Course Code: EEE 4101
Course Title: Electrical Engineering

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Ref. Book: Fundamental of Electrical Circuit: Alexander Sadiku

OHM’s LAW

- **Ohm's law** states that at constant temperature, the current through a conductor between two points is directly proportional to the voltage across the two points.

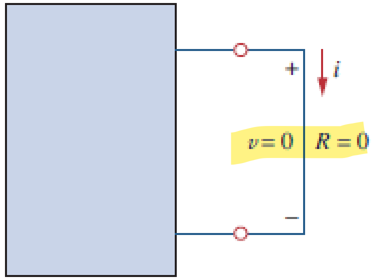
$$I \propto V$$

$$\Rightarrow I = G * V$$

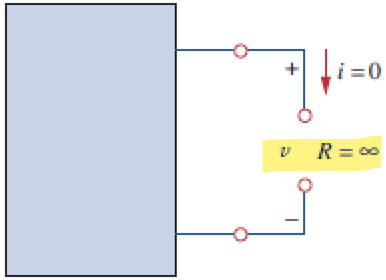
$$\Rightarrow I = \frac{1}{R} V$$

$$\Rightarrow V = I * R$$

A short circuit is a circuit element with resistance approaching zero.



An open circuit is a circuit element with resistance approaching infinity.



Drawbacks of OHM's LAW

Unilateral

1. Ohm's law cannot be applied to unilateral networks. Unilateral networks allow the current to flow only in one direction. Ex. Diodes, transistors, etc.
2. Ohm's law is not applicable in the case of non-linear objects. In these components, the current is not proportional to the voltage applied. This is because, for each value of voltage and current, these components have different resistance values. Ex. Thyristor.
3. Temperature should be constant while applying Ohm's law.

Nodes, Branches, and Loops

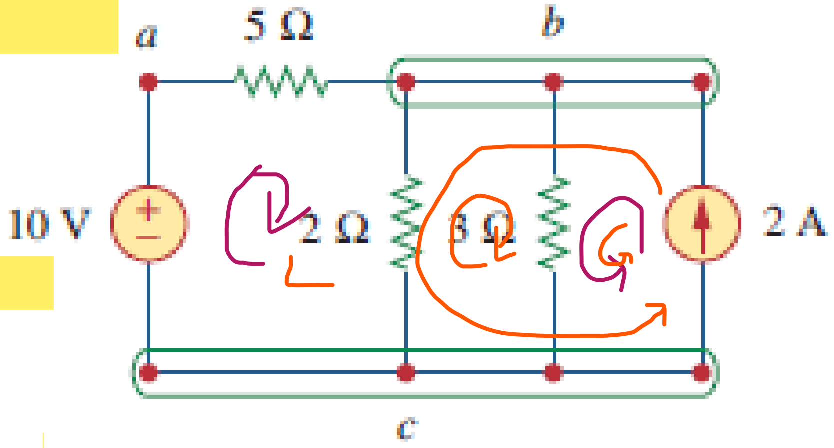
#branch = #independant_loop + #node -1

A node is the point of connection between two or more branches.

Independant loop: a loop that has at least one branch that is not part of any other independant branch

A branch represents a single elen or a resistor.

A loop is any closed path in a circ

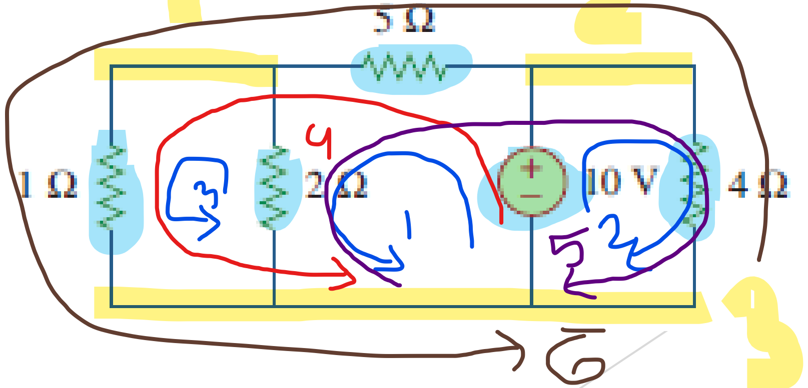


2 indepent loop

6 loops !

5 3 6

Q. How many branches, nodes, and loops does the following circuit have?



3 indedent Loops

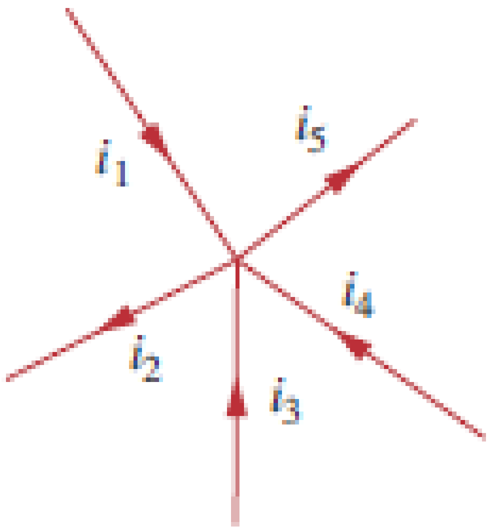
3 meshes

Kirchhoff's Laws

Ohm's law by itself is not sufficient to analyze circuits. However, when it is coupled with Kirchhoff's two laws, we have a sufficient, powerful set of tools for analyzing a large variety of electric circuits.

