Electricity I

Purpose

- To begin building a Model of Electricity
- To examine what is happening in the wires of circuits
- To examine the size of the flow of electricity in circuits with components wired in series and wired in parallel

Equipment

- 2 rechargeable ‘D’ cells.
- 1 charger
- Battery holders
- 3 #14 bulbs that are already in bulb-holders. #14 bulbs have spherical globes.
- 8 alligator-to-alligator wires
- 2 (long) banana-to-alligator wires
- 1 compass

Groups will share rolls of masking tape.

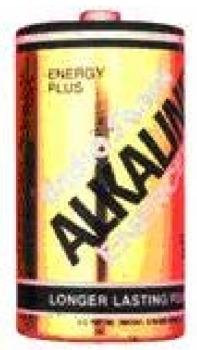
Verify that you have all of the equipment listed. Notify your TA if anything is missing.

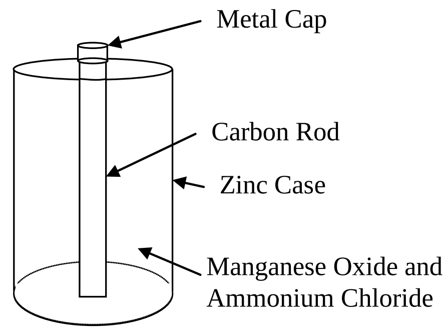
Introduction

This is the first of a series of experiments that are an extended example of the process of building a model and checking its correspondence with physical reality. The phenomenon to be considered is not new to you; we’ll develop a Model of Electricity. The idea is not to introduce the basics of this model. The idea is to let you find out how the parts of the model link together.

It is quite likely that you have encountered the words voltage, current, resistance, power and energy. These names are useful if an understanding of these words is shared by all of us. Until we all share an understanding of these terms, the best approach is to avoid using these terms to explain anything. This might seem a bit strange to you at first. Remember that there is nothing about the words ‘voltage’, ‘current’, ‘resistance’ etc. that we can’t explore with simpler terms. These simpler terms will be refined by you and until you finally use more traditional terminology. We’ll start at the very beginning. I urge you to use the opportunity that this provided by this approach, to think carefully about how electricity ‘works’. If you rush past them, the seeming simplicity of the next two labs can allow you to ignore certain problems that appear in several weeks’ time.

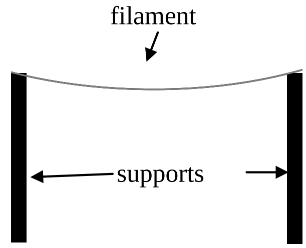
A ‘D’ cell consists of two electrodes and an electrolyte wrapped in a cylindrical metal case.



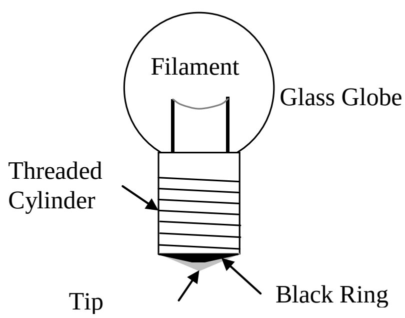


The ends of the two electrodes are attached to conducting terminals at the top and bottom of the cell. On a 'D' cell, the positive terminal is the metal cap on the top of the cell and is usually marked. The negative electrode is larger and is the bottom of the cell.

An important feature (inside the glass globe of a bulb) is a thin length of wire, called a filament, between two supports.



The thin piece of wire is delicate and is surrounded by a glass bulb. The supports are connected to parts outside the bulb so that electrical connections can be made to the filament. The bulbs that we will use look like;

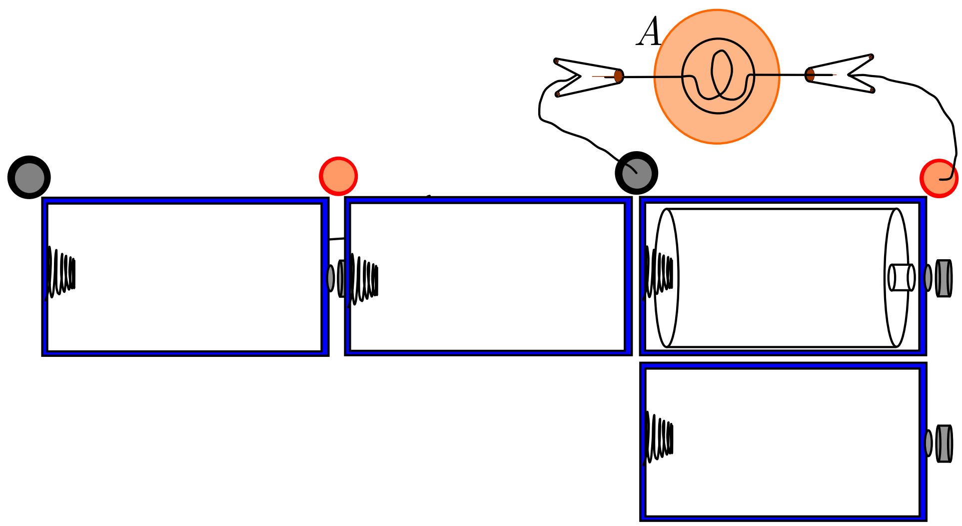


One support to the filament is attached to the threaded cylinder and the other support is connected to the tip of the bulb. We will be using bulb-holders that allow us to see how the tip and threaded cylinder are connected externally. The filament becomes so hot that it glows when the bulb is operating.

