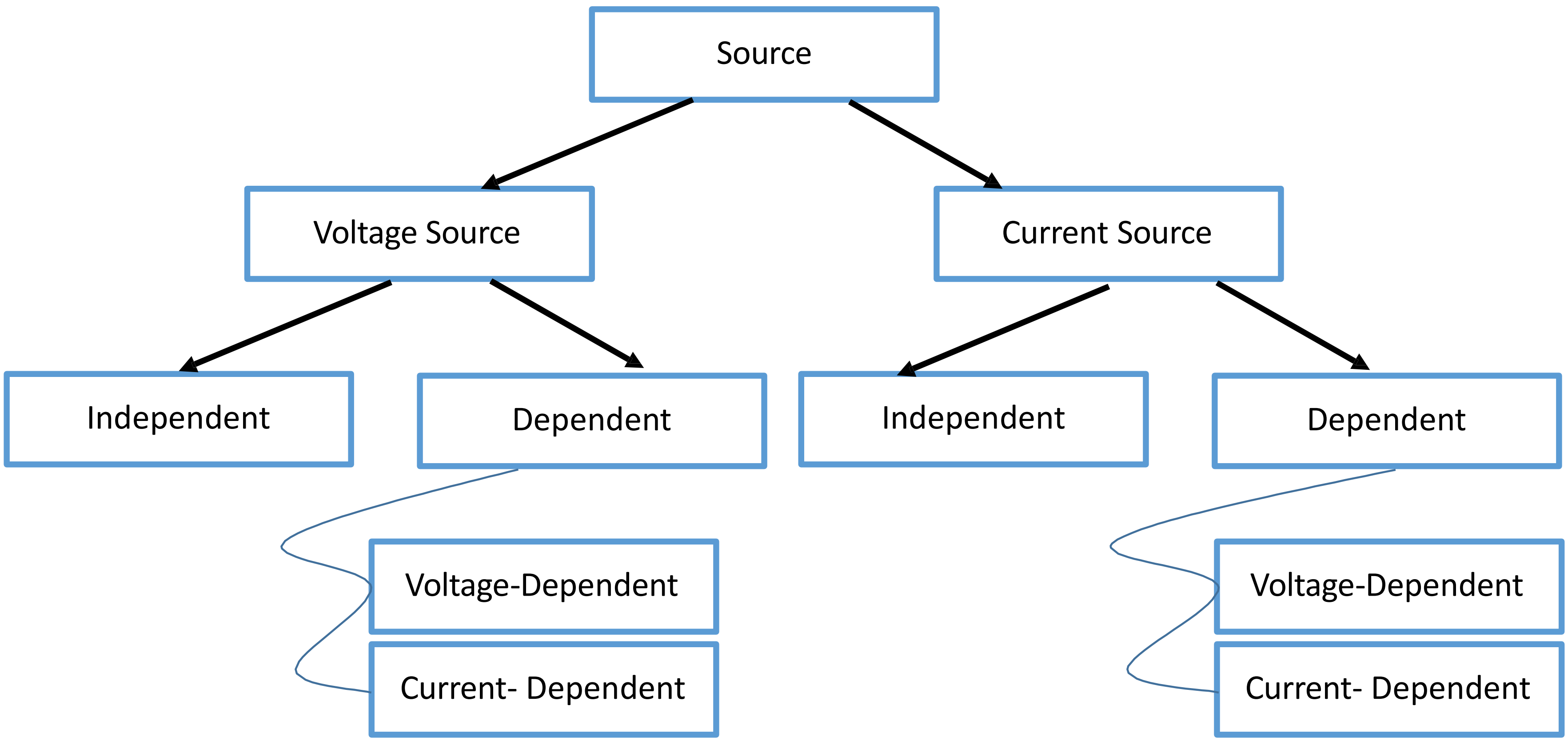
UNIT 1: DC CIRCUITS

Lecture 4 & 5

Energy Sources



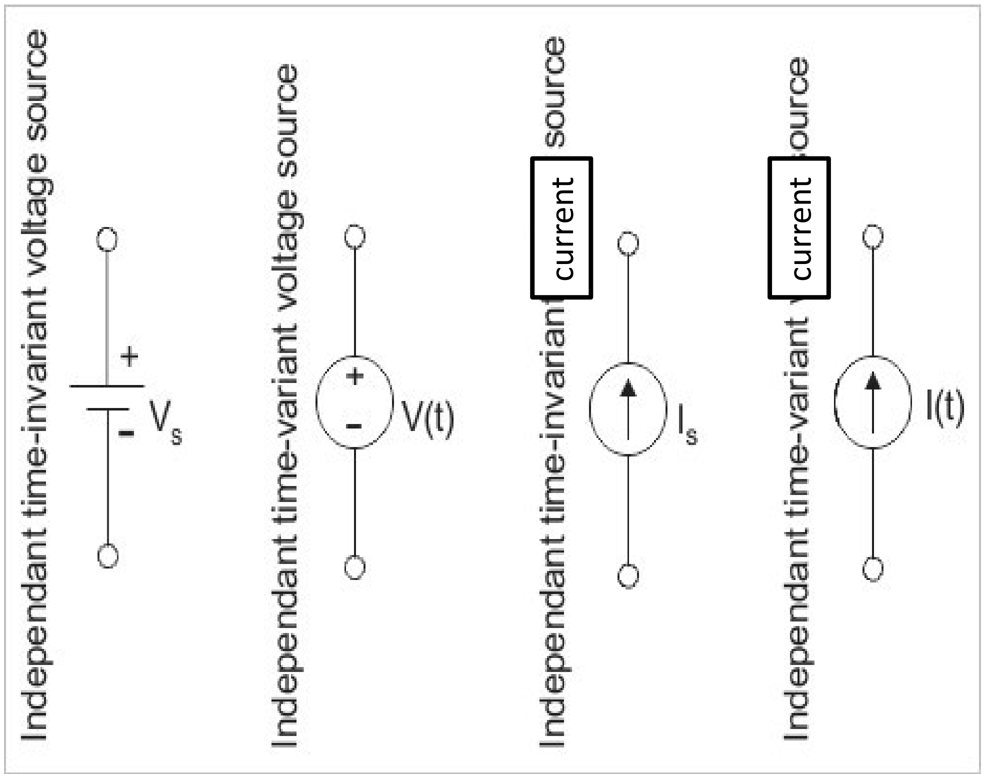
Independent and Dependent Sources

- Independent sources are those which does not depend on any other quantity in the circuit. They are two terminal devices and have a constant value, i.e. the voltage across the two terminals remains constant irrespective of all circuit conditions. The Independent sources are represented by a circular shape.

