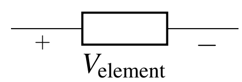
CSM
Spring 2019

Electrical Engineering 16A
Worksheet 5

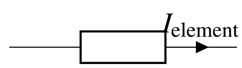
1. Passive (Aggressive) Sign Convention

For the following components, label the V_{element} or I_{element} given the I_{element} or V_{element}, respectively. *Hint: The value of the voltage and current sources shouldn't affect passive sign convention—remember that voltage and current can be negative!*

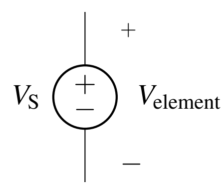
(a)



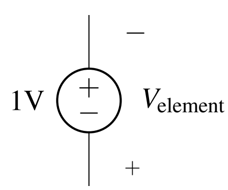
(b)



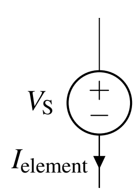
(c)



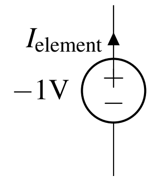
(d)



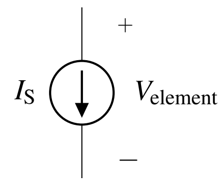
(e)



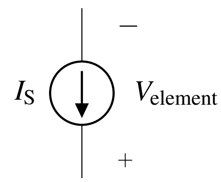
(f)



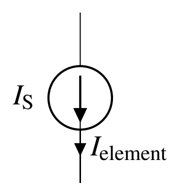
(g) **(PRACTICE)**



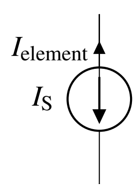
(h) **(PRACTICE)**



(i) **(PRACTICE)**

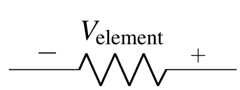


(j) **(PRACTICE)**



(k) **(PRACTICE)**

(l) **(PRACTICE)**



2. Basic Circuit Components

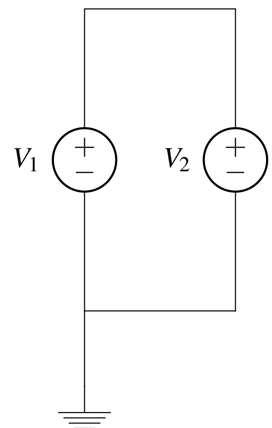
In this problem, we will introduce the fundamental circuit components.

(a) What is a voltage source?

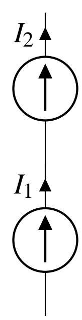
(b) What is a current source?

(c) What is voltage? What is a voltage drop?

(d) What happens in this case if $V_1 \neq V_2$?



(e) What happens in this case if $I_1 \neq I_2$?



(f) What is a resistor?

(g) What is power?

3. **Warning! High Resistivity Zone Ahead!**

Resistivity is a physical property that quantifies how much the material opposes the flow of electric current.

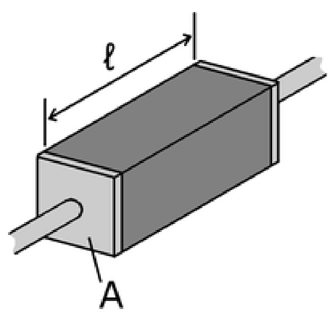
Assume that in an ideal case, the cross-section and physical composition of the wire are uniform, We can find its resistivity with the equation below:

$$\rho = R\frac{A}{l}$$

Here, ρ stands for the resistivity of the wire, R stands for its resistance, A stands for the area of the cross section of the wire, and l stands for the length of the wire. Using this equation, we can also solve for the resistance of a wire:

$$R = \rho\frac{l}{A}$$

(a) Now, consider the rectangular copper wire below. Given that the cross-section of the wire is a square and has a cross section area of A, determine the overall resistance of the wire in terms of ρ_{cu}, L, and A.



(b) Suppose we have N such wires and align them side by side to form a mega-wire in the following fashion. Find the overall resistance of this mega-wire. What is this configuration similar to?

(c) Again, with N identical wires, what's a configuration that can achieve the highest resistance possible? What is this configuration similar to?

