Senior 1

Appendices:
Cluster 3
The Nature of Electricity

Developing a Conceptual Model of Electricity

Introduction

Students are often fascinated with electricity. This guide is a resource for Senior 1 Science teachers and is provided to help students develop a conceptual model of electricity, following the transition from static to current electricity.

TSM Teacher Support Material

Pre-Model Activities (Teacher Support)

No one forgets an electrical shock. Ask students to describe and record their own experiences with electricity in their journals. Discuss as a class. Many students are already familiar with the following experiences:

1. “Static cling” — Ask students if they’ve ever taken off a sweater (especially wool) in the dark. Suggest they try it. They should hear and see the static sparks. Ask them about static cling in the clothes dryer. Include this as part of the home experiment.
2. Electric shocks when walking across a carpet and touching a door knob...OUCH!
3. Touching their tongues to a nine-volt battery and getting a tingling feeling. (Don’t recommend this activity. Although it’s harmless, if you extend this activity to higher voltages it can be extremely dangerous. When students raise this, they should by cautioned. Safety should be emphasized at all times).
4. Rubbing a balloon on their hair, and sticking it to the wall. Suggest that students try to bring together two balloons which have been rubbed on their (or someone else’s) hair.
5. Running a comb or brush through their hair and bringing it near bits of paper or straw. They should find that the bits are attracted to the comb.

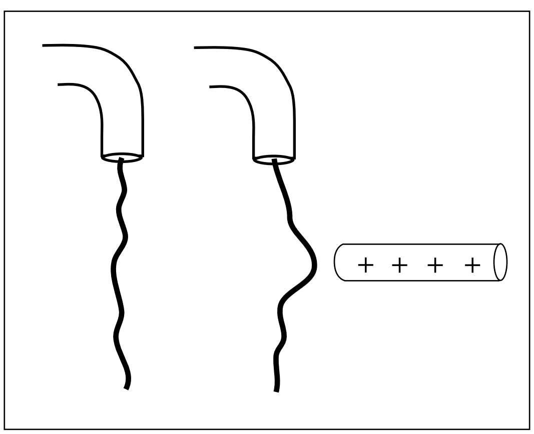


Figure 1

6. Bringing a charged object near a thin stream of water. The flow of water should bend toward the stream (See Figure 1 above).

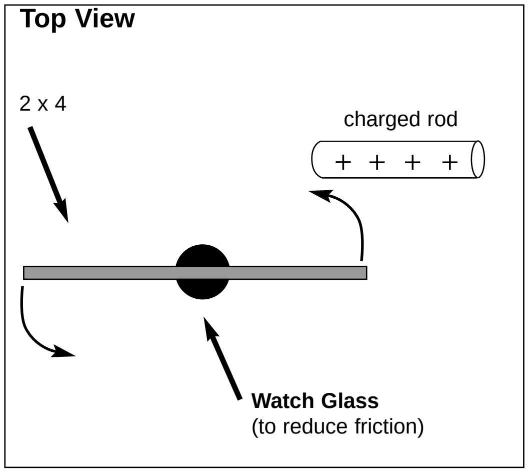


Figure 2

7. Students will likely not have experienced this phenomenon, so a demonstration could be performed. Balance a 2" x 4" x 8' piece of lumber on a watch glass. Bring a charged object near one end of the 2 x 4. It should move towards the charged object (See Figure 2 above).

SLA
Student Learning Activity

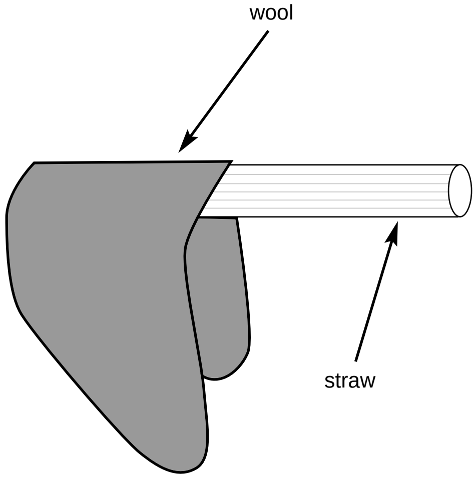
An Introduction to Electrostatics — Home Experiment (Student Version)

Materials:

- plastic straw
- paper bits
- wool
- transparent tape

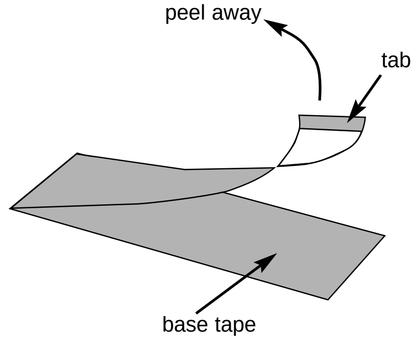
Perform the following experiments at home and discuss with a partner (e.g., mom, dad, sibling, friend). Record your observations and explanations.

1. Scatter paper bits on a table. Rub a plastic straw with the wool material and bring the straw near the paper bits. Record and explain your observations.

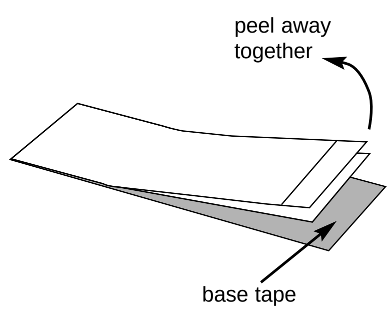


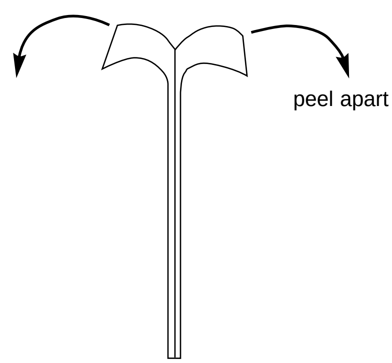
2. Find two materials at home to replace the plastic straw and wool, which demonstrate the same effects.

3. Stick a piece of transparent tape (about 30 cm long) on the table (base tape). On certain surfaces, this tape is not needed. Take a second piece about 10 cm long and fold over the first centimetre of tape to make a tab. Stick this tape to the base tape and press it down well with your finger. Now peel the short tape briskly from the base tape. Bring the tape near the paper bits. What can you conclude about the tape?

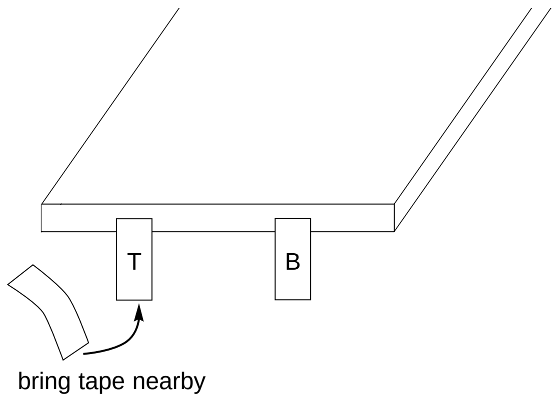


4. Make another 10-cm strip with a tab as before. Press them both down on the base tape, one on top of the other, and then peel them away together. Peel the tapes from one another. What happens when you bring the tapes near each other?





5. Stick the tapes from step #4 to the edge of the table. Call them tape T (top when peeled apart) and tape B (bottom when peeled away). Make another pair of tapes as in step #4 (i.e., another T and B tape) and bring each tape, one at a time, near the tapes on the edge of the table. Summarize your results. How many kinds of “charge” can you identify? Name them. Formulate a simple rule for the interaction of charge.



6. Now bring each tape (T and B) near the paper bits. What charge is on the paper bits?

TSM Teacher Support Material

An Introduction to Electrostatics — Home Experiment (Teacher Version with Answers)

The home experiment is an excellent way to introduce students to static electricity. After the preceding discussion of common phenomena, let the students explore common household materials at home on their own. Students should discuss their observations, explanations, and possible models with a partner (e.g., mom, dad, sibling, friend). This encourages home involvement at the beginning of this cluster.

