A. Building and using an electroscope to detect charge

A.1. Building the foil electroscope

Using the lab materials, construct your electroscope using the photos below as a guide.

A.2. Using the electroscope to show “charged by induction.”

To charge the rod, rub the cloth/fur over the rod tightly a couple of times. The charging process involves the transfer of electrons from the cloth/fur to the rod, leaving the rod with a net negative charge. Slowly bring the acrylic rod up to [BUT DO NOT TOUCH] the copper spiral. Think: do the aluminum sheets acquire charge? If so, are their charges the same sign or opposite sign? Are the charges positive or negative? Draw/describe what happens to the electroscope:

A.3. Using the electroscope to show “charged by conduction.”

Before starting this next experiment, touch the copper spiral with your finger. This provides a path for any excess charges to “ground” via your body. Charge the acrylic rod using the cloth/fur, touch the copper spiral with the rod. Slowly move the rod away from the electroscope. Draw/describe what happens to the electroscope.

A.4. Challenge:

Repeat A.2, but this time touch the copper coil with your finger when the charged rod is in its proximity. Remove your finger, and slowly move the rod away from the electroscope. Draw/describe what happens to the electroscope.

A.5. Discussion points:

1) How does the magnitude of electrostatic force on one of the foil leaves compare that on the other? Draw a free-body-diagram to assist your discussion. 2) Explain the difference between “charged by induction” and “charged by conduction.”
B. Coulomb’s Law in a charged pendulum system

B.1. Using Coulomb’s Law in the context of Newton’s 2nd Law

Consider the scenario illustrated below. Draw a free-body diagram for the pendulum ball and use Coulomb’s Law and Newton’s 2nd Law to derive an expression for the magnitude of the electrostatic force $F$ in terms of $m$ (mass of pendulum ball), $g$, $L$, and $x$ (x-coordinate of pendulum ball). Consider the case of small $\theta$, where $\tan(\theta) \cong \sin(\theta)$. The pendulum ball is **not** accelerating.

![Free-body diagram of a pendulum](image)

\[ F = \frac{kq^2}{r^2} \]

\[ \sum F_x = m \cdot g \sin(\theta) - \frac{kq^2}{r^2} \cos(\theta) = 0 \]

\[ \sum F_y = m \cdot g - \frac{kq^2}{r^2} \sin(\theta) = 0 \]

\[ r = \sqrt{x^2 + y^2} \]

\[ \theta = \arctan\left(\frac{y}{x}\right) \]

B.2. Video experiment in LoggerPro

Open LoggerPro. Navigate to the interactive video experiment: File -> Open -> Additional Physics -> RealTime Physics -> Electricity and Magnetism -> L01A2-3(Coulomb’s Law).cmbl. As indicated in the first frame of the movie (shown above, right), the mass of the pendulum ball is $m=2.93$ g, the length of the pendulum is $L=2.00$ m, and we will assume that the probe ball and the pendulum ball have the same charge $q$.

At each time interval in the movie, record the x and y coordinates of the probe, and then do the same for the pendulum ball. The “Add Point” tool allows you to record the positions of the balls, and the “Set Active Point” tool allows you to switch from the probe (red markers) to the pendulum (green markers).

Double click on the “r” column header. What is shown in this column?

Double click on the “F_coul” column header. What is shown in this column? Use your result from B.1 to correct the error in the “Expression” that is shown in this column. What should it read?

Fit the plot (Analyze -> Curve Fit) to the function $A*r^{(-2)}$. What does the fit tell us? Using the information provided by the fit (the coefficient “$A$”), calculate the charge $q$ of the balls. How many excess electrons does this charge correspond to?

B.3. Discussion points

1) How would this experiment change if the probe ball and the pendulum ball were oppositely charged? 2) Do we need to worry about the gravitational force between the probe ball and the pendulum ball?