DC Circuits Lab

<u>Purpose</u>

The goal of these experiments is for the student to develop an understanding of direct current circuits consisting of batteries and resistors (or other resistances). Series and parallel connections will be explored as well as the resistance properties of batteries, meters, and lamps.

<u>Procedure</u>

All circuits will be constructed on the Vernier Circuit Board. The board is powered by two D-cells, in series provide 3 volts to terminals 1 (+) and 35 (–) when switch SW1 is in the "3V" position. It is good practice to leave this switch off except when actually making observations and measurements of the circuit (the "External" position is equivalent to OFF unless an external power supply is connected to terminals J1 and J2). Jumper cables with alligator clips are used to connect the various parts of the circuit. Note that the circuit elements on the board have binding posts to which two alligator clips may easily be connected – one atop the other.

<u>Parts A, B – Series Resistors, Parallel Resistors</u>

Calculate the theoretical currents and voltages for the circuit shown based on the ratings of the batteries and resistors. Show work in the space provided and enter the results in the table. Note that currents are shown in a certain direction in the diagram – if the conventional positive current is in the opposite direction enter it as a negative in the table.

Construct the circuit and measure the currents and voltages using digital multimeters. The measured values should be fairly close to the values based on ratings – if not check the connections and settings of the meter and also your calculations. Do not expect *perfect* results – ratings for electronic equipment are typically nominal values.

<u>Part C – Batteries, Meters, and Lamps</u>

In this experiment the real properties of electrical elements will be explored. The internal resistance of a battery and of an ammeter, and the varying resistance of a lamp, will be investigated by varying the current and measuring the voltage.

Construct a simple series circuit incorporating the 3 V battery, an ammeter, a "resistance", and a bulb. This circuit should be a single loop such that each element carries the same current as shown on the ammeter. Use a voltmeter to determine the voltage across: the battery, the ammeter, and the bulb. Vary the "resistance" so that different amounts of current flow in the circuit. The "resistance" can be a single resistor or a combination of resistors to achieve a resistance value not available on the board with a single resistor. *And* the "resistance" can be a conductor such that it is essentially zero ohms.

<u>Part D – Rechargeable Cell, Kirchoff's Laws</u>

A single AA rechargeable cell will be charged and discharged using the circuit shown. Changing the value of resistor R_3 controls current in or out of the rechargeable cell. Use two ammeters to simultaneously measure the current out of the 3 V battery and the current out of the AA cell. A negative current value for the single cell indicates it is being charged.

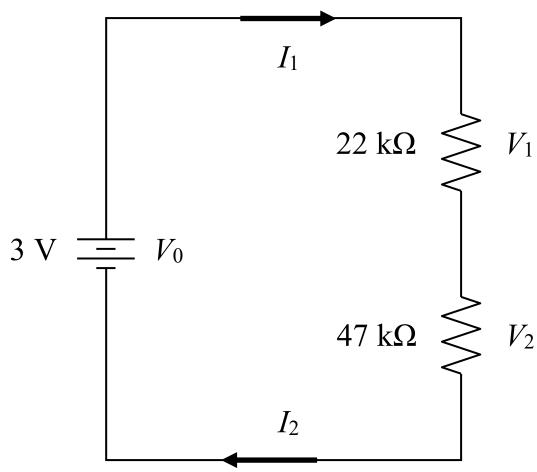
Analyses

1. Produce a graph of voltage vs. current using data from Part C. Show all three devices on one graph using different symbols and/or colors and include a key or legend. Use a calculator or computer to determine the line of best fit for the battery and the meter and an appropriate curve for the lamp. Plot the lines and curve and include the equations on the graph.
2. Produce a graph of current I_2 versus current I_1 using the data from Part D. Include an appropriate line of best fit and include the equation.
3. Produce a graph of V_t versus current I_2 using the data from Part D. Include an appropriate line of best fit and include the equation.

Questions

1. (a) Use the data for voltage and current from Part A and from Part B to determine two different experimental values for the resistance of the 22 kΩ resistor. (b) Do the same for the 47 kΩ resistor. (c) Determine the percent difference between the experimental values determined and the indicated values of resistance.
2. Consider Part C voltage vs. current for the 3 V battery. Determine the values of the emf and internal resistance based on the coefficients of the equation for the best fit.
3. Consider Part C voltage vs. current for the ammeter.
   (a) Based on the results of the curve fit, determine the resistance of the ammeter.
   (b) Does it appear to be an ohmic device? Explain.
4. Consider Part C voltage vs. current for the lamp.
   (a) Does it appear to be an ohmic device? Explain.
   (b) As the power increases, does the resistance of the lamp increase or decrease? Explain.
5. (a) Analyze the circuit used in Part D and derive a theoretical relationship between I_1 and I_2. Give I_2 in terms of $\mathcal{E}_1$, $\mathcal{E}_2$, r_1, r_2, R_1, and I_1. Disregard the resistance of the ammeters when deriving this expression. Show work!
   (b) State whether or not your graph and data for I_1 and I_2 are consistent with the expression derived. Explain.
   (c) The value of r_2, the internal resistance of the AA cell, can be determined using *either* the slope *or* the y-intercept of the best fit line. Make *both* of these determinations, incorporating the results from *Part C* of the lab – taking the internal resistance of the 3 V battery and the resistance of an ammeter to be known values. Show all work.
6. Discuss the graph of the voltage V_t versus I_2. Is this consistent with the expected behavior of the rechargeable AA cell? Is it consistent with the other graphs and determinations? Explain.

