CSE251: Electronic Devices and Circuits

Lecture 1

Alt. Representation, CSE250 Review, IV Characteristics

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Alternative Circuit Representation: Line diagrams

Steps to decompose circuits to line diagram

1. Set a ground so that number of **floating voltage** sources are minimized.

2. Detach the ground

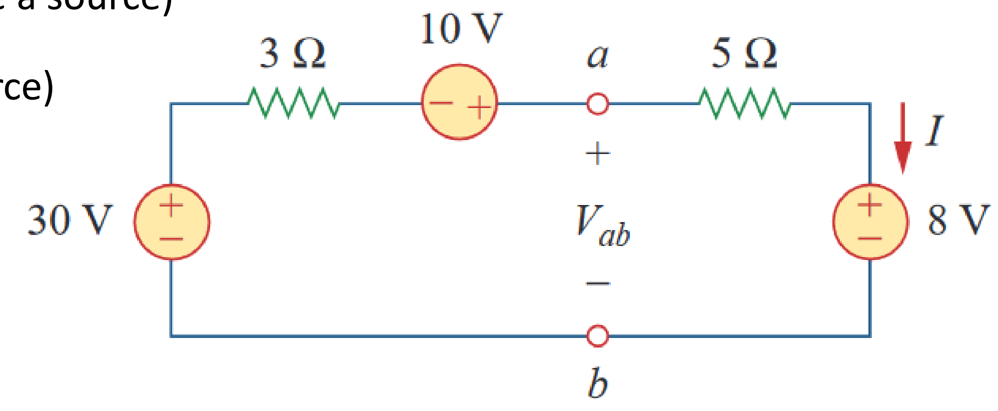
3. Convert the non-floating voltage sources (~~current sources~~) into:

    - Arrow : ($\rightarrow$) **Fixed/Constant voltage source**
    - Open circle dot: ($-\text{o}$) Input/Output node voltage (may or may not be a source)
    - Filled circle dot: ($-\bullet$) Known node voltage (may or may not be a source)

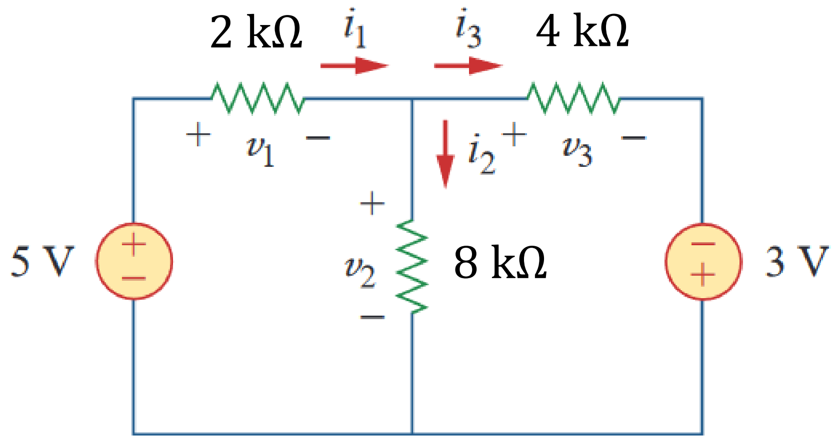
4. Keep passive elements as they are.

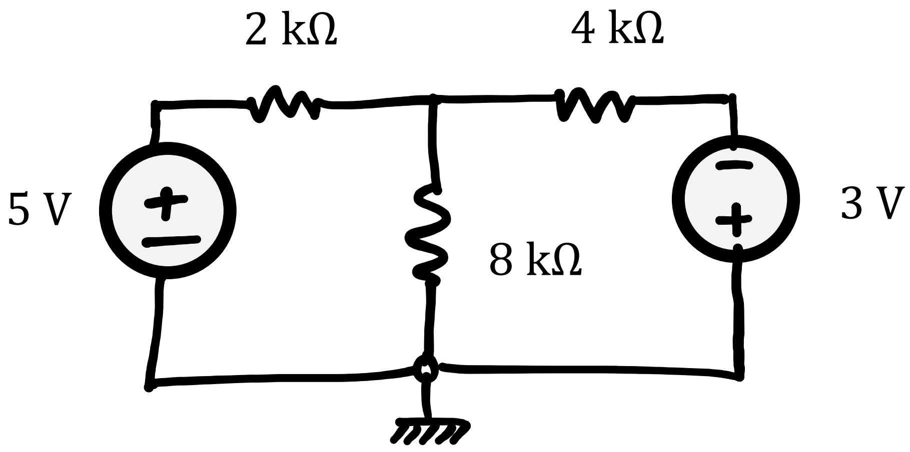
Floating voltage sources:

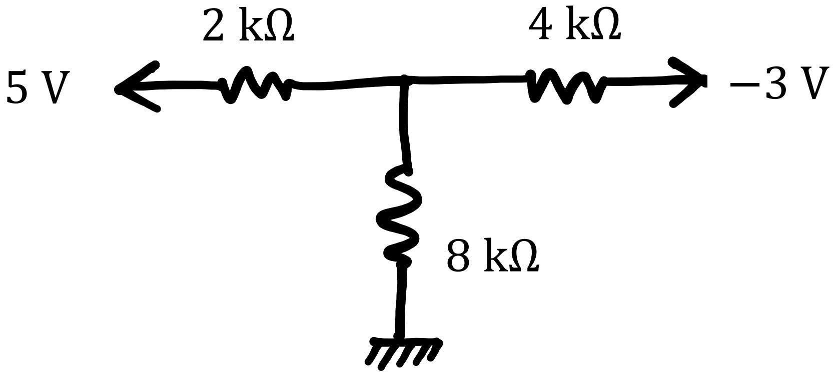
Voltage sources which are **not connected the ground** terminal. In the diagram, the $\mathbf{10\ V}$ voltage source is floating



