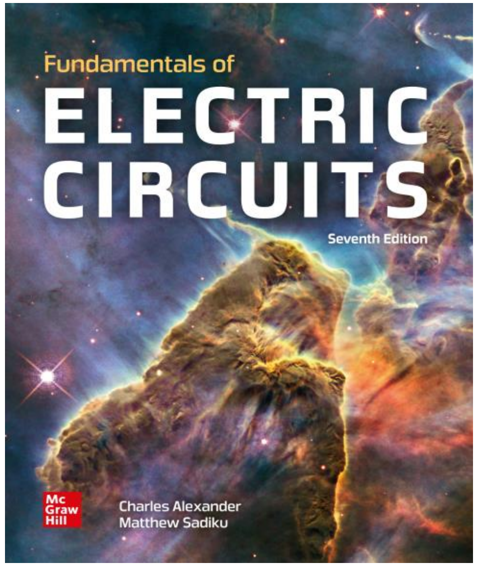
EHB 211E
Basics of Electrical Circuits

Asst. Prof. Onur Kurt

Basic Laws



Fundamentals of Electric Circuits by C. Alexander and M. Sadiku, Seventh Edition (McGraw-Hill Education)

Introduction

- Fundamental laws:
  - Ohm’s law
  - Kirchhoff’s law: Kirchhoff’s voltage law & Kirchhoff’s current law

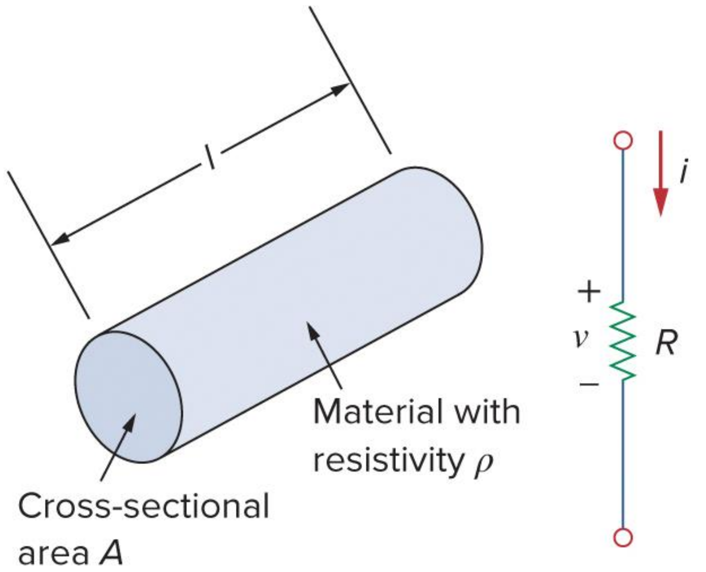
- Techniques applied in circuit design and analysis:
  - Combining resistors in series or parallel
  - Voltage division & current division
  - Delta-to-wye and wye-to-delta transformation

Ohm’s law

- What is resistance?
- Materials in general have a characteristic behavior of resisting the flow of electric charge. This physical property, or ability to resist current, is known as resistance.
- Resistance is represented by R, measure in ohms (Ω)
- Resistance in mathematical form:

$$\boxed{R = \rho\frac{\ell}{A}}$$

ρ is resistivity (Ω-m), l is the length (m), and A is cross-sectional area (m^2)



- Terminology:
  - Resistance: ability to resist current
  - Resistor: passive circuit element that create resistance

Ohm's law

- Resistivity, ρ, is material dependent properties.
- Conductor: low resistivity
- Insulator: high resistivity

Resistivities of common materials.

Material	Resistivity (Ω•m)	Usage
Silver	1.64×10^{-8}	Conductor
Copper	1.72×10^{-8}	Conductor
Aluminum	2.8×10^{-8}	Conductor
Gold	2.45×10^{-8}	Conductor
Carbon	4×10^{-5}	Semiconductor
Germanium	47×10^{-2}	Semiconductor
Silicon	6.4×10^{2}	Semiconductor
Paper	10^{10}	Insulator
Mica	5×10^{11}	Insulator
Glass	10^{12}	Insulator
Teflon	3×10^{12}	Insulator

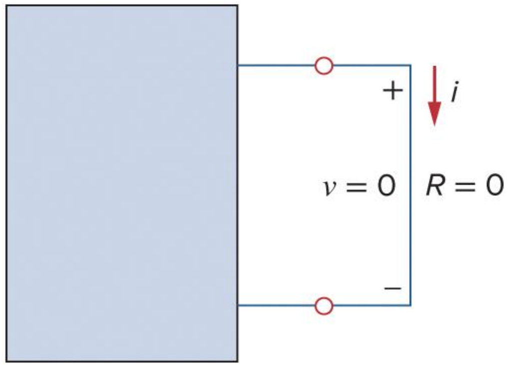
Ohm's law

- What is Ohm's law?
  - Ohm's law states that the voltage v across a resistor is directly proportional to the current i flowing through the resistor, i.e., $v \propto i$
  - By definition: $\boxed{v = i\,R}$ → Relation between voltage and current for a resistor

$$R = \frac{v}{i} \longrightarrow \Omega = \frac{V}{A}$$

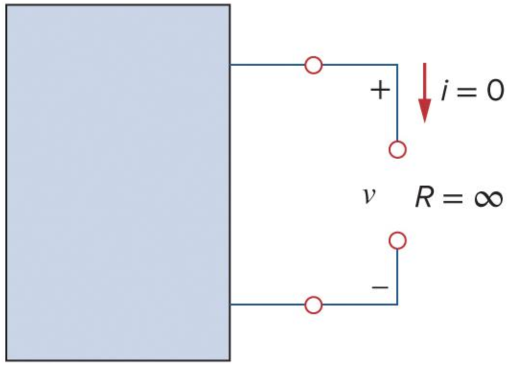
- Two extreme possible values of resistance R:

Short circuit: R approaches zero



$$v = i\,R = 0$$

Open circuit: R approaches infinity

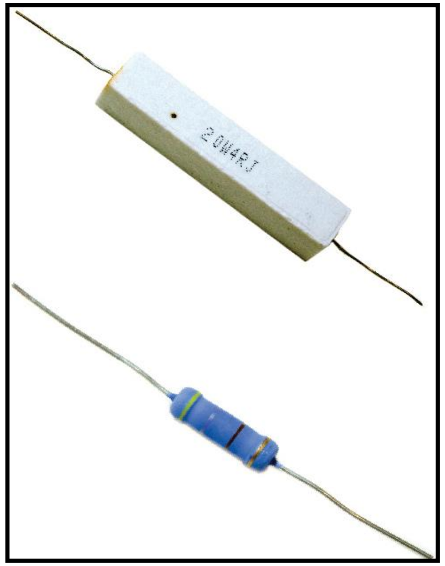


$$i = \lim_{R\to\infty} \frac{V}{R} = 0$$

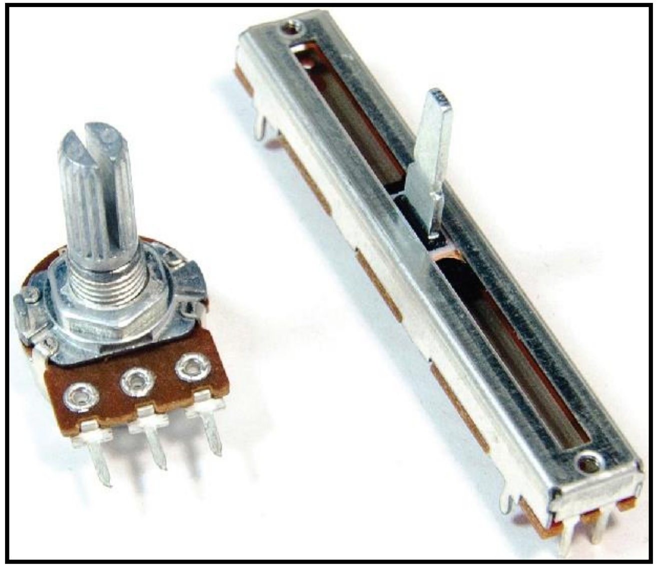
Resistors

- Two kinds of resistors: Fixed or variable

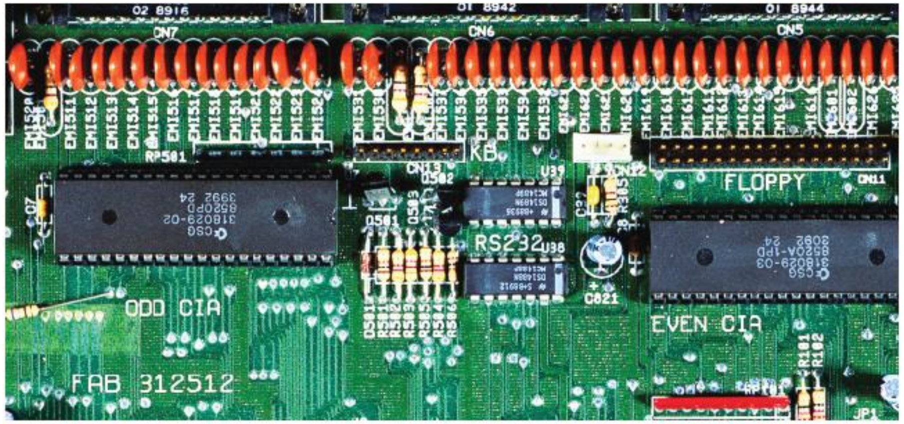
Fixed resistors



Variable resistors



Resistors in an integrated circuit board



Eric Tormey/Alamy

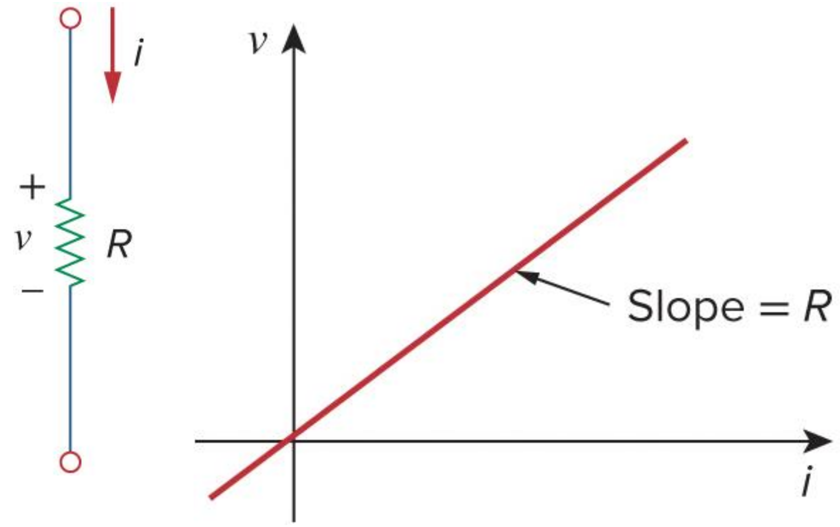
Circuit symbol of fixed resistor

Circuit symbol of variable resistor

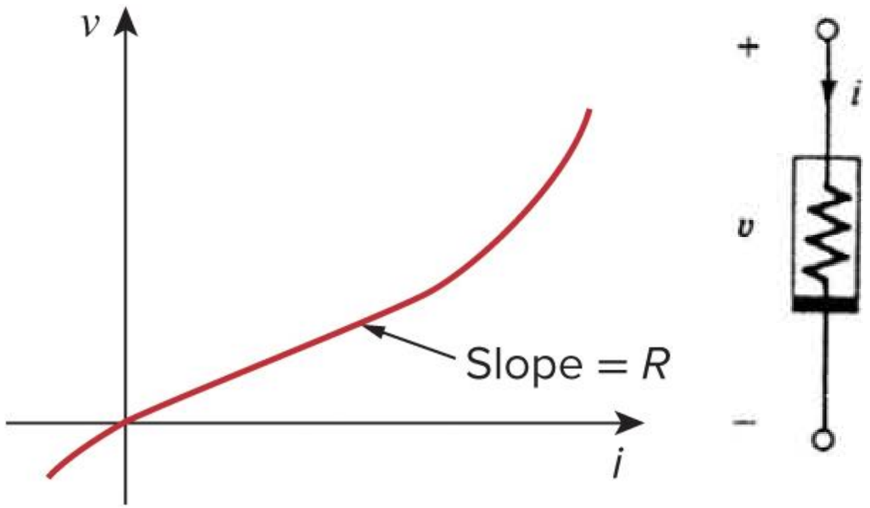
Ohm’s law

- Not all resistors obey Ohm’s law

Linear resistance: Obey Ohm’s law



Nonlinear resistance: Does not Obey Ohm’s law



- It has a constant resistance (slope)
- Its i-v graph is a straight line passing through the origin

- Its resistance (slope) varies with current
- Example: Light bulb, diode

Conductance

- What is conductance?
  - The ability of an element to conduct electric current or reciprocal of resistance R
  - It is denoted by G, and measured in mho(℧) or siemens (S)

$$\boxed{G = \frac{1}{R} = \frac{i}{v}} \longrightarrow \boxed{i = Gv}$$

$$1\,S = 1℧ = 1\,\frac{A}{V}$$

Power dissipated by the resistor (in terms of R):

$$\boxed{p = vi = i^2R = \frac{v^2}{R}}$$

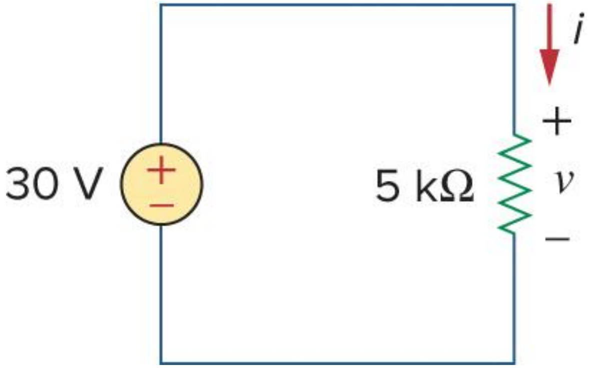
Power dissipated by the resistor (in terms of G)

$$\boxed{p = vi = v^2G = \frac{i^2}{G}}$$

- The power dissipated in a resistor is a nonlinear function of either current or voltage
- Since R and G are both positive, the power dissipated is a resistor is positive. Resistor always absorbs power from the circuit. Resistor is passive element (incapable of generating power)

Example 1:

- In the circuit shown below, calculate the current i, the conductance G, and the power p.



Solution:

- To calculate the current i, we need to use Ohm's law, i.e., $v = iR$
- Voltage across the resistor is same as the source voltage (30 V) since the source and resistor are connected to the same pair of terminals. Therefore, the current is:

$$v = iR \Rightarrow i = \frac{v}{R} \Rightarrow i = \frac{30}{5k} = 6mA$$

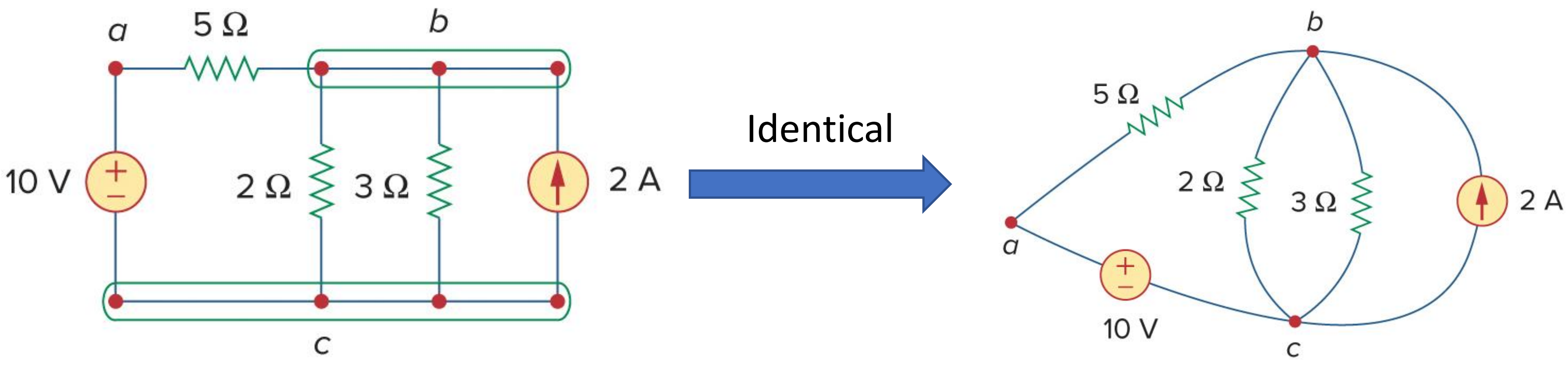
- The conductance G is: $G = \frac{1}{R} = \frac{1}{5k} = 0.2\ mS$

- The power p is: $p = vi = i^2R = \frac{v^2}{R}$ or $p = vi = v^2G = \frac{i^2}{G}$

$p = vi = 30 \times 6 \times 10^{-3} = 180\ mW$

Nodes-Branches-Loops

- Basic concepts of network topology: Nodes, Branches, and Loops.
- What is a branch?
  - A single element such as voltage source or a resistor (any two-terminal element)
- What is a node?
  - The point of connection between two or more branches and usually indicated by a dot.
  - If a short circuit (connecting wire) connects two nodes, the nodes constitute a single node.

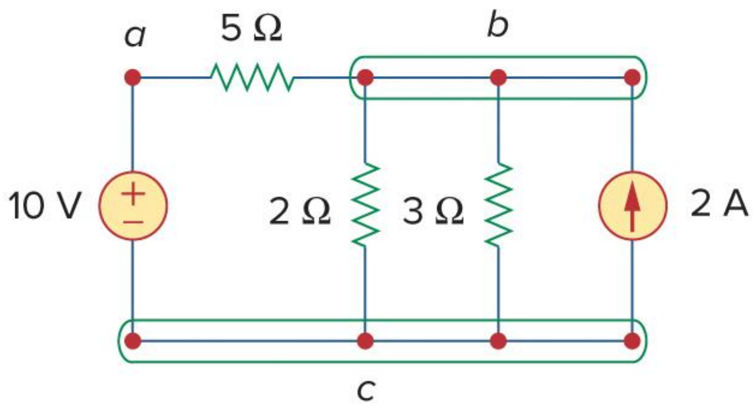


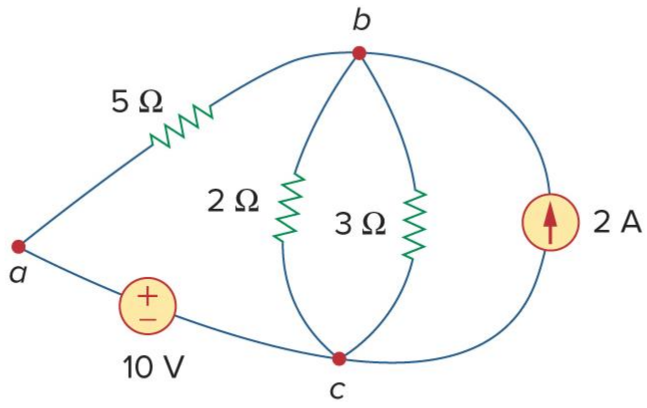
- 5 branches: 10 V voltage source, 2 A current source, and three resistors

- 3 nodes: node a, node b, and node c

Nodes-Branches-Loops

- What is a loop?
  - Any closed path in a circuit.
  - A loop is a closed path formed by starting at a node, passing through a set of nodes, and returning to the starting node without passing through any nodes more than once.
  - A loop said to be independent if it contains at least one branch which is not a part of any other independent loop
  - Independent loops or paths result in independent set of equations.





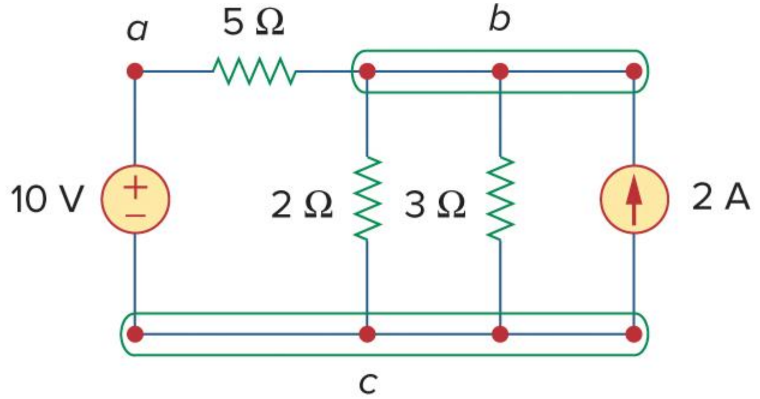
- <u>Three independent loops:</u>
  - 1st loop: voltage source and two resistors (5 Ω & 2 Ω)
  - 2nd loop: voltage source and two resistors (5 Ω & 3 Ω)
  - 3rd loop: voltage source, current source, and a resistor (5 Ω)

Fundamental Theorem of Network Topology

- A network with b branches, n nodes, and l independent loops will always satisfy the fundamental theorem of network topology.