Kirchhoff's current law (KCL) states that the algebraic sum of currents entering a node (or a closed boundary) is zero.

Mathematically, KCL implies that $\sum_{n=1}^{N} i_n = 0$



where N is the number of branches connected to the node and is the nth current entering (or leaving) the node.

Kirchhoff's Laws (Contd.)

Kirchhoff's voltage law (KVL) states that the algebraic sum of all voltages around a closed path (or loop) is zero.

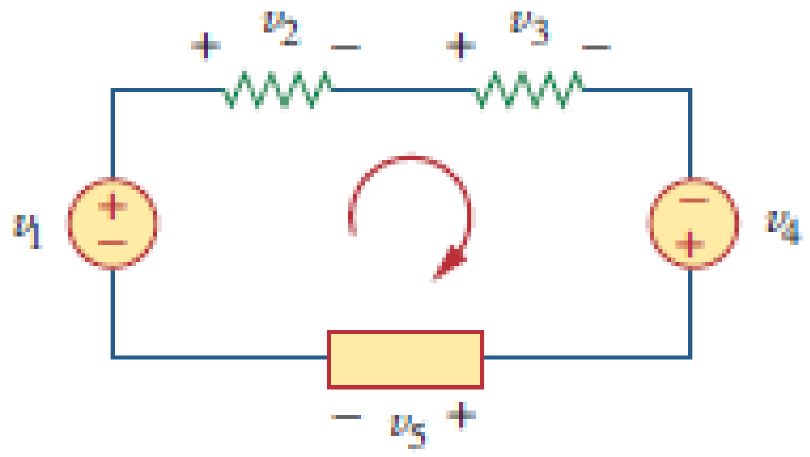
Expressed mathematically, KVL states that, $\sum_{m=1}^{M} v_m = 0$

where M is the number of voltages in the loop (or the number of branches in the loop) and v_m is the mth voltage.

Sum of voltage drops =Sum of voltage rises

$-v_1 + v_2 + v_3 - v_4 + v_5 = 0$

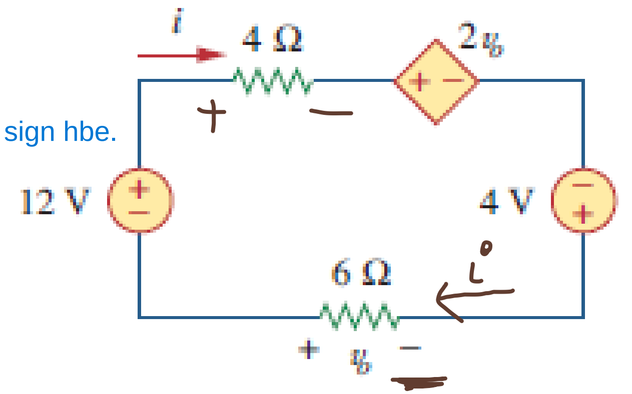
$\Rightarrow v_2 + v_3 + v_5 = v_1 + v_4$



Solved Problem(s)

Determine v_o and i in the circuit shown in following figure.

kintu kirchoff er sutro apply korar ktha bolle
loop er suru theke sesh porjonto gae jei chinho(+/-) dekhba setai voltage er sign hbe.



We apply KVL around the loop as shown in Fig. 2.23(b). The result is

$$-12 + 4i + 2v_o - 4 + 6i = 0$$

$(-V_o)$

Applying Ohm's law to the 6-Ω resistor gives

$$v_o = -6i$$

Substituting Eq. (2.6.2) into Eq. (2.6.1) yields

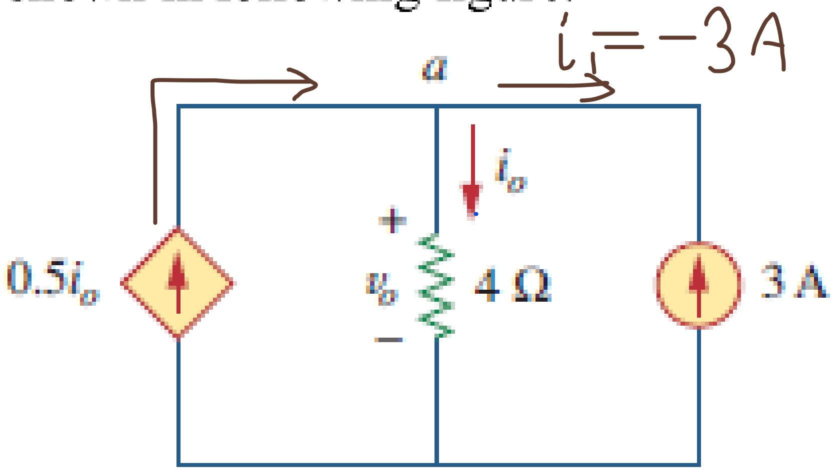
$$-16 + 10i - 12i = 0 \quad \Rightarrow \quad i = -8\ \text{A}$$

and $v_o = 48$ V.

if i flows from $(+) \rightarrow i\,(-)$
,, ,, ,, ,, $(-) \rightarrow i\,(+)$
,, ,, ,, to $(+)$

Solved Problem(s)

Find current, i_o and v_o voltage in the circuit shown in following figure.



