LAB 5
Capacitors

OBJECTIVES

1. Study of the equivalent capacitance of capacitors connected in series and parallel.
2. Investigate the capacitance of the electrometer.

EQUIPMENT

Capacitors (two each: 0.05 μF, 0.10 μF, and 0.22 μF, and one 200 pF), electrometer, DC power supply, digital multimeter, breadboard.

THEORY

Any arrangement that stores charge can properly be called a *capacitor*. The capacitance of a capacitor is a measure of how much charge can be stored on the capacitor for a given potential difference (voltage). The relation between charge *q*, voltage V, and capacitance *C* is given by:

$$q = CV \ \ or \ \ C = \frac{q}{V}.$$

When two or more capacitors are connected together, they may be replaced by a single capacitor that has the same capacitance (C_{eq}) as the combination of capacitors. For two capacitors connected in *parallel*, the equivalent capacitance is given by:

$$C_{eq} = C_1 + C_2 .$$

For two capacitors connected in *series*, the equivalent capacitance is given by:

$$1/C_{eq} = 1/C_1 + 1/C_2 .$$

If a capacitor C_1 is connected to a power supply with voltage V_0, it will acquire a charge q given by $q = C_1V_0$. If that capacitor is then disconnected from the power supply and connected in parallel to an initially uncharged capacitor C_2, the original charge q on capacitor 1 is split between the two capacitors. We therefore end up with the relation $q = q_1 + q_2$, where q_1 and q_2 are the final charges on capacitors 1 and 2. Since capacitors 1 and 2 are in parallel, they must have the same voltage V. The relationship $q = q_1 + q_2$ therefore becomes $C_1V_0 = C_1V + C_2V$.

PROCEDURE

Part 1: Measuring the Unknown Capacitance C_X

(a) Measure the individual capacitance values (using a DMM) of the following two capacitors: 0.05 μF and 0.10 μF.

(b) Using the measured capacitance values, calculate the unknown capacitance $(C_X)_{thy}$ by combining

- 0.05 μF in series with the C_X
- 0.10 μF in series with the C_X
- 0.05 μF and 0.10 μF in series with the C_X
- 0.05 μF and 0.10 μF in parallel with C_X

Average these four values to obtain $(C_X)_{thy}$.

(c) Measure the unknown capacitance $(C_X)_{expt}$ using the DMM and compare it with the averaged $(C_X)_{thy}$ using a percent difference. *How do they compare?*

Part 2: Charged Capacitor Connected in Parallel with Initially Uncharged Capacitors

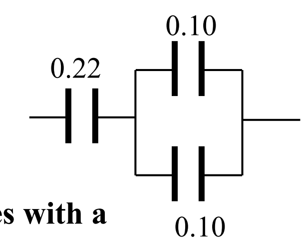
(a) Set the output of the power supply to 10 V using the digital multimeter. After you have set the output voltage to 10 V, **do not** touch the voltage setting of the power supply for the rest of lab. Check the voltage of the power supply using the electrometer.

(b) Connect a 0.05 μF capacitor to two leads on the breadboard and then connect the electrometer to the ends of the capacitor. Keep the electrometer connected across the 0.05 μF capacitor for the entire lab.

(c) Charge the 0.50 μF capacitor by connecting it to the power supply. After the capacitor is fully charged (one or two seconds), disconnect the power supply. **Be careful not the touch either side of the capacitor or you will discharge it.**

(d) *Predict what the voltage across the 0.05 μF capacitor will read after it is connected in parallel with the following six combinations of uncharged capacitors:*

- **one 0.05 μF capacitor**
- **one 0.10 μF capacitor**
- **two 0.10 μF capacitors in *parallel***
- **two 0.10 μF capacitors in *series***
- **a combination of two 0.10 μF capacitors in parallel in series with a third 0.22 μF capacitor**



(e) Connect the initially uncharged capacitor(s) in parallel with the charged 0.05μF capacitor. Measure the voltage across the 0.05 μF capacitor with the electrometer and compare with your prediction. *Was your prediction correct? Report on your results.*

(f) Discharge all capacitors by touching both plates of each capacitor at the same time with a wire. Repeats steps (c) and (e) for all six combinations of uncharged capacitors.

Part 3: Capacitance of the Electrometer

(a) Connect the **200 pF** capacitor to the power supply. After the capacitor is fully charged (one or two seconds), disconnect the power supply.

(b) Predict what the voltage across the 200 pF capacitor will be when you read the voltage using the electrometer.

(c) Use the electrometer to measure the voltage across the 200 pF capacitor. *Was your prediction correct? Report on your results and any possible reasons for the discrepancy*.

(d) *Use your results from part (c) to calculate the capacitance of the electrometer.*

(e) *Why didn't the capacitance of the electrometer have a noticeable effect on the results from Part 2?*