Capacitors

A capacitor is a device that stores electric charge. The objectives of this experiment are to study how charge collects in a capacitor, how charge drains from a capacitor, how two or more capacitors behave when connected to each other, and how to wire circuit elements in series or in parallel with each other.

The time required for a capacitor to gain or lose charge depends on the resistance of the wires and other electrical components attached to it. There is a quantity known as the time constant, τ. The formula for τ is found from the relationship:

$$\boldsymbol{\tau = RC}$$

One time constant, τ, is the amount of time required for a capacitor to change its amount of charge by gaining 63% of its final value or losing 63% of its final value. This is due to the exponential nature of how charge goes onto or comes off the plates of a capacitor.

$$Q(t) = Q_{Total}\left(1 - e^{-t/\tau}\right) \ \ Charging$$

$$Q(t) = Q_{Total}e^{-t/\tau} \ \ Discharging$$

And

$$e^{-t/\tau} = e^{-1} = 0.36788{\sim}0.37 \ \ or\ 37\%$$

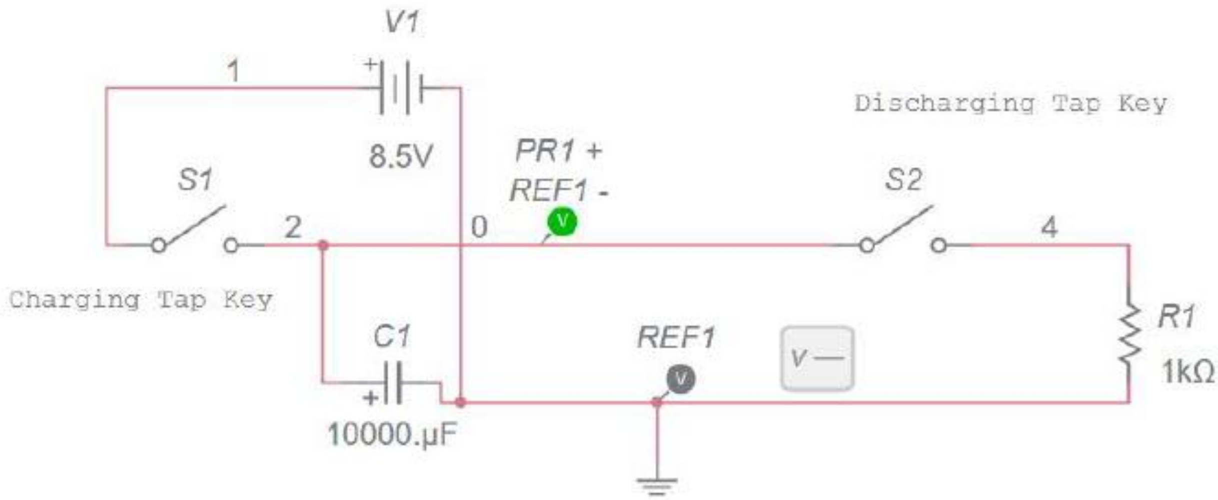
So, when the time t is equal to the time constant τ, our charge on the plates is either 63% of full value when charging or 37% when discharging. As a rule of thumb,

$$e^{-5\tau/\tau} = e^{-5} = 0.00674{\sim}0.01$$

Therefore, when 5 time constants of time have passed, a capacitor is at 99% fully charged or discharged, so we assume a capacitor will be fully charged or fully discharged after 5 time constants have occurred.

In the experiment today, you will charge capacitors to a voltage > 8.0 V. Then you will discharge the capacitors to a voltage < 3.0 V. The PASCO equipment will monitor the voltage across the capacitor and record the time. You will scroll through the table of data and find the value of voltage closest to 8.00 V and note the corresponding time. You will then go find the closest value of voltage closest to 3.00 V and note this time. 37% of 8 is 2.96, which is why we are using 3. How close you will be to these two voltages is somewhat dependent on the charging and discharging behavior of the capacitors. The Capstone data collects data every 0.05 seconds, so you will normally not get exactly 8 or 3 Volts. You will just use the value closest that you find whether it is above or below the desired voltage value.

Experiment 1: Comparing Capacitors
Wire up the circuit below, but do not switch it on until the instructor has seen the circuit.



If you have not done so, download and set up Capstone to control and use the PASCO interface. Open the Capstone Set-Up file for this experiment. The "Charging" tap key will charge up the capacitor. The "Discharging" tap key will cause the charge on the capacitor to drain off through the attached resistance.

Once everything is set, start recording data in Capstone, then tap, and hold the "Charging" key down until the capacitor has a voltage > 8.5 V. Release the "Charging" tap key and now depress and hold the "Discharging" tap key until the voltage is <3 V. You will be creating a table in Capstone that looks like this:

[Table title here]

	Run #1	
	Voltage (V)	Time (s)
114	8.129	5.650
115	8.108	5.700
116	8.086	5.750
117	8.064	5.800
118	8.042	5.850
119	8.020	5.900
120	7.998	5.950
121	7.977	6.000
122	7.955	6.050
123	7.934	6.100

In this table, I have highlighted the two values nearest 8.00 V. Of these two, I would take the 7.998 V being only 0.002 V from 8.00, while 8.020 V is 10 times larger away at 0.020 V. So I would assign the time for this as 5.95 s instead of 5.90 s.

