Electricity V

Purpose

Test the predictions of the model of electricity against observations
Determine physical significance of product of flow and obstacle
Expand model of electricity to include pressure difference

Equipment

- ♦ 3 rechargeable 'D' cells.
- ♦ Battery holders
- ♦ 3 rheostats (with 30 A.W.G. Kanthal A1)
- ♦ 3 #48 bulbs that are already 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

In the following, I'll assume that you convinced yourself in electricity IV that flow and obstacle are inversely related in the circuits that we looked at;

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

(We got this from fitting a curve to data in table 1 of electricity IV. In that case, the 'constant' above was actually a curve-fit constant.) Assuming that flow and obstacle are inversely related, here is the model so far.

1. Electricity flows in electric circuits.

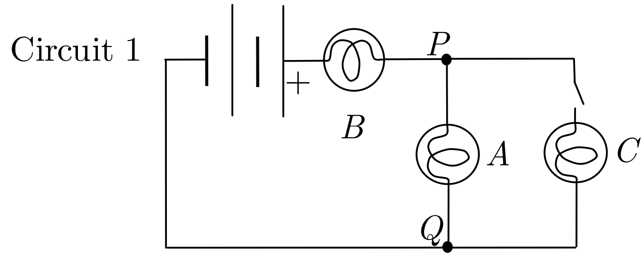
    a. *If two bulbs are identical and the same flow of electricity passes through them then they will light with the same brightness (and vice versa). The brightness of a bulb increases if flow through it increases (and vice versa).*
    b. *No flow is used up by components as it goes around the circuit*
    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.

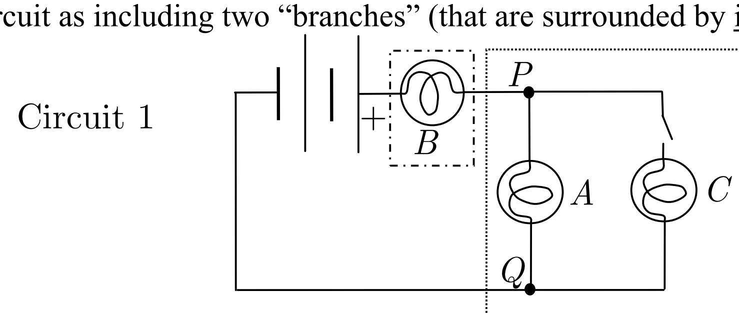
    a. *Two obstacles in series give an obstacle that is the sum of the two obstacles*
    b. *Two obstacles in parallel give a smaller obstacle than the smaller of the two obstacles alone*

c. *Provided that the components are treated in the same way by the battery, the size of the flow increases if a component offers it a smaller obstacle (and vice versa). In fact, the flow through a component is inversely proportional to the obstacle that it presents.*

Consider what the model tells us about the brightness of bulbs in:



When the switch is open then concept [1 a)] from the model of electricity tells us that bulbs *A* and *B* will be equally bright (because the same flow of electricity must pass through each of them). [*When referring to the model of electricity, I'll ask you to refer to labels such as 1 a*) *etc.*] If the switch is closed, it becomes useful to think of this circuit as including two "branches" (that are surrounded by imaginary dotted lines).



Thinking about the branches has the advantage of allowing us to think about a smaller part of the circuit that can be analyzed more easily. Use one of the concepts from our Model of Electricity to **say what happens to the obstacle between points *P* and *Q* when the switch closes**. **Explain, giving the label of the concept (from the model above) that you use**. (Hint: is bulb C between points *P* and *Q* when the switch is closed?) **[2].** The obstacle presented by the other branch is easier to think about; this other branch just contains one bulb; bulb *B*. Now you can think about how the two branches are connected together. **Which is bigger: the obstacle presented to the battery when the switch is open or the obstacle presented to the battery when the switch is closed? Explain, giving the labels of the concepts that you use. [3]**

What will the closing of the switch do to the flow of electricity sent by the battery? Explain, giving the label of the concept that you use. [3]

On the basis of the Model of Electricity, **make a prediction about the brightness of bulb *B* when the switch is closed, as compared with its brightness when the switch is open. Explain, giving the label of the concept that you use. [2]**

The brightness of bulb *B* can also be compared with the brightness of bulb *C*. **Compare the brightness of bulb *B* with the brightness of bulb *C* when the switch is closed. Explain, giving the label of any concepts that you use. [3]**

You will be checking these predictions during the lab and will ***need a record of them***. Record the predictions here;
Circuit 1:

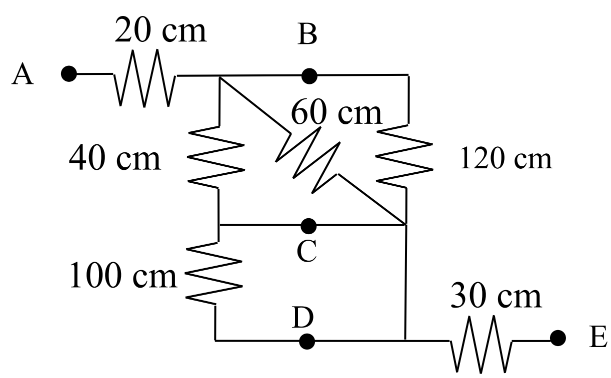
When the switch is open, the model predicts that bulb ___ will have the same brightness as bulb

___. When the switch is closed, the model predicts that bulb ___ will be brighter than either bulb

___or bulb C. Both bulbs ___ and ___ will have the same brightness when the switch is closed.

Notice that we can't make a prediction about the change in brightness of bulb *A* yet. This is because there are two competing factors: the flow from the battery increased when the switch is closed. But only half of the (increased) flow goes through bulb *A* while the other half goes through bulb *C.* We can't say yet which factor is biggest. The inability of the model to make a prediction is an indicator that something is missing from the model.

