Electricity IV

Purpose

- To encourage the building of mental models that correspond with physical reality
- To verify that the model of electricity makes predictions that agree with observations
- To determine a functional relation between the flow through any component and the obstacle that it presents to the flow of electricity
- To begin the identification of another quantity with physical significance

Equipment

- 2 rechargeable 'D' cells.
- Battery holders
- 3 rheostats. (Each rheostat uses 30 A.W.G. Kanthal A1)
- 5 #48 bulbs that are in white bulb-holders
- 1 Meter stick
- 8 alligator-to-alligator wires
- 2 (long) banana-to-alligator wires

Verify that you have all of the equipment listed. Notify your TA if anything is missing.

Introduction

Our first task is to see if there is a pattern to the results that were copied from table 3b in electricity III. That table has the measured value of the obstacle that is equivalent to the obstacle made by having L_1 in parallel with L_2 (where $L_1 \neq L_2$).

If N pieces of wire each present an obstacle L then we found that putting the N pieces in parallel, gave an obstacle of size $L_{eq} = \frac{L}{N}$. This expression needs to be generalized to the case of pieces of wire of different length in parallel. **Write an expression for the number of wires of length L cm that (when put in parallel) would present the same obstacle as a wire of length L_1.** (Call this number of wires, N_1 and give your answer in terms of L and L_1.) **[1] Similarly, write an expression for the number of wires of length L cm that (when put in parallel) would present the same obstacle as a wire of length L_2.** (Call this number of wires, N_2 and give your answer in terms of L and L_2.) **[1]**

Now suppose that $N_1 + N_2$ wires of length L cm are put in parallel. **What size of obstacle (called L_{eq}) is presented by them? (Give your answer in terms of L, N_1 and N_2.) [1]**

Use your previous answers to write your L_{eq} in terms of L, L_1 and L_2. Then simplify so that your answer is in terms of L_1 and L_2. [1] This expression gives the obstacle L_{eq} that is equivalent to obstacles of L_1 in parallel with obstacle $L_2 \neq L_1$.

You can use table 3b from electricity III (that you copied before you submitted that report) to make sure that this generalized expression is correct[1]. **Use your generalized expression to calculate the size of the obstacle that is equivalent to the obstacle that results from having L_1 in parallel with L_2. (Include the calculations both for the case $L_1 = 31$ cm & $L_2 = 59$ cm and for the case $L_1 = 47$ cm & $L_2 = 61$ cm.) [2]**

Compare these two results with the values given by your generalized expression in the case $L_1 = 31$ cm & $L_2 = 59$ cm and for the case $L_1 = 47$ cm & $L_2 = 61$ cm . [2]

Since this is a pre-lab, I'll have to assume that your measured and calculated values were similar. Assuming this, we can't reject the hypothesis of there being an obstacle to the flow of electricity. For now, we measure the size of obstacles by comparing them to the obstacle presented by a length of Kanthal wire. In this pre-lab and in electricity III, you figured out how to combine obstacles that are in series and in parallel.

During the experiment, you will need to (repeatedly) identify a flow of electricity of a definite size. You will be deciding on the size of this flow by looking at the effect of the flow on a bulb. The flow of a definite size will correspond to a brightness that you will specify. No two people in your group need to agree on when a bulb is "just glowing". *Choose one member of your group who will always decide if a bulb is 'just glowing'*. A flow of enough size to make bulb *H* just glow will be called 'a flow of 1 glow' in the rest of this description. This is a good time for you to think about units. In all cases, a choice is made about what will constitute one unit. That choice must be used in all cases to avoid internal contradictions so that the choice needs to be repeatable. (More follows in the Instructions about how you might choose 1 glow.)

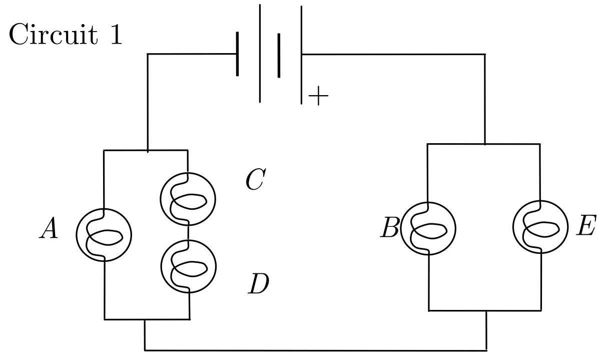
The fact that the size of the flow changes if different components present obstacles of different sizes to the flow has given us a way to measure the sizes of obstacles. This was used in electricity III and allowed us find two rules about obstacles;

a. Two obstacles in series give an obstacle that is the sum of the two obstacles $L_{\text{eq}} = L_1 + L_2$
b. Two obstacles of size L in parallel give an equivalent obstacle of $L_{\text{eq}} = \frac{L}{N}$. When the obstacles in parallel are of different sizes, the equivalent obstacle is smaller obstacle than the smaller of the two obstacles alone; [You will have found a "generalized expression" in the pre-lab that will improve on this statement.]
c. Other factors being equal, the size of the flow increases if a component offers it a smaller obstacle (and vice versa). [A later part of this lab will allow you to improve on this statement.]

