If you did not receive the lecture on series and parallel capacitors, your instructor will give you a short lecture on them now.

**Activity 1: A Quick Quiz on Capacitors**

Read the following information, and take a brief fill-in-the-blanks quiz.

**What is a Capacitor?**

A capacitor is a device that will put charge on its plates in response to an applied voltage. The amount of the charge it puts on its plates is

\[ Q = CV \]  

(1)

where \( V \) is the applied voltage, and \( C \) is the capacitance given by

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

(2)

where \( A \) is the Area of each of the plates, \( d \) is the distance between the plates, and \( \epsilon \) is the permittivity of the material between the plates. The permittivity is sometimes written

\[ \epsilon = \kappa \epsilon_0 \]  

(3)

where \( \kappa \) is the dielectric constant (aka relative permittivity).

**What is the Old-Fashioned Name for a Capacitor?**

A condenser

**A Capacitor Stores Energy. How Much?**

\[ E_{\text{stored}} = \frac{1}{2} CV^2 \]  

(4)
The Electrolytic Capacitors we’re using are very different from conventional capacitors. How so?

The good news: Electrolytic capacitors have much higher capacitance values than most conventional capacitors.

The bad news: They have polarity, so they should not be used with AC. Also, if you hook it up backwards, you can break them. The negative terminal is labelled. Also, these capacitors have a “long leg” and a “short leg.” The long leg is the positive terminal and the short leg is the negative terminal.

**Electrolytic Capacitor Connections**

When connecting electrolytic capacitors in series, the negative terminal of one should be connected to the positive terminal of the other.

When connecting electrolytic capacitors in parallel, the negative terminals of the two capacitors should be connected to each other. Similarly the positive terminal of one should be connected to the positive terminal of the other.

When connecting electrolytic capacitors to batteries, the positive terminal of the capacitor should lead to the positive terminal of the battery and the negative terminal of the capacitor should lead to the negative terminal of the battery.

**What are Typical Capacitance Values?**

From $pF$ to $\mu F$. Interestingly, those in the industry have a special slang for “picofarads”: they call them “puff.” Thus, the 1.5 $F$ electrolytic capacitors have HUGE capacitance values.

**What are Capacitors Good For?**

One of my former students said that they charged up capacitors, and then discharged them on the necks of fellow students DURING CLASS! More seriously, capacitors are everywhere. They are used to store energy. In the movie “Real Genius,” for example, large capacitors are used to stored huge amounts of energy, which is dropped across a laser amplifier which would then power a laser that produced very high power pulses (which were to be used to shoot down enemy aircraft in the movie).

Besides electric energy storage, capacitors are used in electrical filters which act as signal conditioners. High pass filters, low pass filters, bandpass filters, and notch filters all generally use capacitors. A common application would be to filter out noise, which would be present at other frequencies. A typical stereo tuner has an antenna connected to it to pick up your favorite radio station. However, the antenna picks up ALL of the possible stations at once. The tuner uses an adjustable bandpass filter to pick up only the station of interest.

You’ll find capacitors in pretty much every electronic device, including your computer.
**What are Some of the Other Capacitor Characteristics**

In practice, you cannot always just report a single capacitance value for a capacitor. Capacitor values will vary with:

1. Temperature
2. AC Frequency
3. Applied Voltage

For the most part we are going to ignore these subtleties. But, you should keep them in mind. The dielectric used in the capacitor will have a breakdown voltage which, if applied, will destroy it (the experiment has been done by former students, please don’t try it). For more information, see, for example

**More Information about Capacitors**

google "capacitor tutorial"

**Take Quiz**

when everyone is ready.

**Activity 2**

1. It was shown that two capacitors in series can effectively be replaced with a single capacitor of some value. Likewise, two capacitors in parallel can effectively be replaced with a single capacitor of other value.
   (a) Draw two capacitors in series.
   (b) What is the effective capacitance of the series combination?
   (c) Draw two capacitors in parallel.
   (d) What is the effective capacitance of the parallel combination?

2. The same types of arguments may be made for resistors. For capacitors,
   \[ C = \frac{\epsilon A}{d} \]  \hspace{1cm} (5)
   where \( \epsilon \) is the permittivity of the material between the capacitor plates, \( A \) is the area of the plates, and \( d \) is the plate separation. But for resistors,
   \[ R = \frac{\rho l}{A} \] \hspace{1cm} (6)
   where \( \rho \) is the resistivity of the resistor, \( l \) is the length of the resistor, and \( A \) is the cross-sectional area of the resistor. Use arguments similar to those given for capacitors to do the following problems.
(a) Draw two resistors in series.
(b) Obtain the effective resistance of the series combination?
(c) Draw two resistors in parallel.
(d) Obtain the effective resistance of the parallel combination?

3. Once you have finished the above items, check with your lab partners to confirm your answers.

**Activity 3**

1. In the experiment today, you will be using 3 identical capacitors. There are 7 different ways to hook up 3 or less capacitors. If the capacitance of each of the capacitors is C, show the 7 different hookups and the effective capacitance in each case:

<table>
<thead>
<tr>
<th>Configuration #</th>
<th>Schematic</th>
<th>Effective Capacitance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>C</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
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<tr>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td><img src="diagram.png" alt="Diagram" /></td>
<td>2C/3</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Activity 4**

1. The basic experiment will involve the following steps:
   (a) Charge the capacitor (using the Charging Circuit below).
   (b) Discharge the capacitor (using the Discharge Circuit below) measuring time for bulb to go out.
   (c) Repeat this for each of the capacitor configurations in Activity 3 above.
   (d) Repeat steps a) - c) for each person in the lab group so that each person has to connect each of the circuits themselves.
   (e) Take the average of the measurements for each capacitor configuration.
   (f) Use a spreadsheet to make a plot of measured decay time vs. Capacitance. Have your spreadsheet perform a linear curve fit.
   (g) Include the data and the plot in your lab. report.

Notes: The capacitors are electrolytic, MAKE SURE YOU CONNECT THE NEGATIVE TERMINAL OF YOUR CAPACITORS TO THE NEGATIVE TERMINAL OF THE BATTERY.
Charging Circuit:

![Charging Circuit Diagram]

Discharging Circuit:

![Discharging Circuit Diagram]

**Activity 5**

Wilson, Ch. 16. Conceptual Questions