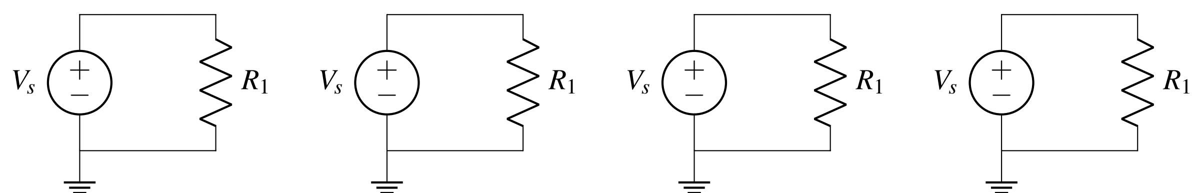
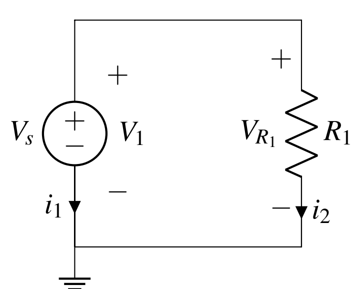
EECS 16A Designing Information Devices and Systems I
Fall 2020 Discussion 7B

1. **Passive Sign Convention and Power**

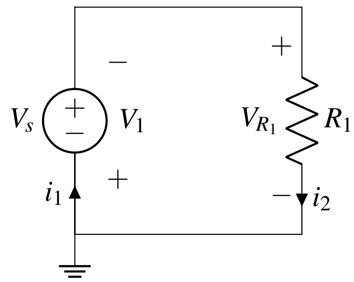
(a) We have made four copies of a circuit below. Following passive sign convention, there are four different possible labelings of current directions and voltage polarities for the circuit. For each copy, label each circuit's voltage source and resistor with current direction and voltage polarity labelings, keeping with passive sign convention.



(b) Suppose we consider one of the possible labelings you have found above. Calculate the power dissipated or supplied by every element in the circuit. Let $V_s = 5\,\text{V}$ and let $R_1 = 5\,\Omega$.



(c) Suppose we choose a second labeling of the circuit as shown below. Calculate the power dissipated or supplied by every element in the circuit. Let $V_s = 5\,\text{V}$ and let $R_1 = 5\,\Omega$.



(d) Did the values of the element voltages and element currents change with the different labeling? Did the power for each circuit element change? Did the node voltages change? If a quantity didn't change with a difference in labeling, discuss what would have to change for quantity to change.

2. Volt and ammeter

Consider the following circuit below. We have also included relevant NVA equations below it.

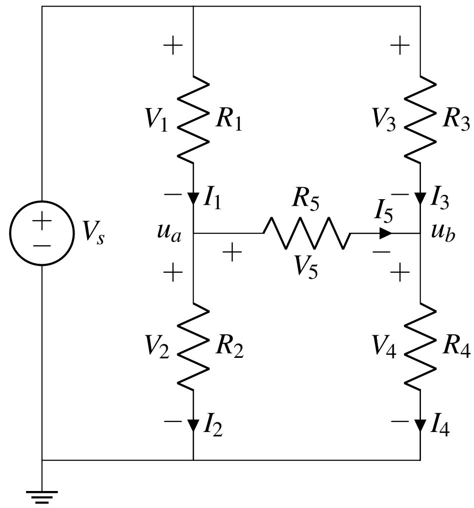


Figure 1: Circuit consisting of a voltage source V_s and five resistors R_1 to R_5.

KCL	Ohm's law in terms of node voltages	Substitute Ohm's into KCL
$I_1 = I_2 + I_5$ $I_5 + I_3 = I_4$	$I_1 = \frac{V_1}{R_1} = \frac{V_s - u_a}{R_1}$ $I_2 = \frac{V_2}{R_2} = \frac{u_a - 0}{R_2}$ $I_3 = \frac{V_3}{R_3} = \frac{V_s - u_b}{R_3}$ $I_4 = \frac{V_4}{R_4} = \frac{u_b - 0}{R_4}$ $I_5 = \frac{V_5}{R_5} = \frac{u_a - u_b}{R_5}$	$\frac{V_s - u_a}{R_1} = \frac{u_a - 0}{R_2} + \frac{u_a - u_b}{R_5}$ $\frac{u_a - u_b}{R_5} + \frac{V_s - u_b}{R_3} = \frac{u_b - 0}{R_4}$

(a) The circuit diagram shown in Figure 1 has been redrawn in Figure 2 by adding a voltmeter (letter V in a circle and plus and minus signs indicating direction) to measure voltage $V_{ab} = u_a - u_b$. Assume that the voltmeter is ideal. Are the values of V_{ab} before adding the voltmeter and after adding the voltmeter different? If so, which of the given equations change when doing NVA?

