PHYS 2426

Engineering Physics II

EXPERIMENT 2

CAPACITORS IN SERIES AND PARALLEL

I. OBJECTIVE:

The objective of this experiment is to measure the equivalent capacitance of several capacitors connected in series and parallel. This will be done in two ways. First, by direct measurement using a capacitance meter. Second, by using the definition $C = Q/V$.

II. INTRODUCTION:

A capacitor consists of two conducting objects (plates) separated by a nonconducting medium (dielectric). Figure (1) shows a capacitor connected to a battery. The capacitance of this capacitor is defined as the ratio of the charge on the conducting plates to the potential difference across them.

$$C = Q/V \tag{1}$$

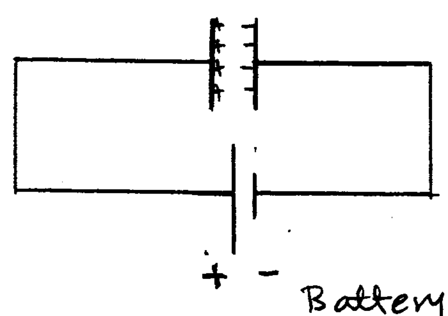

Figure (1)

Capacitors may be combined in series or parallel. Figure (2a) shows three capacitors connected in series and connected to a battery. Figure (2b) shows three capacitors connected in parallel and connected to a battery. Note the polarity in each case. Theoretically the equivalent capacitance for the series connection is given by

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \tag{2}$$

and that for the parallel connection is given by

$$C_{eq} = C_1 + C_2 + C_3. \tag{3}$$

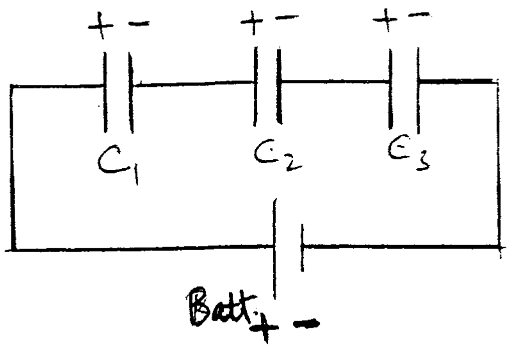

Figure (2a)

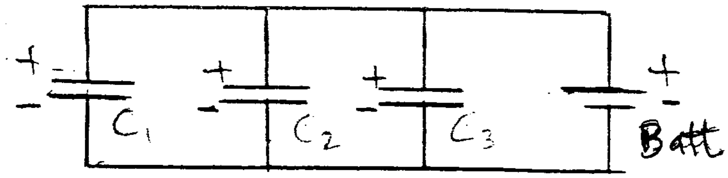

Figure (2b)

III. APPARATUS:

3 capacitors of different values, 6-volt battery, voltmeter, capacitance meter and connecting wires (leads).

IV. EXPERIMENTAL PROCEDURE:

1. Make sure that each capcitor is discharged (V=0) by touching the ends of a lead wire to the terminals of the capacitor.
2. Use the capacitance meter to measure the capacitance of each capacitor. Record the values in your data table.
3. Wire the capacitors in series as shown in Fig (2a) (**but do not connect them to the battery**). Pay close attention to the polarity of the capacitors and the way they are connected. The capacitors used in this experiment are electrolytic capacitors and the polarity of the plates is important. Make sure the ends of the lead wires do not come in contact with each other.
4. Using a capacitance meter, measure the capacitance of the series combination (connect the meter to the free ends). This is $C_{\text{eq,measured}}$.
5. Connect the battery to the series combination of capacitors.
6. Measure the voltage across each capcitor and the battery voltage and record these values in your data table. You are finished with the series compbination.
7. Disconnect the capacitors, discharge each capacitor as you did before and wire the circuit in parallel as shown in Fig. (2b) (**but do not connect them to the battery**).

8. Using a capacitance meter, measure the capacitance of the parallel combination. This is $C_{\mathrm{eq,measured}}$.
9. Connect the battery to the parallel combination of capacitors.
10. Measure the voltage across each capacitor and the voltage across the battery and record in your data table.
11. Show your data to the intructor or the lab assistant to make sure your data are OK. If so, you are finished with the experimental procedure.

V. ANALYSIS:

Series connection:

1. For each case calculate the charge on each capacitor using the relation $Q_{\mathrm{i}} = CiV_{\mathrm{i}}$ where i=1,2,3.
2. The values of the charges should be the same within the limits of experimental error. Find the average value of the charge

$$Q_{\mathrm{ave}} = \frac{1}{3}(Q_1 + Q_2 + Q_3)$$

   This is the charge on the equivalent capacitor.
3. Calculate the experimental equivalent capacitance $C_{\mathrm{eq}} = Q_{\mathrm{ave}}/V_{\mathrm{batt}}$ and record it the data table.
4. Use eq. (2) to calculate the equivalent capacitance predicted by theory, $C_{\mathrm{eq,predicted}}$ and record it in the data table.

