EE 261 **Spring 2025** **Homework 2–Handwritten**

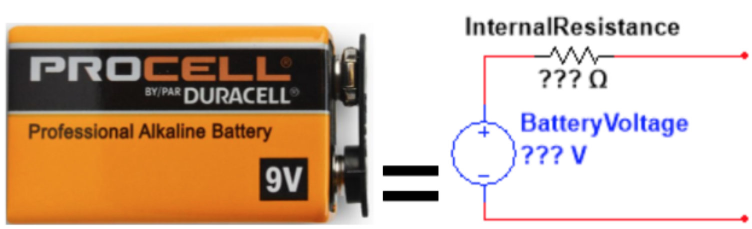
Due Wednesday, Jan. 22, 2025 by 11:59 p.m.

NOTE: This is only the "handwritten" portion of Homework 2. There are also problems you must do online via the Mastering site. For this handwritten portion you must *submit a PDF* scan of your work at Canvas. Please ensure your work is contained in a *single file* and is legible.

The following problems are slightly modified problems courtesy of Prof. Brian Faulkner of the Milwaukee School of Engineering who is keen to ask practical ("real world") problems. With that in mind, note the following:

- Real voltage sources have some internal resistance. This can be modeled as an ideal source in series with a resistance as described in the first problem. In practice, the smaller this resistance, the better.
- Ideal voltmeters measure a voltage but draw no current. They are sometimes depicted as a circle with a "V" inside. You can think of voltmeters as having infinite resistance. (Two voltmeters are drawn in the schematic in the last problem.)

1. You are testing a new battery that nominally has a voltage of 9 V. You first connect a voltmeter directly to the battery and measure 8.9 V between the terminals. Then, you connect a $98\ \Omega$ resistor between the terminals and measure the voltage across this external resistor. This time you measure 8.7 V.
   (a) Draw and label two circuit diagrams, one for each measurement. (You don't need to explicitly draw the voltmeter.)
   (b) Determine the battery voltage and the internal resistance of the battery.



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2. We are "jumping" a car battery because somebody left their headlights on while parked. (Jumping a battery is synonymous with the situation described in Prob. 1.14 of N&R which you solved in the previous homework.) The "fresh" car battery has a chemical voltage 13.5 V in series with an internal resistance of 15 mΩ. The dead battery has a chemical voltage of 11.6 V (not high enough to start) in series with an internal resistance of 70 mΩ. The jumper cables have a resistance of 3 mΩ in the red cable (used to connect the positive terminals) and 3 mΩ in the black cable (used to connect the negative terminals).

   (a) Draw the circuit diagram for this situation and label all components.

   (b) What is the useful power delivered to the dead battery's chemistry? (The "useful" power goes into what we're considering the 11.6 V voltage source. Any power consumed by a resistor is not useful.)

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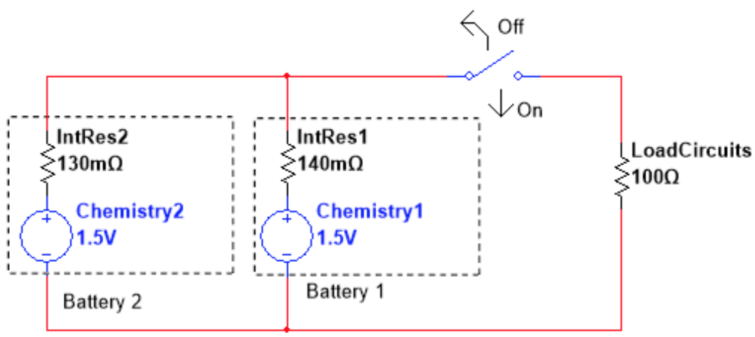
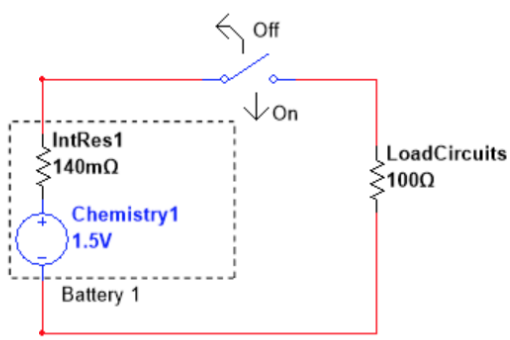
3. Putting batteries in parallel allows them to act like one higher-capacity battery. The following circuit shows such an arrangement for a small consumer electronics device powered by two AA batteries.

