PPT ON

BASIC ELECTRICAL AND ELECTRONICS ENGINEERING

Network Theorems: Superposition, Reciprocity, Thevenin's, Norton's, Maximum power transfer for DC excitations circuits.

Network Topology: Definitions, Graph, Tree, Incidence matrix, Basic Cut Set and Basic Tie Set Matrices for planar networks.

Superposition Theorem

- **Superposition theorem** states that in any linear, active, bilateral network having more than one source, the response across any element is the sum of the responses obtained from each source considered separately and all other sources are replaced by their internal resistance.
- The superposition theorem is used to solve the network where two or more sources are present and connected.

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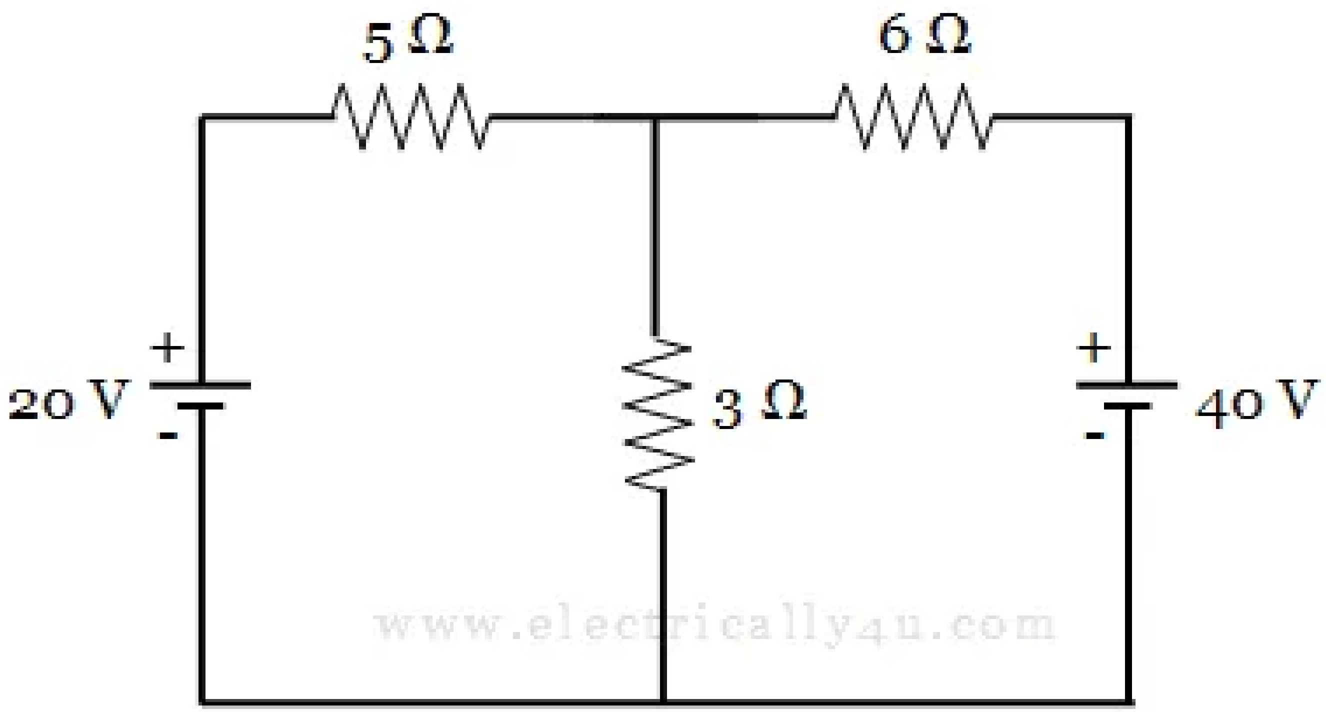
- The superposition theorem is used to solve the network where two or more sources are present and connected.

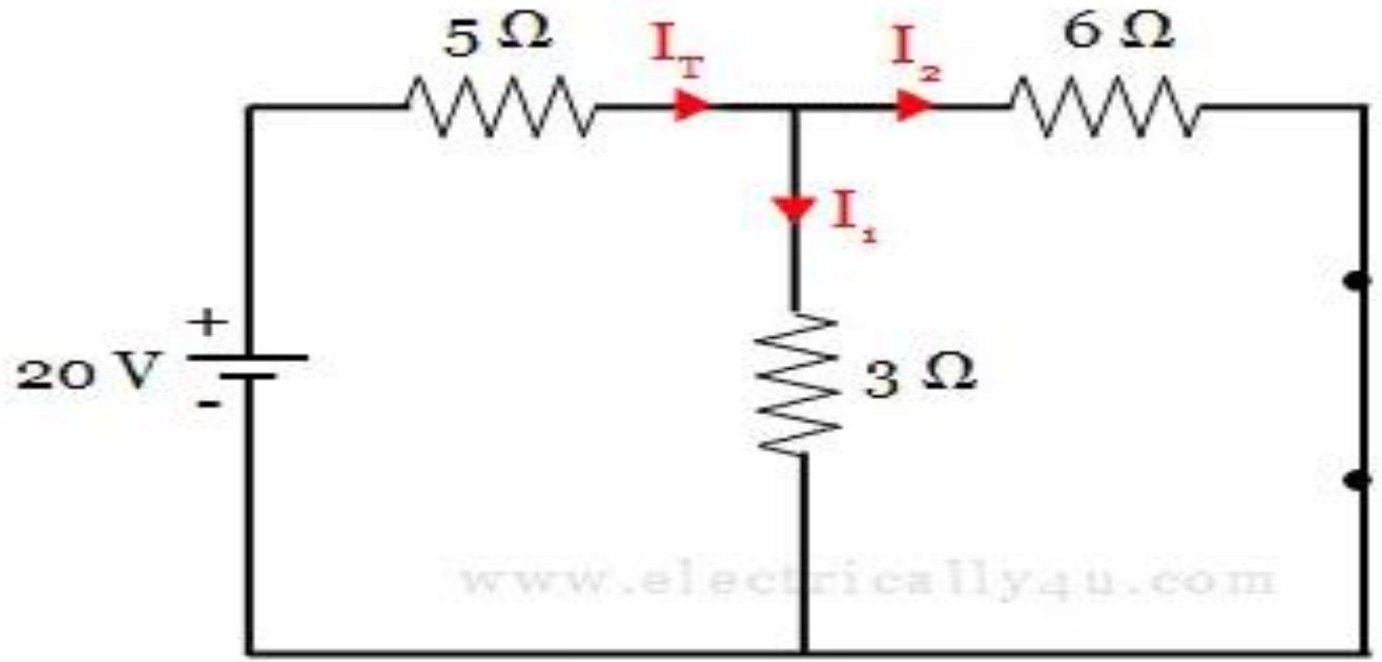
Superposition Theorem

Find the current through 3 Ω resistor using superposition theorem.



Superposition Theorem

Consider **20 v voltage source alone**. Hence, Short circuit the other voltage source and the circuit is redrawn as below,



Superposition Theorem

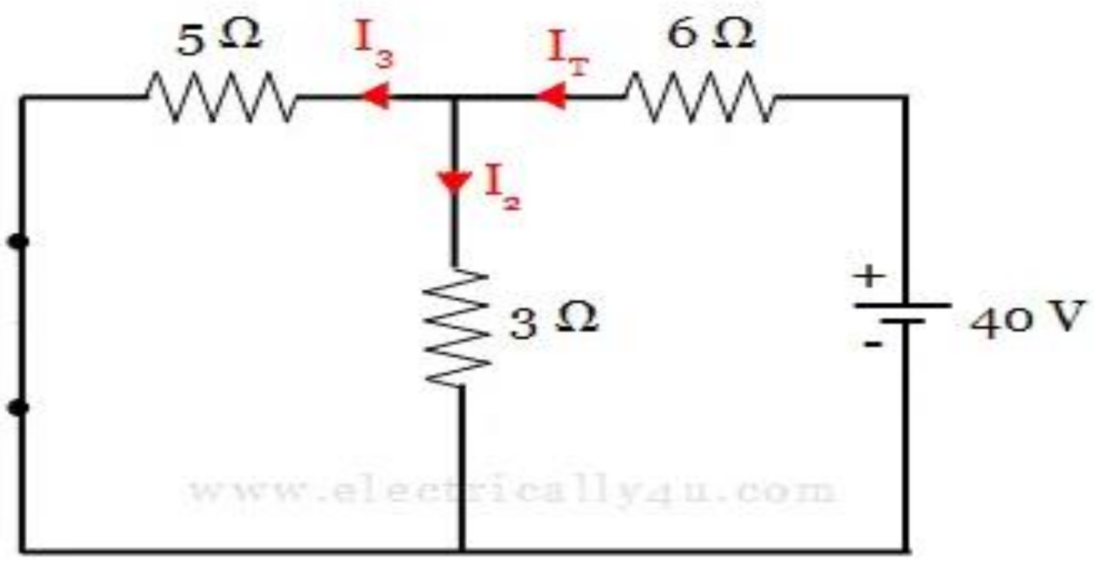
$$R_T = 5 + \frac{3 * 6}{3 + 6} = 7\Omega$$

$$I_T = \frac{V}{R_T} = \frac{20}{7} = 2.857A$$

$$I_1 = I_T * \frac{6}{6+3} = 2.857 * 0.667 = 1.904A$$

Superposition Theorem

Consider **40 v voltage source alone**. Hence, Short circuit the other voltage source and the circuit is redrawn as below,



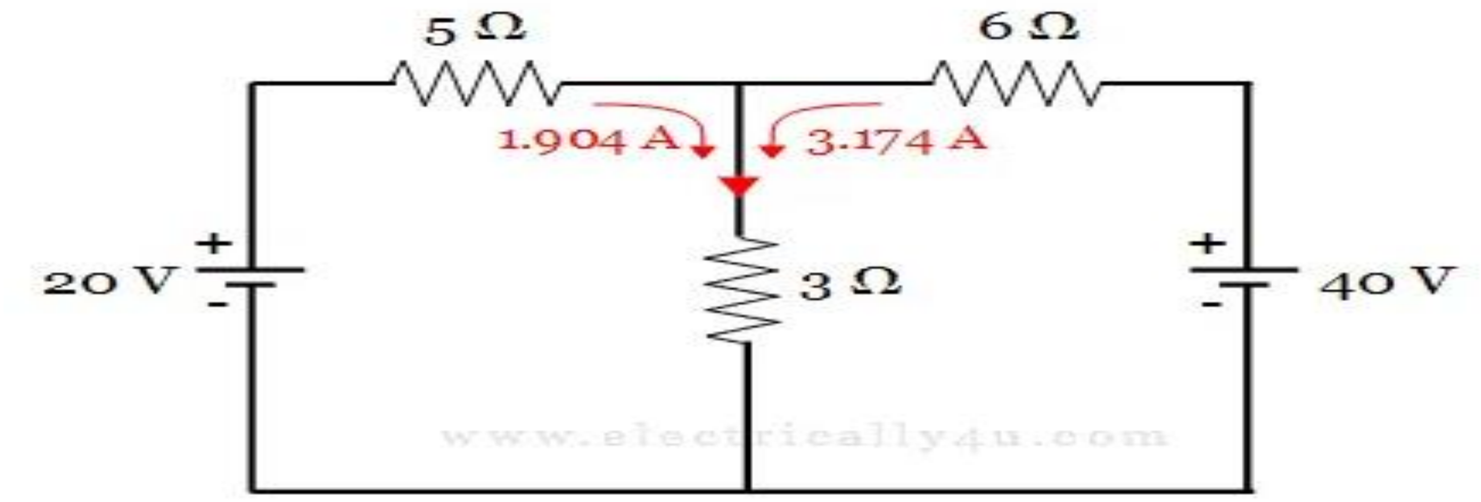
Superposition Theorem

$$R_T = 6 + \frac{3 * 5}{3 + 5} = 7.875\Omega$$

$$I_T = \frac{V}{R_T} = \frac{40}{7.875} = 5.079A$$

$$I_2 = I_T * \frac{5}{5 + 3} = 5.079 * 0.625 = 3.174A$$

Superposition Theorem

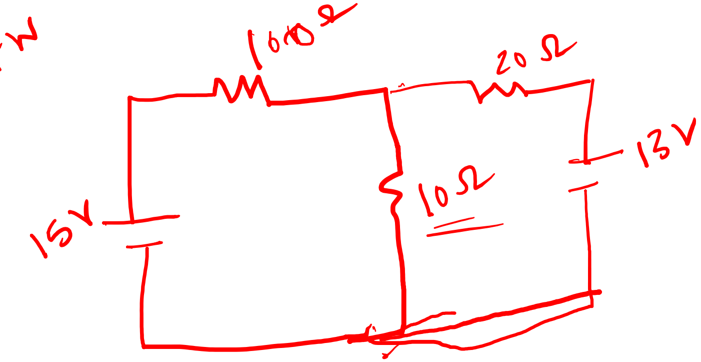


By superposition theorem, the total current is determined by adding the individual currents produced by 20 v and 40 v.

Thus the current through 3 Ω resistor is $= I_1 + I_2 = 1.904 + 3.174 = 5.078\ A$

Superposition Theorem

H.W



find current through 10Ω resistor using superposition theorem

Q

Current or Response through 2Ω

$I_{2\Omega} \rightarrow ?$

35V → I' or I_1 = ; $I = \frac{V}{R} = \frac{35}{4.33} = 8.08\,A$

$R_{eq} = 4.33\,\Omega$

40V → I_2 =

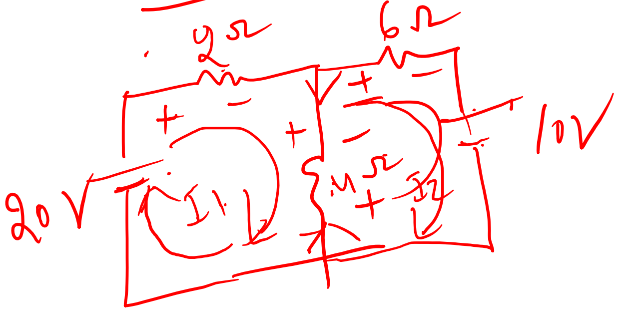
$R_{eq} = 5.2\,\Omega$

$I_2 = \frac{40}{5.2} = 7.69\,A$

$I_{2\Omega} = I_1 + I_2$

Superposition Theorem

Mesh Analysis



mesh1

$2I_1 + 4(I_1 - I_2) - 20 = 0$

$\boxed{2I_1 + 4I_1} - 4I_2 = 20$

$6I_1 - 4I_2 = 20$ — (1)

$6I_1 = 20 + 4I_2$

$I_1 = \frac{20 + 4I_2}{6}$

Mesh2

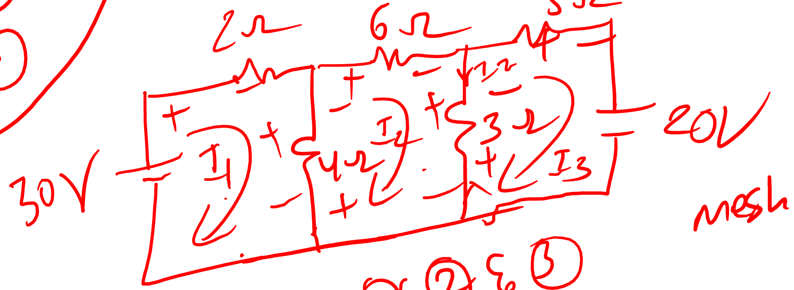
$6I_2 + 10 + 4(I_2 - I_1) = 0$

$6I_2 + 4I_2 - 4I_1 + 10 = 0$

$-4I_1 + 10I_2 = -10$ — (2)

Solve eq (1) & (2)

I_1 & I_2



Solve eq (1) & (2) & (3)

I_1, I_2 & I_3

(3) → Cramer's rule

mesh I

$2I_1 + 4(I_1 - I_2) - 30 = 0$

$\boxed{2I_1 + 4I_1} - 4I_2 = 30$

$6I_1 - 4I_2 = 30$ — (1)

mesh II

$6I_2 + 3(I_2 - I_3) + 4(I_2 - I_1) = 0$

$6I_2 + 3I_2 - 3I_3 + 4I_2 - 4I_1 = 0$

$-4I_1 + 13I_2 - 3I_3 = 0$ — (2)

mesh 3

$5I_3 + 20 + 3(I_3 - I_2) = 0$

$5I_3 + 20 + 3I_3 - 3I_2 = 0$

$-3I_2 + 8I_3 = -20$ — (3)

Superposition Theorem

Nodal Analysis

$I_{3\Omega}$

$I_{3\Omega}$

$$\frac{V_a-10}{2} + \frac{V_a-0}{3} + \frac{V_a-5}{4} = 0$$

$$0.5(V_a-10) + 0.33(V_a) + 0.25(V_a-5) = 0$$

$V_a =$

$$0.5V_a - (0.5\times10) + 0.33V_a + 0.25V_a - (0.25\times5) = 0$$

$$0.5V_a - 5 + 0.33V_a + 0.25V_a - 1.25 = 0$$

$$1.08V_a - 6.25 = 0$$

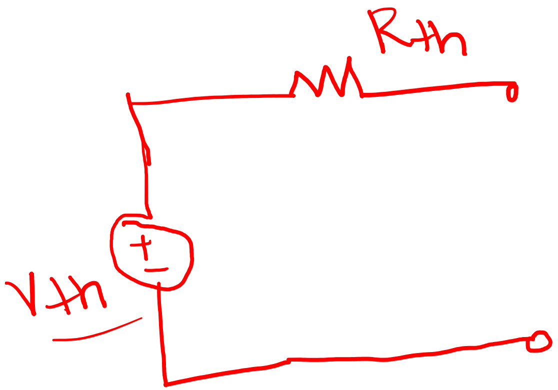
$$V_a = \frac{6.25}{1.08} = 5.787V$$

$$I_{3\Omega} = \frac{V_a}{3} = \frac{5.787}{3}$$

$$= 1.929A$$

Thevenin’s theorem

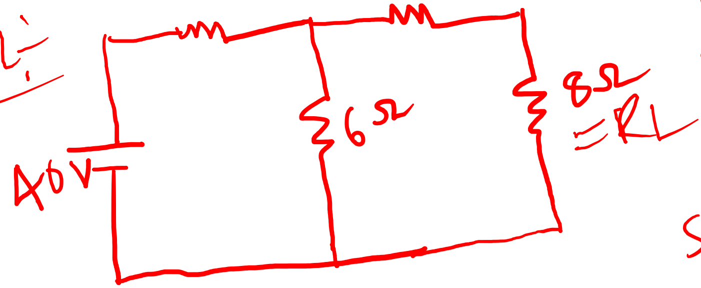
Any linear electric network or a complex circuit with current and voltage sources can be replaced by an equivalent circuit containing of a single independent voltage source **V**$_{\mathbf{TH}}$ and a Series Resistance **R**$_{\mathbf{TH}}$.