Applying KCL to node a, we obtain

$$3 + 0.5i_o = i_o \qquad \Rightarrow \qquad i_o = 6 \text{ A}$$

For the 4-Ω resistor, Ohm's law gives

$$v_o = 4i_o = 24 \text{ V}$$

Problem(s)

Find currents and voltages in the circuit shown in given figure.

$R_p = \left(\frac{1}{6}+\frac{1}{3}\right)^{-1} = 2\Omega$ $\therefore R = 8+2 = 10\,\Omega$

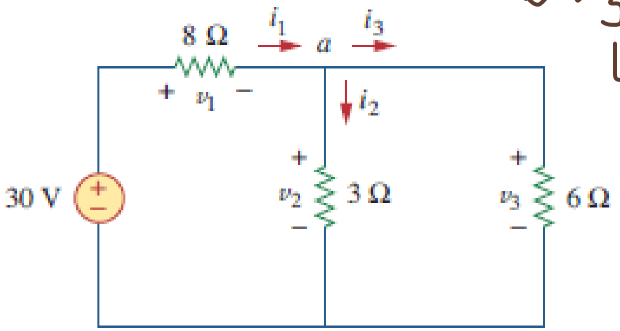
$I = i_1 = \frac{30}{10} = 3A$, $V_1 = 3\times 8 = 24V$

$V_2 = V_3 \Rightarrow 3i_2 = 6i_3 \Rightarrow i_2 = 2i_3$

$i_1 = 3 = i_2 + i_3 \Rightarrow 3 = 3i_3$ $\therefore i_3 = 1A$

$\therefore i_2 = 2A$

$\therefore V_2 = V_3 = 2\times 3 = 6V$



Or,

$i_1 - i_2 - i_3 = 0$

$-30 + 8i_1 + 3i_2 = 0$

$6i_3 \underbrace{-(3i_2)}_{-V_2} = 0$

$(1)(-3i_2)$

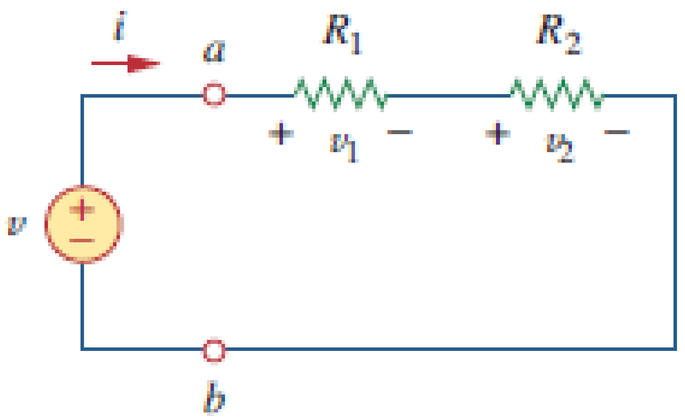
$V_2 = 3i_2$

$\therefore i_1 = 3A$

$i_2 = 2A$

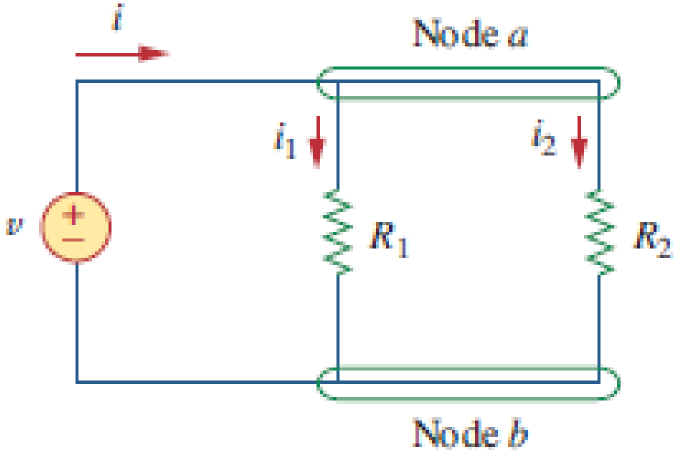
$i_3 = 1A$

Series Resistors and Voltage Division



$$V_1 = V \times \frac{R_1}{R_1+R_2} \;,\quad V_2 = V \times \frac{R_2}{R_1+R_2}$$

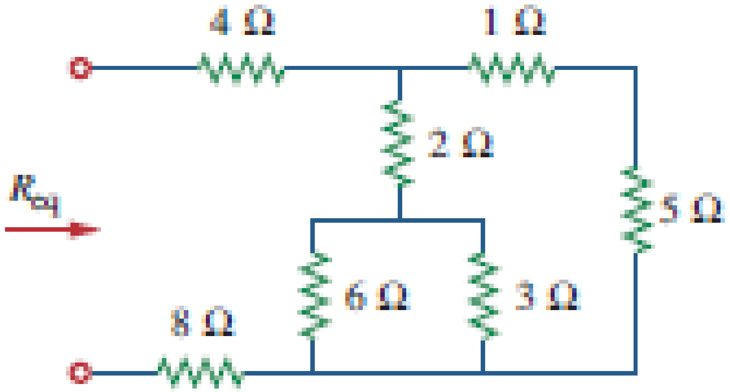
Parallel ~~Series~~ Resistors and Current