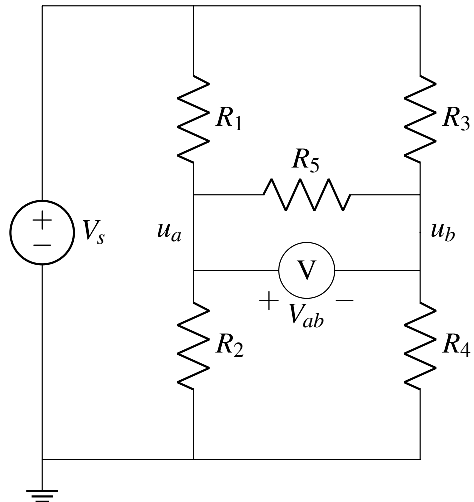


Figure 2: Circuit with voltmeter.

(b) Suppose you accidentally connect an ideal ammeter in part (a) to nodes u_a and u_b instead of an ideal voltmeter. Does the value of V_{ab} with the ammeter connected differ from the value of V_{ab} without the ammeter connected? If so, what equations change when doing NVA?

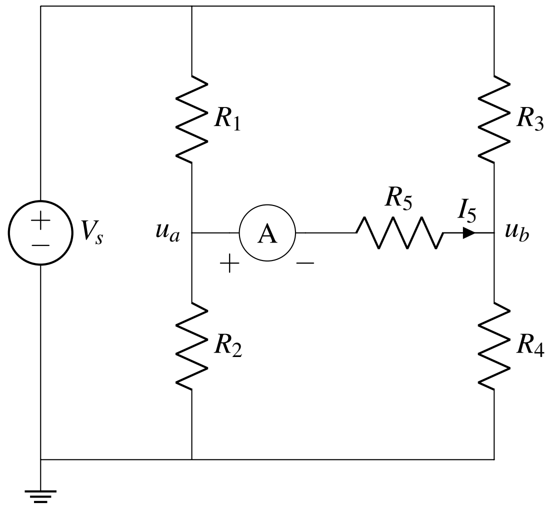


Figure 3: Circuit with ammeter.

(c) The circuit diagram shown in Figure 1 has been redrawn in Figure 3 by adding an ideal ammeter (letter *A* in a circle and plus and minus signs indicating direction) in series with resistor R_5. This will measure the current I_5 through R_5. Are the values of I_5 before adding the ammeter and after adding the ammeter different? If so, what equations change when doing NVA?

(d) Your friend accidentally connects a voltmeter in part (c) above, rather than an ammeter. Are the values of I_5 before adding the ammeter and after adding the ammeter different? If so, what equations change when doing NVA?

3. Practice: Cell Phone Battery

As great as smartphones are, one of their drawbacks is that their batteries don't last a long time. For example, a Google Pixel phone, under typical usage conditions (internet, a few cat videos, etc.) uses 0.3W. We will model the battery as an ideal voltage source (which maintains a constant voltage across its terminals regardless of current) except that we assume that the voltage drops abruptly to zero when the battery is discharged (in reality the voltage drops gradually, but let's keep things simple).

Battery capacity is specified in mAh, which indicates how many mA of current the battery can supply for one hour before it needs to be recharged. The Pixel's battery has a battery capacity of 2770mAh at 3.8V. For example, this battery could provide 1000mA (or 3.8W) for 2.77 hours before the voltage abruptly drops from 3.8V to zero.

(a) How long will a Pixel's full battery last under typical usage conditions?

(b) How many coulombs of charge does the battery contain? How many usable electrons worth of charge are contained in the battery when it is fully charged? (An electron has 1.602×10^{-19} C of charge.)

(c) Suppose the cell phone battery is completely discharged and you want to recharge it completely. How much energy (in J) is this? Recall that a J is equivalent to a W s.

(d) Suppose PG&E charges \$0.12 per kWh. Every day, you completely discharge the battery (meaning more than typical usage) and you recharge it every night. How much will recharging cost you for the month of October (31 days)?

(e) The battery has internal circuitry that prevents it from getting overcharged (and possibly exploding!). We will model the battery and its internal circuitry as a resistor R_{bat}. We now wish to charge the battery by plugging into a wall plug. The wall plug can be modeled as a 5 V voltage source and 200 mΩ resistor, as pictured in Figure 4. What is the power dissipated across R_{bat} for $R_{\text{bat}} = 1\,\text{m}\Omega$, $1\,\Omega$, and $10\,\text{k}\Omega$? (i.e. how much power is being supplied to the phone battery as it is charging?). How long will the battery take to charge for each of those values of R_{bat}?

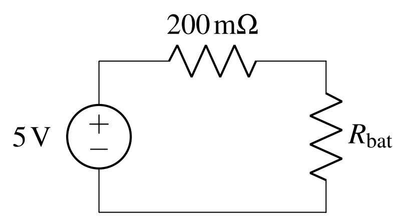


Figure 4: Model of wall plug, wire, and battery.