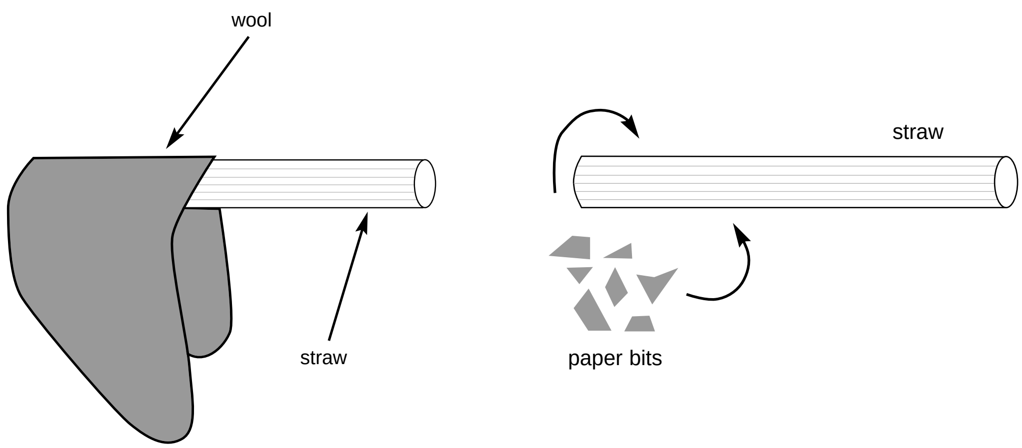
Materials:

- plastic straw
- paper bits
- wool
- transparent tape

Perform the following experiments at home and discuss with a partner (e.g., mom, dad, sibling, friend). Record your observations and explanations.

1. Scatter paper bits on a table. Rub a plastic straw with the wool material and bring the straw near the paper bits. Record and explain your observations.

   The plastic straw becomes charged when rubbed. The paper bits are attracted to the charged rod. After touching the rod, the paper bits may be repelled away. Early model: Charge is the name we give to the "something" the rod acquires when rubbed.

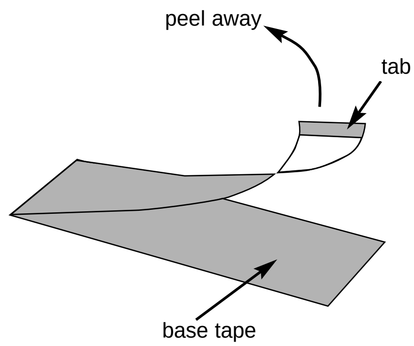


2. Find two materials at home to replace the plastic straw and wool, which demonstrate the same effects.

   Try a toothbrush, pen, CD jewel case, silk, polyester, etc.

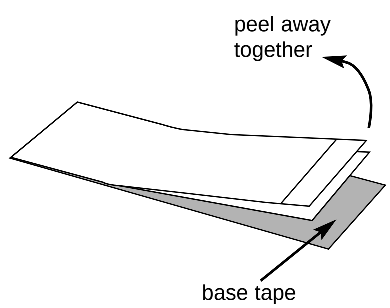
3. Stick a piece of transparent tape (about 30 cm long) on the table (base tape). Take a second piece about 10 cm long and fold over the first centimetre of tape to make a tab. Stick this tape to the base tape and press it down well with your finger. Now peel the short tape briskly from the base tape. Bring the tape near the paper bits. What can you conclude about the tape?

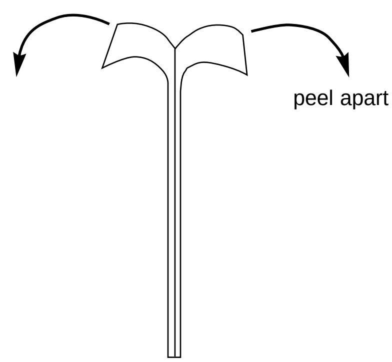
   The tape becomes "charged." It attracts the bits of paper.



4. Make another 10-cm strip with a tab as before. Press them both down on the base tape, one on top of the other, and then peel them away together. Peel the tapes from one another. What happens when you bring the tapes near each other?

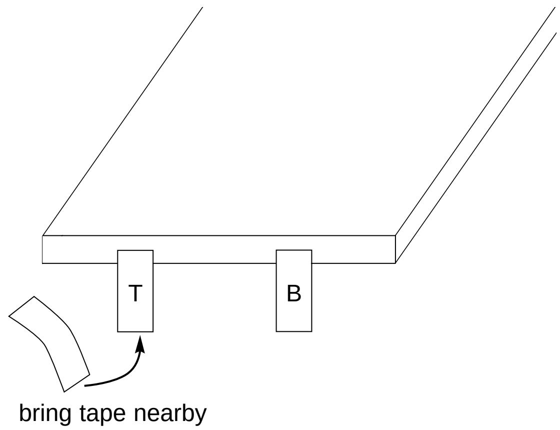
   The tapes are attracted to each other.





5. Stick the tapes (from step #4) to the edge of the table. Call them tape T (top when peeled apart) and tape B (bottom when peeled away). Make another pair of tapes as in step #4 (i.e., another T and B tape) and bring each tape, one at a time, near the tapes on the edge of the table. Summarize your results. How many kinds of "charge" can you identify? Name them. Formulate a simple rule for the interaction of charge.

   Tape T repels tape T, tape B repels tape B, tape T attracts tape B, and tape B attracts tape T. There are two kinds of charges, positive and negative (you can also name them Fred and Barney if you wish; positive and negative are terms which were coined by Ben Franklin). A simple rule for the interaction of charge is like charges repel and unlike charges attract.



6. Now bring each tape (T and B) near the paper bits. What charge is on the paper bits?

   The paper is attracted by tape T and is also attracted by tape B. Two bits of paper have no effect on each other. The paper is neutral and neutral objects are attracted to both kinds of charge.

Home Experiment Summary (a pre-model)

1. Many different materials can be "electrified" by friction.
2. "Charge" is the name we apply to the property we have observed. An object can be "charged" by friction, and charge gives rise to forces of attraction and repulsion.
3. Given the observations of attraction and repulsion, we can say two charge states exist.
4. Charges which are like (that is, created in similar circumstances) repel, and charges which are unlike (that is, created in different circumstances) attract.
5. A neutral object is attracted to both positive and negative charges.
6. The existence of two charge states can be explained by three models:
   a. **one-fluid model** — a neutral object has a "natural" amount of electric fluid. A charged object has either too much or too little fluid. This is Ben Franklin's model. As a result, Franklin coined the terms positive and negative.
   b. **two-fluid model** — a neutral object has equal amounts of each fluid. A charged object has more of one or the other.
   c. **particle model** — there are two kinds of particles, positive or negative. A charged object has more of one particle or the other.

We have come to accept the particle model of electricity because of later discoveries, including Rutherford's gold foil experiment and Millikan's oil drop experiment.

Charging by Contact

The next step is to demonstrate that we can charge an object by contact. Touch a charged positive rod to a neutral pith ball. The pith ball is attracted to the rod (just like the neutral bits of paper). The pith ball sticks to the rod momentarily, and then repels away from the rod. Our model suggests "something" is transferred from one object to the other (i.e., the "charge" flows from the rod to the pith ball). When the pith ball becomes charged, the pith ball and rod repel each other. Because we have come to accept the particle model of matter, we "fix" the positive charge and allow the negative charges to move. (**Note**: This applies to the cases we describe (i.e., solids). In some liquids and gases, both charges — positive and negative — can and do move). Therefore, an object becomes positively charged if it loses negative charges, and becomes negatively charged if it gains negative charges.

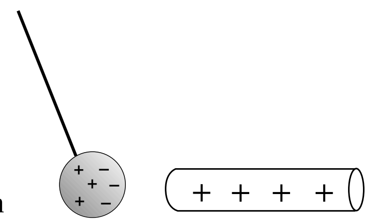
TSM
Teacher Support Material

Attraction of a Neutral Object

The attraction of a neutral object is a discrepant event that challenges students to refine their model.

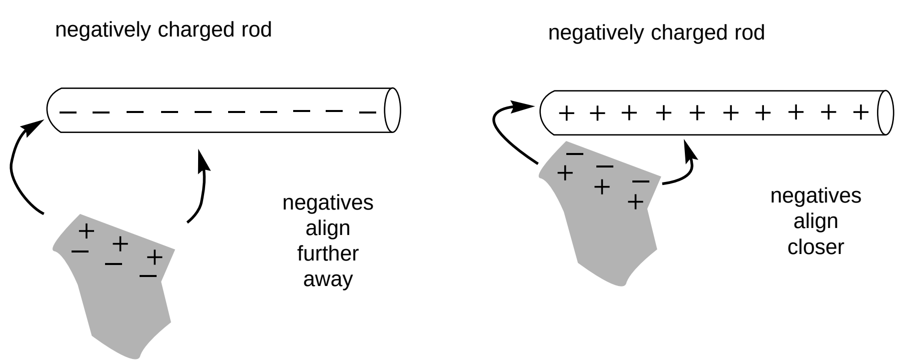
Caution: Introduce this topic clearly and carefully!

1. Bring a positively charged rod near a neutral pith ball. The pith ball is attracted to the rod. Explain using the model of electric charge. Since the negatives on the pith ball are free to move, they move closer to one side attracted by the positives on the rod. The negatives are closer to the positive rod than the positives on the pith, so there is a net force of attraction. When the pith ball and rod touch, the negatives on the pith ball are attracted onto the rod, making the rod less positive and the pith ball more positive.