Copy the following diagram into your pre-Lab. (In the following diagram, all wires are assumed present no obstacle to the flow.) Remember that when three obstacles L_1, L_2 and L_3 are put in parallel then the appropriate generalization of $L_{eq} = \frac{L_1 L_2}{L_1+L_2}$ is $L_{eq} = \frac{L_1 L_2 L_3}{L_1 L_2 + L_2 L_3 + L_3 L_1}$.

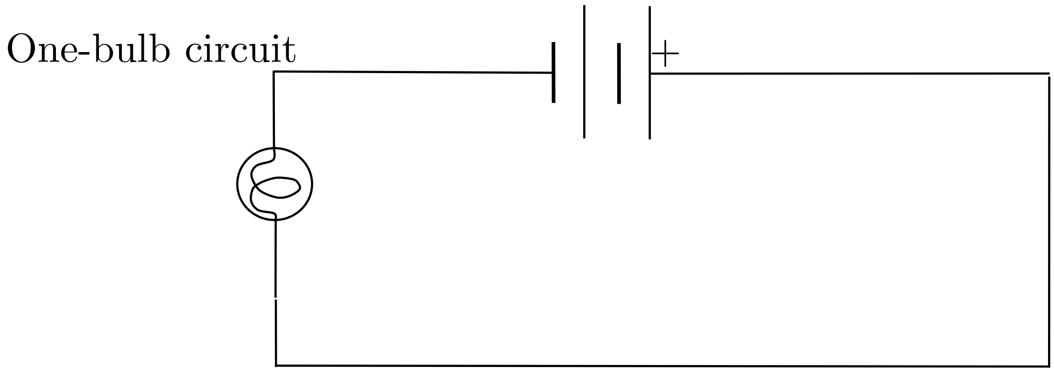


Find the obstacle between the following points; (Write any equations that you use to find equivalent obstacles. Remember that you found these equations in Electricity III.)

- **A and B [1]**
- **E and D [1]**
- **C and B (Give your reasoning.) [2]**
- **D and C (Give your reasoning.) [3]**
- **A and E (Give your reasoning.) [2]**

Instructions

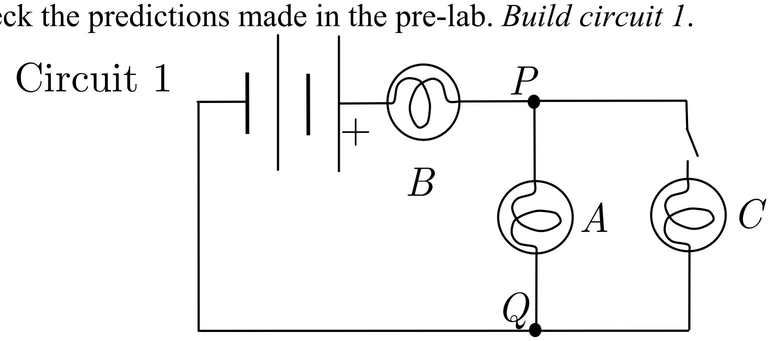
Use 1 D cell to light a single bulb using the one-bulb circuit;



Similarly, check that all your bulbs light in this circuit. Now replace one wire with one of the others so that you verify that the new piece of wire works. Similarly, check all other pieces of wire at your work-area.

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 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 thing is to check the predictions made in the pre-lab. *Build circuit 1.*

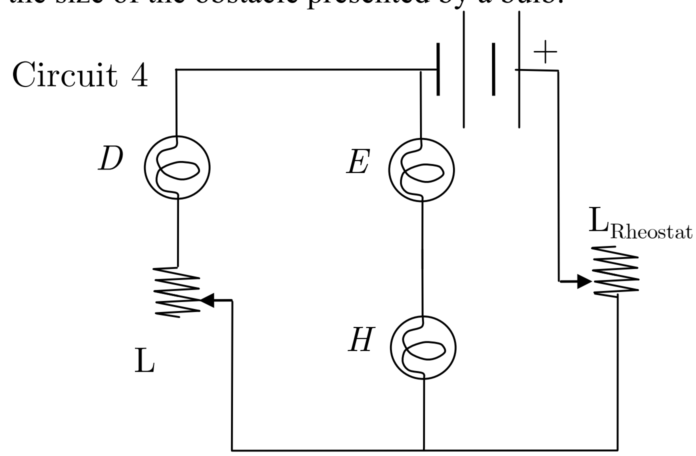


(For best results, use the smallest number of cells that you can. Or put a small rheostat in series with the battery before junction *P* or after junction *Q*.)

How do the predictions of brightness compare with what actually happens? [1] You weren't asked to predict it using the model of electricity, but **how does the brightness of bulb *A* change when the switch is closed? [1]** Circuit 1 allows us to see what actually happens to bulb *A*. It is reasonable to hope that the behavior of bulb *A* will be accounted for by a more adequate model of electricity.