Parallel connection:

1. For each case calculate the charge on each capacitor.
2. Calculate the total charge, $Q_{\mathrm{total}} = Q_1 + Q_2 + Q_3$.
3. Calculate the experimental equivalent capacitance $C_{\mathrm{eq}} = Q_{\mathrm{total}}/V_{\mathrm{batt}}$ and record it in the data table.

4. Use eq. (3) to calculate the equivalent capacitance predicted by theory, $C_{\mathrm{eq,predicted}}$ and record it in the data table.

VI. ERROR ANALYSIS:

Series connection:

1. Calculate the percent difference between the equivalent capacitance predicted by theory and the measured equivalent capacitance

$$\%\text{difference} = \frac{|C_{\mathrm{eq,measured}} - C_{\mathrm{eq,predicted}}|}{\frac{1}{2}\left(C_{\mathrm{eq,measured}} + C_{\mathrm{eq,predicted}}\right)} \times 100$$

2. Calculate the percent difference between the equivalent capacitance predicted by theory and the experimental equivalent capacitance, C_{eq}.
3. For each capacitor, calculate the relative uncertainty in the charge

$$\left|\frac{\delta Q}{Q}\right| = \left|\frac{\delta C}{C}\right| + \left|\frac{\delta V}{V}\right|$$

   and the uncertainty in the charge

$$\delta Q = \left|\frac{\delta Q}{Q}\right| Q.$$

   Notice that the relative uncertainty has no units while the uncertainty has units of Coulomb.
4. Calculate the uncertainty in the average charge

$$\delta Q_{\mathrm{ave}} = \frac{1}{3}\left(\delta Q_1 + \delta Q_2 + \delta Q_3\right)$$

5. Calculate the relative uncertainty in the equivalent capacitance, round it off to one significant figure and record it in percent.

$$\left|\frac{\delta C_{\mathrm{eq}}}{C_{\mathrm{eq}}}\right| = \left|\frac{\delta Q_{\mathrm{ave}}}{Q_{\mathrm{qve}}}\right| + \left|\frac{\delta V_{\mathrm{batt.}}}{V_{\mathrm{batt.}}}\right|$$

Parallel connection:

1. Calculate the percent difference between the equivalent capacitance predicted by theory and the measured equivalent capacitance

$$\%\text{difference} = \frac{|C_{\text{eq,measured}} - C_{\text{eq,predicted}}|}{\frac{1}{2}(C_{\text{eq,measured}} + C_{\text{eq,predicted}})} \times 100.$$

2. Calculate the percent difference between the equivalent capacitance predicted by theory and the experimental equivalent capacitance, C_{eq}.
3. For each capacitor, calculate the relative uncertainty in the charge

$$\left|\frac{\delta Q}{Q}\right| = \left|\frac{\delta C}{C}\right| + \left|\frac{\delta V}{V}\right|$$

and the uncertainty in the charge

$$\delta Q = \left|\frac{\delta Q}{Q}\right| Q.$$

Notice that the relative uncertainty has no units while the uncertainty has units of Coulomb.

4. Calculate the uncertainty in the total charge

$$\delta Q_{\text{total}} = (\delta Q_1 + \delta Q_2 + \delta Q_3)$$

5. Calculate the relative uncertainty in the equivalent capacitance and record it in perecent.

$$\left|\frac{\delta C_{\text{eq}}}{C_{\text{eq}}}\right| = \left|\frac{\delta Q_{\text{total}}}{Q_{\text{total}}}\right| + \left|\frac{\delta V_{\text{batt.}}}{V_{\text{batt.}}}\right|$$

6. Calculate the uncertainty in the equivalent capacitance predicted by theory

$$\delta C_{\text{eq,predicted}} = (\delta C_1 + \delta C_2 + \delta C_3)$$

7. Calculate the relative uncertainty in the equivalent capacitance predicted by theory and record it in percent.

VII. QUESTIONS:

1. For each connection, calculate the amount of energy stored in each of the three capacitors. Add up these energies to get the total energy stored in each of the series and parallel connections.
2. Calculate the amount of energy stored in the equivalent capacitance and show that this energy is equal to the sum of the energies stored in the individual capacitors for the series and parallel connections.
3. Which way should capacitors be connected to give you the largest amount of energy stored.

SERIES CONNECTION			PARALLEL CONECTION		
C	**V**	**Q**	**C**	**V**	**Q**
C_1					
C_2					
C_3					
$C_{eq} = Q_{av}/V_{batt}$	V_{bat}	Q_{av}	$C_{eq} = Q$~~av~~$/V_{batt}$ total	V_{bat}	Q_{tot}
$C_{eq,\ measured}$			$C_{eq,\ measured}$		
$C_{eq,\ predicted}$			$C_{eq,\ predicted}$ $= C1 + C2 + C3$		