We established the fact that there are obstacles to the flow of electricity. But before saying that this fact is 'a concept', we'll see whether the fact is a useful principle that can be used to help our understanding of electric circuits. We will use the Model of Electricity to make predictions about circuit 1 (below). During the lab, you

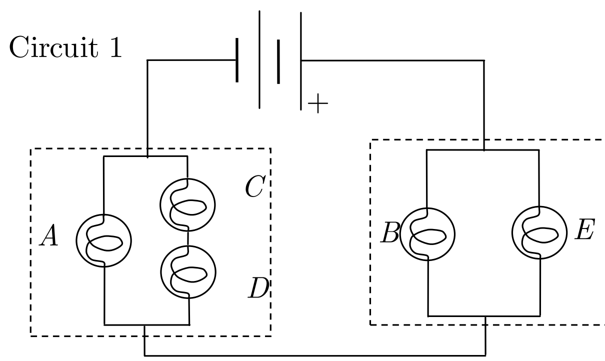
[1] You should be able to generalize further: The equivalent obstacle that is made when three obstacles L_1, L_2 and L_3 are put in parallel is $L_{eq} = \frac{L_1 L_2 L_3}{L_1 L_2 + L_2 L_3 + L_3 L_1}$

will build circuit 1 and check if the predictions are true. This will check both the self-consistency of the model and will check the correspondence of the model with reality.



Assume that the bulbs are identical and that each bulb is ideal (i.e. assume that any given bulb presents the same obstacle to the flow irrespective of the size of the flow through it).

Statement 2 c refers to "other things being equal". *Two networks inside which 'other things are equal' are surrounded with dashed lines.*



This allows you to treat the network of bulbs A, C and D as a single component. In the same way, the network of bulbs B and E is also treated as a single component. This makes circuit one much simpler to think about: two components in series with a battery. This is often a good way to begin thinking about a circuit if we have no information about the flow anywhere in the circuit.

Of course, then you have to separately analyze the networks surrounded with dotted boxes. You'll know about the total flow from the battery from the previous step. Now you'll be in a better position to think about how that flow travels through each network.

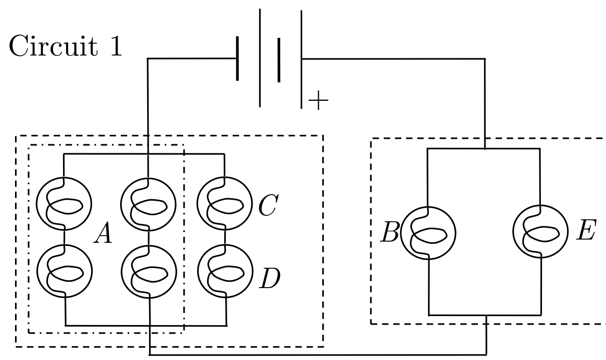
The network on the right is the simpler of the two. **Compare the flow through *B* to the flow through *E*. Explain [1]**

Suppose that *the flow out of the network of bulbs B and E is f*. **How large is the flow through bulb *B* and the flow through bulb *E*? Explain.** (Give your answer in terms of f.) **[1]**

You probably made an assumption to answer the second of these questions. You probably assumed (correctly!) that sum of the flow through bulb B and the flow through bulb E was the same as the flow into & out of the network of bulbs B and E. This is the simplest assumption that might be made and please continue to make it in what follows. In a future pre-lab, we'll use an empirical observation to show that this is how flow behaves.

Recall that we assumed that the flow out of the network of bulbs B and E is f. **How much electricity flows into the network of bulbs A, C and D? [1]**

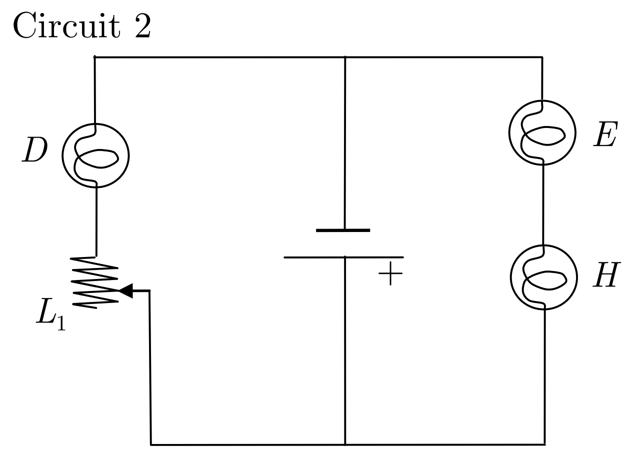
To help with the network of bulbs A, C and D, it might help if you think about the following;



