Electrostatics & Parallel Plate Capacitors
LBS272L

Before doing this lab…..
You should have read the following chapters of the LBS272 (lecture, not lab) course available in LON-CAPA:

- Electrostatics
- Electric Field
- Capacitor – up to "Example: Sphere"

You should have finished the lab-quiz 'lab quiz 1'

Introduction
In an annoying way, everyone is familiar with static electricity. Especially during the winter, charge can accumulate on the surface of objects and when touching them, you feel a spark: charge moving from the object to you. In this lab, you will experiment with static charges and put the things that you have read and heard about in the lecture into practice.
Make a complete lab report in which you describe your procedures and conclusions. In answers to questions in this write-up, not only include your answer, but also your reasoning. If you are not sure about an answer, try to look back to the lbs272 notes or other resources, like a textbook or the internet.

He is the man: Michael Faraday (1791-1867)

In the first part of this experiment, you are essentially repeating an experiment first performed by Michael Faraday (yes, the guy whose name we use for the units of capacitance) and the main piece of equipment you will be using is a Faraday Ice Pail. Photos are displayed at the end of this write-up and some instructions follow next.
In the second part, you will experiment with a parallel plate capacitor and be more quantitative.

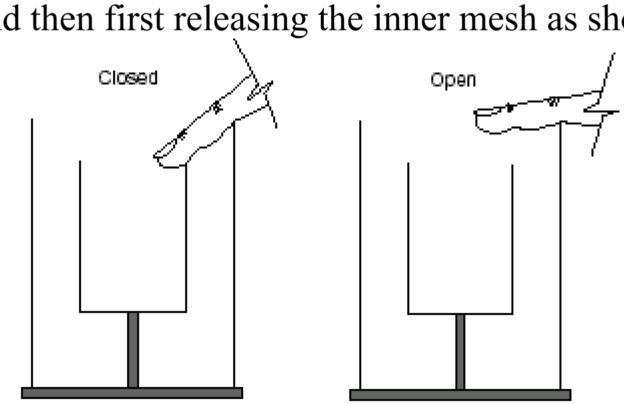
In both parts, you are expected to experiment with the setup so that it works best; consider the impact of the environment on the experiments that you are performing.

Equipment

2 Conducting spheres
Electrostatic voltage source
Electrometer (voltage reader)
3 charge transfer paddles (blue, white and metal)
Faraday Ice Pail (two cylinders of wire mesh on a base)
Variable Capacitor (two silver disks on a black base)
Various connecting wires and cables

The electrostatic voltage source should be connected to one of the conducting spheres. This sphere will be your main source of charge. You have two cables that can be connected to the electrometer. One set should be attached to the Faraday Ice Pail, and the other to the variable capacitor. Unplug the cables at the electrometer to change measurement devices.

To use the Faraday Ice Pail as a sensor, first make sure that the two mesh cylinders are at the same electric potential by electrically connecting and then first releasing the inner mesh as shown in the below figure.



Make sure to zero the electrometer.
(Tip: for best results, keep the one finger connected to the outside mesh during your experiments and stick objects deep inside the pail).

Experiments

1) **Faraday's ice pail.**
   a. Setup and connect the ice pail and one of the conducting spheres. Show, by using the pail, that charge can be picked up from the conducting sphere with a paddle (use the one with the metallic face).
      i. Explain by what mechanism charge can be transferred from the sphere to the paddle.
      ii. Explain how Faraday's Ice pail can be used to measure the charge of an object placed inside it (without touching it) by making a sketch of the charge distributions on the object placed inside the pail and the pail itself.
      iii. Try picking charge from various places on the sphere and record the reading from the electrometer. Does the result (magnitude and sign) depend on where you took the charge from, or how you took it (e.g. just touching or rubbing)? Does that correspond to your expectations? If not, give possible reasons.
      iv. What happens when you use different voltages for the electrostatic voltage source?
   b. Instead of using the paddle with the metallic face, next try also using the ones with the white and blue faces.
      i. Is there any difference when you use different paddles? If so, how can this be explained?
   c. Ground the white and blue paddles and then rub their faces against each other.
      i. What is the readout of the electrometer when you stick the blue paddle in the pail? And for the white paddle? Explain.
      ii. Then, after rubbing the blue and white paddles against each other, stick both of them in the pail, without having them touching each other. What is the readout from the electrometer? Explain.
   d. Next, use the sphere that is not connected to the electrostatic source. Place it close (a few mm) to the sphere that is connected to the source.
      i. Like in a) investigate the charge distribution over the sphere by transferring charge to the metallic paddle

and measuring the charge. Explain your findings (use a drawing if you think it is helpful to explain the findings).

e. Finally, investigate what happens if the charged paddles are brought in contact with the inner mesh.
    i. Use the metallic paddle and charge it with the sphere. Stick it in the pail and then touch the mesh. Remove the paddle; what does the electrometer give? Explain and compare with the case where the paddle has not been brought in contact with the mesh.
    ii. Repeat the process several times, and note the readout of the electrometer after every time the paddle has been brought in contact with the inner mesh. Explain your findings.
    iii. By temporarily grounding the pail, remove all charge from it. Next use the blue and white paddles. As before, rub them together. Bring the blue paddle in contact with the inner mesh. Record the readout of the electrometer. Then, without grounding the pail, bring the white paddle in contact with the inner mesh. What happens? Is this what you expected? Explain.

