Network Analysis

- **Network**

  Any arrangement of the various electrical energy sources along with the different circuit elements is called an electrical network.

Network Analysis means to find a current through or voltage across any branch. Also it is necessary to reduce the complicated electrical network to simple form.

Basic Terminalogy

- **Network Element**
- Any individual circuit element with two terminals which can be connected to other circuit element, is called a network element.
- Network elements can be either **active elements or passive elements**. Active elements are the elements which supply power or energy to the network. Voltage source and current source are the examples of active elements.

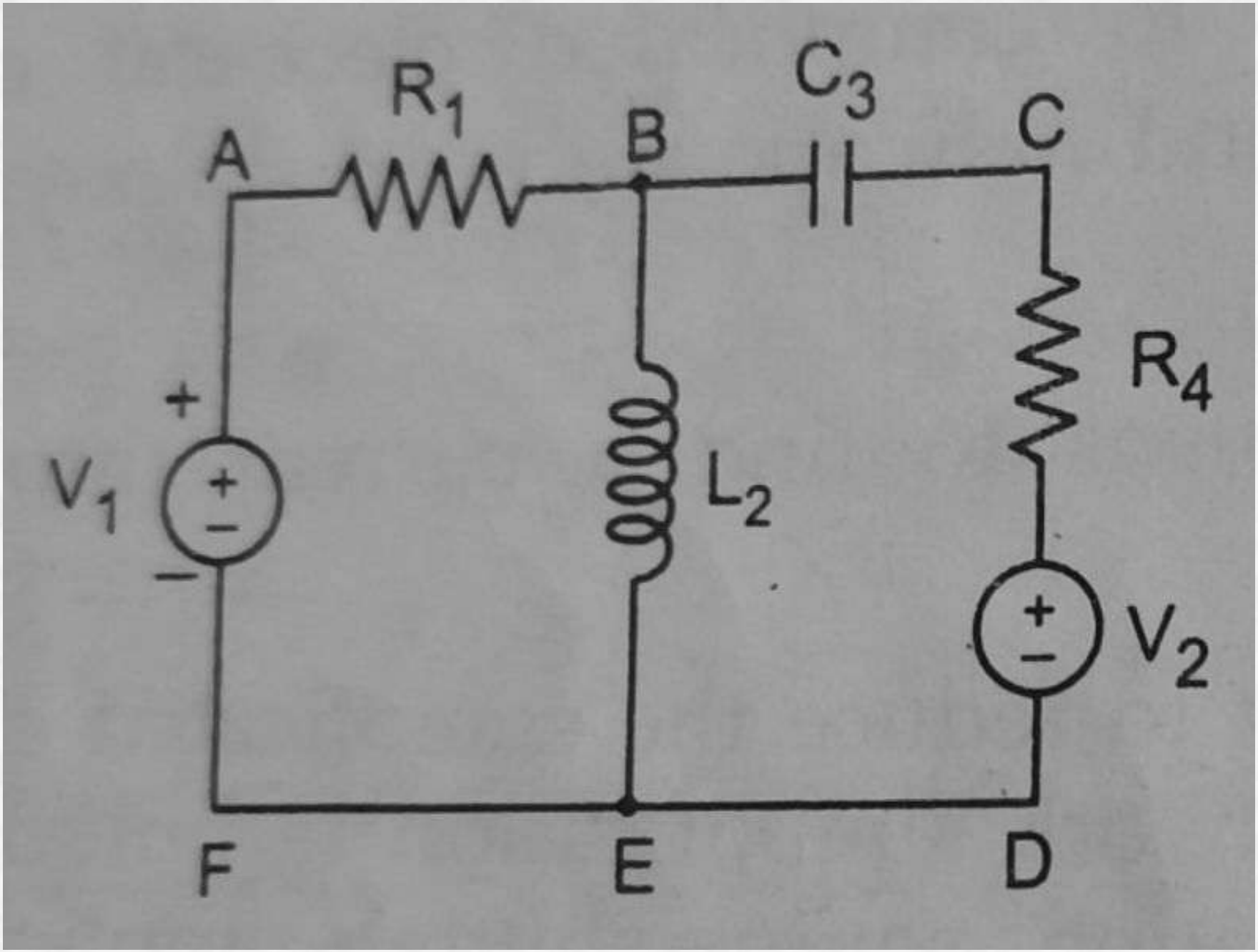
Contd.

- Passive elements are the elements which either store energy or dissipate energy in the form of heat. Resistor, inductor and capacitor are the three basic passive elements. Inductors and capacitors can store energy and resistors dissipate energy in the form of heat.

Contd.

Branch

A part of the network which connects the various points of the network with one another is called a branch. In Fig. 1.1, A-B, B-C, C-D etc. are called the branches of the network.


R1
C3
A
B
C
R4
+
V1
+
−
−
L2
+
−
V2
F
E
D

Contd.

- **Node**

A point at which two or more electrical elements are joined together is called node.

In the Fig, A, B, C, D, E and F are the nodes of the network

- **Mesh (or loop)**

Mesh is a set of branches forming a closed path. If one branch is removed then remaining branches do not form a closed path. ABEFA, BCDEB

Contd.

- Loop also can be defined as a closed path .

Which originates from a particular node, terminating at the same node.

Ex: ABCDEFA

Classification of Networks

- **Linear and non linear network.**

A network whose parameters are constant irrespective of the change in time, voltage , temperature is known as linear network. Also it satisfies principle of superposition and homogeneity.

If does not satisfies known as non linear network.

Contd.

- **Bilateral and unilateral network**

A circuit whose characteristics or behavior is same irrespective of the direction of current.

Ex: Resistor

Unilateral network : Circuit behavior is dependent on the direction of the current.

Ex: Diode

Contd.

- **Active and passive network:**

Circuit which contains a source of energy is called active network.

Circuit which contains passive elements called passive network.

