UNIT 1
EXPLORING THE NATURE OF ELECTROSTATIC FORCES

Objectives

- to learn that scientific models are based on observations and to learn how scientific models are developed from observational evidence
- to learn about the nature of charge
- to understand the difference between observation and inference
- to understand that models may not be complete and that models may change as more experimental evidence is discovered
- to be able to develop experiments with charged objects which would be able to distinguish different types of charges and to understand the nature of charge within macroscopic objects; for example, to be able to develop experiments to distinguish objects with zero net charge from objects with no charge or to distinguish objects with a third type of charge from objects with zero net charge
- to understand the difference between a conductor and an insulator and to develop a model for the arrangements of charges within a conductor or within an insulator in different situations (when charged objects are nearby or not)
- to understand how to discharge a charged object
- to understand the concept of charging by induction

Equipment:

4 10 cm long pieces of transparent tape
2 rod stands
2 styrofoam balls hung from non-conducting threads
2 metal-coated pith balls hung from non-conducting threads
1 ping-pong ball hung from non-conducting threads
1 metal-coated ping-pong ball hung from non-conducting threads
1 rubber rod
1 glass rod
1 piece of fur
1 piece of silk
2 metal rods
2 right angle clamps
1 empty aluminum soda can
2 10-15cm strips of aluminum foil

1.1

a. You and your partners should each place a 10 cm or so long strip of tape on the lab table with the sticky side down, with the end of each tape curled over to make a non-stick handle. Peel your tape off the table and bring the non-sticky side of the tape toward your partner's strip. What happens as the tapes get closer together?

b. Place two strips of tape on the table sticky side down with a non-stick handle and label them "B" for bottom. Press another tape (with a non-stick handle) on top of each of the "B" pieces; label these strips "T" for top. Pull each pair of strips off the table. Then pull the top and bottom strips apart.

Describe the interaction between two top strips.

Describe the interaction between two bottom strips.

Describe the interaction between a top and a bottom strip

In each case, how does the distance between the tapes, affect the interaction between them?

c. We say that the tapes are charged. Based *only* on the experiments you did in part **b**, answer the following questions.

> (i) Do the experiments in part **b** provide evidence of the number of types of charges that exist? Explain your reasoning. If so, for how many types of charge do you have evidence? Explain.
>
> (ii) Do you have sufficient evidence (based on the experiments in part **b**) to determine the number of types of charge that exist (could there be more or less charges than in your answer in part **i** above)?
>
> If so, explain why the evidence in part **b** is sufficient. Explain in detail why the evidence you have is sufficient to determine the number of types of charge that exist and why no further experiments are needed.
>
> If not, explain why the evidence in part **b** is not sufficient. Are there further experiments that need to be done in order to determine the number of types of charge that exist? If so, what experiments would you do? Explain how these experiments would determine if the number of types of charge you found in part **b** is the number of types of charge that exist, or if there is a different number of types of charge than you found in part **b**.

d. Bill and Joe found evidence for two types of charge in part **b**. They called them "Top" and "Bottom" and made a table to indicate how a Top charge would interact with a Bottom charge, how a Top charge would interact with another Top charge, and how a Bottom charge would interact with another Bottom charge. They tried to determine experiments that would give evidence of a third type of charge. They tried to think about

how a third type of charge would interact with the two types of charge they had found so far.

Make a table that would indicate how the number of types of charge *you* found evidence for in part **b** would interact with each other.

If there were an additional type of charge than the number you found evidence for in part **b**, how would you extend your table? Draw the table with an additional type of charge in the space below. Can you determine how an additional charge would interact with each of the charges found so far? Can you definitively fill in all of the spaces in the table for an additional type of charge? Can you fill in possibilities for all of the spaces in the table consistent with an additional type of charge? How would an additional type of charge interact with itself?

Discuss your table with your instructor.

Summarize with your partners your conclusions so far about how many types of charge there are and the experimental evidence you have to support your claims.

