Name ________________________ Date ____________ Partners________________________________

VERIFYING COULOMB'S LAW

Materials:

hanging metal coated pith ball	teflon rod
stationary metal coated pith ball	silk

Source:

Fishbane, Gasiorowicz, and Thornton, ***Physics for Scientists and Engineers 3rd ed.*** Prentice Hall, 2005.

Background:

In 1785, Coulomb developed his method for measuring the electric force between two charged objects. Coulomb created a torsion balance, which is an apparatus similar to the pith ball set you will be using. Coulomb confirmed that the electric force is proportional to the inverse square of the torsion in the fiber (Fig. 1). The electrostatic force of repulsion between the two charged balls causes a rotation in the apparatus. If we know the angle produced by the electrostatic force of repulsion between the two balls, it is possible to measure the force of repulsion between them. The two balls are charged by rubbing a material containing electric charge on one of the balls. the electrical force between the spheres is very large compared with the gravitational attraction; hence the gravitational force can be neglected.

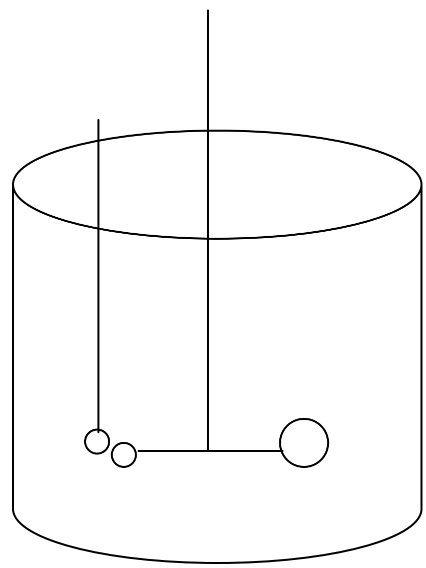

Figure 1

It has been verified that the electric force is inversely proportional to the square of the separation between two particles or point charges and that the force acts along the direct line of separation between the two charges. This force is proportional to the charge of the two particles. Furthermore, this charge is an attractive force if the charges are unlike in sign (positive to negative) and is a force of repulsion if the two charges are the same in sign (positive to positive or negative to negative). Coulomb's law can therefore be expressed in the following relationship:

$$F = k_e q_1 q_2 / r^2$$

where k_e is the Coulomb constant. Using the SI units the Coulomb constant can be written as 8.9875×10^9 N m^2 / C^2 .

Purpose:

In this experiment you will measure the force of repulsion on two oppositely charged pith balls (each of mass 0.3 g) and use it to determine the total charge Q on one of the two equally charged pith balls. By demonstrating that the charge on the two pith balls is what previous experimentation has confirmed it to be, we will be verifying Coulomb's law.

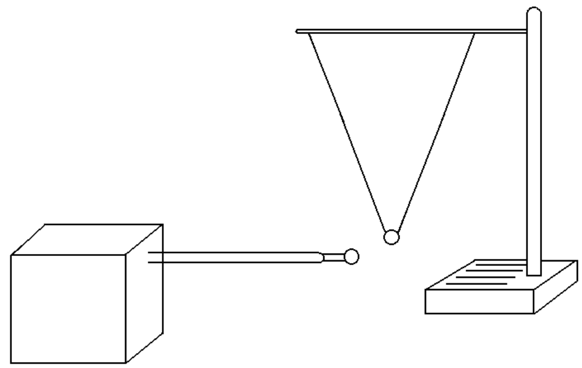

Figure 2

Procedure:

1. Take the pith ball apparatus (Fig. 2) with the scale and set it across from the other pith ball set. The two pith balls should be touching each other and the stationary pith ball apparatus should be perpendicular to the scale on the hanging pith ball's base (Fig. 3). Confirm that the two pith balls are in a straight line with one another and that they are both at the same height.

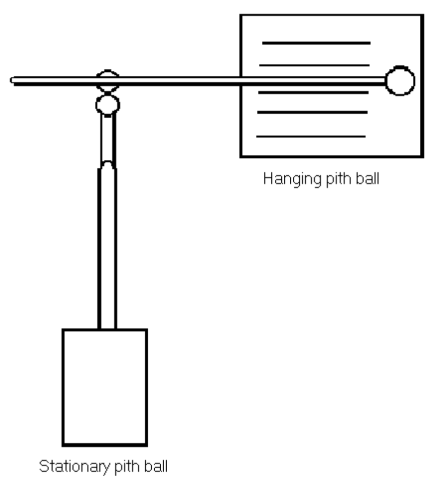

Figure 3
View from Above

2. Once this set up is complete, you will be ready to take the measurement of the charge put on the pith balls. You will first need to charge both pith balls. To do this, you need to wipe the Teflon rod vigorously with the silk and bring the rod in contact with both pith balls simultaneously. Try not to touch the pith balls with your fingers, as you may ground them and cause them to discharge. The pith balls need to either be in contact with each other when you initially charge them or you need to let them momentarily touch each other after you have charged them.

   Question 1: Why do the two pith balls have to touch after you have charged them?

   Question 2: What do you expect the pith balls to do after they have been charged? Why?

3. Now that the pith balls have like charges, they will repel. Let the hanging pith ball stop swinging and measure the distance between them using the scale that is underneath them.