- **Lumped and Distributed network:**

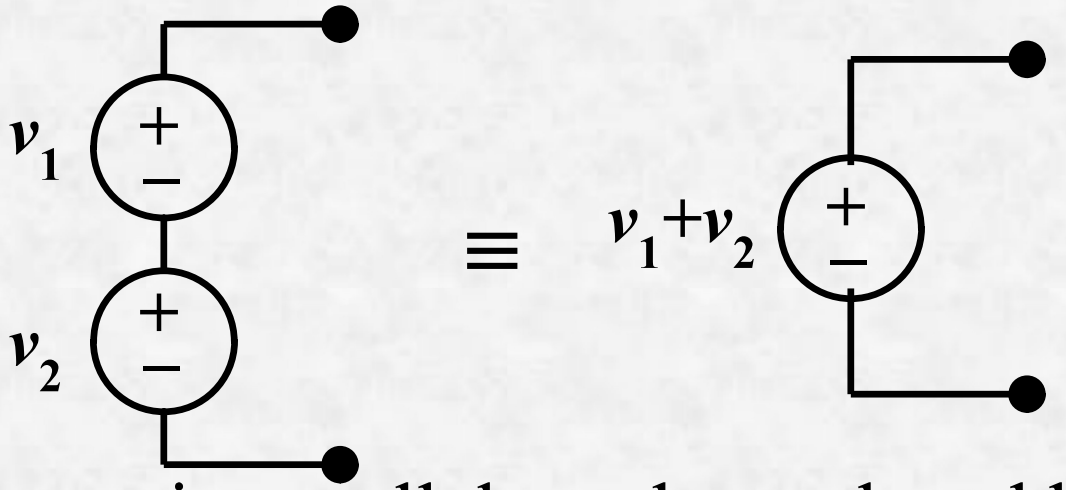
All the network elements are physically separable known as lumped network Ex : R, L, C

Distributed network cannot be physically separable.

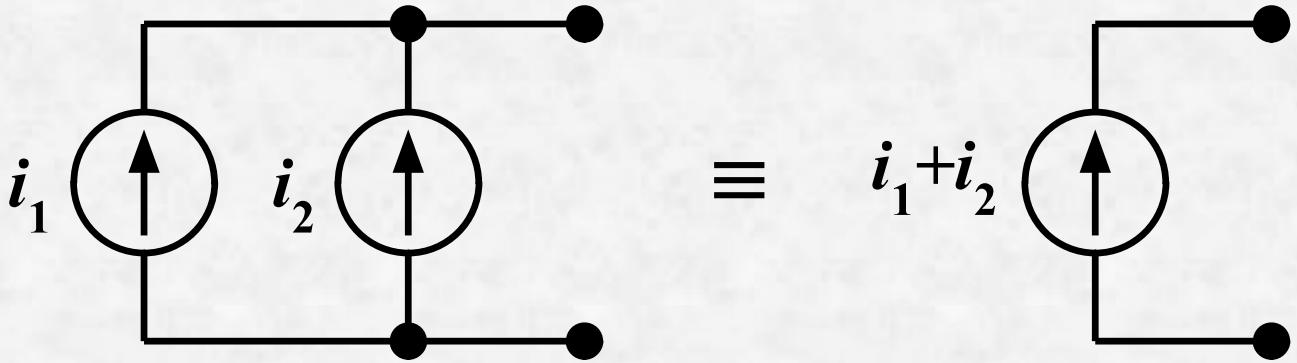
Ex: transmission line, IC

Source Combinations

- Voltage sources in series can be replaced by an equivalent voltage source:



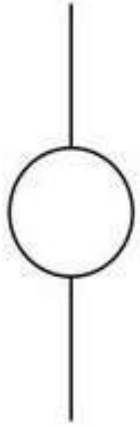
- Current sources in parallel can be replaced by an equivalent current source:



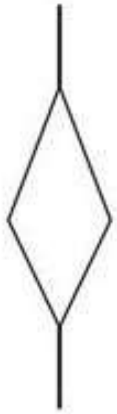
Independent source establishes a voltage or a current in a circuit without relying on a voltage or current elsewhere in the circuit

Dependent sources establishes a voltage or a current in a circuit whose value depends on the value of a voltage or a current elsewhere in the circuit

