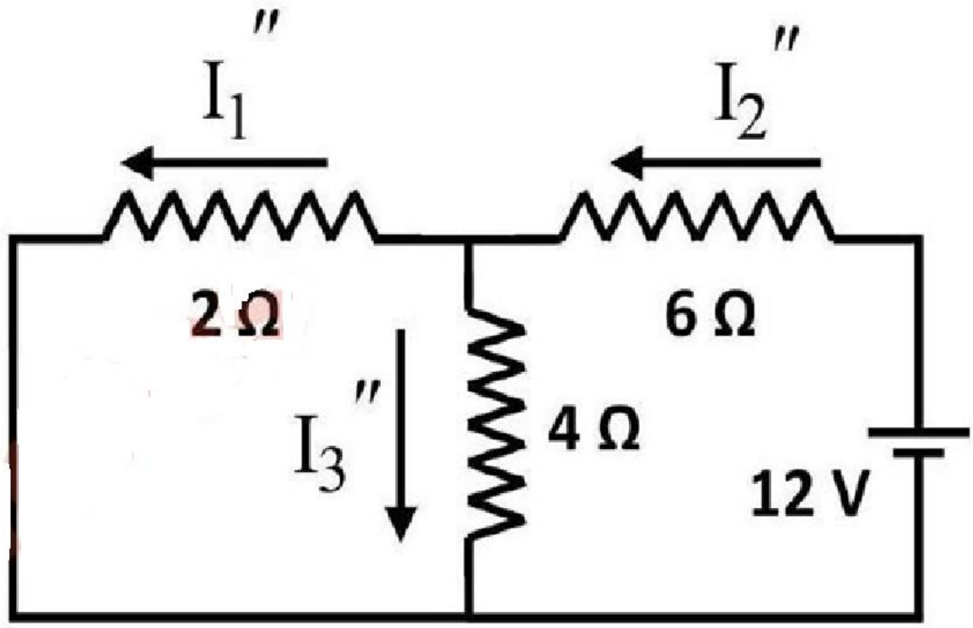


FIGURE - C

$\mathbf{I_1}''$, $\mathbf{I_2}''$ and $\mathbf{I''_3}$ are the currents flowing in the circuit as shown due to the 12 V source only. The total current and branch currents are calculated.

The currents I_1, I_2 and I_3 flowing in the circuit shown in figure-A, can be obtained by combining the values of the currents flowing in figure-B and figure-C.

So the branch currents of figure-A are $\mathbf{I_1} = \mathbf{I_1}' - \mathbf{I_1}''$; $\mathbf{I_2} = \mathbf{I_2}'' - \mathbf{I_2}'$ and $\mathbf{I_3} = \mathbf{I_3}' + \mathbf{I_3}''$

THEVENIN'S THEOREM :

This theorem is quite useful in analyzing complicated networks comprising of a number of voltage or current sources. It helps in simplifying the process of solving for the unknown values of voltage and current in a network.

By Thevenin's theorem, many sources and components, no matter how they are interconnected, can be represented by an equivalent series circuit with respect to any pair of terminals in the network.

In fig. - 1 below the block at the left contains a network connected to terminals A and B , which can be replaced by a single source of emf, V_{TH} in series with a single resistance R_{TH}.

Where V_{TH} is the open circuit voltage across terminals A and B and R_{TH} is the open circuit resistance across terminals A and B

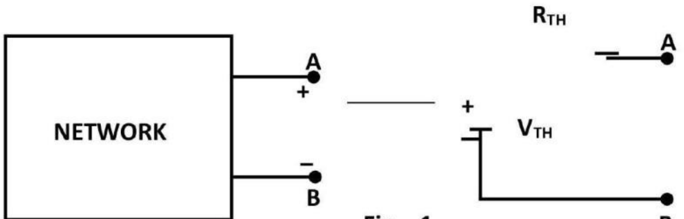


Fig. - 1

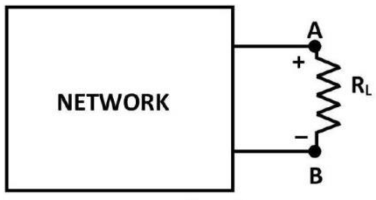


Fig. - 2

STATEMENT: "Thevenin theorem states that the entire network connected to A and B can be replaced by a single voltage source V_{TH} in series with a single resistance R_{TH}, connected to the same two terminals".