(d) Consider part (b) again, but this time, instead of N copper wires, we split the number evenly between aluminum wires and copper wires, and we again align them side by side to form a mega-wire (with the left half all aluminum , and right half all copper). What's the overall resistance of this wire? (In terms of ρ_{cu}, ρ_{Al}, L, and a)

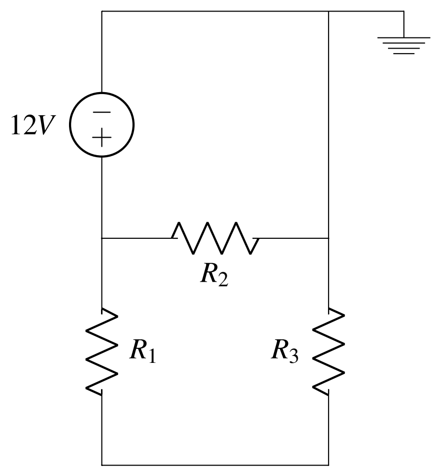
(e) Instead of having all the $N/2$ copper wires on the right side, now all the wires are mixed together (a copper wire can be aligned right next to an aluminum wire), does the overall resistance of this new mega-wire change?

4. Introduction to KVL, KCL

KVL: Kirchhoff's Voltage Law says that the sum of voltage drops going around a closed network (starting and ending at the same point) is 0

KCL: Kirchhoff's Current Law says that the sum of all currents flowing into a node are equal to the sum of all currents flowing out of a node. This is equivalent to saying that the sum of all currents flowing out of a node (representing flows in opposite direction as negative) is equal to the sum of all currents flowing into a node (again, representing flows in opposite direction as negative) which is equal to zero

Consider the following circuit, with $R_1 = 2\Omega$, $R_2 = 3\Omega$, and $R_3 = 4\Omega$:



We will solve this picture using nothing but KCL and KVL in the following steps.

(a) First, draw a reference point (ground) on the circuit, and label all the nodes V_1, V_2, etc.

(b) Next, draw the +s and -s on the resistors.

(c) Finally, draw arrows indicating the direction of current, labeling them as I_1, I_2, etc.

(d) Now write all the equations given by Ohm's law, KCL and any voltages you can find relative to ground

(e) Now that you have all equations written out, solve them to find all unknown voltages and currents.

(f) Now, we're going to solve the same circuit with Nodal Analysis. Notice that in the previous part, you had many equations are variables (corresponding to both voltage and current). This may make the system more tedious to solve. Instead, Nodal Analysis allows us to write a system of equations that only involves the node voltages.

Start by using the ground and voltage source to find any node voltages which are immediately known.

(g) Then, Ohm's law to write a KCL equation for each node purely in terms of voltages and resistances.

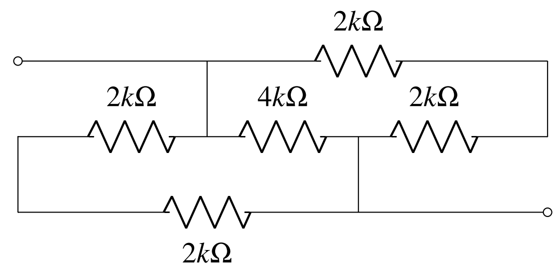
(h) When doing nodal analysis, would it have helped to write a KCL equation at nodes V_1 and V_3? Why or why not?

5. Never Fail at Resistor Equivalence

(a) Using what you learned about resistance above ($R = \frac{\rho \cdot l}{A}$), explain what would happen if you connect two resistors in series.

(b) Using the same resistance equation from part (a), explain what would happen if you connect two resistors in parallel.

(c) Now let's apply some of these ideas to a circuit. For the circuit below, mark all the nodes.



(d) Mark which nodes are 2-nodes and multi-nodes. 2 nodes are connected to only 2 components, and multi-nodes are connected to 3 or more components.
Note: *Whenever nodes are marked across which equivalent resistance must be found, those are considered 'components' because something could be connected there.*

(e) Resistors that are connected to 2-nodes are considered to be in series. Redraw the circuit, and find the 2 and multi-nodes again after combining the resistors connected to 2 nodes.

(f) Now we should be left with only multi-nodes. So far, we have seen that any resistors connected to 2-nodes are in series. We will see what happens to resistors connected to multi-nodes. Begin by writing out the 2 nodes that each resistor is connected to.

(g) If you have 2 or more resistors that are connected to the same 2 nodes, then they are in parallel. What does this mean for the 3 remaining resistors?