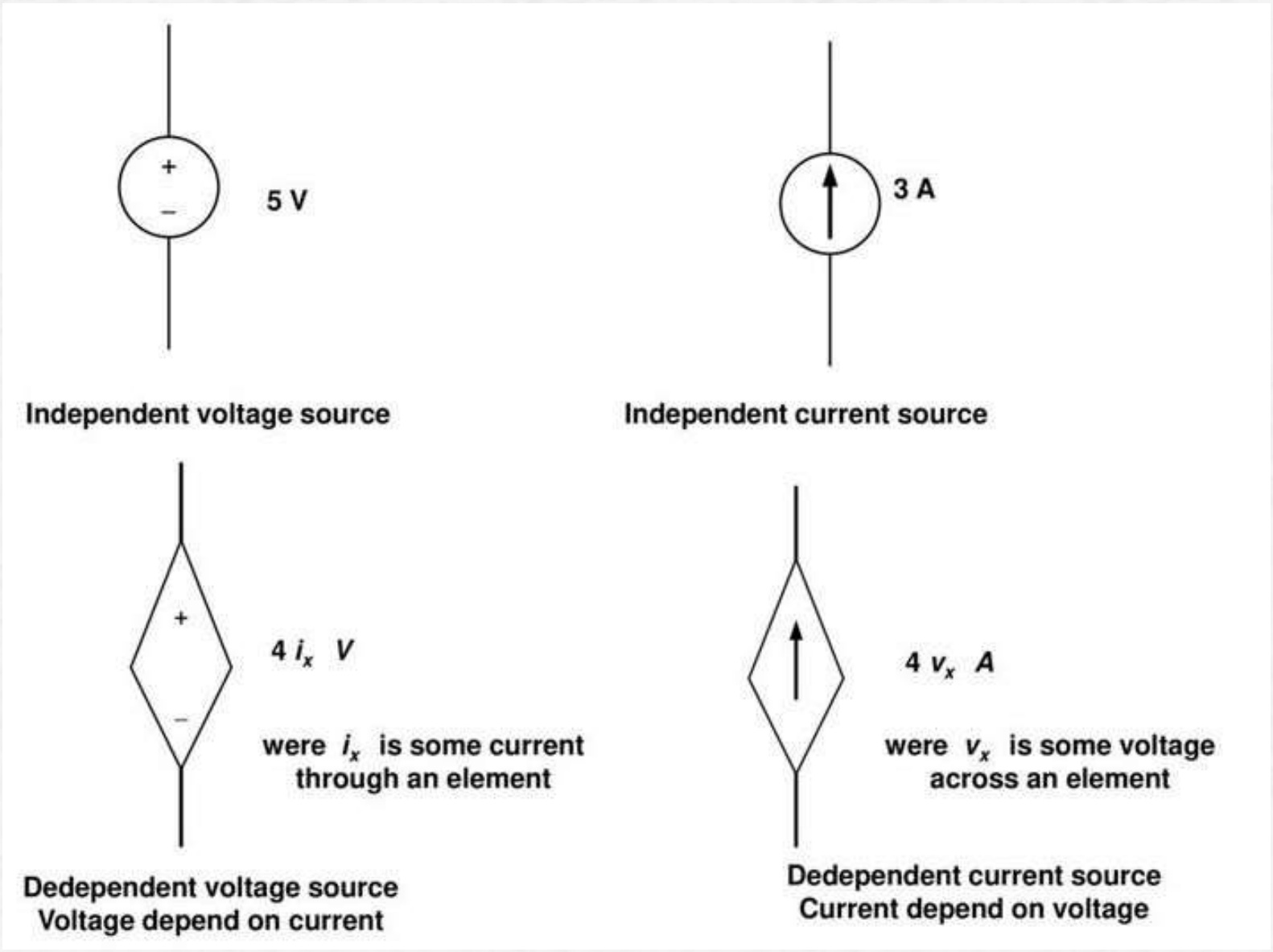
We will use circle to represent Independent source and diamond shape to represent Dependent sources

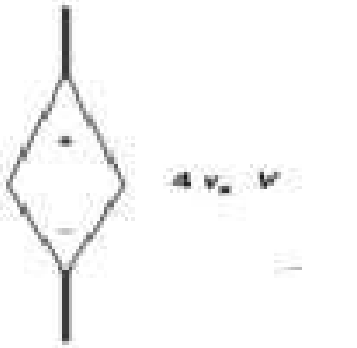


Independent source

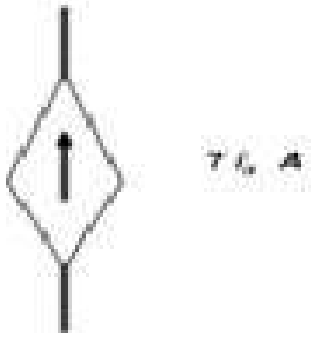


Dependent sources

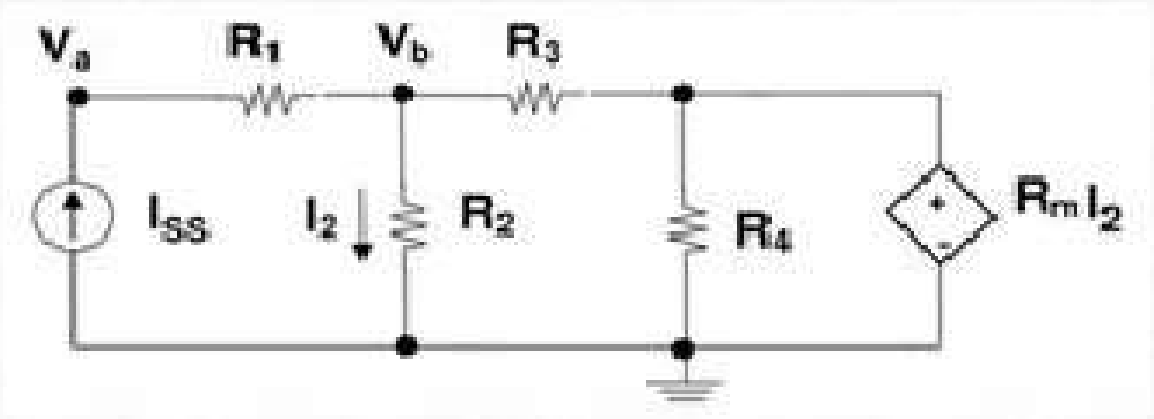

+
–
5 V
Independent voltage source
3 A
Independent current source
+
–
4 i_x V
were i_x is some current through an element
Dedependent voltage source
Voltage depend on current
4 v_x A
were v_x is some voltage across an element
Dedependent current source
Current depend on voltage



