Useful Circuits

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PES 216 Prelab Questions

Lab Station:

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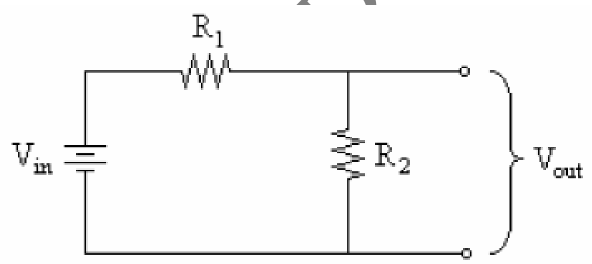
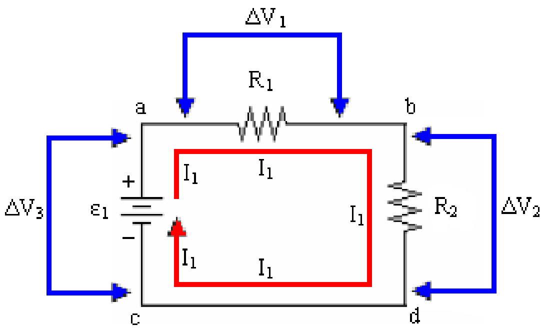
- Calculate the output voltage of a voltage divider with the following:

  $V_{in} = 10$ V
  $R_1 = 3\text{k}\Omega$
  $R_2 = 1\text{k}\Omega$



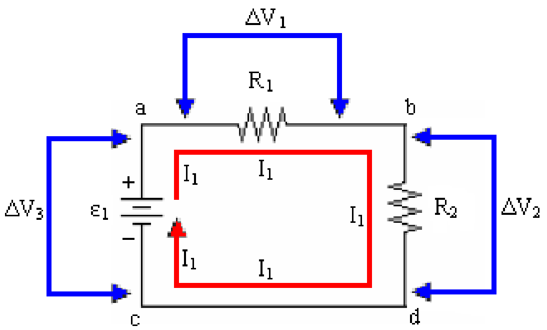
First, let's get this into standard form so we can compare it to the analysis we did for Lab 7. Notice that we've already applied Kirchhoff's Zeroth rule for the current in the circuit:



Next, it is obvious that we need to apply the Loop Rule for the closed loop in the circuit diagram (use Ohm's Law as described at the beginning of the Kirchhoff's Law pre-lab):

We have 1 loop that we need to consider. This loop is (using the letters to describe the loop):

Loop 1 = a-b-d-c-a:



Applying Ohm's Law using the convention set up at the beginning of the pre-lab 7:

From a to b:

$$\Delta V_1 = -I_1 R_1$$

From b to d:

$$\Delta V_2 = -I_1 R_2$$

From d to c:

$$\Delta V = 0$$

From c to a:

$$\Delta V_3 = +\varepsilon$$

According to the loop rule, the sum of the potential rises and decreases around a closed loop must be zero.

$$\sum_{i=1}^{n} \Delta V_i = 0$$

$$\sum_{i=1}^{4} \Delta V_i = -I_1 R_1 - I_1 R_2 + 0 + \varepsilon = 0$$

$$-I_1R_1 - I_1R_2 + \varepsilon = 0 \text{ (eq. 1)}$$

Solve the system of equations for the knowns and unknowns:

We are given the following information from the beginning of the problem:

ε	R_1	R_2
10 V	3 kΩ	1 kΩ

That means that the unknowns are:

$$I_1$$

Here is the list of consolidated equations we found using the loop rule and junction rule on the circuit:

$$-I_1R_1 - I_1R_2 + \varepsilon = 0 \text{ (eq. 1)}$$

First, start by solving equation 1 for I_1:

$$-I_1(R_1 + R_2) + \varepsilon = 0$$

$$-I_1(R_1 + R_2) = -\varepsilon$$

$$\boxed{I_1 = \frac{\varepsilon}{(R_1 + R_2)}}$$

We can now plug in the values of the given information and solve for the numerical value of the current.

$$I_1 = \frac{10\ V}{((3k\Omega) + (1k\Omega))}$$

$$I_1 = \frac{10\ V}{((3\times10^3\,\Omega) + (1\times10^3\,\Omega))} = \frac{10\ V}{(4000\Omega)}$$

$$\boxed{I_1 = 0.0025\ A = 2.5\ mA}$$

Finally, we can determine the potentials (voltages) across component #2 (where Vout is located) by Ohm's Law.

$$\Delta V_2 = -I_1 R_2$$

$$\Delta V_2 = -(2.5\ mA)(1k\Omega) = -(2.5\times10^{-3}\ A)(1\times10^{3}\ \Omega)$$

$$\boxed{\Delta V_2 = -2.5\ V}$$

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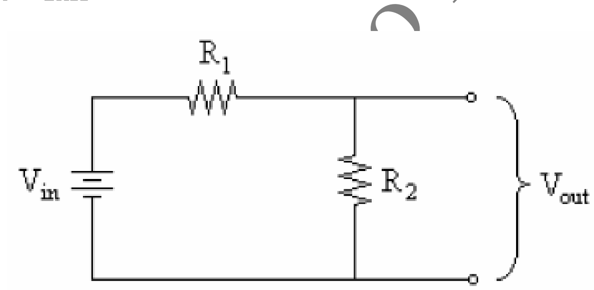
For a voltage divider, you can use either of the two potential drops (negative delta V's) as your voltage out of the divider, depending on what you need. So say you have an EMF of 10 Volts, like our problem but you only need 2.5 Volts for your circuit to run. Then you would use the potential drop across resistor 2 as your "new" EMF for that circuit. It's like conservation of power! ☺