The larger part of this lab is about finding out more about products of flow and obstacle. We can get more quantitative information about 'product' using an approach that is the same as we used for table 1 in electricity IV. In this lab, the battery will be changed systematically. The first thing to do is to change the

number of D-cells that are in series. The second is to see what happens if D-cells are put in parallel with other D-cells.
Even though your bulbs are identical, they will probably not be the same as the ones you used in Electricity IV. This means that the obstacle presented by a bulb (when 1 glow flows through it) will also be different. Thus, the measurement of the obstacle will need to be repeated. You can use the same circuit as you did in Electricity IV to measure the size of the obstacle presented by a bulb.



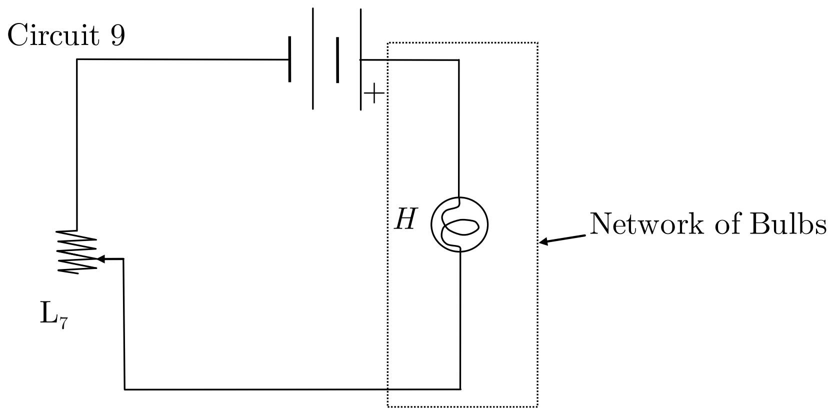
Build this circuit and use it to **measure the obstacle presented by a bulb when 1 glow flows through it.** **[1]** As remarked in electricity IV, there are minor differences between bulbs (even ones that have been identified as being 'identical to bulb *H*'). Thus, the obstacles due to the bulbs are not exactly the same even if the flow through them is exactly the same. In the following, bulb *H* will always be the one for which you have actually measured the obstacle. <u>*So, keep track of bulb H*</u>!

I'll continue the numbering of diagrams from Electricity IV so that the next diagram is of circuit 9. Notice that we use a battery of *two* D-cells in series and we continue using bulb *H*.

Copy the following table into your report;
Table 2; two D-cells in series **[14]**

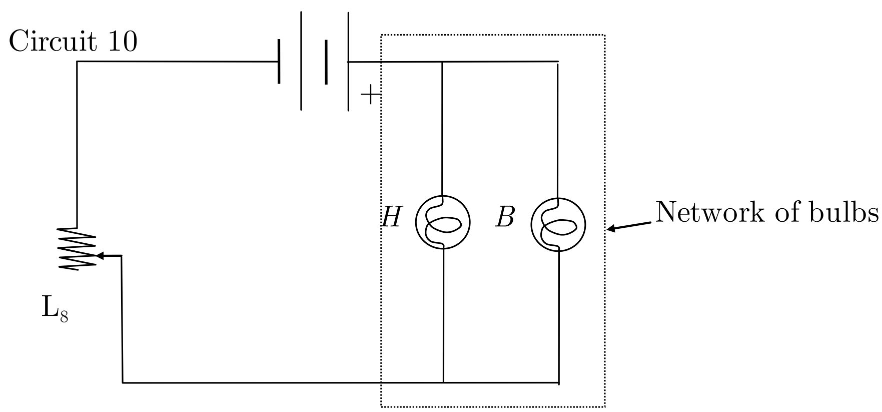
Circuit	**Flow through Network of Bulbs *(glow)***	**Obstacle Presented by Network of Bulbs *(cm)***	**Product for the Network of Bulbs** $(\mathrm{glow}\cdot\mathrm{cm})$	***Flow through the Rheostat (glow)***	***Obstacle Presented by the Rheostat (cm)***	***Product for the Rheostat*** $(\mathrm{glow}\cdot\mathrm{cm})$
9	**1**					
10						
11						

The next three circuits have two D-cells in series. Consider the following circuit;



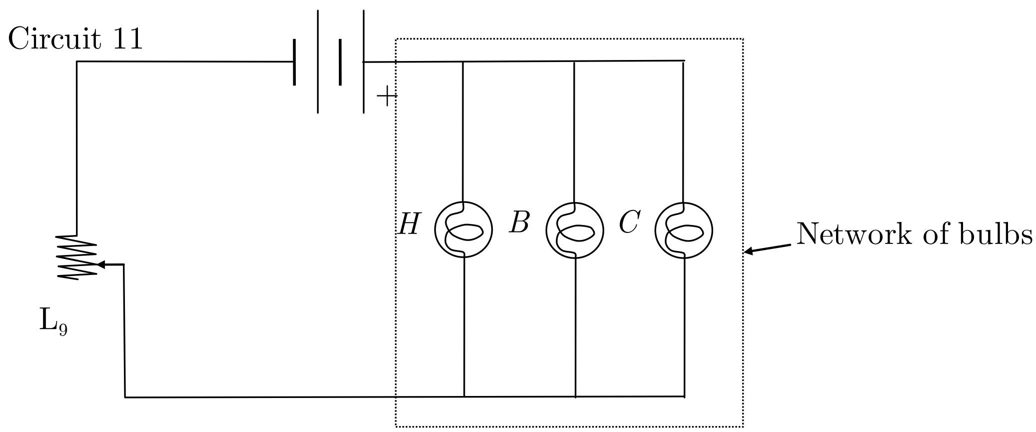
Assume that bulb *H* is the one that you used in circuit 4 and assume that one glow flows through bulb *H*. ***Write the size of the obstacle presented by the 'network of bulbs' (as a numerical length) for circuit 9 in the first row (second column) of table 2*. [1]** ***Fill the product for the network of bulbs or circuit nine into the first row (fourth column) of table 2***. Now ***write the flow through the rheostat in circuit 9 into the first row (fifth column).*** **[1]** We'll return to the last two columns of table 2.