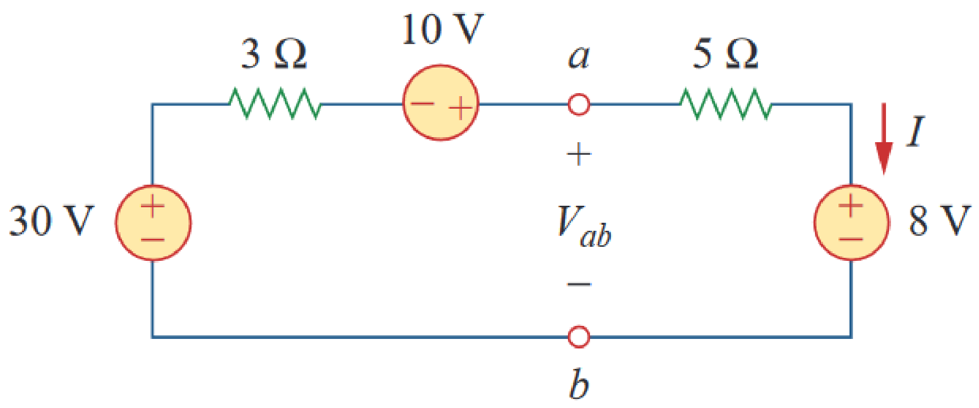
Line diagrams: Example 1

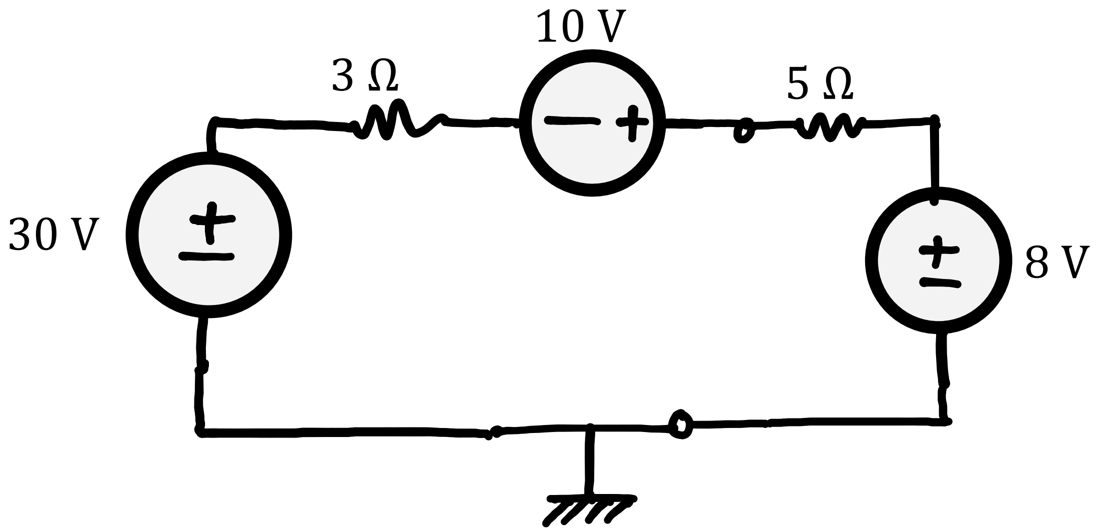


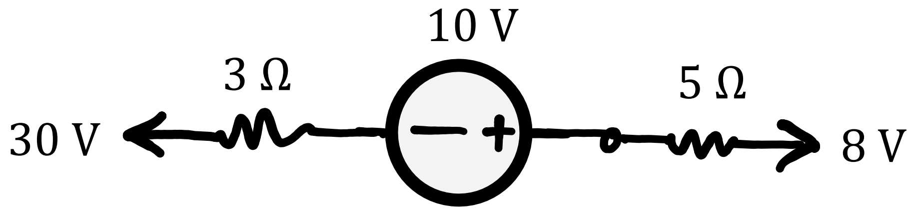




Line diagrams: Example 2

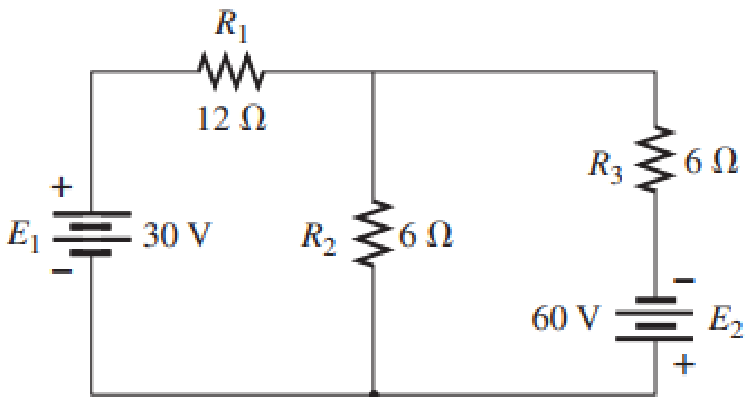






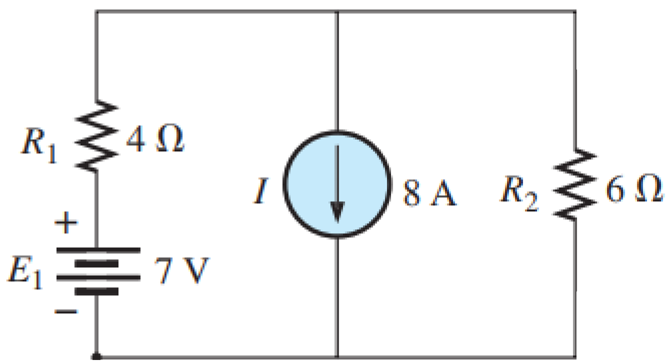
More Examples

Difficulty : 2/5



Example: 2

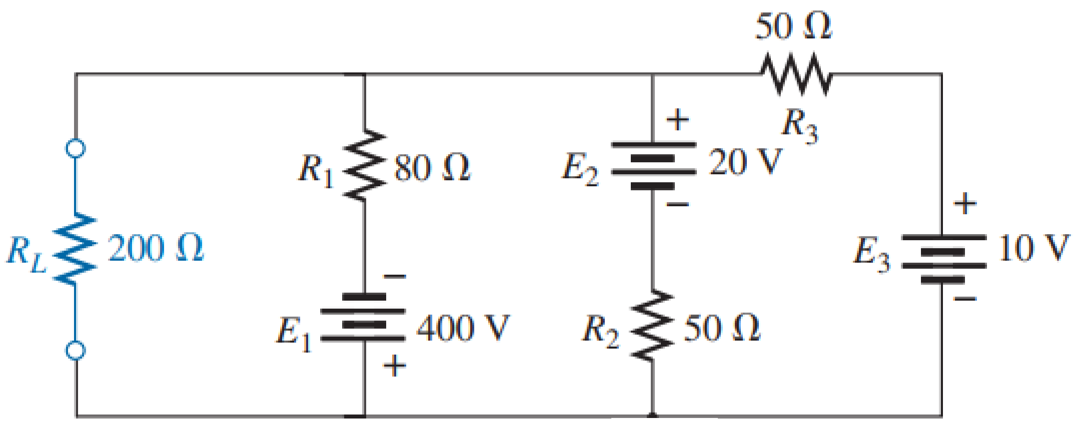
Difficulty : 3/5



Example: 3

More Examples

Difficulty : 4/5



Example: 4

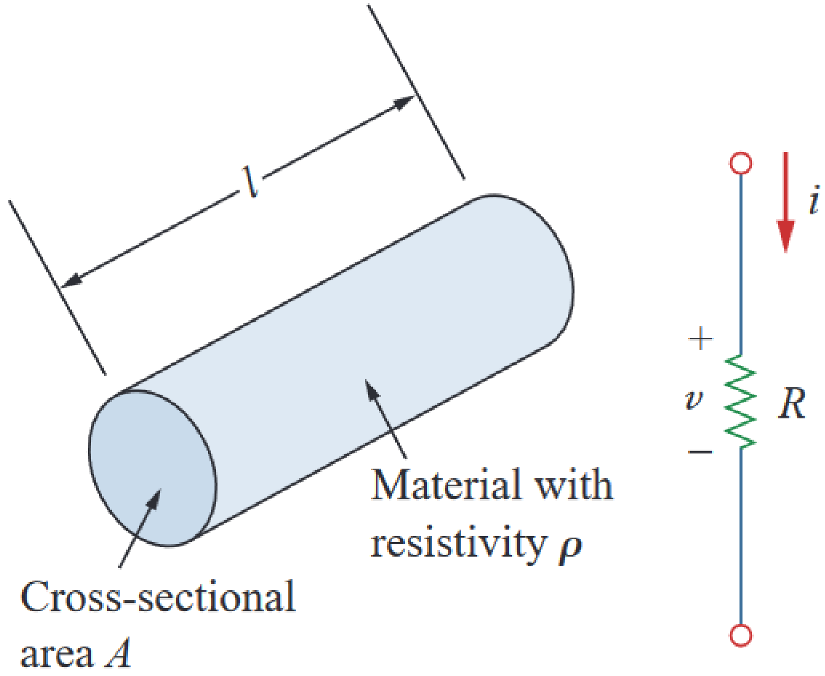
Step – (4) Make all the active elements (dc/ac type, voltage/~~current~~ sources) into single terminals (arrows/circles) using the voltages you wrote as much as you can [***THERE MIGHT BE CASES WHERE YOU CAN'T DO THAT***]

The fundamentals …

Ohm's Law –

- the voltage v across a resistor is **directly proportional** to the current i flowing through the resistor (R)

$$v \propto i$$
$$v = iR$$



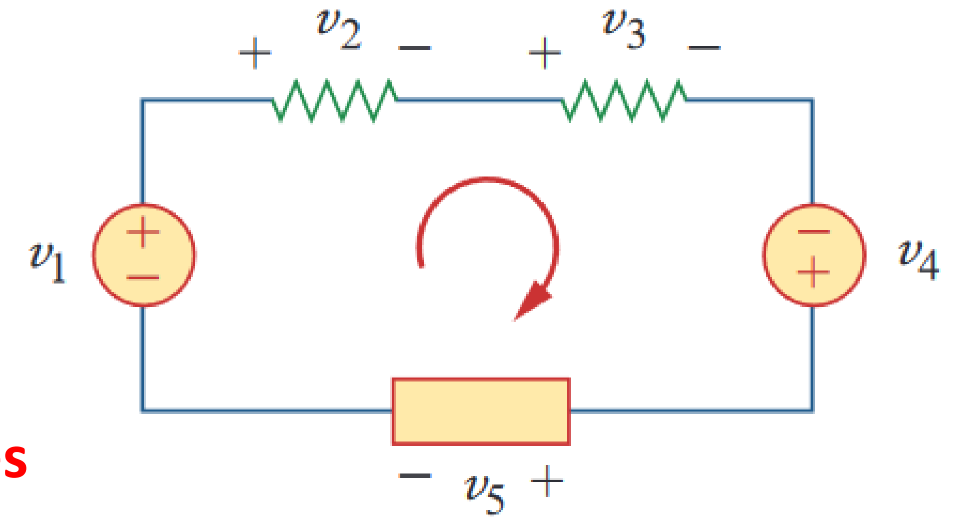
KVL: Kirchhoff's voltage law

The algebraic sum of all **voltages** around **a closed path (or loop)** is zero.