Only the network of A, C & D has changed. Actually, bulbs C and D are still there. What is new is that bulb A has been replaced with two pairs of (identical) bulbs in parallel. Begin by convincing yourself that two pairs of (identical) bulbs in parallel with each other presents the same obstacle as a single bulb. The reason for doing this is that now all three branches are the same as the branch that includes C and D. You already know how much electricity flows into the network of bulbs A, C and D. Recalling the assumption that is underlined above, **what can you say about the flow through the branch that includes C and D?** (Give your answer in terms of f.) **[1] How much of the flow *f* passes through bulb C? [1] What can you say about the flow through bulb A?** (Give your answer in terms of f.) **Explain. [2]**

Use your previous answers to rank the bulbs in order of decreasing brightness. Put an 'equals' sign between bulbs of the same brightness.) **[1]** (For example, $E > D > C = B = A$ would mean that bulb *E* is brightest, followed by bulb *D* and then bulb *C* which is of the same brightness as bulbs *B* and *A*. ***In addition to writing this prediction in your pre-Lab, you'll also need to have it for the lab itself when you'll be checking your prediction.*** *Please write your prediction as the first answer in your report.*

Based on what we have seen so far, a circuit that will measure the obstacle presented by a bulb is;



Bulbs *E & D* are assumed to be identical.

If the length of rheostat L_1 is increased then how will the flow through D and L_1 be affected? [1] Suppose that L_1 is changed so that bulbs *E* & *D* have the same brightness. **Compare the obstacle presented by L_1 and the obstacle presented by bulb *H*. [1]**

How can circuit 2 be used to measure the obstacle presented by bulb *H*? [2] We haven't mentioned bulb *H* so far. **What is the significance of the brightness of bulb *H* when making this measurement? [1]**

There is a complication that you saw in table one of electricity III. **Is the obstacle presented by bulb *H* always the same no matter what flow goes through it? Mention an observation in the electricity labs that supports your answer. [2]**

The obstacle presented by bulb *H* depends on the flow that goes through it. (An 'ideal bulb' presents the same obstacle, irrespective of the flow that passes through it. No real bulb is ideal but assuming that bulbs are ideal is often good enough to get the order of bulb-brightness correct. You (correctly) assumed that the five bulbs in the previous exercise were 'ideal'.) We'll need a circuit that will measure the obstacle presented by a (non-ideal) bulb while a known flow goes through it. By adding another rheostat to the circuit above, **design a circuit that will allow us control the flow through bulb** *H* **while allowing us to measure the obstacle presented by bulb** *H*. **Draw this circuit in your pre-lab.** On your diagram, label;

- the bulbs that must have the same brightness when an obstacle is being measured
- the rheostat that will present the same obstacle as the bulb being measured
- the rheostat that controls the flow from the battery

[5]

Instructions

The #48 bulbs that you use have been sorted into groups of bulbs that are identical. The different groups of bulbs have been marked with different colors of paint on one side of their threaded cylinder. (You probably don't need to take the bulb out of the holder to see the mark.) The bags that bulbs are in have also been marked with the same color of paint. The accuracy of your data depends on your using a group of identical bulbs. *Before you begin, check that all your bulbs have been marked with the same color. Let your TA know if they aren't. When you are finished the lab put the bulbs (and nothing else) back in their marked bag.*

The first part of this lab checks that the model (as developed so far) makes predictions that do not contradict actual observations. You made predictions of brightness of circuit 1 in the pre-lab. These predictions were based on the model and your TA will have reviewed them when introducing this lab. The model can be tested by building circuit 1 and making observations of brightness. *Build circuit 1*. Observe the actual brightness of each bulb compared with bulb *B* and then disconnect the battery. **Write down the ranking of bulb brightness that actually occurs. [4] If your predictions in the pre-lab were incorrect, then write your revised explanation of how the circuit operates in your report.** If the prediction made in your *pre-lab* is incorrect (because the model was applied incorrectly), and no revised explanation is written then the TA will deduct 4 points from the score for this report.

**Ask your TA to check your explanation of circuit 1
if you had to change your explanation in the pre-lab**

I'll assume that you have verified that the model is giving predictions that agree with observations. This is an important check because it shows that "components present an obstacle to the flow", does not conflict with the rest of the model. This fact has also shown itself to be useful in making predictions about the behavior of circuits. Thus, 'obstacle' deserves to be called 'a concept' and should be included in our model of electricity. Here is the model so far;

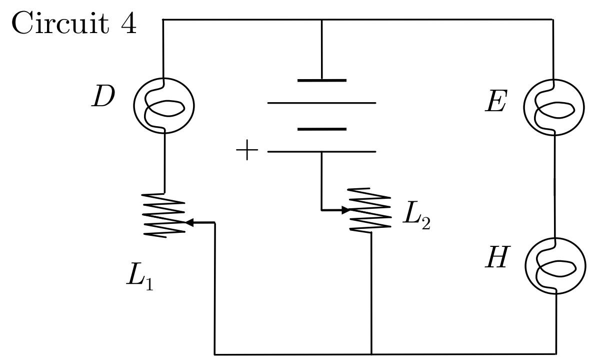
1. Electricity flows in electric circuits.

   a. *If two bulbs are identical and the same flow of electricity passes through them then they will light with the same brightness (and vice versa). The brightness of a bulb increases if flow through it increases (and vice versa).*
   b. *No flow is used up by components as it goes around the circuit*
   c. *The flow through components that are wired in series is the same*
   d. *The flow going into and coming out of a branch (made of components that are in parallel) is the same.*