2) **The variable capacitor**

a. Setup the capacitor as shown in one of the below pictures. Place one of the plates at 0 cm and fix it. Put the other plate about 2 cm away from the first, and connect the two briefly so that they are at the same electrostatic potential, and zero the electrometer (this can be tricky, especially on a cold winter day. Make sure other equipment (especially electronic equipment) is not too close to the capacitors and avoid, as much as possible moving near the capacitors when doing experiments and try to use as large a scale as possible for the electrometer).
    i. Transfer charge to one of the plates (try using the metallic paddle and the sphere and also the white and blue paddles through rubbing them against each other). What happens? What equation governs the relation between charge, voltage and distance between

the two plates? What is the permittivity of the medium we are working in?

ii. Keep transferring charge to the same plate. What happens to the readout of the electrometer? Is this what you expect? Explain.

iii. Next, slowly move the moveable plate very close (1 mm, but don’t touch!) to the fixed one. Read the electrometer. Now slowly (or stepwise) move the plates away from each other until they are far apart (10 cm). What happens? (You can try to make a quantitative measurement and make a graph of voltage readout versus distance.) Is this what you expect based on the theoretical relation? If not, try to explain why? (Hint, sketch the field lines between the two plates for the ideal case where only the two plates are present (and no surrounding material) and for the case of the real experiment.

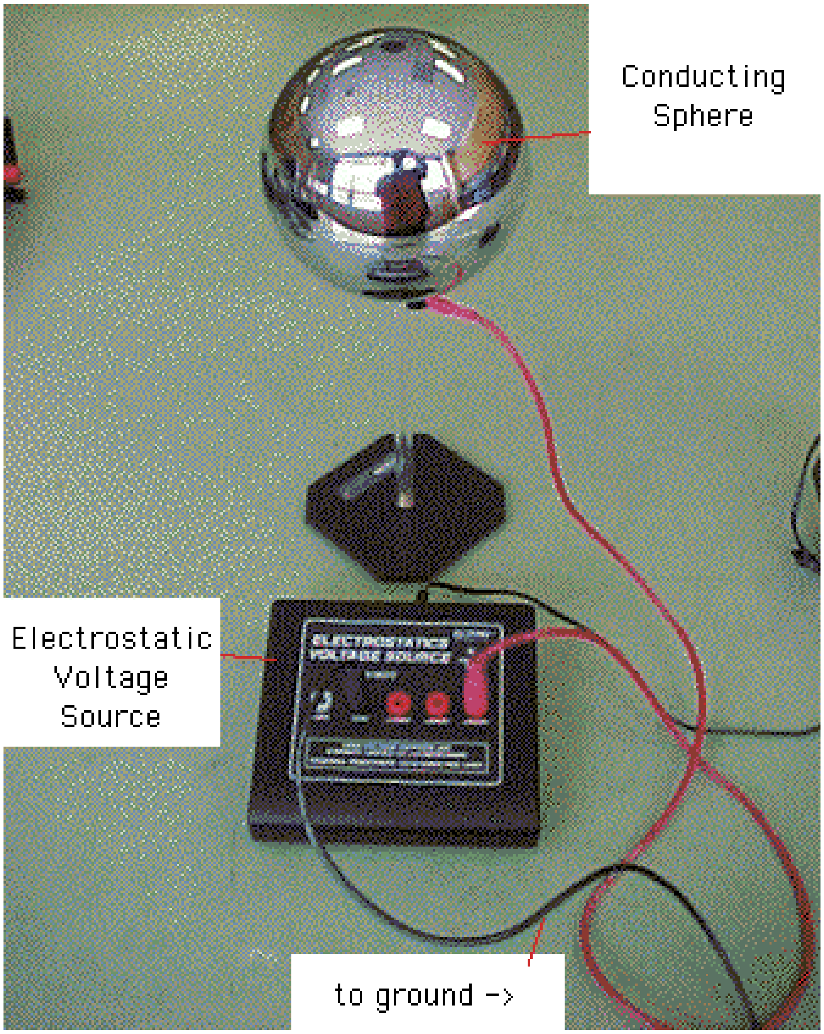
b. Finally, you are going to estimate the amount of charge that you transferred to one of the plates. Put the plates at a distance from each other where you believe the theoretical relation between charge, voltage and distance holds well.

