Objectives

- To discover how the charge on a capacitor and the electric current change with time when a charged capacitor is placed in a circuit with a resistor.
- To determine how total capacitance differs when capacitors are wired in parallel and when wired in series.
- To define capacitance and learn how to measure it with a digital multimeter.
- To discover how the capacitance of a parallel plate capacitor is related to the area of the plates and the separation between them.

The Parallel Plate Capacitor

A capacitor consists of two conductors separated by an insulator. The choice of plate area, plate separation, and insulating material determines the "capacitance" of the capacitor. The typical method for transferring equal and opposite charges to the plates of a capacitor is to use a voltage source such as a battery or power supply to create a potential difference between the two conductors. Electrons will then flow off of one conductor (leaving positive charges) and on to the other until the potential difference between the two conductors is the same as that of the voltage source. The capacitance of a given capacitor is defined mathematically as the ratio of the magnitude of the charge, \(q\), on either one of the conductors to the voltage, \(V\), applied across the two conductors so that:

\[
C = \frac{Q}{V}
\]

Thus, capacitance is defined as a measure of the amount of net or excess charge on either one of the conductors per unit voltage.

You can draw on some of your experiences with electrostatics to think about what might happen to a parallel plate capacitor when it is hooked to a power supply as shown in Figure 9-1. This thinking can give you an intuitive feeling for the meaning of capacitance. For a fixed voltage from a power supply, the net charge found on either plate is proportional to the capacitance of the pair of conductors.

![Figure 1 - A parallel plate capacitor with a voltage V](image)

Part 1 - Capacitor Discharging - Visual Method with Light bulbs

A capacitor will store charge when connected to a power supply. If the capacitor is disconnected from the voltage source, and then connected to a resistor (such as a light bulb), it will "discharge" through the resistor. There will be a current flow, which will drop off with time, as the capacitor loses its charge. (We could think of a charged capacitor as a very limited (short-lived) battery). Most capacitors used in electrical circuits contain microFarads of capacitance, so they don't store much charge. We will use a 1 Farad capacitor (the light green capacitor), with our 5-volt power supply to store a relatively large amount of charge.
1. **Circuit configuration.** Set up the circuit below, using the power supply, the large 1 Farad capacitor, and the small light bulb. The wires shown are the banana plug wires, with alligator clips on the ends in the appropriate places. To the right of the second diagram, there is a location where some wires are open-ended, and can be connected as illustrated to either charge or discharge the capacitor. Do not charge the capacitor yet.

![Circuit diagram](image)

Figure 2 - Capacitor/bulb circuit diagram and wiring picture.

**Predictions** Answer on the Data/Question sheet.

a) What will happen to the bulb when it is connected only to the charged capacitor?  
b) Will the brightness of the bulb remain steady, or change with time?

2. **Charging the capacitor.** In the above circuit, connect all three wires and wait 10-15 seconds, for the capacitor to charge up. Plug the end of wire 1 into the back of wire 2 or 3 ... that way you can unplug just wire 1, and thus remove the power supply from the circuit.

*To insure a good connection, connect the two banana plugs in "piggy-back" fashion, rather than through the side connector - this will allow a more "clean" connection in later sections when it is important.*

3. **Discharging the capacitor.** Disconnect wire 1 (quickly -- use a piggyback connection -- one banana plug directly connected to the back end of the other banana plug). This will discharge the capacitor through the resistor.

**Questions** Answer on the Data/Question sheet.

a) Describe what you observed of the brightness of the bulb, over time, after it was connected only to the capacitor.  
b) If your predictions did not match your observations, can you think of an explanation?

**Preliminary activities**

1. **Prepare equipment.** Connect the voltage probe to the Analog Adapter – and to the Xplorer GLX, and finally to the laptop (please follow the instruction in Blackboard). It would also be very helpful to look at the [online help page for this lab](link). Start the DataStudio software.

2. **Load the experiment file.** Load the DataStudio file `Lab09_RC_Circuits.ds` from the Univ2 folder.
Part 2 - Simple RC circuit - voltage/current vs time

Quantitative Measurements on an RC System

The next task is to do a more quantitative study of your "RC" system. We will do this in two ways. The first involves measuring the voltage across a resistor that has been placed in a circuit with a capacitor. This will give us information about the current as a function of time, and the voltage across the capacitor as a function of time (since this is a simple series circuit). The goal here is to verify the mathematical relationship which best relates the voltage across the capacitor and time as the capacitor discharges. [The bulb would not be a good “constant-value” resistor as its resistance is temperature dependent; its resistance goes up when the current heats it.] For these more quantitative studies we will use a 2.2 kΩ (=2200 ohm) resistor in place of the bulb while attempting to charge a 1000 µF capacitor.

[NOTE: This small blue capacitor (1000 µF) must be connected in a particular way - there are arrows on the side of the capacitor pointing to one of its leads - that should be the negative terminal of the capacitor.]

1. Circuit connections. In your previous circuit, replace the large capacitor with the smaller one, and replace the bulb with the resistor as shown below:

![Circuit Diagram](image)

Figure 3 - Capacitor/resistor circuit diagram and wiring picture.

Prediction Answer on the Data/Question sheet
Based on your observations in the bulb section, what do you think will be the shape of the curve of voltage vs. time for the resistor?

2. Measuring voltage. To measure the voltage across the resistor (and thus the current through the system), connect the Voltage probes across the resistor (the red lead should be closest to the positive lead of the power supply). The leads can just clip onto the wires of the resistor between the resistor and the alligator clips (not on the outside free end of the resistor wire – there isn’t any voltage there!).

