Multimeters

Purpose

- To connect flow of electricity, obstacle and pressure difference to quantities that the DMM can measure.

- To introduce DMM's and use them to make measurements.

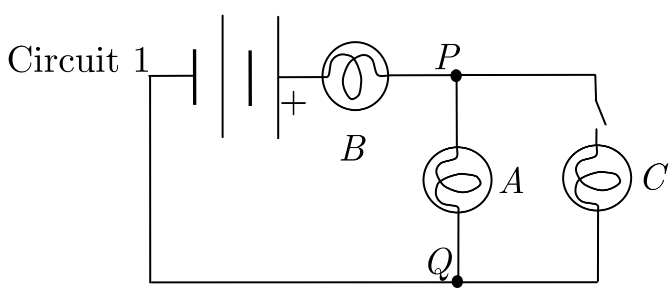
Equipment

- 1 multimeter with an input impedance of at least 10 MΩ
- 2 Rechargeable batteries
- 3 rheostats (with 30 A.W.G. Kanthal A1)
- 3 #48 bulbs in bulb-holders
- 8 alligator-to-alligator wires
- 4 banana-to-alligator wires. 2 need to be long
- 1 pair of banana-to-banana leads
- 1 large resistor (22 MΩ)

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

Introduction

We return to a circuit that you partly examined in the pre-lab for electricity IV. You were in a position to make predictions about the brightness of the identical bulbs in;



But you weren't asked to predict the effect of closing the switch on bulb *A* (although you built and observed the actual brightness of bulb *A* earlier in this lab).

At the end of the pre-lab, we noticed that the flow through bulb *A* involved two competing factors: the flow from the battery increased when the switch was closed. The model of electricity is printed below. **Explain why the flow from the battery increases when the switch is closed. Give the label of the concept(s) that you use from the model of electricity. [3]** However, when the switch is closed, only half of the (increased) flow goes through bulb *A* and the other half goes through bulb *C*. **Explain how we know that the flow splits in this ratio. Give the label of the concept(s) that you use from the model of electricity**. **[2]** The following table will help you to include the idea of pressure difference in the analysis.

There will be a flow from the battery when the switch is open and, for the sake of discussion, we'll call that flow 1 glow. *Assume that the obstacle presented by any of the identical bulbs is* L no matter what flow goes through it. (This is equivalent to; 'assume that the bulbs are ideal'.)

Copy the following table into your report;

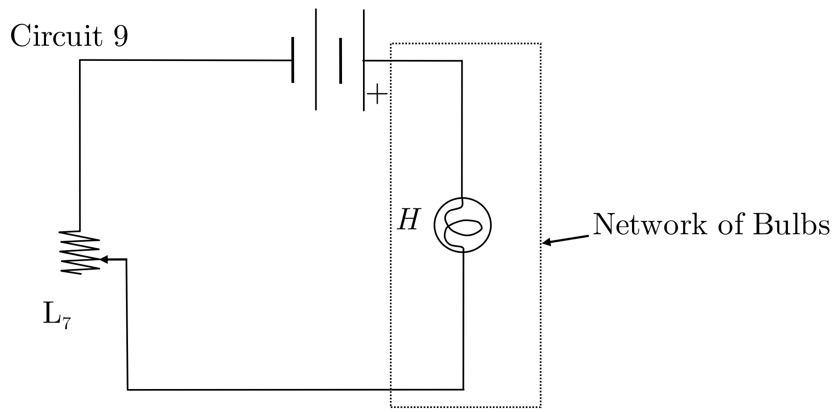
Table 6;

	Obstacle presented to Battery (in terms of L)	Flow from Battery	Pressure Difference caused by the Battery	Flow through bulb *A*
Switch open		1 glow		
Switch closed				

***Fill out the rest of table six in your report.* [7]**

Explain the change in brightness of bulb *A* when the switch closes. [1] Notice that this explanation is not possible without the knowing about pressure difference (as measured by 'product').

At least in this one case, the idea of "difference in pressure" shows its value in predicting brightness changes in DC circuits. Let's see if the idea helps in the context of circuit 9 (below).



