Electrostatics and the Standard Deviation In-class Group

Charge accumulation on conducting globes and a Faraday Pail will be examined by direct measurements of charge accumulation using a charge sensor.

Important Experimental Consideration:

These laboratory measurements can be very sensitive to environmental conditions such as static electricity a student may be carrying on their person. Therefore, before working with any of the equipment – a student should put on the grounding wristband. This will ensure that the student is grounded AND not charged. This is important when working with static charges.

Important Points for General Operation:

1. Between measurements, always press the ZERO-button on the charge sensor to discharge all current (moving charge) from the charge sensor. Again – we want to start with NO charge on the charge sensor or your person – we want to ensure that ALL charge comes from the charging globes you will be working with today.
2. Look at the faraday pail – notice that it is constructed of two cylindrical pieces of wire mesh. Notice in the figure below that the outer wire mesh is grounded (black wire) and the inner banana plug is attached to the red wire indicating the + or positive side of the charge sensor – this means that the outer cylinder will be held at 0V and the inner cylinder will act to enclose the charge wand producer to measure the amount of charge enclosed. Note that this means the lower you place the wand in the conducting shell the larger the charge will be measured on the sensor. Looking at the pail – can you reason why this is true?

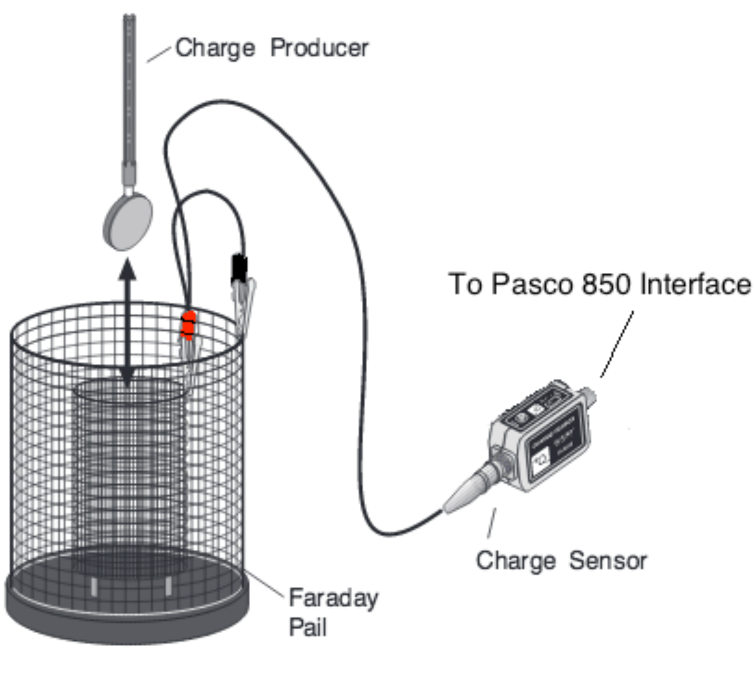

Figure 1: Adapted from Pasco Scientific Charge Sensor Manual: Setup for Exp. 1

Faraday Pail and Charge Production

The purpose of this experiment is to investigate the standard deviation while taking repeated charge measurements using a wand that has been in contact with a charged surface. Students will also produce histograms and calculate the average and standard deviations of these measurements to analyze and make conclusions about datasets.

Students, using a charged sphere and an electrostatic voltage source (the source of charge production for the sphere), will charge the wand. Measurements of the charge on the wand head will be found by placing the wand in the Faraday pail, connected to the charge sensor as shown in Figure 1.