2. There are obstacles to the flow of electricity.
   a. *Two obstacles in series give an obstacle that is the sum of the two obstacles.*
   b. *Two obstacles in parallel give a smaller obstacle than the smaller of the two obstacles alone.*
   c. *Other factors being equal, the size of the flow increases if a component offers it a smaller obstacle (and vice versa).*

The second part of this lab involves finding a relation between ‘flow’ and ‘obstacle’ that will strengthen statement 2c; ‘*Other factors being equal, the size of the flow increases if a component offers it a smaller obstacle (and vice versa)’*. We’ll do this by measuring both the flow through a component and the obstacle presented by the component. Curve-fitting will help us to find a relation between them.

In the pre-lab, you designed a circuit that would measure the obstacle presented by a bulb (bulb *H*) while giving you the freedom to choose the size of the flow through it. I hope that you came up with something equivalent to;



(The circuit that you designed might have looked different but might have been equivalent.) **Which bulb is having its obstacle measured? [1] Which two (identical) bulbs must have the same brightness before any measurements are made? [2] Explain the roles of the two rheostats. [2]**

Notice that the brightness of bulb *H* is significant now: the brightness of *H* can tell you that 1 glow is flowing through it! To help you remember in practice what 1 glow looks like, you might like to make a one-bulb circuit with a cell and a rheostat. Adjust the rheostat so that 1 glow flows through the bulb. This circuit functions as a ‘reference’ circuit to remind you of what 1 glow looks like. Just remember to switch off this reference circuit when you aren’t using it!

Your TA will have discussed circuit 4 in the introduction. *Build circuit 4.* You’ll have to come up with *your own standard as to what constitutes one glow*. Here is how: Begin with the rheostat L_2 [in circuit 4] being so long that bulb *H* doesn’t light. (Hint: If L_2 isn’t long enough then use one cell to make circuit 4.) Then shorten this rheostat until bulb *H* only ***just*** lights. This flow is one glow. Now use circuit 4 to **measure the obstacle presented by bulb *H* when 1 glow flows through bulb *H*. [3]**. Make sure that you measure the length of the correct rheostat when you do this! We’ll assume that all bulbs are ideal in the sense that they present obstacles of the same size, irrespective of the flow through them. This assumption is accurate enough to allow the correct prediction of bulb brightness in the circuits that we analyze. You will have identified other bulbs as being identical to bulb *H*. However, there are minor differences between bulbs, so the obstacles that they present are not exactly the same. In the following, bulb *H* will always be the one for which you have actually measured the obstacle. *So keep track of bulb H!*

Copy the following table into your report;

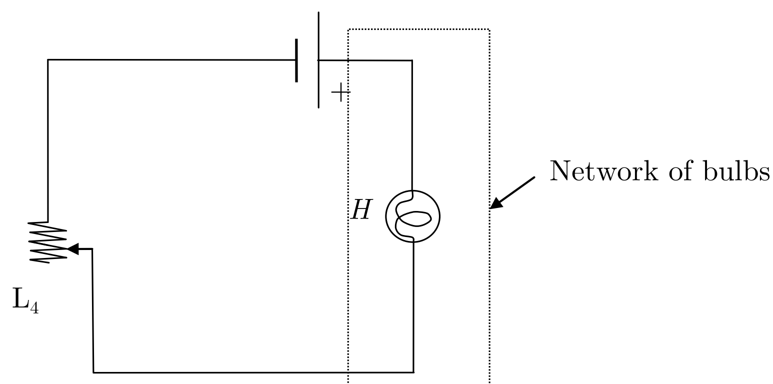
Table 1; one D-cell **[18]**

Circuit	**Flow through Network of Bulbs** ***(glow)***	**Obstacle Presented by Network of Bulbs** ***(cm)***	**Product for the Network of Bulbs** (glow · cm)	***Flow through the Rheostat (glow)***	***Obstacle Presented by the Rheostat (cm)***	***Product for the Rheostat*** (glow · cm)
5	1					
6						
7						
8						

Questions that ask you to fill in table 1 will be in bold and will be italicized. (Other questions to be answered in the report will be asked in bold as usual.)

Consider the following circuit. Bulb *H* is the bulb that you used in circuit four. (For consistency with circuits 6, 7 and 8 below, I'm referring to bulb *H* as 'the network of bulbs'. Those circuits involve networks of more bulbs…..)

Circuit 5



Comment on the following statement: In circuit 5, the rheostat L_2 measures the size of the obstacle presented by the network of bulbs. Therefore the obstacles in the first row (third and sixth columns) should be the same. [2]

You don't have to build circuits 5, 6, 7 and 8 to answer the questions for the first 5 columns of table 1. (You'll build them later so that you can fill in the last two columns of table 1.) [An imaginary dotted box surrounds bulb *H*. The box is included for consistency with circuits that follow.]

