28. Charge and Electric Field

Driving Questions

- What does it mean to electrically charge something?
- How do charged objects affect each other at a distance?

Background

We call atoms that lose or gain electrons "electrically charged," and the magnitude of the charge is proportional to the number of electrons gained or lost during the process. Normally, all atoms have a neutral charge, which means that the number of electrons equals the number of protons. If the number of protons exceed the number electrons (or the number of electrons exceed the number of protons), then the atom is said to have a positive charge or negative charge, respectively. Objects with like charge will repel one another, and objects with unlike charge will attract one another.

Benjamin Franklin's model of electricity implies that during any process, the net electric charge of an isolated system remains constant, or the charge is conserved for a closed system. In the right condition, an object can acquire an electric charge by rubbing it with another object, such as rubbing your shoes on a carpet, sliding across a car seat, or rubbing a balloon against your hair. The charged balloon and hair will have the same amount of charge, but opposite polarities. Therefore, they will attract one another. Rubber and plastic are *insulators* (materials that do not transfer a charge easily), which prevents charge from easily moving through the material. In this experiment, we use a charge sensor and a Faraday ice pail to examine the transfer of electric charges form one material to another.

Materials and Equipment

For each student or group:

- Data collection system
- Charge sensor
- Faraday ice pail
- Charge producers, pair
- Proof planes (2)
- Plastic rod
- Glass rod
- Aluminum rod
- Silk cloth
- Fur cloth

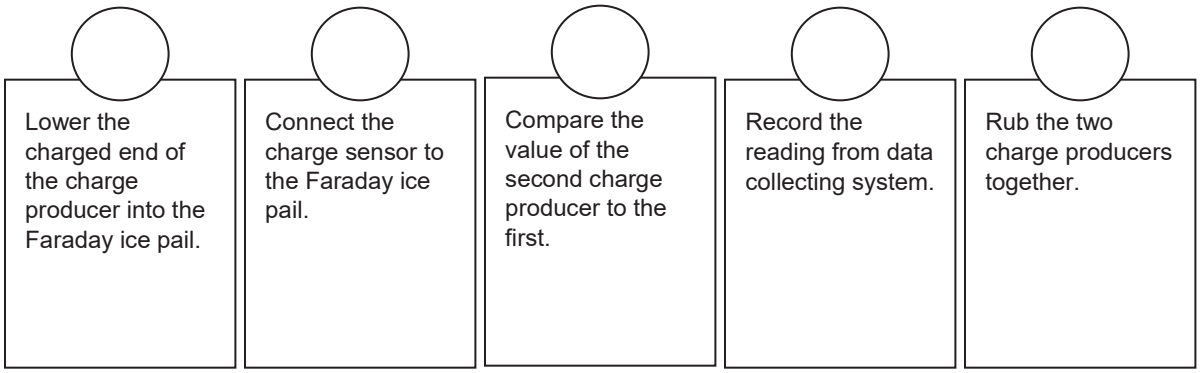
Safety

Add these important safety precautions to your normal laboratory procedures:

- Keep charged items away from sensitive electronics.

Sequencing Challenge

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.



Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "◆" with a superscripted number following a step, refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There you will find detailed technical instructions for performing that step. Your teacher will provide you with a copy of the instructions for these operations.

Set up

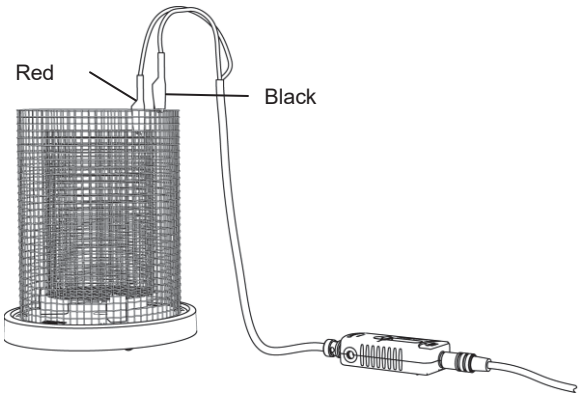
1. ☐ Start a new experiment on the data collection system. ◆(1.2)

2. ☐ Connect the charge sensor to the data collecting system. ◆(2.1)

3. ☐ Display Charge in a digits display. ◆(7.3.1)

4. ☐ Connect the alligator clips from the charge sensor to the Faraday ice pail with the red lead connected to the inner screen and the black lead to the outer screen.