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

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

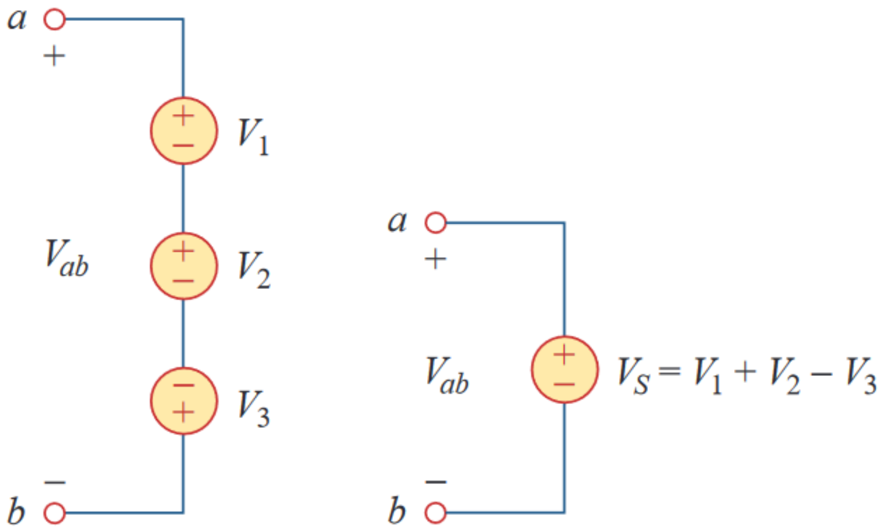
Sum of voltage drops = **Sum of voltage rises**



KVL: Kirchhoff’s voltage law

$$-V_{ab} + V_1 + V_2 + V_3 = 0$$

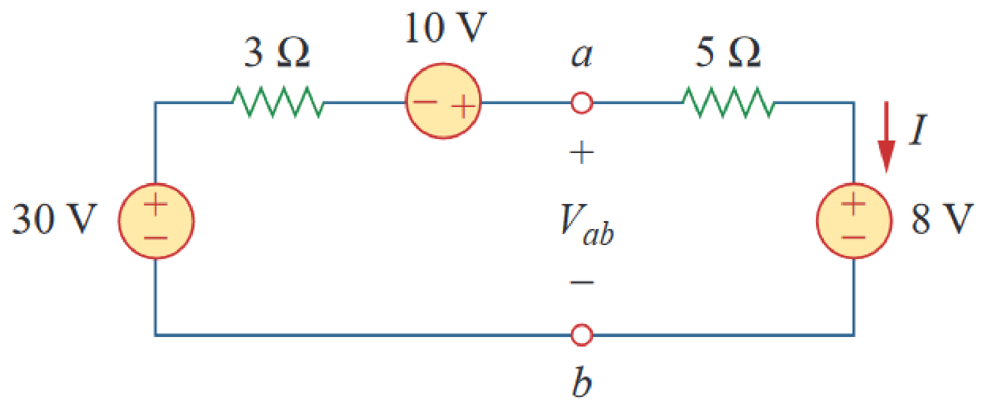
$$V_{ab} = V_1 + V_2 + V_3$$



Equivalent Circuits

KVL – Example 1

Find $\boldsymbol{I}$ and $\boldsymbol{V_{ab}}$ in the circuit



Solution:

KVL

$$-30 + 3\boldsymbol{I} - 10 + 5\boldsymbol{I} + 8 = 0$$

$$\boldsymbol{I} = \frac{32}{8}\,\text{A} = 4\ \text{A}$$

KVL

$$-V_{ab} + 5\boldsymbol{I} + 8 = 0$$

$$\boldsymbol{V_{ab}} = 28\ \text{V}$$

Tip: If you find resistance values in **kΩ** instead of **Ω**, don't convert the **kΩ** values to **Ω**. Just find currents in **mA** instead of **A**.

KVL – Example 2

Find $\boldsymbol{v_1, v_2, v_3, i_1, i_2}$ and $\boldsymbol{i_3}$ in the circuit

Solution:

KVL in first loop

$$-5 + 2\boldsymbol{i_1} + 8(\boldsymbol{i_1} - \boldsymbol{i_3}) = 0$$

$$10\boldsymbol{i_1} - 8\boldsymbol{i_3} = 5$$

KVL in second loop

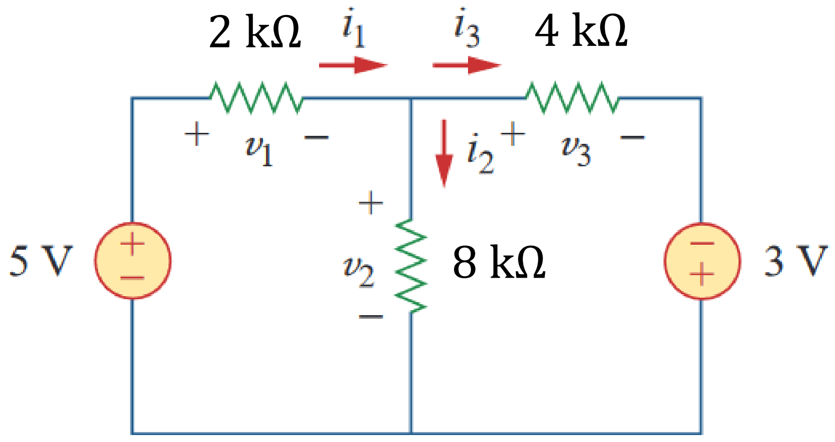
$$-8(\boldsymbol{i_1} - \boldsymbol{i_3}) + 4\boldsymbol{i_3} - 3 = 0$$

$$-8\boldsymbol{i_1} + 12\boldsymbol{i_3} = 3$$

Solving:

$$i_1 = 1.5 \text{ mA}$$
$$i_3 = 1.25 \text{ mA}$$
$$i_2 = i_1 - i_3 = 0.25 \text{ mA}$$

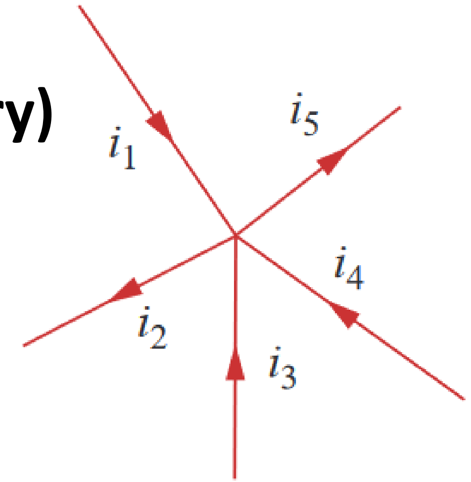
$$v_1 = 3 \text{ V}$$
$$v_2 = 2 \text{ V}$$
$$v_3 = 5 \text{ V}$$



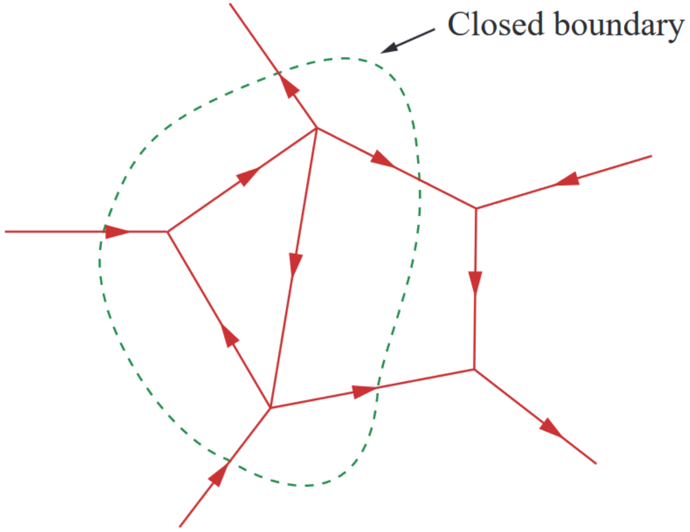
Tip: If you find resistance values in **kΩ** instead of **Ω**, don't convert the **kΩ** values to **Ω**. Just find currents in **mA** instead of **A**.

KCL: Kirchoff’s Current Law

The algebraic sum of the **currents** entering a **node (closed boundary)** is equal to the sum of the currents leaving the node.



$$\boldsymbol{i_1} + (-\boldsymbol{i_2}) + \boldsymbol{i_3} + \boldsymbol{i_4} + (-\boldsymbol{i_5}) = 0$$



Current Entering node: **Positive**
Current Exiting node: **Negative**

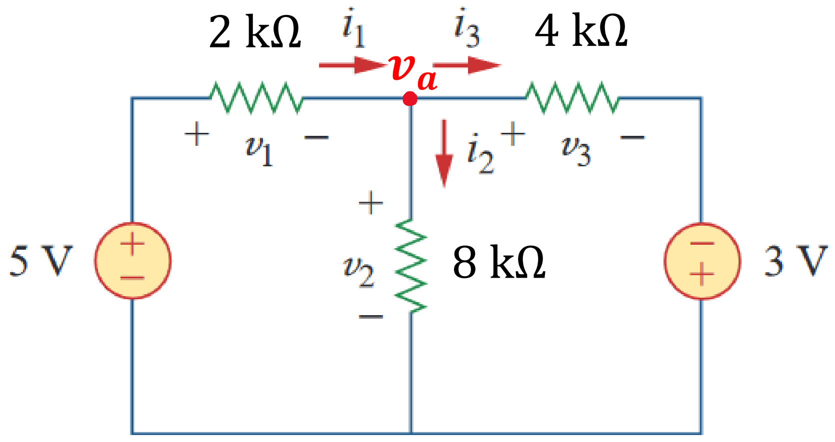
Or vice versa…

KCL- Example 1

Find $\boldsymbol{v_1, v_2, v_3, i_1, i_2}$ and $\boldsymbol{i_3}$ in the circuit

Solution:

KCL in node $\boldsymbol{v_a}$. (PS: $\boldsymbol{v_a = v_2}$)



$$\frac{5 - \boldsymbol{v_2}}{2} - \frac{\boldsymbol{v_2} - (-3)}{4} - \frac{\boldsymbol{v_2} - 0}{8} = 0$$

$$v_2\left(-\frac{1}{2} - \frac{1}{4} - \frac{1}{8}\right) = -\left(\frac{5}{2} - \frac{3}{4}\right)$$

$$\boldsymbol{v_2} = \frac{7}{4} \cdot \frac{8}{7}\ \mathrm{V} = 2\ \mathrm{V}$$

$$\boldsymbol{v_1} = 5 - v_2 = 3\ \mathrm{V}$$

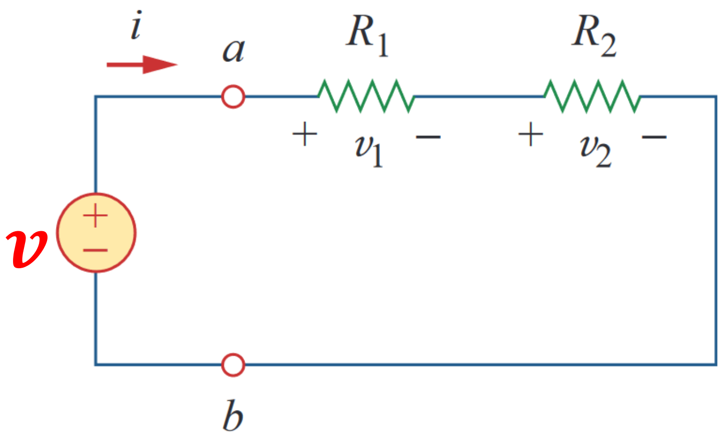
$$\boldsymbol{v_3} = v_2 - (-3) = 5\ \mathrm{V}$$

Series Resistors and Voltage Division

The **equivalent resistance** of any number of resistors **connected in series** is the sum of the individual resistances.

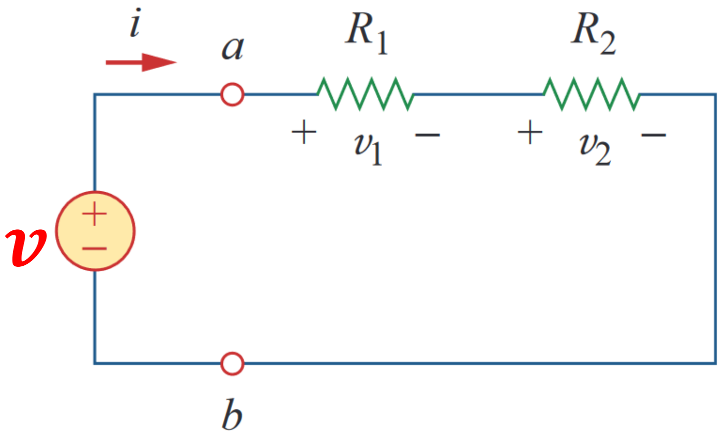
Principle of voltage division

Source voltage v - is divided among the resistors in direct proportion to their resistances; the larger the resistance, the larger the voltage drop.



$$v_1 = \frac{R_1}{R_1 + R_2} v \qquad v_2 = \frac{R_2}{R_1 + R_2} v$$

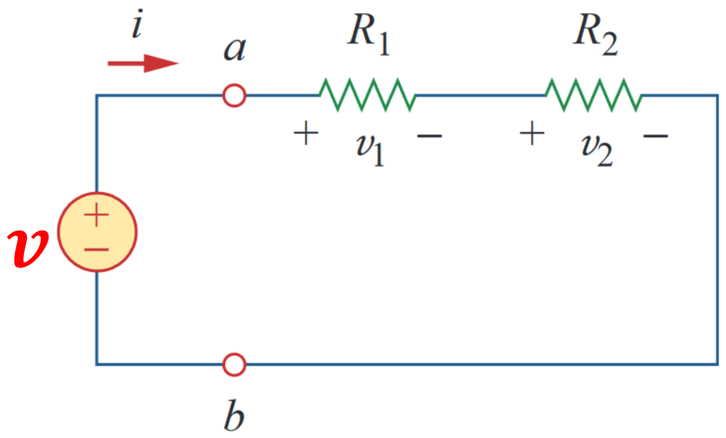
Line diagram: Example 3

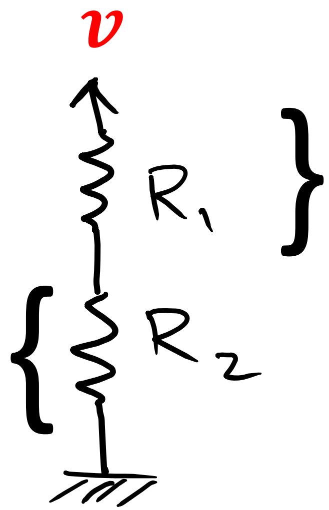


$$\frac{\boldsymbol{R_1}}{\boldsymbol{R_1} + R_2}\boldsymbol{v}$$

$$v_2 = \frac{\boldsymbol{R_2}}{R_1 + \boldsymbol{R_2}}\boldsymbol{v}$$

Line diagram: Example 3





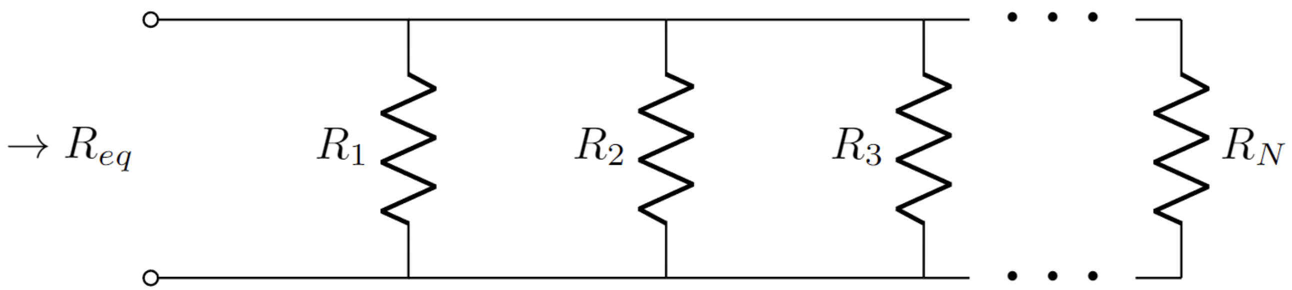
KVL (acts along a line instead of a loop)

$$v - iR_1 - iR_2 = 0$$

Parallel Resistors and Current Division

The **equivalent resistance** of any number of resistors connected in parallel is the inverse of the sum of the individual **conductances**.

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



Simplification for the case when $R_1 = R_2 = R_3 \cdots = R_N$

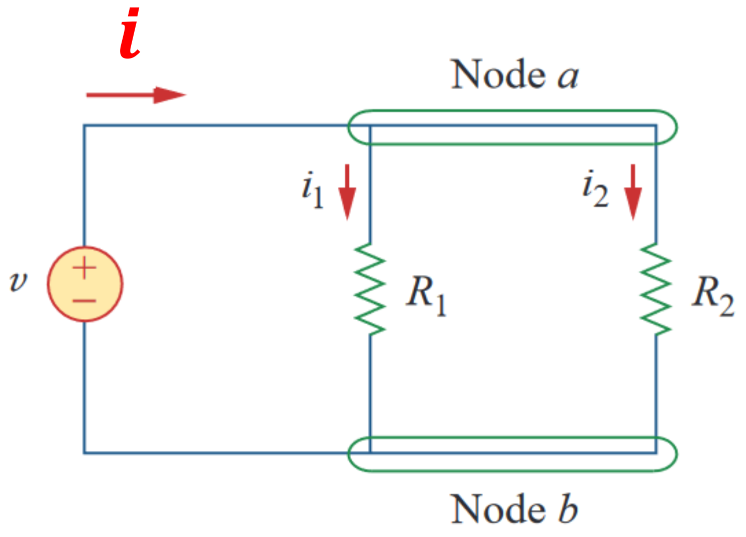
$$R_{eq} = \frac{R_1}{N}$$

Parallel Resistors and Current Division

The **equivalent resistance** of any number of resistors connected in <u>parallel</u> is the <u>inverse of the sum of the individual **conductances**</u>.

