The Capacitor

I. INTRODUCTION

A simple capacitor consists of two parallel plates separated by air or other insulation, and is useful for storing a charge. If a potential difference is placed across the plates, the positive charges on one plate will hold the negative charges on the other.

When the plates are connected to a resistance, electrons flow from the negative plate to the positive plate to neutralize the charge. A capacitor’s ability to hold a charge is called capacitance, \( C \), and is measured in Farads (F). From the relationship \( C = \frac{q}{\Delta V} \), we observe that the charge on a capacitor is proportional to the voltage across it. One Farad will have one coulomb per volt applied. One Farad will have one microcoulomb if one microvolt is applied, and so on. The air-gap capacitor above will have a capacitance given by:

\[
C = \frac{\varepsilon_o A}{d}
\]

where \( A \) is the area of the plates in meters squared, \( d \) is the spacing of the plates in meters, and \( \varepsilon_o \) is a constant called the permittevity of free space and has a value of \( 8.85 \times 10^{-12} \text{ coul}^2/\text{N} \cdot \text{m}^2 \). The charge \( q \) stored on a capacitor is:

\[
q = C \Delta V
\]

so:

\[
C = \frac{q}{\Delta V}
\]

where \( q \) is the charge in coulombs, \( C \) is the capacitance in Farads, and \( \Delta V \) is the voltage in volts.
If a charge is stored on the capacitor and the capacitance changes, the potential difference across the plates will change in order to keep $q$ constant. In this experiment you will verify the capacitor equation (2) above and see how the voltage across the plates changes as the capacitance changes.

II. APPARATUS

You will need the following items for this experiment:
- Variable Capacitor with BNC cable
- Low Voltage Power Supply
- Electrometer
- Connecting Leads and Alligator Clips

Like all electronic devices, the electrometer has a small internal capacitance of its own. This would not present a problem except that it is close to the value of the capacitance of the plates. To account for this, the effective capacitance $C_e$ that you will use in your calculations is the capacitance of the plates $C_p + 27$ pF ($pF = 10^{-12}$ F).

III. PROCEDURE

As with the previous electrostatic experiments, this one is very temperamental. The behavior of electric charges is modified by invisible and unexpected factors, like humidity, clothing, charges on your body, and pointed conductors. To avoid any stray charges from introducing errors into your measurements, take the following precautions:

- Ground your body frequently. Do this by touching the ground lead on the electrometer, or always have one finger touching it while using your other hand.
- Keep away from the plates and from the red wire on the movable plates. Your breath will discharge the plates.
- Do not touch the plates. Oils from your skin will affect your results.

To see how the voltage across the capacitor is related to the capacitance, you will charge the capacitor at a fixed plate separation and then move the plates apart, measuring the voltages at various separations. From these data you can calculate the charge on the plates. The magnitude of the charge should be constant.
Figure 1: Experimental setup: electrometer, power supply, and variable capacitor

1. Connect the black wire from the electrometer to the fixed plate and the red wire from the electrometer to the movable plate. Set the electrometer to the 30 volt range by pressing the range select button until the proper range LED is lit.

2. Set the power supply to 9 volts. Set the plates at an initial separation of 0.003 meters. Zero the electrometer.

3. Connect the negative power supply lead to the fixed plate. Charge the movable plate by touching it with the red wire from the power supply and then immediately slide it to the desired distance corresponding to the value of $d$ listed on the data page. Read the voltage $\Delta V$ on the electrometer and record it in the data table.

4. After each measurement, move the plates back into the original position ($d = 0.003$ m), recharge the capacitor plates and repeat the measurements. You may have to make several trials to get consistent values of $q$.

5. From your data, plot $C_e$ versus $1/\Delta V_{avg}$. Do a linear fit to find the slope of this graph and record the slope on the data sheet. What property of the capacitor does the slope represent?
IV. QUESTIONS (answer on this sheet)

1. A parallel-plate capacitor is charged, then disconnected from the battery. The plates are then pulled a small distance further apart.
   a. What happens to the charge on the plates? Explain.
   b. What happens to the capacitance? Explain.
   c. What happens to the potential difference between the plates? Explain.
   d. What happens to the electric field between the plates? Explain.

2. A 1.3 pF parallel-plate capacitor is connected to a 9.0 V battery.
   a. What is the charge on the capacitor?
   b. How many electrons were moved by the battery from one plate to the other plate?
V. DATA - Capacitor

Name: _______________

Date: _______________

Diameter of the plates = 20 cm

Area of the plates = _______________

In the table below \( d \) is the plate separation, \( C_p \) is the plate capacitance, \( C_e \) is the effective capacitance, where \( C_e = C_p + 27 \text{ pF} \), \( V \) is the plate potential, and \( q \) is the charge on the plates.

<table>
<thead>
<tr>
<th>( d ) (m)</th>
<th>( C_p ) (F)</th>
<th>( C_e ) (F)</th>
<th>( \Delta V ) (trial 1)</th>
<th>( \Delta V ) (trial 2)</th>
<th>( \Delta V_{avg} ) (V)</th>
<th>( q ) (C)</th>
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Slope for the plot of \( C_e \) versus \( 1/\Delta V_{avg} \) = ________________