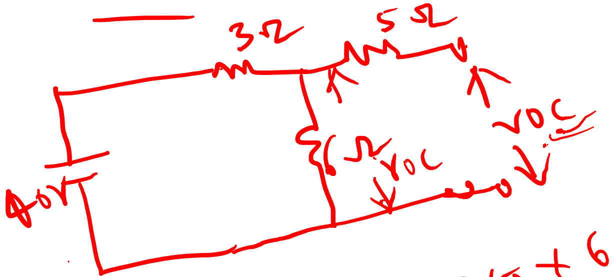
Thevenin's theorem

Q:- Calculate current flowing through 8 Ω Resistor using thevenin's theorem

Q:-



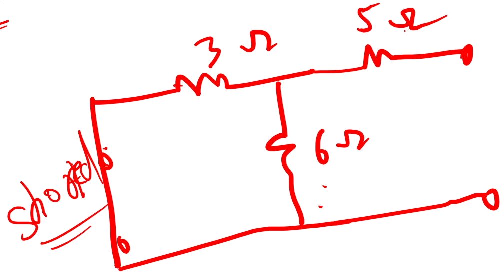
Step 1) Remove R_L



Step 2) $V_{6\Omega} = \frac{V_T \times 6}{3+6}$

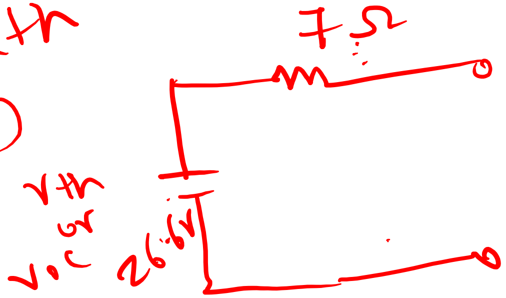
V_{oc} (or) $V_{th} = \frac{40 \times 6}{3+6} = 26.6V$

Step 3) Req : V → shorted, I → opend

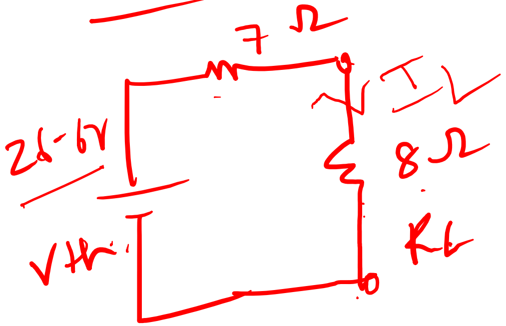


$R_{eq} = \frac{3 \times 6}{3+6} + 5 = 7\,\Omega$

Step 4) Rth



Step 5 Rth



$I_L = \frac{V_{th}}{R_{th} + R_L}$

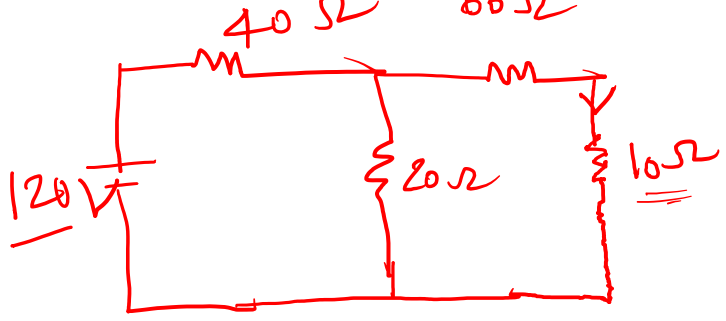
$I_L = \frac{26.6V}{7+8}$

$I_{8\Omega} = 1.77A$

Thevenin's theorem

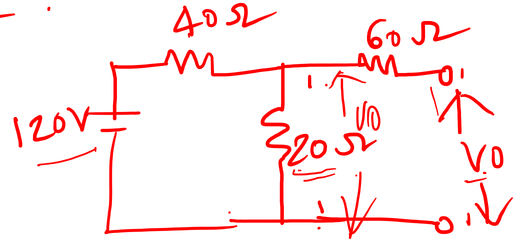
Q :-

Calculate current flowing through 10Ω Resistor using thevenin's theorem.



$I_{10\Omega} = 0.481A$

Step1 : Remove Load Resistance (10Ω − RL)



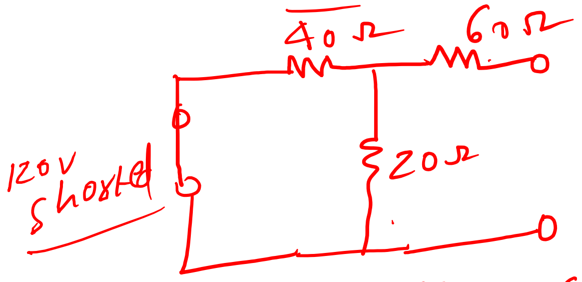
Step2 : V0 or Vth Voltage division Rule

$$V_0 = \frac{V_1 \times 20}{40+20} = 40V$$

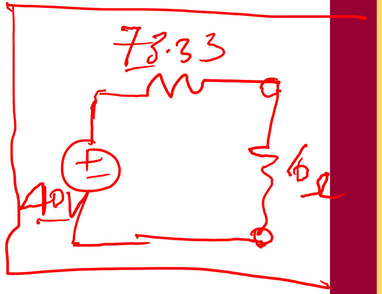
$$= \frac{120 \times 20}{40+20} = 40V$$

Step3: Req or Rth

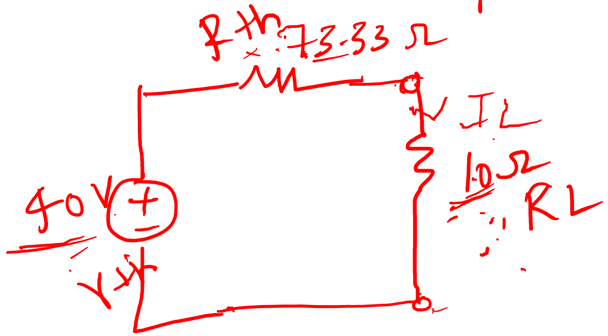
V → shorted or I − open



← Req



$$R_{eq} = \frac{40 \times 20}{40+20} + 60 = 73.33\Omega$$



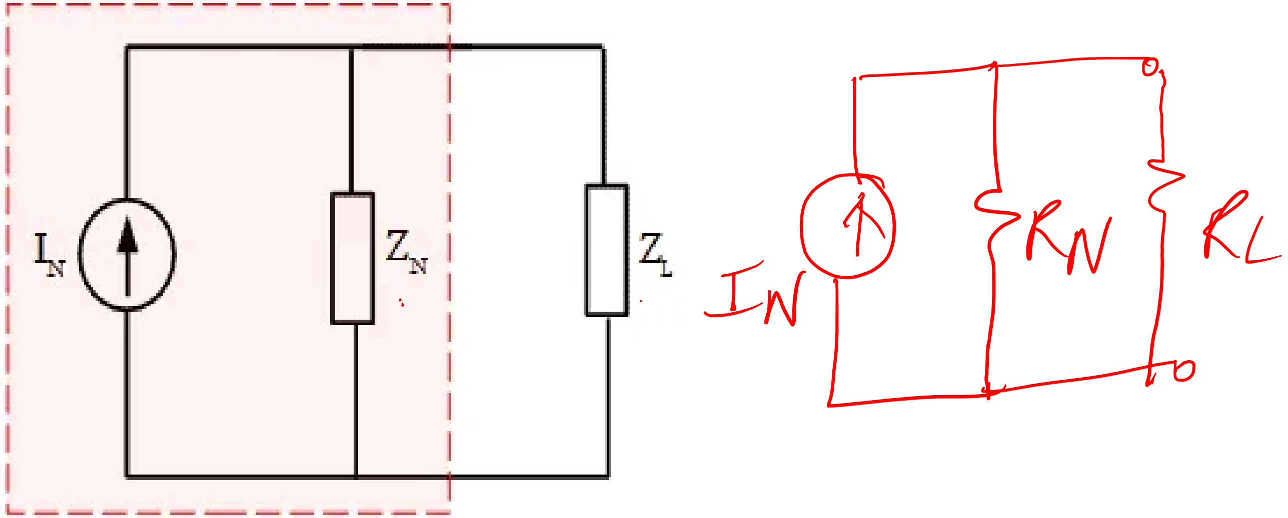
$$I_L = \frac{V_{th}}{R_{th} + R_L}$$

$$= \frac{40}{73.33 + 10}$$

$I_L = 0.481A$

Norton’s theorem

Statement: Norton’s theorem is used to solve the complex circuits consisting of several sources and impedances by converting them into a simple equivalent circuit called Norton’s equivalent circuit. Now let’s look at the statement.



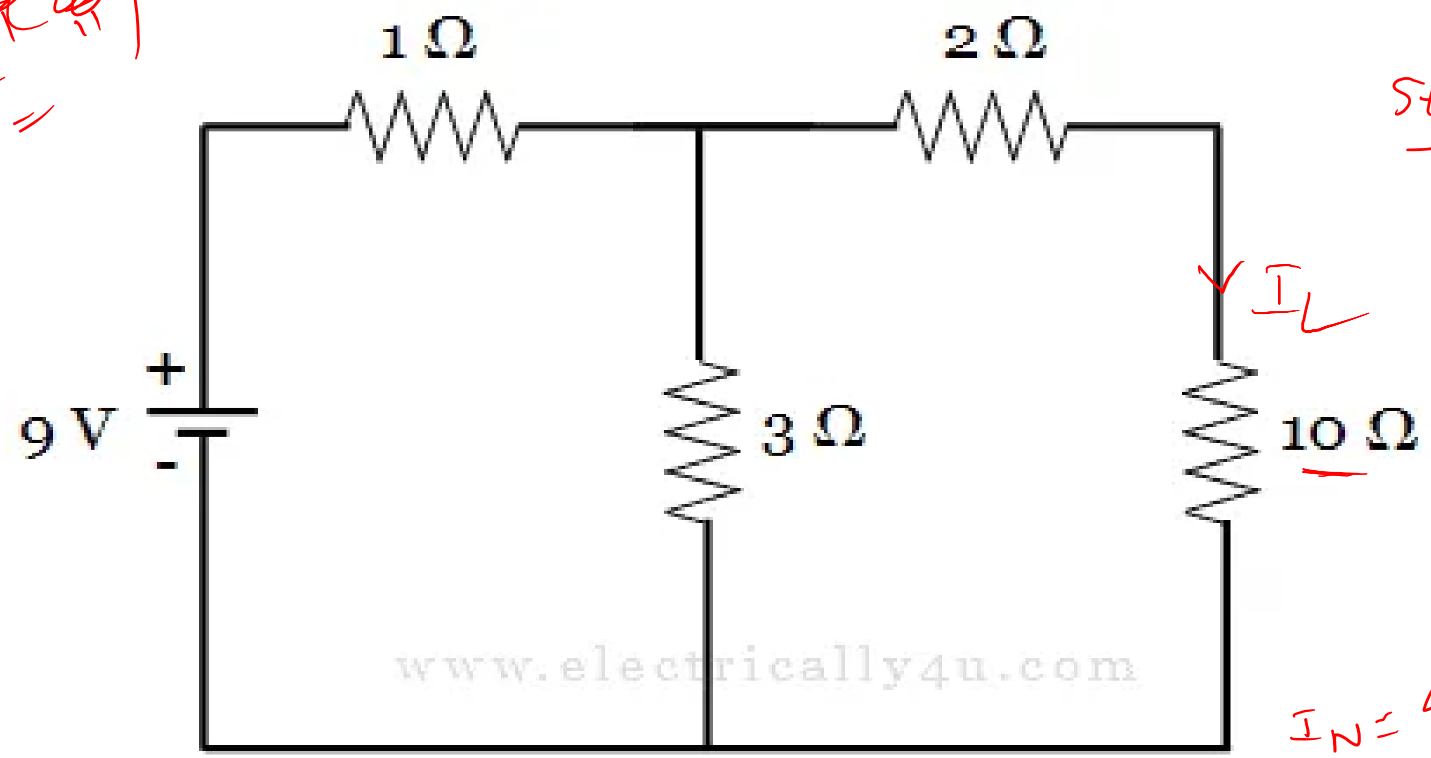
Norton's theorem

For the given circuit, determine the current flowing through 10 Ω resistor using Norton's theorem.

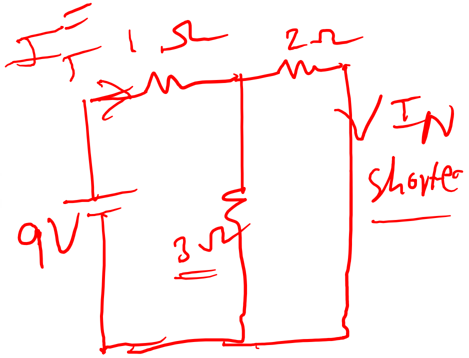
$R_{eq} = \frac{3\times2}{3+2} + 1 = \frac{6}{5} + 1 = \frac{6+5}{5} = 11/5 = 2.2\,\Omega$

$I_T = \frac{V}{R_{eq}} = \frac{9\times5}{11} = \frac{40}{11}$

$= \frac{9}{2.2} = 4.09\,A$



Step 1) $R_L = 10\,\Omega$ shorted



$I_N = \frac{4.09\times3}{3+2} = 2.454\,A$

Norton's theorem

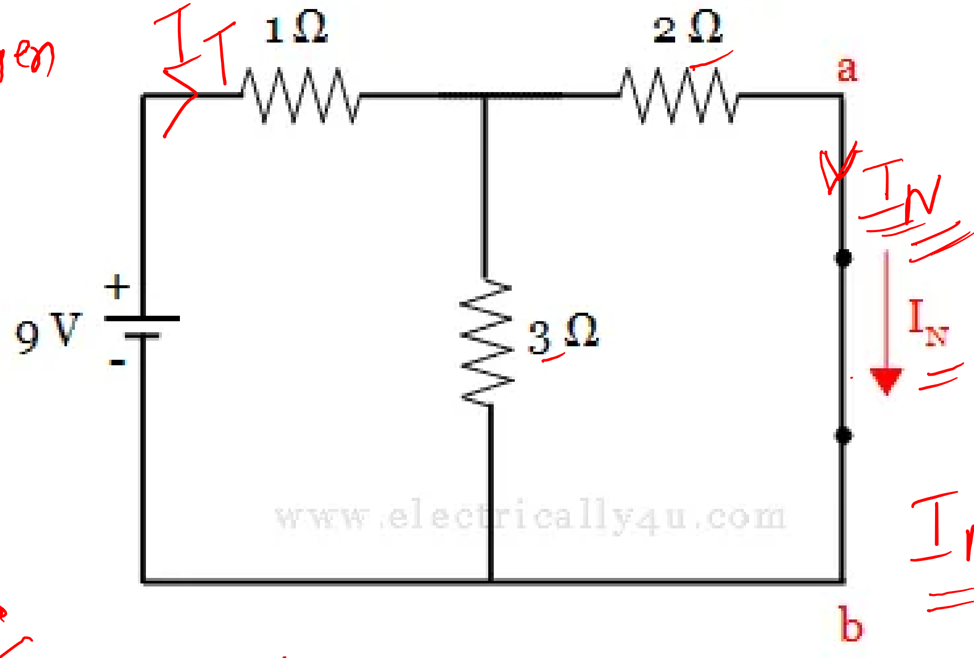
(a) To find Norton's current, Remove the load resistor(10 Ω), short it with a wire and the circuit is redrawn as below.

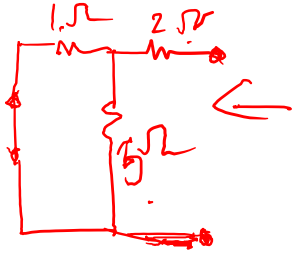
Step 1 — Short Load terminals

Step 2 — Req, V shorted, I open

Step 3 — I_T → Total

Step 4) — I_N





$R_{eq} = \frac{1\times3}{1+3}+2 = \frac{3}{4}+2 = \frac{3+8}{4} = 11/4 = 2.75\Omega$

Step I

$I_L = \frac{2.454\times2.75}{2.75+10}$

$R_{eq} = \frac{3\times2}{3+2}+1\Omega = 2.2\Omega$

$I = \frac{V}{R_{eq}} = \frac{9}{2.2} = 4.09A$

$I_N = \frac{I_T\times3}{3+2} = 2.454A$

$= \frac{4.09\times3}{3+2} = 2.454A$

Norton’s theorem

$$R_{eq} = 1 + \frac{3 * 2}{3 + 2} = 2.2\Omega$$

$$I_T = \frac{V_s}{R_{eq}} = \frac{9}{2.2} = 4.09A$$

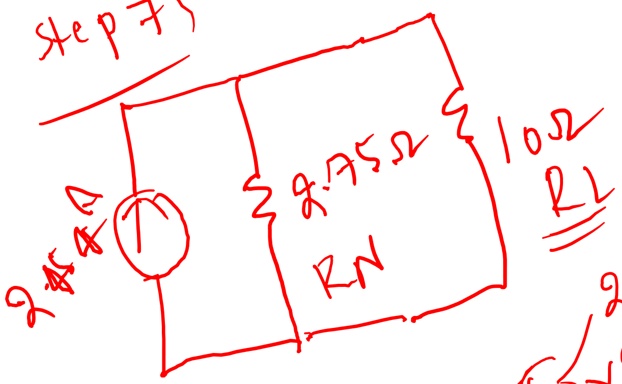
The current through the 2 Ω resistor (or **Norton's current I_N**) is obtained by applying current division rule,

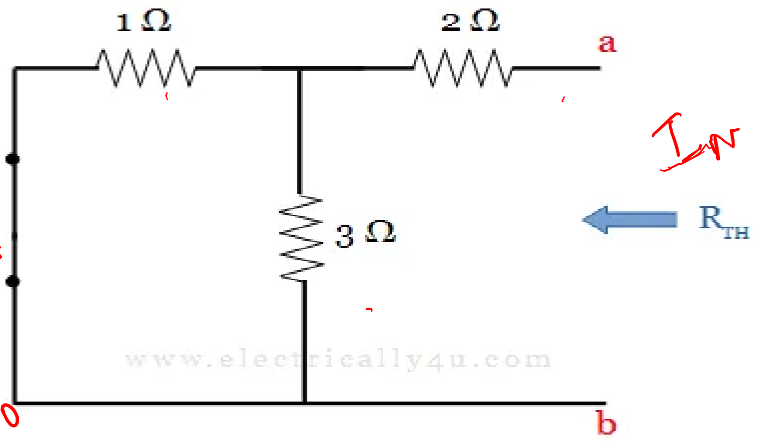
$$I_N = I_T * \frac{3}{3+2} = 4.09 * \frac{3}{5} = 2.454A$$

(b)To find Norton's resistance, Remove the load resistor, short the voltage source and circuit is redrawn as below.

open the current sources

step 7)





I_N

step 6) Req V – shorted
I – open
open circuit

$$Req = RN = \frac{1 \times 3}{1+3} + 2 = 2.75\Omega$$

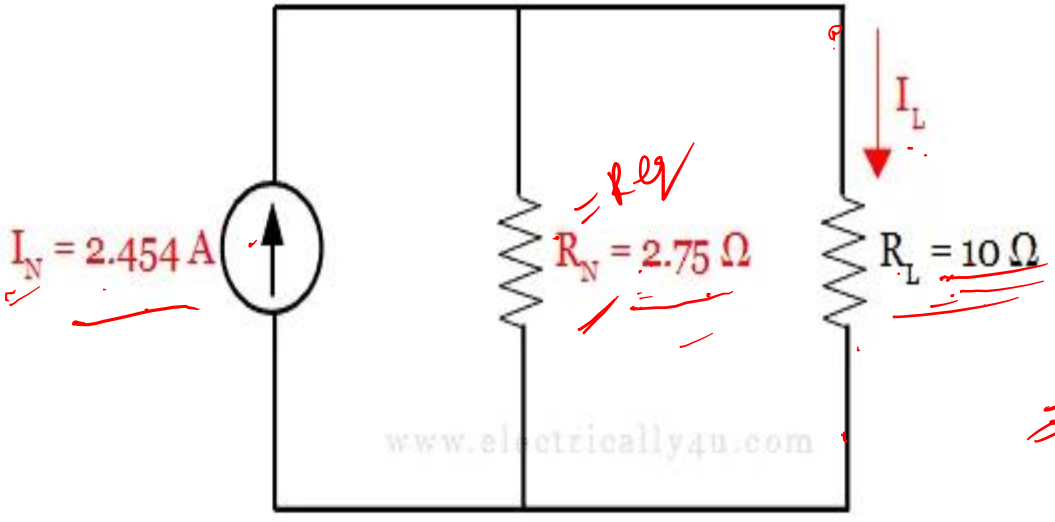
$$I_{10\Omega} = \frac{(I) \times 2.75}{2.75 + 10}$$