Dedependent voltage source
Voltage depend on voltage



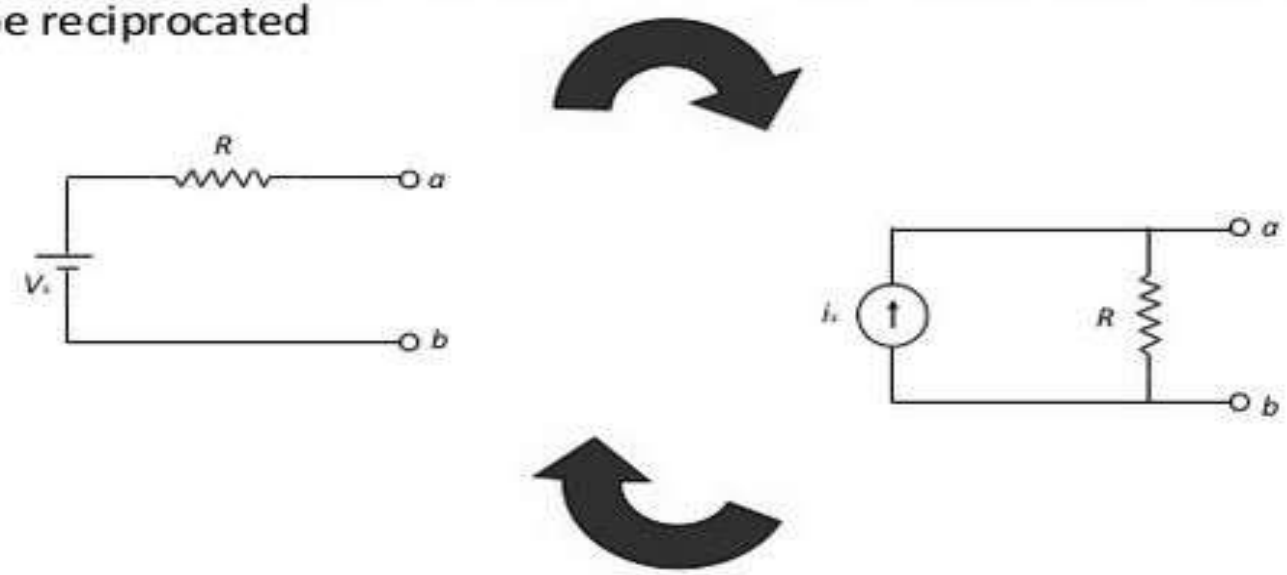
DE dependent current source
Current depend on current



SOURCE TRANSFORMATION

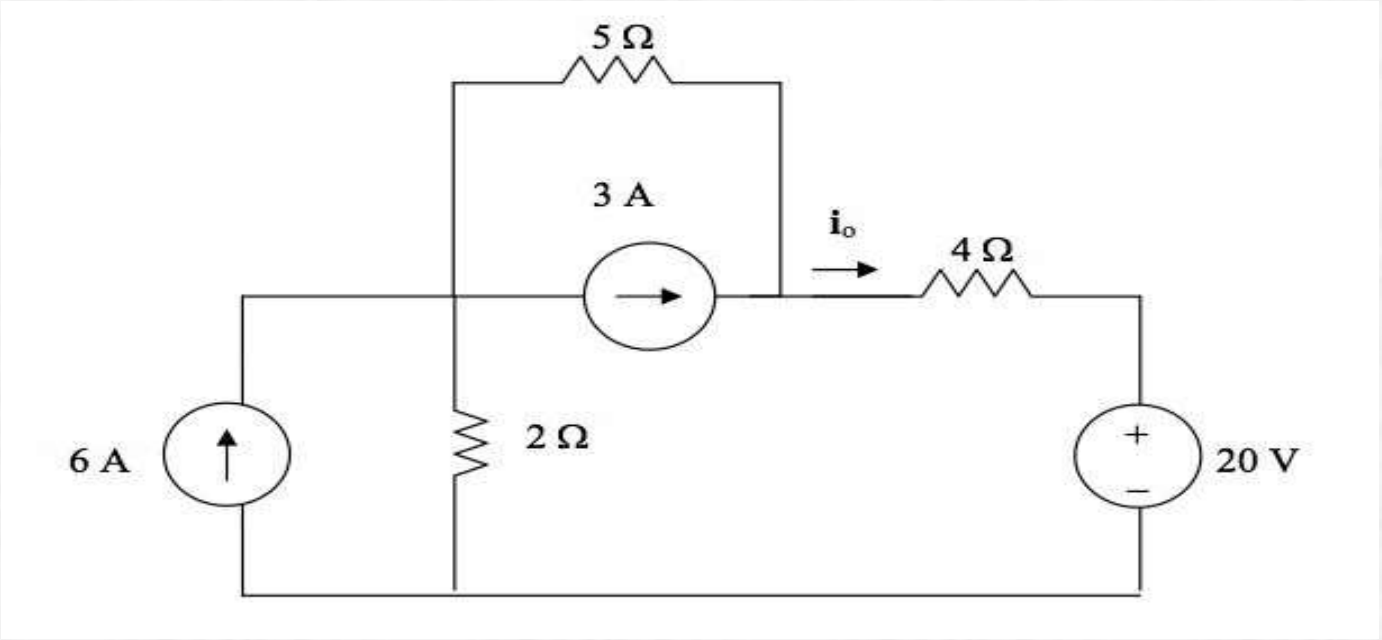
- It is process of in which the circuit can be simplify or modified which make our circuit more is to solve .
- There are many ways to solve the circuit to make it simple

- If any circuit is having the voltage source in series it can be converted into current source with parallel with that resistance . This process can be reciprocated



