Coulomb's Law

Name__________________________________ ID__________________TA__________________

Partners____

Date__________________________________ Section____________________________________

This experiment is sensitive to external disturbances.

1. Introduction

This fundamental law of electrostatics is discovered by Charles Augustin de Coulomb (1785 ~ 1789). This determines the force between two point charges. In fact, the electrostatic force is much stronger than the gravitational force. If you take one gram of protons and place them one meter away from one gram of electrons, the resulting force is equal to 1.5×10^{23} newtons – roughly the force it would take to "lift" an object from the surface of the Earth that had a mass about 1/5 that of the moon (about 3.27×10^{22} pounds or 1.47×10^{22} kg). Another difference is that the electric force has both attractive and repulsive properties.

In this experiment, we measure the force with a sensitive torsion balance since charges are mobile and easily neutralized. In parts A and B, you will investigate the relation between the force and distance, and relation between the force and amount of charges.

➢**Note:** The torsion balance gives a direct and reasonably accurate measurement of the Coulomb's force. The most accurate determinations of Coulomb's law, however, are indirect. It can be shown mathematically that if the inverse square law holds for the electrostatic force, the electric field inside a charged sphere have shown this to be true with remarkable accuracy. The Coulomb force can be expressed by the formula

$$F = \frac{kq_1q_2}{R^{2+n}}.$$

Using this indirect method, it has been demonstrated experimentally that $n \approx 2\times10^{-16}$.

2. Experiment: Part A, Force versus Distance

Charge __________

R (cm)	θ_1	θ_2	θ_3	θ_{avg}
10				
9				
8				
7				
6				
5				

Plot log θ versus log R

- Determine the functional relation between the force which is proportional to the torsion angle, θ, and the distance R.

Plot θ versus R^2

- **Explanation**: If $\theta = bR^n$ where b and n are unknown constants, then log θ is equal to n log R + log b. The slope of the graph of log θ versus log R will therefore be a straight line. Its slope will be equal to n and its y-intercept will be equal to log b. Therefore if the graph is a straight line, the function is determined.

Either of above plots will demonstrate that, for relatively large values of R, the force is proportional to $1/R^2$. For small values of R, however, this relationship does not hold.

Procedure for Part A

1. Setup the Coulomb balance as described in the previous section.
2. Be sure the spheres are fully discharged (touch them with a grounded probe) and move the sliding sphere as far as possible from the suspended sphere. Set the torsion dial to 0 degrees. 0 the torsion balance by appropriately rotating the bottom torsion wire retainer until the pendulum assembly is at its 0 displacement position as indicated by the index marks.
3. With the spheres still at maximum separation, charge both the spheres to a potential 3kV using the charging probe. (One of the terminals of the power supply should be grounded.) Immediately after charging the spheres turn the power supply off to avoid high voltage leakage effect.
4. Position the sliding sphere at a position of 10cm. Adjust the torsion knob as necessary to balance the forces and bring the pendulum back to the 0 position. Record the distance, R, and the angle, θ, in Table 1.
5. Separate the spheres to their maximum separation. Recharge them to the same voltage, then reposition the sliding sphere at the separation of 10 cm. Measure the torsion angle and record your results again. Repeat this measurement several times until your results are reasonable within ± 1 degree. Record all of your results.
6. Repeat steps 3-5 for a distance of 9, 8, 7, 6, and 5 cm.

Analysis

Note: In this part of the experiment, we are assuming the force is proportional to the torsion angle. If you perform part C of the experiment, you will test this assumption when you calibrate the torsion balance.

3. Experiment: Part B, Force versus Charge

R=____________

Charge on sphere 1=___________

Charge on Sphere 2	θ_1	θ_2	θ_3	θ_{avg}

<u>Plot angle versus charge and determine the relationship</u>

With the sphere separation, R, held at a constant value (choose a value between 7 and 10 cm), charge the spheres to different values and measure the resulting force. Keep the charge on one sphere constant, and vary the charge on the other. Then graph angle versus charge to determine the relationship.

The charge can be varied using either of two methods:

Method I:
If your power supply is adjustable, simply charge the spheres to different potentials, such as 1, 2 and 3 kV. (When charging the spheres, they should always be at their maximum separation.) The charge on the sphere is proportional to the charge potential.

Method II:
If your power supply voltage is not adjustable, the charge can be charged by touching one or both of the spheres with an identical sphere that is discharged. The charge will be shared equally between the charged and discharged sphere. Therefore, touch the charged sphere once to reduce the charge by half, twice to reduce the charge by ¼, etc.