2.05A

Norton's theorem

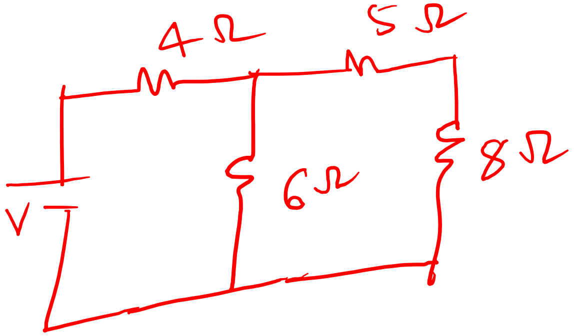
$$R_N = 2 + \frac{1 * 3}{1 + 3} = 2.75\Omega$$

$$I_L = \frac{2.454 \times 2.75}{2.75\,\Omega + 10} = 0.529A$$



$$I_L = I_N * \frac{R_N}{R_N + R_L} = 2.454 * \frac{2.75}{2.75 + 10} = 0.529\,A$$

H.W $I_{8\Omega}$

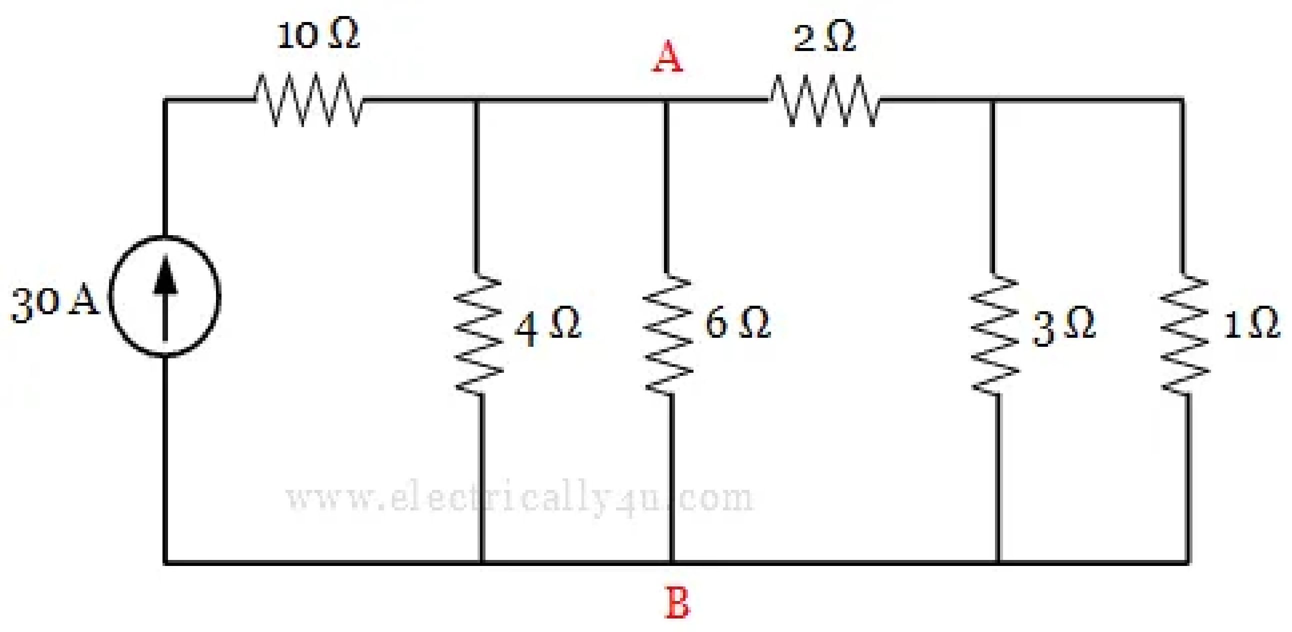


Norton's theorem

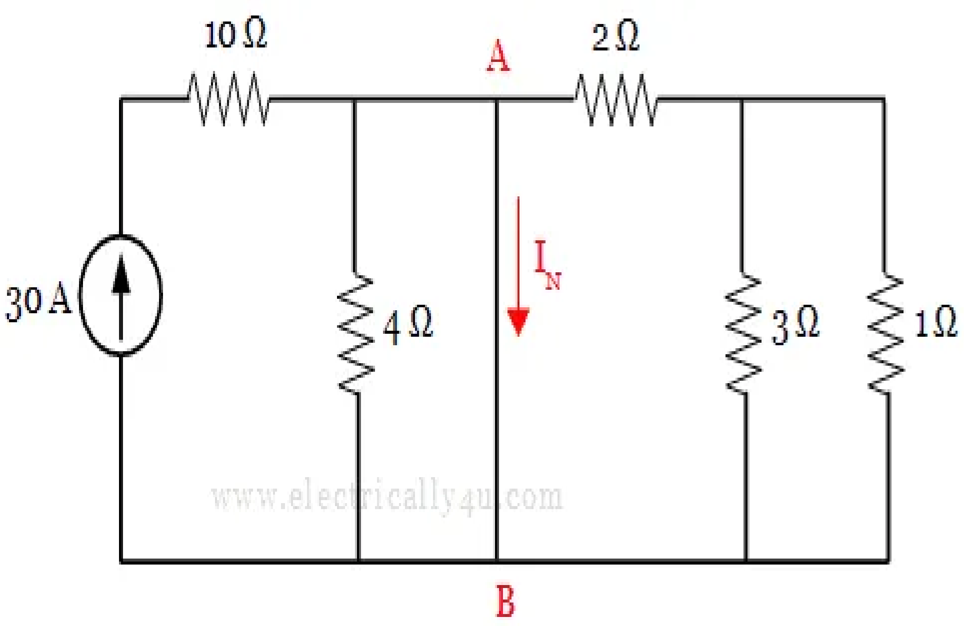
$I_{8\Omega} = 1.55A$

Norton’s theorem

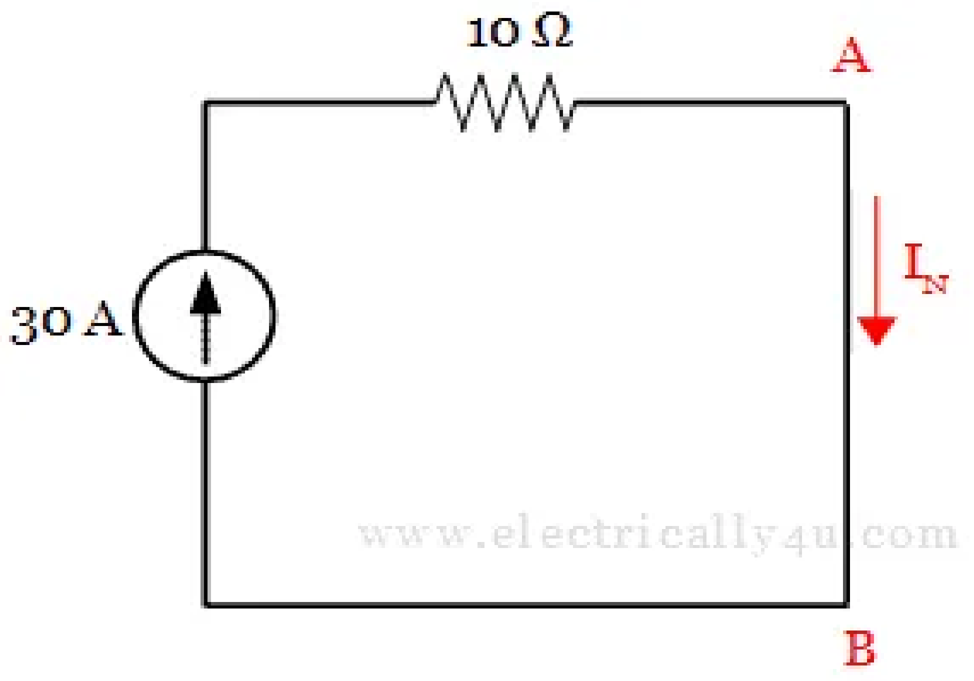
Determine the current through AB in the given circuit using Norton’s theorem.



(a) To find Norton's current, Remove the load resistor(6 Ω), short it with a wire and the circuit is redrawn as below.

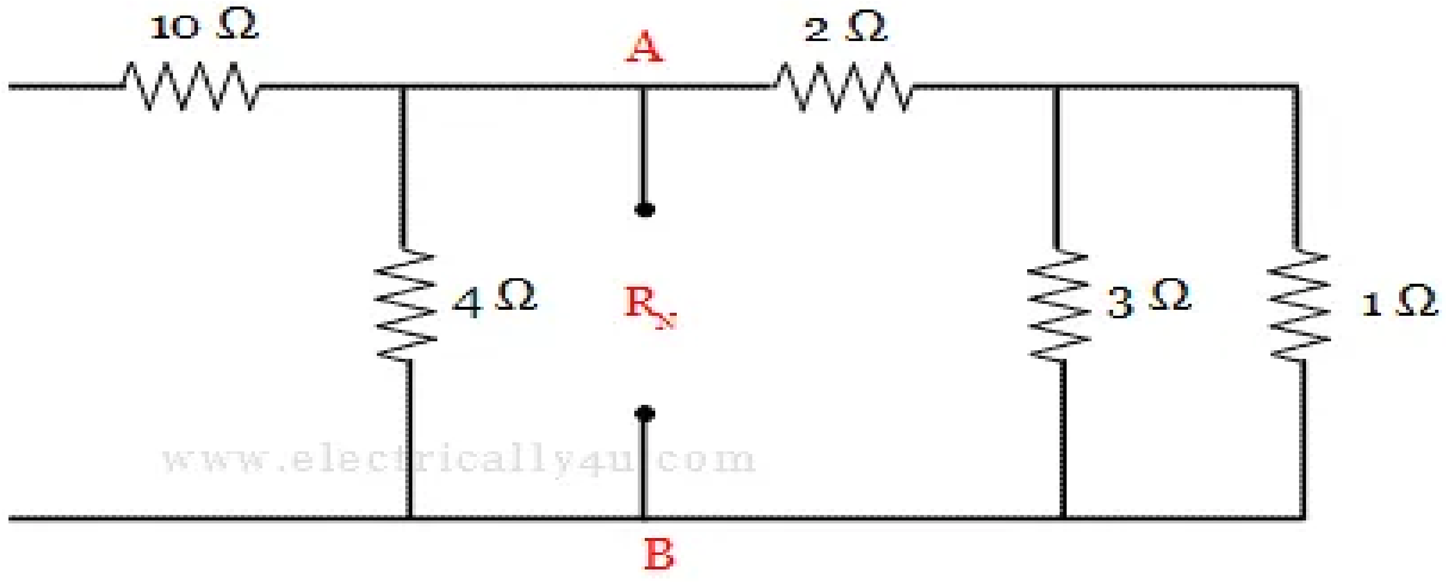


Norton's theorem

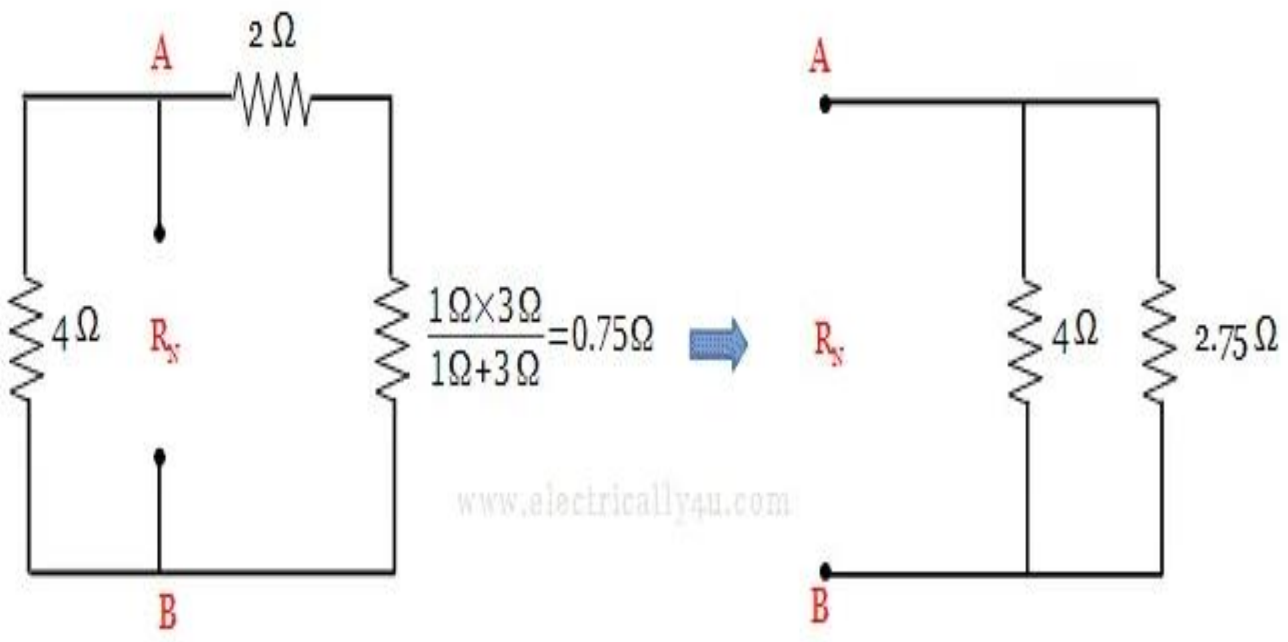


Norton's theorem

(b)To find Norton's resistance, Remove the load resistor, open the current source and the resulting circuit is redrawn as below.



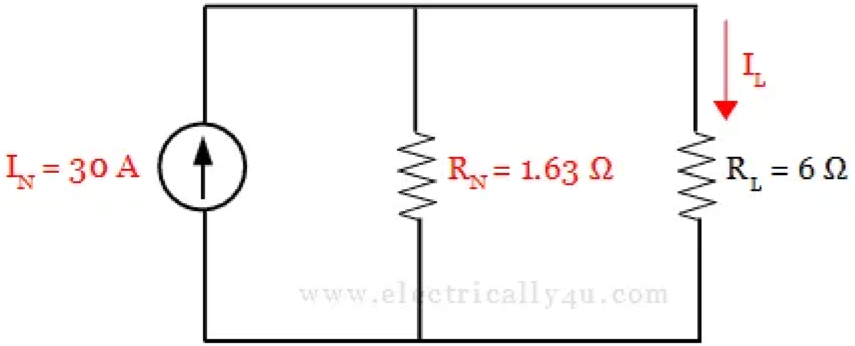
Norton's theorem



Norton’s theorem

$$R_N = \frac{4 * 2.75}{4 + 2.75} = 1.63\Omega$$

(c)Norton’s Equivalent Circuit. It is drawn by connecting Norton’s voltage I_N, Norton’s resistance R_N and load resistor in series, as shown below



$$I_L = I_N * \frac{R_N}{R_N + R_L} = 30 * \frac{1.63}{1.63 + 6} = 6.409A$$

Norton's theorem

Norton’s theorem

Norton's theorem

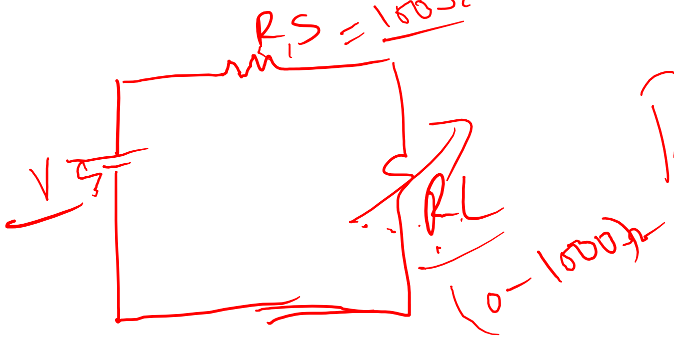
Maximum Power Transfer Theorem

The maximum power transfer theorem is applicable to both AC and DC circuits. In any circuit, the maximum power drawn from the supply depends on the load.

Statement:

"In a linear, bilateral DC network, Maximum Power will be transferred to the load, when the load resistance is equal to the internal resistance of the source."

source

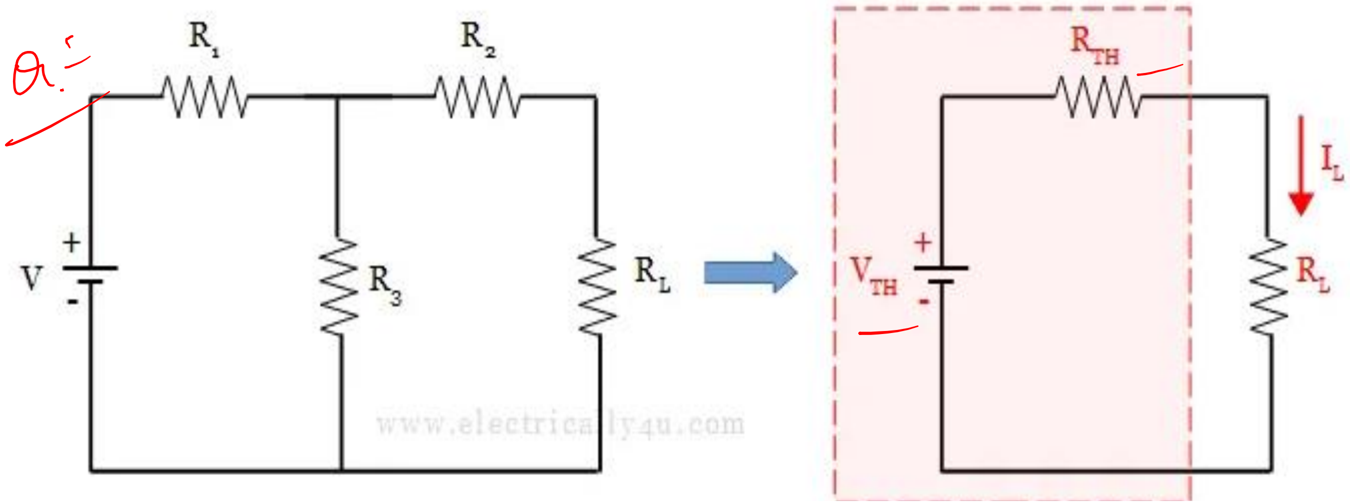


$P_{max} =$

$\boxed{R_S = R_L}$ *

Maximum Power Transfer Theorem

Q:-



The power dissipated across the load resistor is given by,

$$P_L = I_L^2 . R_L - - - - > (1)$$

The current through the load is given by,

$$I_L = \frac{V_{TH}}{R_{TH} + R_L}$$

Substitute the above expression in equation (1), we get,

$$P_L = \left(\frac{V_{TH}}{R_{TH} + R_L} \right)^2 . R_L$$

Maximum Power Transfer Theorem

$$P_L = V_{TH}^2 . \left(\frac{R_L}{(R_{TH} + R_L)^2} \right) - - - - > (2)$$

the maximum power delivered depends on the value of load resistance R_L. Hence, to obtain the maximum power, the above expression is differentiated with respect to R_L and equate it to zero.