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

$$R_{eq} = R_1 || R_2 = \frac{R_1 R_2}{R_1 + R_2}$$



Simplification for the case when $R_1 = R_2$

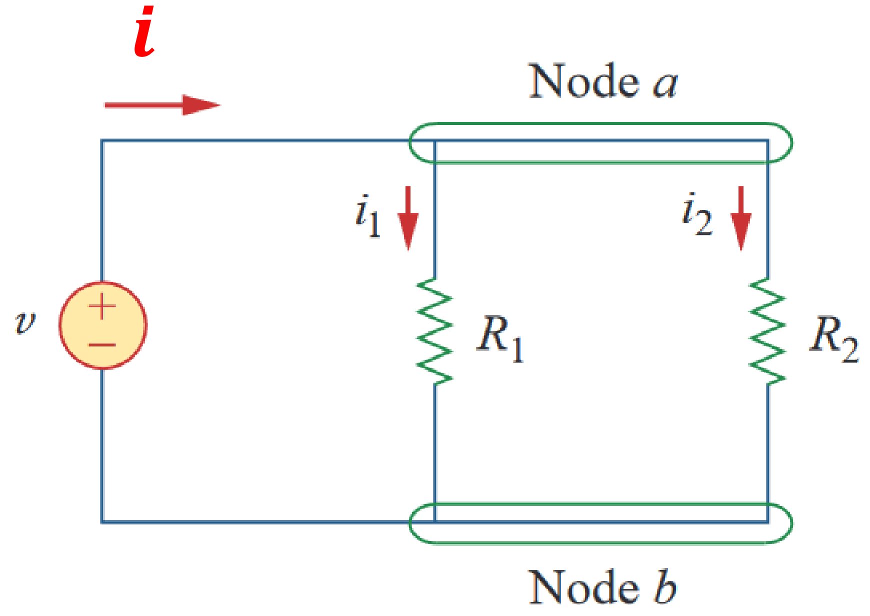
$$R_{eq} = \frac{R_1}{2}$$

Parallel Resistors and Current Division

The **equivalent resistance** of any number of resistors connected in **parallel** is the inverse of the sum of the individual **conductances**.

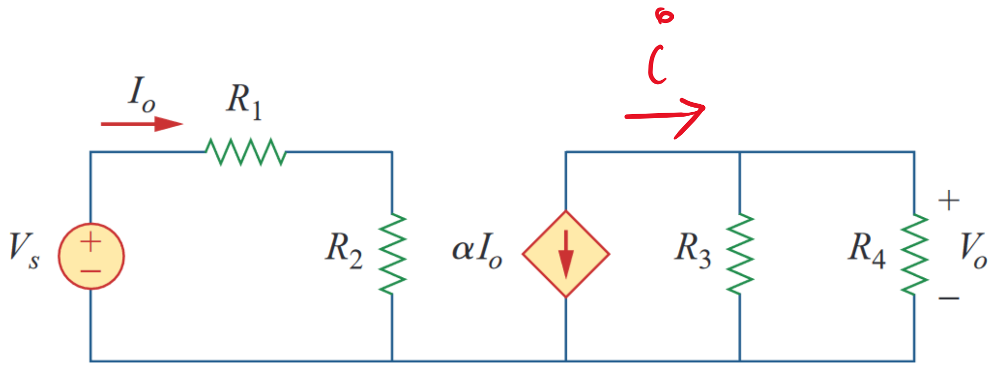
Principle of current division

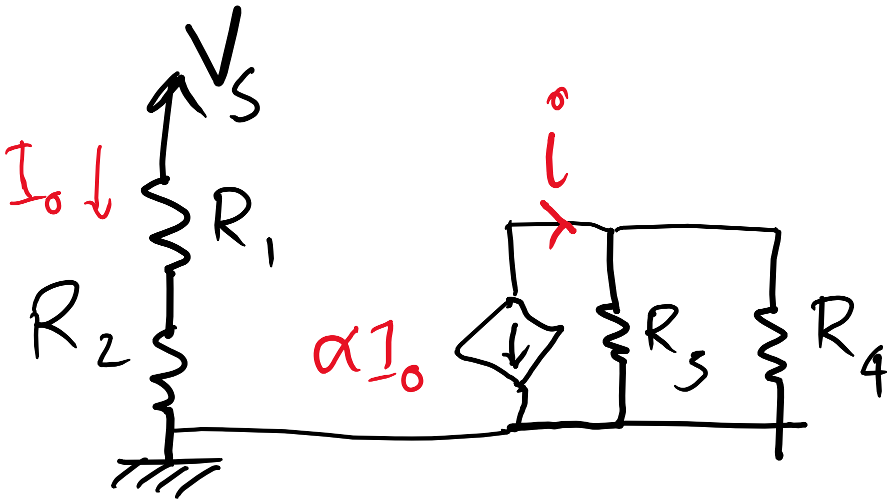
Source current i - is divided among the resistors in direct **inverse** proportion to their resistances; the larger the resistance, the larger the voltage drop.



$$i_1 = \frac{1/R_1}{1/R_1 + 1/R_2} i \qquad i_2 = \frac{1/R_2}{1/R_1 + 1/R_2} i$$

Line diagrams: Example 4





Practice Problem 1

For the circuit, find $\left|\frac{V_o}{V_s}\right|$ in terms of $\boldsymbol{\alpha}, \boldsymbol{R_1}, \boldsymbol{R_2}, \boldsymbol{R_3}$ and $\boldsymbol{R_4}$.

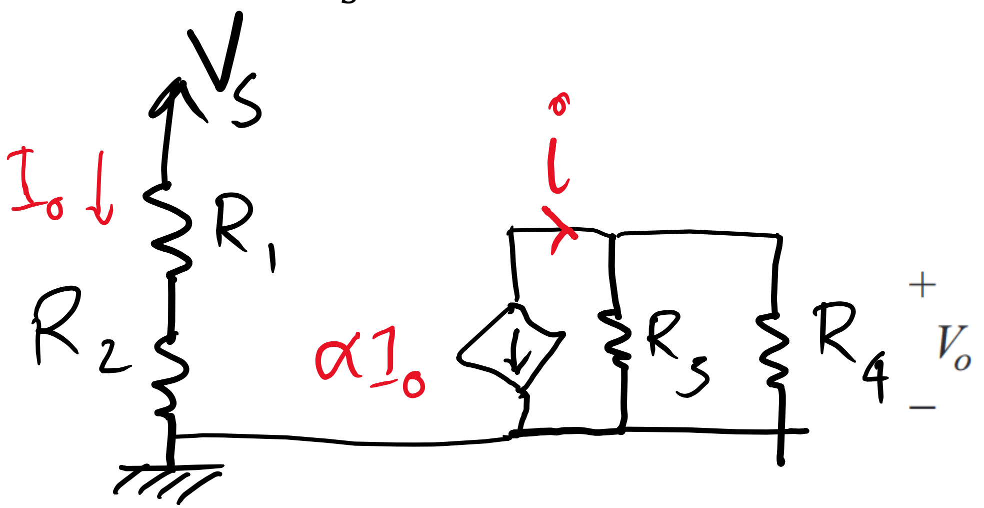
If $\boldsymbol{R_1} = \boldsymbol{R_2} = \boldsymbol{R_3} = \boldsymbol{R_4}$ what value of $\boldsymbol{\alpha}$ will produce $\left|\frac{V_o}{V_S}\right| = 10?$

Solution:

Ohm's Law across $\boldsymbol{R_1} + \boldsymbol{R_2}$.

$$I_O = \frac{V_S}{R_1 + R_2}$$

$$\boldsymbol{i} = -\boldsymbol{\alpha I_O}$$



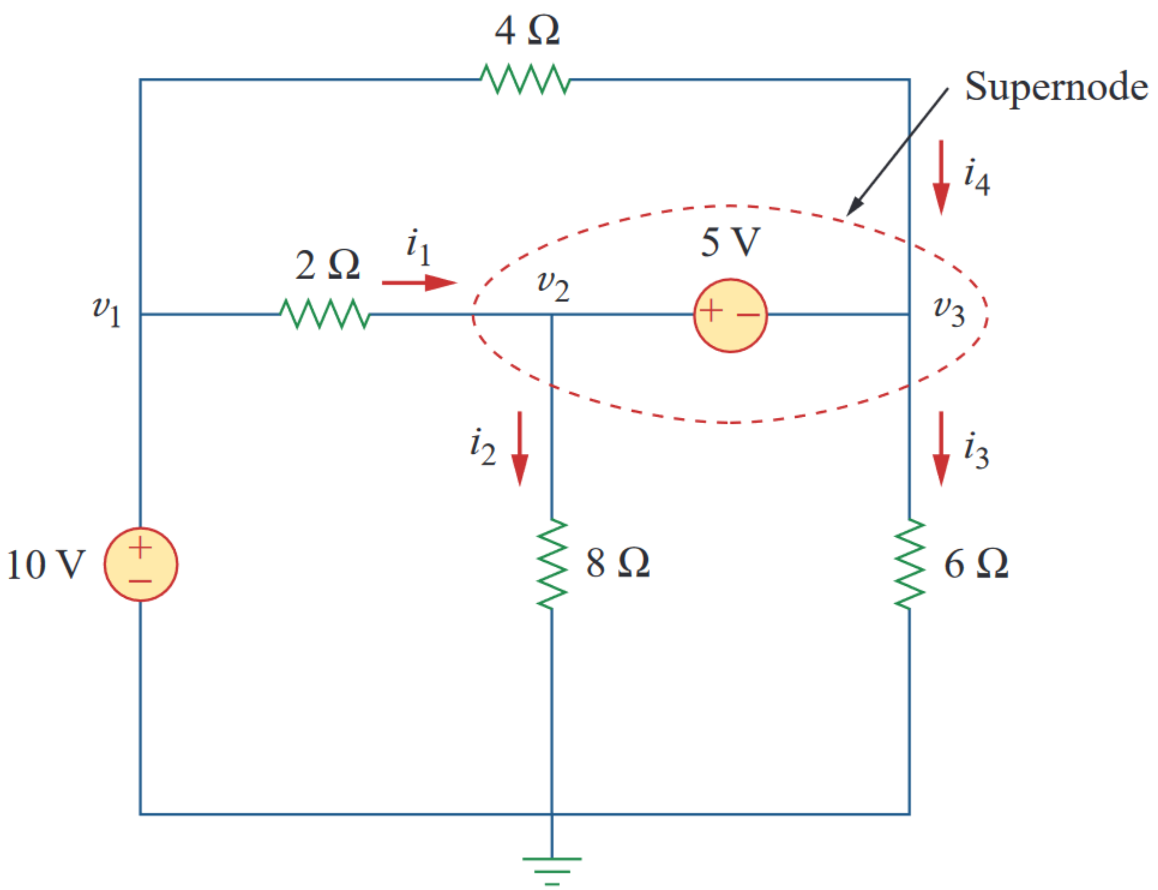
Voltage across **Parallel Resistors** $\boldsymbol{R_3}, \boldsymbol{R_4}$

