

## College Physics II

# Lab 6: Capacitors

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Spring 2012

### Introduction

You will get a feeling for what a capacitor is and you will get practice calculating net capacitance for combinations of capacitors by:

- Building 3 different capacitors,
- Measuring the capacitance of each with a faradometer,
- Calculating what the capacitance should be with various combinations of your 3 capacitors, and then testing your prediction with a faradometer.

Consult section 21.7 in your textbook.

**Note:** For both parts of this lab, the one major pitfall is that some parts of the two pieces of foil (with the paper and/or plastic between them) touch each when they should not; this is called “shorting out.” You need to be very careful to make sure this does not happen. If your results start to look nonsensical, then you probably have shorted out. What you need to do in that case is to rebuild your capacitor from scratch, trying to be more careful.

## Activity 1: Building Capacitors

Construct 2 different capacitors out of aluminum foil and paper—or plastic wrap, or perhaps wax paper). I will show you how. Make one using a sheet of one substance as the dielectric and another with a sheet of a different substance. Make sure that the area of each capacitor is at least 7 cm by 7 cm (about 50 cm<sup>2</sup>); if the area is smaller, the resulting capacitance may be too small to measure. When measuring the capacitance, you will need to lay your capacitors out flat: place a book on them, and stand on the book. This ensures that there is no substantial thickness of air between layers. Measure and write down the following for each capacitor:

- The length,  $l$ , and width,  $w$ , of one of the aluminum foil “plates,”
- The capacitance  $C$ , using a faradometer.
- The total thickness of the material between the plates, using a micrometer.

Recall that the capacitance  $C$  of a capacitor of plate area  $A$  and plate separation  $d$  is:

$$C = \frac{\kappa\epsilon_0 A}{d}$$

where  $\epsilon_0 = 8.85 \times 10^{-12}$  F/m. (This is equation 21.22 in your textbook.)

Since  $A = lw$ , you can solve this equation for  $\kappa$  in terms of measured quantities and  $\epsilon_0$ :

$$\kappa = \frac{dC}{\epsilon_0 lw}$$

You should get  $\kappa > 1$ . Compare your results for  $\kappa$  with at least one other lab group.

### To hand in for activity 1

- Measurements for  $l$ ,  $w$  and  $C$  for each of the two capacitors,
- Result of calculation of  $\kappa_{\text{plasticwrap}}$  and  $\kappa_{\text{paper}}$ . Include equations used and value of  $d$  used in each case.
- Comparisons with other lab groups.

## Activity 2: Combining Capacitors

Build a third capacitor using multiple sheets of paper or of plastic (but not both) as the dielectric. Make sure that the third capacitor is different in some way from either of the first two.

Lay a piece of paper under each of your capacitors (make sure the area of the paper is bigger than the area of either plate), roll up each of your three capacitors into a cylinder, and tape each cylinder so that it doesn't unroll. Re-measure the capacitance of the first two—they will have changed noticeably from when they were being squashed by your book, and measure the capacitance of the third. Draw diagrams for the following combinations of your three capacitors:

- All in parallel,
- All in series,
- Two in parallel, in series with the third,
- Two in series, in parallel with the third.

Measure the total capacitance  $C_T$  for each combination using your three capacitors and the faradometer.

Here are three options for how  $n$  capacitances add:

1. **Direct addition:**

$$C_T = C_1 + C_2 + \dots + C_n$$

2. **Square addition:**

$$C_T^2 = C_1^2 + C_2^2 + \dots + C_n^2$$

3. **Inverse addition:**

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \dots + \frac{1}{C_n}$$

Given your data, which option do you think describes the total capacitance for capacitances in series? What option applies to capacitors joined in parallel? Check how your four measured  $C_T$ 's fit the options you choose.

**To hand in for activity 2**

- A picture of each of the 4 arrangements, labeling which capacitor is which,
- Your measurement of  $C_T$  for each of the 4 arrangements,
- Your decisions on how capacitors add in series and in parallel, with all relevant evidence and calculations.