1.2 So far you have found definitive evidence for two types of charge. We will follow Bill and Joe and call them Top and Bottom.

a. If you rub a rubber rod with a piece of fur, you will find that it interacts like either a Top or a Bottom piece of tape. How does the fur interact? Rub a glass rod with a piece of silk. How do the glass rod and the silk interact with each piece of tape?

b. Hang a metal-coated ping-pong ball attached to a non-conducting thread from a hook attached to a rod stand. Rub a rubber rod with fur and bring it very near but not touching the metal-coated ping-pong ball. Observe the interaction.

c. Hang a ping-pong ball attached to a non-conducting thread from a hook attached to a rod stand. Rub a rubber rod with fur and bring it very near but not touching the ping-pong ball. Observe the interaction.

d. Hang two strips of aluminum foil from a wooden rod using transparent tape. Rub a rubber rod with fur and touch the rod to each piece of aluminum foil.

(i) How do the two pieces of aluminum foil interact with each another?

(ii) What happens when you bring the rod near, but not touching the pieces of aluminum foil?

(iii)What happens when you bring a glass rod rubbed with silk near the two pieces of aluminum foil that were touched by the rubber rod?

e. Consider the following questions. Determine which ones can be definitively answered, *based on your observations only*, and answer them. Determine which questions cannot be answered, *based on your observations only*. Of the questions that cannot be answered based on your observations, only, could you answer them by doing further experiments? If so, describe experiments you could do that might answer the questions.

(i) Is charge a property of an object? Explain.

(ii) Describe the nature of charge.

(iii) Can charge be transferred from one object to another? Explain.

(iv) Is it possible for an object not to have charge? Explain.

(v) Is it possible for an object to have more than one type of charge? Explain.

(vi) A question you make up about charge.

Using the above questions as a guide, the experiments you have done and any you wish to do, develop a model based on both inferences and observations to describe charge and its interactions (how it moves inside an object or from object to object). An inference is a conclusion drawn from your existing evidence and reasoning. Before developing your model, determine what inferences you would make. List your inferences. List your observations. Then write down a model that combines your inferences in a way that could be used to predict and explain observations. Your model may not be complete, in that it may not be able to predict all future observations. Models change. It should be based on your present information. Your model should describe what you know about charge at this time. Do *not* include information from other sources. It should be able to predict your present observations.

Could your model be used to answer questions 1-6 above?

Discuss your model with an instructor.

1.3 Could your model be used to distinguish how an object with equal amounts of "Top" charge and "Bottom" charge would behave differently from an object with no charge?

a. How would an object with no charge interact if brought near an object with mostly "Bottom" charge? How would an object with no charge interact, if brought near another object with mostly "Top" charge? How would an object with no charge interact, if brought near another object with no charge? Explain you reasoning. Base your reasoning on your present model.

b. If an object had equal amounts of "Top" and "Bottom" charges, how would it interact when brought near an object with mostly "Top" charge? How would it interact when brought near an object with mostly "Bottom" charge? Explain your reasoning.

c. Obtain an empty soda can, a rubber rod and fur. Rub the rod with the fur. Lay the can on its side on a table and hold the rod near, but not touching the can.

What happens to the can?

Repeat with a glass rod rubbed with silk.

d. Based on your model, does the soda can contain charge? Does it contain only one type of charge? Does it have more of one type of charge than the other? Could it have equal amounts of "Top" charge and "Bottom" charge? Any other possibilities? Explain.

1.4 Bill and Joe did Experiment **1.3.c** Bill said that the result was exactly consistent with the soda can having a third type of charge.

a. Is Bill correct? Explain your reasoning.

b. If Bill is correct, does this mean that the can is charged with a third type of charge? Or is there another explanation? If there is another explanation, devise an experiment to distinguish if the can is charged with a third type of charge from the other explanation. You do not have to carry the experiment out. Describe the experiment in detail below. Explain your reasoning.

Discuss your experiment and explanation with an instructor.

c. Based on any of your experimentation, do you have evidence for the existence of a third type of charge? Does this mean that a third type of charge does not exist? Could you do experiment(s) to determine if a third type of charge existed? Could you prove the existence of a third type of charge? Are there any experiments that could be done to prove that a third type of charge does not exist? Explain your reasoning.

d. Based on any of your experimentation, do you have evidence for the existence of an object with no charge?