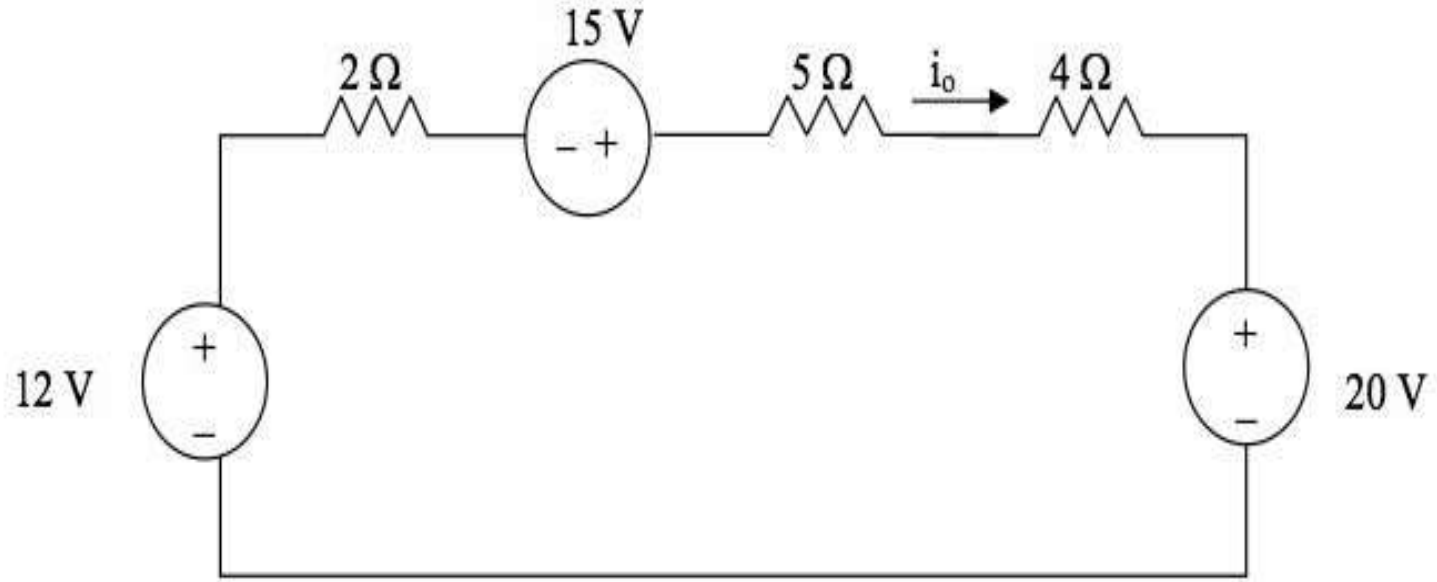
Example : Source Transformation

Use source transformation to find i_o in the circuit



Example : Source Transformation (cont.)

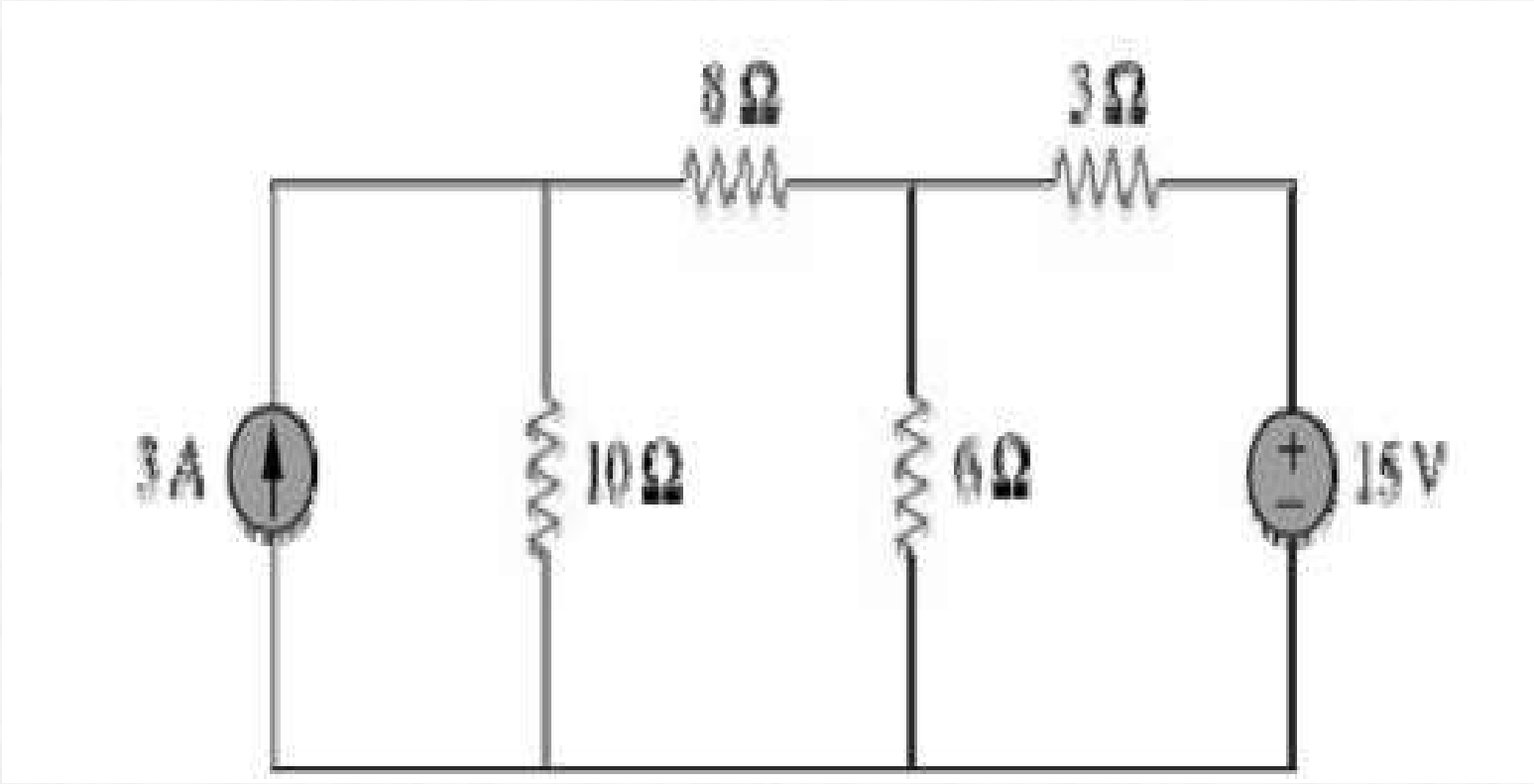
Transforming the current sources gives the circuit below.



$-12 + 11i_o - 15 + 20 = 0$ or $11i_o = 7$ or $i_o =$ **636.4 mA**.