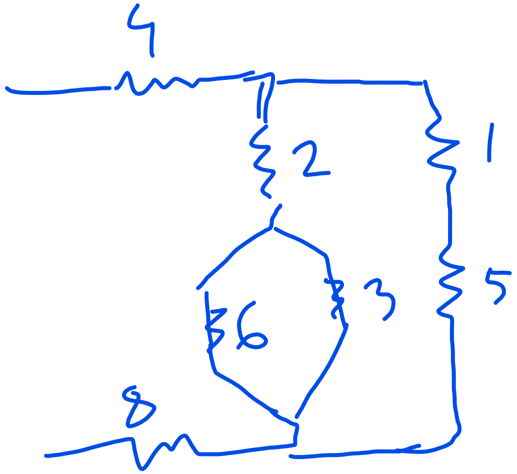


$$i_1 = i \times \frac{R_2}{R_1+R_2} \;,\quad i_2 = i \times \frac{R_1}{R_1+R_2}$$

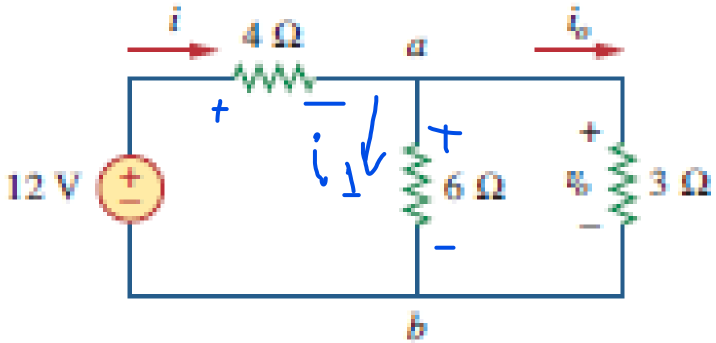
Equivalent Resistance Calculation

Find R_{eq} for the circuit shown below.





Find i_0 and v_o in the circuit shown in the following Figure. Also calculate the power dissipated in the 3- resistor.



$i - i_0 - i_1 = 0$ $i = 2$ A

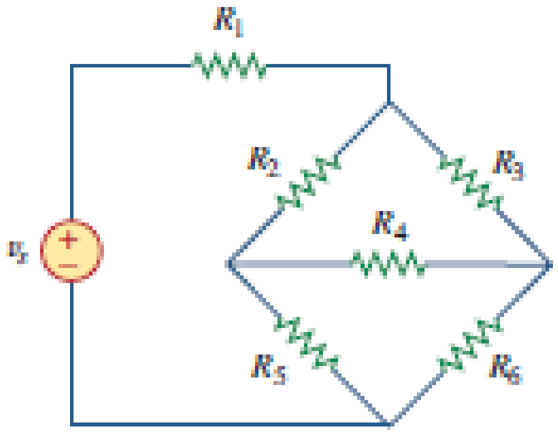
$i_0 = 1.33$ A

$-12 + 4i + 6i_1 = 0$

$3i_0 - 6i_1 = 0$ $i_1 = 0.667$ A

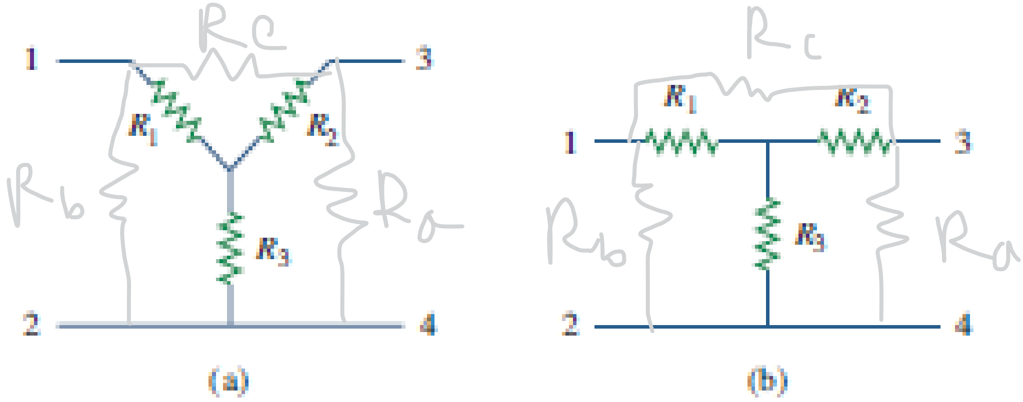
$V_0 = 3i_0 = 3.99$, $V = 4i = 4$, $V_1 = 6i_1 = 4.002$