If so, explain the experiment and your reasoning.

If not, does this mean that an object with no charge does not exist? Could you do experiment(s) to determine if an object with no charge exists? Could you prove the existence of an object with no charge? Are there experiments that could be done to prove that an object with no charge does not exist? Explain your reasoning.

e. If you wish to change your model of charge based on the experiments and discussion in the last few sections, do so at this time. Write your new model in the space below.

Discuss your explanations with an instructor.

1.5 You have determined that objects with equal amounts of "Top" and "Bottom" charge can be distinguished from objects with no charge.

a. How does an object with equal amounts of "Top" and "Bottom" charge interact with another object with equal amounts of "Top" and "Bottom" charge?

b. A metal-coated pith ball interacts with a charged object as if it has equal amounts of "Top" and "Bottom" charge. How do two metal-coated pith balls interact with each other?

c. How do you think an object with no charge would interact with another object with no charge?

d. Based on your model of charge, draw a picture of two objects with equal amounts of "Top" and "Bottom" charge near each other, but not touching. Could your picture be used to help someone understand the interaction of the two objects?

e. Draw a picture of one object with equal amounts of "Top" and "Bottom" charge on the left and one object with more "Top" charge than "Bottom" charge on the right, near each other, but not touching. Could your picture be used to help someone understand the interaction of the two objects?

f. Draw a picture of one object with equal amounts of "Top" and "Bottom" charge on the left and one object with more "Bottom" charge than "Top" charge on the right, near each other, but not touching. Could your picture be used to help someone understand the interaction of the two objects?

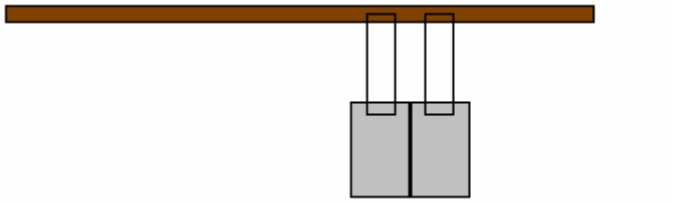
g. Would it make sense to say that an object with equal amounts of "Top" and "Bottom" charges has no total charge? Explain.

Equipment:

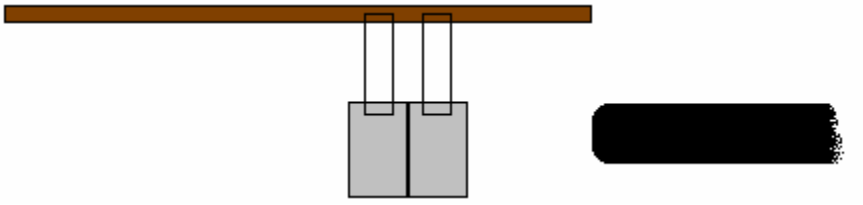
- transparent tape
- 1 rod stand
- 1 wooden rod
- aluminum foil
- index card
- 1 rubber rod
- 1 piece of fur
- 1 metal rod
- 1 right angle clamp

2.1 In the last section, you determined that there was evidence for two types of charges. We called them "Top" and "Bottom" charges. More commonly, they are called "positive" and "negative" charges. When a rubber rod is rubbed with fur, the charge of the rod is called "negative" and the charge of the fur is called "positive". We will use this terminology in the rest of the course. Objects with equal amounts of positive and negative charges are said to have no total charge or no net charge.

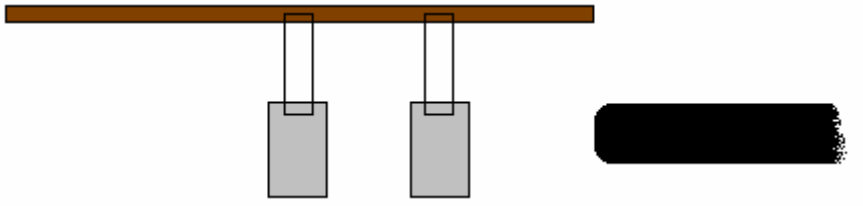
a. Cut two pieces of aluminum foil in a rectangular shape 1cm × 3cm and hang them side by side, touching each other, as in the picture below, from a wooden rod, using a piece of transparent tape.