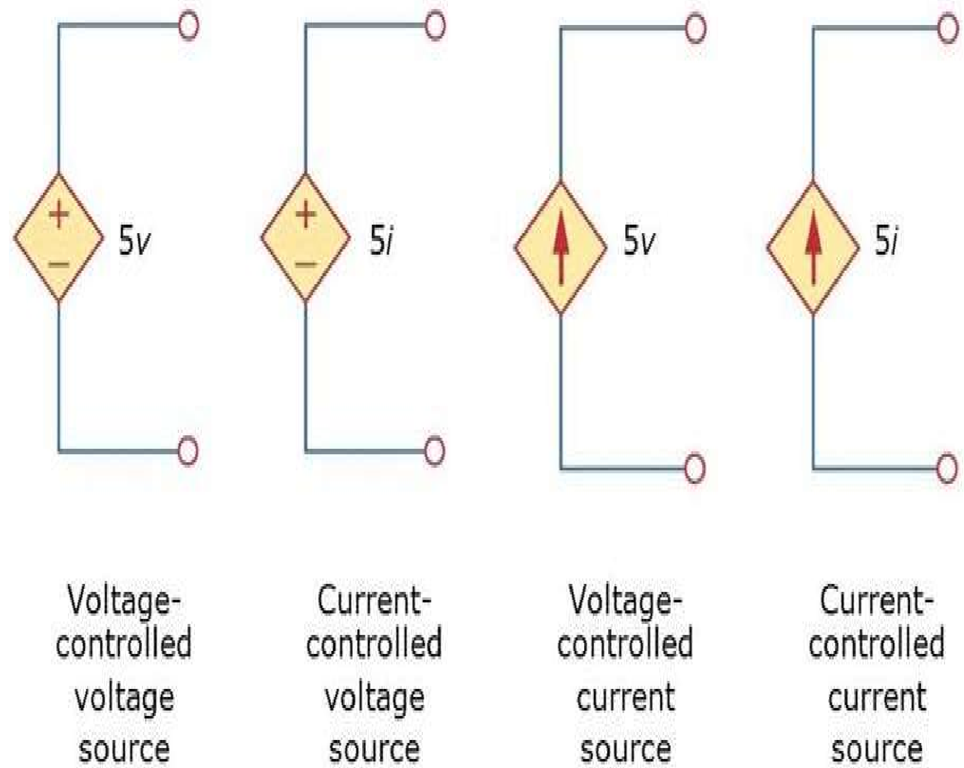
- Dependent or Controlled sources are those whose output voltage or current is NOT fixed but depends on the voltage or current in another part of the circuit. When the strength of voltage or current changes in the source for any change in the connected network, they are called dependent sources. The dependent sources are represented by a diamond shape.

Independent and Dependent Sources

- Independent



- Dependent



Ideal and Practical Voltage Source

- Ideal source is one where internal resistance does NOT exist.

NOTE:

1. For a voltage source, internal resistance must be ZERO.
2. For a current source, internal resistance must be INFINITY.

- Practical source is one where internal resistance is present.

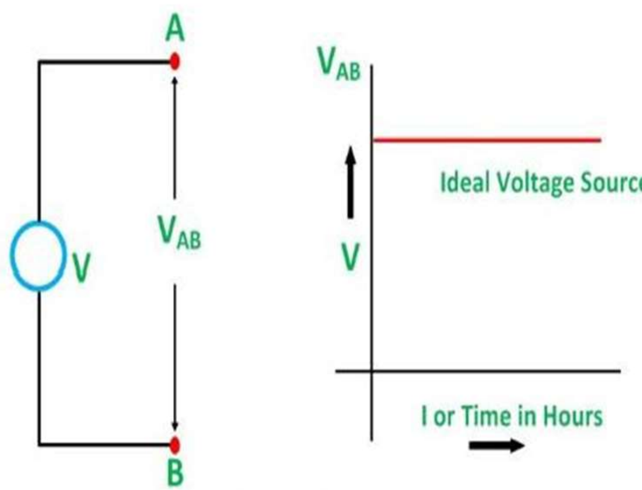


Figure A

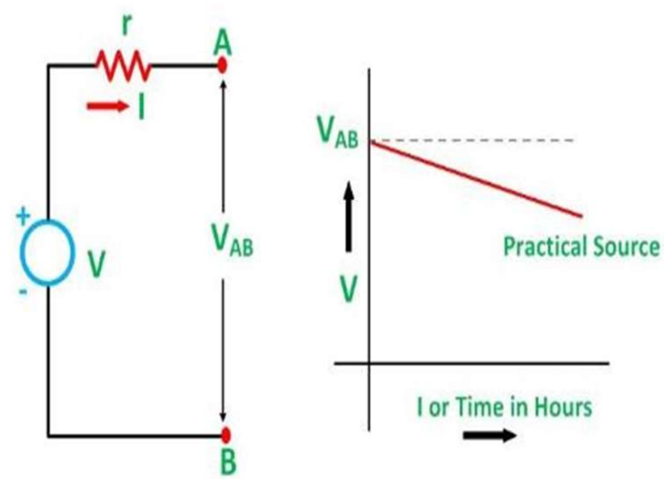


Figure B

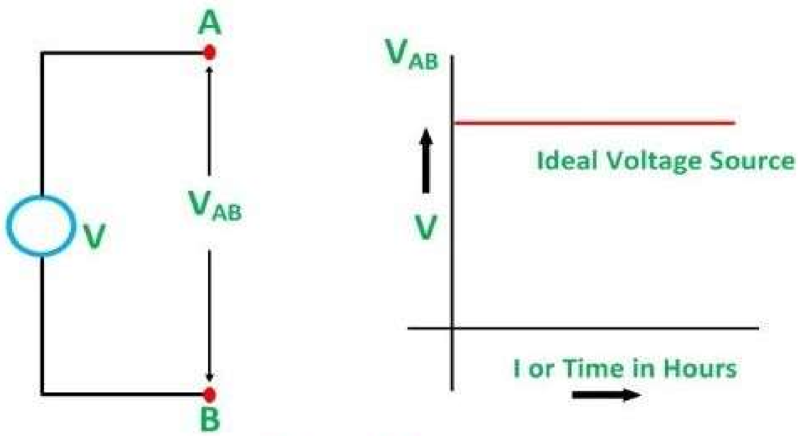


Figure A

The figure B shown below gives the circuit diagram and characteristics of Practical Voltage Source

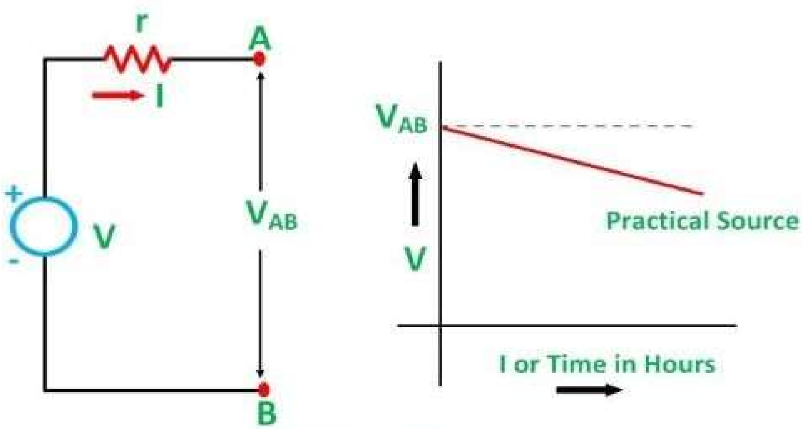


Figure B

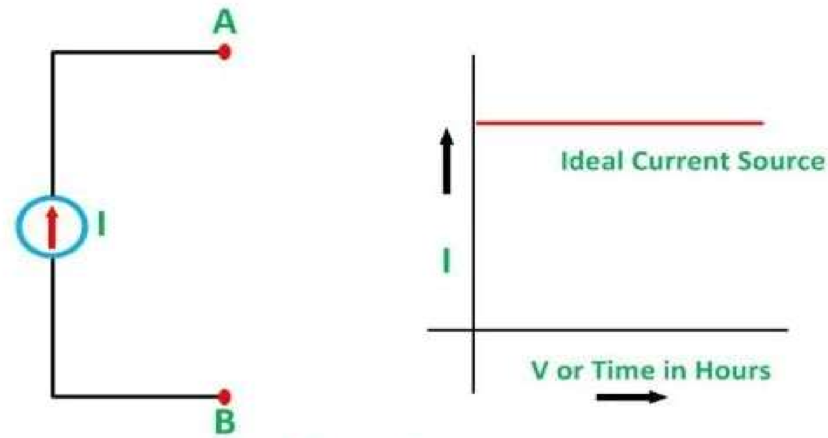


Figure C

Figure D shown below shows the characteristics of Practical Current Source.