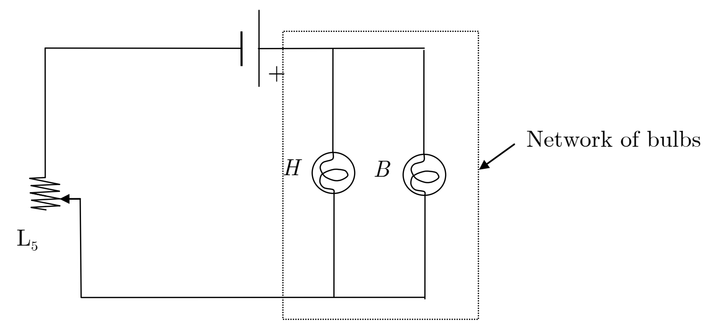
Let's assume that 1 glow flows through bulb *H* (just as it did in circuit 4). **What obstacle is presented by bulb *H* in circuit 5**? **[1]** (Your answer should be a numerical length.) ***Also enter the size of this obstacle in the row corresponding to circuit 5 under the heading, "Obstacle Presented by Network of Bulbs (cm)"***.

For later use, I want you to fill in products of the flow through a certain component and the obstacle presented by the component. Column four of the first row is headed "Product for the Network of Bulbs" and is the product of the flow through the network of bulbs and the obstacle presented by the network of bulbs. ***Fill in the "Product for the Network of Bulbs" in circuit five.*** As yet, there is no physical reason for making this calculation. At the same time, I'd like you to watch for evidence of any physical meaning for 'product' rather taking my word for it that a physical meaning exists.

How is the flow through the rheostat related to the flow through the network of bulbs? Explain. [1] ***Fill in the flow through the rheostat in circuit five (first row, fifth column).*** **[1]** We'll return to the two last columns of table 1 in just over a page when you'll have to build circuit 5.

Now consider,

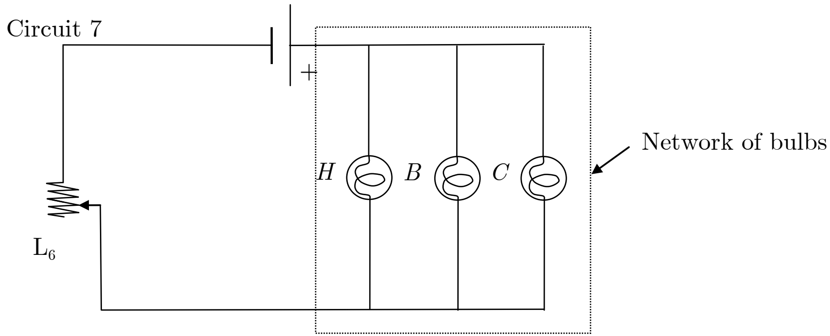
Circuit 6



The only new component in circuit six is bulb *B* and it is identical to bulb *H*. Given that the flow through bulb *H* is 1 glow, what is the flow through the network of two bulbs? ***Write the flow through the network of two bulbs in the second row (second column) of table 1***. **[1]** (Note: as in the pre-lab, we are treating the dotted box as if it were one component. This allows you to think of circuit 6 as a circuit in which all components are in series. The resulting circuit is easier to analyze.) **What obstacle is presented by bulb *B* in circuit 6?** (Hint: You should be able to use your earlier measurements to give a numerical answer.) **[1] Write down the expression that you use to calculate the size of the obstacle that is equivalent to *N* obstacles of size *L* that are in parallel. [1]** Calculate the size of the obstacle that is presented to the flow by the network of two bulbs. ***Write the size of this obstacle (as a numerical length) in the second row of table 1 under the heading, "Obstacle Presented by Network of Bulbs (cm)".*** **[1]** ***Write the product for the network of bulbs in the second row, fourth column.***

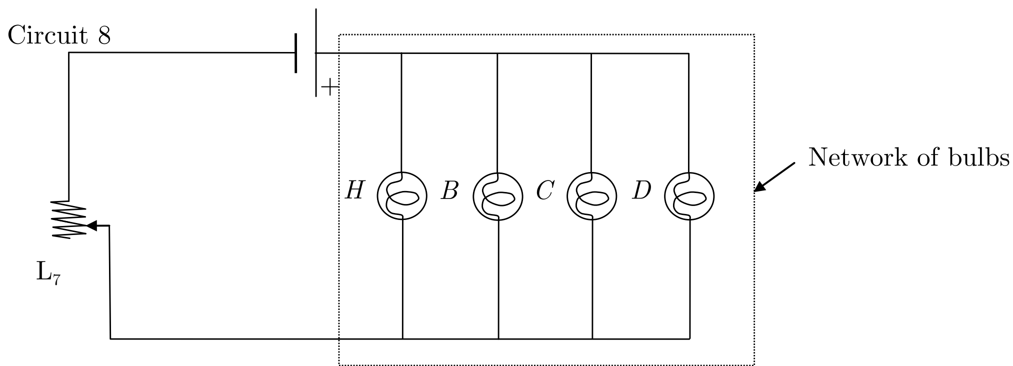
In circuit 6, the flow through the rheostat is related to the flow through the network of bulbs in the same way as in circuit five. ***Fill in the flow through the rheostat of circuit six in the second row (fifth column) of table 1.*** **[1]**