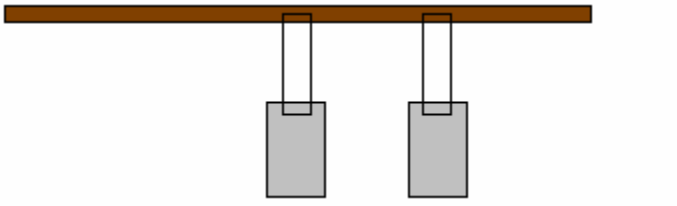
Bring a charged rod near, but not touching the edge of the piece of aluminum foil, as shown in the picture below.



While the rod is still near the foil, move the pieces of foil apart.



Then remove the rod.



Use “Top” and “Bottom” pieces of tape to determine whether there is a net charge on each piece of foil.

b. Repeat part **a** with paper (use an index card) instead of aluminum foil.

c. Discuss the difference between the results of part **a** and part **b**. In which piece of material does charge move more freely?

Objects in which charges move more freely, as in the aluminum foil, are called *conductors*. Objects in which charges don’t move very freely, as in the paper, are called *insulators*.

Equipment:

1 rubber rod
1 piece of fur
1 metal rod
1 meterstick

3.1

a. Ask an instructor for an electroscope. Touch a charged rubber rod to the ball on top of an electroscope. Describe what happens. Use a model of charge and pictures to explain what happens. If an object has more positive charge than negative charge, it is common to draw only the positive charge. If you have questions on this, ask your instructor.

b. While the “leaves” on the electroscope are still apart, touch the top of the electroscope with a large piece of metal (large conductor). Draw a picture and explain what happens.

c. Touch a charged rubber rod to the top of an electroscope again. While the leaves on the electroscope are still apart, touch the top of the electroscope with your finger. Describe what happens.

d. Touch a charged rubber rod to the top of an electroscope again. While the leaves on the electroscope are still apart, touch the top of the electroscope with a meter stick. Describe what happens.

e. Based on your observations in parts **b** and **c**, would you say that you are a conductor or an insulator?

f. Your body consists mostly of salt water? What does this say about the conductivity of water?

g. Draw the following series of pictures, indicating how the net charge is distributed on the electroscope and you in each picture:

(i) The electroscope is charged, before you touch it.

(ii) The electroscope and you, while you are touching it.

(iii) The electroscope and you, after you have removed your hand from the electroscope.

When we touch the electroscope with a large conductor, we are said to have *discharged* the electroscope.

Equipment:

1 rubber rod
1 piece of fur

4.1 One person should touch the ball on top of the electroscope with their finger and hold their finger there, while another person brings a charged rubber rod near, but not touching the leaves of the electroscope. While the rubber rod is near the electroscope, the first person should remove their finger from the top of the electroscope. Then remove the rubber rod from near the electroscope.

a. What is the charge on the electroscope? Use a series of pictures to explain your reasoning.

b. Devise and carry out a test to see if your answer in part **a.** is correct.

This is called *charging by induction*.

SUMMARY

You should understand that scientific models are based on observations and how scientific models are developed from observational evidence. You should understand the difference between observation and inference. You should understand that models may not be complete and that models may change as more experimental evidence is discovered. You should understand the nature of charge. You should be able to develop experiments with charged objects which would be able to distinguish different types of charges and to understand the nature of charge within macroscopic objects; for example, to be able to develop experiments to distinguish objects with zero net charge from objects with no charge or to distinguish objects with a third type of charge from objects with zero net charge. You should understand the difference between a conductor and an insulator and be able to develop a model for the arrangements of charges within a conductor or within an insulator in different situations (when charged objects are nearby or not). You should understand how to discharge a charged object. You should understand the concept of charging by induction.