2. Bring a positively charged rod near some bits of paper. The paper will be attracted to the rod. Students will often conclude (incorrectly) that the paper is charged negatively. But if the paper bits were negatively charged, they would repel each other. Now bring a negative rod nearby the bits. The paper will be attracted to the negative rod.

   We modify the model of electric charge to include reference to materials (like the pith ball) which freely allow the movement of negative charges. When another charge is brought near the pith ball, a charge separation occurs. We call these materials conductors. Materials like paper, which do not allow the free movement of negatives, are called insulators. The charges on insulators do not separate readily but polarize (align themselves). Since opposite charges are always closer to each other, there is a net force of attraction.



   Materials have varying degrees of conductivity. In fact, paper may occasionally acquire a charge and fly off the rod. Demonstrate this by bringing a charged rod near the paper confetti from a hole punch. The pieces of confetti will often oscillate between the table and the rod, alternately attracted and repelled by the rod.

SLA
Student Learning Activity

Electrostatics Lab (Student Version)

Purpose:

To investigate and explain electrostatic phenomena.

Materials:

Contents of electrostatics kit:

- plastic rod
- ebony rod
- acetate strip
- vinyl strip
- silk
- wool
- canvas
- neoprene
- polyester
- two metal spheres or two 6" pieces of half-inch copper pipe
- insulating stand (can be 250 ml beaker or other insulator of similar size)
- pith ball electroscope

Procedure:

Perform the following steps and record your observations, using **diagrams** to explain the results in terms of the charge, charge movement, and the effects of the charge.

1. Touch a suspended pith ball with a charged plastic rod (positive). Draw three diagrams indicating the movement of the negative charges and the effects when

   a. the rod is near the pith ball.

   b. the rod touches the pith ball.

c. the rod and pith ball repel.

2. What charge does the pith ball have? How do you know?

3. Repeat steps 1 and 2 using a negative rod and a pith ball. (Note: You can remove the charge on the pith ball by touching it with your hand.) Explain your results.

4. How can you definitively test an unknown object for charge?

5. Bring a positively charged rod close to one end of a copper pipe on a glass beaker. Touch the other end of the pipe briefly with your finger. Remove your finger first, and then withdraw the nearby rod. Test the pipe for charge. Explain using the model for electric charge.

6. Place a metal pipe on a glass beaker. Suspend a pith ball so that it touches one end of the pipe. Touch the other end of the pipe with a charged rod. Repeat using a wooden dowel in place of the metal pipe. Explain using the model for electric charge.

7. Place two copper pipes on glass beakers so their ends are touching. Bring a charged rod nearby one end and then separate the pipes. Test each pipe for charge. Explain using the model for electric charge.

TSM
Teacher Support Material

Electrostatics Lab (Teacher Version with Answers)

Purpose:

To investigate and explain electric phenomena.

Materials:

Contents of electrostatics kit:

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Procedure:

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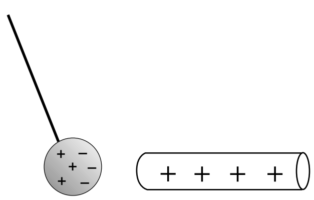
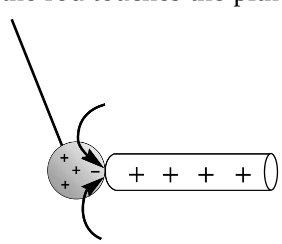
1. Touch a suspended pith ball with a charged plastic rod (positive). Draw three diagrams indicating the movement of the negative charges and the effects when

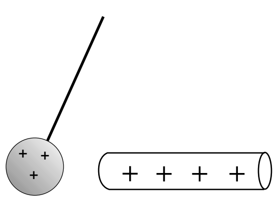
    a. the rod is near the pith ball.



    b. the rod touches the pith ball.



    c. the rod and pith ball repel.



2. What charge does the pith ball have? How do you know?

   The pith ball is positive because it is repelled by the positive rod.

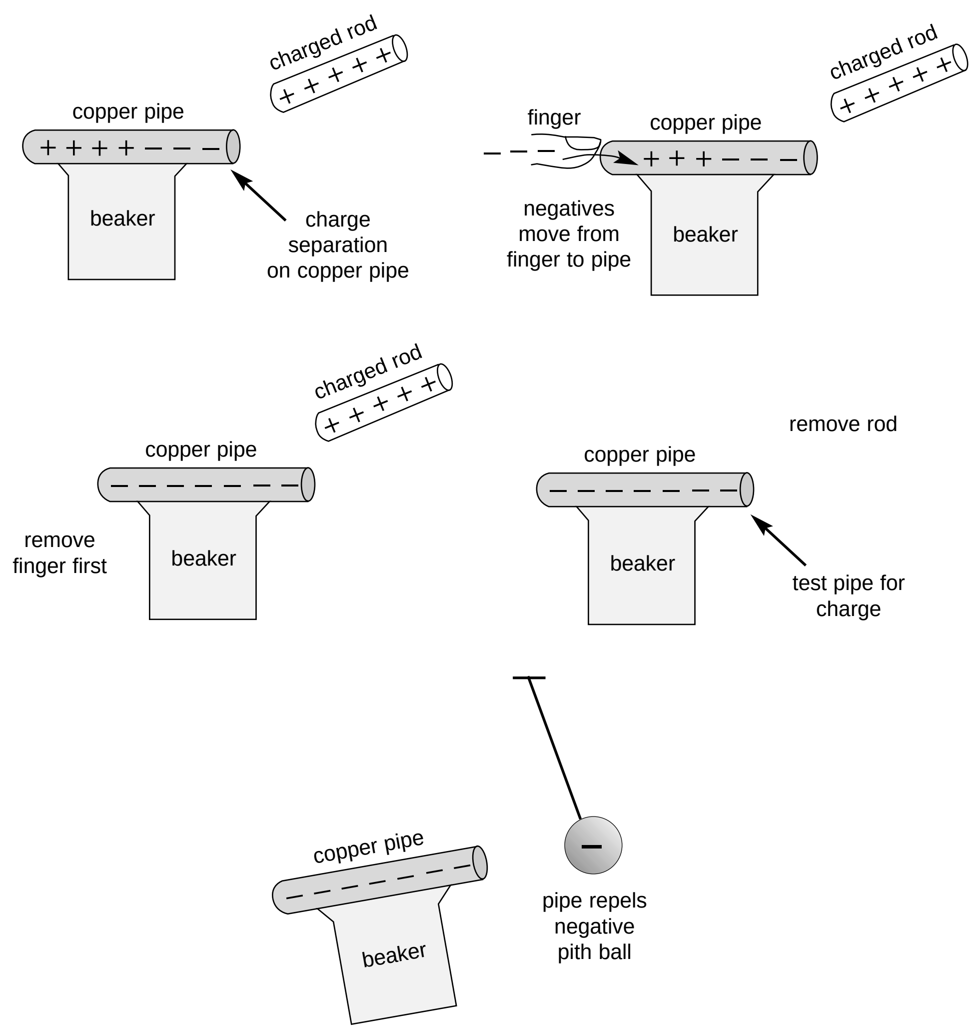
3. Repeat steps 1 and 2 using a negative rod and a pith ball. (Note: You can remove the charge on the pith ball by touching it with your hand.) Explain your results.

   Negatives move from the rod to the pith ball. The pith ball becomes negatively charged and is repelled by the rod.

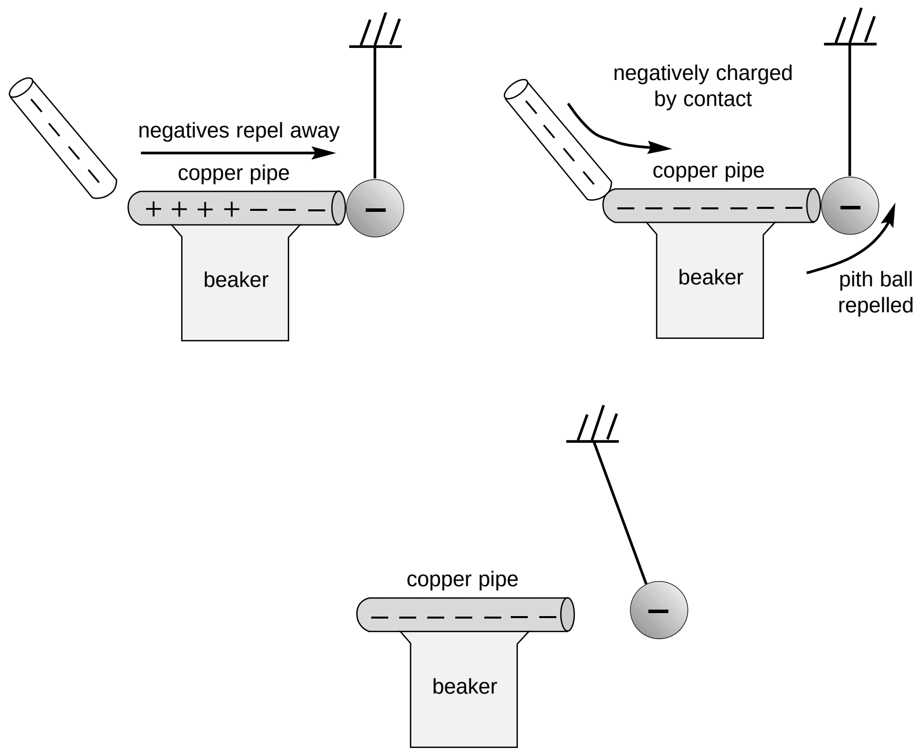
4. How can you definitively test an unknown object for charge?