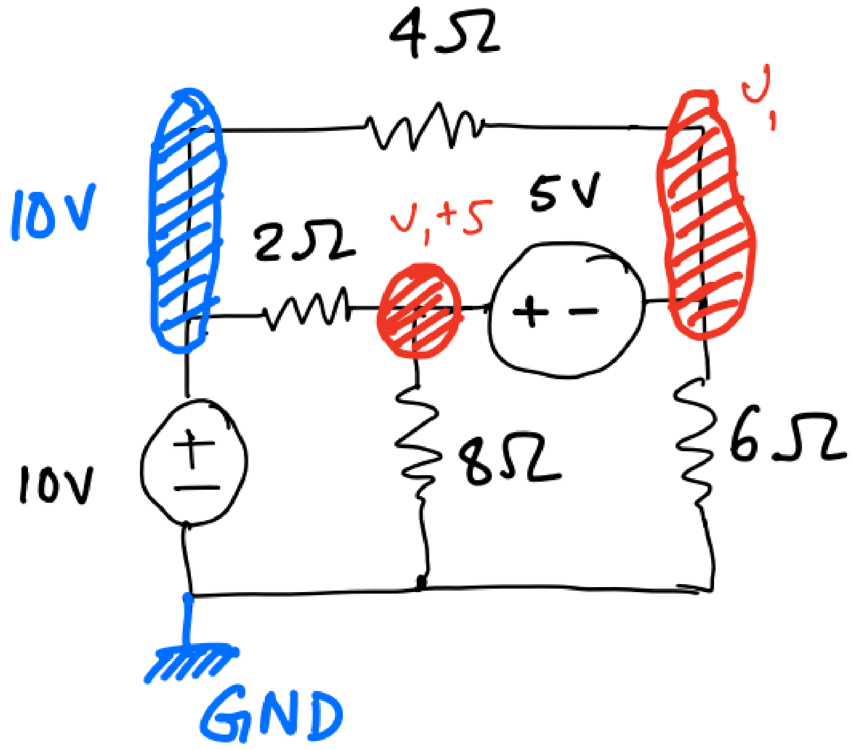
$$V_O = i(\boldsymbol{R_3}||\boldsymbol{R_4}) = -\frac{\alpha V_S}{R_1 + R_2} \cdot \frac{R_3 R_4}{R_3 + R_4}$$

$$\left|\frac{V_O}{V_S}\right| = \frac{\alpha}{R_1 + R_2} \cdot \frac{R_3 R_4}{R_3 + R_4}$$

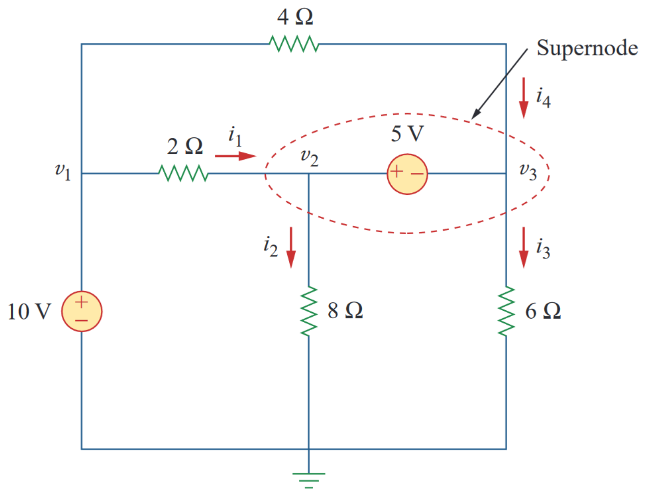
$\alpha = 40$

Example 1- Nodal Analysis





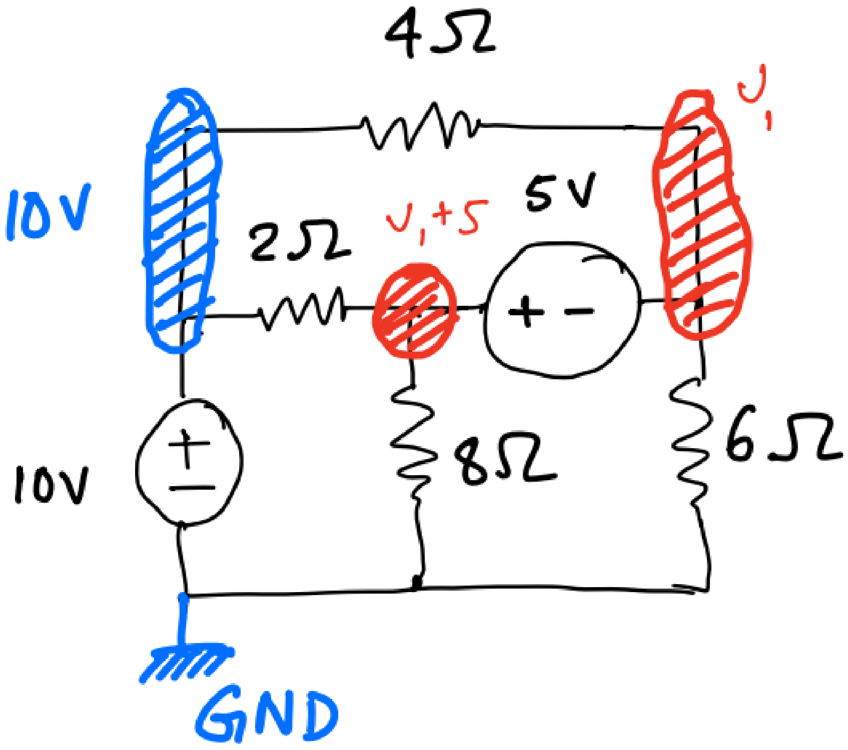
Example 1- Nodal Analysis



10V Node: $10\left(\frac{1}{4}+\frac{1}{2}\right.$

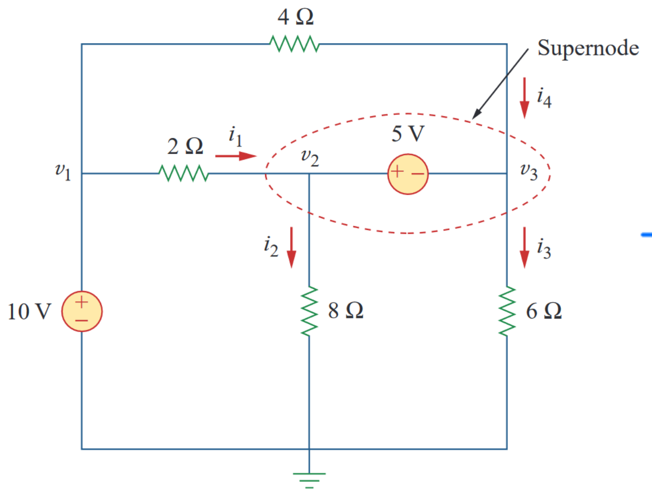
v_1 Node: $v_1\left(\frac{1}{4}+\frac{1}{6}\right.$

v_1+5 Node: $(v_1+5)\left(\frac{1}{2}+\right.$



$$v_1\left(\frac{1}{4}+\frac{1}{6}\right)+(v_1+5)\left(\frac{1}{2}+\frac{1}{8}\right)-10\left(\frac{1}{2}+\frac{1}{4}\right)$$