Wye-Delta Transformation



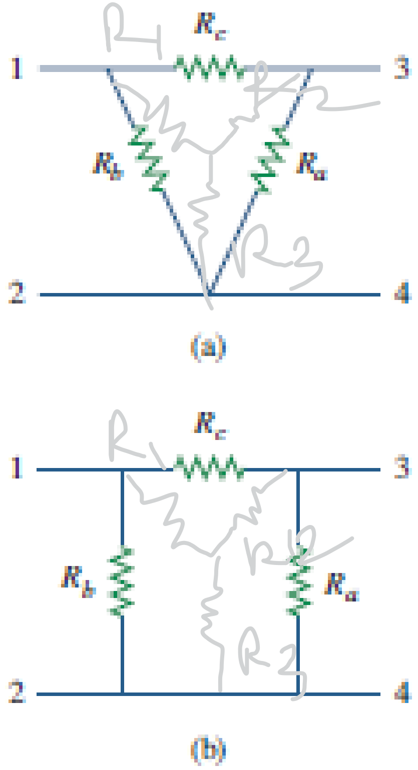
This is a circuit where the resistors are neither in parallel nor in series.

$R_1 = \frac{R_b R_c}{R_a + R_b + R_c}$



Wye (Y) or T network

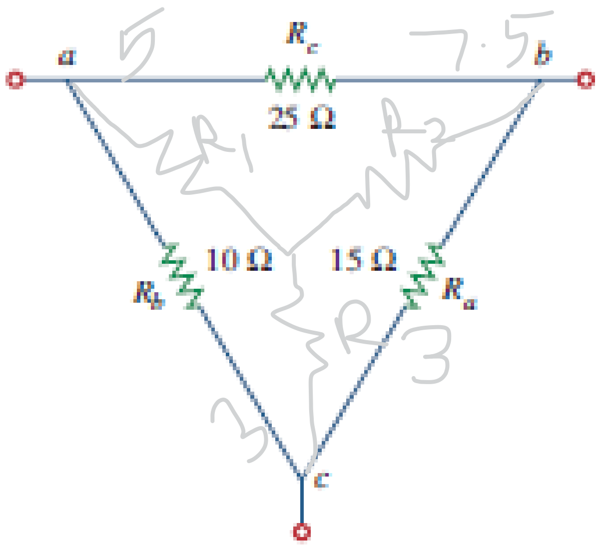
$R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1}$

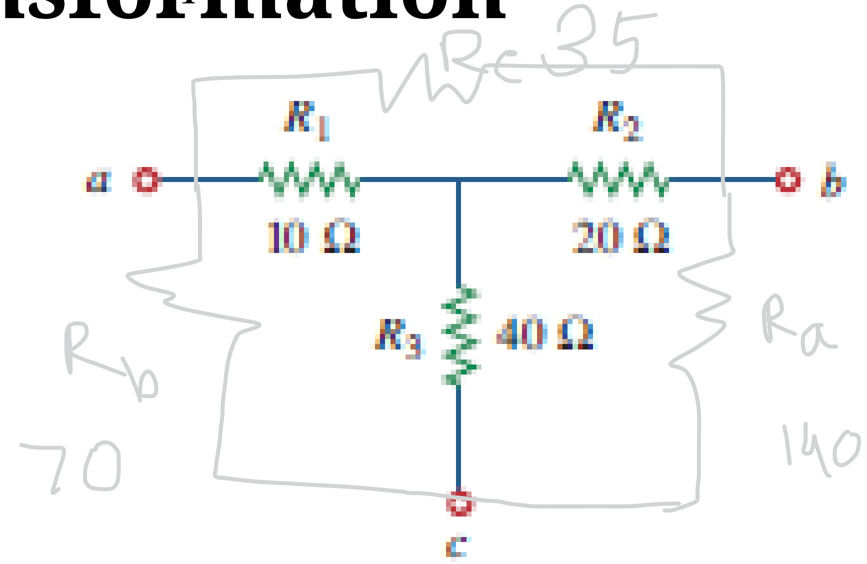


Delta (Δ) or π network

Wye-Delta Transformation

Convert the Δ network in the given figure to an equivalent Y/ T network to Δ.





My trick to remember the formulas:

1. Y is really heavy that the middle wighs down,
   so when it's transformed to 'delta' you get a heavy fraction
2. 'Delta' is so light and empty that when transformed to Y, you get a light fraction

Lighting System

Three light bulbs are connected to a 9-V battery as shown in Fig. 2.56(a). Calculate: (a) the total current supplied by the battery, (b) the current through each bulb, (c) the resistance of each bulb.

(a) The total power supplied by the battery is equal to the total power absorbed by the bulbs; that is,

$$p = 15 + 10 + 20 = 45 \text{ W}$$

Since $p = VI$, then the total current supplied by the battery is

$$I = \frac{p}{V} = \frac{45}{9} = 5 \text{ A}$$

(b) The bulbs can be modeled as resistors as shown in Fig. 2.56(b). Since R_1 (20-W bulb) is in parallel with the battery as well as the series combination of R_2 and R_3,