Now consider,



Assume that bulb *B* is identical to bulb *H*. Given that the flow through bulb *H* is 1 glow, find the flow through the network of two bulbs. ***Write the flow through the network of bulbs for circuit ten in the second row (second column) of table 2.*** **[1]** Calculate the size of the obstacle that is presented by the network of two bulbs**.** ***Write the size of the obstacle presented by the network (as a numerical length) in the second row (third column) of table 2*. [1]** ***Write the product for the network of bulbs in circuit ten, into the second row (fourth column) of table 2. Fill the flow through the rheostat into the second row (fifth column) of table 2*. [1]**

Now consider,



Bulb *C* is also identical to bulb *H* and one glow flows through 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 bulbs for circuit 11 in the third row (second column) of table 2.*** **[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 2***. **[1]** ***Write the product for the network of bulbs in circuit eleven into the third row (fourth column) of table 2***. ***Write the flow through the rheostat in the third row (fifth column) of table 2.*** **[1]**

Filling in the rest of table 2 requires you to make measurements. We have assumed that one glow passes through bulb *H* and will have to arrange this experimentally for each of circuits 9, 10 and 11. Then we can measure the length of the rheostat and fill in the sixth column of the table. The seventh column is just the product of entries in columns five and six and won't be hard to fill.

You will always use bulb *H* and will need two other identical bulbs. (<u>Verify that you have three identical bulbs</u> by putting them in series [with one D-cell]. If they are identical then all will have the same brightness. Try it! It is one of the factors that determines the reliability of your data.) You'll need 2 D-cells for each circuit. After building any of the circuits, put the D-cells that you have just used back in the charger. Use two that are freshly charged for the next circuit. In each case, only leave the circuit connected for long enough to establish that 1 glow flows through bulb *H*.

Build circuit 9. Adjust the rheostat to get 1 glow to go through bulb H. <u>Disconnect the battery after establishing that 1 glow flows through bulb H</u>. ***Measure the obstacle presented by the rheostat. Record the size of this obstacle in the first row (sixth column) of table 2.*** **[2]** ***Fill in the product that goes in the first row (seventh column) of table 2.***

You'll have to modify circuit 9 in order to produce circuit 10. *Just add a bulb that is identical to bulb H (and use fresh D-cells). Adjust the rheostat so that 1 glow flows through bulb H of circuit 10. Disconnect the battery.* ***Measure the obstacle presented by the rheostat. Record the size of this obstacle in the second row (sixth column) of table 2.*** **[2]** ***Fill in the product that goes in the second row (seventh column) of table 2.***

Add a third identical bulb (and use fresh cells) to get circuit 11. Adjust the rheostat so that 1 glow flows through bulb H. Disconnect the battery. ***Measure the obstacle presented by the rheostat. Record the size***

of this obstacle in the third row (sixth column) of table 2.* [2] *Fill in the product that goes in the third row (seventh column) of table 2.

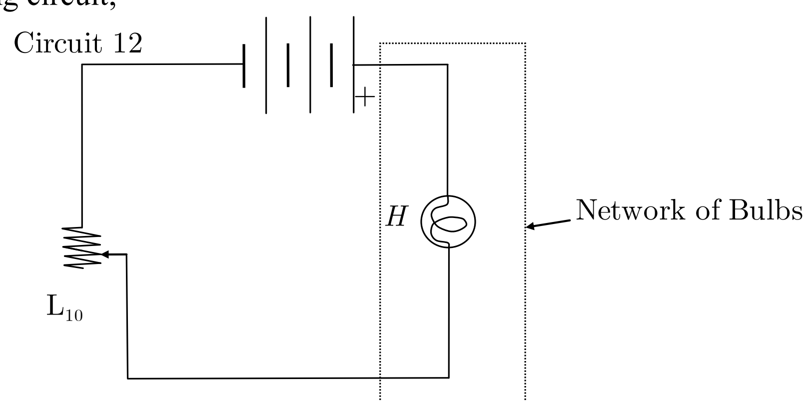
Table two should be complete now.
Ask your TA to check that data in table 2 is consistent with data in table 1 (in electricity IV)

Each of the next three circuits involves three D-cells in series. *Copy the following table into your report*.