Instructions

In your report, please remember to **write answers** to all **questions in bold type.** This lab involves building simple circuits and ***all*** members of the group must contribute to this. Take turns to include all members of the group. Resist the temptation to 'allow' one or two people to do everything in your group. Such an approach doesn't help anyone.

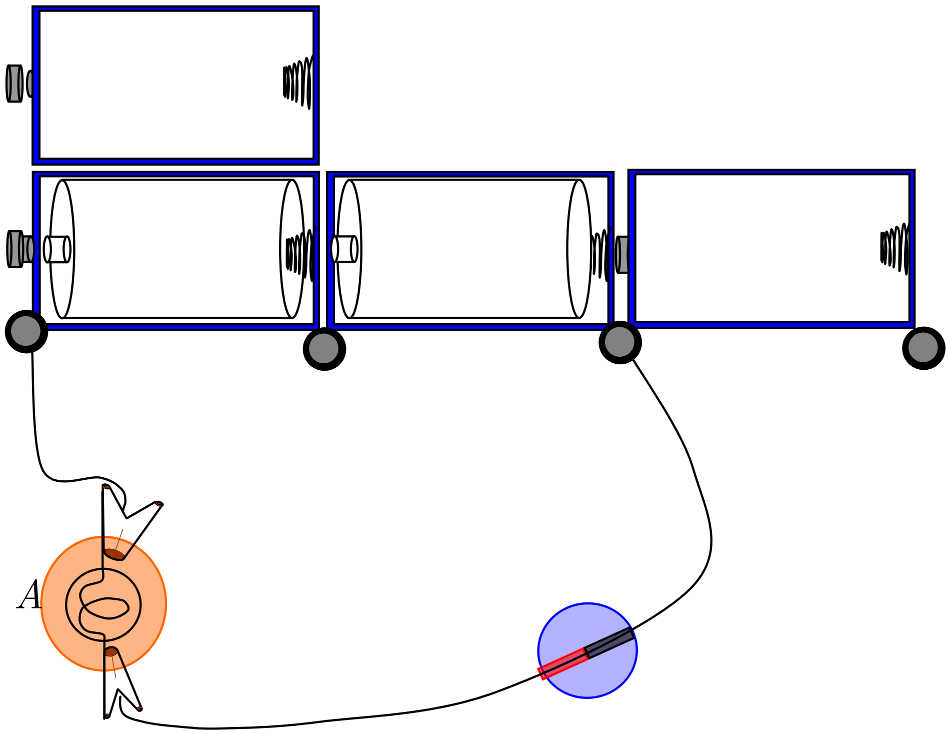
You can make a bulb light up by building the following. (Don't connect both terminals of the battery until directed to. You can connect one of them and leave the other beside the banana terminal that it will plug into.) Put the cell in a battery-holder, use a bulb that is already in a bulb-holder and use two pieces of wire. The continuous loop of wire is called a circuit. The circuit that you have built can be called a 'one-bulb circuit'. *Now connect the battery.*



We begin by asking ourselves; what makes the bulb light under some circumstances and not under others? Is anything happening in the wires? *Disconnect the battery*.

We can see that something is happening in the bulb but it isn't so obvious that anything is (or isn't) happening in the wires. *Fix a compass to your work-bench as follows. Tear off 2" of masking tape. Form it into a loop with the sticky side out. Put the loop on your bench within easy reach! Put the compass on the loop so that the loop gets squashed and sticks the compass onto the bench*. (We'll be using the compass several times so you won't have to move it during or after this lab.) Beware: *the cells & battery holders have steel components and will attract the compass-needle even if the battery isn't connected to anything!*

When using the compass (as in the diagram below), make the wire lie over the whole compass-needle as in the diagram below. (One member of the group will have to hold the wire so that it is along the direction of the needle.) One person should put a finger on the wire on one side of the compass so that the wire doesn't move. They should use another finger to hold down the wire on the other side of the compass. *Remember not to move the compass.*