$$V_1 = V_2 + V_3 = 9 \text{ V}$$

The current through R_1 is

$$I_1 = \frac{p_1}{V_1} = \frac{20}{9} = 2.222 \text{ A}$$

By KCL, the current through the series combination of R_2 and R_3 is

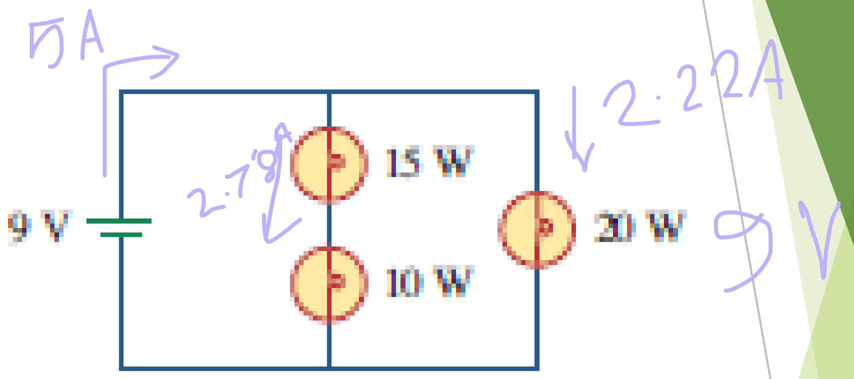
$$I_2 = I - I_1 = 5 - 2.222 = 2.778 \text{ A}$$

(c) Since $p = I^2R$,

$$R_1 = \frac{p_1}{I_1^2} = \frac{20}{2.222^2} = 4.05\ \Omega$$

$$R_2 = \frac{p_2}{I_2^2} = \frac{15}{2.777^2} = 1.945\ \Omega$$

$$R_3 = \frac{p_3}{I_3^2} = \frac{10}{2.777^2} = 1.297\ \Omega$$

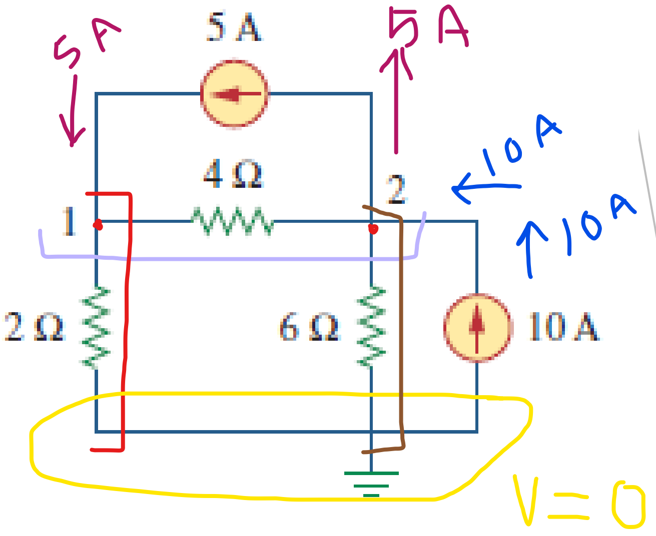


Potential difference between point 1 & 2 is (v1-v2) as v1> v2 because current flows from point 1 to point 2.

Nodal Analysis

$$i = \frac{V_{a-b}}{R}$$

Calculate the node voltages in the circuit shown in the Fig.



At node 1, applying KCL and Ohm's law gives

$$i_1 = i_2 + i_3 \quad \Rightarrow \quad 5 = \frac{v_1 - v_2}{4} + \frac{v_1 - 0}{2}$$

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

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

or

$$3v_1 - v_2 = 20$$

At node 2, we do the same thing and get

$$i_2 + i_4 = i_1 + i_5 \quad \Rightarrow \quad \frac{v_1 - v_2}{4} + 10 = 5 + \frac{v_2 - 0}{6}$$

or, $10 - 5 - \frac{V_2 - V_1}{4} - \frac{V_2 - 0}{6} = 0$

Multiplying each term by 12 results in

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

or

$$-3v_1 + 5v_2 = 60$$

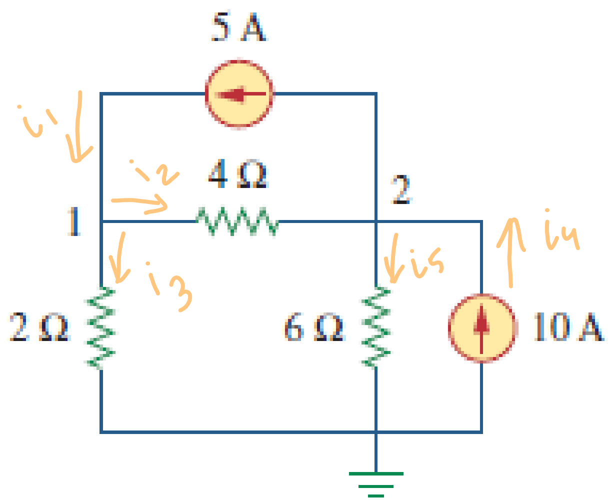
Nodal Analysis

Calculate the node voltages in the circuit shown in the Fig.