Suppose that we want to make bulb *H* dimmer than it was in circuit 9 (when 1 glow flowed through it). What will we need to do to the flow through *H*? [1] In circuit 9, suppose that the obstacle presented by the rheostat and the obstacle presented by bulb *H* are both of size *L*.) For the sake of being definite, suppose that 1 glow is flowing. If the obstacle presented by the rheostat is doubled then the flow from the battery will decrease. **Will the flow decrease to less than half of what it was or to more than half of what it was? Explain. [2] What will happen to the pressure difference across the rheostat? Explain**. **[3]** *Hint: calculate the pressure difference across the rheostat before and after the rheostat changes. Be sure to use the correct obstacle and flow when doing this!* **What will happen to the pressure difference across bulb *H*? Explain. [2] What will this do to the brightness of bulb *H*? Explain. [1]**

Since the concept of 'pressure difference' has been useful in explaining the operation of circuits, we include a new section in our model of electricity;

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.*

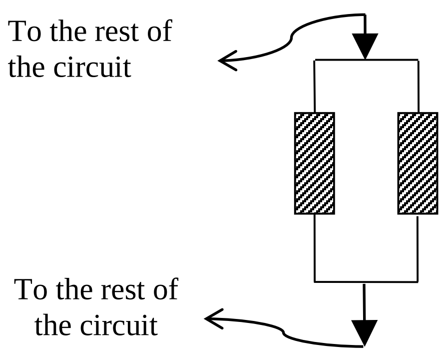
2. There are obstacles to the flow of electricity.
    a. *Two obstacles in series give an obstacle that is the sum of the two obstacles*
    b. *Two obstacles in parallel give a smaller obstacle than the smaller of the two obstacles alone*
    c. *Other factors being equal, the size of the flow increases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

3. Pressure Difference causes electricity to flow.

   a. *The pressure difference across a component is 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.*

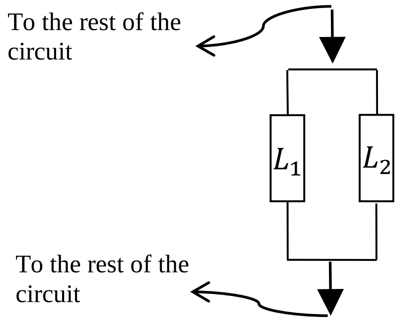
There is more to be said about pressure difference that we found in electricity V. Consider the following question. *Is it possible to say anything about pressure difference across components that are in parallel?*

If the two components are the same then we can use symmetry;



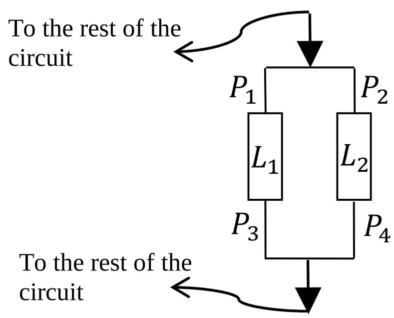
Since both branches have obstacles that are the same, the flow through each branch must be the same. Remembering the definition; $pressure\, difference \equiv flow * obstacle$, **what is the relation between the pressure difference (product) across the component on the left compared with the pressure difference (product) across the component on the right? Explain. [2]**

Now consider the case where the two components present different obstacles.



Since there isn't symmetry between the branches we won't be able to compare the flows in the two branches. Lacking this, we won't be able to relate the products across the two components.

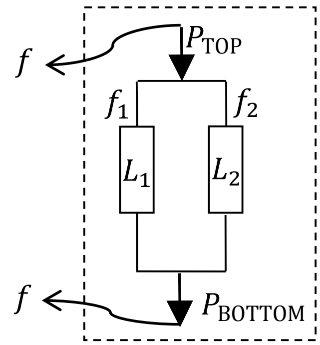
However, we did see that product was a measure of pressure (difference) across a component. For the sake of discussion, imagine that the absolute pressure at each end of the components is as shown;



The pressure difference across the component of the left is $P_3 - P_1$ and the pressure difference across the component of the right is $P_4 - P_2$. If at first $P_2 \neq P_1$ then a flow between the tops of the components will occur that will equalize these absolute pressures. Since there is no obstacle between the tops of the components, this flow will be large and almost instantaneous. After a very short time the pressure on the tops of the components will be P_{TOP}. (This happens so quickly that we will never be able to detect a difference in the absolute potentials at the top or at the bottom of the components.) In the same way, after a very short time flow between the other ends of the components will give a pressure P_{BOTTOM}. **After a very short time, what is the difference in pressure across either component (in terms of the absolute pressures given)? [1]**

Thus, <u>the pressure difference across two components in parallel is the same irrespective of the obstacle presentd by the components</u>. In fact, this relation <u>characterizes components that are wired in parallel</u> (as opposed to components that are wired in series).