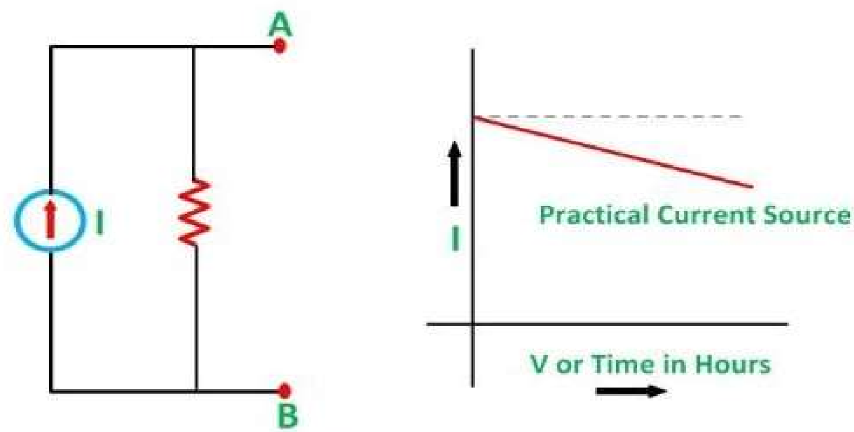
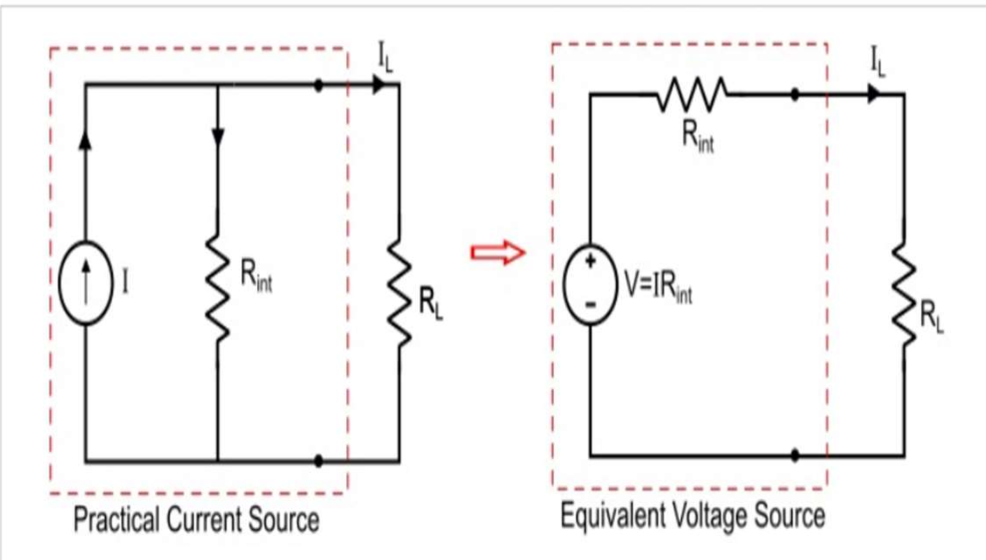


Figure D

Source transformation

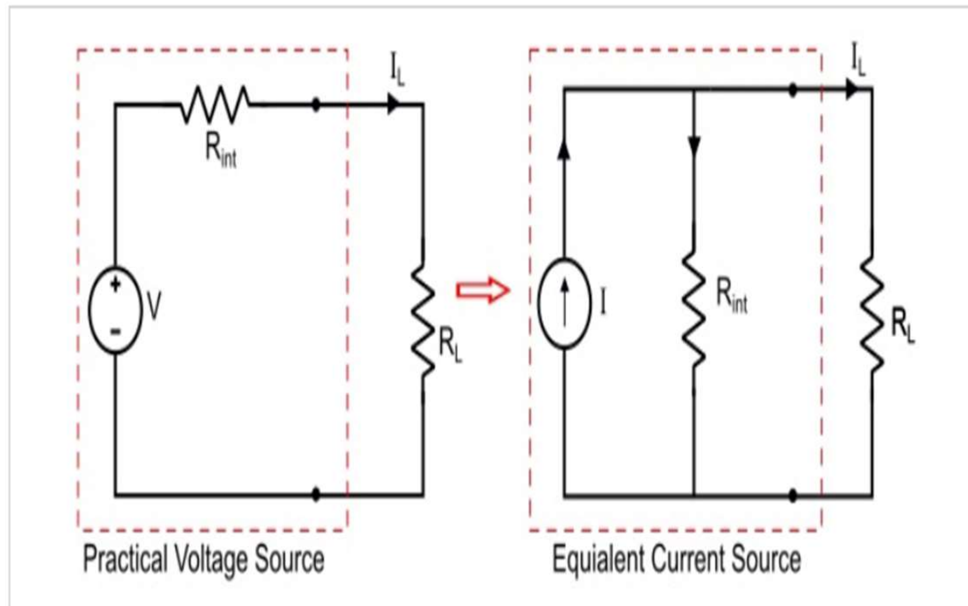
Current to Voltage Source Transformation

Consider a practical current source of constant current I amperes with a parallel internal resistance R_{int}, it can be converted into an equivalent voltage source as follows.



Voltage to Current Source Transformation

Consider a practical voltage of V volts having a series internal resistance R_{int} ohms. A load resistance of R_L ohms is connected across the load terminals.



Source transformation

Numerical Example - 1

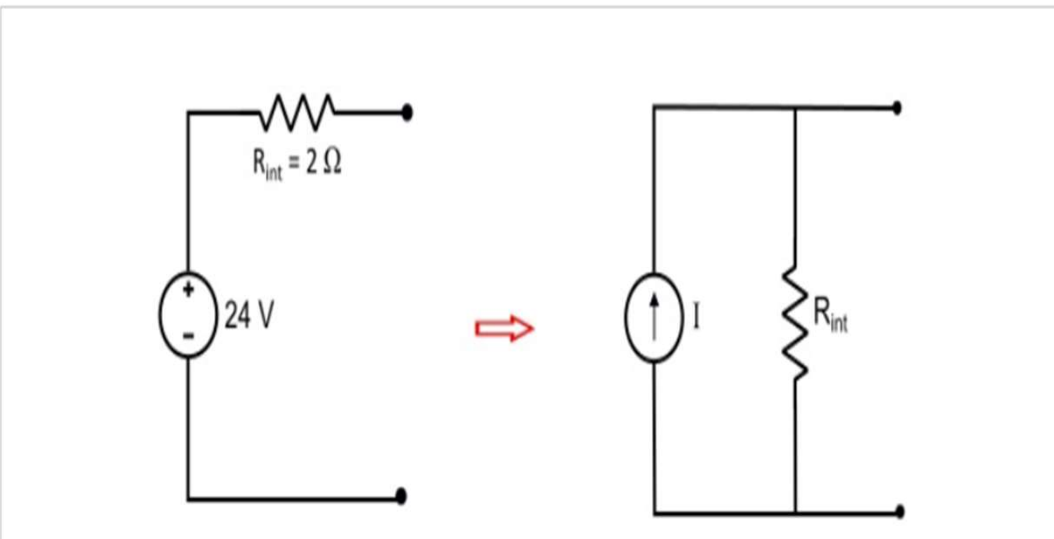
Convert a voltage source of 24 V having a series internal resistance of 2 Ω into an equivalent current source.