$$\frac{dP_L}{dR_L} = V_{TH}^2 . \frac{d}{dR_L} \left[\frac{R_L}{(R_{TH} + R_L)^2} \right] = 0$$

$$=> V_{TH}^2 . \left[\frac{(R_{TH} + R_L)^2 * 1 - R_L * 2(R_{TH} + R_L)}{(R_{TH} + R_L)^4} \right] = 0$$

$$(R_{TH} + R_L)^2 - 2R_L(R_{TH} + R_L) = 0$$

$$(R_{TH} + R_L)[(R_{TH} + R_L) - 2R_L] = 0$$

$$(R_{TH} + R_L) - 2R_L = 0$$

$$\boxed{R_{TH} = R_L}$$

Rs = RL

or Rth = RL

Maximum Power Transfer Theorem

Substitute $R_{TH} = R_L$ in equation (2), we get,

$$P_{Max} = {V_{TH}}^2 . \left[\frac{R_{TH}}{(R_{TH} + R_{TH})^2} \right]$$

RL

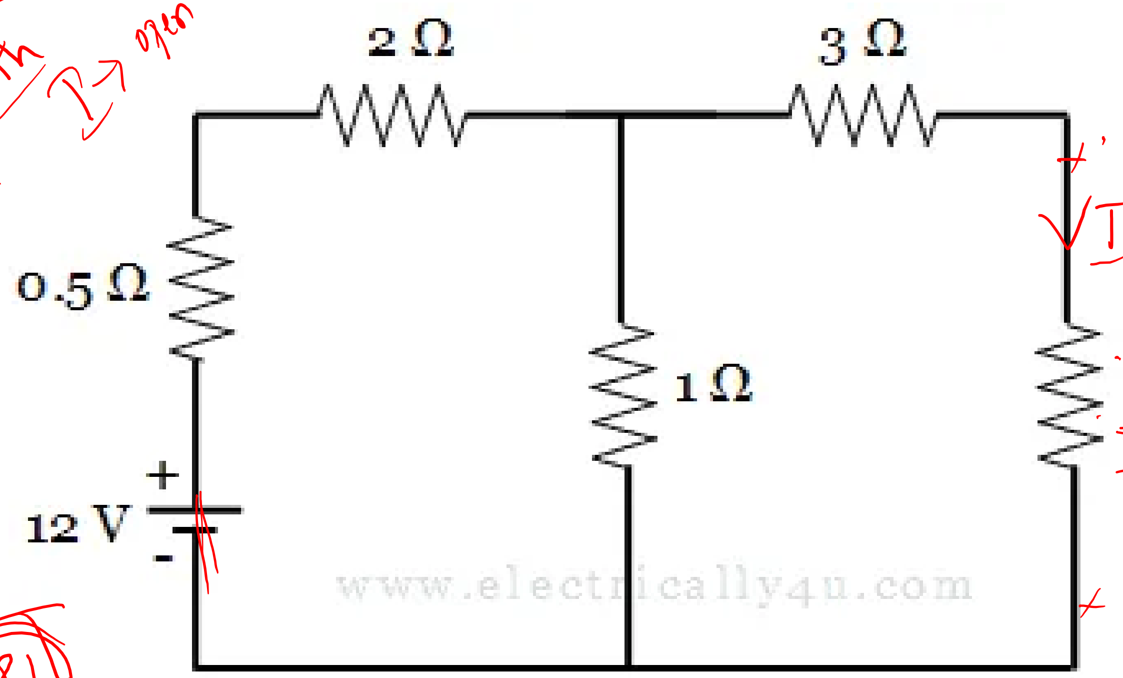
$[R_{th} = R_L]$

$$P_{Max} = {V_{TH}}^2 . \left[\frac{R_{TH}}{4{R_{TH}}^2} \right]$$

$$P_{Max} = \frac{{V_{TH}}^2}{4R_{TH}}$$

(or) $P_{max} = \dfrac{V_{th}^2}{4R_L}$

Find the value of R_L at which maximum power is transferred to the load in the following circuit. Also, find the maximum power transferred.



step1) $R_L \to$ Remove R_L

step2) Req of Rth
V → shorted
I → open

Req =

$\boxed{R_s = R_L}$

step1)

12V, 0.5Ω, 2Ω, 1Ω, 3Ω, V_0

$V_0 = \frac{12 \times 1}{0.5 + 2 + 1}$

$V_0 = 3.428V$

step) Req V → short I → open

$P_{max} = \frac{V_{th}^2}{4R_{th}}$ or $\frac{V_{th}^2}{4R_L}$

3.714

$I_L = \frac{3.428}{(3.714 + 3.714)}$

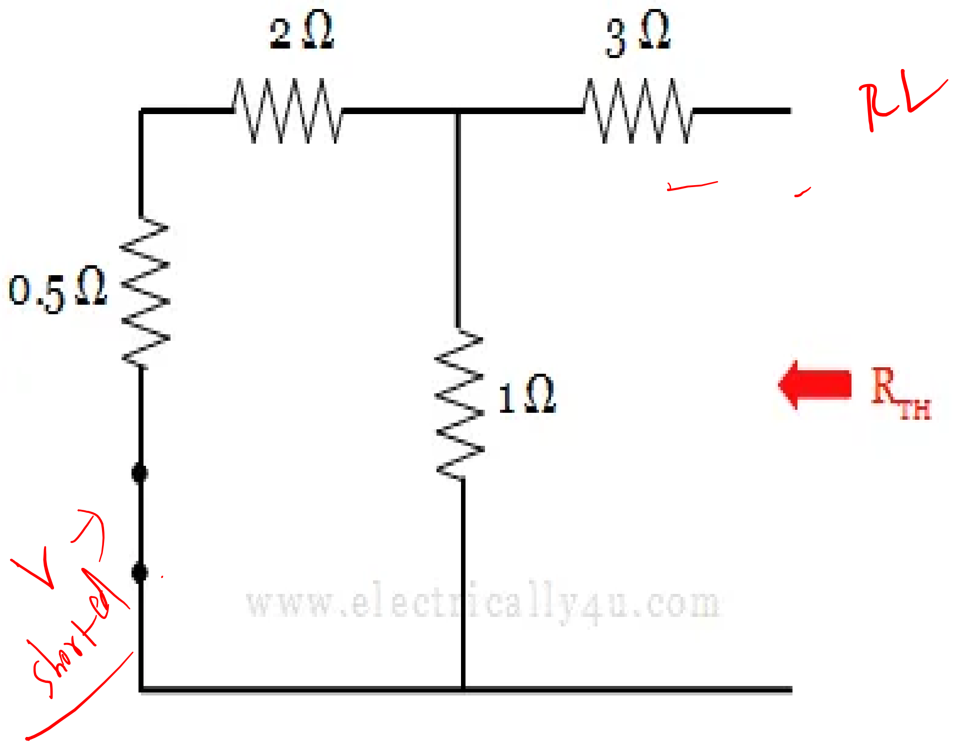
$R_L = 3.714$

$I_L = 0.461 A$

$P_{max} = I_L^2 R_L = (0.461)^2 \times 3.714$ 3.428

$= 0.7912 W$

Maximum Power Transfer Theorem



$$R_{TH} = \frac{1 * 2.5}{1 + 2.5} + 3 = 3.714\Omega$$

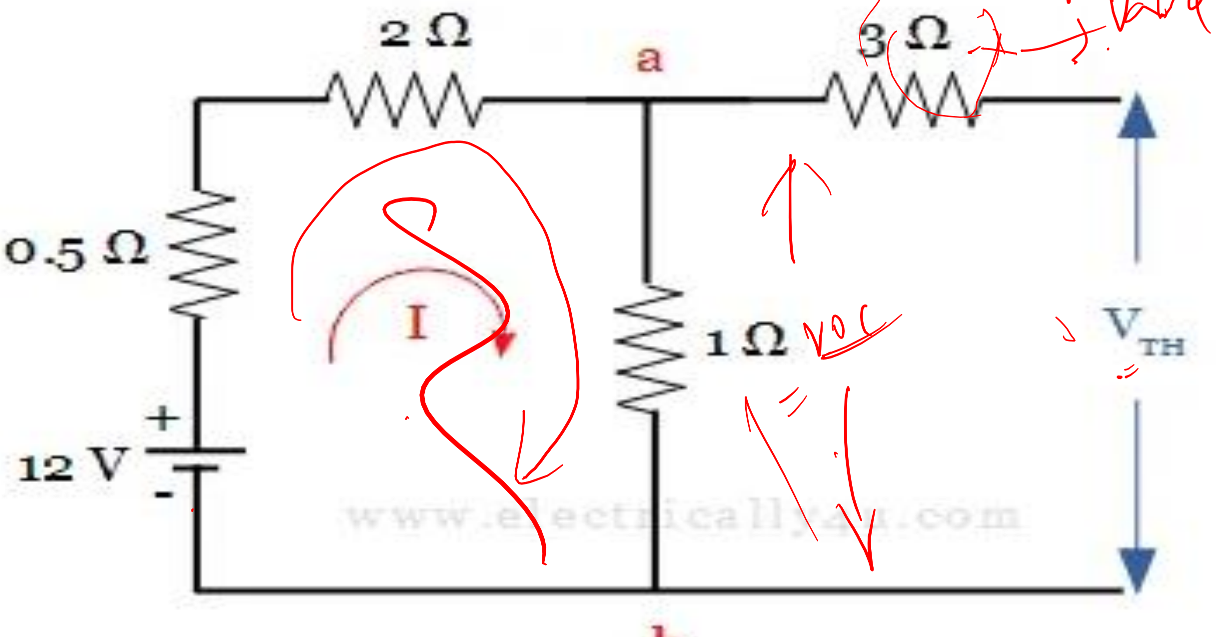
$$R_{TH} = R_L = 3.714\Omega$$

$\frac{2.5 \times 1}{2.5+1} + 3 =$

Req = Rth

step 4) Vth

Maximum Power Transfer Theorem



not valid

RL – open

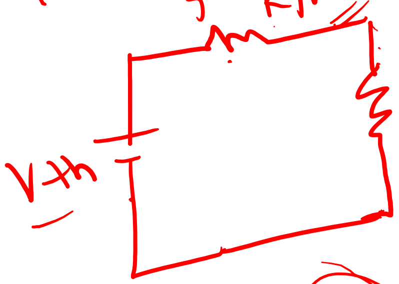
$R_{th} = R_L$

$$V_{ab} = V_{TH} = 3.428V$$

$V_{1\Omega}$ or V_{th} $= \frac{V_T \times 1}{0.5+2+1} = \frac{12 \times 1}{0.5+2+1}$

$V_{th} = 3.428V$

R_{th} 3.714



$R_L = 3.714\Omega$

R_{th} or $R_S = R_L$

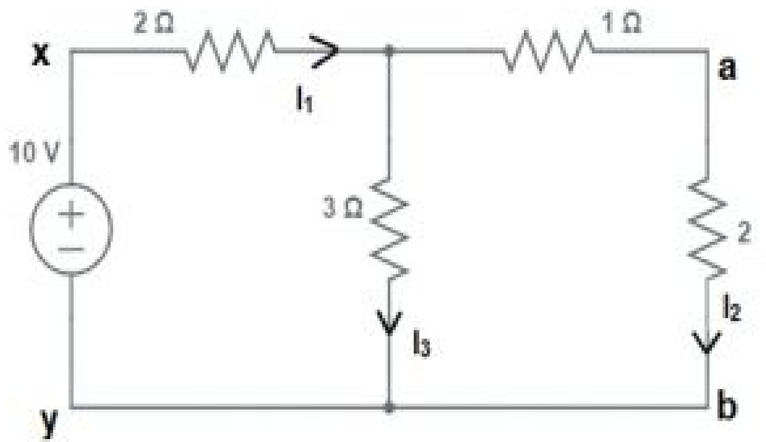
Therefore, Maximum Power delivered to the load is given by,

$$P_{Max} = \frac{{V_{TH}}^2}{4R_{TH}} = \frac{3.428^2}{4 * 3.714} = 0.7912W$$

Maximum Power Transfer Theorem

Maximum Power Transfer Theorem

Reciprocity Theorem



Equivalent resistance among x-y branch

$$R = [(2+1)||3] + 2$$

$$= (9/6) +2 = ((12+9)/6) = 21/6 = 3.5 \text{ ohms}$$

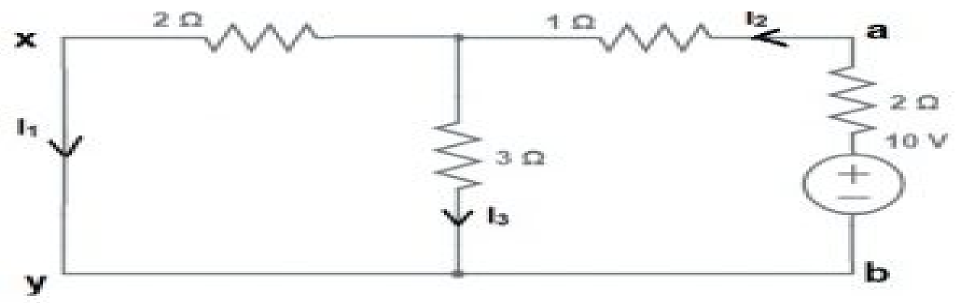
So, current like ‘I1’

$$10/3.5 \text{ A} \Rightarrow 2.86\text{A}$$

Similarly, I2 = 2.86 X (3/3+3) =1.43A

$$I3 = I1 - I2 = 2.86 - 1.43 = 1.43\text{A}$$

Reciprocity Theorem



Voltage Source is Changed

Equivalent resistance across terminals x-y

R = (2||3/5) + 1+2

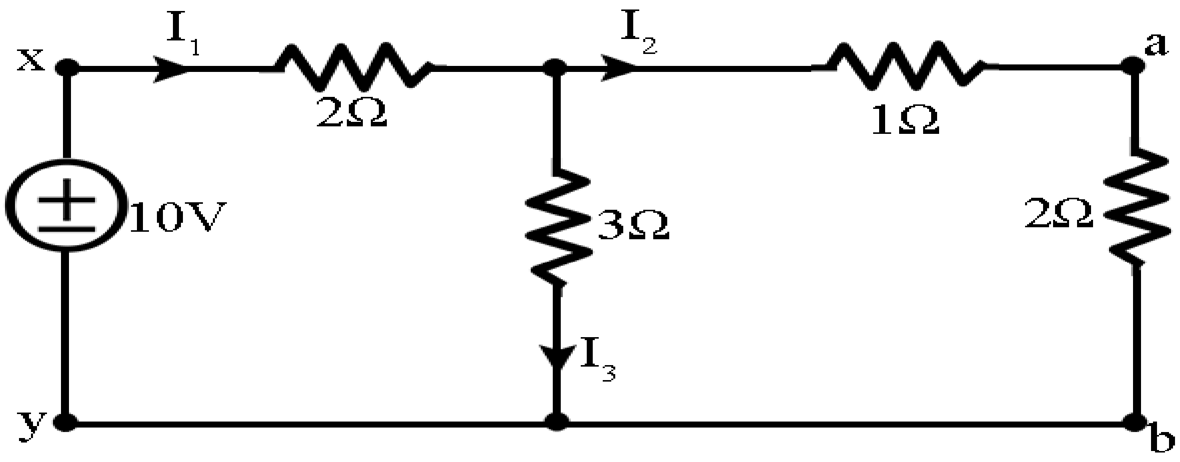
= (6/5) + 3 = 21/5= 4.2 ohms

I2 = 10/4.2 => 2.34A

I1 = I2 X (3/3+2)

= 2.384 x (3/5) = 1.43A

Reciprocity Theorem



With the reference to figure 1, the equivalent resistance across x-y is given by

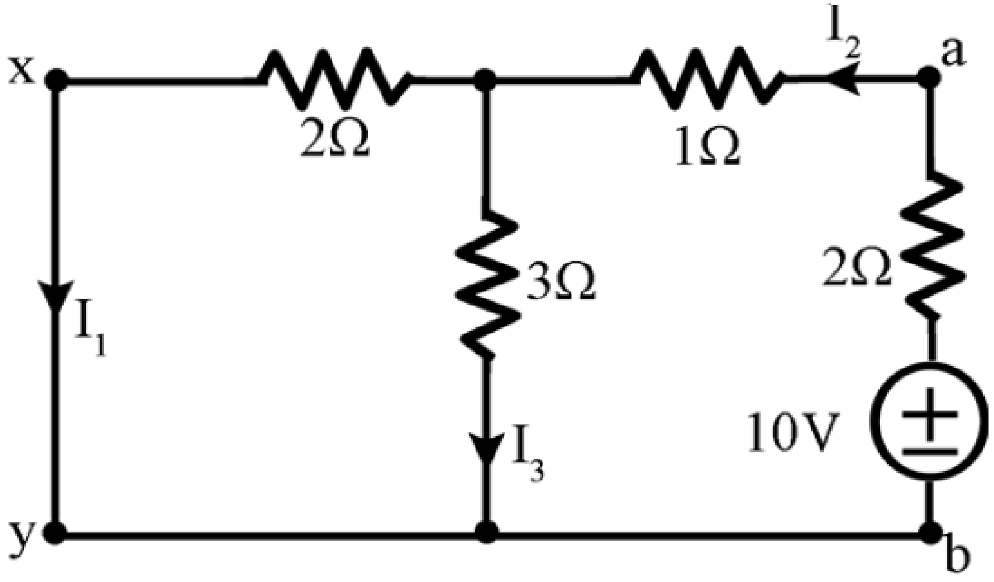
$$R_{eq} = [(2+1)||3] + 2 = 3.5\Omega$$

$$\therefore I_1 = \frac{10}{3.5} = 2.86A$$

$$I_2 = 2.86 \times \frac{3}{3+3} = 1.43A$$

$$I_3 = 2.86 - 1.43 = 1.43A$$

Reciprocity Theorem



$$R_{eq} = (2||3) + 1 + 2 = \frac{6}{5} + 3 = \frac{21}{5} = 4.2\Omega$$

$$\therefore I_2 = \frac{10V}{4.2\Omega} = 2.381A$$

This gives

$$I_1 = I_2 \frac{3}{3+2} = 2.381 \times \frac{3}{5} = 1.43A$$

Reciprocity Theorem

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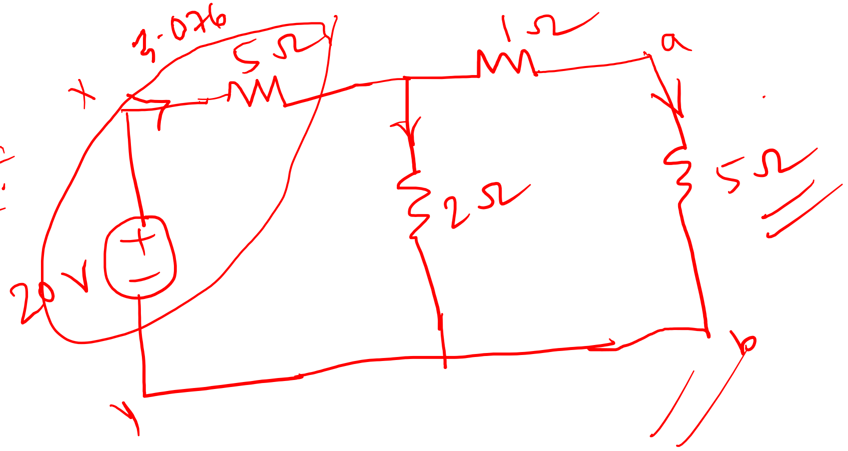
Q:

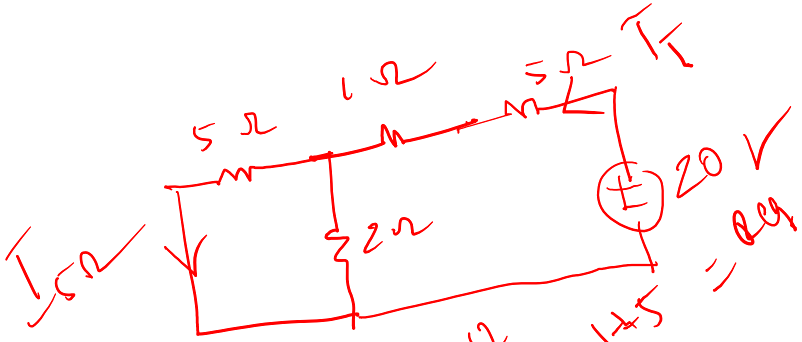


Apply Reciprocity theorem find the Response through 5Ω

$R_{eq} = 6.5\,\Omega$

$I = \frac{V}{R_{eq}} = \frac{20}{6.5} = 3.076A$

$I_{5\Omega} =$



$R_{eq} = \frac{5\times2}{5+2} + 1+5$

$= R_{eq}$

$I = \frac{V}{R_{eq}} = \frac{20}{}$

$I_{5\Omega} = 0.767A$

$I_T = \frac{I_T \times 2}{5+2} = 0.767A$

$I_{5\Omega} = \frac{I_T \times 2}{2+1+5} = 0.767A$

$I_{2\Omega} = I_T - I_{5\Omega}$

$= 3.076 - 0.767$

$= 2.31A$

$I_{2\Omega} =$

Network Topology

What is Network Topology:

Network topology is arrangement of various elements (links, nodes ,etc.) of a electrical network such that there is no distinction between different types of physical elements of network

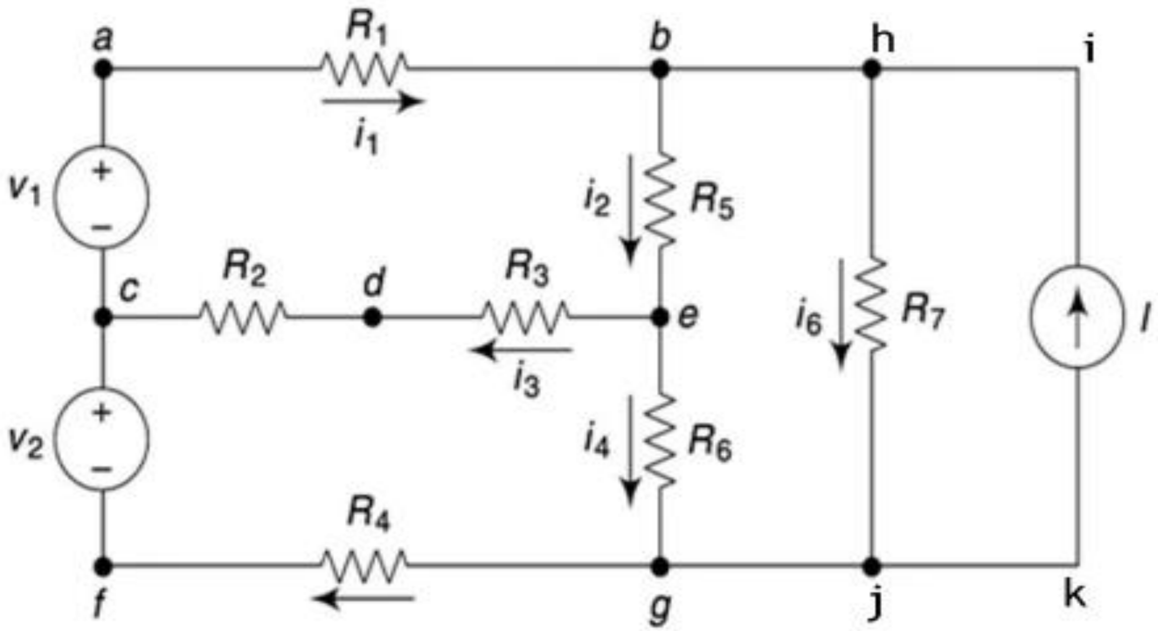
Why we need to learn Network Topology: When a circuit is non planar or complicated with large number of nodes and closed paths, then conventional methods like KCL , KVL , Nodal analysis, Mesh analysis etc becomes highly difficult. Analysis of such networks can be done conveniently using network topology.

Where do we apply Network Topology: Network topology is used to analyze voltage and currents across various branches of an electrical circuit (more particularly complicated circuit)

Basic Definitions

- Node
- Essential Node
- Branch
- Loop
- Mesh
- Graph

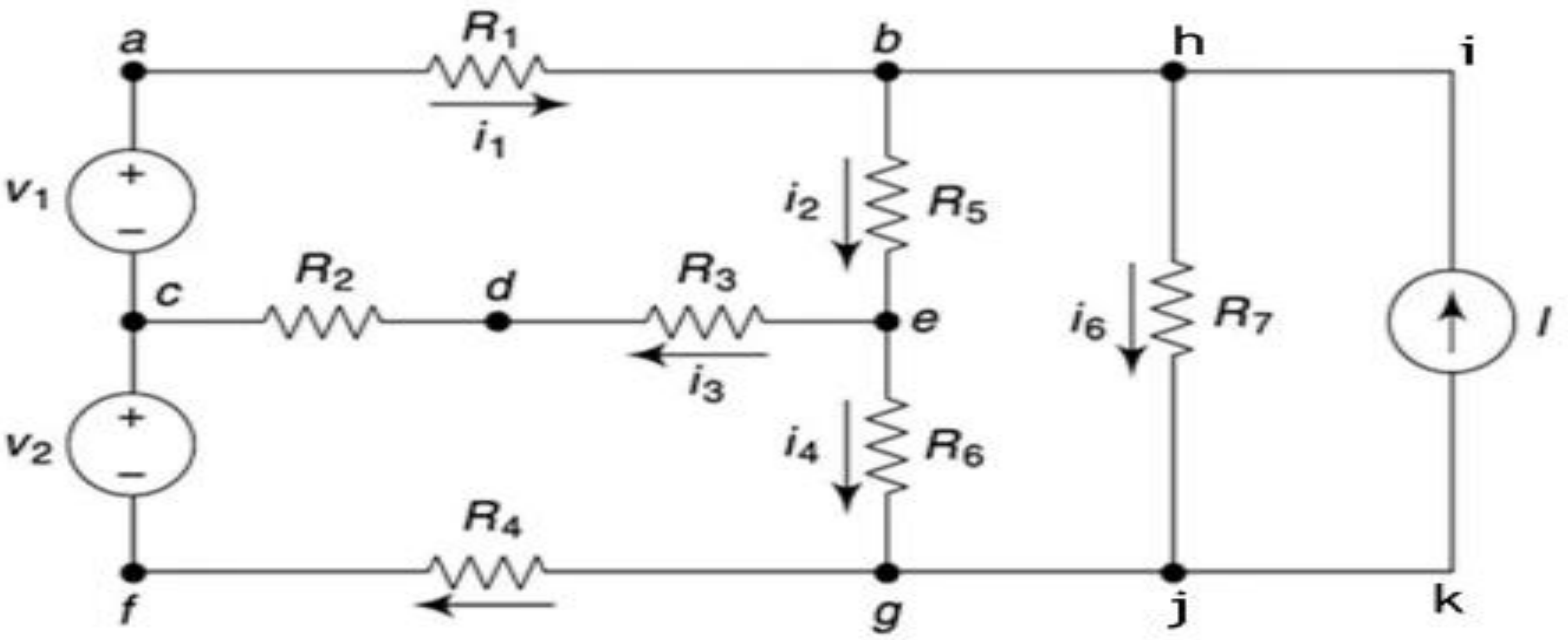
Node



Circuit illustrating terminologies

- A node is a point in a circuit where two or more circuit elements join .
- The number of branches incident to that node is the degree of its node 07 a,b, c, d, e, f and g

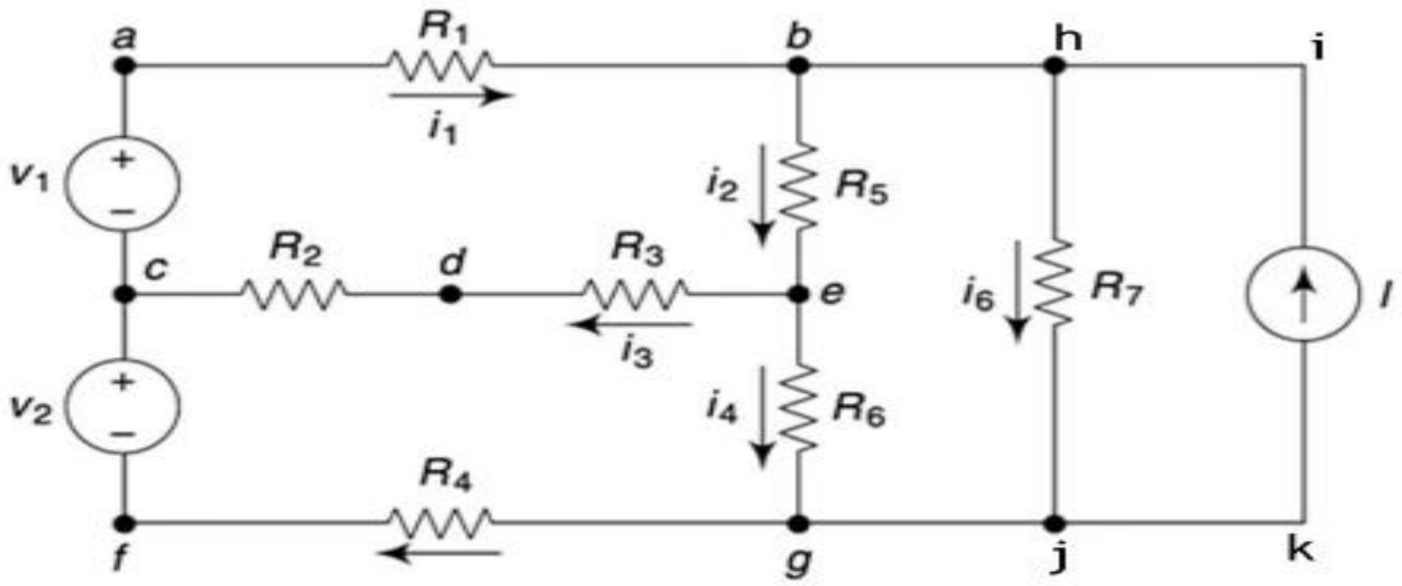
Essential Node



Circuit illustrating terminologies

A node that joins three or more elements. 04 b, c,e and g

Branch

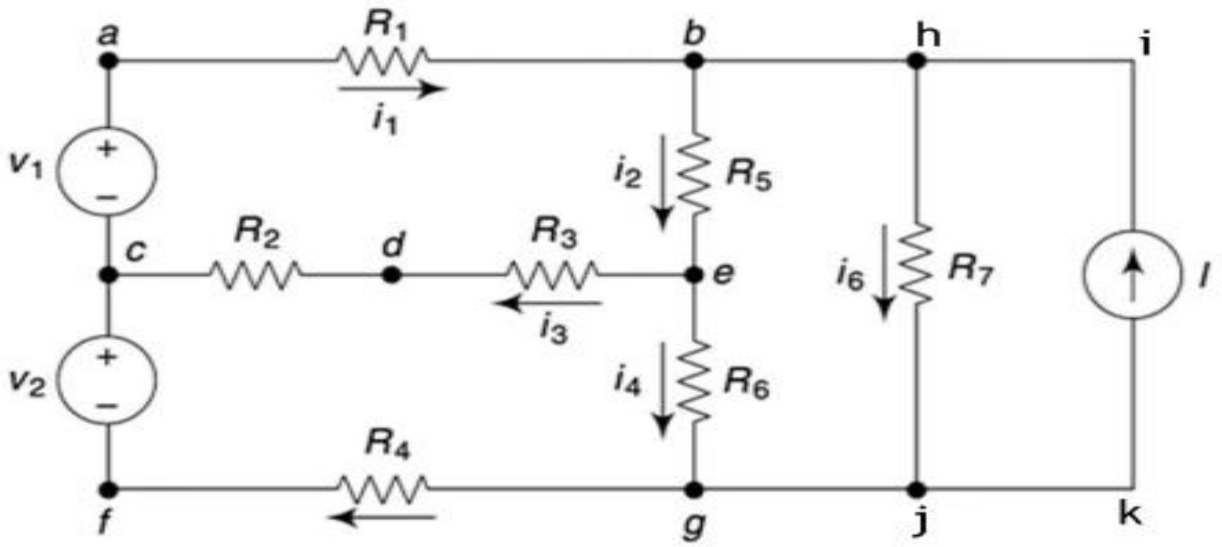


Circuit illustrating terminologies

Branch A single path containing one circuit element that connects one node to other and is represented by solid line

10 V1,R1,R2,R3,V2,R4,R5,R6,R7and I

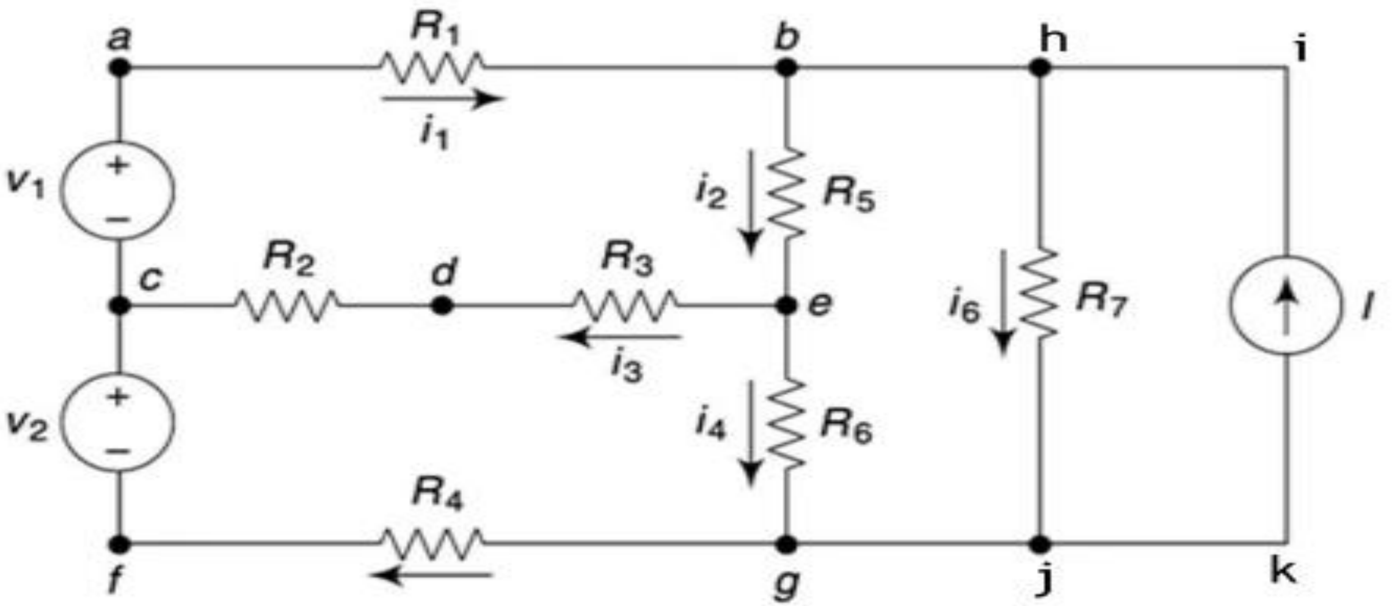
Loop



Circuit illustrating terminologies

Loop A loop is a closed path, i.e., it starts at a selected node, traces a set of connected basic circuit elements and returns to the original starting node without passing through any intermediate node more than once. 11 abhikjgfca ,abhjgfca,abegfca abedca,cdegfc cdebhikjgfc ,cdebhjgfc gebhjg ,jhik, abhjgedca, abhikjgedca

Mesh



Circuit illustrating terminologies

Mesh A mesh is a special type of loop which does not contain any other loops within it. 04 abedca,cdegfc, gebhjg ,jhik

Graph

Graph A graph corresponding to a given network is obtained by replacing all circuit elements with lines

Network Topology

- Graph
- Oriented Graph
- Rank of a graph Graph
- Planar and non - planar graph Planar Graph
- Tree and twings
- Co tree and Links(Chords)

Graph ,Oriented Graph & Rank of a graph Graph :

- A graph corresponding to a given network is obtained by replacing all circuit elements with lines.
- Rank of a Graph : If there are ‘n’ nodes in a graph then rank of the of the graph is (n-1)
- Oriented Graph: If each of the line/branch of the graph has a reference direction [as indicated by an arrow mark],then the resulted graph is called oriented or directed graph

Steps for drawing oriented graph:

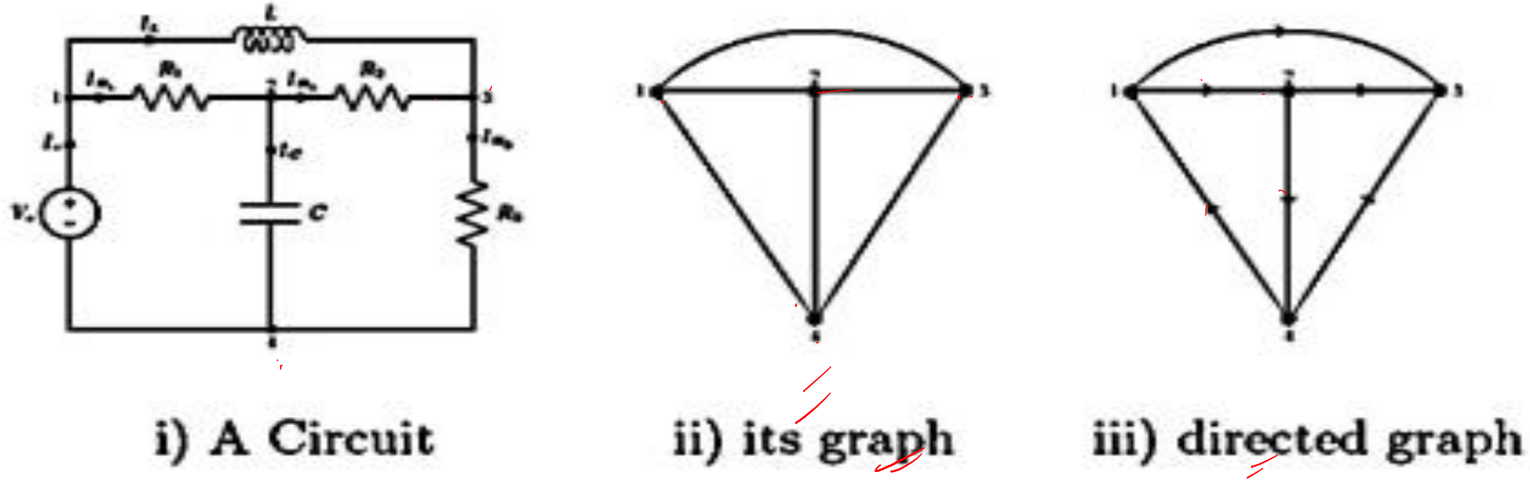
1.Replace all resistors , inductors and capacitors by line segments

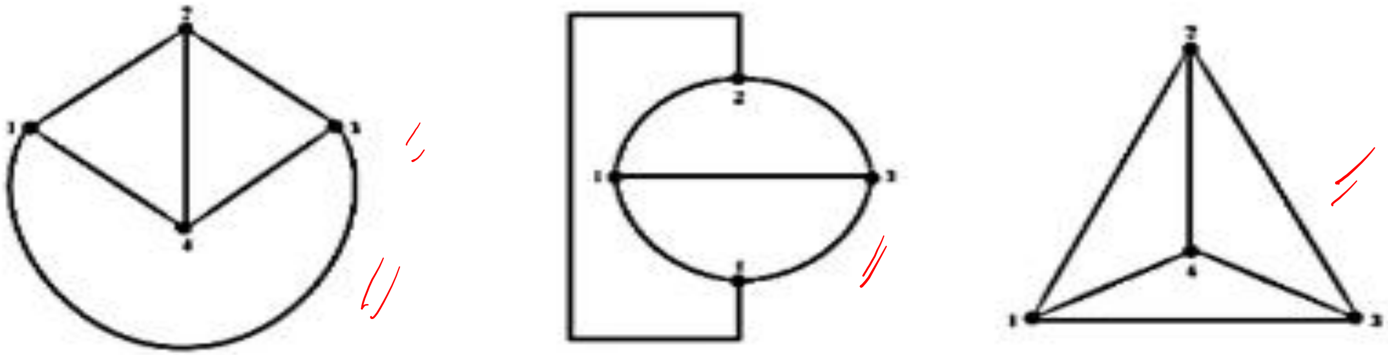
2.Replace voltage source by short circuit and current sources by open circuit

3.Assume directions of branch currents

4. Name all the nodes and branches

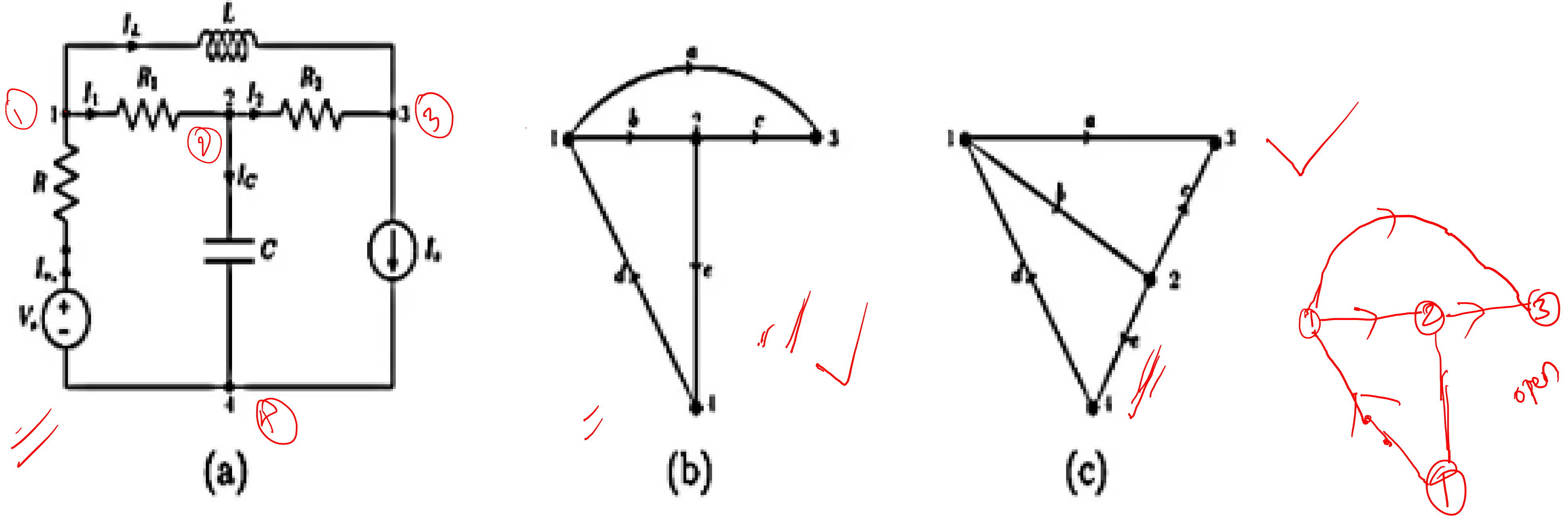
Network Topology





Three topologically equivalent graphs of figure ii).