Note: For better results, the charge sensor and the Faraday ice pail should be kept as far away from each other as possible.



5. ☐ Ground the Faraday ice pail by touching the inner and outer screens of the pail with one finger at the same time.

***Teacher Tip*:** This operation technically only neutralizes the ice pail. To actually ground the device, the outer screen should be connected to earth ground.

6. ☐ Initialize the charge sensor by pressing the "Zero" button on the sensor.

Collect Data

7. ☐ Monitor live data without recording. ◆(6.1)

8. ☐ Verify that the charge reading on the screen is approximately zero, if not, re-ground the Faraday ice pail.

9. ☐ Rub the blue and white surfaces of the charge producers together several times.

Note: Do not touch the white insulating material on the charge producers or proof planes. Any contact with the circular end of a charge producer or proof plane can affect the charge.

10. ☐ Lower the white charge producer into the inner pail without touching the sides or bottom of the screen.

11. ☐ Record the charge value in Table 1 in the data analysis section.

12. ☐ Remove the charge producer.

13. ☐ What do you think the reading will be for the blue charge producer?

_____

_____

14. ☐ Lower the blue charge producer into the inner pail without touching the sides and bottom of the screen.

15. ☐ Record the charge value in Table 1 in the data analysis section.

16. ☐ Remove the charge producer.

17. ☐ Ground the round end of one of the proof planes.

18. ☐ Place the flat round surface of one of the charge producers against the flat round surface of the proof plane.

19. ☐ Lower the proof plane into the inner pail without touching the sides and bottom of the screen.

20. ☐ Record the charge value in Table 1 in the data analysis section.

21. ☐ Remove the proof plane.

22. ☐ Ground the round end of a second proof plane.

23. ☐ Place the flat round surface of the first proof plane against the flat round surface of the second proof plane.

24. ☐ What do you think the reading will be for the second proof plane?

_____

_____

25. ☐ Lower the first proof plane into the inner pail without touching the sides and bottom of the screen.

26. ☐ Record the charge value in Table 1 in the data analysis section.

27. ☐ Remove the proof plane.

28. ☐ Lower the second proof plane into the inner pail without touching the sides and bottom of the screen.

29. ☐ Record the charge value in Table 1 in the data analysis section.

30. ☐ Remove the proof plane.

31. ☐ Vigorously rub one end of the plastic rod (about ¼ of its length) with the silk cloth.

32. ☐ Lower the rod into the inner pail without touching the sides and bottom of the screen.

33. ☐ Record the materials used and the charge value in Table 2 in the data analysis section.

34. ☐ Remove the rod.

35. ☐ Without rubbing the rod again, lower the un-rubbed end of the plastic rod into the inner pail without touching the sides and bottom of the screen.

36. ☐ Record the materials and charge value in Table 2 in the data analysis section.

37. ☐ Remove the rod.

38. ☐ Vigorously rub one end of the glass rod (about ¼ of its length) with the silk cloth.

39. ☐ Lower the rod into the inner pail without touching the sides and bottom of the screen.

40. ☐ Record the materials used and the charge value in Table 2 in the data analysis section.

41. ☐ Remove the rod.

42. ☐ Without rubbing the rod again, lower the un-rubbed end of the plastic rod into the inner pail without touching the sides and bottom of the screen.

43. ☐ Record the materials and charge value in Table 2 in the data analysis section.

44. ☐ Remove the rod.

45. ☐ Vigorously rub one end of the aluminum rod (about ¼ of its length) with the fur cloth.

46. ☐ Lower the rod into the inner pail without touching the sides and bottom of the screen.

47. ☐ Record the materials used and the charge value in Table 2 in the data analysis section.

48. ☐ Remove the rod.

49. ☐ Without rubbing the rod again, lower the un-rubbed end of the plastic rod into the inner pail without touching the sides and bottom of the screen.