Table 3; three D-cells in series **[14]**

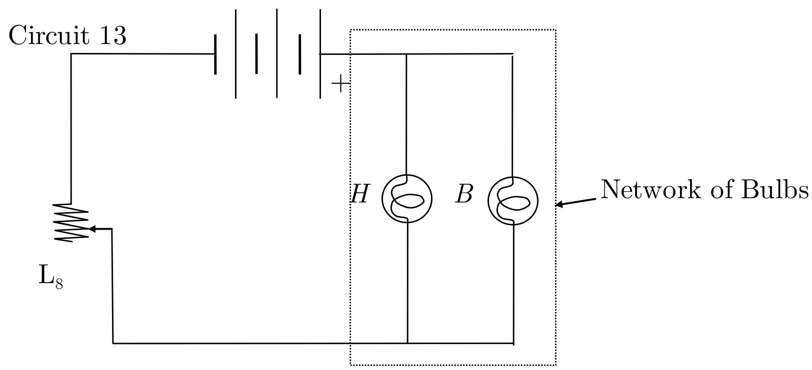
Circuit	**Flow through Network of Bulbs *(glow)***	**Obstacle Presented by Network of Bulbs *(cm)***	**Product for the Network of Bulbs *(* glow · cm *)***	***Flow through the Rheostat (glow)***	***Obstacle Presented by the Rheostat (cm)***	***Product for the Rheostat (* glow · cm *)***
12	**1**					
13						
14						

Consider the following circuit;



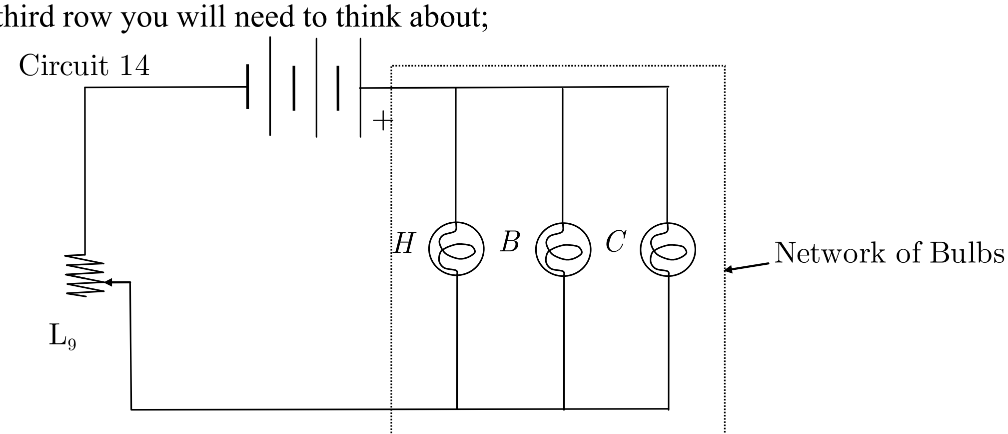
Assume that bulb *H* is the one that you have been using since circuit 4 and assume that 1 glow flows through bulb *H*. ***Write the size of the obstacle presented by the 'network of bulbs' (as a numerical length) in the first row (third column) of table 3*. [1] *Fill in the product for the network of bulbs of circuit twelve into the first row (fourth column) of table 3. Fill the flow through the rheostat into the first row (fifth column) of table 3.* [1]**

Now think about;



Assume that bulb *B* is identical to bulb *H*. Given that the flow through bulb *H* is 1 glow, find the flow through the network of two bulbs. ***Write this flow in the second row (second column) of table 3.*** **[1]** Calculate the size of the obstacle that is presented by the network of two bulbs. ***Write your answer (as a numerical length) in the second row (third column) of table 3*.** **[1]** ***Fill the product for the network of bulbs of circuit thirteen into the second row (fourth column) of table 2.*** Now we turn to the flow through the rheostat. ***Fill the flow through the rheostat into the second row (fifth column) of table 3.*** **[1]**

To fill in the third row you will need to think about;



Bulb *C* is also identical to bulb *H* and one glow flows through bulb *H*. Given that the flow through bulb *H* is 1 glow, calculate the flow through the network of three bulbs. ***Write this flow in the third row (second column) of table 3.*** **[1]** Calculate the size of the obstacle that is presented to the flow by the network of three bulbs. ***Write your answer (as a numerical length) in the third row (third column) of table 3*.** **[1]** ***Fill in the product for the network of bulbs of circuit fourteen into the third row (fourth column) of table 3.*** Consider the flow through the rheostat. ***Write the flow through the rheostat into the third row (fifth column) of table 3.*** **[1]**

Filling in the rest of table 3 requires you to make similar measurements to those for table 2. We have assumed that one glow passes through bulb *H* and will have to arrange this experimentally for each of circuits 12, 13 and 14. Then we can measure the length of the rheostat and fill in the sixth column of table 3. The seventh column is just the product of entries in columns five and six. You will always use bulb *H* and will need two other identical bulbs. You'll need 3 D-cells for each circuit. After building any of the circuits, put the D-cells that you have just used back in the charger. Use cells that are freshly charged for the next circuit. Only leave the circuit connected for long enough to establish that 1 glow is flowing through bulb *H*.

Build circuit 12. Adjust the rheostat to get 1 glow to go through bulb H. Disconnect the battery after establishing that 1 glow flows through bulb H. ***Measure the obstacle presented by the rheostat. Record the size of this obstacle***

in the first row (sixth column) of table 3. **[2]** ***Fill in the product that goes in the first row (third column) of table 3.***

Modify circuit 12 by adding a bulb that is identical to bulb H so that you produce circuit 13. (Don't forget to use fresh cells) Adjust the rheostat so that 1 glow flows through bulb H. Disconnect the battery. Measure the obstacle presented by the rheostat. ***Record the size of this obstacle in the second row (sixth column) of table 3.*** **[2]** ***Fill in the product that goes in the second row (third column) of table 3.***

Add a third identical bulb (and use fresh cells) to get circuit 14. Adjust the rheostat so that 1 glow flows through bulb H. Disconnect the battery. ***Measure the size of the obstacle presented by the rheostat. Record the size of this obstacle in the third row (sixth column) of table 3.*** **[2]** ***Fill in the product that goes in the third row (third column) of table 3.***

Table three should be complete now.

