Name:______________________

Date:______________________

ELECTROSTATICS LAB #3
COULOMB'S LAW OF ELECTROSTATIC FORCE

Purpose:
To investigate Coulomb's Law of electrostatic attraction and repulsion.

Contents:
1. 1 Base with grid
2. 1 chamber with mirror, ruler, and glass window
3. 2 Acetate strips (clear)
4. 2 Vinyl strips (colored)
5. 1 Hardware Package:
    a. 1 Hardboard top (square)
    b. 1 Plastic top (clear square)
    c. 2 Guide blocks
    d. 1 Cork stopper
    e. 2 Cotton squares
    f. 2 Wool squares
    g. 6 Graphite coated spheres (avg. mass 0.066 g apiece)
    h. 4 Polyethylene insulators

Discussion:

The electrical interaction between two charged particles is described in terms of the forces exerted between them. Augustin de Coulomb conducted the first quantitative investigation of these forces in 1784. Coulomb used a very sensitive torsion balance to measure the forces between two "point charges", that is, charged bodies whose dimensions are small compared to the distance between them.

Coulomb found that the force grows weaker as the distance between the charges increases, and that it also depends on the amount of charge on each body. More specifically, Coulomb's force law states that:

> The force of attraction or repulsion between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.

The direction of the force on each particle is always along the line joining the two particles; pulling them together when the two charges are opposite, and pushing them apart when the charges are the same.

The force on the "point charges" are measured in this experiment by balancing their electrostatic repulsion against the force of gravity. By suspending a small charged ball with an insulating thread, the electrostatic force can be found by measuring the deflection of the suspended ball from vertical as a second charged ball is brought near. Thus the force can be determined from the ball's weight and deflection

Procedure:
(NOTE: The graphite coated spheres are CONDUCTIVE.) `

Begin by inductively charging the sphere fastened to the guide block. Vigorously rub the vinyl strip with the wool squares. You may hear the crackle of static discharges as you rub the plastic.

1. Is the vinyl an insulator or a conductor?

2. What is the charge on the vinyl?

3. What is the charge on the wool?

Bring the coated sphere mounted on the guide block NEAR the charges plastic strip. DO NOT touch the plastic strip with the sphere! When the sphere is close to the plastic briefly touch the sphere with our finger. After you've removed your finger from the sphere slowly pull the coated sphere away from the charged plastic strip.

4. What is the name of this process?

5. Why do you touch the ball during the process above?

Work quickly but carefully. If the air is humid, the charges placed on the coated spheres will eventually "leak off". This takes some time to happen but you should be aware of this face and work accordingly. Don't slack off.

If you touch the charged ball with anything at this point, it will immediately discharge and you will have to charge it inductively again.

Insert the charged ball into the chamber through on of the holes in the base. Gently slide the charged ball up to the suspended ball and bring them into contact. When they touch, the charge will be equally distributed between the two balls.

6. What is the charge on each ball <u>just</u> before they touch? (Circle one below)

   The guide ball:

   Is positive   is negative   Has no charge   Has no overall charge but it is polarized

   The suspended ball:

   Is positive   is negative   Has no charge   Has no overall charge but it is polarized

7. What happens just before the balls touch? Did they attract, repel or do nothing?

8. What is the charge on each ball after they touch? (Circle one below)

   The guide ball:

   Has its original full positive charge   Only has half of its original full positive charge

   Has its original full negative charge   Only has half of its original full negative charge

   Has no charge   Has no overall charge but it is polarized

   The suspended ball: (Circle one below)

   Has the same as the original guide ball   Opposite

   The same charge but only half of the original charge on the guide ball

   Only the suspended ball has a charge   Only the guide ball has a charge

   Has no charge   Has no overall charge but it is polarized

9. Offer a possible explanation for the fact that an uncharged ball will be attracted to a charged ball at small distances.

10. How far can you electrically "push" the suspended ball away from center before the two balls are forced together again?