Now consider;



Bulb *C* is identical to bulb *H*. Given that the flow through bulb *H* is 1 glow, calculate the flow through the network of three bulbs. ***Write the flow through the network of circuit 7 in the third row (second column) of table 1.*** **[1]** Calculate the size of the obstacle that is presented to the flow by the network of three bulbs. ***Write the size of the obstacle presented by the network (as a numerical length) in the third row, third column of table 1***. **[1]** ***Fill the product for the network of bulbs of circuit seven into the fourth column (third row).*** Now think about the flow through the rheostat and ***fill in the third row (fifth column) of table 2.*** **[1]**

Finally, consider;



Bulb *D* is identical to the other bulbs in circuit 8. Given that the flow through bulb *H* is 1 glow, what is the flow through the network of four bulbs? ***Write the result in the fourth row (second column) of table 1***. **[1]** Calculate the size of the obstacle that is presented to the flow by the network of four bulbs. ***Write your answer (as a numerical length) in the in the fourth row, third column of table 1***. **[1]** ***Write the product of the flow and obstacle (for the network of bulbs) into the fourth row, fourth column of table 1.*** Think about the flow through the rheostat. ***End by filling in the fourth row (fifth column) of table 1.*** **[1]**

Filling in the sixth column of table 1 requires you to build circuits 5, 6, 7 and 8. Before you do, remember that your bulbs need to be identical. You should check this (by putting all your #48 bulbs in series and making sure that they have the same brightness) because it is one of the factors that determines the reliability of your data.

Build circuit 5 using one newly charged D-cell. <u>Adjust the length of the rheostat so that 1 glow flows through bulb *H*</u>. <u>Disconnect the circuit</u>. (The reliability of your data is also affected by the assumption that each D-cell is the same in later circuits as it was in circuit 5. I want you to disconnect the circuit because cells change if flow is delivered for a long time.) ***Measure the length of the rheostat and write the result in the sixth column (first row) of table 1***. **[2]** The entry in the ***seventh column (first row) is the product of the entries in the first row of columns 5 and 6***. ***Complete the first row of table 1***.

Build circuit 6 <u>using a fresh D-cell from the charger</u>. (Put the other D-cell back in the charger.) Adjust the length of the rheostat so that 1 glow flows through bulb H. After you have done this, <u>disconnect the circuit</u> *and then* ***measure the length of the rheostat. Write the result in the sixth column (second row) of table 1*. [2]** The entry in the ***seventh column (second row) is the product of the entries in the second row of columns 5 and 6*. *Complete the second row of table 1***.

Build circuit 7 *using a fresh D-cell*. Put the used one back in the charger as before. *Adjust the length of the rheostat so that 1 glow flows through bulb H*. After you have done this, <u>*disconnect the circuit*</u>. ***Measure the length of the rheostat and write the result in the sixth column (third row) of table 1*. [2]** The entry in the ***seventh column (third row) is the product of the entries in the third row of columns 5 and 6*. *Complete the third row of table 1***.

Finally build circuit 8 *using a fresh D-cell*. (Put the used one back in the charger again.) *Adjust the length of the rheostat so that 1 glow flows through bulb H*. After you have done this, <u>*disconnect the circuit*</u>. ***Measure the length of the rheostat and write the result in the sixth column (fourth row) of table 1*. [2]** The entry in the ***seventh column (fourth row) is the product of the entries in the fourth row of columns 5 and 6*. *Complete the fourth row of table 1***.

<u>*Table one should be complete now*</u>.

Do the four *products for the rheostat* (in the third column of table 1) change much? [Compare the size of changes in the *product for the rheostat* with the size of changes in the *flow through the rheostat* (column 5) and changes in the *obstacle presented by the rheostat* (column 6)]. Only qualitative comparisons are necessary and you don't have talk about the percent changes. There is quite a bit of uncertainty here so it is not necessary that there is perfect agreement with any trend/comparison that you make[2].] **[1]**

Do the four *products for the network of bulbs* change much? [Compare the size of changes in the *product for the network of bulbs* with the size of changes in the *flow through the network of bulbs* and changes in the *obstacle presented by the network of bulbs*]. **[1]**

The fact the products for given component are at least approximately the same suggests that the product of $flow$ and $obstacle$ has some significance (at least in the context of circuits 5, 6, 7 and 8). But let's make sure that the products are actually constants before we go to the trouble of trying to find physical significance for them.

