# Physics 121 - The Electrostatic Force Law II: Determining the Dependence on Charge Separation

***Introduction*** – In this experiment we will use the Coulomb balance shown in Figure 1 to determine the dependence of the electrostatic force law on the separation between the two charges.. 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 $\kappa$ 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 2: Determining how the electric force law depends on the charge separation.***

Some helpful hints before you begin the experiment with the full Coulomb balance.

- Roll up your sleeves and stand a maximum comfortable distance from the Coulomb balance when performing the experiment. This will minimize the effect of static charges on your clothing.
- Do not make rapid movements around the Coulomb balance because this can create air currents.
- When charging the spheres, turn the power supply on, charge the spheres, and then immediately turn the power supply off. Also, hold the charging probe near the end of the handle, so that your hand is as far from the sphere as possible.

- Perform the measurements as quickly as possible after charging to minimize leakage effects.

- Discharge and then recharge the spheres before each measurement.

1. Make sure that you have your apparatus from the previous week.
2. Using a Vernier caliper to make several measurements of the diameter of the sphere on the slide assembly and record these values along with their uncertainty. Find the radius.
3. Free the arm of the torsion pendulum and check that the etched line in the metal plate connected to the sphere matches up with the line attached to the base when the system is at rest with no charge applied. If they don't line up, turn the torsion pendulum until they do. Read the dial on top and call this your "zero point." You will need to subtract this number for all your future angular displacement measures.
4. Slide the sphere on the slide assembly forward until it just touches the suspended sphere in the equilibrium position. Adjust the mark on the slide so that it shows the correct distance between the center of the spheres, which is the diameter.
5. Turn on the power supply and set the potential to $6.0kV$ and then turn off the power supply. Do not change the voltage knob on the power supply during the experiment, simply turn the supply on, charge the spheres, and then turn it back off every time.
6. Create a data table with the column headings $r(m)$, $\theta_1$(deg), $\theta_2$(deg), $\theta_3$(deg), $\theta_{avg}$(deg).
7. Make a note of the uncertainties in values of your measurements for of $r$ and $\theta_{avg}$ as you do the experiment. Call these $\Delta r$ and $\Delta\theta_{avg}$.
8. Slide the movable sphere as far back from the torsion apparatus as possible. Turn on the power supply and touch each sphere with the grounding probe for a count of 5 seconds. Then turn the power supply back off after you've charged both spheres.
9. Position the sliding sphere at the $5.0cm$ mark on the slide assembly and then adjust the torsion knob to bring the suspended sphere back to its equilibrium position. Record the position of the sliding sphere as *r(m)* and the angle measured on the torsion dial as $\theta_1$ in your data table. The first time doing this it may take you a little bit of time, during which the spheres may lose some charge to the humidity in the air. If so, charge the spheres again (turn the power supply back on and touch the spheres for a few seconds) and measure the torsion angle again.
10. Repeat steps 8 – 9 two more times and record the angle measurements as $\theta_2$ and $\theta_3$. Consult your instructor if the angle measurements are not consistent within a few degrees.
11. Repeat steps 8 – 10 to fill in your data table for distances of separation $6.0cm$, $7.0cm$, $8.0cm$, $9.0cm$, $10.0cm$, $14.0cm$ & $20.0cm$.
12. Calculate the average angle, $\theta_{avg}$, for each value of *r* and record the values in your data table. Estimate the uncertainty in *r* and θ and record these in the data table.
13. Use Excel to create a graph of $\theta_{avg}$ as a function of $r$. From the introduction we have that $F_e \propto \theta$. Examining Coulomb's law, we see that the functional form of the relationship between θ and *r* should be a power law. To test this with your data, construct two additional graphs: the first a plot of $\ln\theta_{avg}$ versus $r$ and the second a plot of $\log\theta_{avg}$ versus $\log r$. Which curve linearizes your data? From the plot that linearizes your data, determine the values of $n$ and $C$. Display the equation and the fit on the plot that linearizes your data.
14. Using the proportionality constant $C$, determine the charge on one of the conducting spheres.
15. Print your all your data and your plots.