Lab 2 – Capacitance

Name ____

Partner's Name ____

I. Introduction/Theory

A capacitor is a device that can store energy by storing electric charge, +Q on one plate and -Q on a second plate insulated from the first. The capacitance of this device is the relation between the net charge +Q and the potential difference V (ΔV) between +Q and -Q. In other words, Q = CV, where Q is the amount of charge on one plate, V is the potential difference between the plates, and C is the capacitance. Capacitance has units of farads, 1 farad = 1 coulomb/volt (1 F = 1 C/V).

Some meters that measure capacitance do so by charging the capacitor for a known time (e.g. 1 sec.) with a known current and then measure the voltage across the capacitor. Since current, i, is the flow of charge $\left(i = \frac{dQ}{dt} \cong \frac{\Delta Q}{\Delta t}\right)$, current times the charging time equals charge, Q (Q = i Δt). A meter can then measure the capacitance using the definition of capacitance C = Q/V. In this experiment, you will use a similar method to determine the capacitance of some individual capacitors and capacitor combinations.

As the charge on a capacitor changes, the voltage must also change in the same direction. The capacitance is completely independent of the charge, Q, and potential difference, V, on the device! The capacitance is dependent on the geometrical properties of the device. For a parallel plate capacitor the capacitance is given by $C = \varepsilon_o \frac{A}{d}$, where A is the area of the plates and d is the separation distance between the plates.

A capacitor with capacitance C_1 can be connected to another capacitor with capacitance C_2 to form a capacitor with effective capacitance C_{eff}. In Figure 1, if the two capacitors (C_1 and C_2) connected in *Parallel* with the same separation distance d, then. $C_{eff} = \varepsilon_o \frac{A_1 + A_2}{d} = \varepsilon_o \frac{A_1}{d} + \varepsilon_o \frac{A_2}{d} = C_1 + C_2$. And likewise in Figure 1, if the two capacitors (C_1 and C_2) connected in *Series* with the same area A, then $\frac{1}{C_{eff}} = \frac{1}{\varepsilon_o}\frac{d_1 + d_2}{A} = \frac{1}{\varepsilon_o}\frac{d_1}{A} + \frac{1}{\varepsilon_o}\frac{d_2}{A} = \frac{1}{C_1} + \frac{1}{C_2}$ or $C_{eff} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}}$.

Two capacitors in Parallel   Two capacitors in Series

Figure 1.

II. Equipment

Constant current source (~1 mA)
Capacitors: C_1 (~3300 μF) and C_2 (~1000 μF)
Stop watch
Multimeters (2)
Connectors (~six banana plugs with clip leads)

III. Procedure/Data

1. Connect the constant current source to capacitor C_1 (~3300 μF) with an ammeter in series. Connect a voltmeter in parallel with the capacitor. The circuit should be analogous to Figure 2.
2. Verify the constant current source produces ~1 mA in the circuit, adjust as necessary. When the constant current source has been verified, discharge the capacitor such that there is no potential difference across the capacitor (V = 0!). NOTE: The constant current source will produce a constant current up to ~5.0 volts, under no circumstances exceed 5.0 volts across the capacitor!

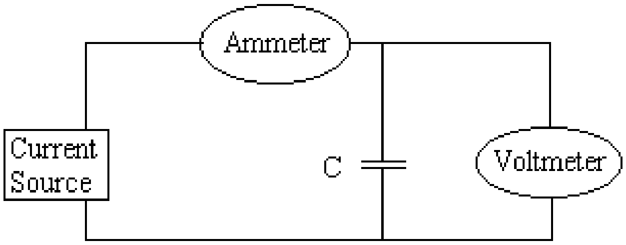

Figure 2.

3. Using the constant current source, make three runs, charging the capacitor to roughly 3 volts each time, and recording the average current, charging time, and final voltage in Table 1. After each run, discharge the capacitor such that there is no potential difference across the capacitor (V = 0!).