Use Excel to make a graph of the <u>*flow*</u> *through the* <u>*rheostat*</u> (y-axis) against the <u>*obstacle*</u> *presented by the* <u>*rheostat*</u>. (The relevant data is in the fifth and sixth columns of table 1.) Assume that a power law relates the flow and obstacle so that Excel fits your data to the equation; flow = (constant)*(obstacle)^p. **What is the regression coefficient of your curve-fit? [1] What is the power (*p*) to which obstacle is raised in the equation, flow = (constant)*(obstacle)^p? [1] Print the graph (with trend-line & equation & R^2) and include it with your report.** In the following, <u>I'll refer to the coefficient of (obstacle)^p in this curve-fit equation as being '*the curve-fit constant for the rheostat*'</u>. **Quote the curve-fit constant for the rheostat. [1] Compare the curve-fit constant for the rheostat with (the average) of the products for the rheostat. [1]**

Use Excel to make a graph of the <u>*flow*</u> *through the* <u>*network*</u> *of bulbs* (y-axis) against the <u>*obstacle*</u> *presented by the* <u>*network*</u> *of bulbs*. (The relevant data is in the second and third columns of table 1.) Fit your data to the equation;

[2] This underlines the point that we are making measurements so that we can discover the major features of a 'Model of Electricity'. We aren't making measurements for the sake of having very precise numbers.

flow = (constant)*(obstacle)^p, by assuming that a power law relates the flow and obstacle. **What is the regression coefficient of your curve-fit? [1] What is the power (*p*) to which obstacle is raised in the equation, flow = (constant)*(obstacle)^p? [1] Print the graph (with trend-line & equation & R^2) and include it with your report.** In the following, I'll refer to the coefficient of (obstacle)^p in this curve-fit equation as '*the curve-fit constant for the network of bulbs'*. **Quote the curve-fit constant for the network of bulbs. [1] Compare the curve-fit constant for the network of bulbs with (the average) of the products for the network of bulbs. [1]**

We have already concluded 2 c: *Other factors being equal, the size of the flow increases if a component offers it a smaller obstacle (and vice versa).* In the next answer, you'll need your answer to improve on this statement. **Say how these fits suggest that the flow through *component X* is functionally related to the size of the obstacle presented by *component X*. [1]**

Have your TA check your last answer.

The following comments assume that regression coefficients in your graphs were close to one. These comments also assume when you fit *flow* = (constant)*(*obstacle*)^p to your data, you got $p = -1$ (almost). If so, the curve-fit tells us that we have,

$$flow = \frac{\text{constant}}{obstacle},$$

(at least in circuits 5, 6, 7 and 8). Re-arranging this equation gives $flow \times obstacle = \text{constant}$. But we defined $product \equiv flow \times obstacle$. Thus the curve-fit constant will be the same as the 'product' for a given component. This explains why the (average) products (in table 1) were the same as your curve-fit constants.
Notice that we don't claim that the product is the same for a given component in all circuits. In general, the numerical value for the product (or curve-fit constant) for a given component can change. The next lab will involve very similar circuits to this one, in which the products adopt different constant values. We'll also identify the physical significance of these 'products'.

Remember leave the apparatus as it was when you arrived.
Ask your TA to check your apparatus before you turn in your reports.

Shut-down the computer.

Take all cells out of the battery-holders and put them in recharger. (Make sure that you get the polarity of the battery right.) Connect your battery holders in series before you give the TA your report.

PRE-LAB

NAME:___________________________ Course & Section: __________________

Feel free to draft your answers in pencil but remember that the report to be given to your TA must be in pen.

Table 3b (from electricity III)

Length L_1	Length L_2	Obstacle presented by L_1 and L_2 in parallel
31 cm	59 cm	
47 cm	61 cm	

Write an expression for the number of wires of length L cm that (when put in parallel) would present the same obstacle as a wire of length L_1. (Call this number of wires, N_1 and give your answer in terms of L and L_1.)

$N_1 =$ ____ **[1]**

Similarly, write an expression for the number of wires of length L cm that (when put in parallel) would present the same obstacle as a wire of length L_2 (Call this number of wires, N_2 and give your answer in terms of L and L_2.)

$N_2 =$ ____ **[1]**

What size of obstacle (called L_{eq}) is presented when the $N_1 + N_2$ wires of length L are put in parallel? (Give your answer in terms of L, N_1 and N_2.)

____ **[1]**

Use your previous answers to write your L_{eq} in terms of L, L_1 and L_2.

____ **[2]**

Then simplify so that your answer is in terms of L_1 and L_2.

____ **[1]**

Use your generalized expression to <u>calculate</u> the size of the obstacle that is equivalent to the obstacle that results from having L_1 in parallel with L_2. (Include the calculations both for the case $L_1 = 31$ cm & $L_2 = 59$ cm and for the case $L_1 = 47$ cm & $L_2 = 61$ cm .)

____

____ **[2]**

Compare these two results with the values given by your generalized expression in the case $L_1 = 31$ cm & $L_2 = 59$ cm and for the case $L_1 = 47$ cm & $L_2 = 61$ cm .

____**[1]**

Compare the flow through *B* to the flow through *E*. Explain.

____**[1]**

How large is the flow through bulb *B* and the flow through bulb *E*? (Give your answer in terms of f.) Explain.

____**[1]**

How much electricity flows into the network of bulbs A, C and D?

____**[1]**

…what can you say about the flow through the branch that includes C and D? (Give your answer in terms of f.)

____**[1]**

How much of the flow f passes through bulb C?

