Capacitors Lab

1 Equipment

In order to investigate electric fields you will need the following equipment

- Home-made parallel capacitor with wax paper in between
- DC voltage supply
- Electrometer
- Variable capacitor box, and individual capacitors
- Plastic or Mylar sheets, plexiglass, and other dielectrics
- Connecting wires
- Graph paper

2 Introduction

In this lab you will be constructing your own capacitors, and determining their capacitance by measuring how much charge they can store. You will need to know the laws for adding capacitors in parallel:

$$C_{tot} = C1 + C_2$$

and in series:

$$\frac{1}{C_{tot}} = \frac{1}{C_1} + \frac{1}{C_2}$$

You will use these to determine unknown capacitances from known ones.

3 Safety:

First a word or two about safety. The resistance of the human body is such that any voltage greater than about 40V is sufficient to stop the heart. However, it takes a minimum current (about 50 milliamps) to cause a fatal stoppage. Thus most high-voltage devices, in addition to having a grounded case, will have a built in current-limiting resistor so that the power source voltage will drop when such currents are drawn from the supply. This is an example where one *wants* a “non-ideal” voltage source. Any power supply, particularly those above 40V, can be dangerous, and should be treated with respect. Remember, they are all connected to a line current

of 120V, so even lower voltage supplies are potentially dangerous.
Whenever you are changing your circuit (that is, connecting new capacitors, or moving leads), you should turn the voltage supply **off.**

Notify your TA if you see a bad power cord, a non-grounded case, or any other potentially dangerous situation. **Never** substitute a high voltage power supply for a low voltage supply.

4 Advice:

This lab requires a few delicate measurements. It is easy for things to go wrong. Here are a few points to watch:

1. A capacitor (ideally) has an infinite internal resistance. That means that if you put charge on it and disconnect it from the original circuit, the charge will remain. Consider a pair of capacitors connected in series: If any stray charge gets stored in the central region, it won't simply flow away. Thus every time you change the configuration of your circuit, you should turn the voltage supply off and discharge the capacitors. This can be done by simply connecting a piece of metal across the plates of the capacitor such as a ring,[1] or by using a wire. Make sure your electrometer reads zero volts before continuing.

2. Your electrometer must be a very sensitive device. There are very few charges stored on your capacitors, and the electrometer must measure the voltage without draining them off the capacitors. The problem with this is that... electrometers are very sensitive devices. If you wave a piece of plastic nearby them, they will register the voltage induced by this electrostatic charge. If you move around a lot while making a measurement, they will read the effects from *you.* The experiment works best if you keep the electrometer as far from the other equipment and yourself as the wires allow. You should also make sure the electrometer reads "zero" after you discharge the capacitors. (The "zero" is set for the center of the dial, so that you can measure negative voltages without pinning the meter.) If necessary, you can tweak the "zero adjust". Your TA will show you how.

   If your electrometer is acting flakey during a measurement. Try some of the following steps.

   (a) Turn off the voltage supply, and discharge all of the capacitors.

   (b) Turn off the electroscope and then connect one of its voltage probes to the other.

   (c) If neither of the above works, replace the electrometer leads.

Because your electrometer is a sensitive instrument, it is also easy to destroy. Don't hook it up to high voltages.

1 *Only* do this with the smaller capacitors we use in this lab. Don't discharge a capacitor this way if it is a substantial fraction of a Farad!

5 Procedure

Task 1 Measure the area of the capacitor. Calculate the capacitance of the discs assuming that they are separated by 1cm. (Assume that ε of the air is equal to ε_0)

Area =

C =

Task 2 Assume that two capacitors, C_1 and C_2 are connected in series, and a voltage is applied across the two of them. The voltage will induce a positive charge on the left hand side of the first capacitor, and a negative charge on the left hands side of the right capacitor. Indicate in the drawing below how the charges will redistribute themselves in the interior region between the two:

The sum of the voltage drop across them must be the total voltage. Using this information, and the fact that Q = *CV*, calculate the voltage drop across each capacitor, if the total voltage is V_{tot}. Make sure you have the right answer by consulting with the TA before proceeding.

Assume you have a large and a small capacitor hooked up in series with a voltage supply. From your above expression, across which of the two capacitors will the voltage drop be largest?

The larger capacitor The smaller capacitor

If you want the voltage drop across the two capacitors to be comparable, how should you choose C_1 and C_2*?*

This is how you will measure capacitance: you will connect a known capacitor in series with the unknown capacitor, and charge them with the voltage source. Then, using the electrometer, you will measure the voltage drop across the unknown capacitor, using the above formula to calculate its value.