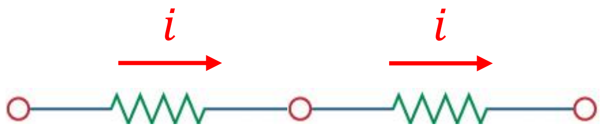
$$\boxed{b = l + n - 1}$$

b: # of branches,
l: # of independent loop
n: # of nodes



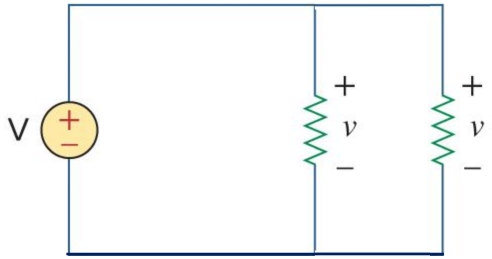
$$b = 5, l = 3, n = 3$$

<u>Series Connection</u>



Two or more elements carry same current if they are in series

<u>Parallel Connection</u>



Two or more elements have same voltage if they are in parallel

Kirchhoff’s Law

- Ohm’s law: not sufficient to analyze circuits by itself
- Ohm’s law coupled with Kirchhoff’s law: very powerful set of tools for analyzing a large variety of electric circuits.

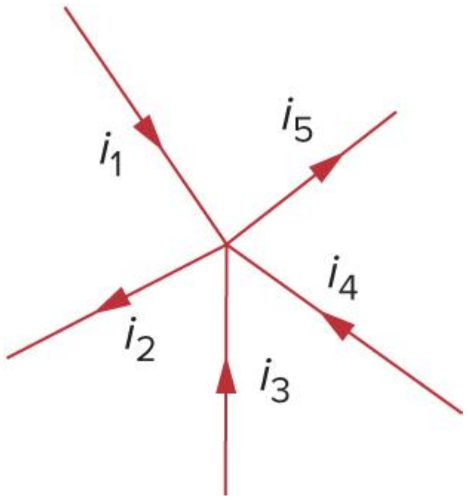
- Two Kirchhoff’s law:
    - Kirchhoff’s Current Law (KCL)
    - Kirchhoff’s Voltage Law (KVL)

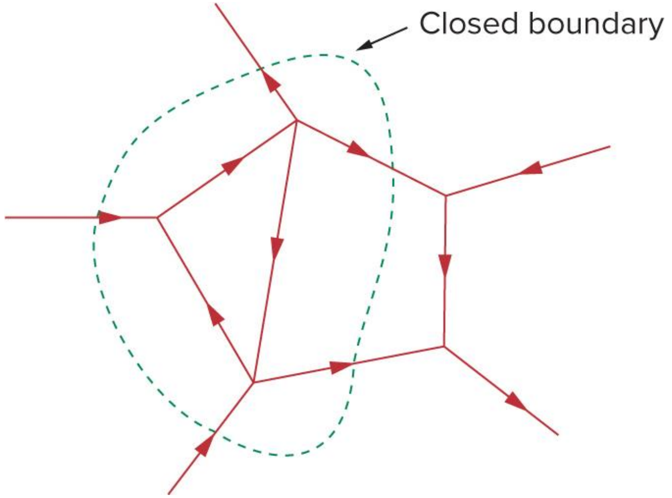
Kirchhoff’s Current Law (KCL)

- What is Kirchhoff’s Current Law (KCL)?
  - Algebraic sum of currents entering a node (or a closed boundary) is zero.
  - Sum of currents entering a node is equal to the sum of currents leaving from that node.
- Mathematically, KCL is given by:

$$\boxed{\sum_{n=1}^{N} i_n = 0}$$

N: # of branches connected to the nodes
i_n : *n*th current entering (or leaving) the node





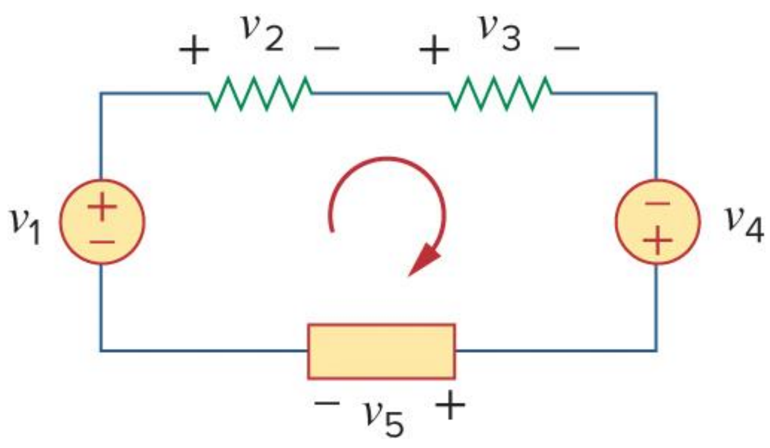
$i_1 + i_3 + i_4 = i_2 + i_5$ or $i_1 + (-i_2) + i_3 + i_4 + (-i_5) = 0$

Kirchhoff's Voltage Law (KVL)

- What is Kirchhoff's Voltage Law (KVL)?
  - Algebraic sum of all voltages around a closed path (or loop) is zero.
- Mathematically, KVL is given by:

$$\boxed{\sum_{m=1}^{M} V_m = 0}$$

M: # of voltages in the loop
V_m : mth voltage

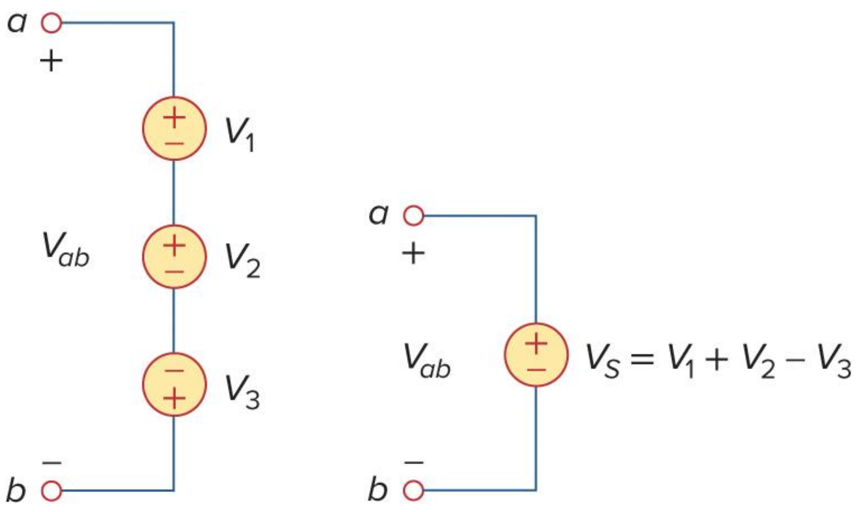


$$-v_1 + v_2 + v_3 - v_4 + v_5 = 0$$

or

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

Sum of voltage drop = sum of voltage rise

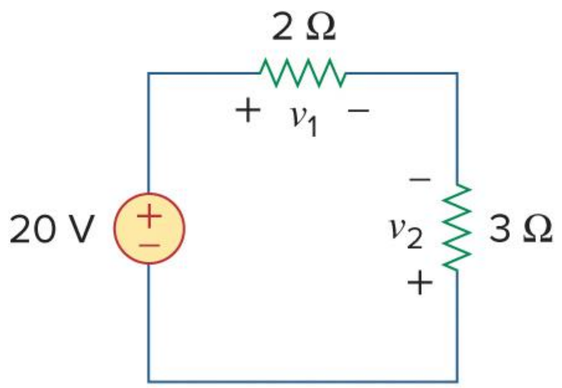


$$-v_{ab} + v_1 + v_2 - v_3 = 0$$

$$v_{ab} = v_1 + v_2 - v_3$$

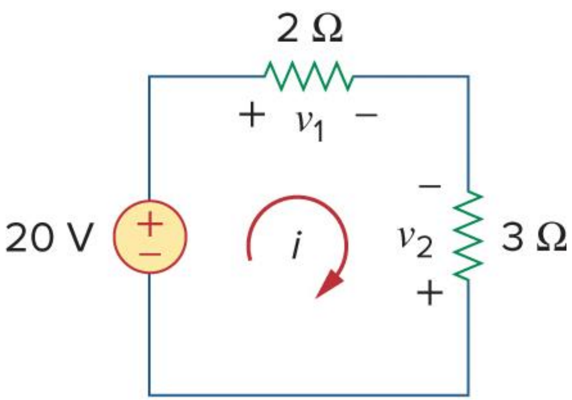
Example 2:

- For the circuit shown below, find v_1 & v_2



Solution:

- In order to find v_1 & v_2 , we apply Ohm's law and Kirchhoff's voltage law.