$$4v_2 = 80 \quad \Rightarrow \quad v_2 = 20\text{ V}$$

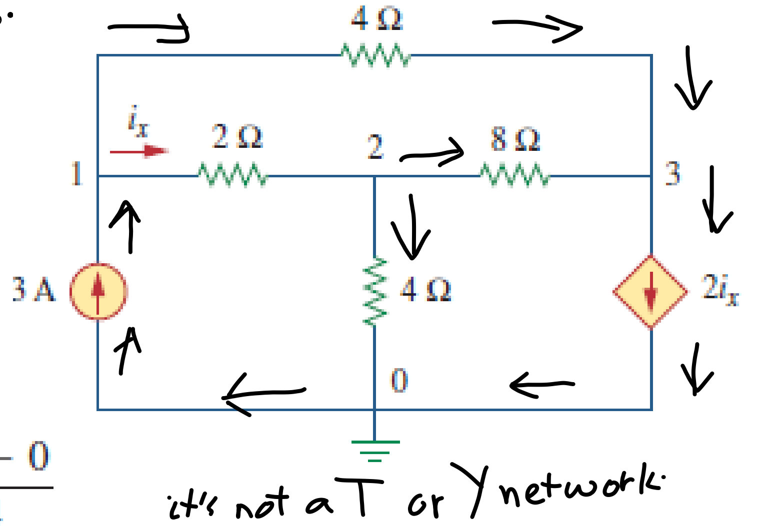
Substituting $v_2 = 20$ in Eq. (3.1.1) gives

$$3v_1 - 20 = 20 \quad \Rightarrow \quad v_1 = \frac{40}{3} = 13.333\text{ V}$$



Nodal Analysis

Determine the voltages at the nodes in the Fig.



At node 1,

$$3 = i_1 + i_x \quad \Rightarrow \quad 3 = \frac{v_1 - v_3}{4} + \frac{v_1 - v_2}{2}$$

At node 2,

$$i_x = i_2 + i_3 \quad \Rightarrow \quad \frac{v_1 - v_2}{2} = \frac{v_2 - v_3}{8} + \frac{v_2 - 0}{4}$$

At node 3,

$$i_1 + i_2 = 2i_x \quad \Rightarrow \quad \frac{v_1 - v_3}{4} + \frac{v_2 - v_3}{8} = \frac{2(v_1 - v_2)}{2}$$

$v_1 = 4.8$ V, $\quad v_2 = 2.4$ V, $\quad v_3 = -2.4$ V

Nodal Analysis with Voltage Source

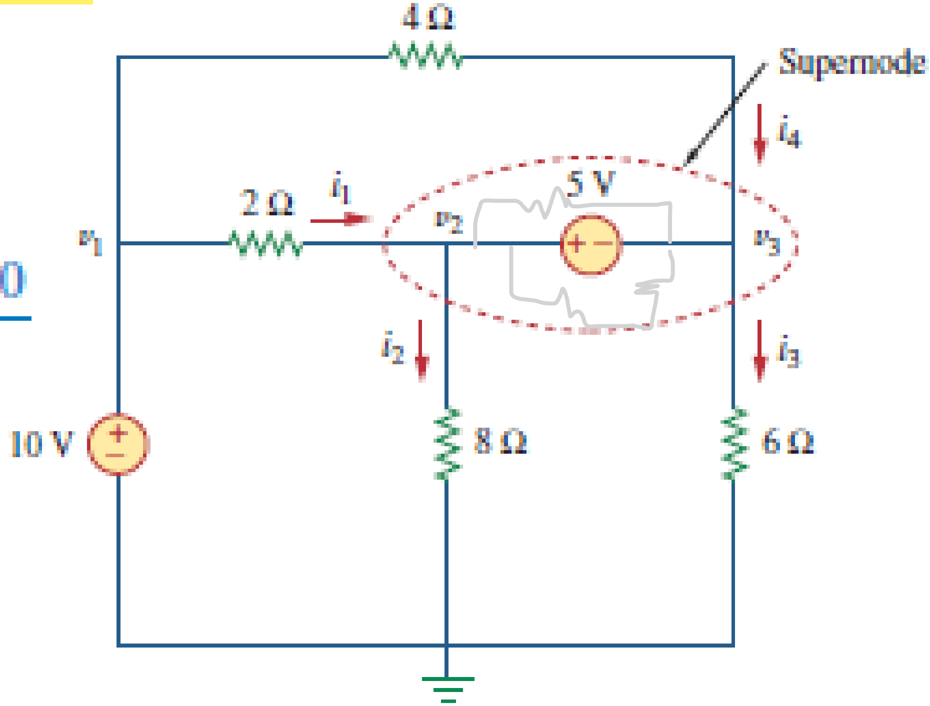
A **supernode** is formed by enclosing a (dependent or independent) voltage source connected between two nonreference nodes and any elements connected in parallel with it.

enclosing a dependent

$$v_1 = 10\text{ V}$$

$$\frac{v_1 - v_2}{2} + \frac{v_1 - v_3}{4} = \frac{v_2 - 0}{8} + \frac{v_3 - 0}{6}$$