   A positive rod will attract negatives and a neutral body. A negative rod will attract positives and a neutral body. Therefore, the definitive test for charge is one of repulsion.

5. Bring a positively charged rod close to one end of a copper pipe on a glass beaker. Touch the other end of the pipe briefly with your finger. Remove your finger first, and then withdraw the nearby rod. Test the pipe for charge. Explain using the model for electric charge.

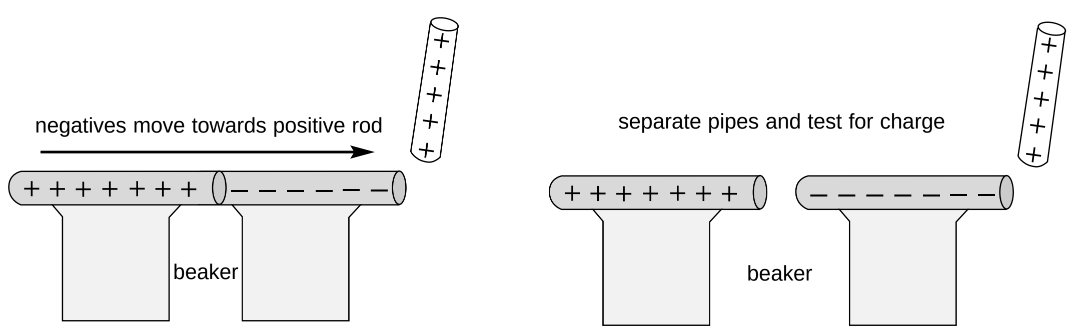


6. Place a metal pipe on a glass beaker. Suspend a pith ball so that it touches one end of the pipe. Touch the other end of the pipe with a charged rod. Repeat using a wooden dowel in place of the metal pipe. Explain using the model for electric charge.



Since a wooden dowel is an insulator, no charge is conducted to the pith ball. Hence, it does not move.

7. Place two copper pipes on glass beakers so that their ends are touching. Bring a charged rod nearby one end and then separate the pipes. Test each pipe for charge. Explain using the model for electric charge.



Post-Lab Discussion

Reinforce the previous activities with a post-lab discussion. Students should be able to:

1. Observe the effects of friction.
2. Discuss the concept of charge (it is the name of a property; it leaks away; it moves through metal objects; it is transferable by contact.)
3. Outline experimental evidence that two charges exist.
4. Operationally define positive and negative and discuss how we can test for charge. Because of the attraction of a neutral insulator, the only definitive test of charge is one of repulsion. Positive charges repel a pith ball that has been charged by a glass rod rubbed with silk. Negative charges repel a pith ball charged by an ebony rod rubbed with neoprene.
5. Define grounding as the sharing of charge with a large object (often the Earth, hence the name). Grounding can neutralize a charged object or serve as a “reservoir of charge” (i.e., charges may be attracted from or repelled to the ground by induction).
6. Discuss the mobility of negative charge. Many students know electrons are negative without understanding that one way we know this is because electrons are repelled by negatively charged objects.
7. Identify the properties of conductors and non-conductors.
8. Diagram charging an object by induction.

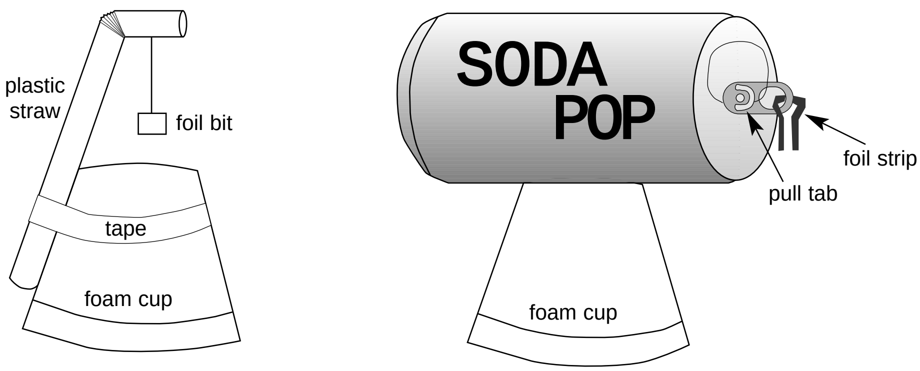
BLM
Blackline Master

Electrostatic Devices — Background Information

After observing electrostatic phenomena, students should consider an historical perspective. In the industrial revolution of the 1700s, machines and machinery were studied extensively. Studies included the detection of electricity, the production of large amounts of electricity, and the storage of electricity. Some early useful devices include the electroscope, the electrophorus, and the leyden jar. These devices can be easily produced in class (see instructions below).

E.g., Electroscope

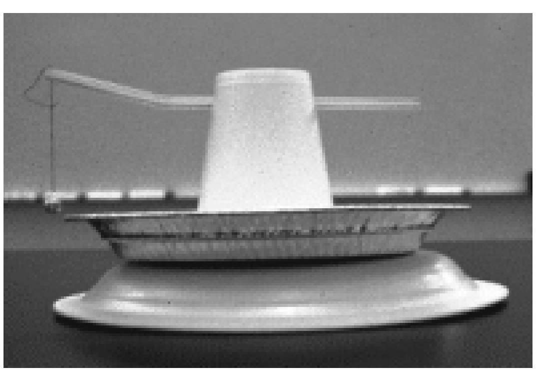
An electroscope is a device which is used to detect charge. The simplest kind of electroscope is the pith ball or foil bit electroscope which can be constructed with common materials (see below). Many commercially made devices, including models on overheads, are also readily available.



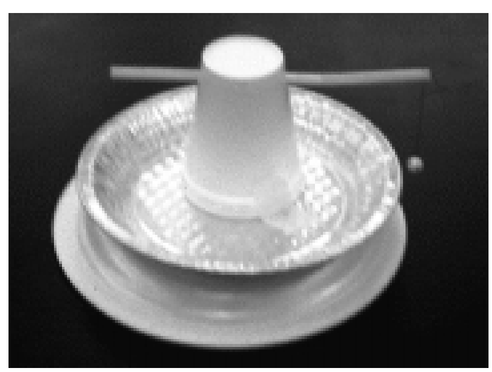
Homemade "foil bit" electroscope

E.g., Electrophorus

The electrophorus is most often used to produce a stronger charge than by simply rubbing a rod. A very inexpensive and reliable electrophorus can be made from a plastic foam plate, an aluminum plate, a foam cup, and some tape, as shown in the diagram below.



