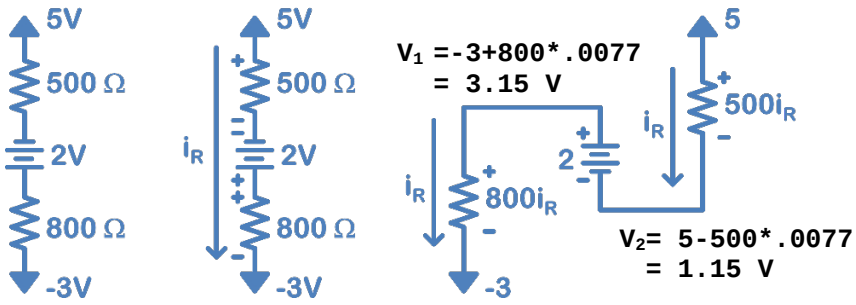
Circuit Analysis Review

Traversing the Circuit Analysis Voltage Tower:

One way to conceptualize circuit analysis is to view components as stairs and voltages as floor levels. To determine if we are moving up or down the stairs, we need to label voltages across the components (according to the specific device and current direction) and orient the components accordingly. Apply KVL and i-v characteristics from known voltage points along the path.

Example 1:



Start at 3 floors below ground → End at 5 floors above ground.
start -3, go up $800i_R$, go down 2, go up $500i_R$, end 5
$-3 + 800i_R - 2 + 500i_R = 5$ ... $i_R = 10/1300 = 7.7mA$

Go back down.
start 5, go down $500i_R$, go up 2, go down $800i_R$, end -3
$5 - 500i_R + 2 - 800i_R = -3$ ... $i_R = 10/1300 = 7.7mA$

Note, we can define i_R in either direction. What does the image look like?

Start 3 floors below ground, end on 5 floors above ground.
start -3, go down $800i_R$, go down 2, go down $500i_R$, end 5
$-3 - 800i_R - 2 - 500i_R = 5$ ... $i_R = -10/1300 = -7.7mA$

Go back down.
start 5, go up $500i_R$, go up 2, go up $800i_R$, end -3
$5 + 500i_R + 2 + 800i_R = -3$ ... $i_R = -10/1300 = -7.7mA$

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Nodal and Mesh Analysis:

One way to approach circuit analysis is to write out as many equations as possible from knowledge of KCL, KVL, and i-v relationships (i=f(v), Ohm's Law for example is $i_R=v_R/R$). Then stumble through the math to come up with the desired answer. We can call this the shotgun approach.

Two other commonly used methods are Mesh and Nodal Analysis:

> Nodal: Identify all unknown voltages and use KCL with i=f(v) for each device to come up with a system of equation. *Note: series batteries (voltage sources) provide a known voltage drop between two nodes and therefore can be considered a single node (unknown or not) – see example 1 below.*
>
> Mesh: Identify all unknown currents and use KVL with i=f(v) for each device to come up with a system of equation. *Note: parallel current sources provide a known current drop between two loops and therefore can be considered a single loop (unknown or not).*

What method did we apply in Example 1? Mesh or Nodal?

How would we apply the other method to Example 1?

Example 1:

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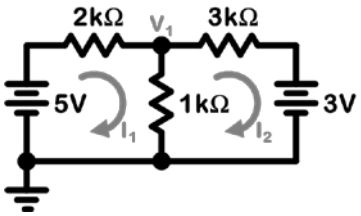
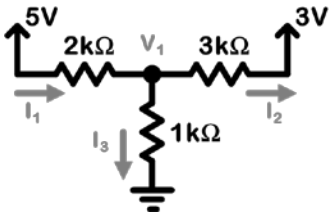
Example 2:

The two images below all represent the same circuit. Find all labeled voltages and currents using both Mesh and Nodal Analysis.



(a)



(b)

Mesh Analysis using (a):

Nodal Analysis using (b):

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Characterizing Devices:

Symbol: Commonly used devices have known symbols that identify how they operate.

I-V Graph: Graph that shows the relationship between the current and voltage of a device.

I-V Equation: I-V Characteristic equation of the device – matches the graph. Usually simplified to make analysis easy.

> ***Rapid analysis*** *is a key topic of this course. Most devices are more complex than the given i-v equation, but by using simplified models, we can quickly evaluate/design a circuit. For example, there is no such thing as a constant voltage source as there will be some internal resistance, but that internal resistance is negligible enough to not include in a quick (rapid) analysis. More in-depth analysis is best left for CAD tools.*

Examples:

Device	Symbol	Graph	Equation	Linear?
Resistor				
Voltage Source				
Current Source				
Capacitor				
Inductor				
Short Circuit Equivalent to?				
Open Circuit Equivalent to?				

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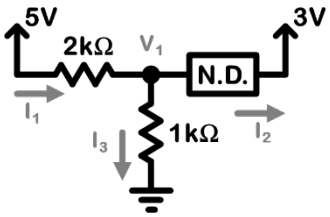
Example 3: We have created a new device!!!

A new device exhibits a current voltage relationship:

$$\text{N.D.: } i_N = f(v_N) = v_N^3/50k$$

And is used in the same circuit as example 2. Use Nodal Analysis to find the labeled voltage, V_1.



Nodal Analysis:

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Linearity:

Q1. What is it and how to test for it?
Q2. Why do we care about it?

A1. A device described by i=f(v) if linear if:
Given $\mathbf{i_1 = f(v_1)}$ and $\mathbf{i_2 = f(v_2)}$:
If $\mathbf{v_3 = a \cdot v_1 + b \cdot v_2}$,
Then $\mathbf{i_3 = f(a \cdot v_1 + b \cdot v_2) = a \cdot i_1 + b \cdot i_2}$.

A2. Apply superposition of sources to a circuit.
Resistor: $\mathbf{i_1 = v_1/R}$, and $\mathbf{i_2 = v_2/R}$
$\mathbf{i_3 = (a \cdot v_1 + b \cdot v_2)/R = a \cdot v_1/R + b \cdot v_2/R = a \cdot i_1 + b \cdot i_2}$

Q3. Why do we want to apply superposition?