Network Topology

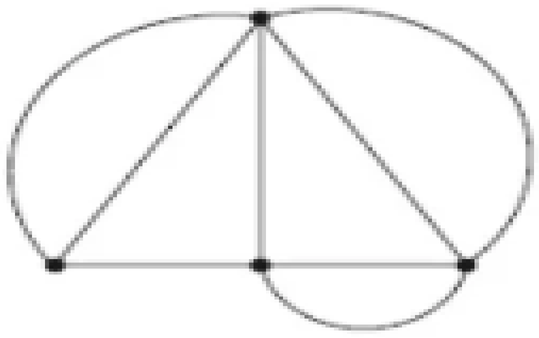


(a) A circuit, and (b),(c) its directed graphs.

Planar and non - planar graph Planar Graph :

Planar Graph:

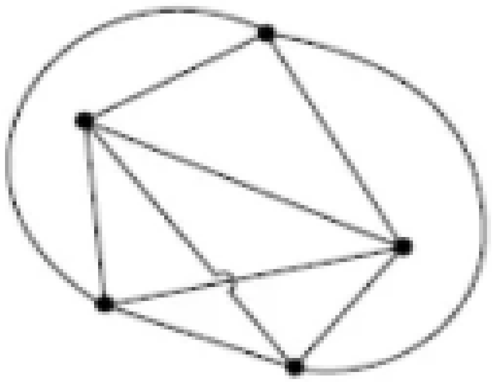
A graph drawn on a 2 - dimensional plane is said to be planar if two branches do not intersect or cross at a point which is other than a node .



Planar graph

Non Planar Graph :

A graph drawn on a 2 - dimensional plane is said to be planar if two branches intersect or cross at a point which is other than a node .



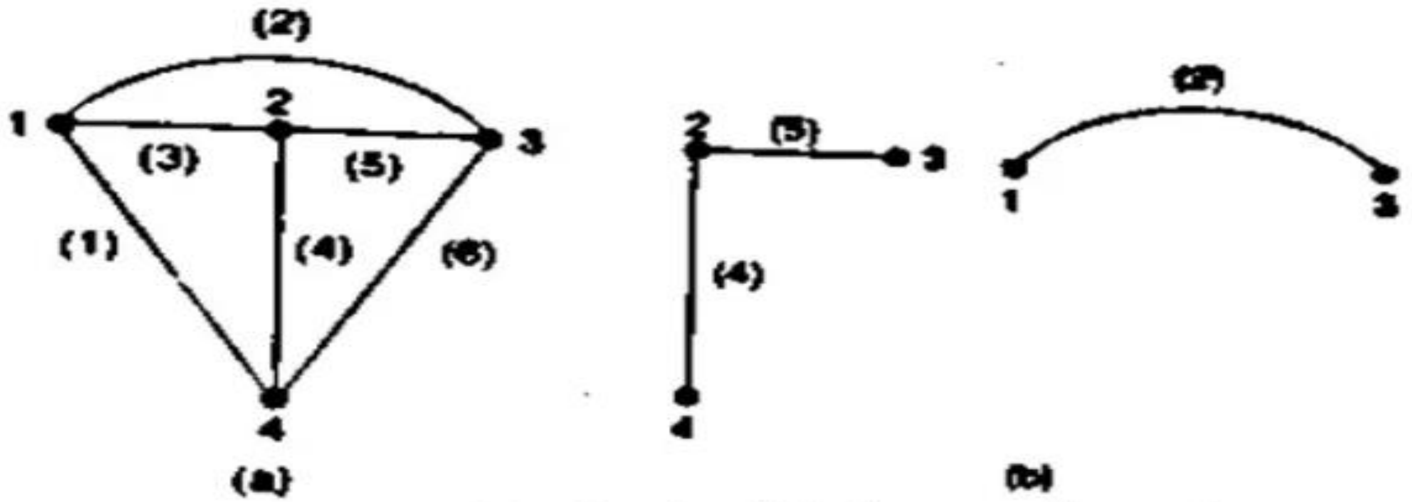
Non-planar graph

Path and sub graph Path

Path : A set of elements that may be traversed in order without passing through the same node twice.

Sub Graph : It is a sub set of branches and nodes of a graph.

It is a proper sub-graph if it contains branches and nodes less than those on a graph. A sub graph can be just a node or only one branch of the graph.



(a) Graph (b) Proper sub-graph

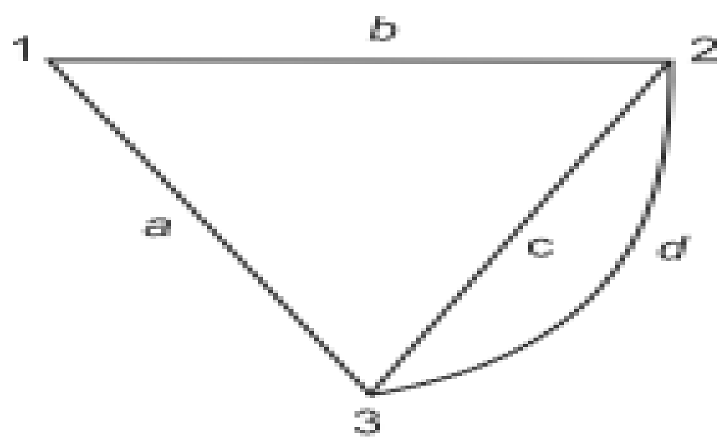
Tree

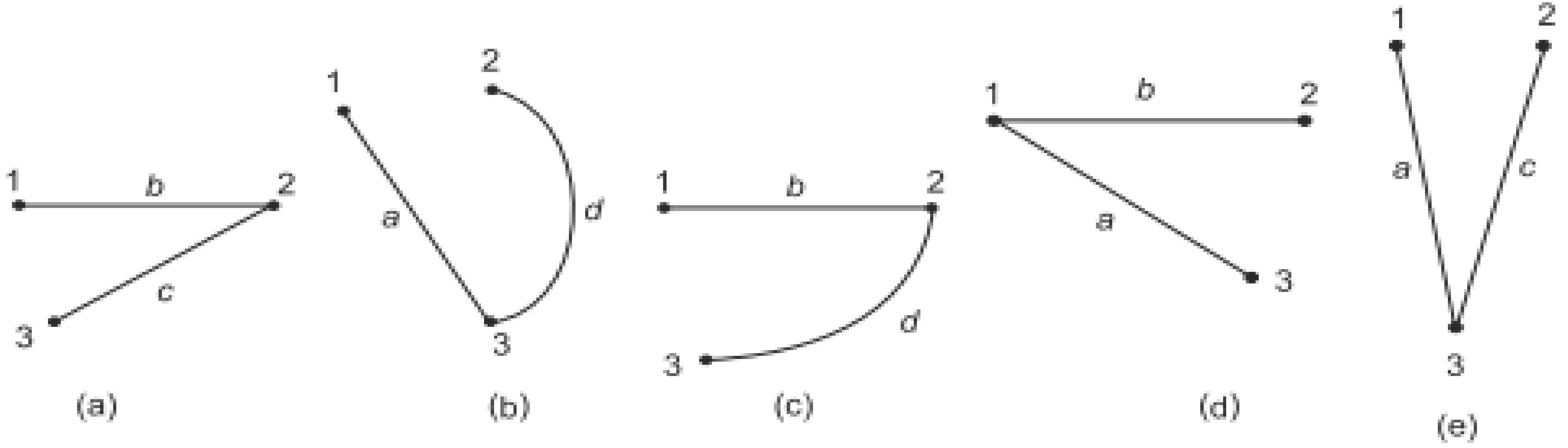
A tree is a connected subgraph of a network which consists of all the nodes of the original graph but no closed paths.

The graph of a network may have a number of trees.

The number of nodes in a graph is equal to the number nodes in the tree.

Tree





Tree

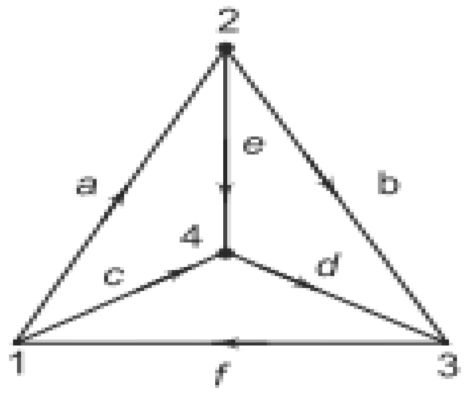
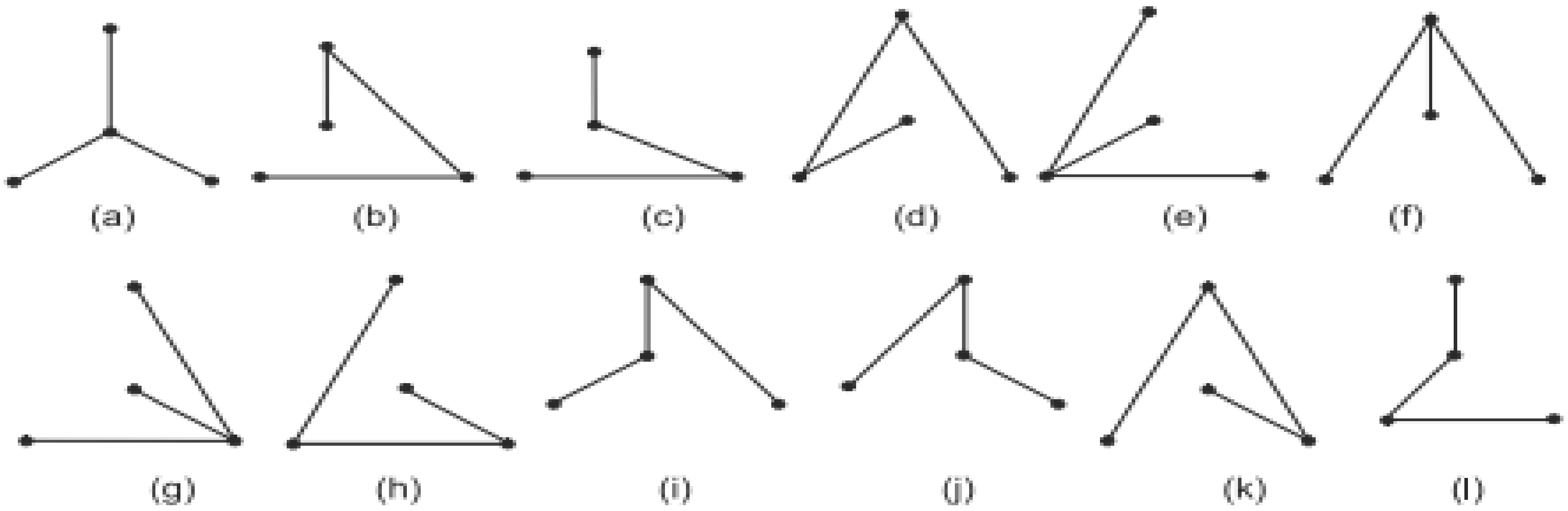


Fig. 2.7



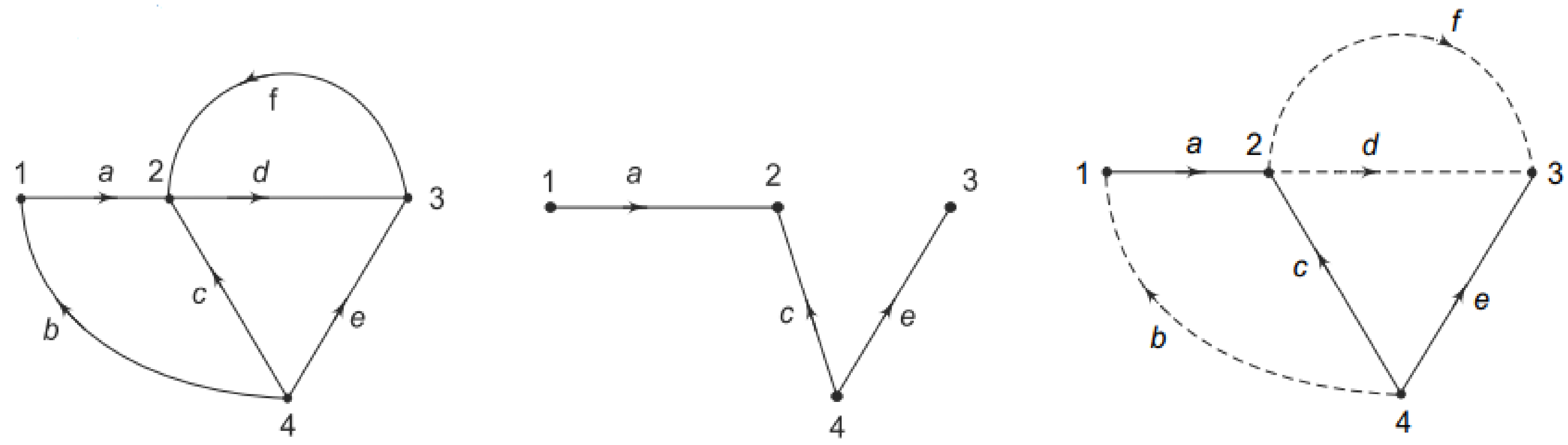
Tree and Twigs of graph

Tree & Twigs : A connected sub graph having all the nodes of a graph without any loop is called a tree and branches of a tree are called twigs.

Properties of Tree .

- There exists only one path between any pair of nodes in a tree
- A tree contains all nodes of the graph
- If n is the number of nodes of the graph, there are (n-1) branches in the tree
- Tree do not contain any loops
- Every connected graph has at least one tree
- The minimum terminal nodes in a tree are two

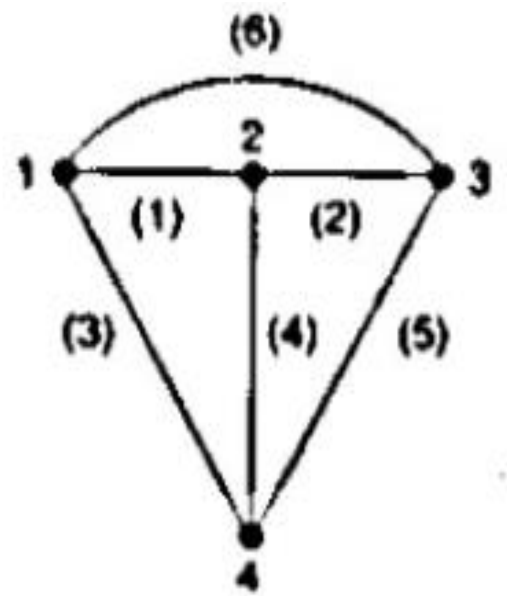
Tree



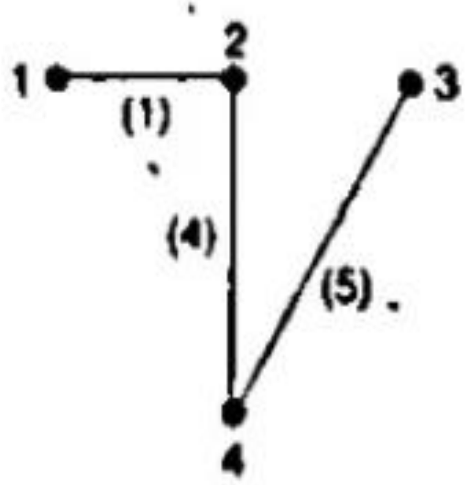
The branches a, c, and e are the twigs while the branches b, d, and f are the links of this tree. It can be seen that for a network with b branches and n nodes, the number of twigs for a selected tree is (n – 1) and the number of links l with respect to this tree is $(b - n + 1)$.

The number of twigs (n – 1) is known as the tree value of the graph. It is also called the rank of the tree.