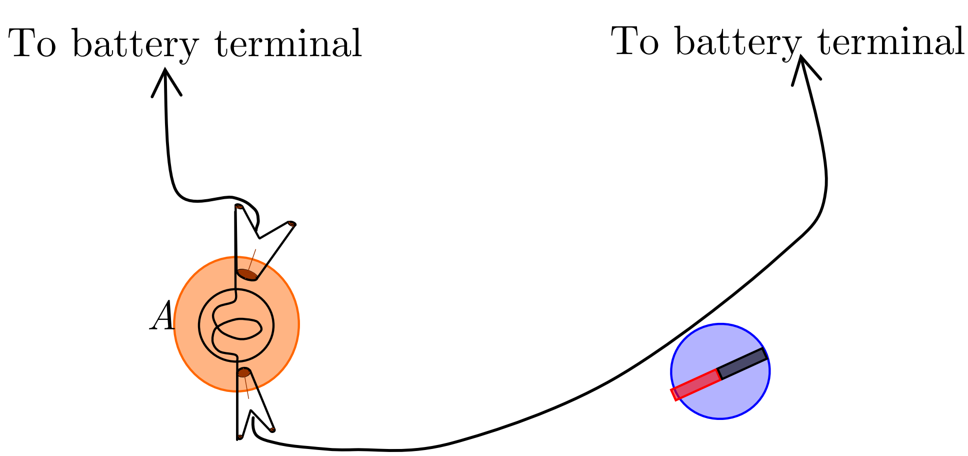


Connect the battery. **Does the compass-needle deflect when the bulb lights? [1].** (Movement of the compass-needle is hard to see. The easiest way to see it is to be looking at the needle <u>before</u> (as well as after) the battery is connected.)

Let's see what is affecting what. *Keep the shape of the circuit exactly the same. Move the whole circuit so that the wire that was over the compass-needle moves at least an inch away from the compass.* **Does the brightness of the bulb change when we move the <u>whole</u> <u>circuit</u> away from the compass? [1]. Do you think that the compass affects the electrical activity in the wires? Explain why. In your answer, consider whether the electrical activity in the wires might be affecting the compass.**

<u>Disconnect one of the wires to the battery the circuit as soon as you have made these observations</u>.

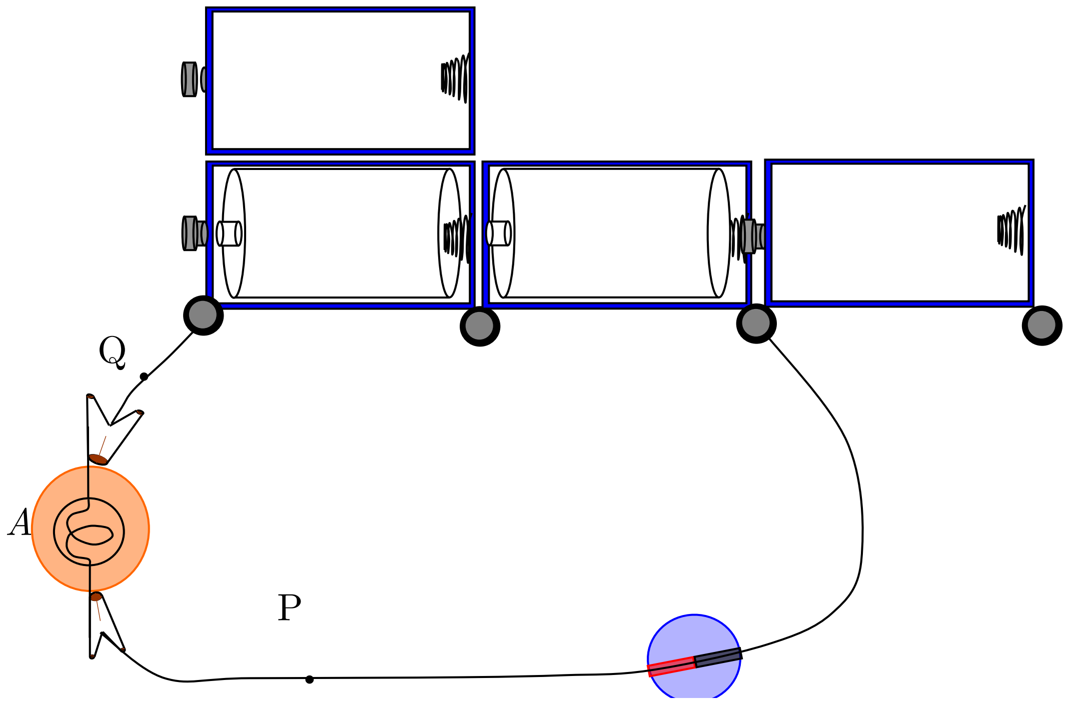
In the previous circuit, a wire was right over the compass. *Now move the wire* $2\,cm$ *from the compass-needle*. (The base of the compass extends to about 2 cm from the compass needle. This will measure the distance quite adequately.)