Before beginning any experiment using the faraday pail, the pail must be momentarily grounded. When the pail is connected to the charge sensor, simply press the ZERO-button whenever you need to discharge both the pail and the charge sensor. **While conducting an experiment, it is convenient to keep yourself grounded, by continuously resting one hand on the upper edge of the outer shield on the pail, or by direct contact with an earth-ground connector by wearing a grounding wristband.**

General Procedure Outline – Groups need to fill in specifics steps that are not provided and report the exact procedure used during the experiment with the data results and analysis

Part I:

1. Setup experiment as shown in Figure 1. Connect the metal sphere to the RED +2000V Electrostatic Voltage Source port with a banana wire – connect the other end of the banana port (the alligator clip) to the sphere at the screw nob. Turn ON the voltage source and make sure that it is connected to the ground, COM port, as is your wristband. Make sure that the charged sphere is kept well away from the Faraday Pail – your measuring device. Your instructor can ensure you are setup correctly and ready to start if you have questions.
2. Press the ZERO-button to completely remove all charge from the charge sensor and pail. Don't push down so hard on the sensor that you pull on the sensor port attachment – this needs to stay secure.
3. Before inserting the charged wand head into the pail, make sure you wearing the grounded wristband and you have put on gloves supplied. The goal is to not transfer oils onto the wands or the spheres – so try to not touch these with your bare hands. We want the conducting services to be clean.
4. Carefully insert the wand and record the maximum value from the graph in Capstone, (it is a good idea to drag the Graph icon only on the RHS to the white space so you can see the change in charge as you lower the wand. Examine how the max charges changes when the wand is at different levels in the pail – comment in your write up your group's hypothesis on why this happens. Repeat at least 5 times where you keep your procedure the same. Remember that you need many measurements to do statistical analysis.
5. Now look at these measurements and ask yourself about the precision of the measurements. (You can use the position button on the graphing options to measure

the max value on each peak and manually enter into a table. Make sure to label the header of the table with the proper name and units for the Max charges.) How could your group change experimental procedure to increase precision? Think what happened when you varied how low the wand was in the pail? What other procedural steps could introduce variability in the measurement? Make a list of your group's hypotheses about how to increase measurement precision.

6. Review your list and discuss in your group. Write down your group's procedure modifications to increase precision and repeat measurements. Do you see an increase in precision? Discuss.
7. Now, with your most precise procedural steps take even more repeated measurements. Make sure each student takes at least 10-20 measurements using the same procedure created and refined above.
8. This data should create a bell curve when graphed as a histogram. Note that since each student only has between 10-20 data points – the graph may not appear identical to a bell curve but should have a most frequent measurement value.
9. Create a histogram. To do this your group will need to figure out how to separate your data into bin ranges. Refer to your pre-lab assignment about how to 'bin' your data and create the graph in Excel (or Capstone if you choose).
10. Now – if each student conducted the same experiment procedure in an identical fashion within each group, do you think data should be able to be combined into a larger dataset? If so – use all data sets as if it were 1 data set and average every 3 readings. (For example: If you had a group of 3 students who took 15 measurements each, the total would be 45, if your group averaged every 3, the new dataset would be made up of 15 averaged measurements. Create a new histogram of this averaged data and discuss. How does this new combined histogram compare with your individual histograms?
11. Does your group see signs of systematic uncertainty in any particular data sets from a student in your group? How would this affect the combined bell curve? Would it make sense to combine this data thinking about your group's independent graphs? Explain your reasoning. Thinking about this – do you think that combining data from different experimenters is a generally accepted way to measure data in an experiment? What possible problems do you see could happen? Explain.

Part II:

12. Next, we want to examine what happens when a charged sphere (as you used above) is put in the vicinity of another sphere that is held at ground. To do this, take the 2nd identical sphere on the table and using a wire and alligator clip - attach to ground.
13. Using your conducting wand – measure the charge on the 2nd sphere making sure the 1st sphere is well away (about 2 ft). Measure both sides of this sphere – record maximum values.
14. Now, repeat step #13 for the charged sphere you used earlier (not moving it).

15. Discuss it in your group and make a prediction as to what would happen if the spheres were brought very close to each other but not touching. Write this down to be turned in with your report.
16. Finally, bring the charged sphere close to the grounded sphere and repeat the measurements (close is within 2” but not touching) – making sure to measure the sides of both spheres that are closest together and the sides of the spheres that are the farthest apart. Repeat the measurements to ensure the recorded values are repeatable.
17. How do your group’s results compare with your group’s predictions? Can you make sense of the measurements? Explain clearly.