Assume that current i flows through the loop (clockwise direction)

Ohm's law: $v = iR$

$$v_1 = 2i \qquad v_2 = -3i$$

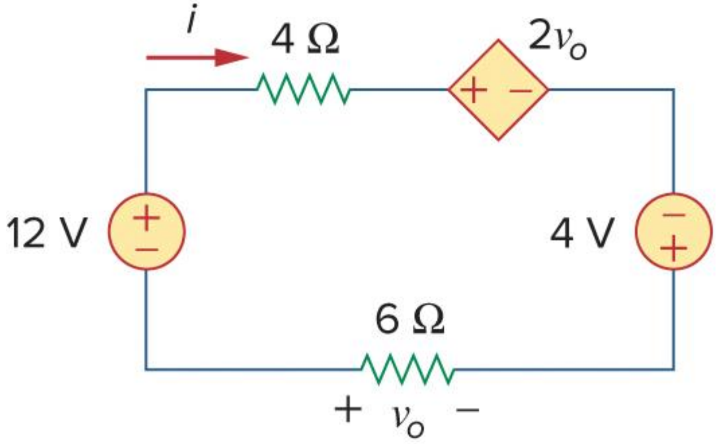
Applying KVL around the loop gives

$$-20 + v_1 - v_2 = 0$$

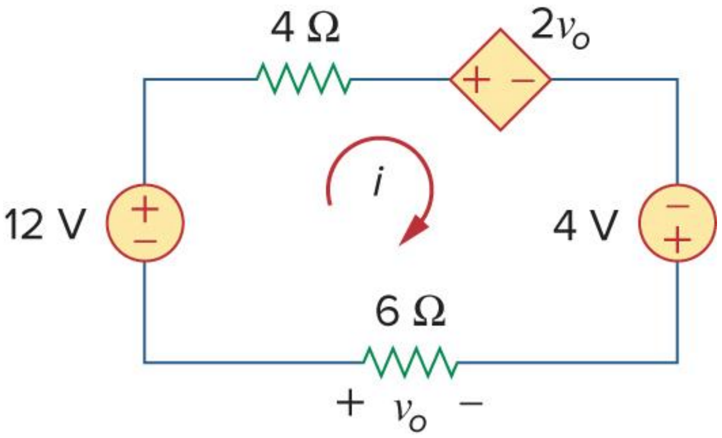
$$-20 + 2i - (-3i) = 0 \Rightarrow \boxed{i = 4\ A}$$

Example 3:

- Determine v_0 & i in the circuit shown below



Solution:



Applying KVL around the loop gives

$$-12 + 4i + 2v_0 - 4 - v_0 = 0$$

$$-12 + 4i + 2(-6i) - 4 - (-6i) = 0$$

$$\boxed{i = -8\ A}$$

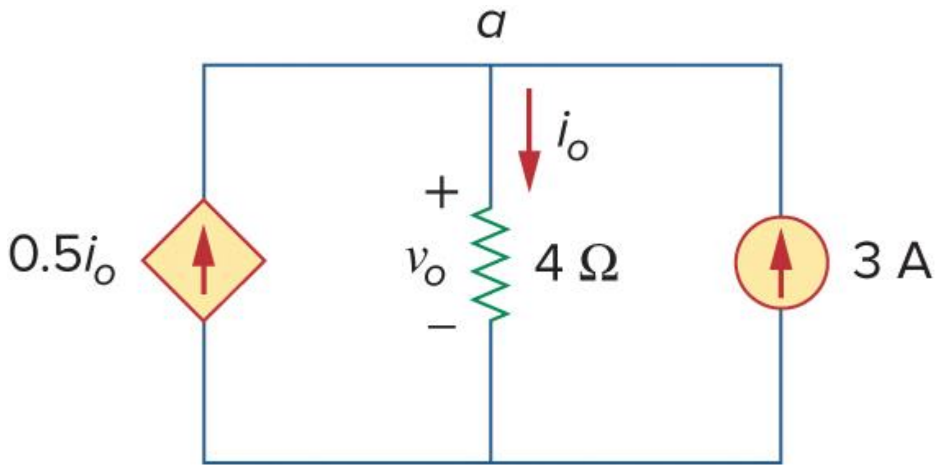
$$v_0 = -6i \Rightarrow \boxed{v_0 = 64\ V}$$

Ohm's law: $v = iR$

$$v_0 = -6i$$

Example 4:

Find current i_o and voltage v_o in the circuit



Solution:

Applying KCL to node a, we obtain

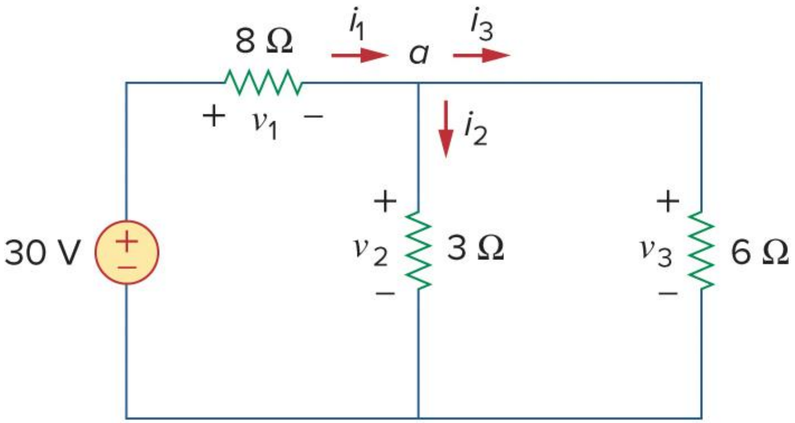
$$3 + 0.5i_o = i_o \qquad \Rightarrow \qquad i_o = 6 \text{ A}$$

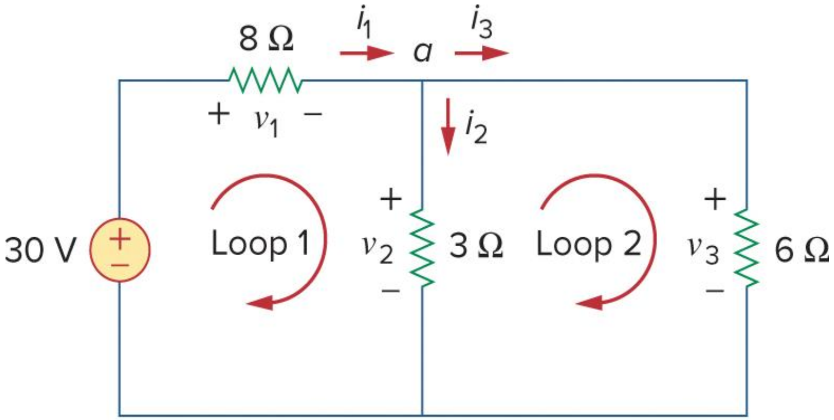
For the 4-Ω resistor, Ohm's law gives

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

Example 5:

Find currents and voltages in the circuit





Solution:

We apply Ohm's law and Kirchhoff's laws. By Ohm's law,

$$v_1 = 8i_1, \qquad v_2 = 3i_2, \qquad v_3 = 6i_3$$

At node a, KCL gives

$$i_1 - i_2 - i_3 = 0$$

Applying KVL to loop 1

$$-30 + v_1 + v_2 = 0$$

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

$$i_1 = \frac{(30 - 3i_2)}{8}$$

Applying KVL to loop 2,

$$-v_2 + v_3 = 0 \quad \Rightarrow \quad v_3 = v_2$$

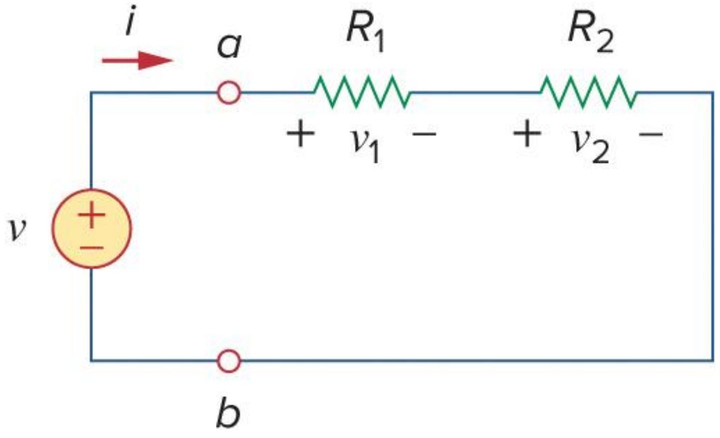
$$6i_3 = 3i_2 \quad \Rightarrow \quad i_3 = \frac{i_2}{2}$$

$$\frac{30 - 3i_2}{8} - i_2 - \frac{i_2}{2} = 0 \Rightarrow i_2 = 2\text{ A}$$

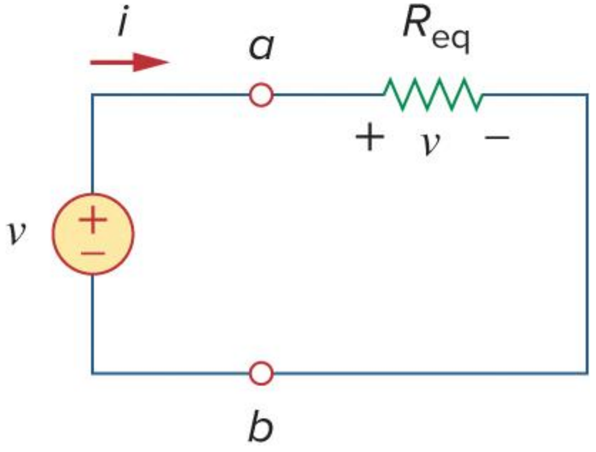
$$i_1 = 3\text{ A}, \qquad i_3 = 1\text{ A}, \qquad v_1 = 24\text{ V},$$

$$v_2 = 6\text{ V}, \qquad v_3 = 6\text{ V}$$

Series Resistors and Voltage Division



Equivalent Circuit



R_1 & R_2 are in series since same current i flows through them

Apply Ohm's law: $v_1 = iR_1$ & $v_2 = iR_2$

Apply KVL to the loop (Clockwise): $-v + v_1 + v_2 = 0$

Combining equations, we get:

$$v = v_1 + v_2 \Rightarrow iR_1 + iR_2 \Rightarrow \mathrm{i}(R_1 + R_2)$$

$v = \mathrm{i}(R_1 + R_2)$ or $i = \frac{v}{(R_1+R_2)}$

This equation can be written as follows:

$\mathrm{v} = \mathrm{i}(R_{eq})$ where $R_{eq} = R_1 + R_2$

Equivalent resistance of any number of resistors connected in series is the sum of the individual resistance