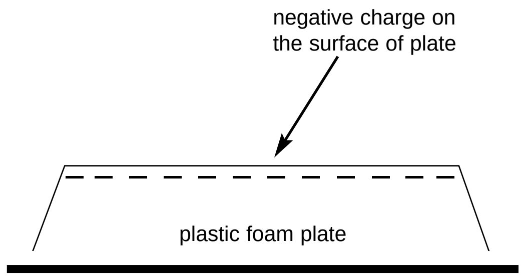
Side View



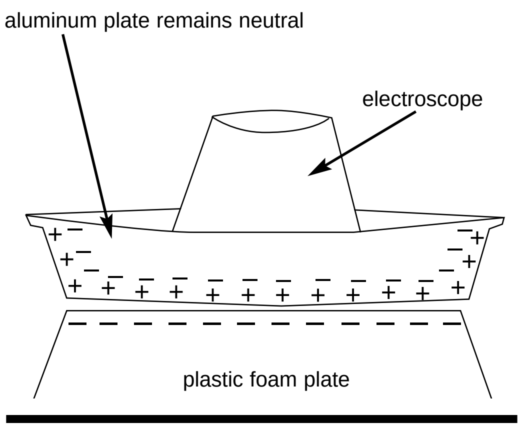
Top View

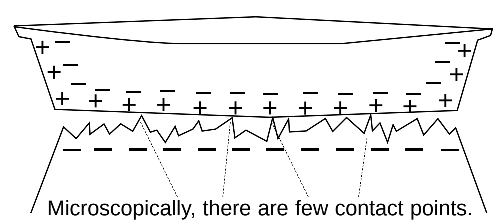
To charge the electrophorus:

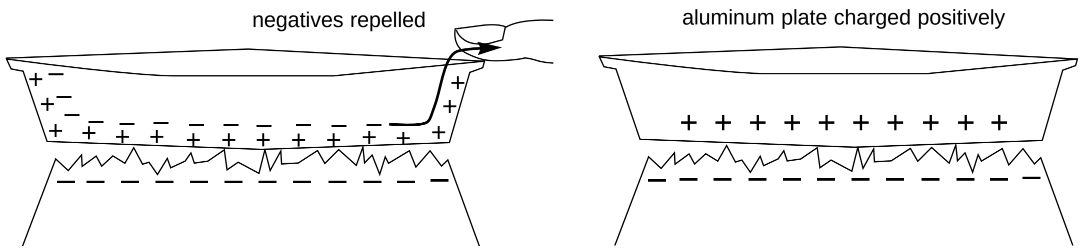
1. Rub the plastic foam with wool (or a similar material). This will place a negative charge on the plate. Test for charge using the electroscope as follows:



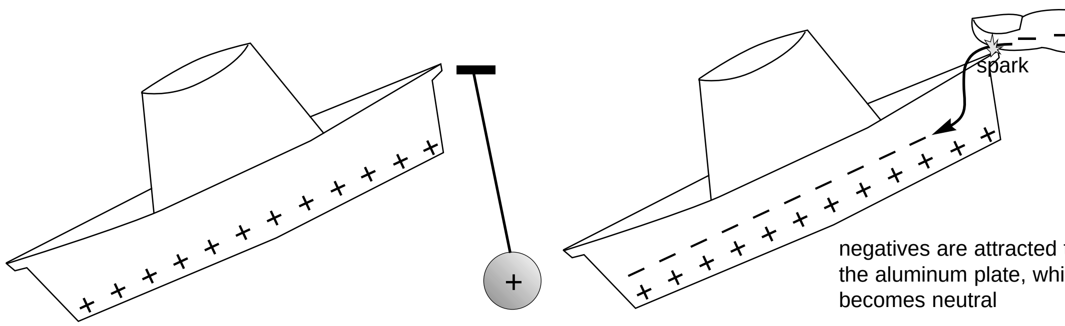
- Place the aluminum plate on the plastic foam plate, and then try to remove the aluminum plate. You will find there is a force of attraction between the two plates (they try to hold together), but the aluminum plate remains neutral. No charge from the plastic foam has moved onto the aluminum plate because very few contact points exist through which the negatives can move to the aluminum plate. The plate is charged by induction. The negative charge on the plastic foam will repel the negatives on the aluminum plate towards the inner surface.
- Now ground the aluminum plate. The negatives are repelled to the ground and the aluminum plate becomes positive. Ground the pieplate again by touching it with your finger. A spark will jump from the pieplate to your finger as the negatives are repelled to ground through your finger. While this is harmless for simple electrostatic demonstrations, it is NOT generally a safe practice to become a ground (more on this later). See the following diagrams which illustrate the tests described above.



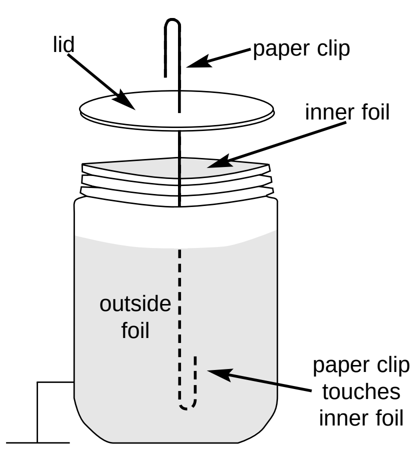




- Test the aluminum plate for charge by bringing it near an electroscope.
- Discharge the aluminum plate, by touching it again with your finger. Negatives are attracted to the aluminum plate and it becomes neutral.
- Charge the electrophorus again by placing it on the plastic foam and touching it with your finger. You can charge the aluminum plate repeatedly without having to continually rub the plastic foam.



E.g., Leyden Jar



Students can make small leyden jars with plastic cups, plastic film canisters, or any other container constructed of glass or plastic. Commercial leyden jars are also available.

The film canister leyden jar is easy to assemble. Cover the inside of a film canister with tin foil. A glue stick can be used to apply a small amount of glue to hold the foil in place. Cover the outside of the film canister with tin foil. Push a paper clip through the lid so that it touches the bottom of the canister when the lid is on. Now charge the leyden jar using a charged rod or an electrophorus. The charge on the inside induces the opposite charge on the outside. The opposite charges "hold" the charge. The charge is transferred through the paper clip to the inner foil lining, giving it the same charge. This charge induces an opposite charge on the outer foil lining, and will remain for a fairly long time. Disconnect the leyden jar by touching the paper clip and the outside foil at the same time. You will feel a small shock. Large leyden jars can hold a considerable amount of charge. Caution should be exercised when discharging.

TSM
Teacher Support Material

Transition from Static to Current Electricity

In a discussion of the pedagogical order of statics and current electricity, Arons (1991) suggests that the order of the topics is not critical but that a connection between the two sets of phenomena is important. The historical order is valid and the intellectual struggle which took place provides a useful pedagogical model to develop a transition between static and current electricity.

Historical Order

A significant problem of the 18th century was the identification of different kinds of electricity — animal electricity, chemical electricity, static electricity, and current electricity. Faraday performed countless experiments to demonstrate the characteristics and similar nature of the various electricities. Consider the following table constructed by Michael Faraday in his experiments.

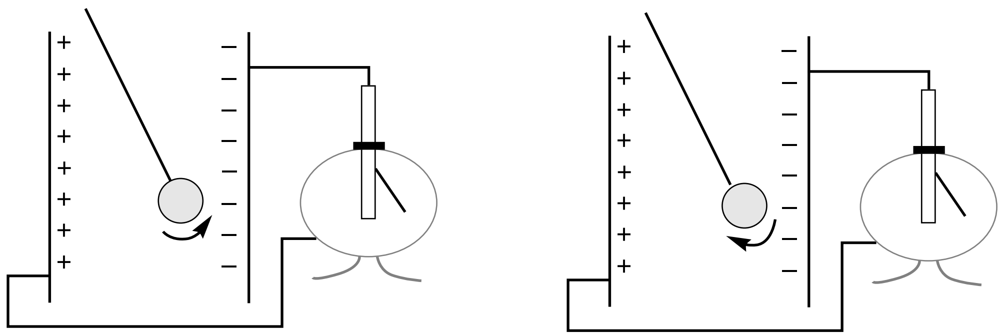
Faraday's Table*

Type of Electricity	Physiological Effects	Magnetic Deflection	Magnets Made	Spark	Heating Power	True Chemical Action	Attraction and Repulsion	Discharge by Hot Air
Voltaic	X	X	X	X	X	X	X	X
Common	X	X	X	X	X	X	X	X
Magneto	X	X	X	X	X	X	X	
Thermo	X	X	+	+	+	+		
Animal	X	X	X	+	+	X		

* 'x' denotes a characteristic found by Faraday.

To provide a transition from static to current electricity, we try to establish as many links as possible from Faraday's table (remember Faraday took many years to establish his table). The easiest to demonstrate in the classroom is the connection between static electricity, voltaic batteries, and ultimately the household outlet.

Arons (1991) began demonstrating the dynamic nature of charge by suspending a positively charged pith ball between two parallel conducting plates (see below). The electroscope monitors the charge on the plates.



When the plates are charged, the pith ball is attracted to the negative plate. When it touches the plate, negative charges move from the plate to the ball, charging it negatively. (The ball becomes a little more negative as the plate becomes a little less negative, as indicated by the leaves on the electroscope which move closer together.) The negatively charged ball is repelled by the negative plate and attracted by the positive plate and, therefore, swings towards the positive plate.