$$v_2 - v_3 = 5$$



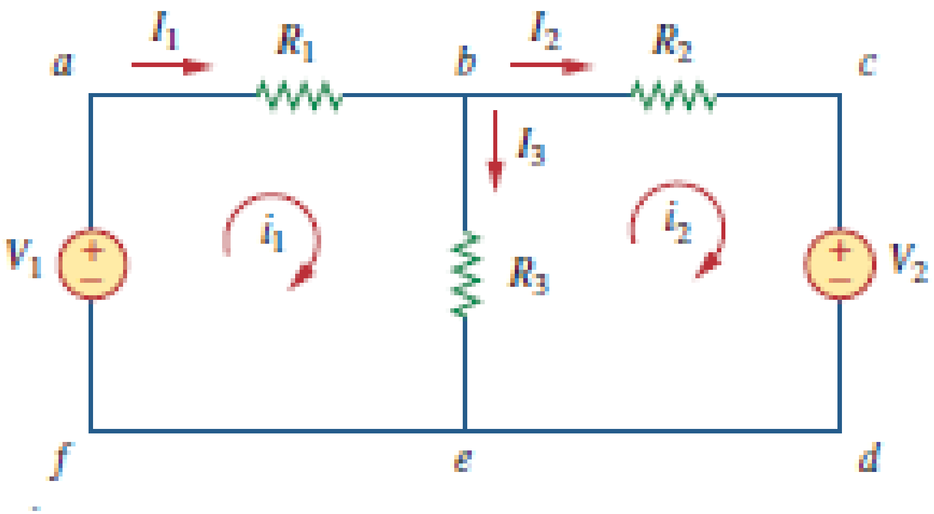
Consider this a single node

Mesh Analysis

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

$$-V_1 + R_1 i_1 + R_3(i_1 - i_2) = 0$$

$$R_2 i_2 + V_2 + R_3(i_2 - i_1) = 0$$



Mesh Analysis

For the circuit in the Fig., find the branch currents I_1, I_2 and , I_3 using mesh analysis.

We first obtain the mesh currents using KVL. For mesh 1

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

or

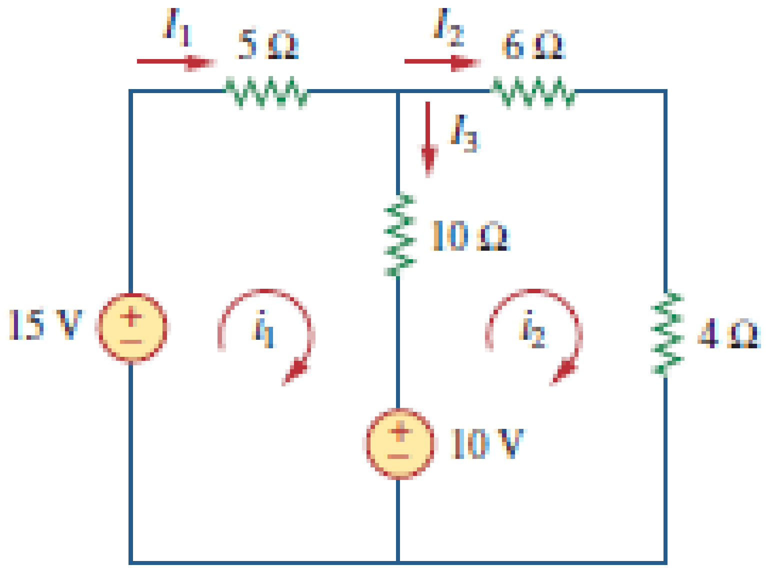
$$3i_1 - 2i_2 = 1$$

For mesh 2,

$$6i_2 + 4i_2 + 10(i_2 - i_1) - 10 = 0$$

or

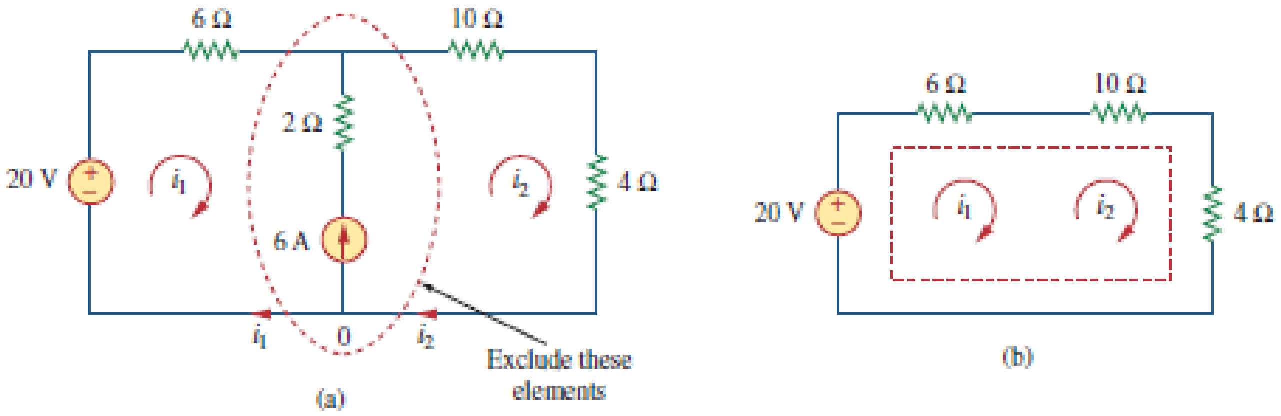
$$i_1 = 2i_2 - 1$$



Mesh Analysis with Current Source

A supermesh results when two meshes have a (dependent or independent) current source in common.

2 meshes



considered as one mesh

$$-20 + 6i_1 + 10i_2 + 4i_2 = 0$$

$$i_2 = i_1 + 6$$

Thank You