We can get a useful relation by knowing that the pressure differences across components in parallel are the same.



In the preceding diagram, the absolute pressure at the top is P_{TOP} and the absolute pressure at the bottom is P_{BOTTOM}. The flow into the network of two components is f and the flows through the individual components are f_1 and f_2. There is a simple relation between f, f_1 and f_2.

Use the fact that the pressure differences across the two components are equal, to show that $\boxed{f_2 = f_1 \frac{L_1}{L_2}}$. **[1]**

If we think of the dotted box as a single component, then how large is the obstacle that it presents (in terms of L_1 and L_2)? Show how you get your answer. [1]

The pressure difference across the dotted box is $f \times \left(\frac{L_1 \times L_2}{L_1 + L_2}\right)$. In this case, the pressure difference across the dotted box is the same as the pressure difference across either of the components in it. **Equate the pressure difference across the dotted box to the pressure difference across the component on the left of the diagram to show that $f_1 = f \frac{L_2}{L_1 + L_2}$. [3] Show that $f_2 = f \frac{L_1}{L_1 + L_2}$. [2]**

Use your two previous answers to show that $\boxed{f = f_1 + f_2}$. **[2]**

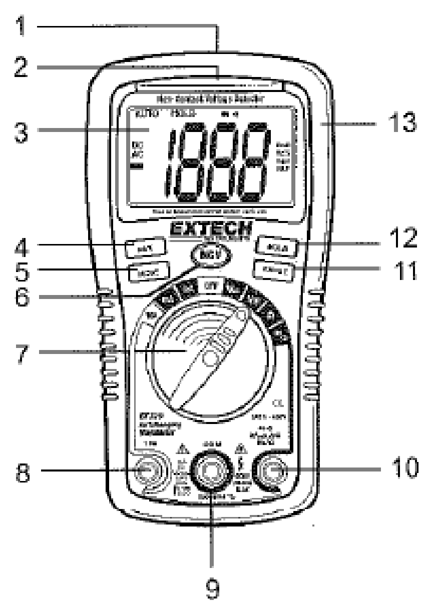
Instructions

We have developed a model of electricity using our own observations. While the model will account for electrical phenomena, we did not spend time developing techniques of measuring the quantities that the model identified as being significant. The reason for doing this is simple: it makes sense to think about how to measure some quantity ***after*** that quantity has been shown to be important to our understanding. The 'flow of electricity', 'obstacles presented' and 'pressure difference' have been observed to be important enough to put in our model. The digital multimeter (DMM) is a device that measures these quantities more conveniently. We will take each of the three quantities in turn and show that the display on the DMM corresponds to the quantities that we recognize from our experiments about electricity.

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.*

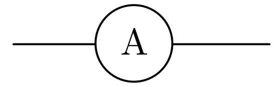
Measuring the Flow of Electricity

Numbers in parentheses refer to the picture of the Extech 320.



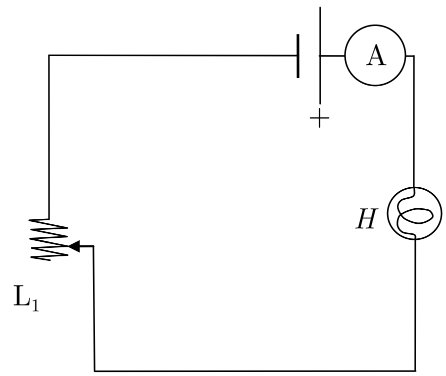
(Other meters might be in use too. All have the features that we need for this lab.)

Twist the function switch (7) so that the pointer points the symbol mA on the DMM[i].

The circuit-symbol used for the meter (when in this configuration) is 

. To see what the meter does, we need to build a circuit that allows electricity to flow through the DMM. Build;

Circuit 1



Copy the following table into your report.