STEP BY STEP PROCEDURE IN THEVENIZING A CIRCUIT:

The step by step procedure adopted to solve any network by Thevenin's theorem is given below :

a. The load resistor R_L of the network through which the current flowing has to be determined is identified.

b. The load resistor R_L is temporarily disconnected from the network.

c. Let the points be named A and B.

d. The open circuit voltage which appears across the points A and B is determined. This is called Thevenin voltage V_{TH}.

e. In order to determine the Thevenin resistance of the network behind the points A and B.

f. The voltage sources in the network are replaced by their internal resistances and the current sources are replaced by an open circuit.

g. The equivalent resistance across the terminals A and B is determined which is called Thevenin resistance R_{TH} .

h. Replace the entire network by the Thevenin source, whose voltage is V_{TH} and whose internal resistance is the Thevenin resistance R_{TH}.

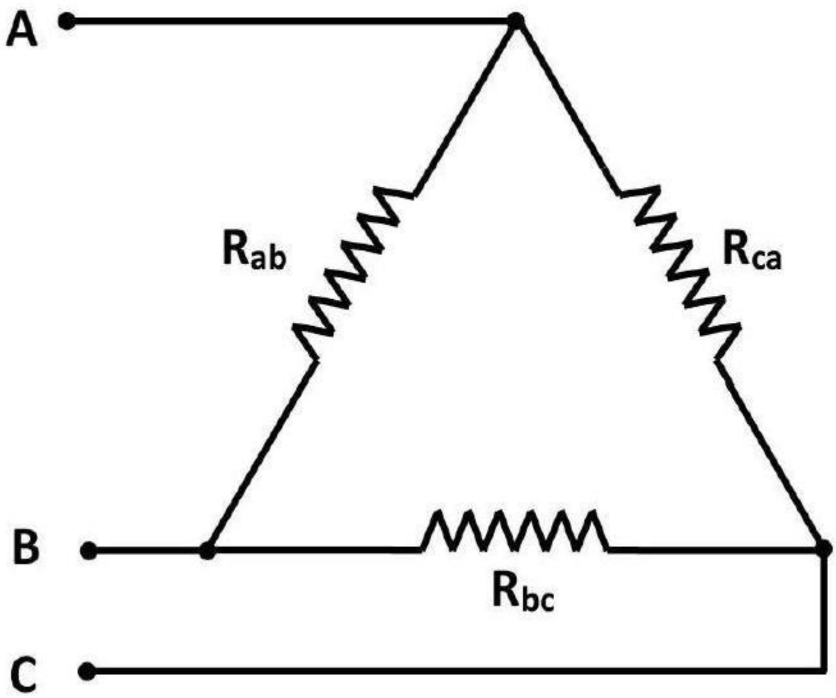
i. Connect the load resistor R_L back across the points A and B, from where it was removed earlier.
j. Calculate the current flowing through the load resistor using the relation :