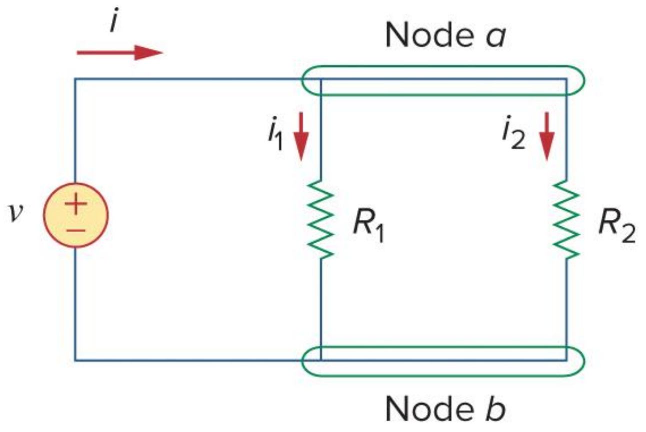
In general, for N resistors in series:

$$R_{eq} = R_1 + R_2 + R_3 + \cdots + R_N = \sum_{n=1}^{N} R_N$$

<u>Voltage division:</u>

$$v_1 = \frac{R_1}{(R_1 + R_2)} v \quad \text{and} \quad v_2 = \frac{R_2}{(R_1 + R_2)} v$$

Parallel Resistors and Current Division



Equivalent resistance of two parallel resistors is equal to the product of their resistances divided by their sum

R_1 & R_2 are connected in parallel and therefore they have same voltage across them

Apply Ohm's law: $v = i_1 R_1 = i_2 R_2$

Apply KCL at node a: $i = i_1 + i_2$

Combining equations, we get:

$$i = \frac{v}{R_1} + \frac{v}{R_2} = v\left(\frac{1}{R_1} + \frac{1}{R_2}\right) \Rightarrow \frac{v}{R_{eq}}$$

where $R_{eq} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{R_1 \times R_2}{R_1 + R_2}$

In general, for N resistors in parallel:

$$R_{eq} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_N}$$

If $R_1 = R_2 = R_3 = \cdots = R_N = R$,

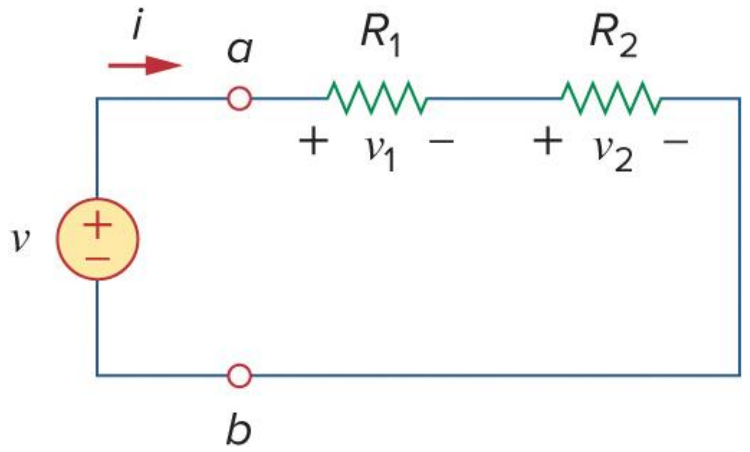
$$R_{eq} = \frac{R}{R_N}$$

Current division:

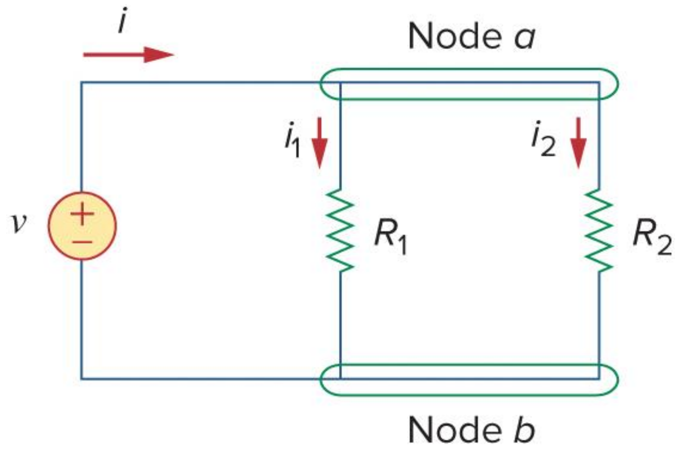
$$i_1 = \frac{R_2}{(R_1 + R_2)} i \quad \text{and} \quad i_2 = \frac{R_1}{(R_1 + R_2)} i$$

Equivalent Conductance

- By definition: $G = \dfrac{1}{R}$ (Reciprocal of resistance)



$$\frac{1}{G_{eq}} = \frac{1}{G_1} + \frac{1}{G_2}$$



$$G_{eq} = G_1 + G_2$$

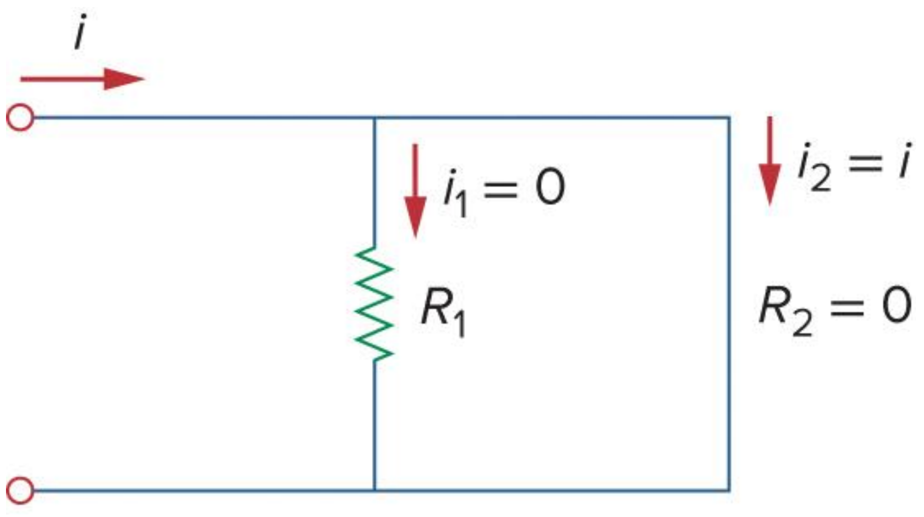
Equivalent conductance for N resistors in series:

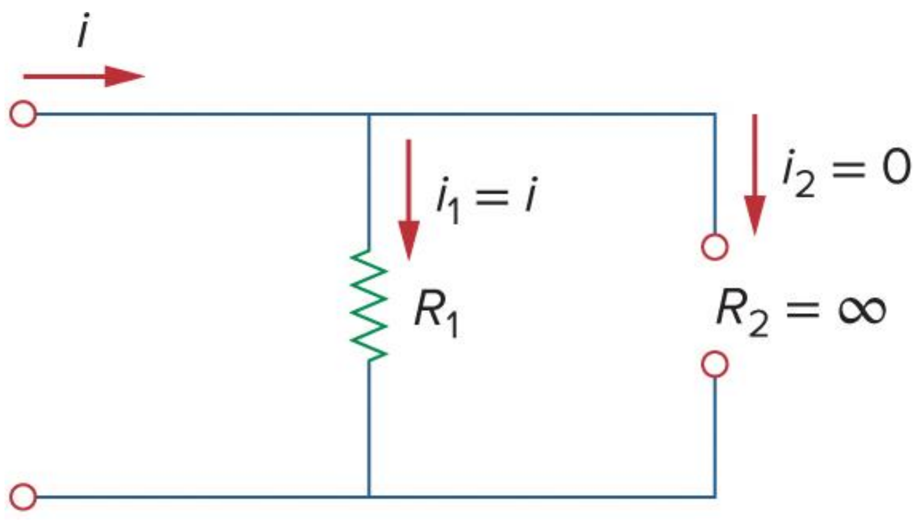
$$\frac{1}{G_{eq}} = \frac{1}{G_1} + \frac{1}{G_2} + \frac{1}{G_3} + \cdots + \frac{1}{G_N}$$

Equivalent conductance for N resistors in parallel:

$$G_{eq} = G_1 + G_2 + G_3 + \cdots + G_N$$

Short Circuit and Open Circuit Case





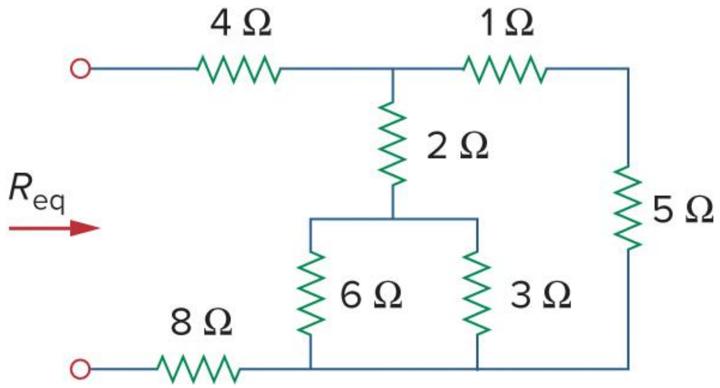
Entire current i bypasses R_1 and flows through the short circuit

Current always prefers to use path without resistance if possible

Entire current i flows through R_1 since there is an open circuit on the other side.

