# Pre-Lab Information

Purpose Conduct an investigation to explore the number of electrons transferred to a balloon as a result of generated static electricity.

Time Approximately 45 minutes

Question How many electrons are transferred to a balloon that has been rubbed a given number of times with animal fur or wool?

Summary This investigation will allow you to determine the number of electrons transferred from fur or wool to a pair of charged balloons. Using vector diagrams, trigonometry, algebra, and the fundamental forces of the universe, you can calculate how many electrons were transferred to each balloon under each set of conditions. To find the number of electrons transferred, you will need to know the total charge on the system and divide it by the charge of a single electron.

# Safety

* Always wear a lab coat and safety goggles when conducting an investigation.
* Behavior in the lab needs to be purposeful. Use caution and be aware of your surroundings.
* Do not overinflate the balloons.
* Report all accidents—no matter how big or small—to your teacher.

# Lab Procedure

1. **Gather materials.**

|  |  |  |
| --- | --- | --- |
| * Balloons
* Protractor
* Triple beam balance
 | * Fur
* String
* Compass
 | * Wool
* Paperclip
 |
|  |  |  |

1. **Find the mass of a balloon.**
	1. Using the triple beam balance, find the mass of a balloon.
	2. Convert the mass of the balloon in grams to kilograms. Record the mass of the balloon in kilograms in Table A.
2. **Prepare the balloons.**
	1. Inflate the balloons to 4 inches in diameter and tie the ends of the balloons in a knot.
	2. Cut the string into two pieces, each longer than 1 meter.
	3. Tie one piece of string to each balloon.
3. **Hang the balloons.**
	1. Use a paperclip to hang the balloons from the ceiling according to your teacher’s instructions.
	2. The distance between each balloon and the paperclip needs to be 1 meter. Record the length of the string, 1.0 m, in Table A.
4. **Draw a diagram of the system.**
	1. In Table B, Figure 1 of the data section, draw a diagram of the system.
	2. Create your diagram with the four fundamental forces of the universe in mind.
	3. Draw vectors to represent the forces and label them appropriately.
	4. Write an equation that describes the primary force at work on the hanging balloons in Table B, Figure 1 under “Equation.”
5. **Rub each balloon 10 times with fur.**
	1. Rub the ballons with the fur in a back-and-forth motion.
	2. Be careful not to let the balloons touch anything after they are charged.
	3. The balloons should now be hanging free of obstruction, with space between them.
	4. Record the material used and the number of rubs in Table E and Table F for trial 1.
6. **Draw a diagram of the system.**
	1. In Table B, Figure 2 of the data section, draw a diagram of the system.
	2. Label the angle between the strings as *θ*.
	3. Draw vector representations of the forces with the four fundamental forces of the universe in mind. Be sure to label the forces.
	4. Write an equation that describes the force pushing the hanging balloons apart in Table B, Figure 2 under “Equation.”
	5. Use the variable *d* to denote the distance between the balloons.
7. **Measure the angle between the strings holding the balloons.**
	1. Use the protractor to measure the angle between the balloons.
	2. Record the angle in Table E. Note: You can match the angle of the string using a compass, and then measure the angle of the compass with a protractor.
8. **Draw a force vector diagram.**
	1. In Table C, Figure 3 of the data section, draw a force vector diagram.
	2. Label the vectors, using *Fg* for gravity and *Fe* for the electromagnetic force. Form a triangle by including the resultant vector that shows the tension on the string, labeling it with the equation *FT* = *Fg*+ *Fe*.
	3. Label the angle between the force of gravity and the tension as $\frac{θ}{2}$ since the gravity vector bisects the angle *θ* in Figure 2.
9. **Calculate the forces.**
	1. Calculate the force of gravity using Newton’s second law. Record this force in Newtons in Table A.
	2. Using the tangent of $\frac{θ}{2}$, write an equation to calculate the distance between the balloons. Write this equation in Table C, Figure 3 under “Equation.”
	3. Solve the equation for the electromagnetic force, and record the answer in Table C, Figure 3 under “Answer.”
10. **Draw a distance vector triangle.**
	1. In Table C, Figure 4 of the data section, draw a distance vector triangle.
	2. Label the angle between the force of gravity and the tension as $\frac{θ}{2}$ since the gravity vector bisects the angle *θ* in Figure 2.
	3. Label the hypotenuse as *L* for the length of the string.
	4. Label the bottom of the triangle as *r* for the radius or ½ the distance, *d*, between the balloons.
11. **Calculate the distance between the balloons.**
	1. Using the sine of $\frac{θ}{2}$, write an equation to calculate the distance between the balloons. Write this equation in Table C, Figure 4 under “Equation.” Remember that the distance between the balloons is *d*, which is twice as large as *r*.
	2. Calculate the value of *d* and record your answer in Table C, Figure 4 under “Answer.”
12. **Write an equation for the total charge (*Q*) on the balloons.**
	1. In Table D, write an equation for the total charge (*Q*) on the balloons.
	2. Since both balloons were charged with the same number of rubs, you can assume that *q*1 and *q*2 are equal. Change (*q*1*q*2) to *Q*2 in the electromagnetic force equation.
	3. Recall that k is a constant, sometimes called Coulomb’s constant, with a value of 8.988 × 109 N • m2/C2.
13. **Calculate the total charge (*Q*) on the balloons.**
	1. Using the equation in Table D, find the total charge, *Q*, on the balloons.
	2. Record the total charge, *Q*, in Table D under “Answer.”
14. **Find the total number of electrons on a balloon.**
	1. Divide the total charge, *Q*, by the charge per electron. The value of the charge on an electron is $1.602 x 10^{–19}C.$
	2. Record your answer in Table F.
15. **Perform more trials with fur.**
	1. Repeat steps 6 and 8–15 for 15 and 20 rubs of fur.
	2. Record only the resulting angle in Table E and the number of electrons transferred in Table F.
16. **Perform additional trials with wool.**
	1. Repeat steps 6 and 8–15 for 10, 15, and 20 rubs of wool.
	2. Record only the resulting angle in Table E and the number of electrons transferred in Table F.
17. **Clean up the lab.**
	1. Remove the paperclip from the ceiling and dispose of the strings and balloons.
	2. Put the triple beam balance, protractor, compass, fur, and wool in locations specified by your teacher.
18. **Answer the follow-up questions.**