Table 1: (Circuits 1, 2 and 3)

Circuit	Flow through bulb *H*	Flow through the DMM (glows)	Reading on DMM (milliamps)
1	1 glow		
2	1 glow		
3	1 glow		

Connect the positive terminal to (10) on the DMM. Connect port (9) on the DMM to bulb H in the circuit diagram. Adjust the length of the rheostat so that 1 glow flows through bulb H[ii]. ***Fill out the first row of table 1.*** **[1]**

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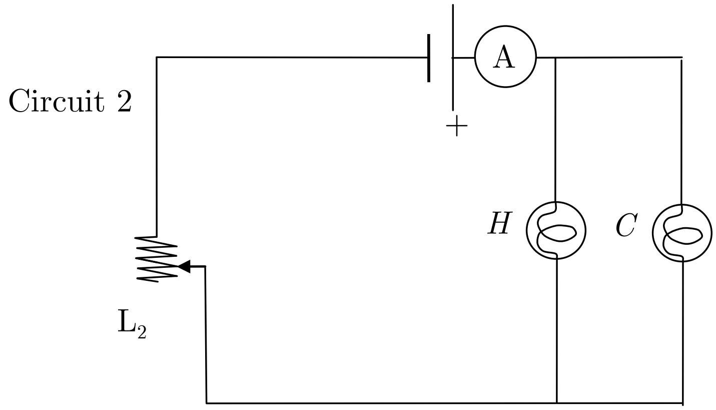
i If a small picture of a battery appears in this display then you have a low battery. Ask your TA to show you how to replace it. However, the meter works correctly as long as the display is visible.

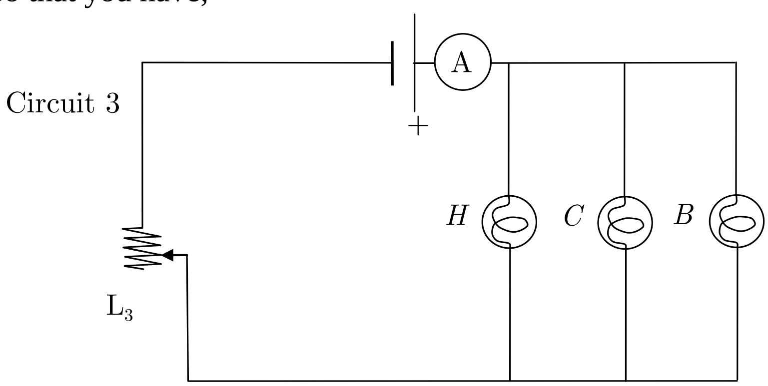
ii If you make L_1 small enough, you might be able to get the meter to tell you that the flow through it is too large for the range selected by (1). If you increase the size of L_1 then the normal display will return.

Now build;



Adjust the length of the rheostat so that 1 glow flows through bulb H. ***Fill out the second row of table 1.*** **[1]** All of the digits of the multimeter reading are important so they all need to be recorded but at this stage, you can ignore any sign in front of those digits.

Now modify the circuit so that you have;



Adjust the length of the rheostat so that 1 glow flows through bulb H. Fill out the third row of table 1. **[1]**

We used another unit (glow) for the flow of electricity so that previous measurements wouldn't require a meter. However, the conventional unit for the flow of electricity is the ampere (or Amp). If the number of glows and the number of amperes are always linearly related, then the physical quantity being measured in units called glows is the same as the physical quantity being measured in units called amperes. The only difference between them is the system of units being used. To see if there is a linear relation between the number of glows and the number of amperes, **use Excel to draw a graph of data in the last two columns of table 1.** (Put flow on the y-axis.) **Add a linear trend-line.** (Attach the graph to your report.) **[3] Does your trend-line go through the origin? (If not, how near to the origin does it go?) [1] What value of R^2 do you get for this graph and what is the significance of this number? [2] What can you conclude about the concept of 'flow' and the physical quantity**

measured in amps? [1] What is the slope of this graph? Comment on how the slope can be used to convert amps to glows. [2]

Now that we have connected our concept of the flow of electricity (measured in glows) to the concept of ‘current’ (measured in amps), we can use the more conventional term ‘current’ instead of saying ‘flow of electricity’. <u>It is important to realize that we are only changing the name of the unit and not changing the underlying physical quantity</u>.

When using the meter, you pointed the function switch on the DMM at mA. By doing this, you asked the meter to measure currents between 0 Amps and 200 milliAmps. Begin by measuring with 0 to 200 mA range when dealing with a current of unknown size. Turn the function switch to more sensitive ranges only if necessary (it won’t be today). Switch back to the mA range if the flow is too large for the chosen range. (If the flow is too big then the DMM displays ‘OL’.) <u>The DMM is often referred to as an ammeter when it is configured in a range that measures current</u>.