Example 6:

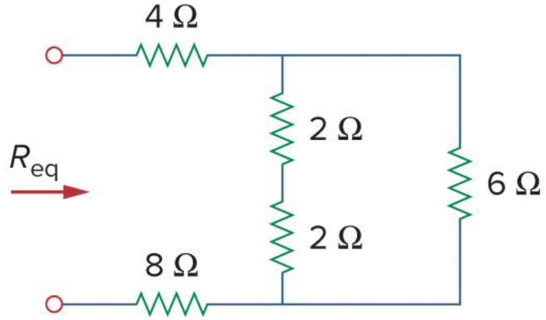
Find R_{eq} for the circuit



Solution:

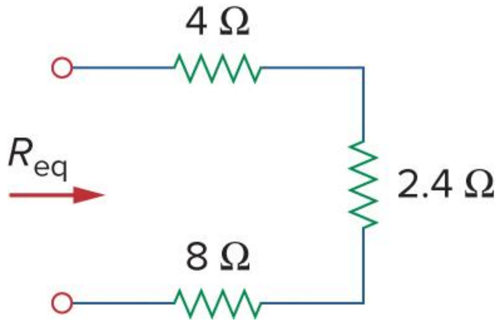
$$6\ \Omega \parallel 3\Omega = \frac{6 \times 3}{6 + 3} = 2\ \Omega$$

$$1\ \Omega + 5\ \Omega = 6\ \Omega$$



$$2\ \Omega + 2\ \Omega = 4\ \Omega$$

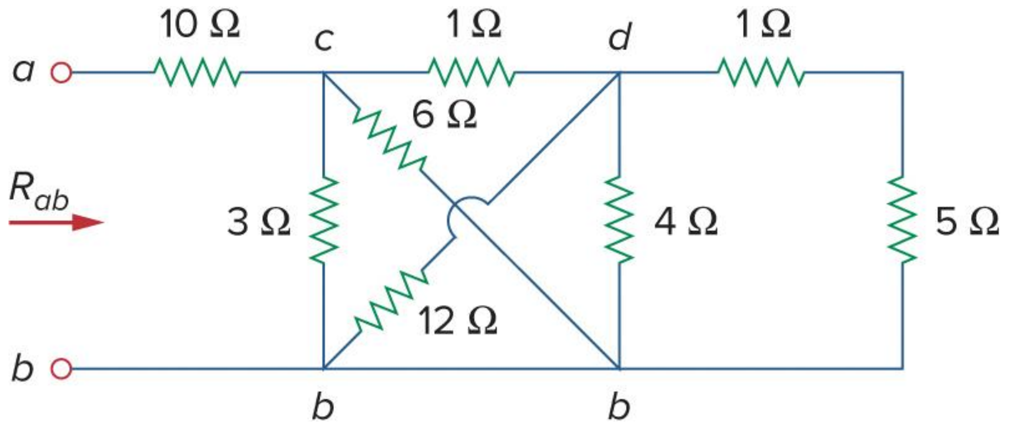
$$4\ \Omega \parallel 6\ \Omega = \frac{4 \times 6}{4 + 6} = 2.4\ \Omega$$



$$R_{eq} = 4\ \Omega + 2.4\ \Omega + 8\ \Omega = 14.4\ \Omega$$

Example 7:

Calculate the equivalent resistance R_{ab}

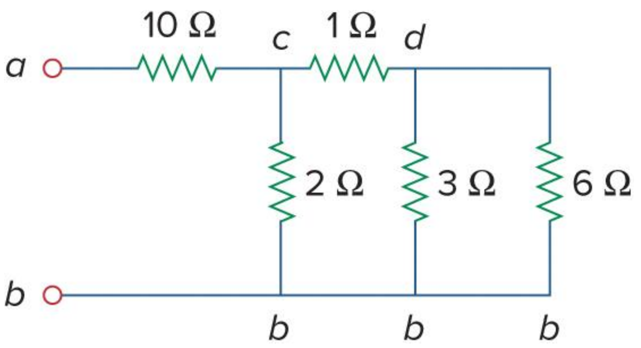


Solution:

$$3\ \Omega \parallel 6\ \Omega = \frac{3 \times 6}{3 + 6} = 2\ \Omega$$

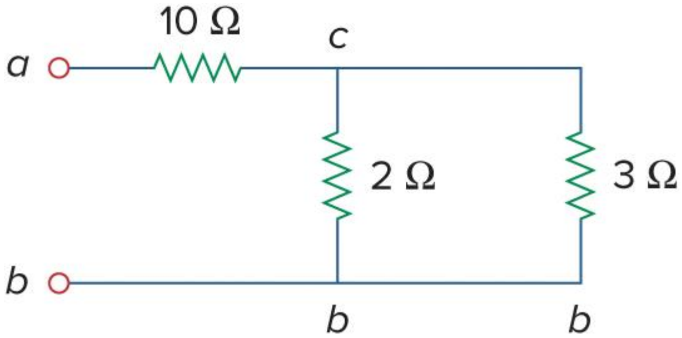
$$12\ \Omega \parallel 4\ \Omega = \frac{12 \times 4}{12 + 4} = 3\ \Omega$$

$$1\ \Omega + 5\ \Omega = 6\ \Omega$$



$$3\ \Omega \parallel 6\ \Omega = \frac{3 \times 6}{3 + 6} = 2\ \Omega$$

$$1\ \Omega + 2\ \Omega = 3\ \Omega$$

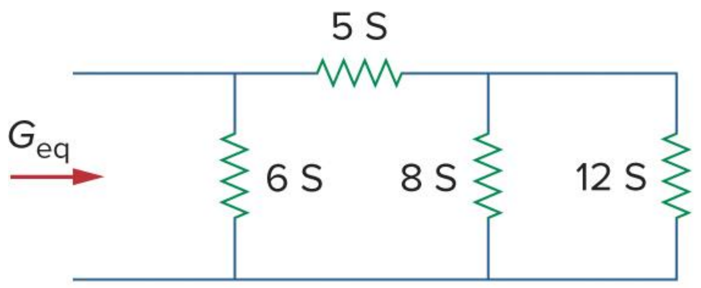


$$2\ \Omega \parallel 3\ \Omega = \frac{2 \times 3}{2 + 3} = 1.2\ \Omega$$

$$R_{ab} = 10 + 1.2 = 11.2\ \Omega$$

Example 8:

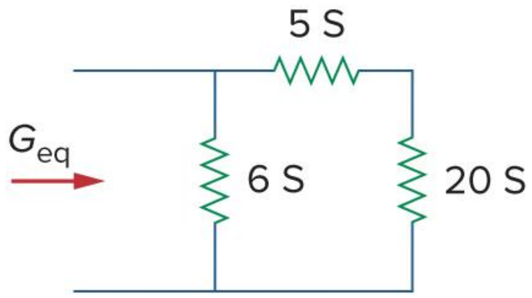
Find the equivalent conductance G_{eq}



Solution:

The 8-S and 12-S resistors are in parallel, so their conductance is

$$8\text{ S} + 12\text{ S} = 20\text{ S}$$



This 20-S resistor is now in series with 5 S

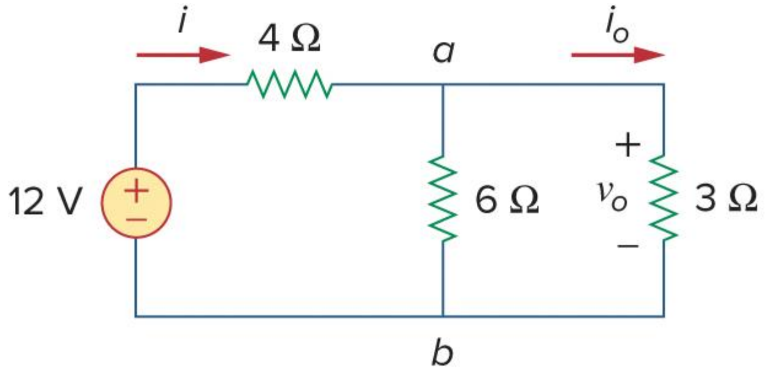
$$\frac{20 \times 5}{20 + 5} = 4\text{ S}$$

This is in parallel with the 6-S resistor.

$$G_{eq} = 6 + 4 = 10\text{ S}$$

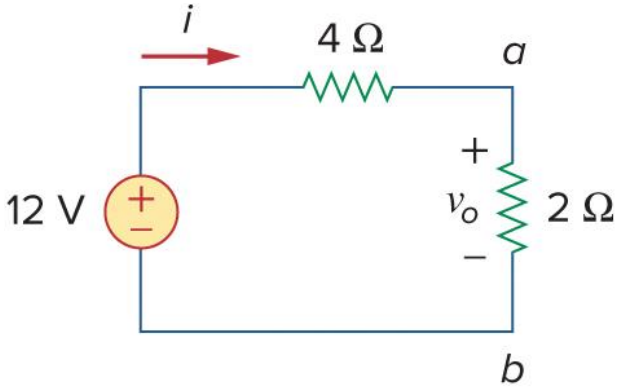
Example 9:

Find i_o and v_o in the circuit shown below. Calculate the power dissipated in 3-Ω resistor.



Solution:

$$6\Omega || 3\Omega = \frac{6 \times 3}{6+3} = 2\Omega$$



Apply voltage division: $v_0 = \dfrac{R_1}{(R_1 + R_2)} v$ $\Rightarrow$ $v_0 = \dfrac{2}{(2+4)} 12 = 4\ V$

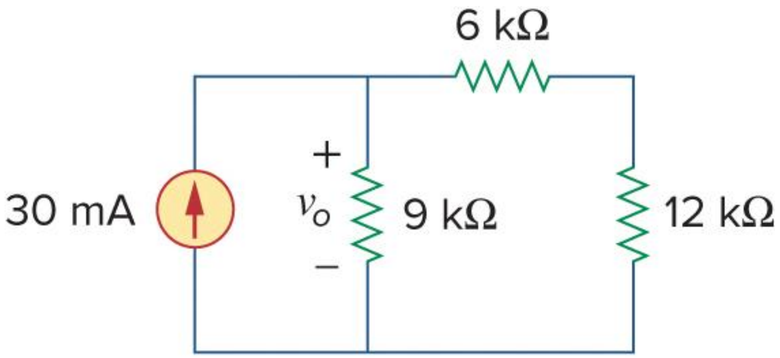
Apply Ohm's law: $v = iR$ $\Rightarrow$ $v_0 = i_0 3 \Rightarrow i_0 = \dfrac{4}{3} A$

Power dissipation: $p_0 = v_0\, i_0$ $\Rightarrow$ $p_0 = 4 \times \dfrac{4}{3} = \dfrac{16}{3} = 5.333\ W$

<u>Recall:</u>
Supply power: Negative (-)
Absorb power: Positive (+)
Resistor: passive element

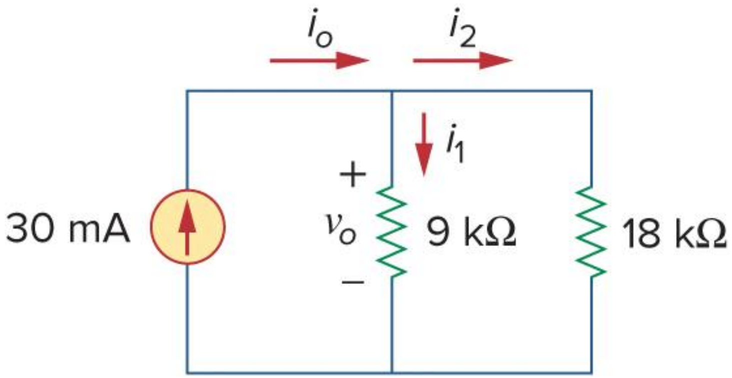
Example 10:

For the circuit shown below, determine: a-) voltage v_o, b-) the power supplied by the current source, and c-) the power absorbed by each resistor.