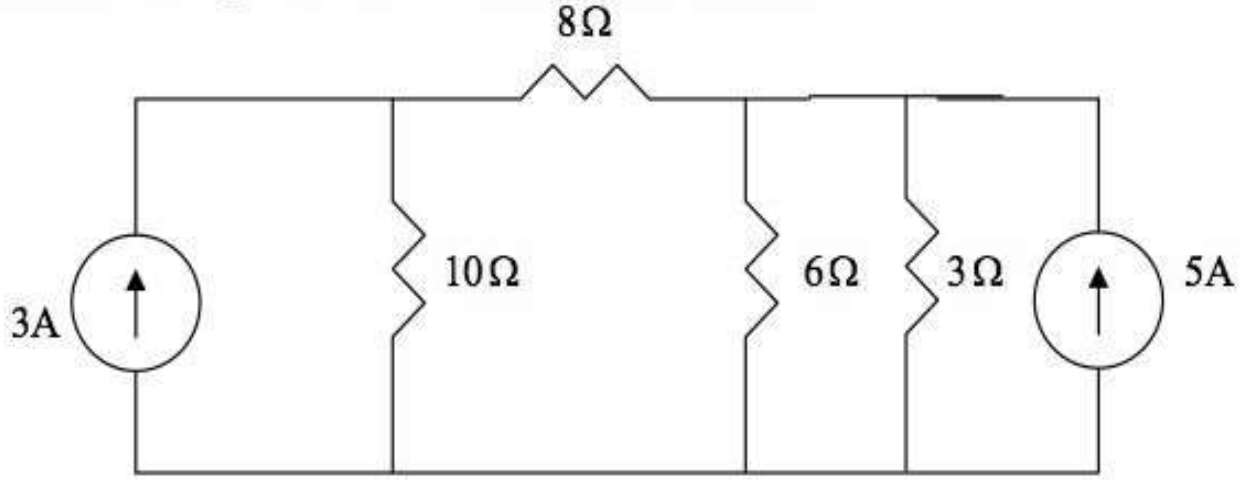
Example : Source Transformation

Use source transformation to determine the current and power in the 8 Ω resistor

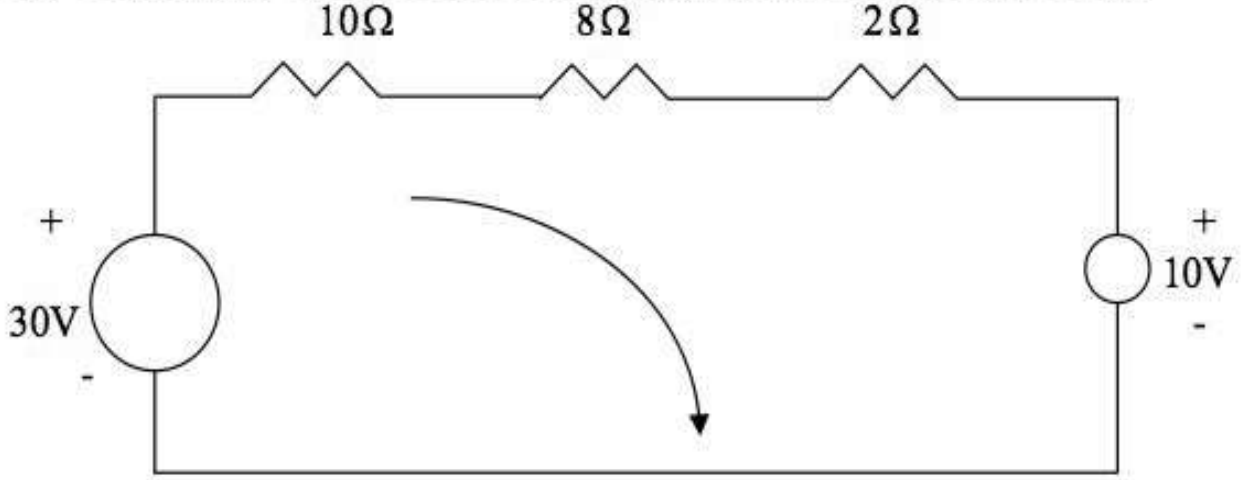


Example : Source Transformation (cont.)

If we transform the voltage source, we obtain the circuit below.



3//6 = 2-ohm. Convert the current sources to voltages sources as shown below.



Example : Source Transformation (cont.)