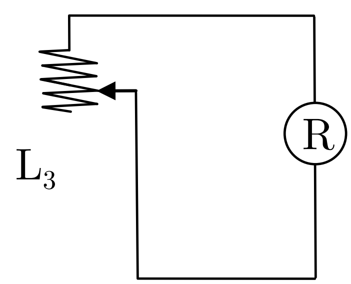
The sign on the display (when the meter is configured as an ammeter) indicates the direction of the flow. The conventional [iii] direction is from the positive terminal towards the negative terminal. If the DMM is connected so that the flow is into port (10) and out of port (9), then the DMM will display a positive number.

The meter is protected by a fuse and stops working as an ammeter if the fuse blows. <u>***Take the DMM out of the circuit when changing the function of the DMM to (or from) the measurement of current***</u>.

Measuring the size of obstacles -- Resistance

The DMM measures resistance when the function switch (7) points at Ω.

Circuit 4



Disconnect the rheostat from the rest of the circuit. Put banana-to-alligator wires in ports (9) and (10) of the DMM. Connect one of the alligator clips to one end of the Kanthal wire. Connect the other

iii The conventional direction is in the direction of the flow of positive charge-carriers. In many materials, negative charges actually flow. In electrolytes, ions of both charges can flow. However, for many purposes it does no harm if we assume that the mobile charges are all positive.

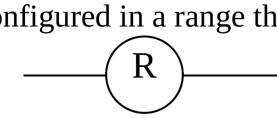
alligator clip to any other point along the Kanthal wire. *Copy the following into your report;*

Table 2: (for circuit 4)

Length of Rheostat (cm)	Reading on the DMM (Ohms)
20 cm	
30 cm	
40 cm	

Adjust the length of the rheostat to the lengths in table 2. Use the DMM to find the corresponding resistances. **Fill in table two in your report. [3]** To see if there is a linear relation between the length of the rheostat and the number of ohms, **use Excel to draw a graph of resistance from the DMM (on the y-axis) obstacle (on the x-axis). Add a linear trend-line.** (Attach the graph to this report.) **[3] Does your trend-line go through the origin? (If not, how near to the origin does it go?) [1] What value of R^2 do you get for this graph and what is the significance of this number? [2] What can you conclude about the concept of obstacle and the physical quantity measured in ohms? [1]**

You may have come across the relation $R = \rho\frac{L}{A}$ in your physics class. You have graphed obstacle versus length so that the slope of your graph was $\rho/_A$. The resistivity of Kanthal wire used in this lab is $1.45 \text{ x } 10^{-4}$ Ohm $*$ cm. The diameter of the 30 awg wire is 0.254 mm. **Calculate the cross-sectional area, A, of the wire (assuming that the wire is circular). Calculate the ratio $\rho/_A$ and compare it with the slope of your graph. Do they agree? [2] Comment on how the slope of the graph can be used to convert ohms to cm of Kanthal. [1]**

The DMM is often called an Ohmmeter when it is configured in a range that measures resistance. The symbol used for an Ohmmeter in circuit diagrams is 

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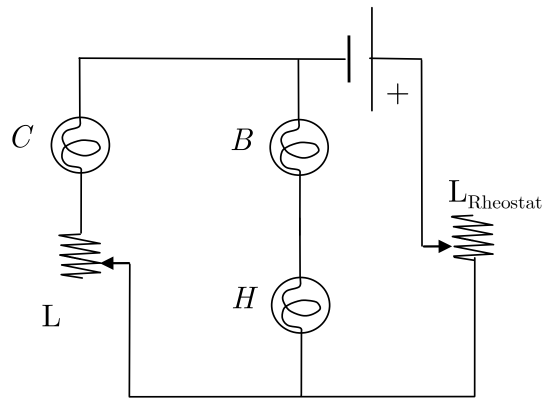
Try to measure the resistance of the 22 MΩ resistor. **How does the meter indicate that this resistance is too large to be measured? [1]**

Measuring the 'Pressure Difference' on Electricity – Voltage

In this section, you'll need to use the circuit below to measure the obstacle presented by a bulb when 1 glow flows through it;