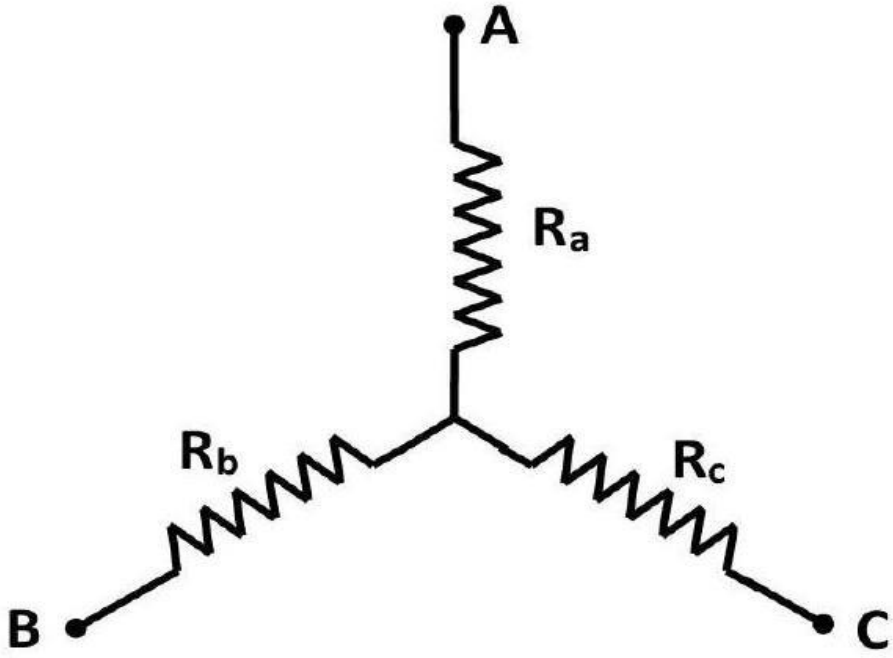
$$I = \left(\frac{V_{TH}}{R_{TH} + R_L}\right)$$

STAR-DELTA RELATIONS:

- When a three terminal circuit is encountered in any network the star delta relations can be used to simplify the circuit.
- By initially converting the three terminal network from one form to another and by applying other simplifying techniques the network can be solved.

DELTA TO STAR CONVERSION:





Let us consider aDelta circuit shown above. Let us find the resistance between the terminals A and C with terminal B is observed that the resistors R_{ab} and R_{bc} will be in serieswith each other and this series combination will be in parallel with R_{ca}. Hence, the equivalent resistance between the terminals A and C can

$$R_{ca}(R_{ab} + R_{bc})$$

be written as, $\boldsymbol{R_{ca}} = \overline{\boldsymbol{R_{ab}+R_{bc}+R_{ca}}}$

$$R_{ab}(R_{ca} + R_{bc})$$

Similarly, resistance between terminals A and B, $\boldsymbol{R_{ab}} = \overline{\boldsymbol{R_{ab}+R_{bc}+R_{ca}}}$

the resistance between terminals B and C, $\boldsymbol{R_{bc}} = \frac{\boldsymbol{R_{bc}(R_{ab}+R_{ca})}}{\boldsymbol{R_{ab}+R_{bc}+R_{ca}}}$

Considering the Star circuit shown above, the resistance between the terminals A and C = $\boldsymbol{R_G} + \boldsymbol{R_C}$

Between A and B = $\boldsymbol{R_a} + \boldsymbol{R_b}$ and between B and C = $\boldsymbol{R_b} + \boldsymbol{R_c}$

Equating resistance between similar terminals in the two circuits, we get,

$$R_a + R_c = \frac{R_{ca}(R_{ab} + R_{bc})}{R_{ab} + R_{bc} + R_{ca}}$$

$$R_a + R_b = \frac{R_{ab}(R_{ca} + R_{bc})}{R_{ab} + R_{bc} + R_{ca}} \qquad (1)$$

$$R_b + R_c = \frac{R_{bc}(R_{ab} + R_{ca})}{R_{ab} + R_{bc} + R_{ca}} \qquad (2)$$

Subtracting equation (3) from equation (1), we get, $\boldsymbol{R_a - R_b = \frac{R_{ab} \cdot R_{ca} - R_{ab} \cdot R_{bc}}{R_{ab} + R_{bc} + R_{ca}}}$

Adding equation (2) to equation (4) and dividing by 2, we get, $\boldsymbol{R_a = \frac{R_{ab} \cdot R_{ca}}{R_{ab} + R_{bc} + R_{ca}}}$