   Question 3: Do not do this, but what happen to the pith balls if you touch them with your hand?

Question 4: What would be the effect on the pith balls if the humidity in the room were raised?

Data Analysis:

Now measure the charge on the pith balls.

1. First let's look at the forces acting on the hanging pith ball (see Figure 4). There are three forces acting directly on this body: the gravitational force, the electrostatic force of repulsion between the two like charges, and the tension in the string. The direction of the gravitational force acts downward and the force of repulsion on the right pith ball acts to the right. The tension in the string provides a force acting in a straight line between the suspension and the pith ball. While the actual pith ball model has two strings supporting each pith ball, it is fine for our 2-dimensional examination to assume that there is just one string acting as a force of tension directly between the bar and the pith ball.

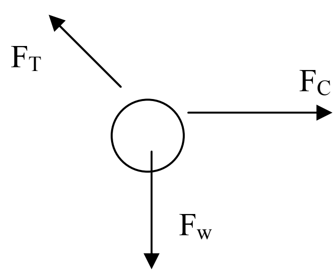

Figure 4

2. Without the Coulomb force involved, we know that the orientation of the pith ball will be completely vertical. With the Coulomb force involved, the pith ball rises in a circular path with respect to the suspension because of the force of tension in the string.

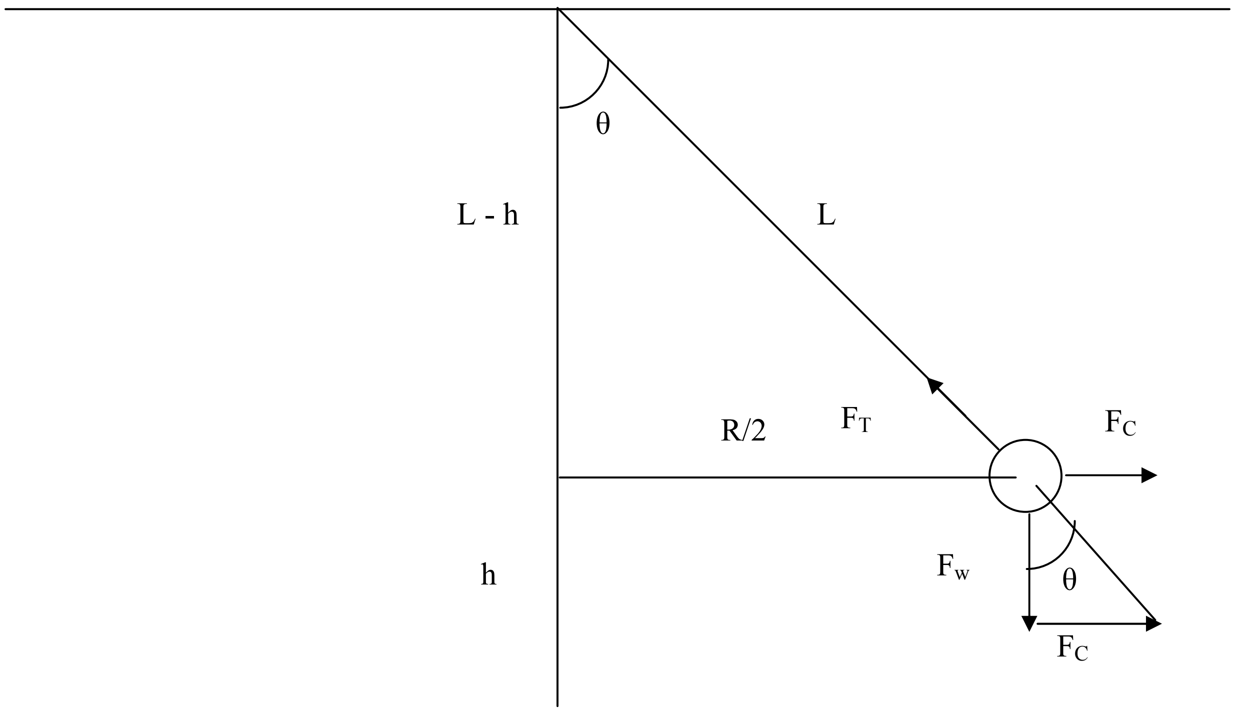

Figure 5

3. As shown in Figure 5, as a result of the Coulomb force, the pith ball will rise to a height h above its original position. We can now calculate the charge on the pith ball based on the forces involved.

   a. From similar triangles we notice that $F_c / F_W = (R / 2) / (L – h)$.

   b. $F_C = (R / 2) F_W / (L – h)$

   c. $kQ^2 / R^2 = (R / 2)\, m\, g / (L - h) \approx R\, m\, g / 2L$

   d. $Q = ((m\, g\, R^3) / (2\, k\, L))^{1/2}$

   e. $Q = 4.0 \times 10^{-7} (R^3 / L)^{1/2}$

   f. Given L and R, you can solve for the charge on the pith balls Q.

4. Use this measurement and equation (e) above to determine the charge on each pith ball. It should be on the order of 10^{-9} C.

5. Determine the number of free electrons that were placed on the pith ball using the elementary charge e = 1.602×10^{-19} C.

6. Gauss' law states that the electric field due to a point charge at a radius R from the charge is $E = Q / 4\pi\varepsilon_0 R^2$. How does this compare to the field created by a spherical, charged pith ball?