Objectives
At the end of this activity, the student should:

- be able to explain Coulomb’s Law and use it in the context of Newton’s 2nd Law.
- be able to explain how an electroscope works to detect the charge of an object.
- observe and be able to explain the difference between an object being “charged by induction” and “charged by conduction.”
- demonstrate the inverse-squared ($1/r^2$) nature of the force that exists between two charged objects.

Materials/Equipment Needed
Mason jar, about 30 cm of bare copper wire, self-adhesive cork, tape, blank compact disk (CD), acrylic rod, cloth or fur, aluminum foil, laptop w/ LoggerPro installed, calculator, and a pencil/pen.

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.

Tip: the electroscope will perform better if the coil is more tightly spiraled increasing the amount of copper per unit width of the spiral.
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? On the Lab Report Sheet (found at the end of these lab instructions) or wherever directed by your instructor, answer the above questions and 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. On the Lab Report Sheet or wherever directed by your instructor, 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 then slowly move the rod away from the electroscope On the Lab Report Sheet or wherever directed by your instructor, draw/describe what happens to the electroscope.

A.5. Discussion points:

On the Lab Report Sheet or wherever directed by your instructor, answer the following discussion points:

- 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.

- 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

We will analyze the forces at play when a fixed charge $q$ exerts an electrostatic force on a pendulum ball with charge $q$. Consider the scenario illustrated below. On the Lab Report Sheet or wherever directed by your instructor, 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 $X_{\text{ball}}$ ($x$-coordinate of pendulum ball). Consider the case of small $\theta$, where $\tan(\theta) \approx \sin(\theta)$. The pendulum ball is not accelerating.

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 below), 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).
On the Lab Report Sheet or wherever directed by your instructor, follow the below steps and answer the associated questions:

- 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 the expression be?
- Fit the plot (Analyze -> Curve Fit) to the function A*r^(-2). What does the fit tells us?
- Using the information provided by the fit (the coefficient “A”), calculate the charge q of the balls assuming they are equally charged. Is it possible to know whether one sphere is positive or negatively charged?
- How many excess electrons does this charge correspond to?

B.3. Discussion points
On the Lab Report Sheet or wherever directed by your instructor, answer the following discussion points:

- How would this experiment change if the probe ball and the pendulum ball were oppositely charged?
- Do we need to include the gravitational force between the probe ball and the pendulum ball? Why or why not?

Clean-Up

Golden Rule: “Do unto others as you expect them to do unto you.”
This applies as much here in the lab as it does in the Fleet. As future Naval Officers, how can you expect your enlisted sailors to maintain a clean work area if your stateroom, work areas, mess area, etc. is a “pig sty?” So as officers it is imperative that we clean up after ourselves not only to follow the Golden Rule, but also to lead by example for the enlisted personnel under our charge.

Before leaving the laboratory, tidy up the equipment at the workstation and quit all running software.

The lab station should be in better condition than when you arrived and more importantly, should be of an appearance that you would be PROUD to show to your legal guardians during a “Parents Weekend.” Have your instructor inspect your lab station and receive their permission to leave the Lab Room.

You SHALL follow this procedure during every lab for SP212!
Experiment A

Description of the experiment:

A2:

*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:
A3:

Draw/describe what happens to the electroscope:

A4:

Draw/describe what happens to the electroscope:
Lab Report Worksheet

Date:________________

A5 Discussion Points:

- 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.

- Explain the difference between “charged by induction” and “charged by conduction.”
Experiment B

Description of the experiment:

B1:

FBD: 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 $\tan(\theta) \approx \sin(\theta)$. The pendulum ball is not accelerating.
Results:

- What is shown in the “r” column header?
- What is shown in the “F_coul” column header?
- What is the correct expression that should be used in the “F_coul” column header?
- What does the results of Analyze -> Curve Fit to the function A*r^(-2) tell us?
- Using the information provided by the fit (the coefficient “A”), calculate the charge $q$ of the balls assuming they are equally charged. Is it possible to know whether one sphere is positive or negatively charged?
- How many excess electrons does this charge correspond to?