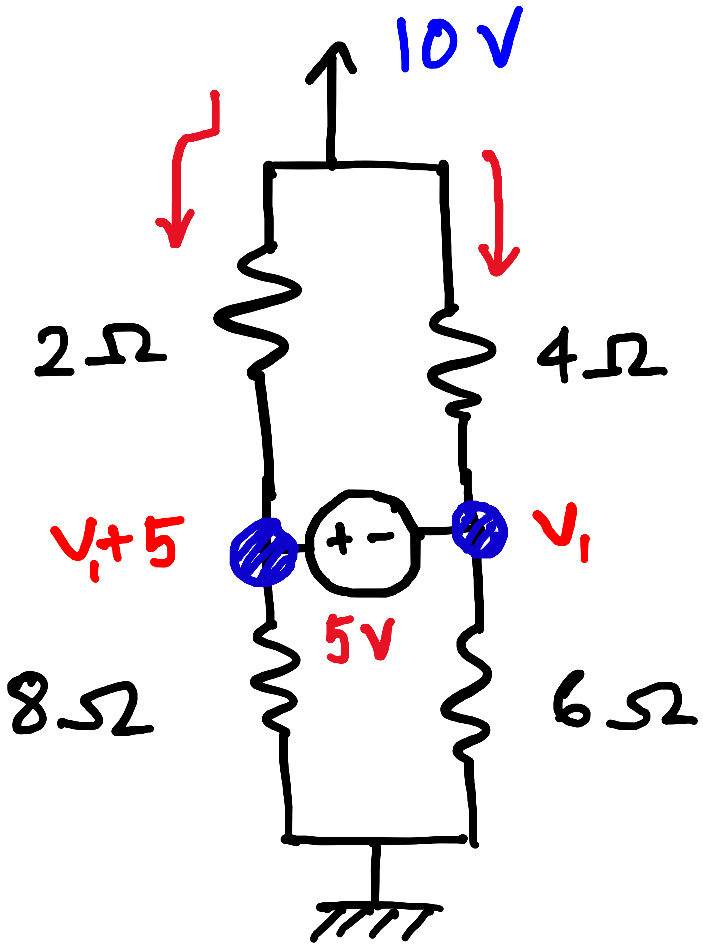
Example 1- Nodal Analysis



10V Node: $10\left(\frac{1}{4}+\frac{1}{2}\right)$

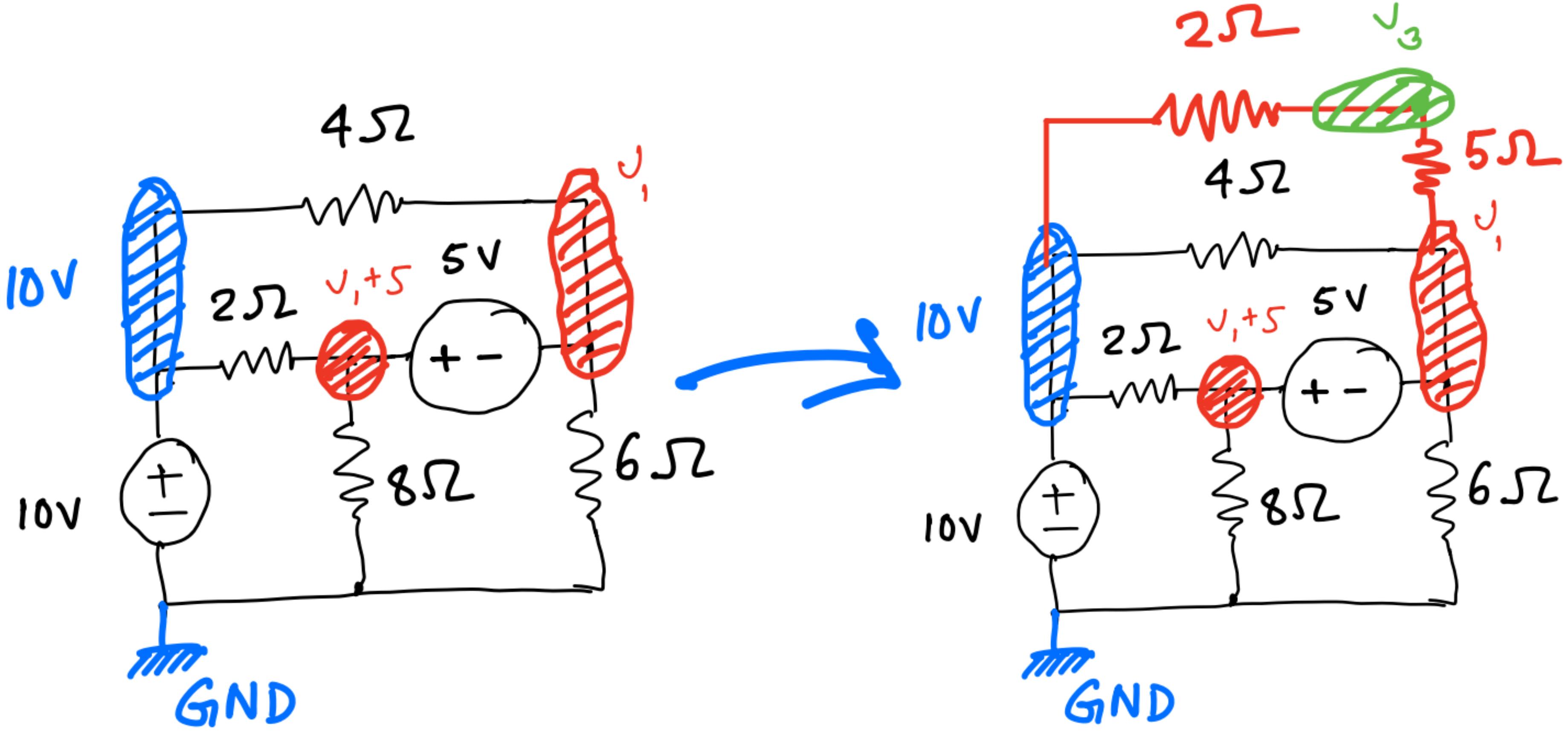
V_1 Node: $V_1\left(\frac{1}{4}+\frac{1}{6}\right)$

V_1+5 Node: $(V_1+5)\left(\frac{1}{2}+\frac{1}{8}\right)$



$$v_1\left(\frac{1}{4}+\frac{1}{6}\right)+(v_1+5)\left(\frac{1}{2}+\frac{1}{8}\right)-10\left(\frac{1}{2}+\frac{1}{4}\right)=0$$

Example 2- Nodal Analysis – **Home Task 1**



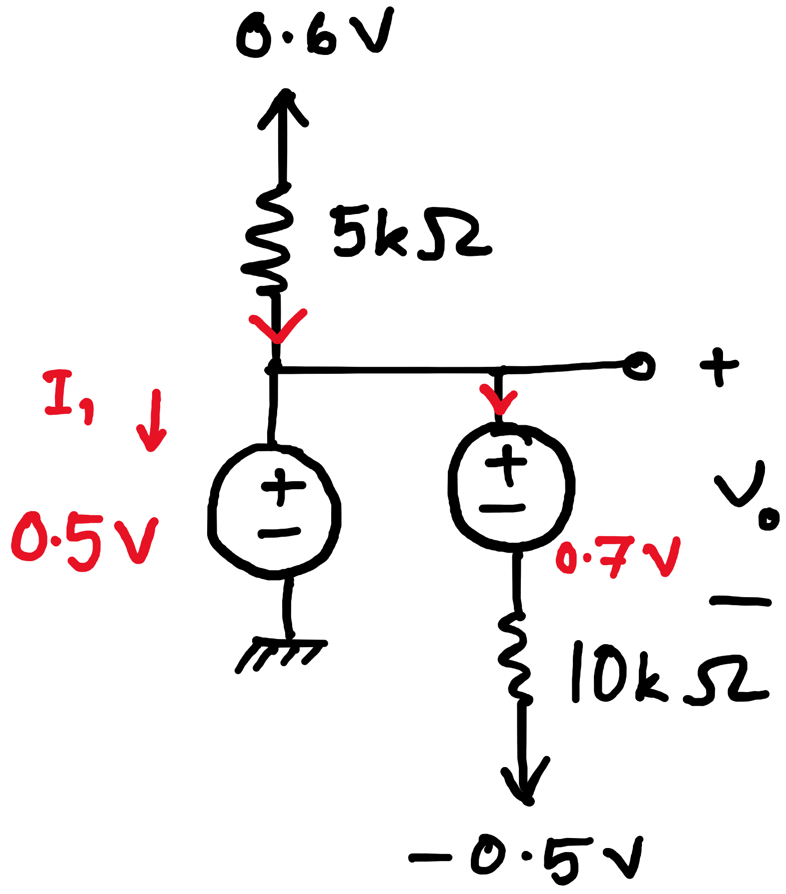
Find the two node v_1 and v_3 equations!