Applying KVL to the loop gives

$$-30+10+I(10+8+2)=0 \longrightarrow \underline{I=1\,\text{A}}$$

$$p=VI=I^2R=\underline{8\,\text{W}}$$

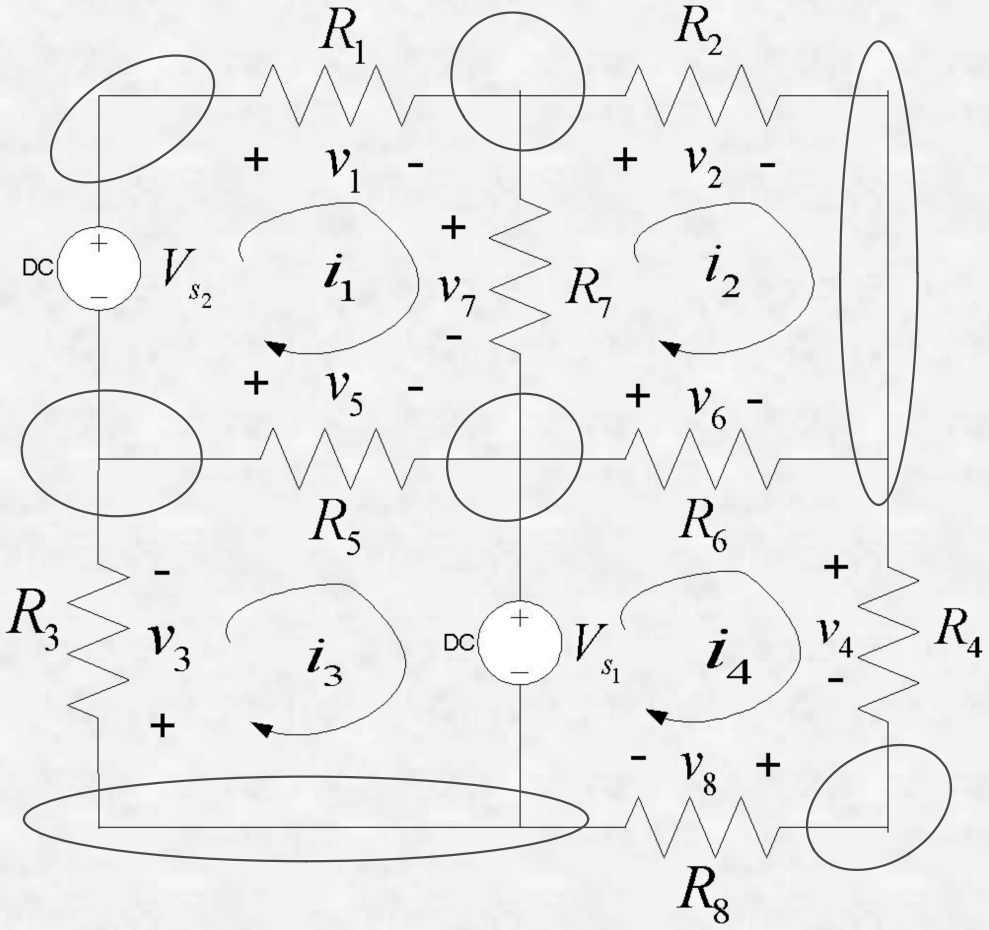
Mesh Analysis

- Mesh analysis applies KVL to find unknown currents.
- A mesh is a loop that does not contain any other loops.
- The current through a mesh is known as the mesh current.

Mesh Analysis Steps

1. Assign mesh currents i_1, i_2, i_3, … i_l, to the l meshes,
2. Apply KVL to each of the l meshes and use Ohm's law to express the voltages in terms of the mesh currents,
3. Solve the l resulting simultaneous equations to find the mesh currents.