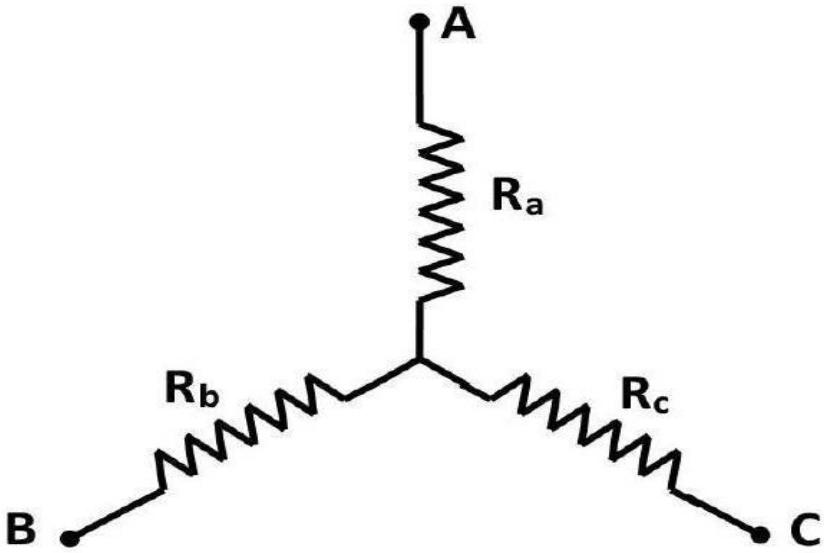
Similarly, $\boldsymbol{R_b = \frac{R_{bc} \cdot R_{ab}}{R_{ab} + R_{bc} + R_{ca}}}$ (6) and $\boldsymbol{R_c = \frac{R_{ca} \cdot R_{bc}}{R_{ab} + R_{bc} + R_{ca}}}$

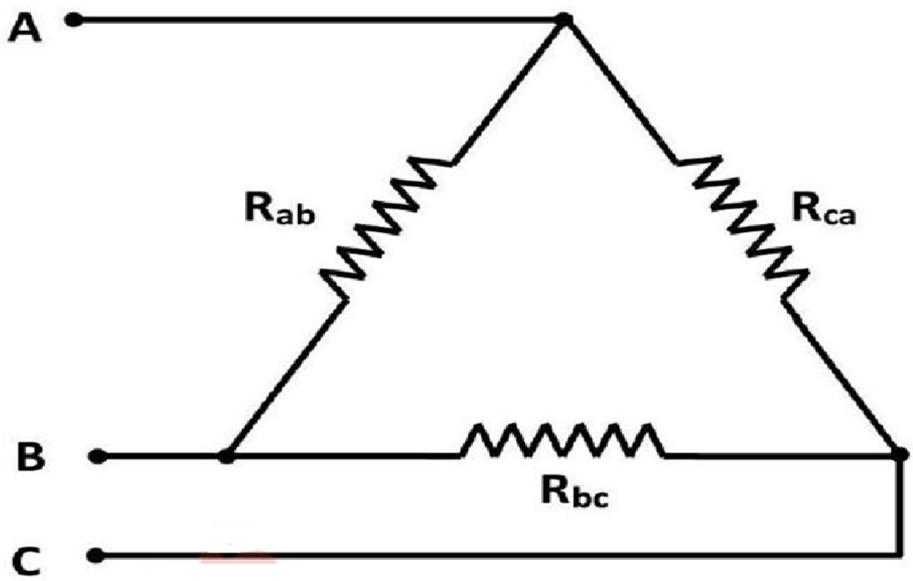
Hence the Star values of resistors in terms of the Delta resistors are expressed as:

$$\boldsymbol{R_a = \frac{R_{ab} R_{ca}}{R_{ab} + R_{bc} + R_{ca}}; \; R_b = \frac{R_{bc} R_{ab}}{R_{ab} + R_{bc} + R_{ca}}; \; R_c = \frac{R_{ca} R_{bc}}{R_{ab} + R_{bc} + R_{ca}}}$$

STAR TO DELTA CONVERSION :

Let us consider a Star connected circuit shown above. The resistance between the terminals A and C is found to be $= \boldsymbol{R_a + R_c}$. The resistance between B and C $=$ $\boldsymbol{R_b + R_c}$ and that between A and B $= \boldsymbol{R_a + R_b}$.