   (a) Find the current that flows out of Battery 1 when the load is connected, i.e., the switch is in the "On" position. (We take "out of" the battery to mean current flowing out of the positive terminal.)

   (b) Find the current that flows out of Battery 1 when the load is connected, i.e., the switch is in the "On" position, *and* Battery 2 has been removed from the circuit.



(a)



(b)

Hint: You can solve part (a) using KCL and Ohm's Law. Consider starting by labeling the current through, and the voltage across, the load. You can relate the load current to the currents through each of the batteries which must also be the current through their respective resistors. Putting these facts together you should be able to obtain one equation for the load voltage (that also includes the known battery resistances, the load resistance, and the battery voltages). Once the load voltage is known, you can determine all the currents.

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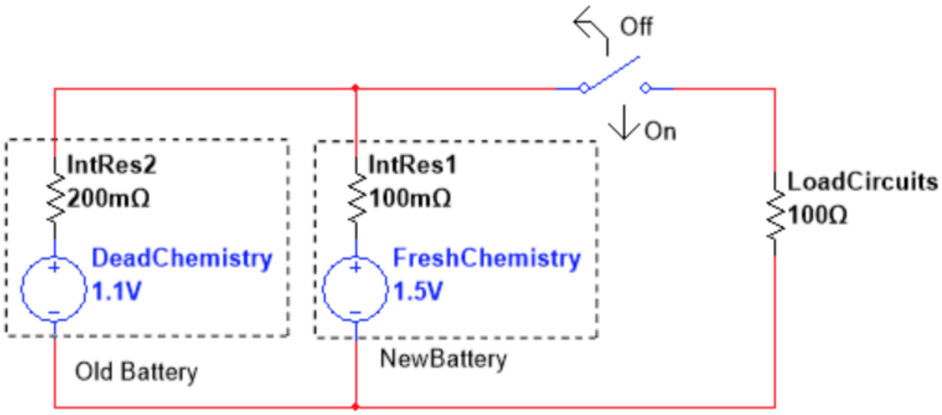
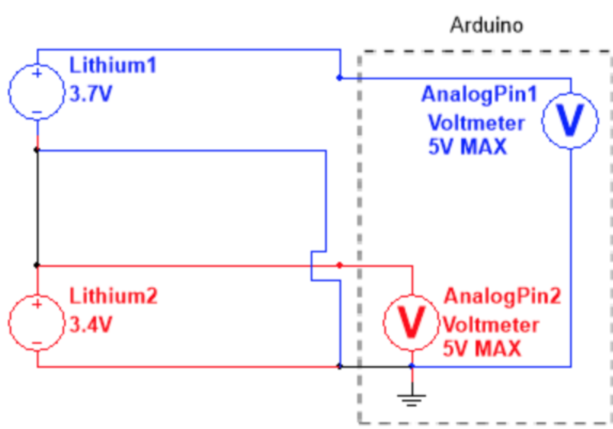
4. Manufacturers recommend always powering devices using batteries of the same brand and freshness. This is important. Batteries change voltage as they discharge, which can cause old batteries to drag down new ones. To illustrate this, consider the circuit shown below. Show that when the load is connected, most of the current that leaves the new battery does *not* go through the load.



5. Assume a project (that is not shown) uses two lithium batteries in series. We want to monitor the voltages of these batteries individually as they discharge. Arduinos are low-cost microprocessor boards that are popular with hobbyists and the do-it-yourself community. Arduinos have analog connections, i.e., "pins" that can be used to measure voltage (using analog to digital converters within the Arduino). It seems we can monitor a battery by connecting the lower polarity to the ground pin and the higher polarity to the analog pin. Indeed, for a single battery the voltage measured at this pin is just what we want. But, assume we connect the plus terminal of each battery of these series batteries to two separate analog pins and the minus terminal of each battery to ground as depicted below.



What we have hooked up will *not* work as we intended. What is wrong with this circuit? (You may assume the analog pins act as ideal voltmeters such that they merely sense an applied voltage and draw no current, i.e., they behave as open circuits.)

Note: Late homework will not be accepted!