Electrostatics

Goals: Observe the effect electric charge on an uncharged and charged conductor. Measure the effects of charge and distance as different variables on the electric force.

APPARATUS

Graphite is a good conductor of electric charge and wood and string are not. This experiment uses a graphite-coated sphere with a weight (W) of 6.5 x 10^{-4} N at the end of a string of length (L) as a pendulum. Other graphite-coated spheres are mounted on wood blocks and used to charge the pendulum and exert an electric force on the pendulum.

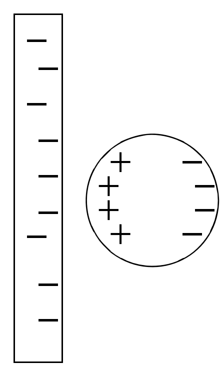

FIGURE 1. **Charged strip and polarized sphere.**

The graphite is charged using the triboelectric effect and induction. When wool is rubbed on vinyl the wool gives electrons to the vinyl causing the vinyl to become negatively charged. This is the tribolectric effect. When the strip is brought near the conducting graphite sphere, negatively-charged electrons move away from the strip leaving a positive charge on the side facing the strip as illustated in Figure 1. When the negatively-charged side of the sphere is touched by a finger, negative charges leave the sphere giving it a net positive charge.

THEORY

A pendulum mass at the end of string is subject to three forces: the weight due to gravity (W) the tension in the string (F_T), and the electric force between charges (F_e) exerted in the horizontal direction. When the pendulum is at rest the sum of the forces in both the horizontal and vertical directions must be zero. When the pendulum mass displaced from the vertical at an angle (θ) the vertical component of tension needed to oppose gravity is $F_T \cos\theta = W$, or $F_T = W/\cos\theta$. The horizontal component of the tension must oppose the electric force, $F_T \sin\theta = F_e$. Combining these expressions gives an equation that relates the electric force to the weight in EQ 1.

$$F_e = W\frac{\sin\theta}{\cos\theta} = W\tan\theta \qquad \text{(EQ 1)}$$

The sine of the angle is related to the horizontal displacement (d) and the length (L) by $\sin\theta = d/L$. For small angles the sine is approximately equal to the tangent so the electric force in EQ 1 can be expressed in terms of the displacement in EQ 2.

$$F_e = \frac{Wd}{L} \qquad \text{(EQ 2)}$$

According to Coulomb's law the electric force between two charges q_1 and q_2 separated by a distance r is given by EQ 3.

$$F_e = \frac{kq_1q_2}{r^2} \qquad \text{(EQ 3)}$$

The constant k is Coulomb's constant and only depends on the medium separating the charges.

Coulomb's law can be tested by varying either the amount of one of the charges or by changing the distance. The easiest way to test the effect of distance is to plot the force as a function of the quantity $1/r^2$. This plot should be a straight line with a slope equal to kq_1q_2 and an intercept of zero.

DATA COLLECTION

1. Measure and record the length (L) of the pendulum from the pivot point to the center of the sphere.
2. Record the position of the center of the pendulum sphere as it hangs freely.
3. Place one block in the apparatus with the sphere far from the pendulum and place the other block upright on the table.
4. Wrap the wool cloth around the vinyl strips and rub vigorously for about 20 s then remove the wool.

5. Move the ends of the vinyl strips as close as possible to the top of an upright wood block with graphite sphere without touching the vinyl to the sphere and tap the sphere with a finger. Repeat this as needed if there is humidity present.
6. Insert the wood block into the apparatus and move it slowly toward the pendulum sphere until they just touch.
7. Remove the charged sphere wood block and repeat steps 4 through 6 two times.
8. Move the charged sphere wood along the ruler to four positions, each of which has some deflection of the pendulum. At each position record the displacement of the pendulum from equilibrium (d) and distance between the two spheres (r).
9. Repeat steps 3 through 7 to recharge the apparatus.
10. Touch the uncharged sphere to the pendulum and remove that block from the apparatus.
11. Repeat step 8.

DATA ANALYSIS

12. Place the data from step 8 in a table and for each value of d find the force F_e using EQ 2 adding that as a third column in the table.
13. Use the data in the table from step 12, and plot the force (F_e) vs. the inverse distance ($1/r$).
14. Use the data in the table from step 12, and plot the force (F_e) vs. the inverse square distance ($1/r^2$). Estimate a straight line and find the slope and intercept.
15. Place the data from step 11 in a table and for each value of d find the force F_e using EQ 2 adding that as a third column in the table.
16. Use the data in the table from step 15, and plot the force (F_e) vs. the inverse distance ($1/r$).
17. Use the data in the table from step 15, and plot the force (F_e) vs. the inverse square distance ($1/r^2$). Estimate a straight line and find the slope and intercept.
18. Find the ratio of the slope of the line from step 17 divided by the slope of the line from step 14.

OBSERVATIONS

For each of these questions make your observation and support it by answering the question “Why?”.

How did the pendulum ball move the first time the charged ball was brought near it during step 6?

How did the pendulum ball move as it was recharged during step 7?

According to your data and graphs in steps 13 and 16, could the force be related to the inverse distance? Explain.

According to your data and graphs in steps 14 and 17, could the force be related to the inverse square distance? Explain.

Were the intercepts of the lines found in steps 14 and 17 close to zero? If not, what experimental factors may have caused the discrepancy?

Based on the ratio found in step 18, what fraction of the charge was transfered to the uncharged sphere when they touched?