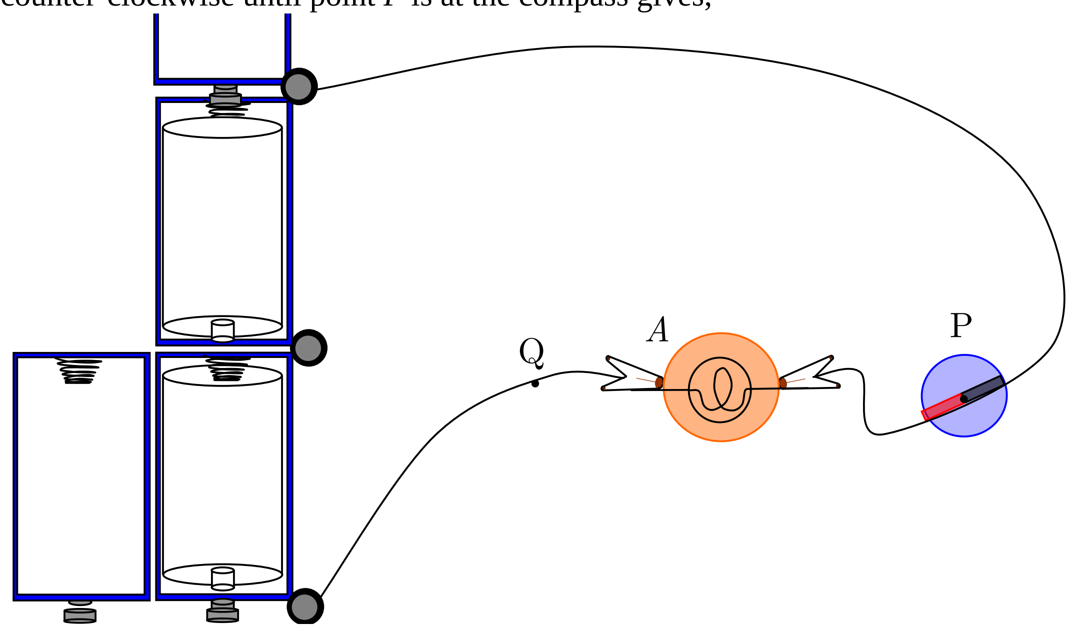
With this minor modification, is the compass-needle deflected? (Compare the movement of the compass-needle to its movement when the wire was over the compass.) **Approximately how far from the compass-needle does the wire have to be so that no deflection is seen? [1]**

The compass obviously responds to electrical activity in the circuit. **Do you think that the compass responds to electrical activity <u>in all parts of the circuit</u> or do you think that the compass only responds to electrical activity in the wire that is closest to it? (Give a reason for your answer.) [2]**

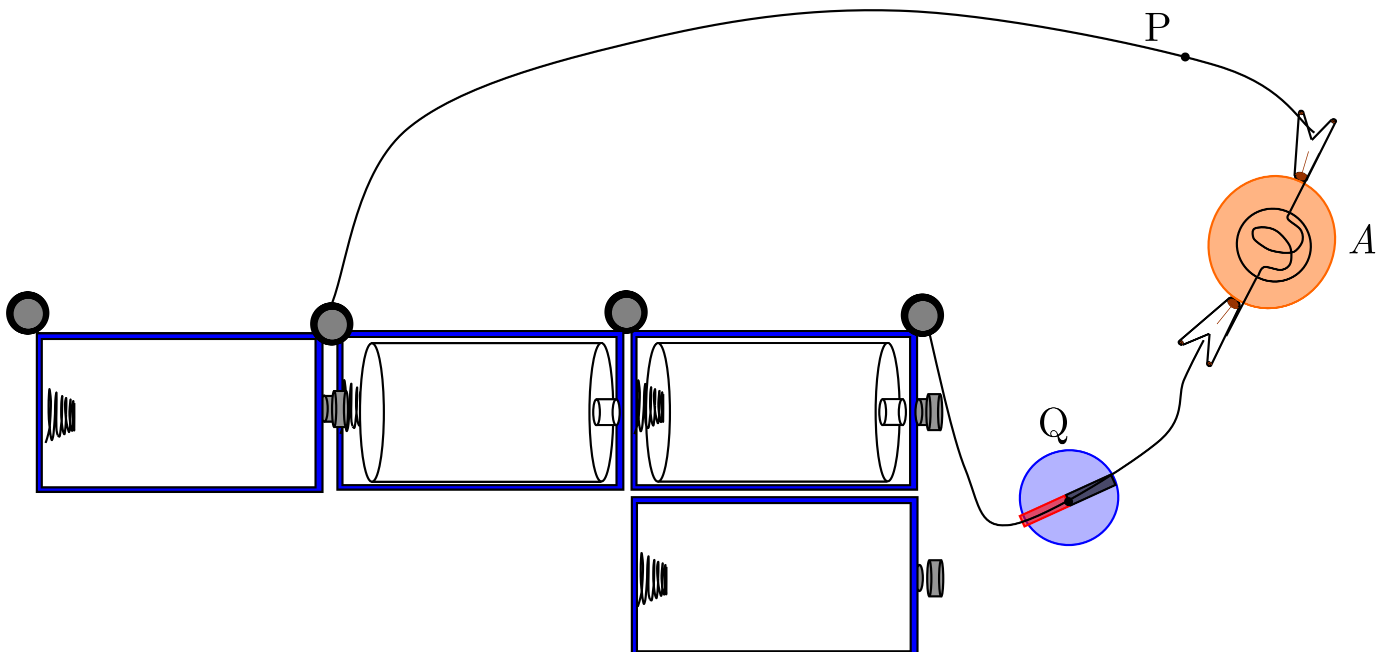
Suppose that we want to examine electrical activity at points *P* and *Q* (below).