Circuit for measuring the size of obstacles



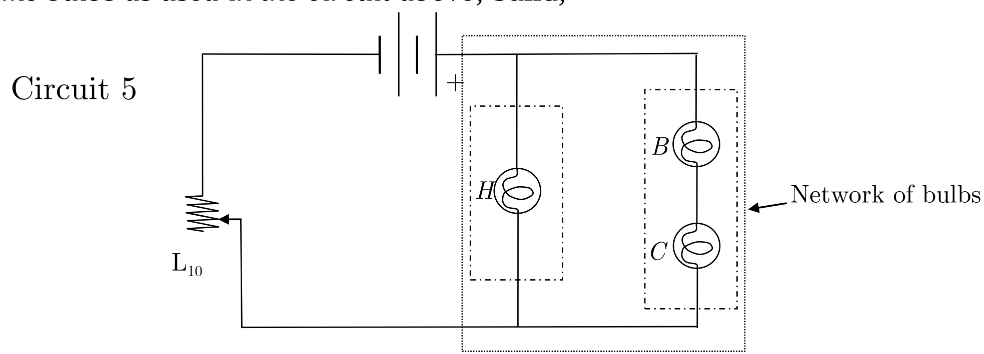
Measure the size of the obstacle presented by a bulb when 1 glow flows through it. [2] Record the obstacle presented by the bulb in table 3. (Write it in the column headed "Obstacle Presented (cm)" and row corresponding to bulb *H*.) The remainder of table 3 is for circuit 5.

Copy the following table into your report.

Table 3 (for circuit 5);

	Obstacle Presented (cm)	Flow (glow)	Pressure Difference (glow · cm)	Reading on the DMM (ΔV)
Rheostat				
Bulb *H*		1		
Network of bulbs *B* & *C*				
Bulb *B*				
Bulb *C*				
Battery				

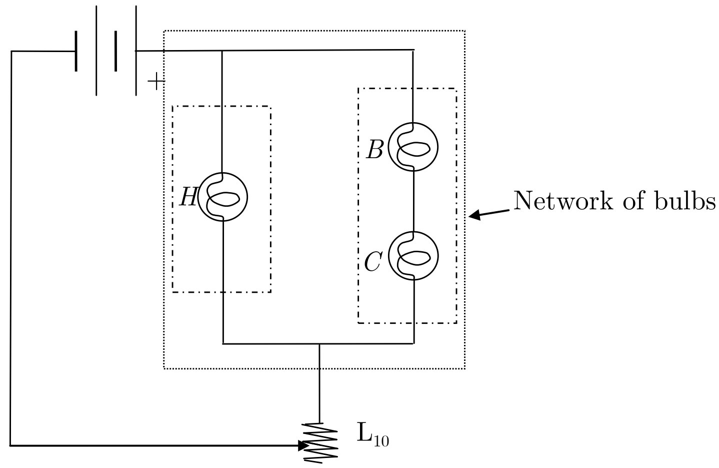
Using the same bulbs as used in the circuit above, build;



Connect the battery and ***adjust the rheostat so that 1 glow flows through bulb H***. ***Measure the length of the rheostat and record it in first cell under the heading "Obstacle Presented"*** **[1].** Disconnect the battery. Since you have measured the obstacle presented by bulb *H*, and since you have checked that bubs *B* and *C* are identical to it, you can fill in the rest of the column headed "Obstacle Presented" in table 3. **[1]** (You don't have to fill in the obstacle presented by the battery.) You analyzed this circuit in the pre-lab for electricity V. *Infer the flow through the network of bulbs B and C*. ***Record this flow in the fifth cell under the heading "Flow"***. **[1]** *Also infer the flow through bulb B, the flow through bulb C, the flow that comes from the battery and the flow through the rheostat*. **Record these in the appropriate cells under the heading "Flow"**. **[4]**

Use first two columns of table 3 to calculate the difference in pressure across the rheostat, bulb H, the network of bulbs B and C, bulb B and across bulb C. ***Record these pressure differences in the appropriate cells under the heading "Pressure Difference"***. **[5]** The pressure difference across the battery can't be calculated in the same way since we don't know about the obstacle that it presents. However, if you think about "the Sum of Pressure differences" (table 4 of electricity V) you can figure out what the pressure difference across the battery must be. ***Record it in the last cell in table 3 that is under the heading "Pressure Difference"***. **[1]** *Hint: while electrically equivalent, you might prefer circuit 5 to be drawn as*;