____**[1]**

What can you say about the flow through bulb A? (Give your answer in terms of f.) Explain.

____

____ **[2]**

Use your previous answers to rank the bulbs in order of decreasing brightness. Put an 'equals' sign between bulbs of the same brightness. (For example, $E > D > C = B = A$ would mean that Bulb *E* is brightest, followed by bulb *D* and then bulb *C* which is of the same brightness as bulbs *B* and *A*.)

____**[1]**

If the length of rheostat L_1 is increased then how will the flow through D and L_1 be affected?

____**[1]**

Compare the obstacle presented by L_1 and the obstacle presented by bulb H

____ **[1]**

How can circuit 2 be used to measure the obstacle presented by bulb H?

____

____ **[2]**

What is the significance of the brightness of bulb H when making this measurement?

____ **[1]**

Is the obstacle presented by bulb H always the same no matter what flow goes through it? Mention an observation in the electricity labs that supports your answer.

____

____ **[2]**

…design a circuit that will allow us control the flow through bulb H while allowing us to measure the obstacle presented by bulb H. Draw this circuit in your pre-lab. On your diagram, label;

- the bulbs that must have the same brightness when an obstacle is being measured
- the rheostat that will present the same obstacle as the bulb being measured
- the rheostat that controls the flow from the battery

[5]

REPORT

NAME:_____________________________ Course & Section: ___________________

Feel free to draft your answers in pencil but remember that the report to be given to your TA must be in pen.

Copy your prediction (of the ranking of brightness in circuit 1) from your pre-lab into your report.

____**[0]**

Write down the ranking of bulb brightness that actually occurs.

____**[4]**

<u>If your predictions in the pre-lab were incorrect</u> (because the model was incorrectly applied), then write your revised explanation of how the circuit operates in your report. [If you used the model correctly to make the pre-lab predictions then go on to the next question. If the prediction made in your *pre-lab* is incorrect (because the model was applied incorrectly), and no revised explanation is written then the TA will deduct 4 points from the score for this report.]

Which bulb is having its obstacle measured?

____[1]

Which two (identical) bulbs must have the same brightness before any measurements are made?

____[2]

Explain the roles of the two rheostats.

Rheostat L_1: ____

Rheostat L_2: ____[2]

…measure the obstacle presented by bulb *H* when 1 glow flows through bulb *H*.

____[3]

Comment on the following statement: In circuit 5, the rheostat L_2 measures the size of the obstacle presented by the network of bulbs. Therefore the obstacles in the first row (third and sixth columns) should be the same.

____

____[2]

Table 1; one D-cell **[18]**

Circuit	**Flow through Network of Bulbs** *(glow)*	**Obstacle Presented by Network of Bulbs** *(cm)*	**Product for the Network of Bulbs** (glow · cm)	***Flow through the Rheostat*** *(glow)*	***Obstacle Presented by the Rheostat*** *(cm)*	***Product for the Rheostat*** (glow · cm)
5	**1**					
6						
7						
8						

What obstacle is presented by bulb *H* in circuit 5? (Give your answer as a numerical length.)

____**[1]**

How is the flow through the rheostat related to the flow through the network of bulbs? Explain.

____**[1]**

What obstacle is presented to the flow by bulb *B* in circuit 6?

____**[1]**

Write down the expression that you use to calculate the size of the obstacle that is equivalent to *N* obstacles of size *L* that are in parallel.

____**[1]**

Do the four *products for the rheostat* (in the seventh column of table 1) change much? (Only qualitative comparisons are necessary…)

____**[1]**

Do the four *products for the network of bulbs* change much? (Only qualitative comparisons are necessary…)

____**[1]**

…make a graph of the *flow through the rheostat* (y-axis) against the *obstacle presented by the rheostat*… What is the regression coefficient of your curve-fit?

____**[1]**

What is the power (p) to which obstacle is raised in the equation, flow = (constant)*(obstacle)^p?

____**[1]**

Print the graph (with trend-line & equation & R^2) and include it with your report.

Quote the curve-fit constant for the rheostat.

____**[1]**

Compare the curve-fit constant for the rheostat with (the average) of the products for the rheostat.

____**[1]**

Use Excel to make a graph of the *flow through the network of bulbs* (y-axis) against the *obstacle presented by the network of bulbs*. (Choose the best kind of trend-line.) What is the regression coefficient of your curve-fit?

____**[1]**

What is the power (p) to which obstacle is raised in the equation, flow = (constant)*(obstacle)^p?

____**[1]**

Print the graph (with trend-line & equation & R^2) and include it with your report.

Quote the curve-fit constant for the network of bulbs.

____**[1]**

Compare the curve-fit constant for the network of bulbs with (the average) of the products for the network of bulbs.

____**[1]**

Say how these fits suggest that the flow through *component X* is functionally related to the size of the obstacle presented by *component X*. (We have already concluded 2 c: *Other factors being equal, the size of the flow increases if a component offers it a smaller obstacle (and vice versa)* so you'll want to improve on this statement.

____**[1]**

Have your TA check your results.