The model stated in the introduction to this lab has no concept of 'something that makes the electricity flow'. For the sake of giving this a name, I'll call it 'pressure difference'. (I hope that the idea of the difference in 'pressure' across a component doesn't seem odd. We already have shown that the concepts of *electricity flowing* and *things presenting an obstacle* to this flow make sense in the context of DC circuits so the idea of pressure-difference seems to fit in quite naturally.)

However, as yet, 'pressure-difference' (in the context of DC circuits) is just an idea with no evidence behind it. If the idea of pressure difference operates as a mental image[1] suggests then the following should be true; if the flow stays constant while the obstacle presented increases then the pressure difference that (we imagine) causes the flow must have increased. Similarly, increased pressure difference (combined with an obstacle of constant size) ought to correspond to increased flow. If this turns out to be the way that electricity really operates then the idea of 'pressure difference' will have turned out to be a meaningful concept.

When we thought of the idea of 'obstacle' in electricity II, we used 'length of Kanthal wire' to measure 'obstacle' in electricity III. We have not developed a measure of 'pressure difference' and will have to look for one in the data in tables 1, 2 & 3. (Remember that table 1 was in Electricity IV so that you will need to refer to that report.)

Consider the behavior of electricity at the rheostat (in columns 5 and 6) by looking at the following data;

- The flow in the 1st row of table, the 1st row of table 2 and the 1st row of table 3.

[1] I intend something simple by the phrase 'mental image'. I am thinking of the common experience of pushing a heavy box along a rough floor. The model of electricity contains something that flows (depending on the size of obstacles that are encountered). But the model doesn't contain something that is analogous to someone pushing the box…

What do the flows and obstacles in rows 1 of the three tables suggest has happened to the 'pressure difference' across the rheostat? Explain why the data suggests this. What happens to the product for the rheostat (also on the first rows)? [2] (It might help if you also look at the behavior of electricity at the rheostat in the 2nd rows of the three tables.)

Also consider the behavior of electricity at the rheostat (columns 5 and 6) by looking at the following data;

- The 1st row of table 1, the 2nd row of table 2 and the 3rd row of table 3.

What do the flows and obstacles on row 1 of table 1, row 2 of table 2 and row 3 of table 3 suggest has happened to the 'pressure difference' across the rheostat? Explain why the data suggests this. What happens to the product for the rheostat? [2] (It might help if you also compare the 2nd row of table 1 and the third row of table 2.)

Using the evidence that we have found, can we say that products are a measure of anything? If so, specify the quantity that 'products' measure. Explain. [2] (If patterns in the data are difficult to see then you might like to consider the behavior of electricity at the network of bulbs instead. This will mean looking at columns 2 and 3 instead of 5 and 6. The rows to be looked at are the same as in the 'bulleted' statements.

We now have another 'fact' about electricity; 'product' is a measure of a physical quantity and so 'product' has physical significance. It is special though: we saw in tables 1 (from electricity IV), 2 and 3 (from electricity V), that it plays the role of causing the flow in the face of obstacles that are presented. Our criterion for the elevation of a 'fact' (about electricity) to the level of 'concept' (that is worth including in the model), has been the usefulness of the fact in explaining the operation of circuits. Before 'pressure difference' (as measured by 'product') can be used, we need to know a little more about it.

Now that we can interpret 'product' as a measure of 'pressure difference', we can get a little more out of tables 1, 2 and 3. Now we can interpret the fourth and seventh columns as being 'Pressure difference across the Network of Bulbs' and 'Pressure difference across the Rheostat'. Notice that for all the rows of a given table, there is only one value of 'Pressure difference across the Rheostat' and one value of 'Pressure difference across the Network of Bulbs'. The values will be approximate (or 'have uncertainty') because they have been measured. In such cases, the average is usually used. Ex. If you need the Product for the Rheostat from table 3 then rather than reading this product from just one row of table 3, use the average Product for the Rheostat instead. [In this example, I am assuming that the Product for the Rheostat in each row of table 3 is approximately the same,]) Another table will be used to see if pressure difference is related to anything. *Copy the following table into your report;*

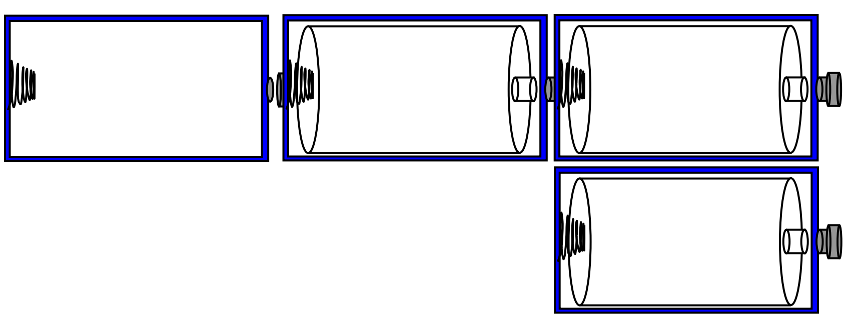
Table 4; Sum of pressure differences in tables 1, 2 and 3.