This can be done by <u>rotating the whole circuit while keeping the compass fixed</u>. Rotating the circuit counter-clockwise until point *P* is at the compass gives,



Notice the amount of deflection (in degrees) and the direction of the deflection when the compass is at point P. To look at point *Q*, we rotate the circuit counter-clockwise a bit more.



Notice the amount of deflection (in degrees) and the direction of deflection when the compass is at point Q. Repeat at two other points along the circuit. (You chose the locations of these points.) **Compare the amount of deflection (in degrees) of the compass at the four points around the circuit. Is the sense of deflection (either clockwise or counter-clockwise) the same at all four points? [2]** *Disconnect the wires that go to the terminals. Re-connect the wires to the opposite terminals of the battery. Note the amount of deflection (in degrees) and sense of rotation of the compass-needle at four points around the circuit.* **Compare the amount of deflection and the sense of deflection before and after exchanging the wires to the battery terminals**. **[2] What do these comparisons tell you about the size and direction of the flow when the wires to the terminals are exchanged? [2]**

We need to form a hypothesis about the electrical activity in the wires. The hypothesis must account for the observations so far. This hypothesis needs to involve two directions since the compass deflected in two possible ways. One possible <u>hypothesis is that something is flowing through the wires when both ends of a battery are connected with a conducting path</u>. *Check the hypothesis for plausibility in the light of your observations. For example, if you saw the compass-needle deflect in different directions, does it still make sense to think of electricity as involving something flowing around the wires?* [For now, you can refer to it as 'flow of electricity' or just 'flow'.] We'll assume that the size of the deflection of the compass indicates the size of the flow of electricity**.** We'll assume that the sense of the deflection indicates the direction of the flow.

The hypothesis is plausible if it helps to explain our observations. Let's see if it does.

Electrical activity happens most clearly at the bulb (because it lights). We can say more about flow if we use the hypothesis. **What does the hypothesis suggest/imply about the size and direction of flow at all points around the circuit? Give two observations that support these suggestions/implications. [3]**

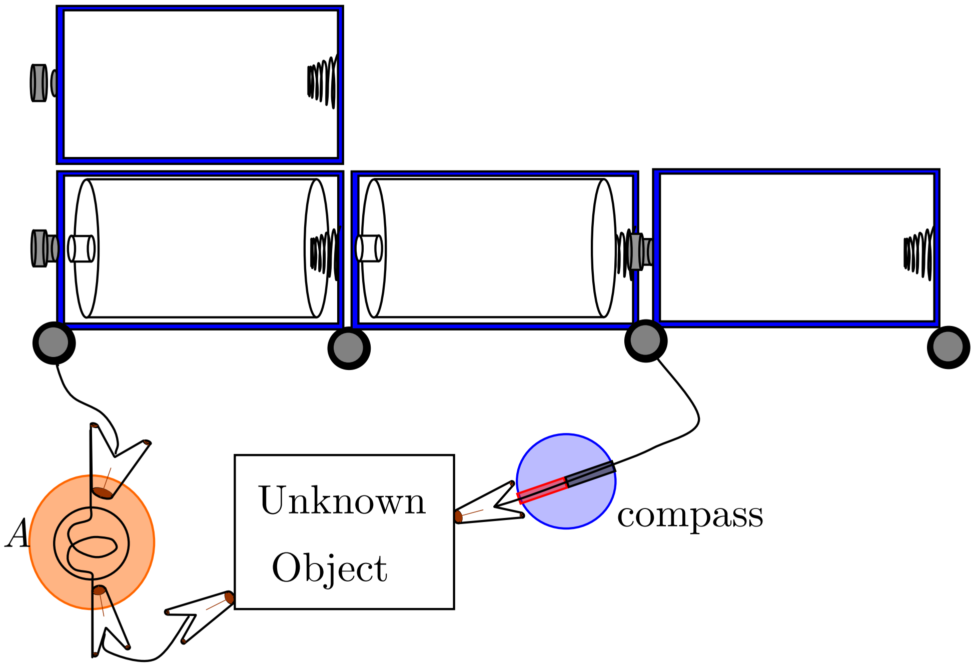
<u>*The first statement in our Model of Electricity is that,*</u>

1. *Electricity flows in electric circuits.*

If we need to think about the direction of the flow, we'll use the convention that the flow is along the direction from the positive terminal to the negative terminal.[1] Notice that this convention doesn't imply that flow begins at the one terminal and ends at the other one.

What do the observations so far tell us about the role of the battery? (Include some direct evidence that supports your answer.) [2]

Electricity must be able to flow through the wires. We can use a modified one-bulb circuit to see what other substances allow electricity to flow through them. Substances that allow electricity flow through them (easily) are called conductors. Insulators don't allow electricity to flow through (easily).



