Physics 121 - The Electric Force Law I: Torsion Constant of the Balance

Introduction – In this experiment we will use the Coulomb balance shown in Figure 1 to determine the charge that was placed on an insulated sphere. The apparatus is a very delicate torsion balance. A conductive sphere is mounted on an insulating rod, counterbalanced, and suspended from a thin torsion wire. An identical sphere is mounted on a slide assembly so that it can be positioned at various distances from the suspended wire.

To perform this experiment, you will charge both spheres and place the sphere on the slide assembly at a fixed distance from the equilibrium position of the suspended sphere. The electrostatic force between the two spheres will cause the torsion wire to twist. You will then untwist the torsion wire to bring the suspended sphere back to its equilibrium position. The torque experienced by the torsion wire is given by $\tau = (moment\ arm) \times F_e = \kappa\theta \rightarrow F_e \propto \theta$, where κ is the torsion constant. Therefore, the angle through which the torsion wire must be twisted is proportional to the electrostatic force between the two spheres, where the magnitude of the electrostatic force is given by Coulomb's law, $F_e = k\frac{q_1 q_2}{r^2}$.

Figure 1: The Coulomb Balance apparatus (https://www.pasco.com)

The Coulomb balance is a sensitive instrument that must be properly adjusted before you make your measurements. Also, air currents, humidity, and static charges can affect your results. However, if you are careful and follow the steps below, you should be able to get good results.

Activity 1: Determining the torsion constant of the wire

1. Carefully unscrew the slide assembly from the torsion balance.
2. Even more carefully turn the torsion balance on its side as shown in Figure 2.
3. Use the round aluminum cylinder to help support the torsion balance.
4. Make sure the side arm is perpendicular the table and carefully twist the knob on the torsion balance to align the marks on the side arm and the counterweight ensuring that the rod holding the conducting sphere is parallel to the table.
5. Add a small $20g$ mass to the conducting sphere. This will cause a torque about the torsion wire and the torsion wire will twist.
6. Record the initial angular position of the knob and slowly twist the know to realign the marks on the side arm and the counterweight.

7. Record the new angular position of the knob and determine the angle through which the wire had to be untwisted to return it to equilibrium. Call this value ϕ.
8. Remove the $20g$ mass and adjust the system so that it is in equilibrium again by turning the knob back to the original setting.

Figure 2: Torsion balance on its side with the slide assembly removed.

9. Repeat steps 4 – 8 for masses $40g$, $50g$, $70g$, & $90g$.
10. Determine an expression for the torque created by the added masses and plot the torque versus ϕ. From the plot, determine the torsion constant κ of the wire.