Complete table 01in the Worksheet you will turn in for this lab.:

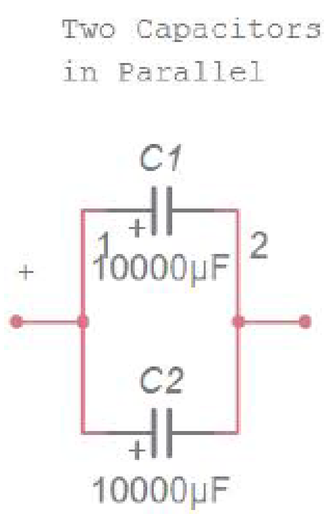
Fill it in for the trials, then calculate the discharge times. Finally, calculate the averages of the trials. Now recall that discharge time is related to capacitance by:

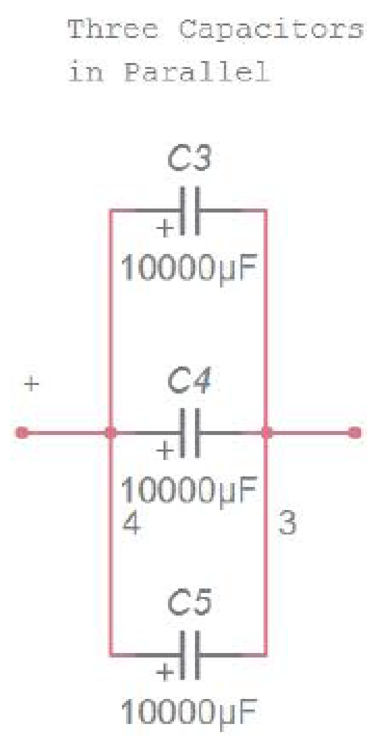
$$\tau = RC$$

As you should find, the three capacitors are close in value to each other.

Experiment 2: Capacitors wired in Parallel

You will use the same circuit as above but replace the lone capacitor with either two in parallel as shown below on the left or three in parallel as shown on the right. The professor will help you with the wiring again.





Once again, you will start the Capstone program recording and then touch the charging tap key and once the voltage is above 8 V, usually around 8.5 V, you will release the charging key, depress the discharging tap key, and hold it until the voltage is below 3.00 V. Note that capacitors in parallel increase their capacitance, so the discharging time will be increased. Do not let the discharge key break contact once you depress it until you are below 3.00 V.

Complete table 02 in the Worksheet:

Once again, fill it in for the trials, then calculate the discharge times, and then determine the averages of the trials. Capacitors in parallel follow the relationship:

$$C_{Parallel} = C_1 + C_2 + \cdots + C_n$$

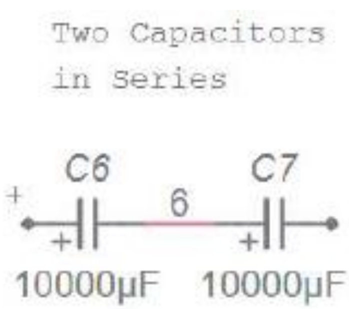
Therefore, for two capacitors you should find the average discharge time is the sum of the two individual discharge times. In addition, for the three of them, it should be the sum of all three.

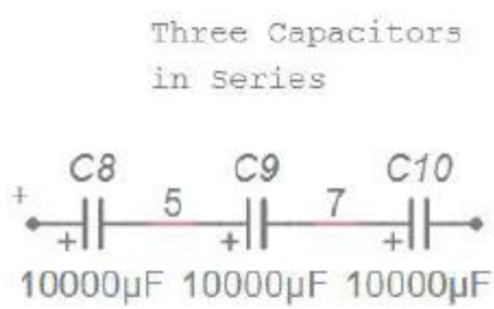
Complete the calculations asked for in the table for the % difference use the following formula:

$$\%diff = \frac{Ave\ Discharge\ time - Calculation\ from\ solo\ capacitors}{Ave\ Discharge\ time}\ x\ 100\%$$

Experiment 3: Capacitors wired in Series

You will use the same circuit as in Experiment 1 above but replace the lone capacitor with either two in series as shown below on the left or three in series as shown on the right. The professor will help you with the wiring again.





Once again, you will start the Capstone program recording and then touch the charging tap key and once the voltage is above 8 V, usually around 8.5 V, you will release the charging key, depress the discharging tap key, and hold it until the voltage is below 3.00 V. Note that capacitors in series decrease their capacitance, so the discharging time will be decreased. Do not let the discharge key break contact once you depress it until you are below 3.00 V.

Complete table 03 in the Worksheet:

Once again, fill it in for the trials, then calculate the discharge times, and then determine the averages of the trials. Capacitors in Series follow the relationship:

$$\frac{1}{C_{Series}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n}$$

Therefore, for two in series, you will find the discharge time is now about $^1/_2$ the time and for three in series you will find it to be about $^1/_3$ the time.

Complete the calculations asked for in the table for the % difference use the following formula:

$$\%diff = \frac{Ave\ Discharge\ time - Calculation\ from\ solo\ capacitors}{Ave\ Discharge\ time}\ x\ 100\%$$