# Data

Record your data either in your lab notebook or in the space below.

**Table A**

|  |  |
| --- | --- |
| **Balloon mass (kg)** |  |
| **String length (m)** |  |
| **Force of gravity (N)** |  |

**Table B**

|  |  |  |
| --- | --- | --- |
| **Figure #** | **Drawing** | **Equation** |
| 1 |  |  |
| 2 |  |  |

**Table C**

|  |  |  |
| --- | --- | --- |
| **Figure #** | **Drawing** | **Equation** |
| 3 |  |  |
| **Answer** |
|  |
| 4 |  | **Equation** |
|  |
| **Answer** |
|  |

**Table D**

|  |  |
| --- | --- |
| **Equation for *Q*** | **Answer** |
|  |  |

**Table E**

|  |  |  |  |
| --- | --- | --- | --- |
| **Trial #** | **Material** | **Number of Rubs** | **Resulting Angle *θ*** |
| 1 |  |  |  |
| 2 |  |  |  |
| 3 |  |  |  |
| 4 |  |  |  |
| 5 |  |  |  |
| 6 |  |  |  |

**Table F**

|  |  |  |  |
| --- | --- | --- | --- |
| **Trial #** | **Material** | **Number of Rubs** | **Number of Electrons****Transferred** |
| 1 |  |  |  |
| 2 |  |  |  |
| 3 |  |  |  |
| 4 |  |  |  |
| 5 |  |  |  |
| 6 |  |  |  |

# Follow-Up Questions

Answer the following questions.

1. Did the number of electrons increase with the number of rubs? Does this make sense? Why or why not?
2. Is there a relationship between the angle between the balloons and the number of electrons? If so, why?
3. Which was better at transferring electrons, the wool or the fur? Why?