50. ☐ Record the materials and charge value in Table 2 in the data analysis section.

51. ☐ Remove the rod.

52. ☐ Vigorously rub one end of the plastic rod (about ¾ of its length) with the silk cloth.

53. ☐ Lower the rod into the inner pail without touching the sides and bottom of the screen.

54. ☐ Record the materials used and the charge value in Table 2 in the data analysis section.

55. ☐ Remove the rod.

56. ☐ Without rubbing the rod again, lower the un-rubbed end of the plastic rod into the inner pail without touching the sides and bottom of the screen.

57. ☐ Record the materials and charge value in Table 2 in the data analysis section.

58. ☐ Remove the rod.

Data Analysis

Table 1: Charge data for proof planes and charge producers

Parameters	Charge (nC)
Charge on the white charge producer	
Charge on the blue charge producer	
Charge on the proof plane	
Charge on the first proof plane, after contact	
Charge on the second proof plane, after contact	

Table 2: Charge data for rods

Parameters	Charge (nC)	Classification
Plastic rod, 1/4 end rubbed with silk		
Plastic rod, un-rubbed end		
Glass rod, 1/4 end rubbed with silk		
Glass rod, un-rubbed end		
Aluminum rod, 1/4 end rubbed with fur		
Aluminum rod, 1/4 end un-rubbed end		
Plastic rod, 3/4 end rubbed with silk		

A material that transfers charge easily is called a conductor. A material that prevents the movement of charge is an insulator. Classify each of the rod materials, and enter the classification in Table 2

Analysis Questions

1. According to the data, which rod obtained the greatest charge?

2. Which objects gained a negative charge? Which objects gained electrons?

3. What charge did the silk gain when rubbed with the plastic rod? What charge did it gain when rubbed with the glass rod?

4. Which end of the plastic rod (the rubbed or un-rubbed end) indicated a larger charge?

5. **What material transferred its charge easier from one end to the other? What material did not?**

6. **Would rubbing the objects longer increase or decrease the electric charge?**

7. **Describe a method that would increase the amount of charge transferred between two objects.**

Synthesis Questions

Use available resources to help you answer the following questions.

1. **Why are power cables made with metal wire inside and plastic covering outside?**

2. **If you were to drag your feet across a carpet and build up a significant charge on your body that you wanted to remove, would you touch the metal frame of a window or the pain of glass? Why?**

3. **Suppose that you rubbed one end of a balloon on your hair, then lowered it into a Faraday ice pail, and saw a reading of -54.1. Then, when you lowered the other end into the ice pail, it only read -2.1. What would this tell you about the balloon?**

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. If silver is a very good conductor, then silver can:

A. Transfer a charge slowly
B. Transfer a charge easily
C. Not transfer a charge
D. not be considered a metal

2. If Object A has twice the charge as Object B, which statement is correct?

A. Object A has a negative charge.
B. Object A has twice the excess electrons or protons as Object B.
C. Object B has twice the excess electrons or protons as Object A.
D. Object B has a positive charge.

Key Term Challenge

Fill in the blanks from the list of randomly ordered words in the Key Term Challenge Word Bank.

1. _____ involves the study of electrical charges. A _____ is a device used to measure the charge of an object. The atoms in an object are normally _____ because the number of protons equals the number of electrons. One method of charging objects is by _____. When you rub objects together, electrons _____ from one object to another. The _____ of charge can be determined measuring the field around the object, or by seeing if it attracts or repels an object of a known charge, because a _____ charged object repels other positively charge objects.

2. Metals, compared to _____, are normally good conductors because they allow charges to move easily. To remove a charge from an object, you should use a _____ to connect the object to _____. That is why people who work with sensitive electronics are required to wear a grounding strap. Any _____ can more easily move through the conductor of the grounding strap than through the components of the circuit.

Key Term Challenge Word Bank

Paragraph 1

Charge sensor
Contact
Electrostatics
Isolate
Negatively
Neutrally
Polarity
Positively
Transfer

Paragraph 2

Conductor
Electrons
Faraday ice pail
Ground
Insulators
Protons