Solution:

6-kΩ and 12-kΩ resistors in series. Thus, 6+12=18-kΩ



Apply current division:

$$i_1 = \frac{R_2}{(R_1 + R_2)} i_0 \Rightarrow i_1 = \frac{18}{(9+18)} 30\ (mA) = 20\ mA$$

$$i_2 = \frac{R_1}{(R_1 + R_2)} i_0 \Rightarrow i_2 = \frac{9}{(9+18)} 30\ (mA) = 10\ mA$$

Power supplied = power absorbed

Apply Ohm's law: $v_0 = i_1 9 = 20 \times 9 = 180\ V$

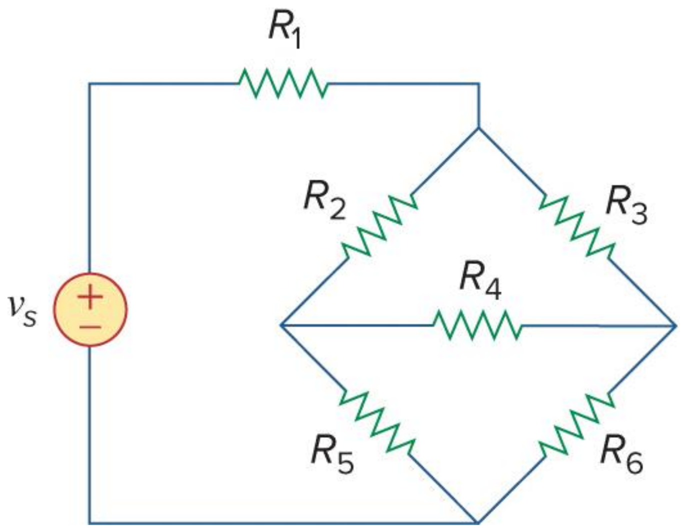
Power dissipation: $p = vi$

$$p_9 = 180 \times 20 = 3600\ mW = 3.6\ W$$

$$p_{12} = vi = (i_2 R) i_2 = {i_2}^2 R = 10^2 \times 12 = 1.2\ W$$

$$p_6 = 10^2 \times 6 = 0.6\ W,\ p_{cur} = 180 \times 30 = 5.4\ W$$

Wye-Delta Transformations

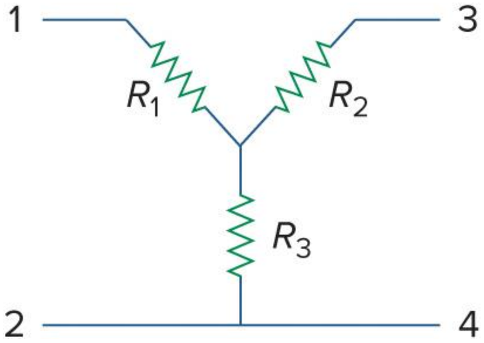


Resistors are neither in parallel nor in series

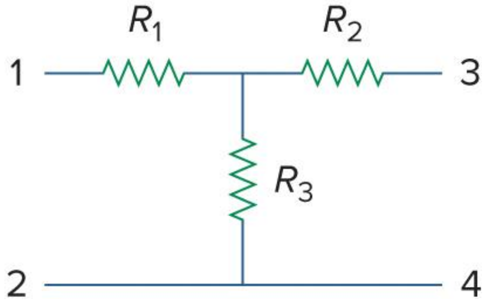
How do we combine resistors R1 through R6?

- These types of circuits can be simplified by using three-terminal equivalent networks:

Wye (Y) network

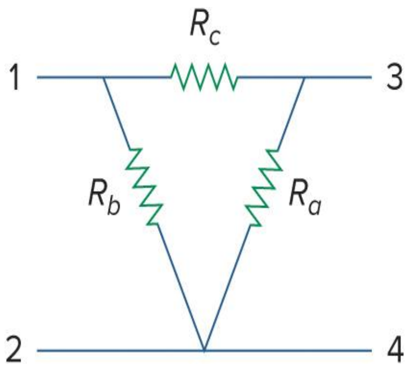


Tee (T) network

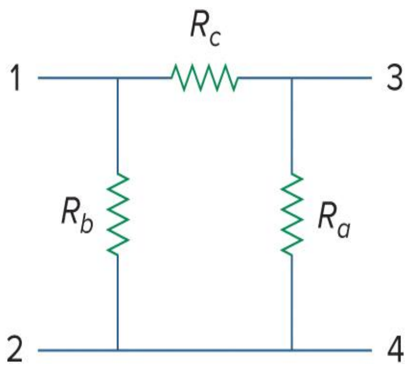


Two forms of same network

Delta (Δ) network

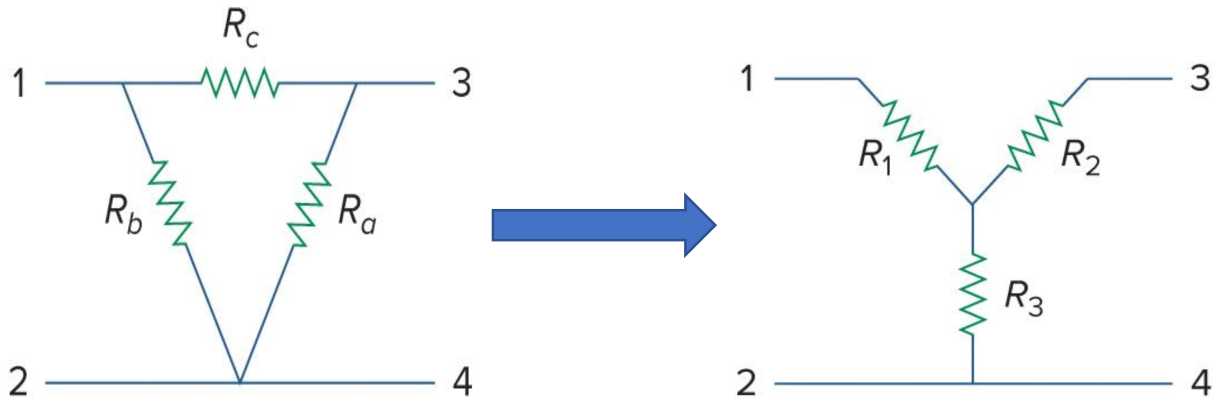


Pi (Π) network



Two forms of same network

Delta to Wye Conversion



For terminal 1 & 2:

$$R_{12}(\mathrm{Y}) = R_1 + R_3$$
$$R_{12}(\Delta) = R_b \parallel (R_a + R_c)$$

Setting $R_{12}(Y) = R_{12}(\Delta)$: $R_{12} = R_1 + R_3 = \dfrac{R_b(R_a + R_c)}{R_a + R_b + R_c}$ Eq 1

Similarly,

$$R_{13} = R_1 + R_2 = \frac{R_c(R_a + R_b)}{R_a + R_b + R_c} \quad \text{Eq 2}$$

$$R_{34} = R_2 + R_3 = \frac{R_a(R_b + R_c)}{R_a + R_b + R_c} \quad \text{Eq 3}$$

Subtracting eq 1 & eq 3: $R_1 - R_2 = \dfrac{R_c(R_b - R_a)}{R_a + R_b + R_c}$ Eq 4

Adding eq 4 & eq 2:

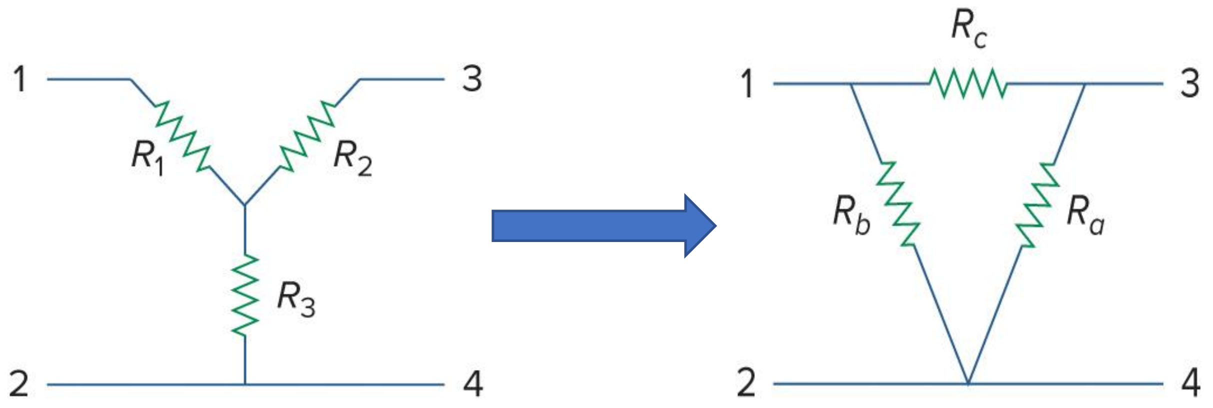
$$\boxed{R_1 = \frac{R_b R_c}{R_a + R_b + R_c}}$$

$$\boxed{R_2 = \frac{R_c R_a}{R_a + R_b + R_c}}$$

$$\boxed{R_3 = \frac{R_a R_b}{R_a + R_b + R_c}}$$

Each resistor in the Y network is the product of the resistors in the two adjacent Δ branches, divided by the sum of the three Δ resistors.

Wye to Delta Conversion



Combining eqs 1, 2, and 3 obtained in the previous step, we get:

$$R_1R_2 + R_2R_3 + R_3R_1 = \frac{R_aR_bR_c(R_a + R_b + R_c)}{(R_a + R_b + R_c)^2} = \frac{R_aR_bR_c}{R_a + R_b + R_c}$$

Dividing the eq by each eq (1, 2, and 3) obtained in the previous step, we get:

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

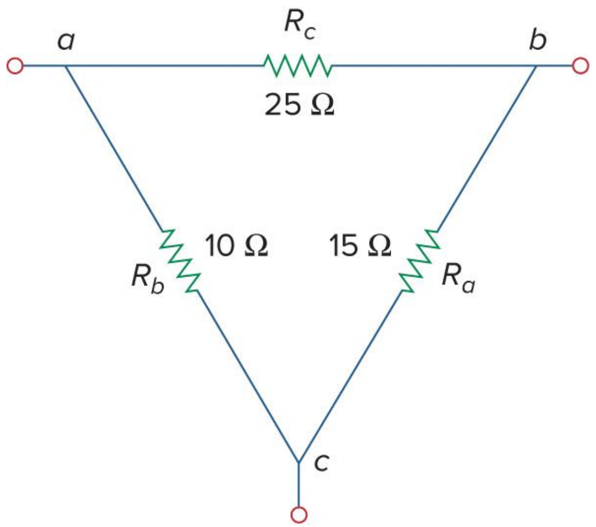
$$\boxed{R_b = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2}}$$

$$\boxed{R_c = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3}}$$

Each resistor in the Δ network is the sum of all possible products of the Y resistor taken two at a time, divided by the opposite Y resistor.