11. What happens to the distance between the two balls as the suspended ball is pushed further and further from center?

It may be necessary to charge the two balls several time to get a sufficient repulsive force. Simply charge the ball on the guide block by induction then bring it into contact with the suspended ball. The more charge you put on the suspended ball, the further it will "run away" before you can contact it with the charged ball. It may take a little practice to get the right amount of charge for you situation. Remember, the greater the charge, the greater the displacement and the better the resolution in your measurements.

12. Draw the forces acting on the balls and their charge distributions.

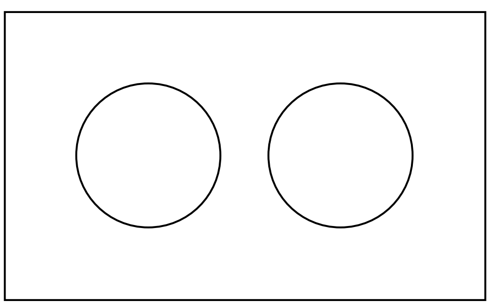


Figure 1
Balls just be contact

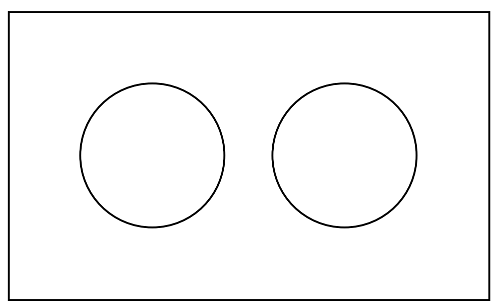
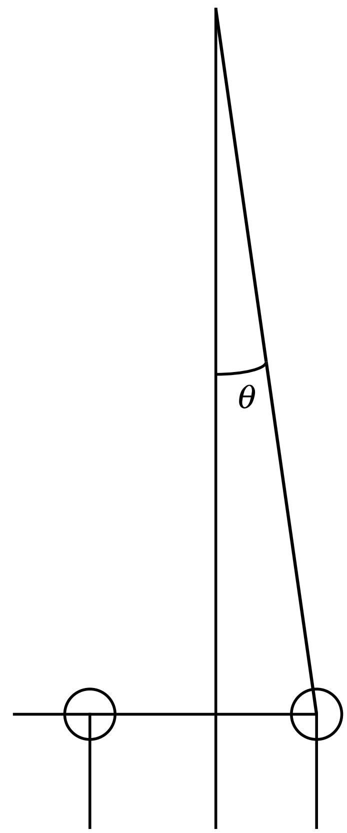


Figure 2
Balls after contact

13. Label the diagram to the right to show all of the forces acting on the two balls.



You will develop a formula from this diagram to express the electrostatic force between the two balls as a function of the suspended balls weight and displacement from equilibrium.

For small angles, tan θ = d/L. Looking at the diagram we can see that tan $\theta = F_e$/mg. Combining these equations results in:

$$F_e/mg = d/L$$
$$F_e = mg * d/L$$

Where:

- F_e = the electrostatic repulsion between the spheres
- mg = the weight of the suspended sphere; for this experiment, mg = 6.5 x 10^{-4} N
- d = the suspended ball's distance from the its equilibrium position (center to center).
- L = the length of the suspension
- r = the separation between the two balls (center to center)

Since we are not concerned with particular units of force, we can measure the force in terms of d. Therefore we can study the dependence of F_e on r by plotting d as a function of r. Note that the weight given for the suspended sphere is based on its average mass.

14. Plot a graph of the force as a function of the separation of the two balls (r).

15. What does your graph look like if you plot the force as a function of $1/r^2$?

16. If the graph is linear, what does that tell you?

To investigate the way in which the force between the two balls depends on the charges of the balls, recharge them and position the guide block ball (A) near the suspended ball (B) so that the suspended ball is displaced a few centimeters. To change the charge on the ball (B), touch (B) with an uncharged ball (C) that has been glued to an insulation rod. The charge on (B) will be equally distributed between (B) and (C) thus leaving (B) with one half of its original charge. Remove ball (C) and note the new distance between the guide block ball (A) and the suspended ball (B).

This process can be repeated to obtain several date points.

17. Plot a graph of the force between the two balls as a function of the product of the charges on the two balls. How does the force depend on the product charge?`