Source transformation

Numerical Example - 1

Convert a voltage source of 24 V having a series internal resistance of 2 Ω into an equivalent current source.

Solution



Here, the source current of equivalent current source is

$$I = \frac{V}{R_{int}} = \frac{24}{2} = 12\text{ A}$$

The internal resistance R_{int} of the equivalent current source has the same value as the original voltage source, thus

$$R_{int} = 2\,\Omega$$

QUICK QUIZ (Poll 3)

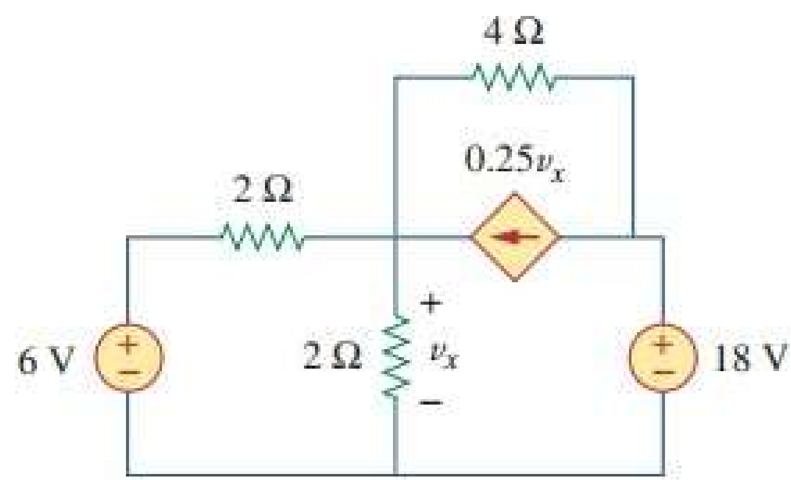
Identify the type of dependent source used in the network:

A. VCVS

B. CCCS

C. VCCS

D. CCVS



Nodal Analysis

- Nodal analysis provides a general procedure for analyzing circuits using node voltages as the circuit variables.

- Choosing node voltages instead of element voltages as circuit variables is convenient and it *reduces the number of equations.* (one must solve simultaneously)

- Applicable to nodes only.

- It is used to find the unknown node voltages.

- This Method is Application of KCL+ Ohm's Law Only.

There are two types of nodes in nodal analysis:

- Non-reference node
- Reference node (Ground or datum node)

Node: The common point where two or more elements are connected. principal node -

P

Procedure: 1) Identify the total number of nodes.

2) Assign the voltage at each node. One node is taken as reference node (datum).

3) Develop the KCL equation for each non-reference node.

4) Solve the KCL equations to get the node voltage.

pot. = 0V

Steps to Determine Node Voltages

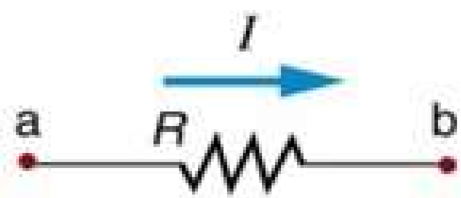
1. Select one nodes out of ‘n’ node as the reference node. Assign voltages to the remaining nodes. The voltages are referenced with respect to the reference node.

2. Apply KCL to each of the non-reference nodes. Use Ohm’s law to express the branch currents in terms of node voltages.

3. Solve the resulting simultaneous equations to obtain the unknown node voltages.

- The number of non-reference nodes is equal to the number of independent equations that we have to derive.

- Current flows from a higher potential to a lower potential in a resistor



$$i = \frac{v_{\text{higher}} - v_{\text{lower}}}{R}$$

QUICK QUIZ

For “N” number of nodes, the number of non-reference nodes is equal to:

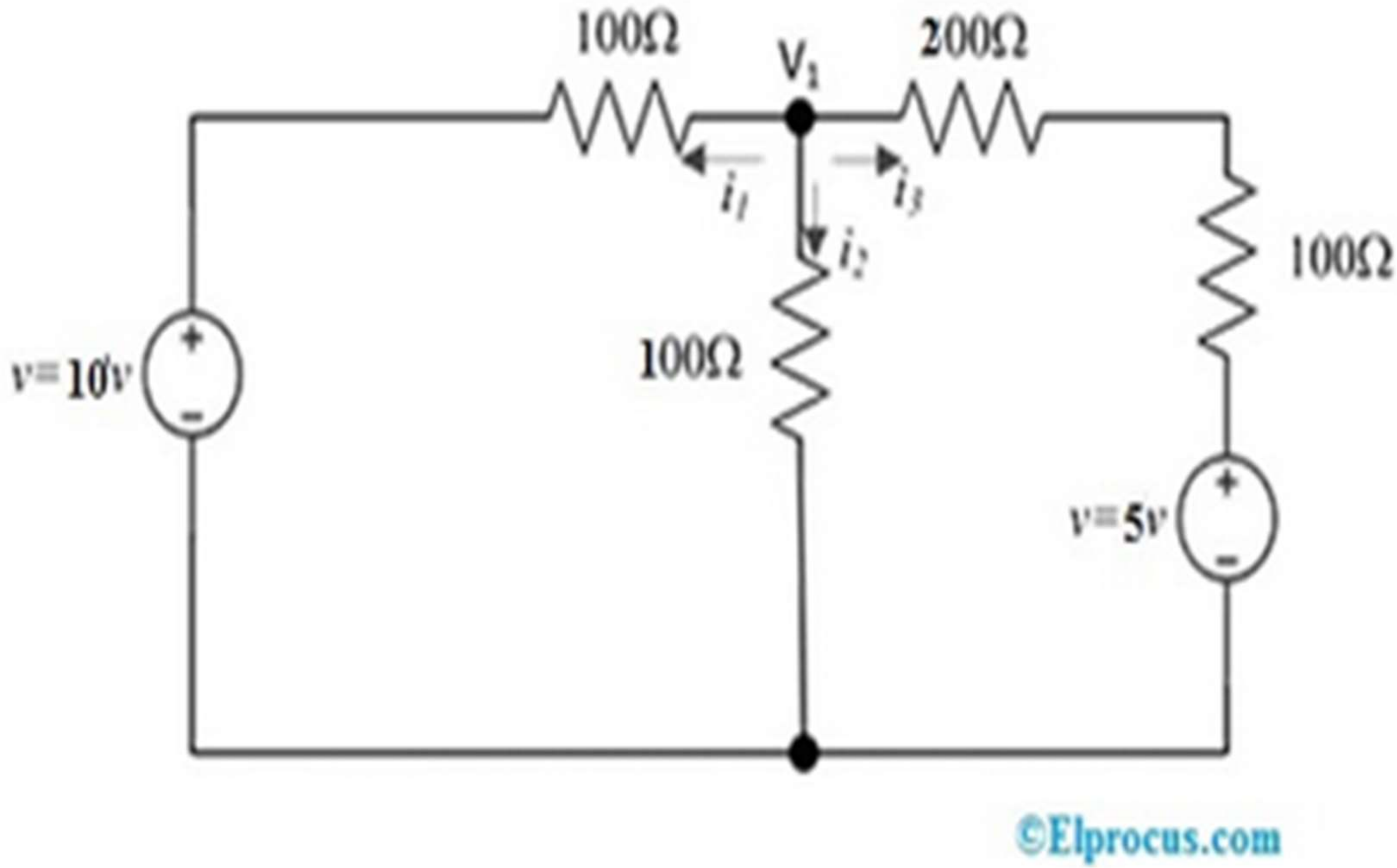
A. $N + 1$

B. $N - 1$

C. 2N

D. $2N - 1$

Find the node voltage ‘V1’ by applying nodal analysis in the following circuit.