Example



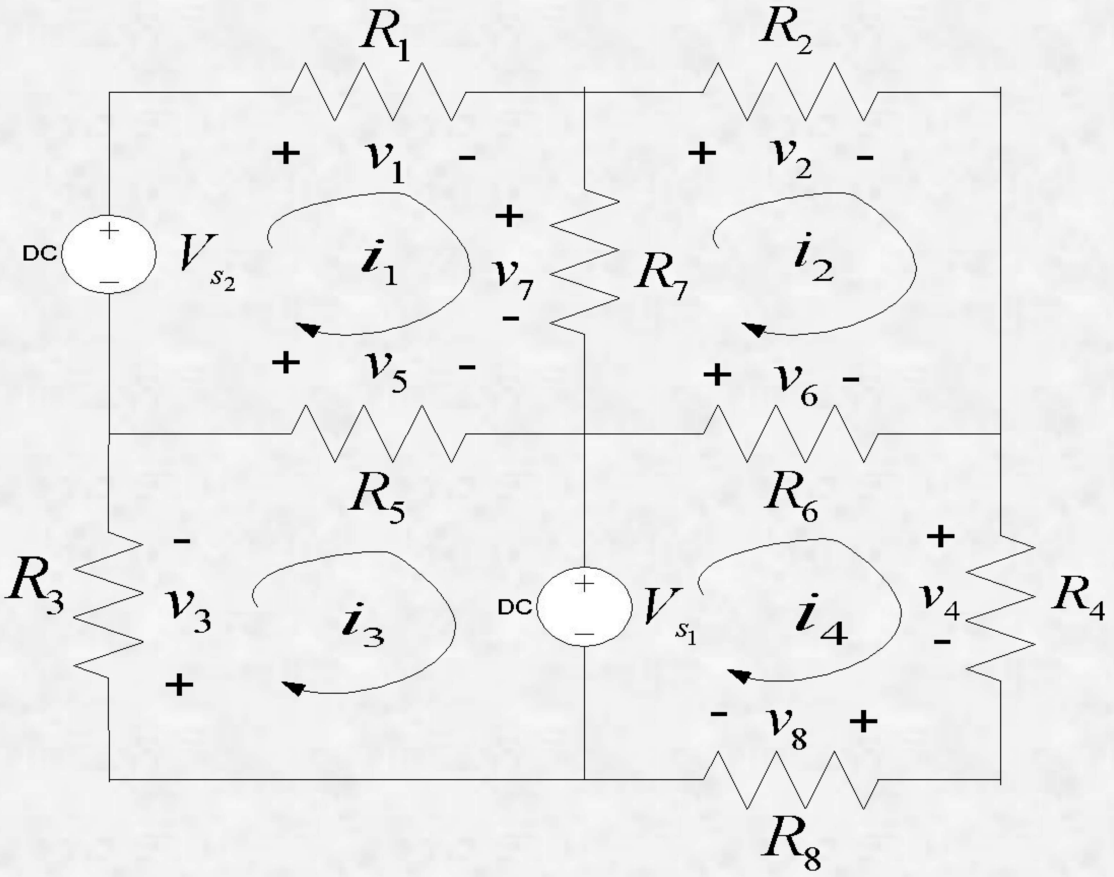
Number of nodes, $n =$ **7**

Number of loops, $l =$ **4**

Number of branches, $b =$ **10**

$$l = b - n + 1$$

Example



Apply KVL to each mesh

Mesh 1: $-V_{s_2} + v_1 + v_7 - v_5 = 0$

Mesh 2: $v_2 - v_6 - v_7 = 0$

Mesh 3: $v_5 + v_{s_1} + v_3 = 0$

Mesh 4: $v_4 + v_8 - V_{s_1} + v_6 = 0$

Mesh 1: $-V_{s_2} + v_1 + v_7 - v_5 = 0$

Mesh 2: $v_2 - v_6 - v_7 = 0$

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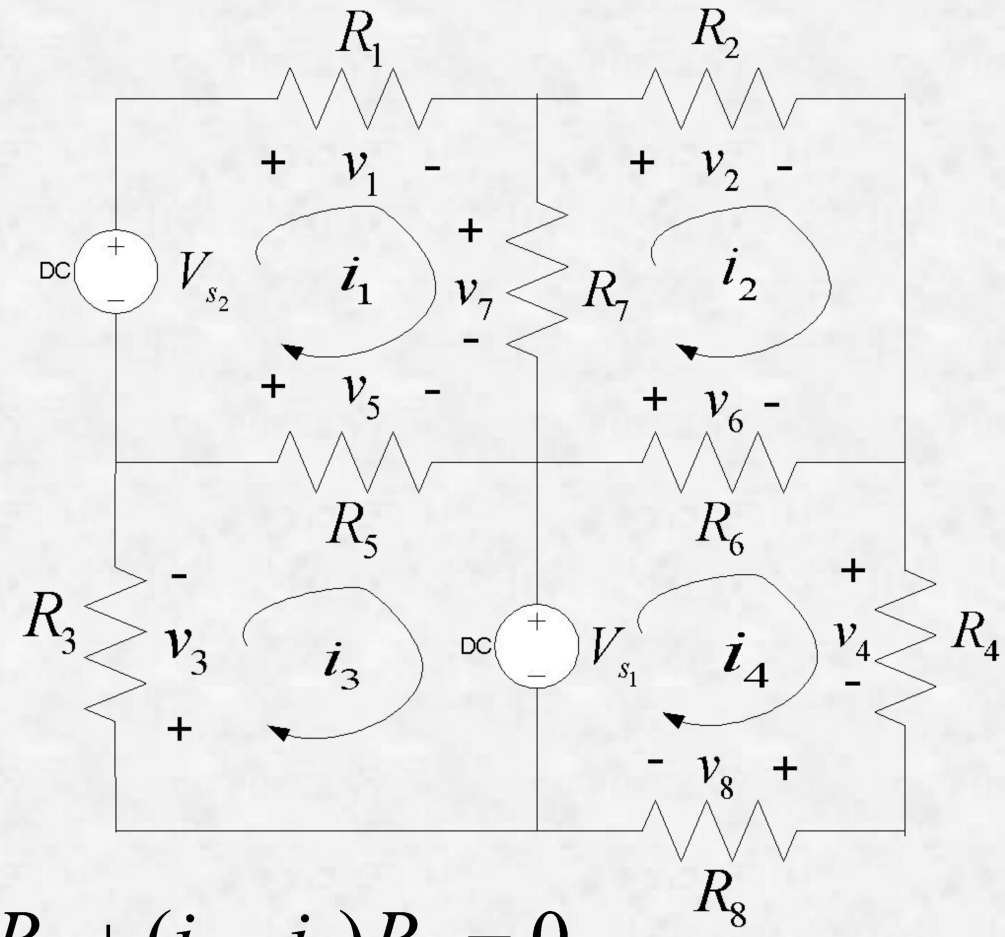

Express the voltage in terms of the mesh currents:

Mesh 1: $-V_{s_2} + i_1 R_1 + (i_1 - i_2) R_7 + (i_1 - i_3) R_5 = 0$

Mesh 2: $i_2 R_2 + (i_2 - i_4) R_6 + (i_2 - i_1) R_7 = 0$

Mesh 3: $(i_3 - i_1) R_5 + V_{s_1} + i_3 R_3 = 0$

Mesh 4: $i_4 R_4 + i_4 R_8 - V_{s_1} + (i_4 - i_2) R_6 = 0$

Mesh 1: $-V_{s_2} + i_1 R_1 + (i_1 - i_2) R_7 + (i_1 - i_3) R_5 = 0$

Mesh 2: $i_2 R_2 + (i_2 - i_4) R_6 + (i_2 - i_1) R_7 = 0$

Mesh 3: $(i_3 - i_1) R_5 + V_{s_1} + i_3 R_3 = 0$

Mesh 4: $i_4 R_4 + i_4 R_8 - V_{s_1} + (i_4 - i_2) R_6 = 0$

Mesh 1: $(R_1 + R_5 + R_7) i_1 - R_7 i_2 - R_5 i_3 = V_{s_2}$

Mesh 2: $-R_7 i_1 + (R_2 + R_6 + R_7) i_2 - R_6 i_4 = 0$

Mesh 3: $-R_5 i_1 + (R_3 + R_5) i_3 = -V_{s_1}$

Mesh 4: $-R_6 i_2 + (R_4 + R_6 + R_8) i_4 = V_{s_1}$

Mesh 1: $(R_1 + R_5 + R_7)i_1 - R_7 i_2 - R_5 i_3 = V_{s_2}$

Mesh 2: $-R_7 i_1 + (R_2 + R_6 + R_7)i_2 - R_6 i_4 = 0$

Mesh 3: $-R_5 i_1 + (R_3 + R_5)i_3 = -V_{s_1}$

Mesh 4: $-R_6 i_2 + (R_4 + R_6 + R_8)i_4 = V_{s_1}$

$$\begin{pmatrix} R_1 + R_5 + R_7 & -R_7 & -R_5 & 0 \\ -R_7 & R_2 + R_6 + R_7 & 0 & -R_6 \\ -R_5 & 0 & R_3 + R_5 & 0 \\ 0 & -R_6 & 0 & R_4 + R_6 + R_8 \end{pmatrix} \begin{pmatrix} i_1 \\ i_2 \\ i_3 \\ i_4 \end{pmatrix} = \begin{pmatrix} V_{s_2} \\ 0 \\ -V_{s_1} \\ V_{s_1} \end{pmatrix}$$

$$\begin{pmatrix} R_1+R_5+R_7 & -R_7 & -R_5 & 0 \\ -R_7 & R_2+R_6+R_7 & 0 & -R_6 \\ -R_5 & 0 & R_3+R_5 & 0 \\ 0 & -R_6 & 0 & R_4+R_6+R_8 \end{pmatrix} \begin{pmatrix} i_1 \\ i_2 \\ i_3 \\ i_4 \end{pmatrix} = \begin{pmatrix} V_{s_2} \\ 0 \\ -V_{s_1} \\ V_{s_1} \end{pmatrix}$$

Ri = v

R is an *l* x *l* *symmetric* resistance matrix

i is a 1 x *l* vector of mesh currents

v is a vector of voltages representing "known" voltages