Physics Department
Kuwait University

EXP. ONE
Course 127

February, 2001

Coulomb Balance

Objective

- To study coulomb's law using a torsion balance.
- To study the dependence of the force between two charged objects on their separation and on the magnitude of their charges.

Theory

If two, point charges q_1, and q_2 are separated, in air, by a distance r, each will experience an electric force

$$F = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r^2},$$

where, ε_o is the permittivity constant of free space. These forces, as Newton's third law requires, act along the line joining the charges but point in opposite directions. Like charges repel whereas unlike ones attract each other.

In this experiment a delicate torsion balance is used to investigate the force acting on one charge due to the other. A conducting sphere is mounted on a rod, counterbalanced, and suspended from a thin torsion wire. An identical sphere is mounted on a slide assembly so it can be positioned at various distances from the suspended sphere (see Fig. 1).

When both spheres are charged, the electrostatic force between the spheres causes the torsion wire to twist. By twisting the torsion wire, you can bring the balance back to its equilibrium position. The angle θ through which the torsion wire must be twisted to reestablish equilibrium is directly proportional to the electrostatic force between the spheres. Therefore, by varying the separation distance and measuring the corresponding angle, a plot of θ versus $1/r^2$ should result in a straight line.

Since the charges used in this experiment are not point charges, the relation between θ and $1/r^2$ deviates from the proportionality at small distances. Therefore, a correction factor, B, can be used to correct for the above deviation. Simply multiply each value of θ by $1/B$, where

$B = 1 - 4a^3/r^3$,

a = radius of spheres,

r = separation between the spheres.

The two spheres are charged using a charging probe connected to a high voltage power supply. Since the charge of an object is directly proportional to its potential, if the distance between the two spheres and the potential of one of them, say V_1, is kept fixed, then by varying the potential V_2 of the other sphere and measuring the corresponding angle, a plot of θ versus V_2 yields a straight line.

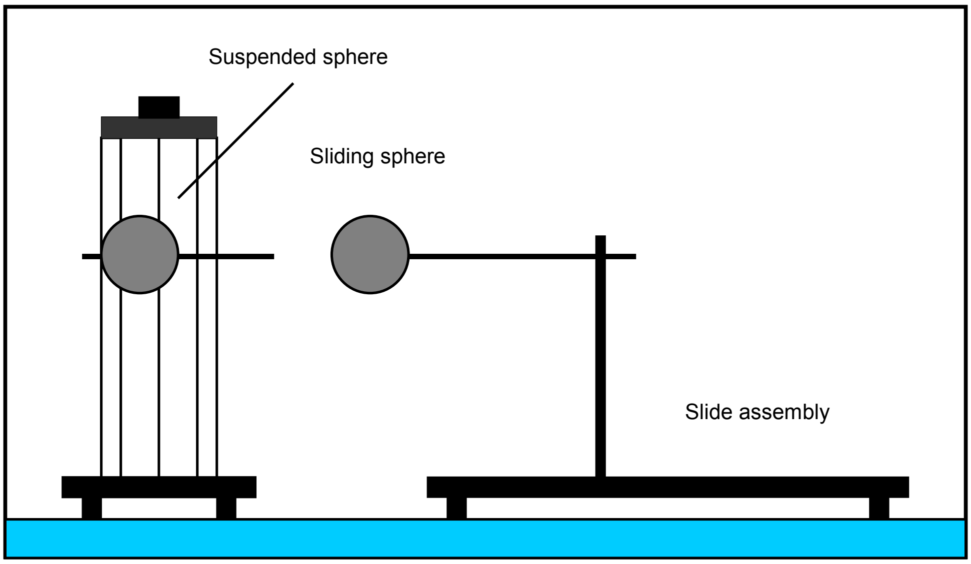

Figure 1: The Coulomb Balance Set up

Procedure

Part one: (*Force versus distance*)

1. 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 one. Set the torsion dial to 0 , then rotate the lower screw slowly so that to center the suspended sphere.

2. Release the screw which tightens the sliding sphere rod, then move the sliding sphere further away from the other one so as to adjust the zero of the separation distance.
3. Measure the radius *a* of either sphere using a vernier caliper, then move the sliding piece of the sliding assembly towards the other sphere setting the pointer to a the minimum separation value which equals twice the radius of the spheres.
4. While the suspended sphere is at the center of its range, move the rod holding the sliding sphere towards the other so that they just touch. Tight the screw of the rod, then again move the sliding sphere to maximum separation.
5. With the spheres at maximum separation, charge both of them to 6 kV potential using the charging probe. Immediately after charging the spheres, turn the power supply off to avoid high voltage leakage effects.
6. Position the sliding sphere at a separation of 18 cm. Adjust the torsion knob as necessary to balance the forces and bring the pendulum back to the zero position. Record the distance (r) and the angle (θ), in Table I.
7. Repeat steps 5 & 6 three times at least, so your result is repeatable within 1 degree. Record all your results.
8. Repeat steps 5-7 for separation of 15, 12, 9, and 6 cm.
9. Plot a graph for θ_{avg} versus $1/r^2$.
10. Calculate the correction factor B for each of the separation r that you used. Record your results in Table I.
11. Multiply each of your collected values of θ_{avg} by $1/B$ and record your results as, $\theta_{corrected}$.
12. Plot a graph for $\theta_{corrected}$ versus $1/r^2$ on the same graph paper. How does the correction factor affect your results?

Part two: (*Force Versus Charge*).

1. Hold the sphere separation r at a constant value of 9 cm.
2. Keep the charge on the suspended sphere constant, i.e. let the charging potential on it be always at 6 kV.
3. Charge the sliding sphere to different potentials, such as 2, 3, 4, 5 and 6 kV (when charging the spheres, they should always be at their maximum separation).

4. Record the charging potential V and the angle θ, in Table II on the data sheet.
5. Repeat this measurement three times, then plot the average value of θ (which is proportional to force) versus the charging potential V (which is proportional to the charge).

Table I (*Force versus distance*)

r (cm)	θ_1	θ_2	θ_3	θ_{vag}	B	$\theta_{corrected}$	$1/r^2$
18							
15							
12							
9							
6							

Table II (*Force versus Charge*)

$V_1 = 6$ kV, $r = 9$ cm

V_2 (kV)	θ_1	θ_1	θ_1	θ_{vag}
2				
3				
4				
5				
6				

Questions

1. Draw a schematic graph showing how the electrostatic force F changes with r.
2. In part two of the experiment, if both spheres are charged to the same potential, and their potentials are varied simultaneously according to Table II, sketch the relation between θ and V.
3. With the same charging potential, if smaller spheres were used, would their charge be the same? Smaller or bigger? Explain?
4. Explain the reason for the deviation of the relation for θ_{avg} versus $1/r^2$ from a straight line?

Home