$$i1+i2+i3 = 0$$

$$(V1-10/100)+(V1/100)+(V1-5/200+100)$$

$$(V1/100 -10/100) + V1/100+ (V1-5/200+100)$$

$$(V1/100+V1/100+V1/300) –(10/100)-(5/300)$$

$$V1(1/100+1/100+1/300) –(10/100)-(5/300)$$

$$(3+3+1/300)V1 = (30/300+5/300)$$

$$(7/300)V1 = 30+5/300$$

$$V1 = (35/300)x(300/7)$$

$$V1 = (35/7)$$

$$V1 = 5V$$

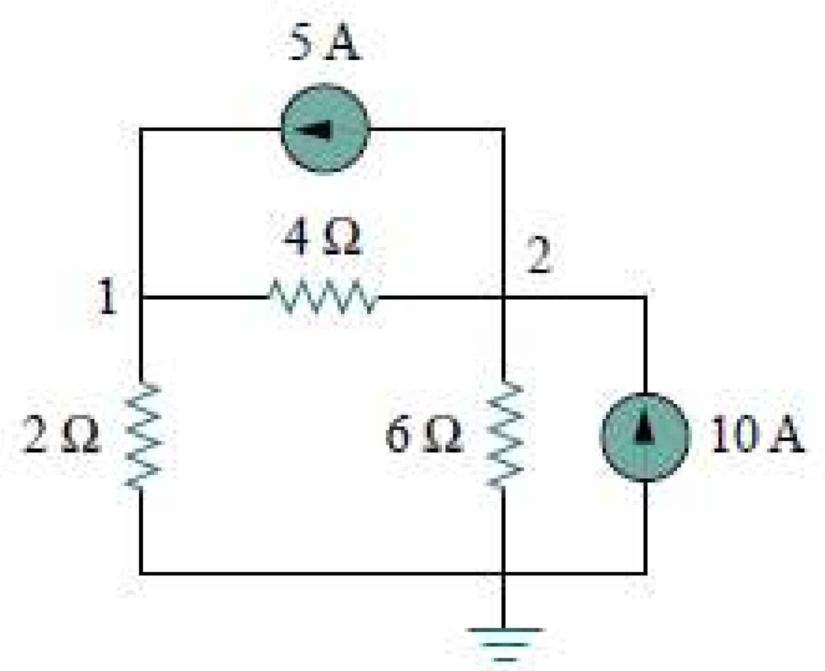
QUICK QUIZ

Nodal analysis, which is based on KCL is used to find unknown:

A. current
B. voltage

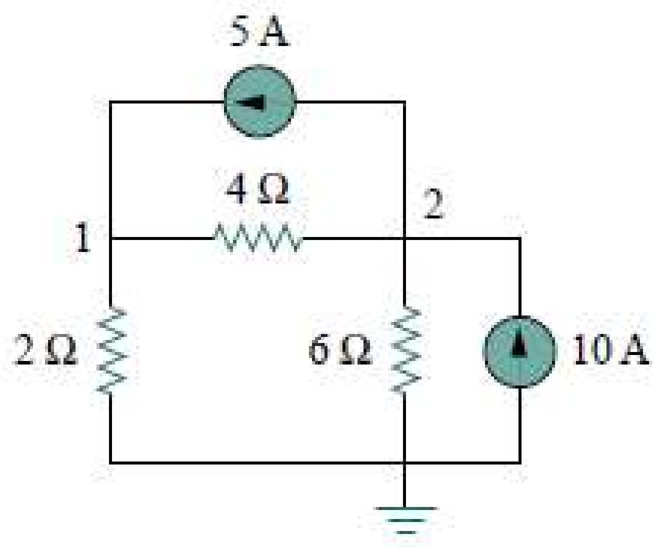
Example 1

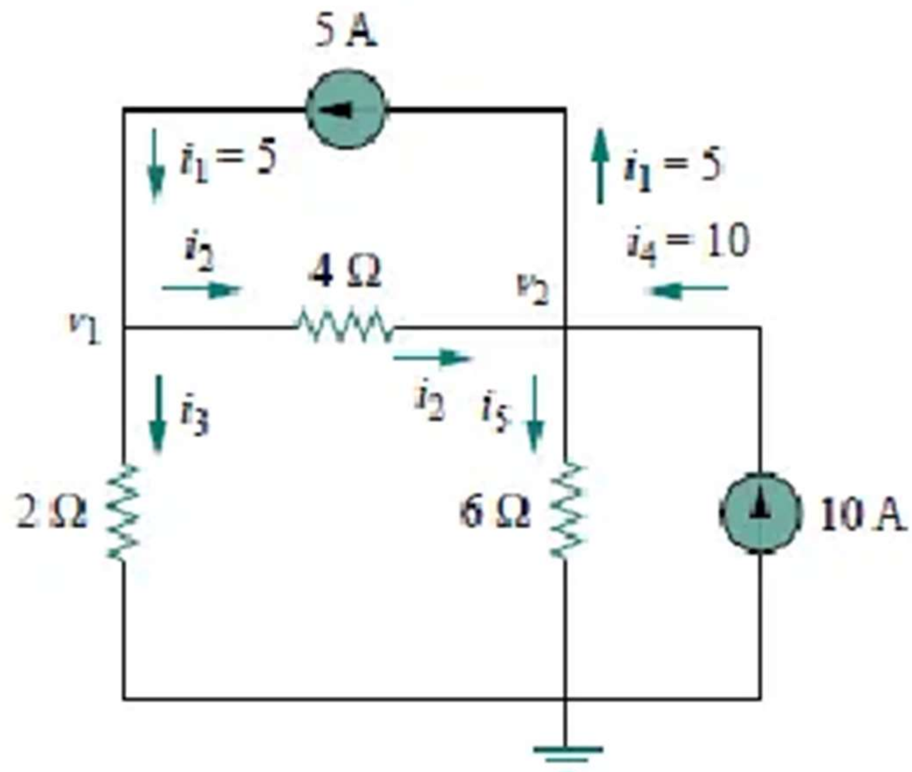
- Obtain the node voltages in the given circuit?