Table	Sum of Pressure Differences ($glow \times cm$)
1	
2	
3	

Begin with table 1. Find the (average) Pressure Difference across the Rheostat and (average) Pressure Difference across the Network of Bulbs. ***Add the (average) Pressure Difference across the Rheostat to the (average) Pressure Difference across the Network of Bulbs and put their <u>sum</u> into the first row of table four***. **[1]** ***Repeat, using averages from table 2 so that you can fill row two of table four***. **[1]** ***Then fill in the third row of table four (using averages from table 3)***. **[1]** ***Use Excel to fit a curve to the data in table 4. Put the table number on the x-axis and the Sum of pressure differences on the y-axis.*** **What is the (functional) relation between the 'table number' and the 'Sum of Pressure *Differences*'? [1]** (Is the functional relation exponential, linear or logarithmic?)

The term 'Sum of Pressure Differences' deserves comment. Notice that is *<u>not</u>* the same as 'the sum of <u>all</u> of the pressure differences in a circuit'. By asking you to look at the pressure difference across the <u>network</u> of bulbs in tables 1, 2 and 3, you will have counted the pressure difference across bulbs in parallel just once, irrespective of the number of bulbs in parallel that made the network of bulbs. [This is how our mental picture of pressure difference ought to work: the pressure difference across bulb *H* won't change if other bulbs are put in parallel with it. The way to see this experimentally is to notice that the product for the network of bulbs (column four in tables 1, 2 or 3) is essentially constant no matter of how many bulbs (in parallel) were used to make the network of bulbs.]

The 'table number' has no physical meaning. But the 'table number' represents a variable that has physical meaning. **Which variable (that has physical meaning) varies linearly with 'table number'?** (Hint: you might see it if you can say what we change when we go from one table to another.) **[1]** Your previous answer might be missing a word and the following might help you find it. The battery for table 2 was made of three D-cells in series. However, we could ask what would happen if we had two of the D-cells in series and put a third cell in parallel with them.



Replace the battery of circuit 12 with this to make circuit 12 b.

Copy the following table into your report;

Table 5; two cells in series with one cell in parallel

Circuit	**Flow through Network of Bulbs *(glow)***	**Obstacle Presented by Network of Bulbs *(cm)***	**Product for the Network of Bulbs** $(\text{glow} \cdot \text{cm})$	***Flow through the Rheostat (glow)***	***Obstacle Presented by the Rheostat (cm)***	***Product for the Rheostat*** $(\text{glow} \cdot \text{cm})$
12 b	**1**					
13 b						
14 b						

Fill out columns 2, 3, 5 and 6 of table five. **[4]** *(Circuits 13 b and 14 b are just circuits 13 and 14 with this modified battery.)*

Is table 5 an (approximate) copy of table 2 or an (approximate) copy of table 3 or is table 5 very different from either of these? [1] From what we have seen so far, **what causes pressure difference in these circuits? [1]**

Now we can return to a previous question; "Which variable (that has physical meaning) varies linearly with 'table number'. Perhaps your answer mentioned 'batteries'. **Can you improve on your answer to this question by adding a word or two? Explain. [1]**

Now we can summarize what we know about product (pressure difference);

a. *The pressure difference across a component can be calculated as the product of the flow through a component and the obstacle presented to it.*
b. *The pressure difference across components that are wired in parallel is the same*
c. *The sum of pressure differences around a loop that joins one end of the battery to the other is a constant that is a characteristic of the battery. The loop doesn't go through any points more than once: the pressure difference across a component (that is in parallel with others) is only counted once.*

In the pre-lab for 'Multimeters', you'll return to a circuit that you have partly examined in the pre-lab for electricity IV to see that pressure difference is useful in explaining the operation of circuits.

Shut-down the computer.

Take all cells out of the battery-holders and put them in the charger. (Make sure that you get the polarity of the battery right.) If your group used any apparatus from another work-area then please return it. Ask your TA to check that your apparatus is back in-place before you turn in your reports.

PRE-LAB

NAME: Jovanni Ochoa Course & Section: 2126.605

Circuit 1:

1. … say what happens to the obstacle between points *P* and *Q* when the switch closes. (Explain, giving the label of the concept that you use.)

The obstacle between P and Q decreases according to 2b because the circuit changes from

series to parallel. **[2]**

2. Which is bigger: the obstacle presented to the battery when the switch is open, or the obstacle presented to the battery when the switch is closed? (Explain, giving the label of the concept that you use.)

The obstacle given to the battery when the switch is opened is better because according to label

2b, obstacles in parallel are smaller, so when it closes is smaller **[2]**

3. What will the closing of the switch do to the flow of electricity sent by the battery? (Explain, giving the label of the concept that you use.)

The flow of electricity increases according to label 2c because as explained by 2b, the obstacle decreases.

If a small obstacle is present, the flow increases. **[2]**

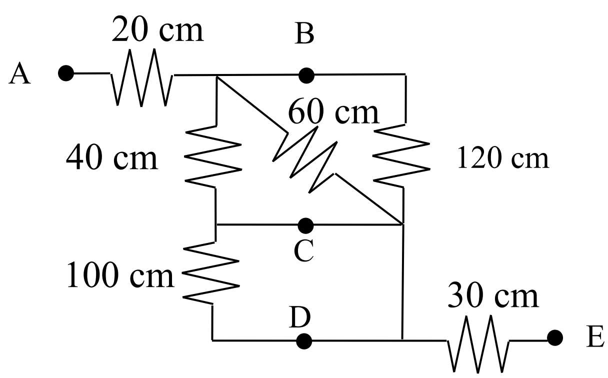
4. … make a prediction about the brightness of bulb *B* when the switch is closed, as compared with its brightness when the switch is open. (Explain, giving the label of the concept that you use.)