Part A – Series Resistors

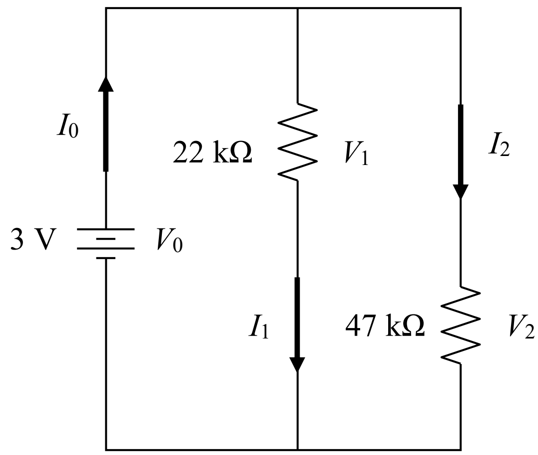


	Based on Ratings:	Based on Measurements:
I_1		
I_2		
V_0	3.00 V	
V_1		
V_2		
R_{eq}		

Note: R_{eq} represents the combined equivalent resistance of the two resistors. For the value based on measurements, apply Ohm's Law to the overall voltage V_0 and current I_1.

Show all calculations necessary to complete the table:

Part B – Parallel Resistors



	Based on Ratings:	Based on Measurements:
I_0		
I_1		
I_2		
V_0	3.00 V	
V_1		
V_2		
R_{eq}		

Note: R_{eq} represents the combined equivalent resistance of the two resistors. For the value based on measurements, apply Ohm's Law to the overall voltage V_0 and current I_0.

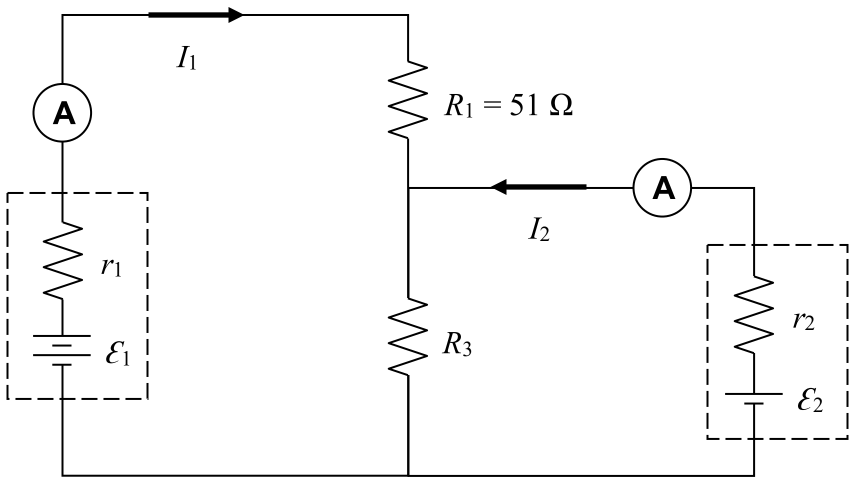
Show all calculations necessary to complete the table:

Part C – Batteries, Lamps, Meters, etc.

Current (mA)	Potential Difference (V)		
	Battery	Ammeter	Lamp
0.000		0.000	0.000

Draw a schematic diagram showing all circuit elements including placement of meters. Note: show the voltmeter in three locations illustrating the various voltage measurements.

Part D – Rechargeable Cell & Kirchoff's Laws



Note: The currents are drawn showing each battery discharging. A negative current value would indicate a battery recharging.

Use a voltmeter to measure each emf <u>before</u> connecting either battery or cell to the circuit. The column labeled V_t is to be completed by calculation using values from the first three columns.

	measured emf $\mathcal{E}_1$:		
	measured emf $\mathcal{E}_2$:		
R_3 (Ω)	I_1 (mA)	I_2 (mA)	$V_t = (I_1 + I_2)R_3$ (V)
∞			N/A
68.0			
51.0			
20.0			
10.0			
5.0			