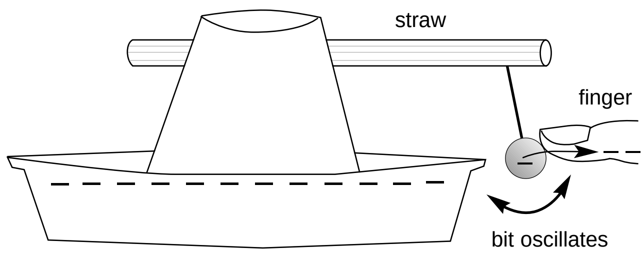
When it touches the positive plate, negative charges are transferred from the pith ball to the positive plate. The pith ball loses negative charges and becomes more positive. The plate gains negatives and becomes less positive. The positively charged pith ball is then repelled by the positive plate and attracted to the negative plate. As the pith ball touches the negative plate, the process is repeated until the plates are discharged. The leaves on the electroscope gradually come together as the swinging slows to a stop. This illustrates the dynamic nature of charge (i.e., the pith ball oscillates back and forth, transporting charge between the two plates, sort of like an electrostatic "motor").

TSM
Teacher Support Material

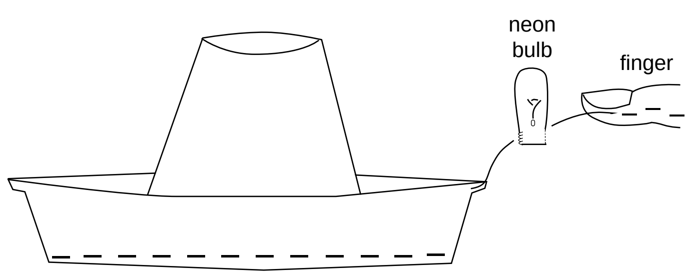
Pieplate Electrophorus

This demonstration can be easily adapted to the classroom using the aluminum plate electrophorus. To begin, charge the aluminum plate. The foil bit will be repelled from the plate, indicating the negative foil bit is repelled by the negative aluminum plate. Bring your finger nearby the foil bit. Charge is then transferred from the bit to the finger. The bit is then attracted back to the plate, and negatives are transferred from the plate to the bit. The bit oscillates back and forth between the plate and finger until the plate is discharged. (See the diagram below.) This demonstrates the dynamic nature of charge effectively.

To continue to do as Faraday did, replace your finger with a metal plate which is attached to a Wimshurst machine. By generating a charge on the Wimshurst, we can do work oscillating the ball between the metal plate and the aluminum plate. In other words, the system maintains a continuous transport of charge.



You can further extend the connection between static and current electricity by using a neon bulb (model NH–2), batteries, and an electrophorus. Connect the neon bulb in a simple circuit (requires about 70 v). The bulb flashes. Hold one terminal of the bulb between your fingers and bring it near a charged electrophorus. The bulb flashes in a similar fashion. The neon bulb emits electrons from the negative electrode which crash into the neon atoms emitting a reddish-orange glow at the negative electrode. By observing which electrode flashes, you can determine the direction of the current flow.



TSM Teacher Support Material

Batteries and Bulbs

Conceptually tieing together static and current electricity permits the model for current electricity to be developed further.

Elaboration of our Model of Electricity

After the previous discussion of the transition from static to current electricity, extend the model to include basic circuits. Using batteries and bulbs, try to establish the following postulates.

1. An electric current is moving charges (electrons). The brightness of a bulb depends on the current through the bulb. As the electrons move through the conductor, they collide with the fixed particles of the conductor and the kinetic energy is transferred into heat and light in the resistance. More current means more electrons collide and, therefore, more energy is dissipated in the resistance. The brightness of the bulb is a qualitative measure of current.

2. Current is conserved. What goes in one end must come out the other end (Kirchhoff's current rule).

Use the brightness and conservation postulates to predict the lighting of bulbs in simple circuits. Resistance should be considered an obstacle to flow. Less resistance implies more flow and vice versa.

Current Summary:

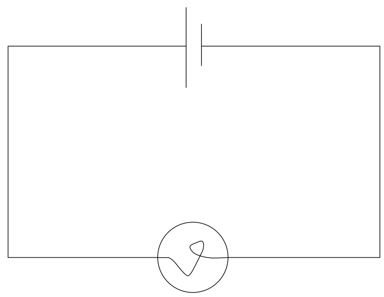
1. The greater the current, the brighter the glow.
2. Current is conserved.
3. Current is determined by the resistance.
4. Two objects in series are a larger resistance than one.
5. Two objects in parallel are a smaller resistance than one.

SLA
Student Learning Activity

Simple Circuits Lab (Student Version)

Build the following circuits one at a time. Record your observations in terms of the brightness of the bulb and the current through the bulb. Use the circuit in Question #1 as your standard (i.e., the brightness of the bulb, and consequently the magnitude of the current, is the same, less than, or greater than circuit #1).

1. Schematic of a Simple Circuit



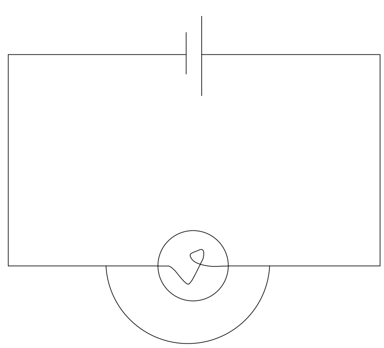
Observation:

2. Reverse the direction of the current in circuit #1, and illustrate the result in a schematic diagram. Compare your results to circuit #1.

Observation:

3. Short Circuit

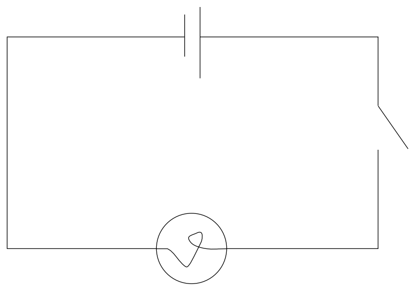
   Connect a wire across the terminals of the bulb. What happens to the light?



Observation:

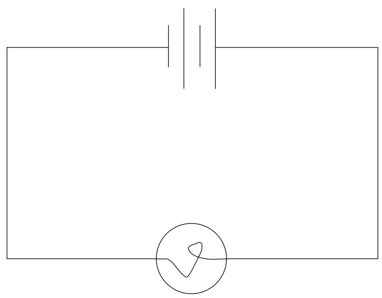
4. **Simple Circuit (Switched)**

   When does the light go off? Explain.



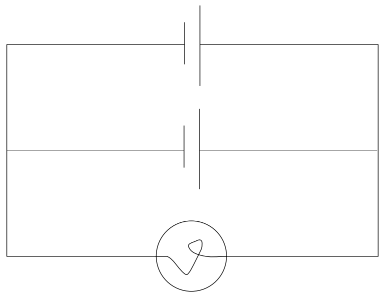
5. **Cells in Series**

   Compare to circuit #1.

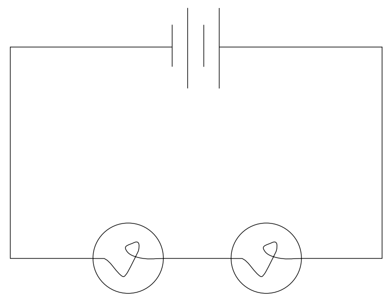


6. **Cells in Parallel**

   Compare to circuit #1.

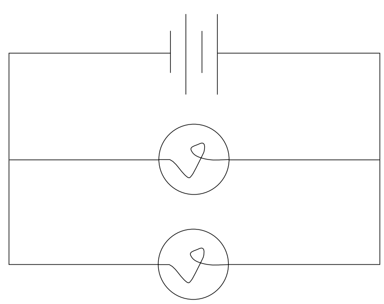


7. a. Make and compare the following circuit to circuit #1. Explain your observations in terms of the resistance of the circuit, brightness of the bulbs, and the current delivered to each bulb.



   b. Unscrew one of the bulbs. Explain what happens.

8. a. Make and compare the following circuit to circuit #1. Explain your observations in terms of resistance of the circuit, brightness of the bulbs, and the current delivered to each bulb.



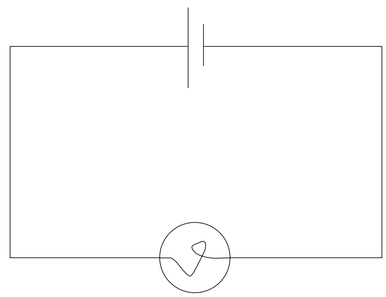
   b. Unscrew one of the bulbs. Explain what happens.

TSM Teacher Support Material

Simple Circuits Lab (Teacher Version with Answers)

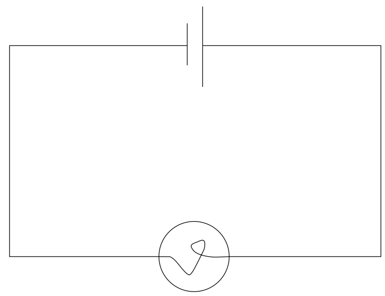
Build the following circuits one at a time. Record your observations in terms of the brightness of the bulb and the current through the bulb. Use circuit #1 as your standard (i.e., the brightness of the bulb, and consequently the magnitude of the current, is the same, less than, or greater than circuit #1).