Trial	Average Current, i	Charging Time, t	Total Charge, Q = i t	Final Voltage, V	Capacitance, $C_1 = Q/V$
1					
2					
3					
XXXXXXX	XXXXXXX	XXXXXX	XXXXXXX	Average Capacitance	
XXXXXXX	XXXXXXX	XXXXXX	XXXXXXX	Standard Deviation	
XXXXXXX	XXXXXXX	XXXXXX	XXXXXXX	Standard Error	

Table 1

4. Replace capacitor C_1 (~3300 μF) with capacitor C_2 (~1000 μF) in the circuit (Figure 2.). Repeat the previous step for capacitor C_2 (~1000 μF) in Table 2.

Trial	Average Current, i	Charging Time, t	Total Charge, Q = i t	Final Voltage, V	Capacitance, $C_2 = Q/V$
1					
2					
3					
XXXXXXX	XXXXXXX	XXXXXX	XXXXXXX	Average Capacitance	
XXXXXXX	XXXXXXX	XXXXXX	XXXXXXX	Standard Deviation	
XXXXXXX	XXXXXXX	XXXXXX	XXXXXXX	Standard Error	

Table 2

5. Connect the constant current source to *Parallel* capacitors C_1 (~3300 μF) and C_2 (~1000 μF) with an ammeter in series. Connect a voltmeter in parallel with the capacitors. The circuit should be analogous to Figure 3.

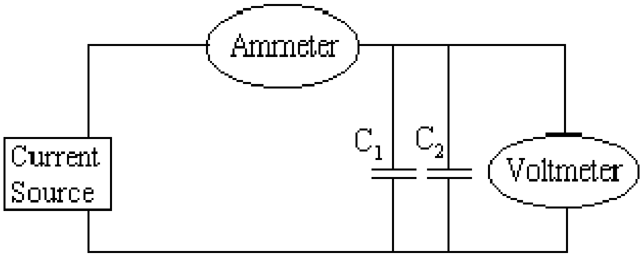

Figure 3.

6. Measure the effective capacitance of the parallel capacitors C_1 and C_2 by completing the first line (parallel configuration) of Table 3.
7. Connect the constant current source to *Series* capacitors C_1 (~3300 μF) and C_2 (~100 μF) with an ammeter in series. Connect a voltmeter in parallel with the capacitors. The circuit should be analogous to Figure 4.

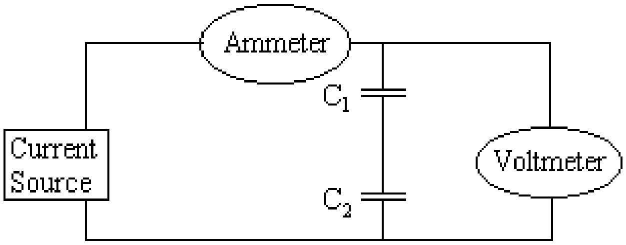

Figure 4.

8. Measure the effective capacitance of the series capacitors C_1 and C_2 by completing the second line (series configuration) of Table 3

Configuration	Average Current, i	Charging Time, t	Total Charge, Q = i t	Final Voltage, V	Capacitance, $C_{eff} = Q/V$
Parallel					
Series					

Table 3.

III. Analysis

1. Complete Tables 1, 2, and 3.
2. Using the relation for *parallel* capacitors, $C_{eff} = C_1 + C_2$, calculate the effective capacitance of C_1 and C_2 in parallel with uncertainty based on data in Table 1 and 2. Statistically compare this effective capacitance to that measured in Table 3, comment as necessary. Show all work (attach additional pages to the end of this lab via a staple, if necessary).

3. Using the relation for *series* capacitors, $\frac{1}{C_{eff}} = \frac{1}{C_1} + \frac{1}{C_2}$, calculate the effective capacitance of C_1 and C_2 in series with uncertainty based on data in Table 1 and 2. Statistically compare this effective capacitance to that measured in Table 3, comment as necessary. Show all work (attach additional pages to the end of this lab via a staple, if necessary).

V. Conclusions (include physical concepts and principles investigated in this lab, independent of your experiments success, and summarize without going into the details of the procedure.)