Example 1

- Obtain the node voltages in the given circuit?





$$i_1 = i_2 + i_3$$

$$5 = \frac{v_1 - v_2}{4} + \frac{v_1 - 0}{2}$$

Multiplying each term in the last equation by 4, we obtain

$$20 = v_1 - v_2 + 2v_1$$

or

$$3v_1 - v_2 = 20 \qquad (1)$$

At node 2, we do the same thing and get

$$i_2 + i_4 = i_1 + i_5$$

$$\frac{v_1 - v_2}{4} + 10 = 5 + \frac{v_2 - 0}{6}$$

Multiplying each term by 12 results in

$$3v_1 - 3v_2 + 120 = 60 + 2v_2$$

or

$$-3v_1 + 5v_2 = 60 \qquad (2)$$

Using the elimination technique, we add Eqs. (1) and (2).

$$4v_2 = 80 \Rightarrow v_2 = 20V$$

Substituting $v_2 = 20$ in Eq. (1) gives

$$3v_1 - 20 = 20 \Rightarrow 3v_1 = 40$$

$$v_1 = 13.33V$$

Mesh Analysis

- Mesh analysis provides another general procedure for analyzing circuits, using mesh currents as the circuit variables.
- It is based on KVL.

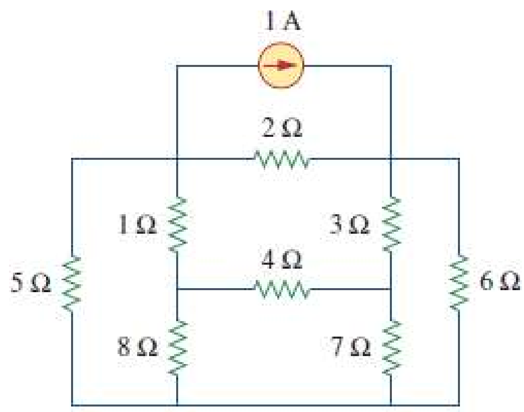
RECALL!

- LOOP: A loop is **any closed path going through circuit elements.**
- MESH: A mesh is a loop that does not contain any other loop within it.
- Mesh analysis is not quite as general as nodal analysis because it is only applicable to a circuit that is planar.
- **PLANAR CIRCUIT:** A planar circuit is one that can be drawn in a plane with no branches crossing one another; otherwise it is nonplanar.

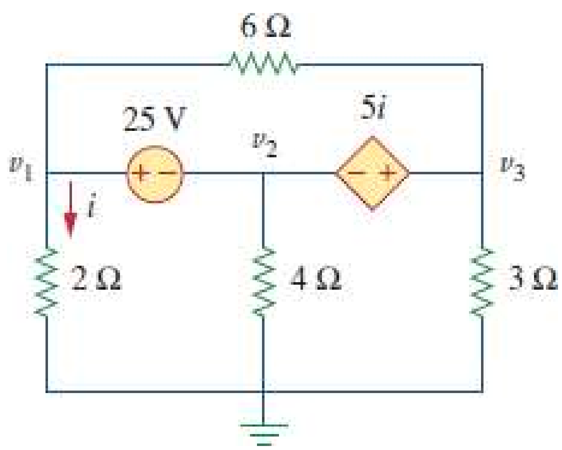
Steps to Determine Mesh Currents

1. Assign mesh currents to ‘n’ meshes
2. Apply KVL to each of the ‘n’ meshes.
3. Solve the resulting ‘n’ simultaneous equations to obtain the unknown mesh currents.

Examples of Planar Circuits



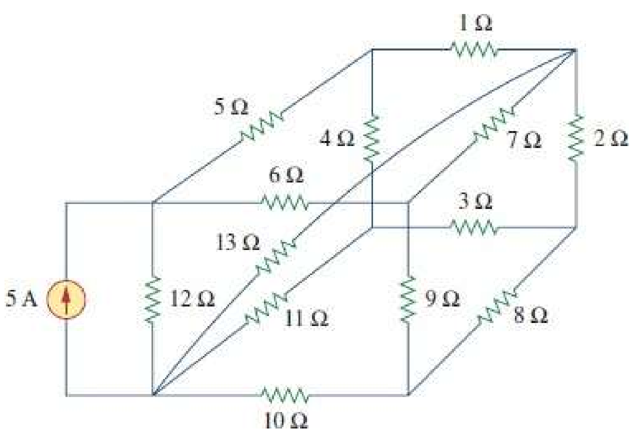
(b)

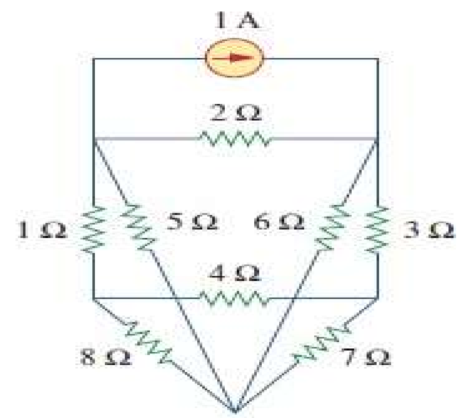


NOTE: A mesh is a loop which does not contain any other loops within it.

Mesh Analysis can be applied to meshes only inside the circuit, Not to LOOP.

Examples of Non-Planar Circuits





(a)

QUICK QUIZ

Mesh Analysis to applicable to______type networks.:

A. Planar and Loop
B. Non planar and mesh
C. Planar and mesh
D. Non planar and Loop

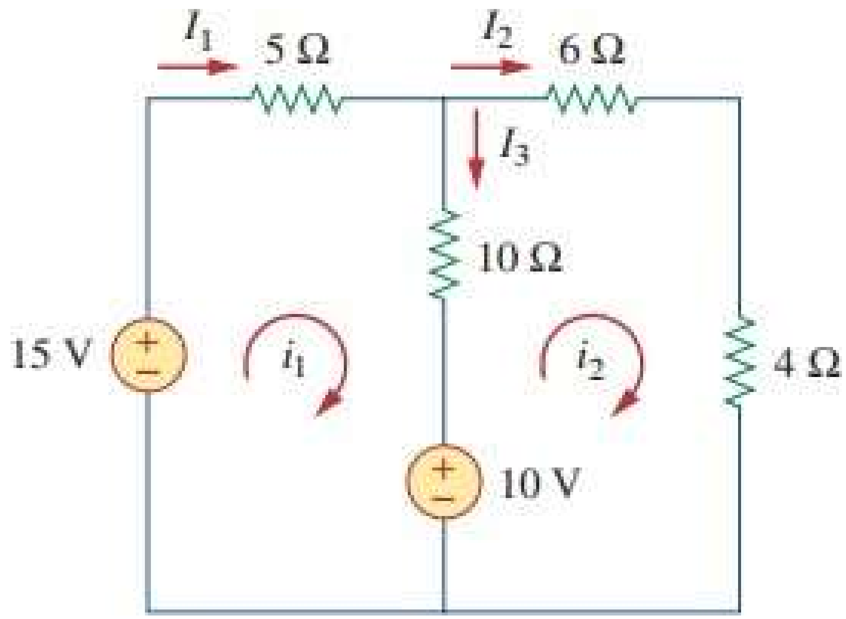
QUICK QUIZ

Mesh analysis, which is based on KVL is used to find unknown:

A. current
B. voltage

Example 1

- Obtain the mesh currents in the given circuit?