[2]

5. Compare the brightness of bulb *B* with the brightness of bulb *C*, when the switch is closed. (Explain, giving the label of any concepts that you use.)

Bulb B is brighter than Bulb C when the switch is closed. According to label 2b, the sum of the obstacles is now smaller. With the obstacles being smaller, there is less flow going through them; thus the bulb is less bright. **[3]**

Your predictions about the brightness of bulbs *B* and *C* will be needed in the first paragraph of your report. Please fill in these predictions before you submit your pre-lab.



(All wires in this diagram are assumed to present no obstacle to flow.)

6. Find the obstacle between the following points: (Write any equations that you use to find equivalent obstacles. Remember that you found these equations in Electricity III and one of them is in the first footnote in electricity IV. Please prove any other equation taken from any other source.)

- ❖ A and B
  20 cm [1]
- ❖ E and D 30 cm [1]
- ❖ C and B (Give your reasoning for this one.)
  20 cm because we have to use the formula to calculate the obstacle in total of it being in parallel
  [2]

- D and C (Give your reasoning for this one. Hint: **think** of this like the previous answer where one of the obstacles gets smaller and smaller.)

  0 cm. There is no obstacle in between this. There is no way for me to calculate it when there is

  nothing in between, except wire, so that means that the obstacle is 0.

  ______ [3]

- A and E (Give your reasoning for this one.)

  70 cm because you have to add all of the obstacles into one by adding in both parallel and

  series. [2]

REPORT

NAME:____________________________ Course & Section: ___________________

The following paragraph is about the **brightness** of bulb *B* and brightness of bulb *C* in circuit 1 as predicted by the Model developed so far. These were **predicted in your pre-lab** and are repeated for later comparison;

Circuit 1:

When the switch is open, the model predicts that bulb A *will have the same brightness as bulb* B*. When the switch is closed, the model predicts that bulb* B *will be brighter than either bulb* A *or bulb C. Both bulbs* A *and* C *will have the same brightness when the switch is closed.* **[0]**

Circuit 1:

1. How do the predictions compare with what actually happens?

The predictions are correct. **[1]**

Circuit 1:

2. …how does the brightness of bulb *A* change when the switch is closed?

Bulb A get's dimmer **[1]**

Circuit 4:

3. …measure the obstacle presented by a bulb when 1 glow flows through it.

59.3 cm **[2]**

Table 2; two D-cells in series **[14]**

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)
9	**1**	59.3	59.3	1	220.8	220.8
10	2	29.62	59.3	2	110.2	220.4
11	3	19.76	59.3	3	70.5	211.5

Table 3; three cells in series

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)
12	**1**	59.3	59.3	1	378.4	378.4
13	2	29.62	59.3	2	181.2	362.4
14	3	19.76	59.3	3	125.1	375.3

[14]

4. What do the flows and obstacles in rows 1 of the three tables suggest has happened to the 'pressure difference' across the rheostat? Explain why the data suggests this. What happens to the product for the rheostat (also on the first rows)?

Pressure difference increases because obstacle increases. The product increases because the pressure difference increases.

[2]

5. What do the flows and obstacles on row 1 of table 1, row 2 of table 2 and row 3 of table 3 suggest has happened to the 'pressure difference' across the rheostat? Explain why the data suggests this. What happens to the product for the rheostat?

Pressure difference increase beacuse the flow increases and the obstacle remains the same. The product of the rheostat stays the same.

[2]

6. Using the evidence that we have found, can we say that 'products' are a measure of anything? If so, specify the quantity that 'products' measure. Explain

The product is the measure of pressure difference, so they must remain the same. Pressure difference is the same when flow and obstacle are the same. **[1]**

Table 4; Sum of pressure differences in tables 1, 2 and 3.

Table	Sum of Pressure Differences ($glow \times cm$)
1	152.8
2	276.85
3	431.33

[3]

7. What is the (functional) relation between the table number and the 'Sum of Pressures Difference'? (Is the functional relation exponential, linear or logarithmic?)

The functional relation is linear **[1]**

8. Which variable (that has physical meaning) varies linearly with 'table number'? (Hint: you might see it if you can say what we change when we go from one table to another.)

The number of cells that changes linearly varies from table to table **[1]**

Table 5; two cells in series with one cell in parallel

Circuit	**Flow through Network of Bulbs *(glow)***	**Obstacle Presented by Network of Bulbs *(cm)***	**Product for the Network of Bulbs** $(\text{glow} \cdot \text{cm})$	***Flow through the Rheostat (glow)***	***Obstacle Presented by the Rheostat (cm)***	***Product for the Rheostat*** $(\text{glow} \cdot \text{cm})$
12 b	**1**	45	45	1	221	221
13 b	2	22.5	45	2	111.5	223
14 b	3	15	45	3	69.5	208.5

[6]

9. Is table 5 an (approximate) copy of table 2 or an (approximate) copy of table 3 or is table 5 very different from either of these?

Table 5 is an approximate copy of table 2. **[1]**

10. Can you improve on your answer to (the previous) question by adding a word or two? Explain

number of cells because with increased number of cells, our pressure difference fluctuates **[1]**

11. …what causes pressure difference in these circuits?

The number of cells **[1]**