1. **Simple Circuit**



The light goes on.

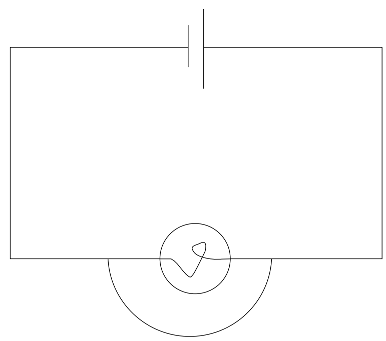
2. Reverse the direction of the current in circuit #1 and compare your results to circuit #1.



The direction of the current does not matter as the negative charges still pass through the bulb.

3. **Short Circuit**

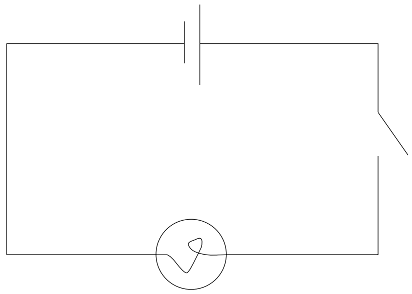
Connect a wire across the terminals of the bulb. What happens to the light?



The bulb goes out. The bulb has a high resistance and the wire has a very low resistance. Most of the electrons take the path of least resistance.

4. **Simple Circuit (Switched)**

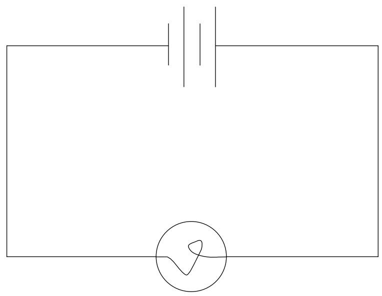
When does the light go on? Explain.



The light goes on when the switch is closed and the electrons have a complete path.

5. **Cells in Series**

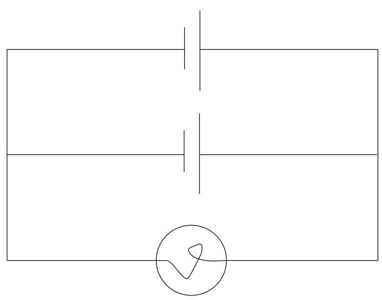
Compare to circuit #1.



The bulb is brighter than circuit #1. Therefore, more current passes through the bulb for cells in series.

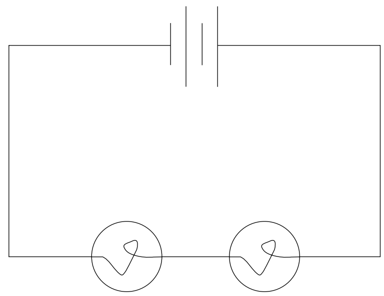
6. **Cells in Parallel**

Compare to circuit #1.



The bulb is the same brightness as circuit #1. Therefore, the same amount of current must pass through the bulb.

7. a. Make and compare the following circuit to circuit #1. Explain your observations in terms of the resistance of the circuit, brightness of the bulbs, and the current delivered to each bulb.

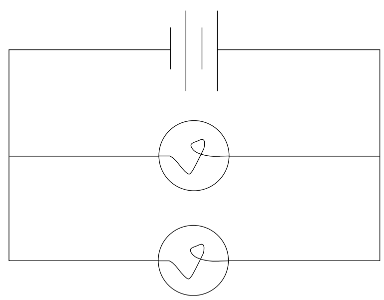


The brightness of the bulbs is the same as circuit #1. The voltage increases but the resistance also increases and the current is the same.

b. Unscrew one of the bulbs. Explain what happens.

The bulbs go out. The circuit is broken (like a switch) and the current does not have a complete path.

8. a. Make and compare the following circuit to circuit #1. Explain your observations in terms of resistance of the circuit, brightness of the bulbs, and the current delivered to each bulb.



Both bulbs are brighter than the bulb in circuit #1. The resistance is less and the voltage and current are greater.

b. Unscrew one of the bulbs. Explain what happens.

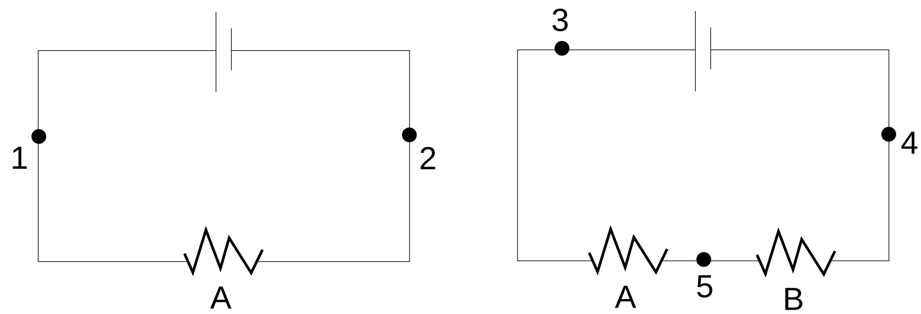
The bulb that is unscrewed will go out but the other bulb stays lit. The lighted bulb still makes a complete path with the battery.

BLM Blackline Master

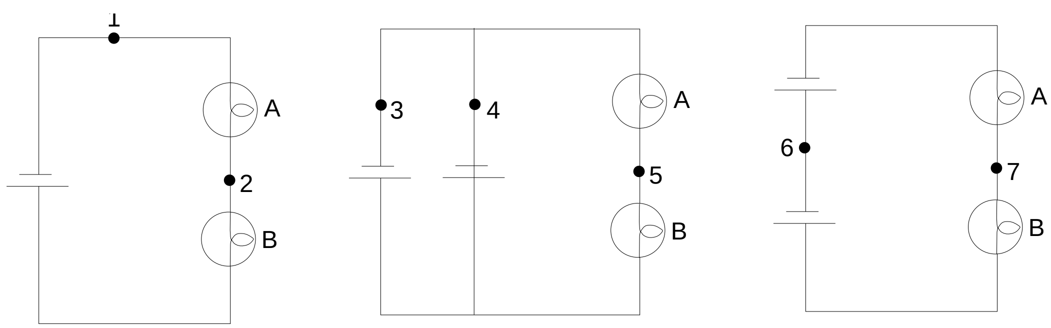
DC Circuits and Schematic Diagrams

Use the following questions to assess your understanding of DC circuits.

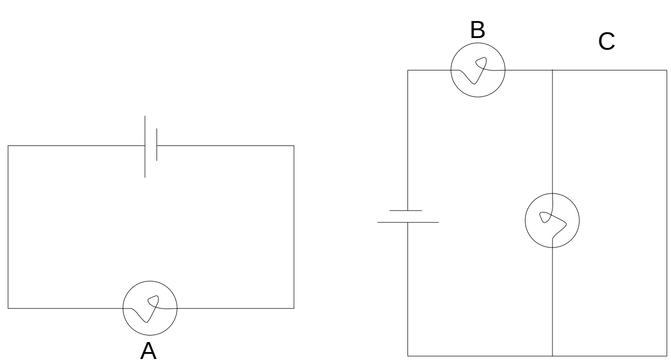
1. Are charges used up in the production of light in a light bulb?
2. How can birds rest on a high voltage line without being electrocuted?
3. When you turn the tap on at home, the water comes out of the tap immediately. You do not have to wait for it to flow down from the water tower, reservoir, or well. Explain.
4. Suppose the current at point 1 is I. What value will the current be at points 1, 2, 3, 4, 5?



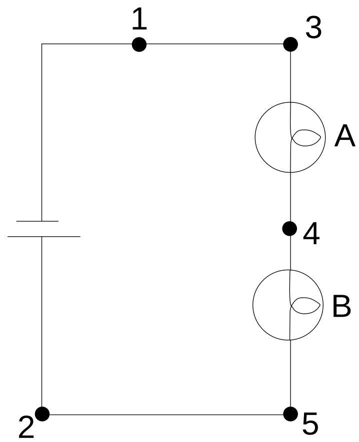
5. Suppose the current at point 1 is I. What value is the current at points 2, 3, 4, 5, 6, 7?



6. Why do the bulbs in the circuits built earlier come on instantaneously when you complete the circuit?
7. Compare the brightness of bulbs A, B, and C.