Example 1

$$+15 - 5I_1 - 10(I_1 - I_2) - 10 = 0$$

$$+15 - 5I_1 - 10I_1 + 10I_2 - 10 = 0$$

$$15I_1 - 10I_2 = 5 \quad -(1)$$

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

$$-10I_1 + 20I_2 = 10 \quad -(2)$$

$$\Rightarrow I_1 = I_2 = 1A$$

as $I_1 = I_2 + I_3$

$$I_3 = 0$$

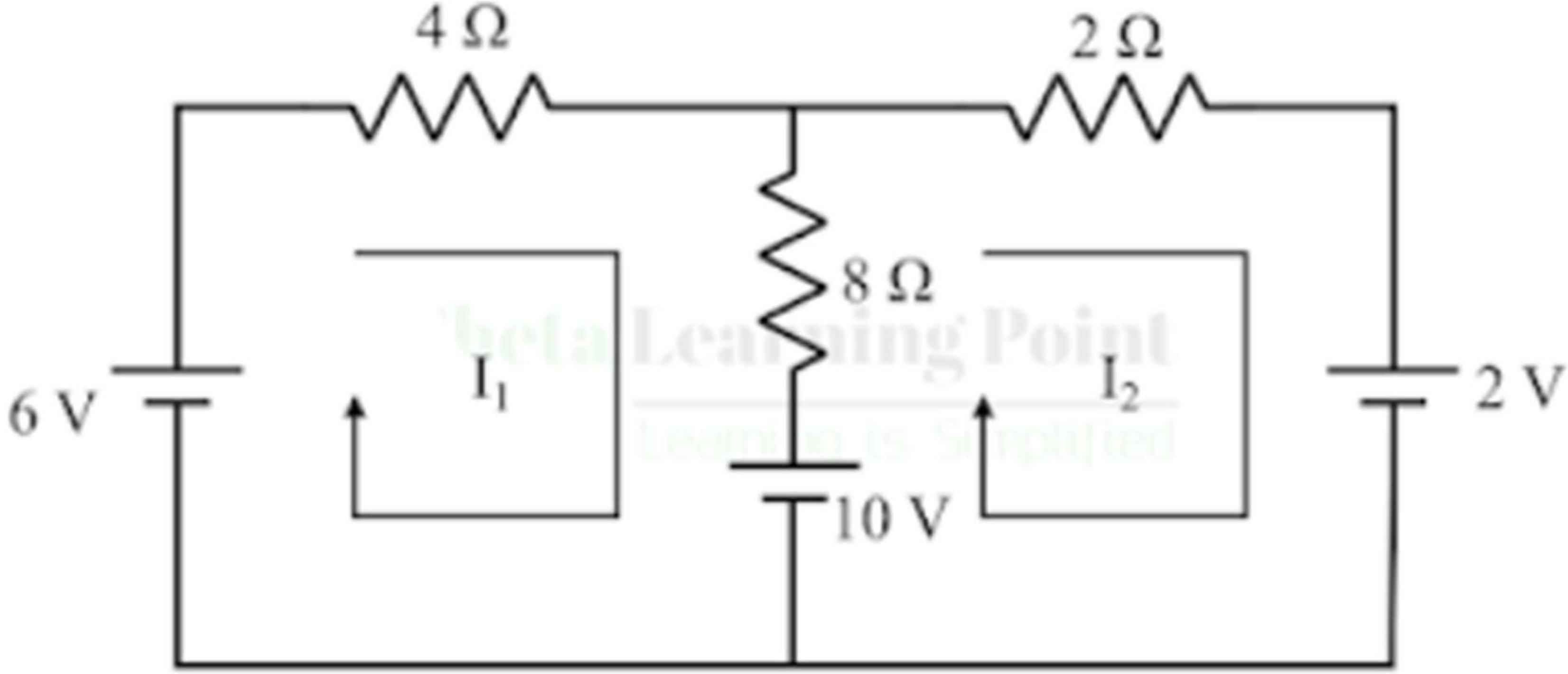


Figure 1 - Mesh Analysis with Voltage Sources Only

The KVL equation for mesh 1 is,

$$6-4I_1-8(I_1-I_2)-10=0$$

$$\Rightarrow \quad -12I_1+8I_2=4 \quad ...(1)$$

The KVL equation for mesh 2 is,

$$-2+10-8(I_2-I_1)-2I_2=0$$

$$\Rightarrow 8I_1-10I_2=\ -8 \quad ...(2)$$

By rearranging equation (2), we get,

$$I_1=\frac{10I_2-8}{8} \quad ...(3)$$

On substituting the value of current I1 from equation (3) into equation (1), we get,