Complete the sentence in your report: **If an unknown object is put in the circuit then the bulb will only light if the object ______________ [1]**

Examine whether the threaded cylinder, black ring and tip are conductors or insulators. Use the bulb that isn't in a holder for this. (You will have to hold alligator clips against parts of this bulb.) **Copy the following table into your report. Two results have already been put into the column headed 'Result of Measurement'. Put in the three other entries. [3]**

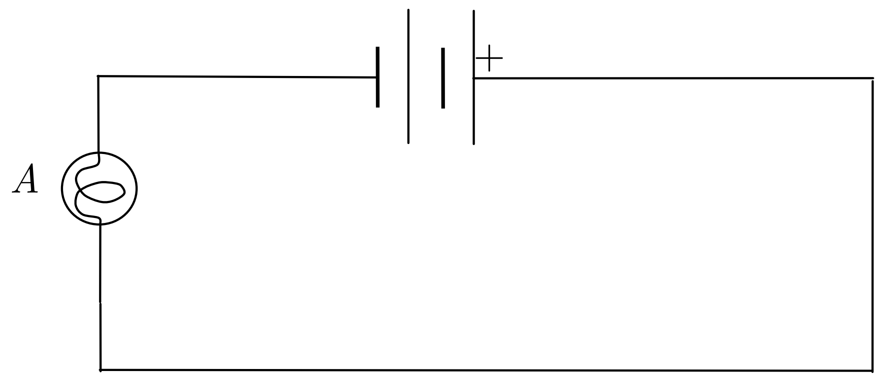
Part	***Result of Measurement***
Glass globe	Insulator
Filament	Conductor
Threaded Cylinder	
Black Ring	

[1] The opposite convention might have been chosen instead. While the two conventions give the same conclusions, individual observations will be different. For that reason, we'll always adopt the convention that flow is along the direction from the positive terminal to the negative terminal.

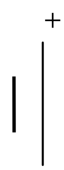
Tip	

A *circuit diagram* of the *one-bulb circuit* is;

Circuit 1



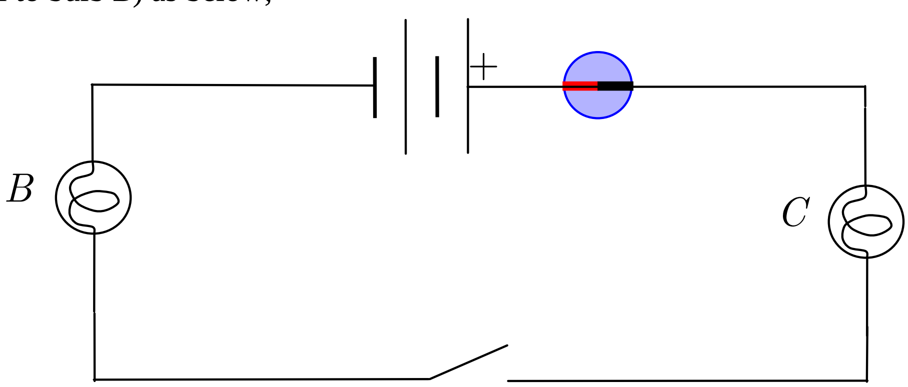
The straight lines represent the conducting paths provided by the wires & alligator clips. The symbol;

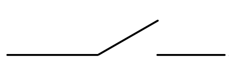


represents an ideal cell (and rechargeable cells are close to this ideal.) The positive terminal of the cell is indicated with a ‘plus’ sign. (If there is no ‘plus’ sign then the positive terminal is assumed to be the longer line.)

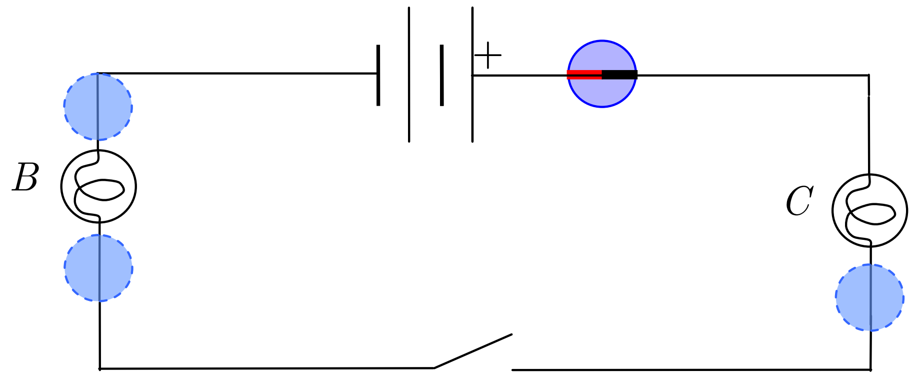
Circuit diagrams rarely look like circuits that we build but they do show us how components are connected together. You should use this fact to your advantage; begin building the circuit from some point (I tend to begin at the positive terminal). Follow the wire towards the negative terminal, connecting components as you go.