Example 3

KCL at node v_o

$$\frac{0.6 - 0.5}{5} = \frac{(0.5 - 0.7) - (-0.5)}{10} + I_1$$

$$I_1 = -\mathbf{0.01}\ \mathrm{mA}$$

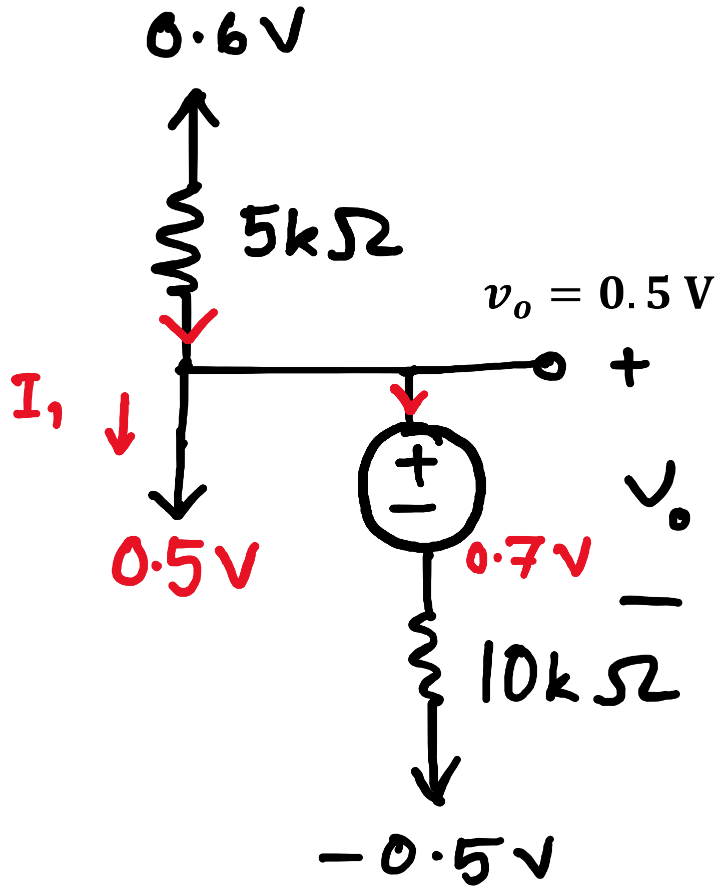


Example 3

KCL at node $\boldsymbol{v_o}$

$$\frac{0.6-0.5}{5}=\frac{(0.5-0.7)-(-0.5)}{10}+\boldsymbol{I_1}$$

$$\boldsymbol{I_1=-0.01}\ \mathrm{mA}$$



Example 4

KCL at node $\boldsymbol{v_i}$

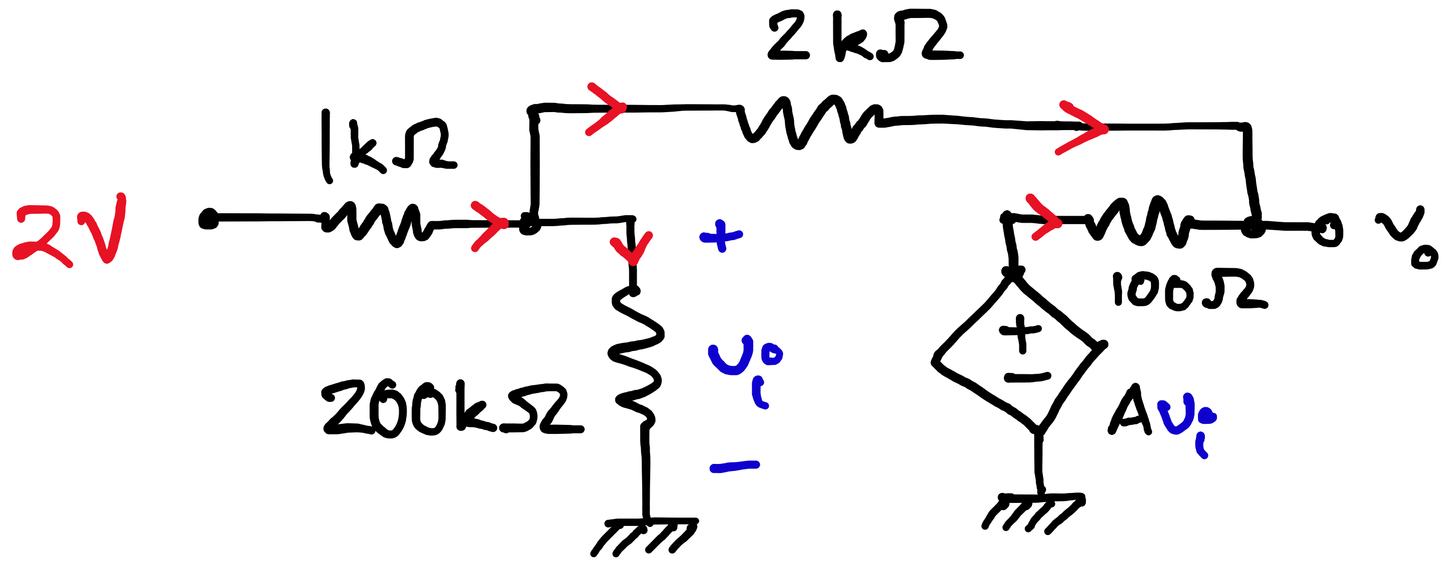
$$\frac{2 - v_i}{1} = \frac{v_i - v_o}{2} + \frac{v_i}{200}$$

$$\frac{301}{200} v_i - \frac{1}{2} v_o = 2$$

KCL at node $\boldsymbol{v_o}$

$$\frac{v_i - v_o}{2} + \frac{Av_i - v_o}{0.1} = 0$$

$$(2 \times 10^6 + 0.5) v_i - 10.5 v_o = 0$$



$A = 2 \times 10^5$

Example 5

KCL at node $\boldsymbol{v_i}$

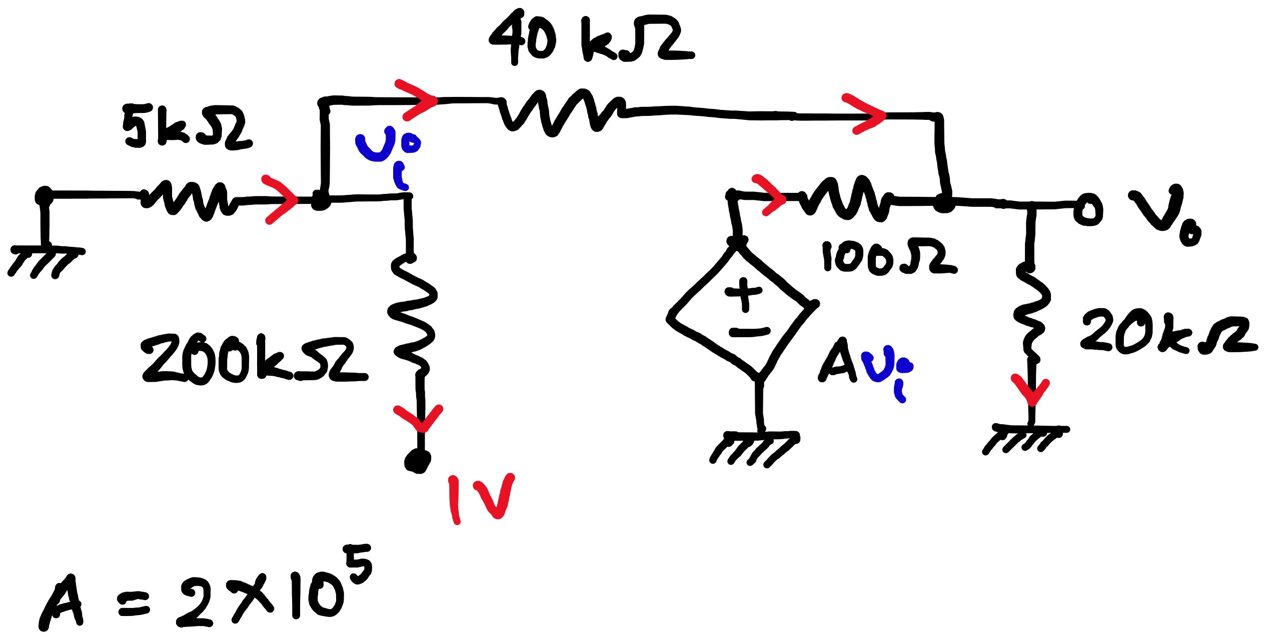
$$\frac{0 - v_i}{5} = \frac{v_i - v_o}{40} + \frac{v_i - 1}{200}$$

$$\frac{23}{100} v_i - \frac{1}{40} v_o = \frac{1}{200}$$

KCL at node $\boldsymbol{v_o}$

$$\frac{v_i - v_o}{40} + \frac{Av_i - v_o}{0.1} = \frac{v_o}{20}$$

$$(2 \times 10^6 + 0.025)v_i - 10.075v_o = 0$$



Example 6 – Home Task 2

For $\boldsymbol{R} = 100\ \Omega$, $\boldsymbol{R_L} = 10\ \mathrm{k}\Omega$, $\boldsymbol{r_z} = 20\ \Omega$, $\boldsymbol{V_{ZO}} = 3\ \mathrm{V}$, and $\boldsymbol{I_Z} = 1\ \mathrm{mA}$.

a. Find $\boldsymbol{V_O}$

b. Find $\boldsymbol{I_L}$

c. Find $\boldsymbol{I}$

d. Find $\boldsymbol{V^+}$