Tree and Twigs of graph

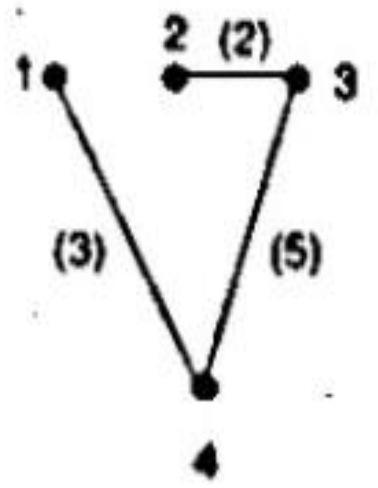


(a) Graph



(b)

Twigs: {1, 4, 5}

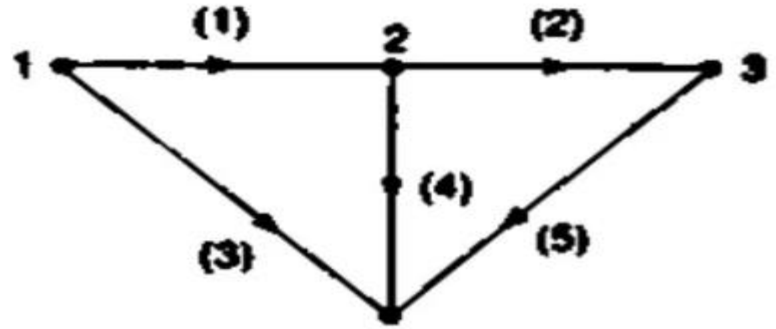


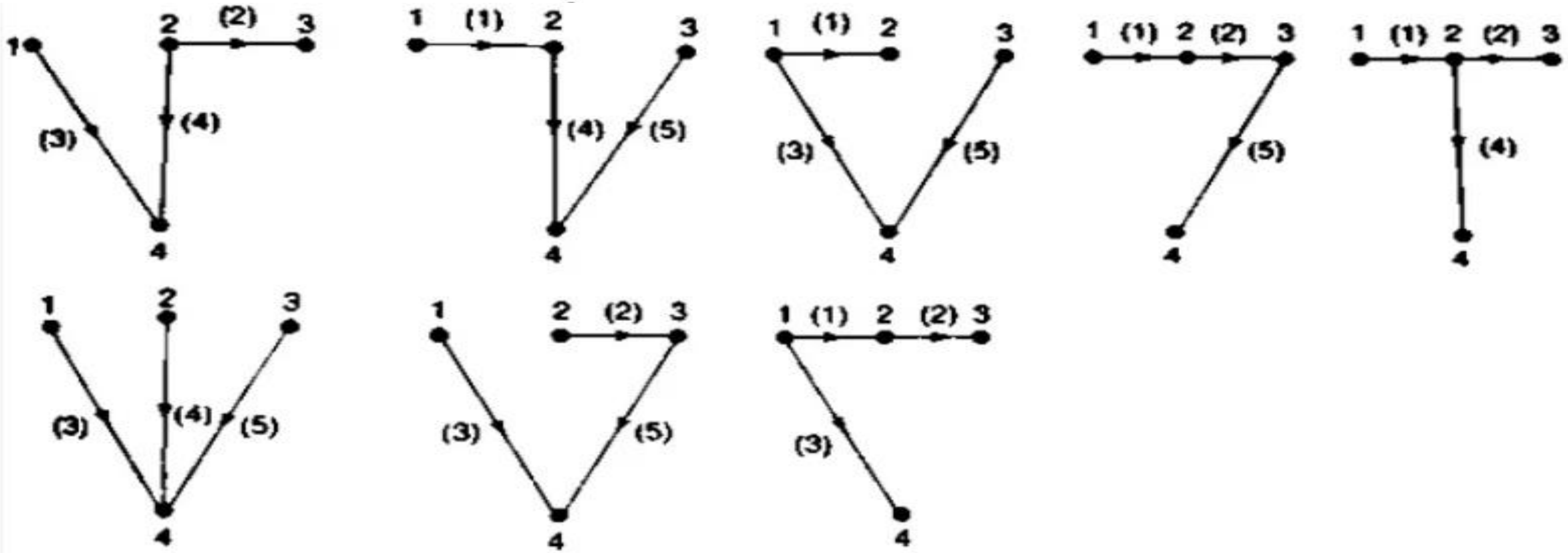
(c)

Twigs: {2, 3, 5}

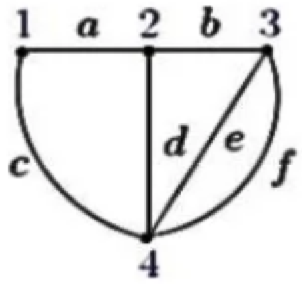
Tree and Twigs of graph

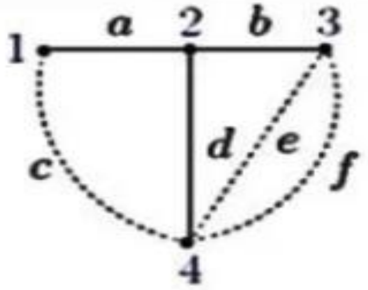
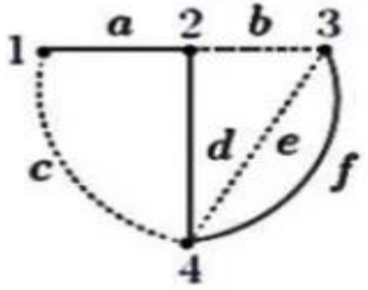
Identify Trees in the graph





Tree and Twigs of graph



Tree	Twigs of tree	Links of cotree
	{a,b,d}	{c,e,f}
	{a,d,f}	{c,b,e}

Incidence Matrix

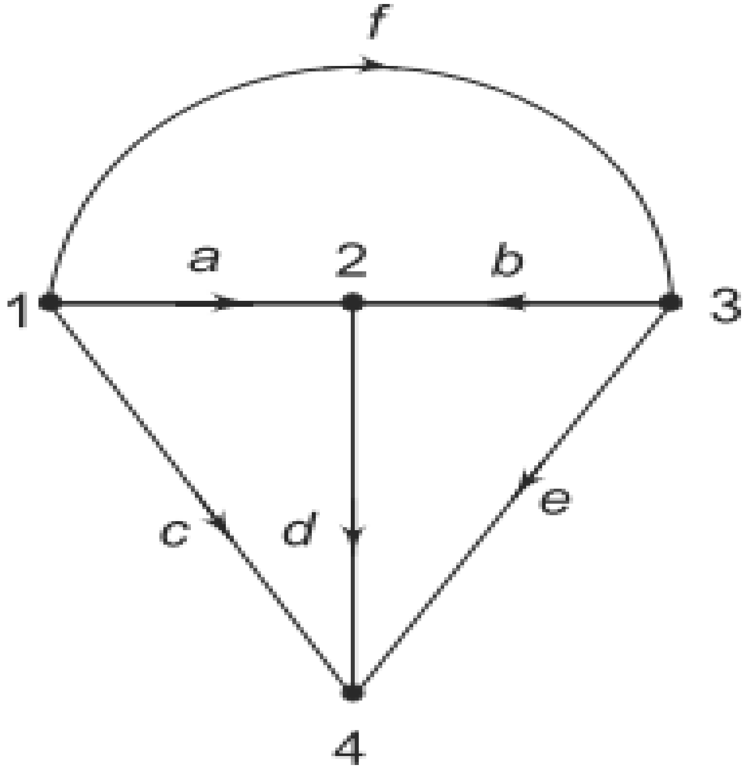
In the matrix A with n rows and b columns, an entry a_{ij} in the ith row and jth column has the following values.

$a_{ij} = 1$, if the jth branch is incident to and oriented away from the ith node.

$a_{ij} = -1$, if the jth branch is incident to and oriented towards the ith node.

$a_{ij} = 0$, if the jth branch is not incident to the ith node.

Incidence Matrix



$$
A = \begin{array}{c} \text{nodes} \\ \downarrow \\ 1 \\ 2 \\ 3 \\ 4 \end{array}
\begin{array}{c} \text{branches} \rightarrow \\ \begin{array}{cccccc} a & b & c & d & e & f \end{array} \\
\begin{bmatrix} 1 & 0 & 1 & 0 & 0 & 1 \\ -1 & -1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & -1 \\ 0 & 0 & -1 & -1 & -1 & 0 \end{bmatrix} \end{array}
$$

PROPERTIES OF INCIDENCE MATRIX A

1. Each column representing a branch contains two non-zero entries 1 and –1; the rest being zero. The unit entries in a column identify the nodes of the branch between which it is connected.
2. The unit entries in a row identify the branches incident at a node. Their number is called the degree of the node.
3. A degree of 1 for a row means that there is one branch incident at the node. This is commonly possible in a tree.
4. If the degree of a node is two, then it indicates that two branches are incident at the node and these are in series.
5. Columns of A with unit entries in two identical rows correspond to two branches with same end nodes and hence they are in parallel.

Incidence Matrix

6. Given the incidence matrix A, the corresponding graph can be easily constructed since A is a complete mathematical replica of the graph. 7. If one row of A is deleted the resulting (n – 1) 3 b matrix is called the reduced incidence matri

Incidence Matrix

In the matrix A with n rows and b columns, an entry a_{ij} in the ith row and jth column has the following values.

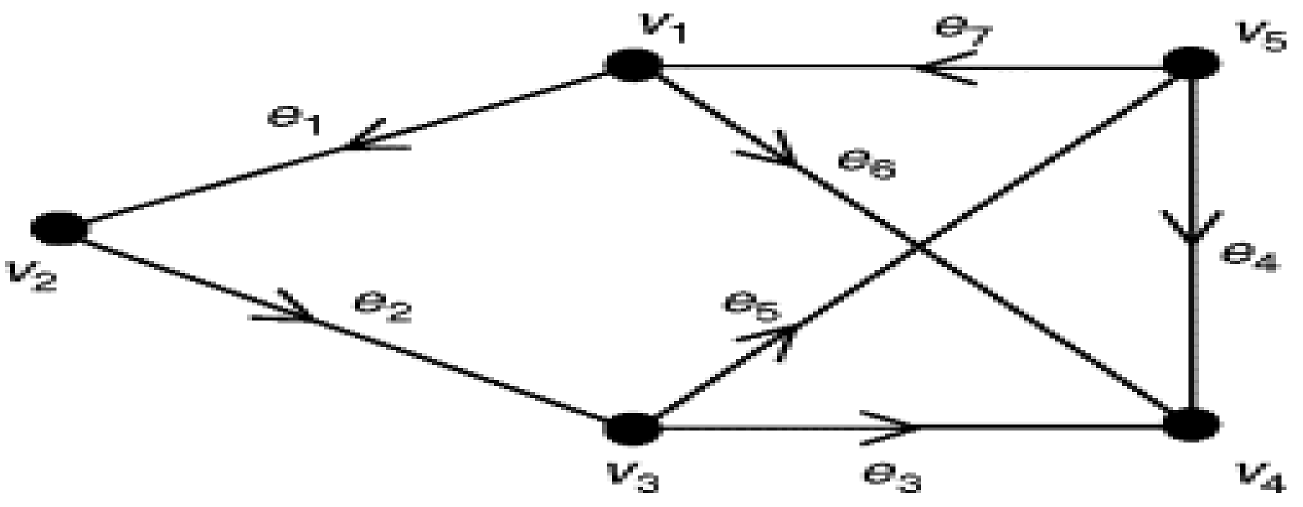
$a_{ij} = 1$, if the jth branch is incident to and oriented away from the ith node.

$a_{ij} = -1$, if the jth branch is incident to and oriented towards the ith node.

$a_{ij} = 0$, if the jth branch is not incident to the ith node.

Incidence Matrix

$$
\begin{array}{c} \\ v_1 \\ v_2 \\ v_3 \\ v_4 \\ v_5 \end{array}
\begin{array}{c}
\begin{array}{ccccccc} e_1 & e_2 & e_3 & e_4 & e_5 & e_6 & e_7 \end{array} \\
\begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 1 & -1 \\
-1 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & -1 & 1 & 0 & 1 & 0 & 0 \\
0 & 0 & -1 & -1 & 0 & -1 & 0 \\
0 & 0 & 0 & 1 & -1 & 0 & 1
\end{bmatrix}
\end{array}
$$

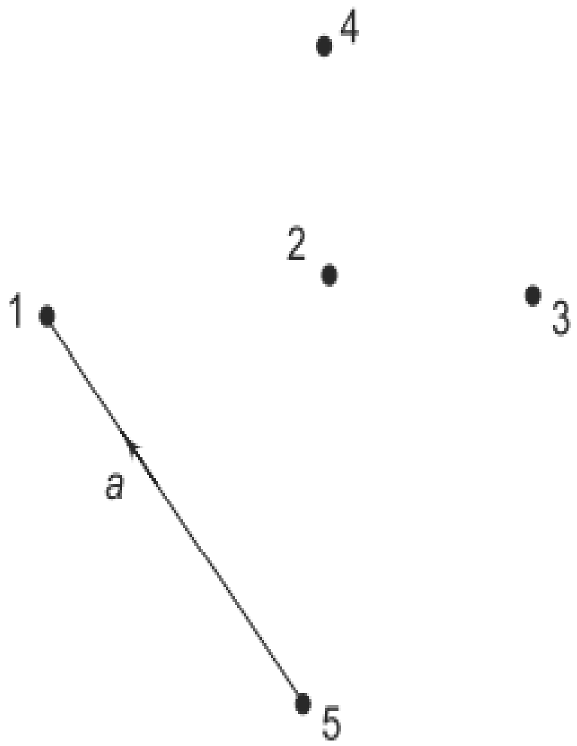


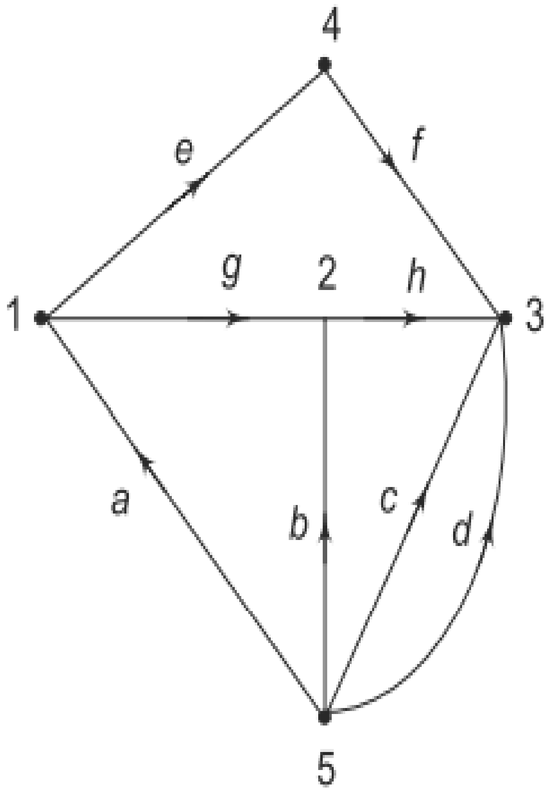
Draw the graph corresponding to the given incidence matrix

$$A = \begin{bmatrix} -1 & 0 & 0 & 0 & +1 & 0 & +1 & 0 \\ 0 & -1 & 0 & 0 & 0 & 0 & -1 & +1 \\ 0 & 0 & -1 & -1 & 0 & -1 & 0 & -1 \\ 0 & 0 & 0 & 0 & -1 & +1 & 0 & 0 \\ +1 & +1 & +1 & +1 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Incidence Matrix

$$A = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{array} \begin{array}{c} \begin{array}{cccccccc} a & b & c & d & e & f & g & h \end{array} \\ \begin{bmatrix} -1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & -1 & 0 & 0 & 0 & 0 & -1 & 1 \\ 0 & 0 & -1 & -1 & 0 & -1 & 0 & -1 \\ 0 & 0 & 0 & 0 & -1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \end{bmatrix} \end{array}$$





Incidence Matrix

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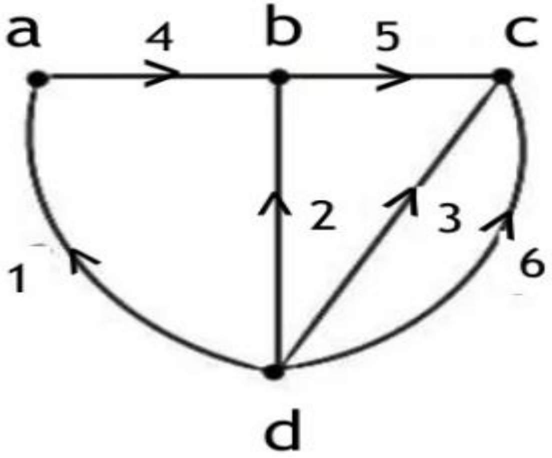
$a_{ij} = 1$, if the jth branch is incident to and oriented away from the ith node.

$a_{ij} = -1$, if the jth branch is incident to and oriented towards the ith node.

$a_{ij} = 0$, if the jth branch is not incident to the ith node.

Incidence Matrix



Complete Incident Matrix (A_a)

$A_a =$

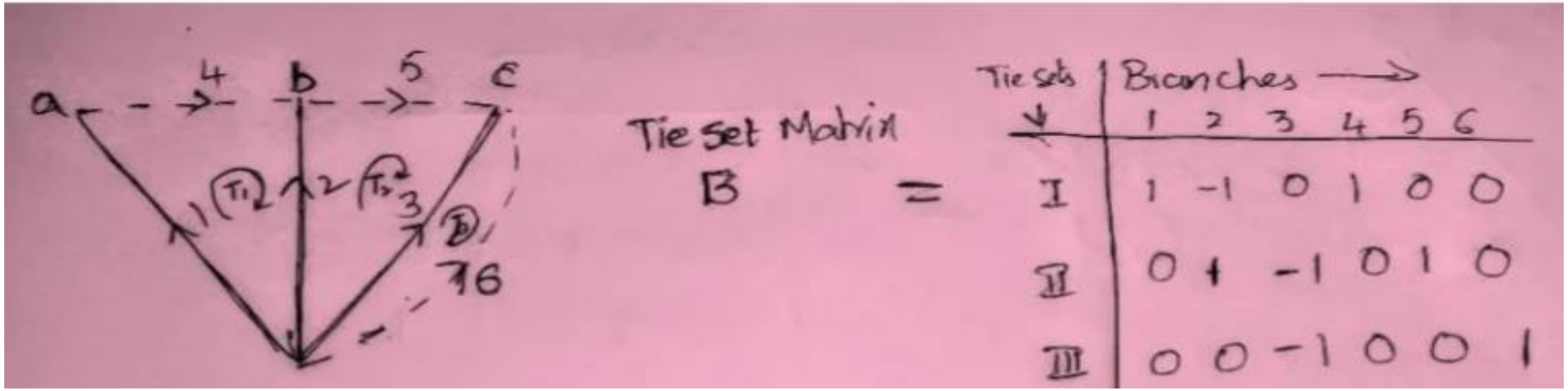
Nodes ↓	Branches → 1	2	3	4	5	6
a	-1	0	0	1	0	0
b	0	-1	0	-1	1	0
c	0	0	-1	0	-1	-1
d	1	1	1	0	0	1

Incident Matrix (A)

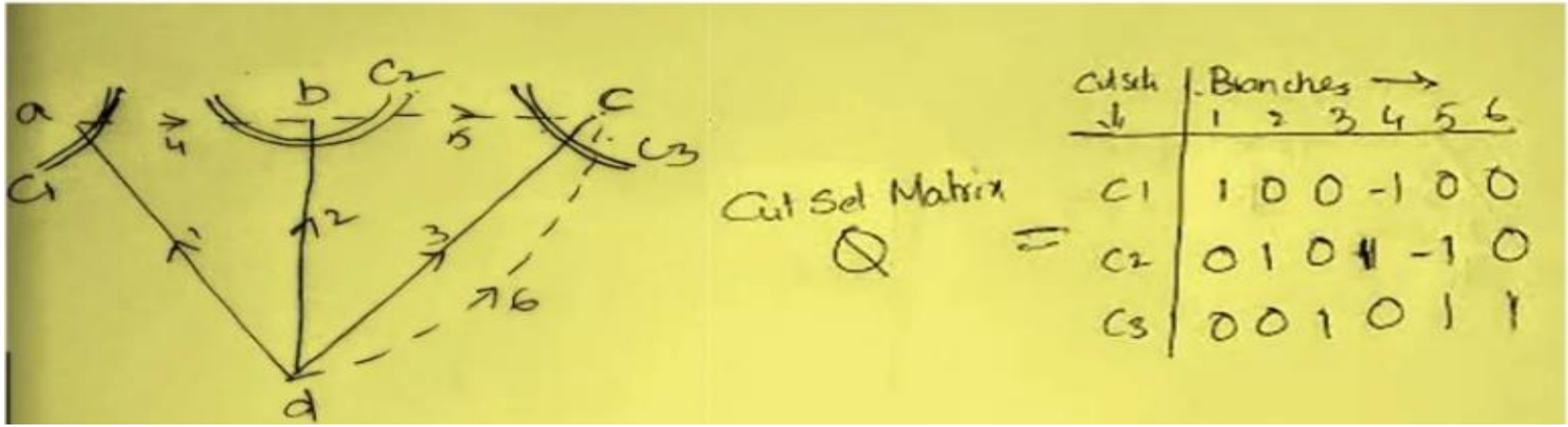
$A =$

Nodes ↓	Branches → 1	2	3	4	5	6
a	1	-1	0	1	0	0
b	0	-1	0	-1	1	0
c	1	1	1	0	0	1

Tie set Matrix (B)