Next you will build a circuit in which two bulbs light. One way to do this is to position bulb *C* (that we assume is identical to bulb *B*) as below;



The circuit symbol for a switch is . In circuit diagrams, switches are usually drawn in this open position. Instead of a real switch, make the connection between bulb *C* and bulb *B* with a piece of wire when you want to close the switch. Disconnect the wire when you want to open the switch. Bulbs *B* and *C* are said to be connected in series. The series configuration of two bulbs can be characterized by both bulbs being along the same conducting path that joins the terminals. The two cells are also in series and form the battery. (You will find a better way of defining 'in series' later on.) We'll be interested in the flow when this circuit is operating so the following diagram of circuit 2 shows a compass. (There is only one compass; the dotted circles show three other places at which you'll examine the flow.)

Circuit 2



Build circuit 2 with identical bulbs. (Refer to the circuit diagram to see how the components are connected.) Compare the brightness of bulb B relative to the brightness of bulb C when they are in series with each other. No numerical comparison is needed. You only need to notice if one bulb is brighter than the other or if both bulbs are of the same brightness. **What does the compass tell you about the size and direction of the flow at the four points in circuit 2? What observations tell you this? [3]** *Now compare the compass measurements in circuit 2 to the compass measurements in circuit 1*. **What do the compass measurements tell us about the flow at any point in circuit 1 compared with the size of the flow at any point in circuit 2? Use direct evidence to support your answer. [2]**

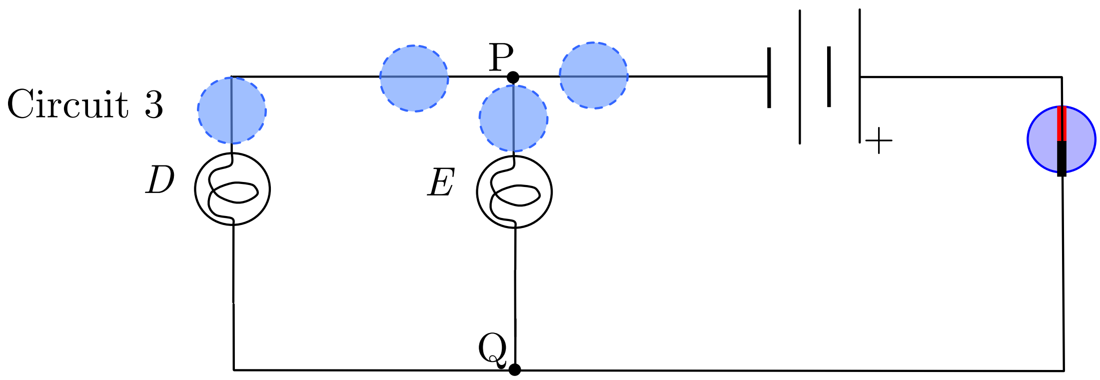
Does any observation suggest that the brightness of a bulb depends on the size of the flow through it? Cite the observation that tells you this. [2] We include this in the first statement in our Model of Electricity:

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*

Previously, 'in series' referred to a geometric relation between bulbs *B* and *C* in a circuit diagram. However, we can't rely on geometric relationships because the same circuit can be drawn in several ways. **Compare the size and direction of the flow through either of the bulbs in series (circuit 2) with the flow that leaves the battery. What observation allows you to make this comparison? [3]** Actually, this result about flow through two bulbs is a better way to figure out if the bulbs are in series than relying on a geometrical relation in circuit diagrams.

You have looked at one way in which to arrange two bulbs so that they are lit by a battery. But there is another, and it can also be thought of as a modification of the one-bulb circuit. The other modification involves putting the second bulb along a separate wire that begins and ends at the points P and Q below.



We say that the bulbs are connected ‘in parallel’ because of the geometry of the wires connected to the bulbs. You will find a better way of characterizing ‘in parallel’ in a later experiment. Before you build the circuit, **predict the relative size of the flow through bulb D and the flow through bulb E. [1]**

Build circuit 3 with identical bulbs. (Remember to begin at the positive terminal and complete loops back to the negative terminal.) Begin by putting the compass at the position on the right. *Compare the brightness of bulb D with the brightness of bulb E. Notice the number of degrees that the compass deflects*. The lighter dotted circles show four more positions of your compass. *Rotate the circuit so that the compass is in each of these other positions. Each time, compare the brightness of bulbs E & D and notice the deflection of the compass*. *Compare the deflection of the compass at the five positions.* In circuit 3, you compared the relative size of the flow through bulb D with the size of the flow through bulb E. **What <u>observations</u> let you make the comparison? [2] Compare the size of the flow through either of the bulbs in parallel (in circuit 3) with the size of the flow that leaves the battery. Include an observation that supports your answer. [2]**

Notice what happened in the last two paragraphs. You made a prediction about circuit 3 on the basis of what you had thought about the flow of electricity. Then you built circuit 3 and checked to see if your prediction was correct. Previous ideas of the properties of the flow of electricity may, or may not, reflect what actually happens. However, scientific models must agree with physical reality and the only way to see if they do is to check their predictions. If your later observation agreed with your prediction then, in at least this instance, your model of electricity (probably implicit) does not conflict with physical reality. If your prediction and observation didn’t agree something in your previous (unspoken) model of electricity might be the problem. As a prelude to putting a better model off electricity in its place, <u>you</u> need to identify the ideas that you have that are flawed and be on the look-out for better ideas to replace them.