Example 11:

Convert the Δ network in the figure below to an equivalent Y network

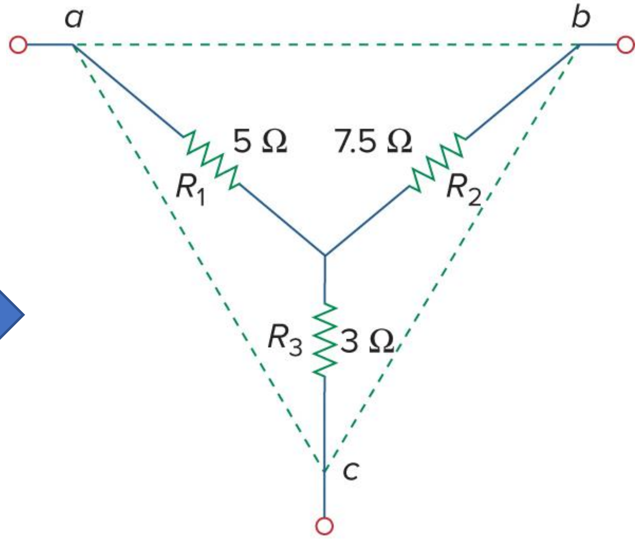


Solution:

$$R_1 = \frac{R_b R_c}{R_a + R_b + R_c} = \frac{10 \times 25}{15 + 10 + 25} = \frac{250}{50} = 5\ \Omega$$

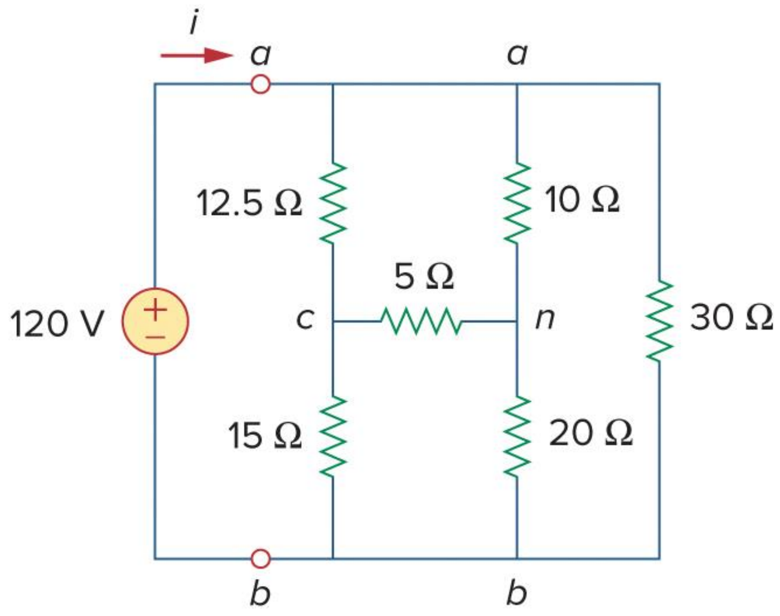
$$R_2 = \frac{R_c R_a}{R_a + R_b + R_c} = \frac{25 \times 15}{50} = 7.5\ \Omega$$

$$R_3 = \frac{R_a R_b}{R_a + R_b + R_c} = \frac{15 \times 10}{50} = 3\ \Omega$$



Example 12:

Obtain the equivalent resistance R_{ab} for the circuit shown on the right and use it to find i.



Solution:

In the circuit, there are two Y networks (one at node n and the other at node c) and three Δ networks (can, abn, cnb).

If we convert the Y network comprising the 5-Ω, 10-Ω, and 20-Ω resistors, we may select

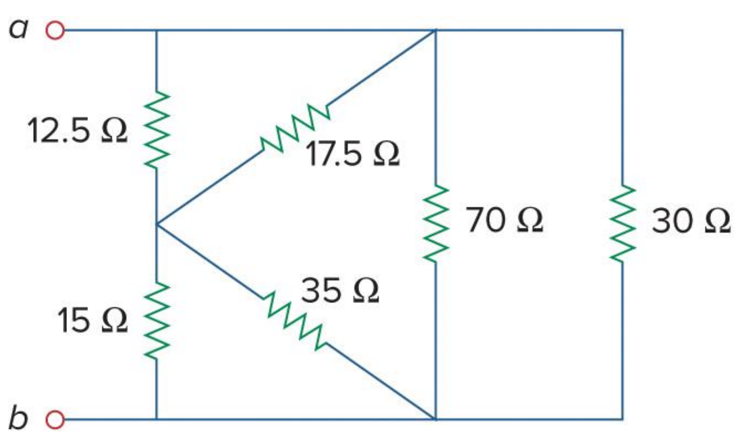
$$R_1 = 10\ \Omega, \qquad R_2 = 20\ \Omega, \qquad R_3 = 5\ \Omega$$

$$R_a = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_1} = \frac{10 \times 20 + 20 \times 5 + 5 \times 10}{10}$$

$$= \frac{350}{10} = 35\ \Omega$$

$$R_b = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_2} = \frac{350}{20} = 17.5\ \Omega$$

$$R_c = \frac{R_1R_2 + R_2R_3 + R_3R_1}{R_3} = \frac{350}{5} = 70\ \Omega$$



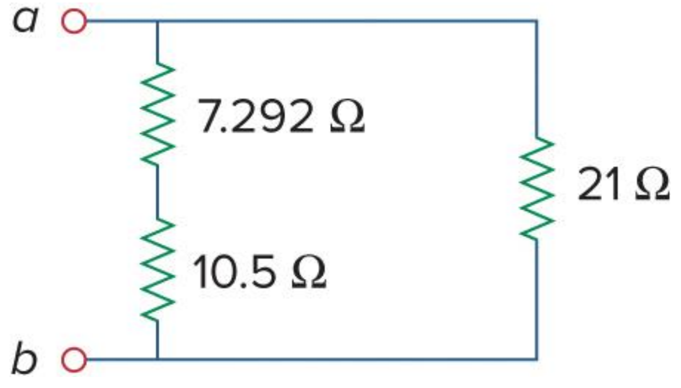
Example 12 Continuing:

Combining the three pairs of resistors in parallel, we obtain

$$70 \parallel 30 = \frac{70 \times 30}{70 + 30} = 21\ \Omega$$

$$12.5 \parallel 17.5 = \frac{12.5 \times 17.5}{12.5 + 17.5} = 7.292\ \Omega$$

$$15 \parallel 35 = \frac{15 \times 35}{15 + 35} = 10.5\ \Omega$$



$$R_{ab} = (7.292 + 10.5) \parallel 21 = \frac{17.792 \times 21}{17.792 + 21} = \mathbf{9.632\ \Omega}$$

Ohm's law: $v = iR \Rightarrow i = \frac{v_s}{R_{ab}} = \frac{120}{9.632} = \mathbf{12.458\ A}$

Example 12: Second Way

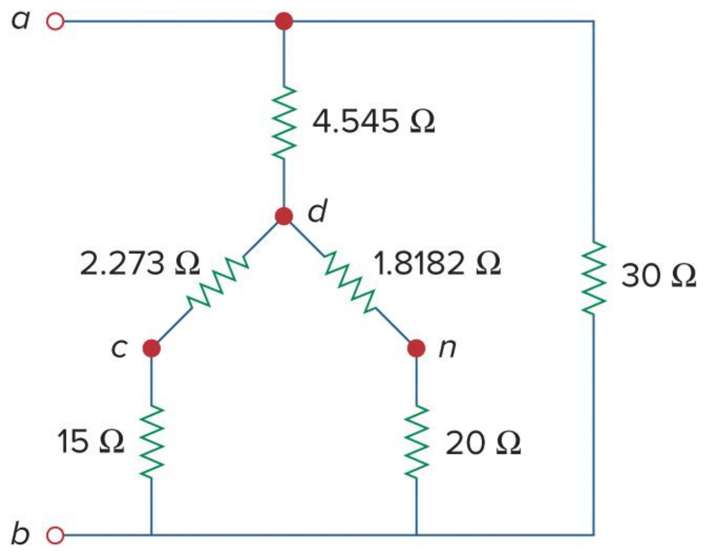
Solving with Δ to Y conversion. Transform Δ (can) to Y

Let $R_c = 10\ \Omega$, $R_a = 5\ \Omega$, and $R_n = 12.5\ \Omega$. This will lead

$$R_{ad} = \frac{R_c R_n}{R_a + R_c + R_n} = \frac{10 \times 12.5}{5 + 10 + 12.5} = 4.545\ \Omega$$

$$R_{cd} = \frac{R_a R_n}{27.5} = \frac{5 \times 12.5}{27.5} = 2.273\ \Omega$$

$$R_{nd} = \frac{R_a R_c}{27.5} = \frac{5 \times 10}{27.5} = 1.8182\ \Omega$$



Resistance between d and b, we have two series combination in parallel, i.e.,

$$R_{db} = \frac{(2.273 + 15)(1.8182 + 20)}{2.273 + 15 + 1.8182 + 20} = \frac{376.9}{39.09} = 9.642\ \Omega$$

This is in series with the 4.545-Ω and the resultant resistance parallel with 30- Ω resistor.

$$R_{ab} = \frac{(9.642 + 4.545)30}{9.642 + 4.545 + 30} = \frac{425.6}{44.19} = \mathbf{9.631\ \Omega}$$

Ohm's law: $v = iR \Rightarrow i = \frac{v_s}{R_{ab}} = \frac{120}{9.632} = \mathbf{12.458\ A}$