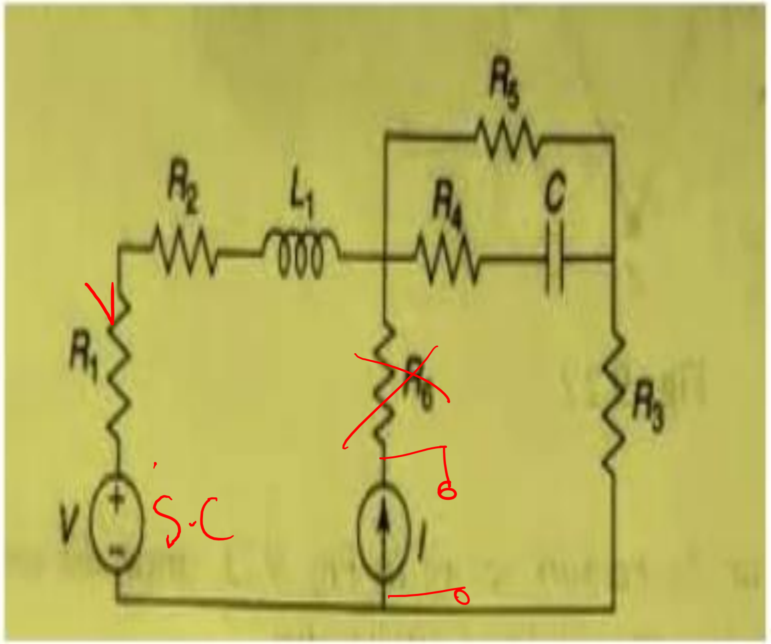
Cut set Matrix (Q)

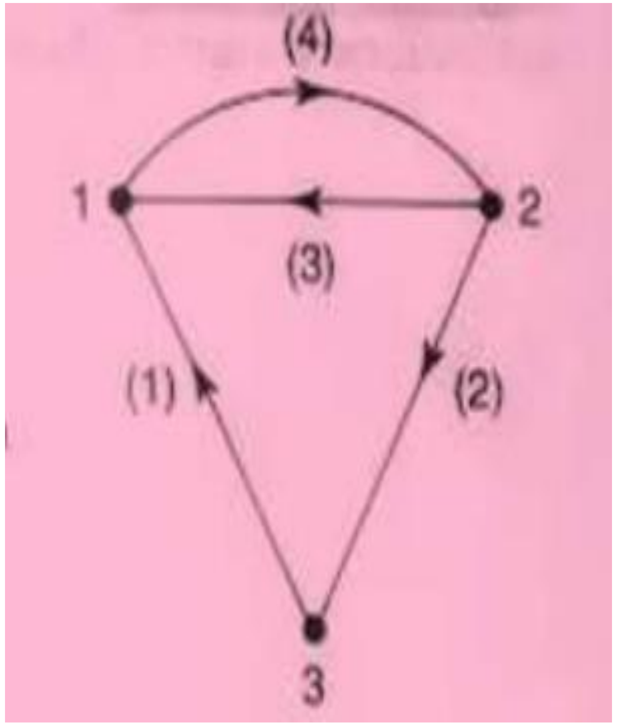


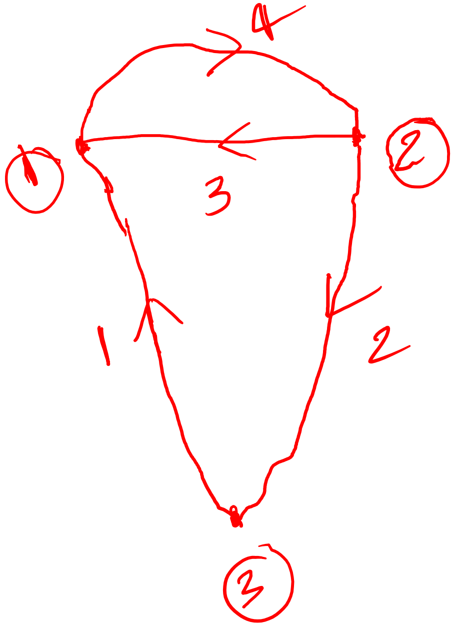
Tree and Twigs of graph

Electrical Network

Q:-







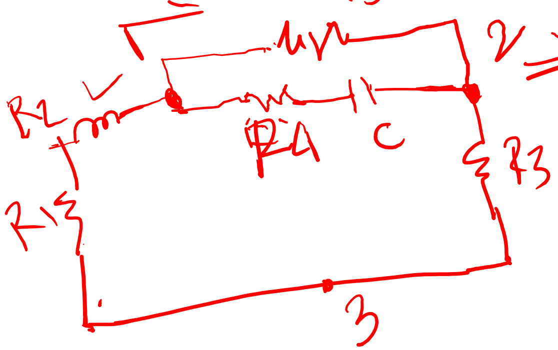
→ Draw the graph

→ Draw oriented or directed graph

→ Voltage, I

V → Shorted

I → open

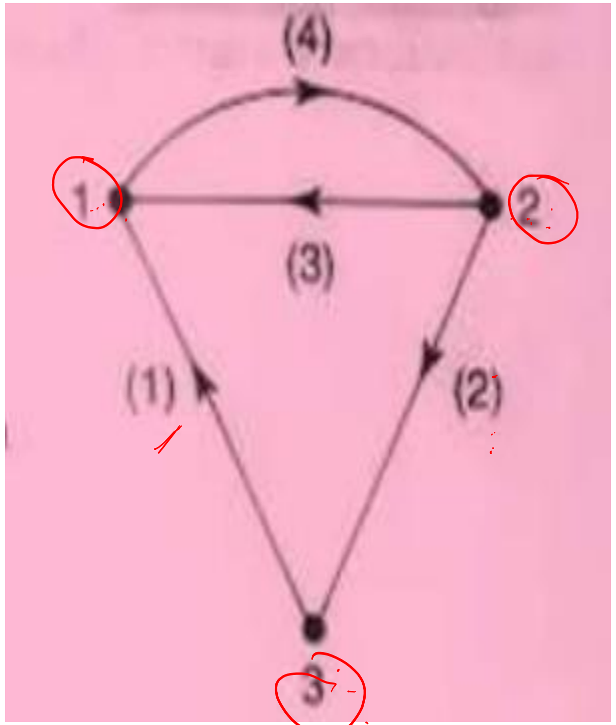


⇒ graph

straight line

Tree and Twigs of graph

oriented or direct graph → Incidence matrix



(a) Incidence Matrix (A)

Nodes ↓	Branches → 1	2	3	4
1	−1	0	−1	1
2	0	1	1	−1
3	1	−1	0	0

$$A_a = \begin{bmatrix} -1 & 0 & -1 & 1 \\ 0 & 1 & 1 & -1 \\ 1 & -1 & 0 & 0 \end{bmatrix}$$

Eliminating the third row from the matrix A_a, we get the incidence matrix A.

Reduced incidend matrix

$$A = \begin{bmatrix} -1 & 0 & -1 & 1 \\ 0 & 1 & 1 & -1 \end{bmatrix}$$

(b) Tieset Matrix (B)

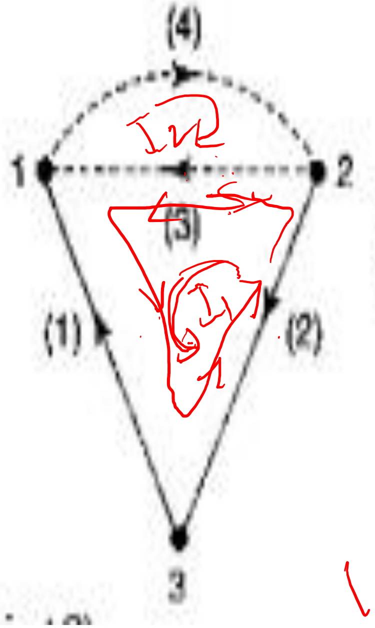
Tree and Twigs of graph

(b) Tieset Matrix (B)

The oriented graph, selected tree and tiesets are shown in Fig. 9.21.

$l = b - n + 1$

→ Draw Tree N/w



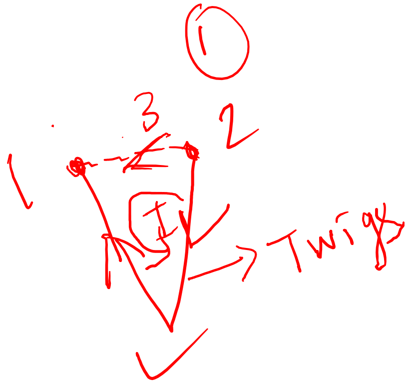
Links: {3, 4}

Tieset 3: {3, 1, 2}

Tieset 4: {4, 1, 2}

$$B = \begin{array}{c} \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} -1 & -1 & 1 & 0 \\ 1 & 1 & 0 & 1 \end{bmatrix} \end{array}$$

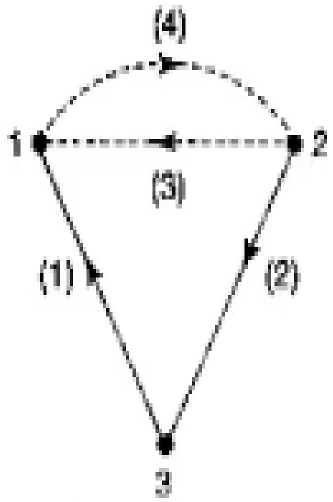
Links



	1	2	3	4
I_1				
I_2				

Tree and Twigs of graph

(b) Tieset Matrix (B)



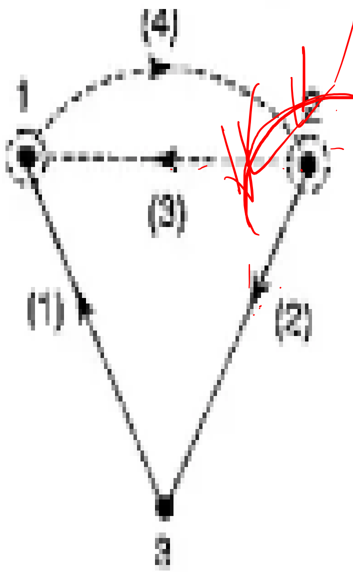
Links: {3, 4}
Tieset 3: {3, 1, 2}
Tieset 4: {4, 1, 2}

$$B = \begin{array}{c} \\ 3 \\ 4 \end{array}\begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} -1 & -1 & 1 & 0 \\ 1 & 1 & 0 & 1 \end{bmatrix} \end{array}$$

Tree and Twigs of graph

Cut set matrix

(c) *f*-cutset Matrix (Q)

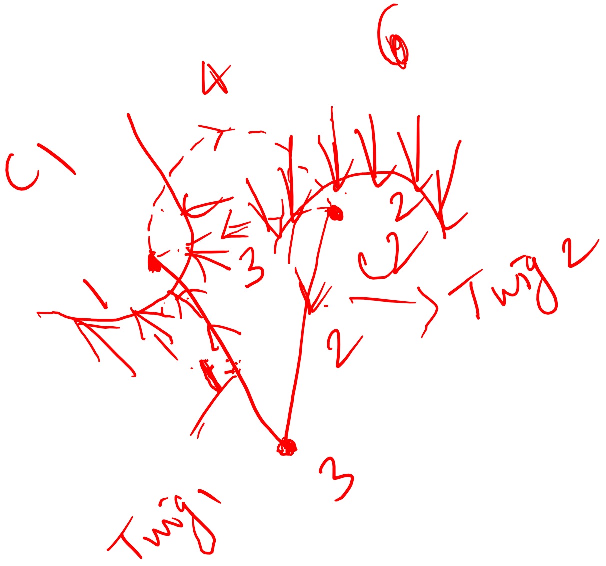


Twigs: {1, 2}

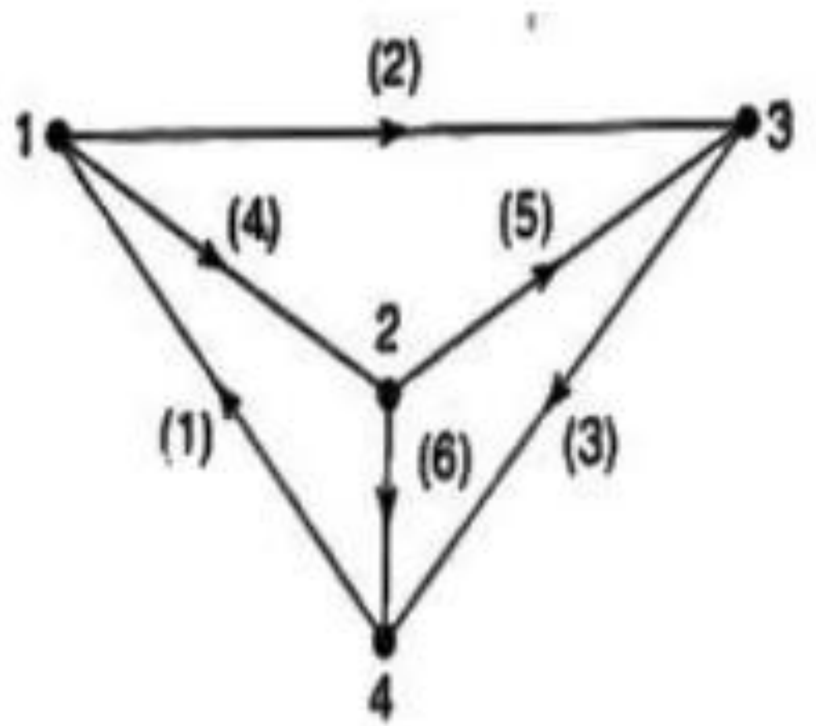
f-cutset 1: {1, 3, 4}

f-cutset 2: {2, 3, 4}

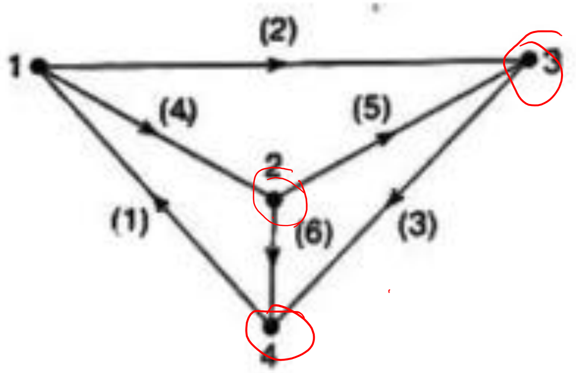
$$Q = \begin{array}{c} \\ 1 \\ 2 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} 1 & 0 & 1 & -1 \\ 0 & 1 & -1 & +1 \end{bmatrix} \end{array}$$



Tree and Twigs of graph



Tree and Twigs of graph



(a) **Incidence Matrix (A)**

Branches

Nodes

$$A_a = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \begin{bmatrix} -1 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & -1 & 1 & 1 \\ 0 & -1 & 1 & 0 & -1 & 0 \\ 1 & 0 & -1 & 0 & 0 & -1 \end{bmatrix} \end{array}$$

The incidence matrix A is obtained by eliminating any row from the matrix A_a

$$A = \begin{bmatrix} -1 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & -1 & 1 & 1 \\ 0 & -1 & 1 & 0 & -1 & 0 \end{bmatrix}$$

Reduced incidence matrix

Tree and Twigs of graph

I_2 link 2, twigs 5 & 6

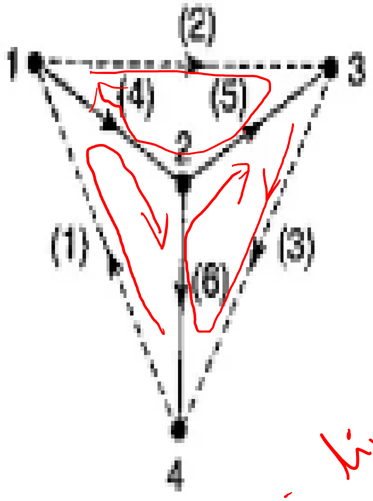
I_3 link 3, 5 & 6 twigs

(b) Tieset, Matrix (B)

The oriented graph, selected tree and tiesets are shown in Fig

Tree

1) Draw the ~~graph~~



Links: {1, 2, 3}

Tieset 1: {1, 4, 6}

Tieset 2: {2, 4, 5}

Tieset 3: {3, 5, 6}

Branches

$$B = \begin{array}{c|c} & \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 \end{matrix} \\ \begin{matrix} I_1 \; 1 \\ I_2 \; 2 \\ I_3 \; 3 \end{matrix} & \begin{bmatrix} 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & -1 & -1 & 0 \\ 0 & 0 & 1 & 0 & 1 & -1 \end{bmatrix} \end{array}$$

I_1 links 4th, 6th twig

I_1

1,2&3

links

4,5&6 → Twigs

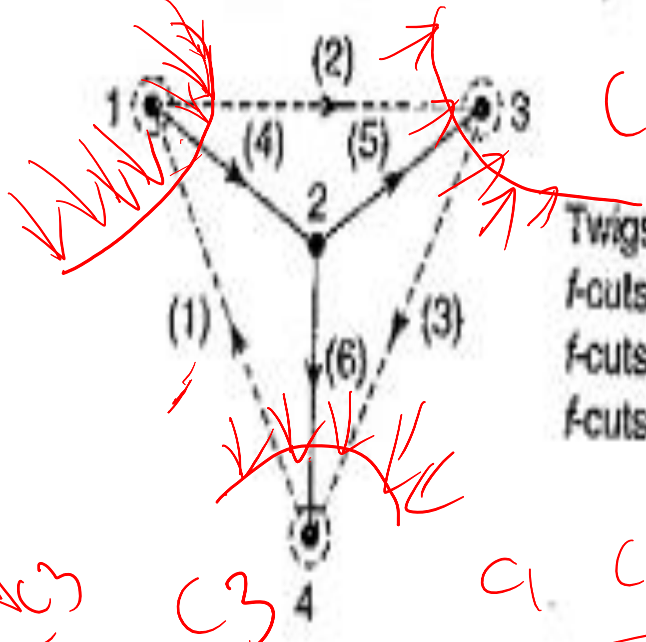
Twigs 4, 5 & 6

Node 1
4 - twig
1 & 2 links

Node 3
Link 2 & 3
Twig 5

(c) *f*-cutset Matrix (Q)

The oriented graph, selected tree and *f*-cutsets are shown in Fig.



Twigs: {4, 5, 6}
f-cutset 4: {4, 1, 2}
f-cutset 5: {5, 2, 3}
f-cutset 6: {6, 1, 3}

Branches

$$Q = \begin{array}{c} \\ 4 \\ 5 \\ 6 \end{array}\begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \begin{bmatrix} -1 & 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & -1 & 0 & 1 & 0 \\ -1 & 0 & 1 & 0 & 0 & 1 \end{bmatrix} \end{array}$$

C1 C2 C3

Node 4
1, 3 & 6

Tree and Twigs of graph

UNIT-III DC Machines

DC Generators

DC Motors

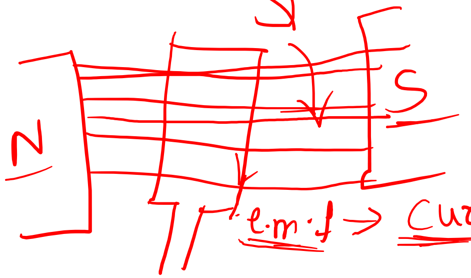
Function: mech-energy — electrical Energy

Principle of Generator: Faraday's law of electromagnetic induction

electro magnetic induction:

Stator

Rotor



Working

EMF

Types of Generators