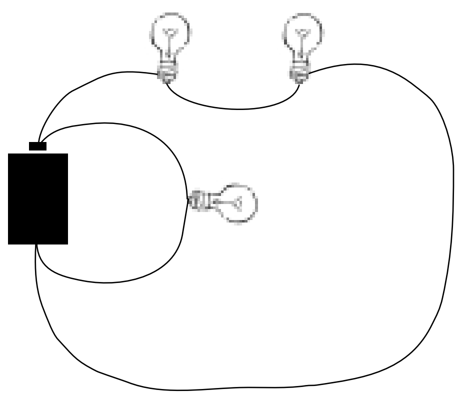


8. If the potential difference across the battery is V, what is the potential difference between the following points?



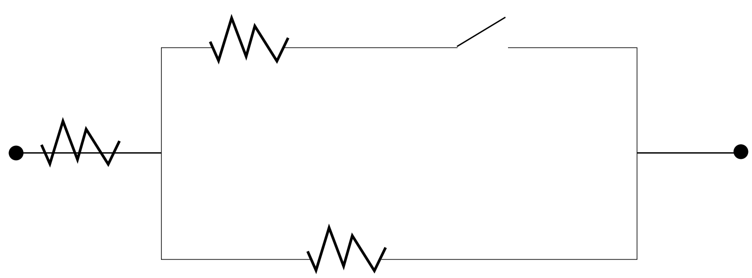
a. 1 and 2
b. 1 and 3
c. 3 and 4
d. 4 and 5
e. 2 and 5

9. Draw a schematic for the following circuit.



Schematic

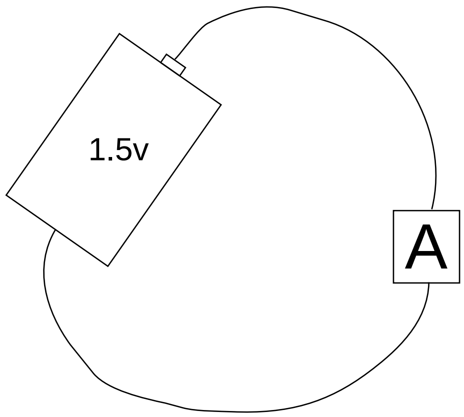
10. What is the resistance between the endpoints before and after the switch is closed if each resistance has a value of R?



SLA Student Learning Activity

Circuits Lab 2 — Measuring Current, Voltage, and Resistance (Student Version)

1. Measure the current between the electrodes of a 1.5 volt battery.



2. Measure the current through a single bulb. Infer a rule for current and resistance.

   Draw a Schematic.

3. Compare the voltage across the battery in a simple circuit (circuit #1 from Activity 3.9) to the voltage across the resistance. Infer a rule for the voltage supplied to the cell and the voltage used in the circuit. What happens if you apply a large voltage to a circuit?

   Draw a Schematic.

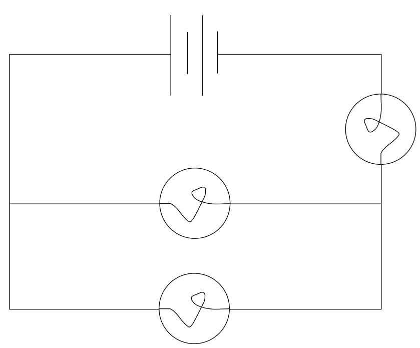
4. Measure the voltage and current in a simple circuit with one bulb and one cell.

   Draw a Schematic.

5. Measure the voltage and current in a simple circuit with one bulb and two cells. Compare to question #4. Infer a rule between voltage and current if resistance remains constant.

   Draw a Schematic.

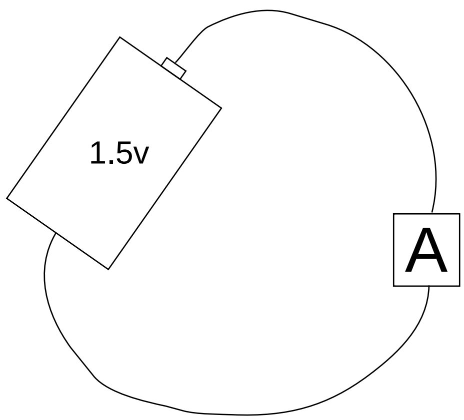
6. *Optional*. Combine the relations from question #2 and question #5 to make a simple law relating voltage, current, and resistance. Check your law using the following circuit. Draw a schematic to show where you would place the meters.



TSM
Teacher Support Material

Circuits Lab 2 — Measuring Current, Voltage, and Resistance (Teacher Version with Answers)

1. Measure the current between the electrodes of a 1.5 volt battery.



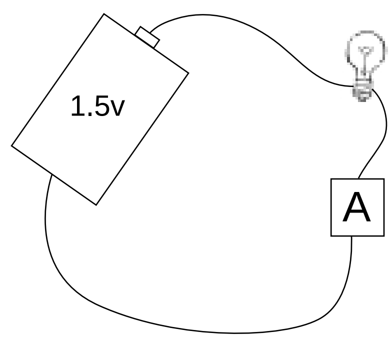
The current is about 3-4 A (be sure to use an ammeter which is capable of measuring up to 5 Amperes).

2. Measure the current through a single bulb. Infer a rule for current and resistance.

   The current is approximately 0.2 A. If resistance increases, current decreases.

Draw a Schematic.

Draw a diagram like this:

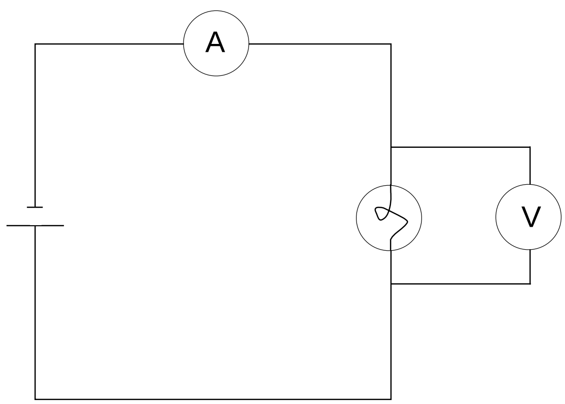


3. Compare the voltage across the battery in a simple circuit (circuit #1 from Activity 3.9) to the voltage across the resistance. Infer a rule for the voltage supplied to the cell and the voltage used in the circuit. What happens if you apply a large voltage to a circuit?

   Draw a Schematic.

   The voltages are equal. The voltage supplied to a circuit is used in the circuit. If a large voltage is applied, it will be dissipated in the circuit. If it is too large, the wires will burn.

4. Measure the voltage and current in a simple circuit with one bulb and one cell.

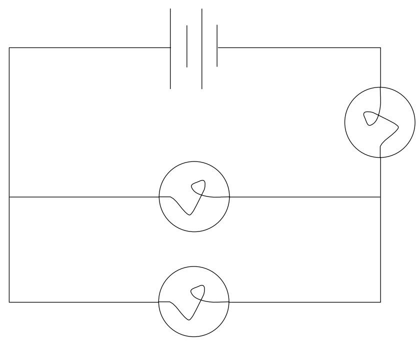


5. Measure the voltage and current in a simple circuit with one bulb and two cells. Compare to question #4. Infer a rule between voltage and current if resistance remains constant.

   Draw a Schematic.

   The voltage increases for cells in series (about 3.0 v for two flashlight batteries). The current is about 0.4 A. Therefore, for a constant resistance, if the voltage increases, the current increases.

6. *Optional*. Combine the relations from question #2 and question #5 to make a simple law relating voltage, current, and resistance. Check your law using the following circuit. Draw a schematic to show where you would place the meters.



V = IR.

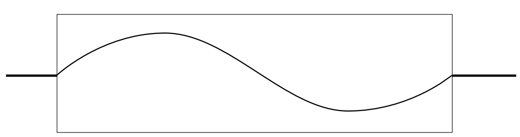
From #2, $I \propto \frac{1}{R}$

From #4, $V \propto I$

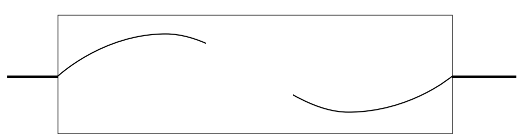
Therefore, $V = I \cdot R$ *(Ohm's Law)*

The Electric Panel

Fuse



Fuse burns and circuit breaks



SLA
Student Learning Activity

Power Calculations

Questions:

1. Calculate the power of each appliance.

   a. A 120 V can opener draws 2.5 A of current.

   b. A TV connected to a 120 V line draws 1.2 A.

   c. A flashlight using four 1.5 V cells draws 80 mA.

2. Find the potential drop across a 1200 W toaster which draws 9.8 A of current.

3. What current is drawn by a 1400 kW iron in a 120 V circuit?

4. Rationalize the units of Volts x Amperes to Joules (i.e., show that a Volt-Ampere is the same unit as a Joule).