Task 3 Connect a known capacitor of a few micro-farads in series with a parallel capacitor holding wax paper between the sheets. Make sure the paper is held tightly. We will change the number of wax paper sheets that we put between the plates. You will repeat the above, now measuring the voltage across the capacitor. With the voltage supply off, check the capacitor so that the electrometer gives a true null reading. Turn the electrometer off. Turn the voltage supply to 20V across the system of the two capacitors and measure the capacitance of the parallel capacitor. Electrometer and connecting cables have a certain capacitance which is connected in parallel with the measured capacitor. This capacitance of approximately 150 pf must be taken into account during the measurement. Record your data for at least 6 different distances. To measure the thickness of the wax paper, you may need to use a micrometer, or measure the thickness of a stack of sheets and divide by the total number. Using this information you should be able to calculate the dielectric constant of the wax paper: $\kappa \equiv \frac{\varepsilon}{\varepsilon_o}$ Repeat this for a variety of different materials, such as plexiglass and paper.

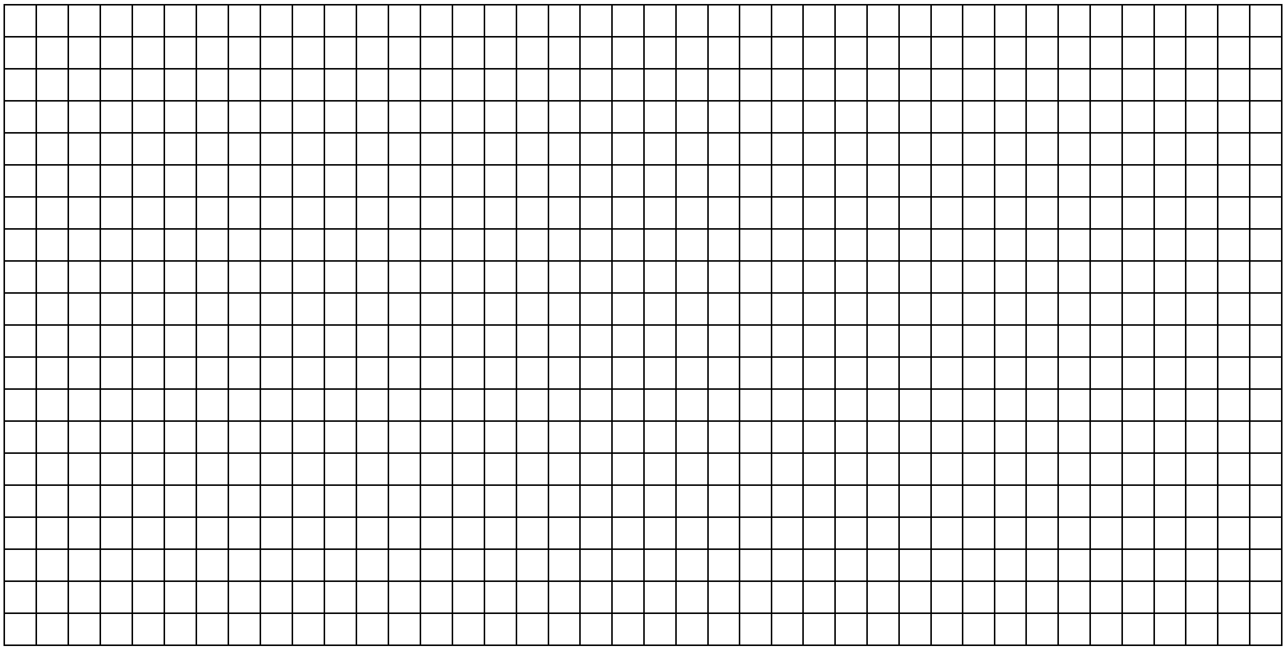
C_{known}	V_{tot}	V_{unk}	d	C_{unk}(calculated)	κ

C_{known}	V_{tot}	V_{unk}	d	C_{unk}(calculated)	κ

Do your measured values of the capacitance agree with each other? Repeat the experiment until you can get reasonable agreement, or are frustrated to a maddening degree.

Plot the value of your measured capacitance versus the distance between the plates. What relationship *should* you see? What relationship do you observe? Comment on your observations.

From the above measurements, calculate a value for the dielectric constant of wax paper



From the above measurements, calculate a value for the dielectric constant of plexiglass

6 Questions

Discuss the following questions with your lab partners. You must all come to the same conclusions. Then write your answers to the questions in the space provided below.

1. Why don’t you connect the capacitors in parallel for these measurements. Wouldn’t it then be easier to calculate the unknown *C?*

2. The electroscope provides a path to discharge the capacitor when you measure the voltage across the capacitor. The time it takes to discharge the capacitor is of order $\tau \sim RC$, where C is

the capacitance in Farad, and R is the resistance in Ohms. Estimate the internal resistance of your electrometer.

3. The dielectrics you insert between your capacitor plates may have a large static charge. Why does this not affect your result, if you shorted your capacitors before measuring?