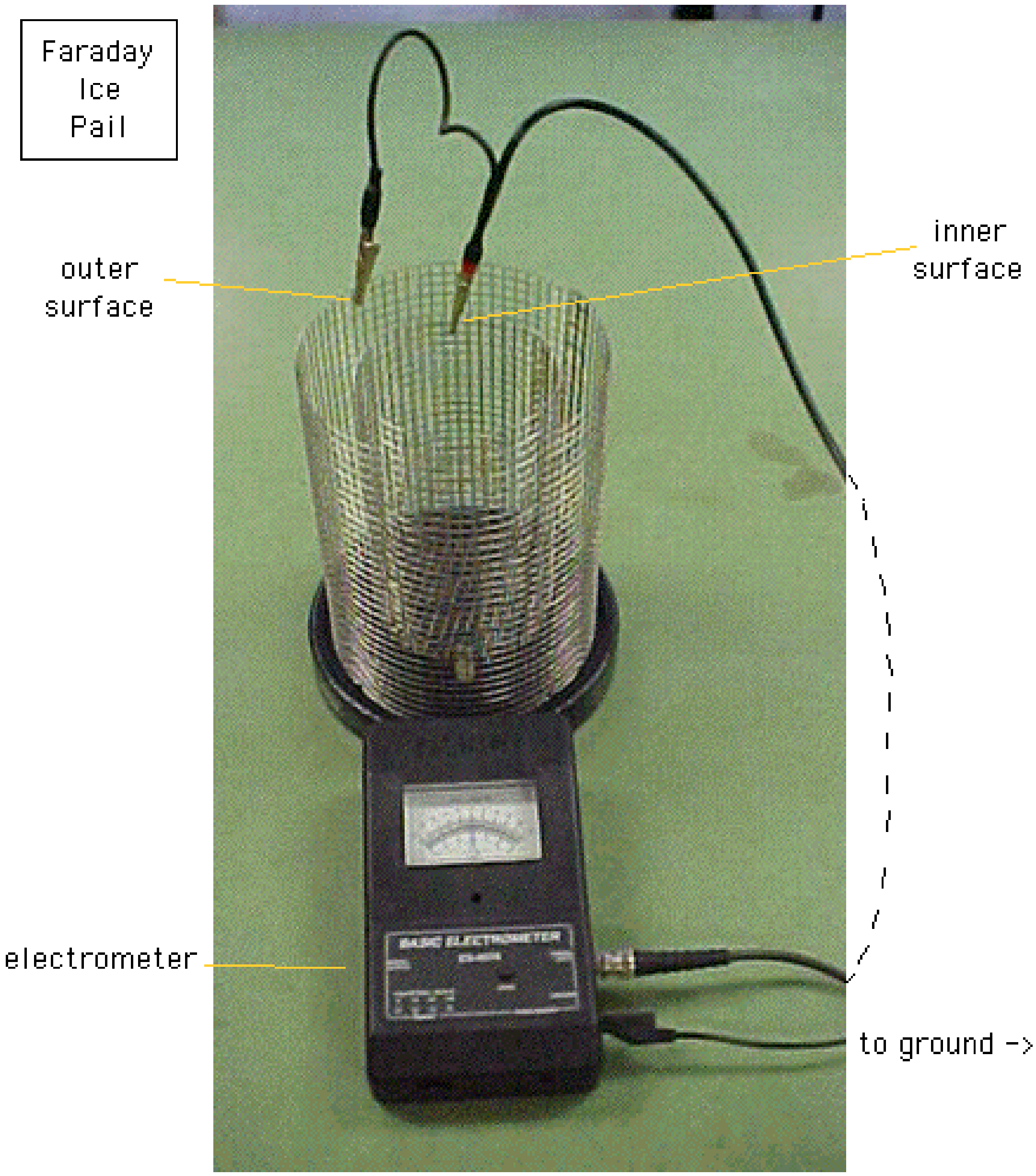
   i. Determine/estimate all parameters in the theoretical equation, except for the charge. Be sure to also include reasonable error bars and explain your choice for the error bar! Think about consistency of units.

   ii. Calculate the transferred charge, including the error. Use error propagation. Refer to the LBS272L webpage for help, if necessary.

   iii. Finally, put the moveable plate a very different distance away from the fixed plate. Repeat the calculation. Should the result be the same as for the first calculation, based on theory? If it is not, why not?

Pictures of Equipment




Faraday Ice Pail
outer surface
inner surface
electrometer
to ground ->


Variable
Geometry
Capacitor
BASIC ELECTROMETER
to ground ->
Electrometer