Circuit 5



Turn the function switch to V_{DC}. The aim is to connect the DMM in parallel with the rheostat. (*This must be done while 1 glow flows through bulb H.* It is perfectly OK to connect one alligator clip to another in order to make the necessary connections.) *Connect port (9) to the end of the wire that is closest to the negative terminal of the battery. Connect port (10) to the other end of the rheostat.* ***Record the reading (for the rheostat) on the DMM in the first cell under the heading "Reading on the DMM".*** **[1]** *Disconnect the DMM from the rheostat.*

Connect port (9) to the negative terminal of the battery. Use another banana-to-alligator wire to connect port (10) to the positive terminal. ***Record the reading (for the battery) in the column headed "Reading on the DMM".*** **[1]** *Disconnect the DMM from the battery.*

Use a banana-to-alligator wire to connect port (10) of the DMM to the end of bulb H that is directly connected to the positive terminal. Use another banana-to-alligator wire to connect port (9) to the other the end of bulb H. ***Write the reading (corresponding to bulb H) in the second cell under the column headed "Reading on the DMM".*** **[1]** *Disconnect the DMM from bulb H.*

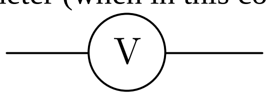
Now connect port (10) of the DMM to the end of bulb *B* that is directly connected to the positive terminal. Connect port (9) to the end of bulb *C* that is connected to the rheostat. ***Write the reading (corresponding to the network of bulbs B & C) in the third cell under the heading "Reading on the DMM".*** **[1]** *Disconnect the DMM.*

Connect port (9) to the end of bulb *B* that is connected to bulb *C*. Connect port (10) connected to the other end of bulb *B*. **Write the reading (for bulb *B*) in the fourth cell under the heading "Reading on the DMM". [1]** *Disconnect the DMM from bulb B.*

Connect port (10) to the end of bulb *C* that is connected to the negative terminal. Connect port (9) to the other end of bulb *C*. ***Write the reading (corresponding to bulb C) in the fifth cell under the heading "Reading on the DMM".*** **[1]** *Disconnect the DMM from bulb C. Disconnect the battery*

We want to see if pressure difference is related to the readings of the DMM when the function switch is turned to V_{DC}.To see if there is a linear relation between the 'pressure difference' and the number of volts, **use Excel to draw a graph of pressure difference (on the y-axis) versus the reading on the DMM.** (Both are in table 3)**. Add a linear trend-line.** (Attach the graph to this report.) **[3] Does your trend-line go through the origin? (If not, how near to the origin does it go?) [1] What value of** R^2 **do you get for this graph and what is the significance of this number? [2] What can you conclude about the concept of 'pressure difference' and the physical quantity measured in volts? [1] What is the slope of this graph? Comment on how the slope of the graph can be used to convert volts to 'pressure difference' (measured in units of glow** $\times$ **cm). [2]**

Voltage is measured in units called volts. The DMM displays DC voltage if the function switch is turned to V_{DC}. (<u>DC</u> means that the flow is in <u>one</u> <u>direction</u> only.) The symbol used in circuits for the meter (when in this configuration) is



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Someone asks; **I hear about 9 volt batteries and 1.5 volt batteries. Why do I never hear of 1 Amp batteries or 1 mA batteries? What answer can you give? Make sure to explain your answer. [2]**

Remember to 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.

After this experiment, you will have identified flow (all kinds of current), obstacle (resistance) and the difference in pressure (voltage) as are related by $\Delta V = RI$***. Feel free to use any of those terms in forthcoming work.***

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.

Explain why the flow from the battery increases when the switch is closed. Give the label of the concept(s) that you use from the model of electricity.

____

____

____**[4]**

Explain how we know that the flow splits in this ratio. Give the label of the concept(s) that you use from the model of electricity.

____

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____**[2]**

Assume that the obstacle presented by a bulb is always L . Use this to fill out the rest of table five.

Table 6;

	Obstacle to Battery (in terms of L)	Flow from Battery	Pressure Difference caused by the Battery	Flow through bulb *A*
Switch open		1 glow		
Switch closed				

[7]

Explain the change in brightness of bulb *A* when the switch closes.

____**[1]**

Suppose that we want to make bulb *H* dimmer than it was in circuit 9 (when 1 glow flowed through it). What will we need to do to the flow through *H*?