Let us consider the Delta connected circuit shown above, the resistance between the terminals A and C with

$$R_{ca}(R_{ab}+R_{bc})$$

terminal B open can be written as,

$$R_{ac}=\frac{R_{ab}+R_{bc}+R_{ca}}{R_{ab}(R_{ca}+R_{bc})}$$

Similarly, resistance between terminals A and B,

$$R_{ab}=\frac{R_{ab}+R_{bc}+R_{ca}}{}$$

and the resistance between terminals B and C, $\boldsymbol{R_{bc}}=\frac{\boldsymbol{R_{bc}(R_{ab}+R_{ca})}}{\boldsymbol{R_{ab}+R_{bc}+R_{ca}}}$

Equating resistance between similar terminals in the two circuits, we get,

$$R_a+R_c=\frac{R_{ca}(R_{ab}+R_{bc})}{R_{ab}+R_{bc}+R_{ca}}.$$

$$R_a+R_b=\frac{R_{ab}(R_{ca}+R_{bc})}{R_{ab}+R_{bc}+R_{ca}}.$$

$$R_b+R_c=\frac{R_{bc}(R_{ab}+R_{ca})}{R_{ab}+R_{bc}+R_{ca}}.$$

$$R_{ab} \cdot R_{ca} - R_{ab} \cdot R_{bc} \quad (4)$$

Subtracting equation (3) from equation (1), we get, $\boldsymbol{R_a} - \boldsymbol{R_b} = \frac{\boldsymbol{R_{ab}+R_{bc}+R_{ca}}}{}$

Adding equation (2) to equation (4) and dividing by 2, we get, $\boldsymbol{R_a} = \frac{\boldsymbol{R_{ab} \cdot R_{ca}}}{\boldsymbol{R_{ab}+R_{bc}+R_{ca}}}$

Similarly, $\boldsymbol{R_b} = \frac{\boldsymbol{R_{bc}R_{ab}}}{\boldsymbol{R_{ab}+R_{bc}+R_{ca}}}$

$$\boldsymbol{R_c} = \frac{\boldsymbol{R_{ca}R_{bc}}}{\boldsymbol{R_{ab} + R_{bc} + R_{ca}}}$$

From equations (5), (6) and (7), we get,

$$R_aR_b + R_bR_c + R_cR_a = \frac{\left(R_{ab}{}^2 \cdot R_{bc} \cdot R_{ca} + R_{bc}{}^2 \cdot R_{ab} \cdot R_{ca} + R_{ca^2} \cdot R_{ab} \cdot R_{bc}\right)}{(R_{ab} + R_{bc} + R_{ca})^2}$$

$$R_aR_b + R_bR_c + R_cR_a = \frac{(R_{ab} + R_{bc} + R_{ca})(R_{ab} \cdot R_{bc} \cdot R_{ca})}{(R_{ab} + R_{bc} + R_{ca})^2}$$

$$\boldsymbol{R_aR_b + R_bR_c + R_cR_a} = \frac{(\boldsymbol{R_{ab} \cdot R_{bc} \cdot R_{ca}})}{(\boldsymbol{R_{ab} + R_{bc} + R_{ca}})} \quad (8)$$

Dividing Equation (8) by equation (7), we get,

$$\boldsymbol{R_{ab}} = \frac{(\boldsymbol{R_aR_b + R_bR_c + R_cR_a})}{\boldsymbol{R_c}}$$

Dividing Equation (8) by equation (5), we get,

$$R_{bc} = \frac{(R_aR_b + R_bR_c + R_cR_a)}{R_a}$$

Dividing Equation (8) by equation (6), we get,

$$R_{ca} = \frac{(R_aR_b + R_bR_c + R_cR_a)}{R_b}$$

Hence the Delta values of resistors in terms of the Star resistors are expressed as:

$$R_{ab} = \frac{R_aR_b + R_bR_c + R_cR_a}{R_c}; R_{bc} = \frac{R_aR_b + R_bR_c + R_cR_a}{R_a}; R_{ca} = \frac{R_aR_b + R_bR_c + R_cR_a}{R_b}$$

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THANK YOU