$$-12\left(\frac{10I_2-8}{8}\right)+8I_2=4$$

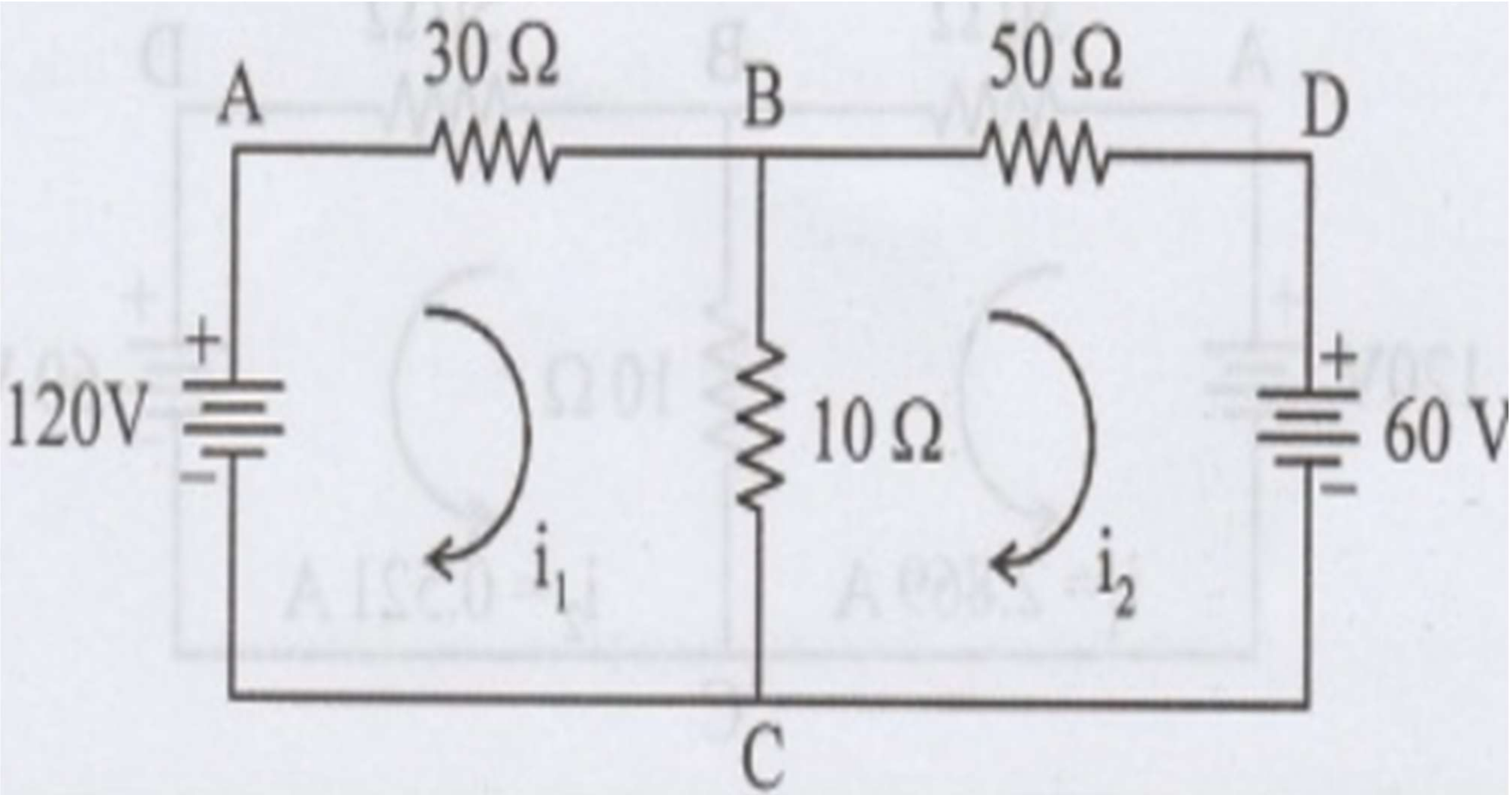
On solving this equation, we get,

$$I_2=\frac{8}{7}\ \ \mathbf{A}$$

Also, by putting this value of current I2 into equation (3), we get,

$$I_1=\frac{\left(10\times\frac{8}{7}\right)-8}{8}$$

$$\therefore I_1=\frac{3}{7}\ \ \mathbf{A}$$



30 Ω
50 Ω
A
B
D
120V
+
−
10 Ω
60 V
+
−
i_1
i_2
C

$- 30i_1 - 10(i_1 - i_2) + 120 = 0$

$-30i_1 - 10\ i_1 + 10\ i_2 + 120 = 0$

$-40\ i_1 + 10\ i_2 + 120 = 0$

$120 = 40\ i_1 - 10\ i_2$ ....(1)

Mesh BDCB

$-50i_2 - 60 - 10(i_2 - i_1) = 0$

$-50i_2 - 10\ i_2 + 10\ i_1 - 60 = 0$

$-60\ i_2 + 10\ i_1 - 60 = 0$

$-60 = -10\ i_1 + 60\ i_2$ ....(2)

Multiplying equ (2) by 4 and adding the equ (2) in to equ (1)

$120 = 40i_1 - 10i_2$

$-240 = -40i_1 + 240i_2$

$-120 = 230i_2$

$i_2 = -120/230 = -0.521$ A

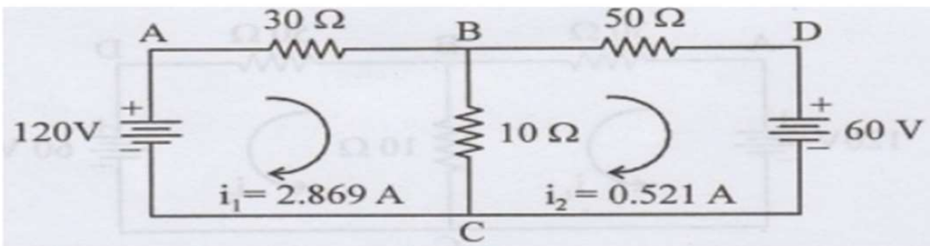
The i, value is substituted in equ (1)

$40\ i_1 - 10\ (-0.521) = 120$

$40\ i_1 + 5.21 = 120$

$40\ i_1 = 114.79$

$i_1 = 114.79/40 = 2.869$ A



The actual direction of flow of mesh currents is shown in above fig

The mesh currents $i_1 = 2.869$ A

$i_2 = 0.521$ A

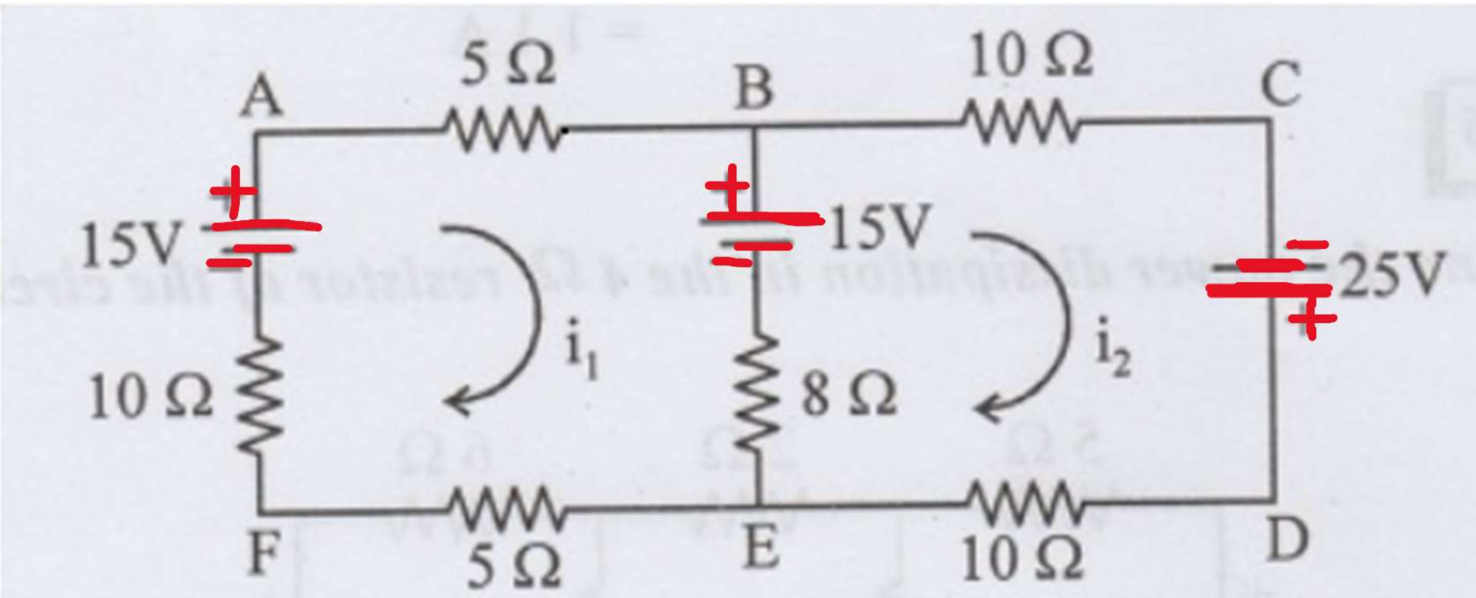
Current in branch CAB is

$i_1 = 2.869$ A

Current in branch CDB is

$i_2 = 0.521$ A

Find the current in the 8 Ω resistor in the circuit shown in figure.



$-10\ (i_1) + 15 - 5\ i_1 - 15 - 8\ (i_1 - i_2)\ -5\ i_1 = 0$

$-10\ i_1 - 5\ i_1 - 8\ i_1 + 8\ i_2 - 5\ i_1 = 0$

$-28\ i_1 + 8\ i_2 = 0$

$-28\ i_1 = -8\ i_2$

$i_2 = 28\ i_1/8 = 3.5\ i_1$

For mesh BCDEB

$-10\ i_2 + 25 - 10\ i_2 - 8\ (i_2 - i_1) + 15 = 0$

$-10\ i_2 + 25 - 10\ i_2 - 8\ i_2 + 8\ i_1 + 15 = 0$

$-28\ i_2 + 8\ i_1 + 40 = 0$

$40 = 28\ i_2 - 8\ i_1$ ....(2)

Sub i_2 in equ (2)

$40 = 28\ (3.5\ i_1)\ - 8i_1$

$40 = 98i_1 - 8i_1$

$40 = 90i_1$

$i_1 = 40/90 = 0.44$ A

$i_2 = 3.5\ (0.44)$