____**[1]**

Will the flow decrease to less than half of what it was or to more than half of what it was? Explain.

____

____**[2]**

What will happen to the pressure difference across the rheostat? Explain. *Hint. Calculate the pressure difference across the rheostat before and after the rheostat changes. Be sure to use the correct obstacle and flow when doing this!*

____

____

____**[3]**

What will happen to the pressure difference across bulb *H*? Explain.

____

____**[2]**

What will this do to the brightness of bulb *H*? Explain.

____**[1]**

…what is the relation between the pressure difference (product) across the component on the left compared with the pressure difference (product) across the component on the right? Explain**.**

____

____**[2]**

After a very short time, what is the difference in pressure across either component (in terms of the absolute pressures given)?

____**[1]**

Use the fact that the pressure differences across the two components are equal to show that $\boxed{f_2 = f_1 \frac{L_1}{L_2}}$.

____**[1]**

If we think of the dotted box as a single component, then how large is the obstacle that it presents (in terms of L_1 and L_2)? Show how you get your answer.

____**[1]**

Equate the pressure difference across the dotted box to the pressure difference across the component on the left of the diagram to show that $f_1 = f\frac{L_2}{L_1+L_2}$.

____

____

____**[3]**

Show that $f_2 = f\frac{L_1}{L_1+L_2}$.

____**[2]**

Use your two previous answers to show that $\boxed{f = f_1 + f_2}$.

____**[2]**

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.

Table 1: (Circuits 1, 2 and 3)

Flow through bulb *H*	Flow through the DMM (glows)	Reading on DMM (milliamps)
1 glow		
1 glow		
1 glow		

[3]

…use Excel to draw a graph of data in the last two columns of table 1. Add a linear trend-line. Display the equation of the trend-line and the value of R^2 (Attach the graph to this report.)

[3]

Does your trend-line go through the origin? (If not, how near to the origin does it go?)

____**[1]**

What value of R^2 do you get for this graph and what is the significance of this number?

____

____**[2]**

What can you conclude about the concept of 'flow' and the physical quantity measured in amps?

____**[1]**

What is the slope of this graph? Comment on how the slope can be used to convert amps to glows.

____**[2]**

Table 2: (Circuit 4)

Length of Rheostat (cm)	Reading on the DMM (Ohms)
20 cm	
30 cm	
40 cm	

[3]

… use Excel to draw a graph of data in table 2. Add a linear trend-line**.** Display the equation of the trend-line and the value of R^2 (Attach the graph to this report.) **[3]**

Does your trend-line go through the origin? (If not, how near to the origin does it go?)

____**[1]**

What value of R^2 do you get for this graph and what is the significance of this number?

____

____[2]

What can you conclude about the concept of obstacle and the physical quantity measured in ohms?

____[1]

Calculate the cross-sectional area, A, of the wire (assuming that the wire is circular). Calculate the ratio $\rho/_A$ and compare it with the slope of your graph. Do they agree?

____

____[1]

Comment on how the slope of the graph can be used to convert ohms to cm of Kanthal.

____[1]

How does the meter indicate that this resistance is too large to be measured?

____[1]

Measure the size of the obstacle presented by a bulb when 1 glow flows through it

____[2]

Table 3 (circuit 5); **[19]**

	Obstacle Presented (cm)	Flow (glow)	Pressure Difference $(\text{glow} \cdot \text{cm})$	Reading on the DMM $((\Delta V)$
Rheostat				
Bulb H		1		

Network of bulbs B & C				
Bulb B				
Bulb C				
Battery				

… use Excel to draw a graph of pressure difference (on the y-axis) versus the reading on the DMM (both in table 3) **[3]**

Does your trend-line go through the origin? (If not, how near to the origin does it go?)

____**[1]**

What value of R^2 do you get for this graph and what is the significance of this number?

____

____**[2]**

What can you conclude about the concept of 'pressure difference' and the physical quantity measured in volts?

____**[1]**

What is the slope of this graph? Comment on how the slope of the graph can be used to convert volts to 'pressure difference' (measured in units of glow $\times$ cm).

____

____**[2]**

Someone asks; “I hear about 9 volt batteries and 1.5 volt batteries. Why do I never hear of 1 Amp batteries or 1 mA batteries?” What answer can you give? Make sure to explain your answer.

____

____

____**[2]**