- Calculate R_1 for the following voltage divider:
  $V_{in} = 1000$ V
  $V_{out} = 20$ V
  $R_2 = 1k\Omega$



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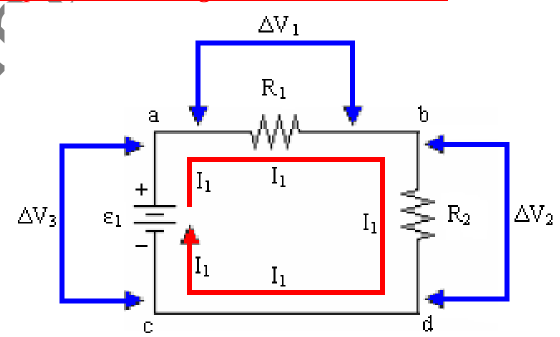
Again, setting this up as before, using the standard notation:



It is obvious that V_{in} is ΔV_3 (or simply the EMF) and V_{out} is ΔV_2. Hence, we are given:

ε	ΔV_2	R_2
1000 V	-20 V	1 kΩ

Notice that the sign on the potential drop across resistor two is negative. Recall from the previous problem we had the following from Ohm's Law:

$$\Delta V_2 = -I_1 R_2$$

Also, we found an expression for the current:

$$I_1 = \frac{\varepsilon}{(R_1 + R_2)}$$

Let's plug the current into the potential drop equation and then solve for R_1:

$$\Delta V_2 = -\left(\frac{\varepsilon}{(R_1 + R_2)}\right) R_2 = \frac{-\varepsilon R_2}{R_1 + R_2}$$

$$\Delta V_2 (R_1 + R_2) = -\varepsilon R_2$$

$$\Delta V_2 R_1 + \Delta V_2 R_2 = -\varepsilon R_2$$

$$\Delta V_2 R_1 = -\varepsilon R_2 - \Delta V_2 R_2$$

$$\boxed{R_1 = \frac{-\varepsilon R_2 - \Delta V_2 R_2}{\Delta V_2} = \frac{-R_2(\varepsilon + \Delta V_2)}{\Delta V_2}}$$

Plugging in the value that we were given,

$$R_1 = \frac{-(1\ k\Omega)(1000\ V + (-20\ V))}{-20\ V}$$

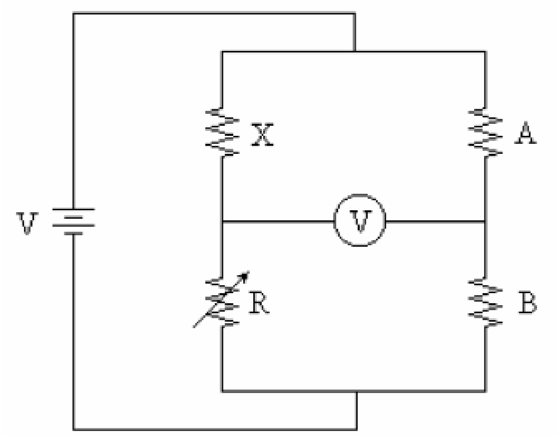
$$R_1 = \frac{-(1\ k\Omega)(980\ V)}{-20\ V} = 49\ k\Omega$$

$$\boxed{R_1 = 49\ k\Omega}$$

- **For the next ~~2~~ 3 questions assume a Wheatstone Bridge with A = 1kΩ, B = 100kΩ and R set such that the voltmeter is reading 0V. Find the resistance value of X based on the following R values.**

  R = 200Ω
  R = 4Ω
  R = 0.1Ω

** Note that this question is a little flakey. Typically, the values of R are HUGE. (Like on the order of mega-ohms). This may be more believable if the values were kilo-ohms or mega-ohms, but these just seem WAY too small for a typical Wheatstone Bridge. **



From Kirchhoff's Rules (and a lot of algebra) we can show that:

$$X = \frac{RA}{B}$$

For the resistance substitution box set to 200Ω:

$$X = \frac{(200\ \Omega)(1\ k\Omega)}{(100\ k\Omega)}$$

$$X = \frac{(200\ \Omega)(1000\ \Omega)}{(100000\ \Omega)} = 2\ \Omega$$

$$\boxed{X = 2\ \Omega}$$

For the resistance substitution box set to 4Ω:

$$X = \frac{(4\ \Omega)(1\ k\Omega)}{(100\ k\Omega)}$$

$$X = \frac{(4\ \Omega)(1000\ \Omega)}{(100000\ \Omega)} = 0.04\ \Omega$$

$$\boxed{X = 0.04\ \Omega}$$

For the resistance substitution box set to 0.1 Ω:

$$X = \frac{(0.1\ \Omega)(1\ k\Omega)}{(100\ k\Omega)}$$

$$X = \frac{(0.1\ \Omega)(1000\ \Omega)}{(100000\ \Omega)} = 0.001\ \Omega$$

$$\boxed{X = 0.001\ \Omega}$$

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