You can also use circuit 3 to compare the brightness of bulb *D* with the brightness of an identical bulb in a one-bulb circuit. **Compare the size of the flow through either of the bulbs in parallel (in circuit 3) with the size of the flow through the bulb in a one-bulb circuit. (Quote the direct evidence.) [2]** (You don’t have to remember the brightness that you saw for the one-bulb circuit. You can make a one-bulb circuit out of circuit 3 if you disconnect one wire to bulb *D*.) **Compare the size of the flow from the battery of circuit 3 with the size of the flow from the battery in a one-bulb circuit. (Quote the direct evidence.) [2]**

In summary,

- **Does the same battery always deliver the same amount of flow to any circuit? Mention two observations of any circuits that you have seen in this lab to support your answer**. **[3]**

- **Some people think that the flow of electricity is 'used up' by the bulbs. (This belief implies that the flow of electricity leaving a component is not the same as the flow of electricity entering it.) Give one observation that contradicts this belief. Explain your reasoning. Draw the circuit diagram for (or give the circuit number of) any circuit that you use to explain your answer. [3]**

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

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

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.

Does the compass-needle deflect when the bulb lights?

____**[1]**

Does the brightness of the bulb change when we move the whole circuit away from the compass?

____**[1]**

Do you think that the compass affects the electrical activity in the wires? Explain why. In your answer, consider whether the electrical activity in the wires might be affecting the compass.

____

____**[1+1]**

Approximately how far from the compass-needle does the wire have to be so that no deflection is seen?

____**[1]**

Do you think that the compass responds to electrical activity in all parts of the circuit or do you think that the compass only responds to electrical activity in the wire that is closest to it? (Give a reason for your answer.)

____

____**[2]**

Compare the amount of deflection (in degrees) of the compass-needle at the four points around the circuit. Is the sense of deflection (either clockwise or counter-clockwise) the same at all four points?

____

____**[2]**

Compare the amount of deflection and the sense of deflection before and after exchanging the wires to the battery terminals.

____

____**[2]**

What do these comparisons tell you about the size and direction of the flow when the wires to the terminals are exchanged?

____

____**[2]**

What does the hypothesis suggest/imply about flow at all points of the circuit? Give two observations that support these suggestions/implications. (Include some direct evidence that supports your answer.)

____

____

____**[3]**

Ask your TA to check your answer to the previous question.

What do the observations so far tell us about the role of the battery? (Include some direct evidence in your answer.)

____

____**[2]**

Complete the sentence in your report:
If an unknown object is put in the circuit then the bulb will only light if the object ________________**[1]**

Part	***Result of Measurement***
Glass globe	Insulator
Filament	Conductor
Threaded Cylinder	
Black Ring	
Tip	

[3]

What does the compass tell you about the size and direction of the flow at the four points in circuit 2? What observations tell you this?

____

____

____**[3]**

What do the compass measurements tell us about the size of the flow at any point in circuit 1 compared with the size of the flow at any point in circuit 2? Use direct evidence to support your answer.

____

____**[2]**

Ask your TA to check your answer to the previous question.

Does any observation suggest that the brightness of a bulb depends on the size of the flow through it? Cite the observation that tells you this.

____

____

____**[2]**

Compare the size and direction of the flow through either of the bulbs in series (circuit 2) with the flow that leaves the battery. What observation allows you to make this comparison?

____

____

____**[3]**

...predict the relative size of the flow through bulb D and the flow through bulb E.

____**[1]**

In circuit 3, you compared the relative size of the flow through bulb D with the size of the flow through bulb E. What <u>observations</u> let you make the comparison?

____

____**[2]**

Compare the size of the flow through either of the bulbs in circuit 3 with the size of the flow that leaves the battery. Include an observation that supports your answer.

____

____**[2]**

Compare the size of the flow through either of the bulbs in circuit 3 with the size of the flow through the bulb in a one-bulb circuit. (Quote the direct evidence.)

____

____**[2]**

Compare the size of the flow from the battery of circuit 3 with the size of the flow from the battery in a one-bulb circuit. (Quote the direct evidence.)

____

____**[2]**

Ask your TA to check your answer to the previous question.

Does the same battery always deliver the same amount of flow to any circuit? Mention two observations of any circuits that you have seen in this lab to support your answer.

____

____

____

____**[3]**

Some people think that the flow of electricity is 'used up' by the bulbs. (This belief implies that the flow of electricity leaving a component is not the same as the flow of electricity entering it.) Give one observation that contradicts this belief. Explain your reasoning. Draw the circuit diagram for (or give the circuit number of) any circuit that you use to explain your answer.

____

____

____

____**[3]**