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Making Voltage vs. Time measurements with DataStudio as a voltmeter

**General procedure that we will follow in the next few steps:**

- Charge the capacitor (for at least 10 seconds)
- Start graphing with DataStudio (see the online help page .. there is a “trigger” before the graph starts)
- Quickly disconnect the power supply (wire 1) ... so the capacitor discharges through the resistor
- Graph might stop by itself in about 15 seconds (we can change that if we wish)

3. **Charging the capacitor.** When all the connections are reset, connect the wire from the high side of the power supply and charge the capacitor.

4. **Start graphing.** Click START to graph the data. (The “trigger” condition won’t be met until after you start the discharge in the next step – but you should see a flickering datapoint indicator at around 4.7 volts on the voltage axis.)

5. **Discharging the capacitor.** Quickly disconnect wire 1 to discharge the capacitor. When the capacitor discharges through this resistor, it will happen within about a minute. But, the data rate is high enough that we can capture this decay curve very smoothly. You should see a graph similar to the one below:

![Discharge graph](image)

**Figure 4 – Discharge graph for single capacitor and resistor. (Your time axis will be different!)**

6. **Rename/hide your single capacitor run.** Name this single capacitor run (maybe “single”?), and save the experiment file under a new name (in case we need to call up the original file).

Questions

- Answer on the Data/Question sheet.

  a) How did your prediction match your observation?

**Part 3 - Calculating the Charge on the Capacitor**

The main features of the previous graph match what we should expect: When the power supply is disconnected, and once the trigger condition is reached, the graph starts and the voltage begins to drop off. The charge on the capacitor is depleted as the current flows around the circuit. If the connection is not good, the start of the drop will not be sharp ... the "piggyback" method should provide a reasonably clean disconnect. One other benefit to starting our graph after the decay has begun ... the initial disconnect of the power wire might not be “clean” – so the start of the decay might be a little “jagged” – we avoid it with our trigger. The beauty of the exponential decay is that it doesn’t matter where we start, there is a predictable decay from that point on.
If we know the voltage across the plates of a charged capacitor, we can determine how much charge is on it. From the capacitance relationship, we know that \( Q = CV \). This will give us our first technique for calculating the amount of charge in our particular system.

1. **Starting voltage.** Using the Smart Tool, position the crosshairs on the very first data point (the x/y numbers should turn RED when you are actually on a data point). Record your value for this initial voltage on the Data/Question sheet.

2. **Calculating charge on the capacitor.** Calculate the charge on the capacitor. (This is actually the charge that was on the capacitor at that moment in time we just found above.) Show the calculation on the Data/Question sheet.

Now, there must be another way we can find the amount of charge on the capacitor. The graph that we made was the voltage across the resistor as a function of time. The resistor was chosen so that it would remain at a stable value, for the current in the system. Thus, our Voltage vs. time curve can be considered a Current vs. time curve (by dividing the voltage by the known resistance - we get the current!). What is the area under a current vs. time curve? (Current x time = charge ... the area under the Current vs. Time curve is the charge that flowed during that time interval!) DataStudio can automatically calculate the area under the curve (thus the integral of the curve). The curve we are looking at is really voltage vs. time; if we calculate the area, we will get volts-seconds as unit for the integral value. If we then divide by the resistance we will get the charge.

3. **Selecting the area under the curve.** Turn off the Smart Tool and go to the Statistics button and select AREA. The graph should automatically fill in – if not, click once near the data curve. The “area” value is the integral of the voltage vs time curve – record this value on the Data/Question sheet.

4. **Calculating the charge.** To calculate the charge, divide the integral value by the known resistance (\( R = 2200 \) ohms). Also calculate the % difference with the calculated charge value from Part 3.2. Show calculations on the Data/Question sheet.

**Part 4 - Voltage vs Time Relationship**

The voltage vs. time curve appears to be an exponential decay curve. We can check that with the FIT capabilities of the DataStudio.

1. **Calculating the time constant from the resistance/capacitance values.** Consider the physics equation below, which we use with the exponential decay of the voltage. The time \( \tau = RC \) is known as the time constant. It is a characteristic of the circuit. This is the time it takes the circuit to drop to 36.8% (or 1/e) of its original voltage. We have the values of the resistance (2200 ohms) and the capacitance (1x10^{-3} F), and can calculate the time constant on the Data/Question sheet.

\[
V = V_0 e^{-t/\tau} = V_0 e^{-t/RC} \quad \text{(physics)} \quad \tau = RC_{\text{capacitor}}
\]

2. **Fitting an equation to the whole graph.** We can have DataStudio curve-fit the data with an exponential equation, so we will be able to use the power of the exponent to get another value for the time constant. Since we have limited the time of the graph, we could reasonably just fit the entire curve, instead of selecting a region. So, click on the FIT button and select NATURAL EXPONENTIAL FIT.
3. Connecting the Physics variables to the DataStudio constants. It is unfortunate that DataStudio chose then letter C for the constant – since we have a capacitor with the same variable name! Comparing the important parts of the DataStudio equation with our physics equation:

\[ V = Ae^{-ct} \quad (DS) \quad V = V_o e^{-t/\tau} = V_o e^{-t/RC} \quad (physics) \]

As shown on the online help page, the DataStudio exponent constant C is the one we need to record on the Data Question sheet.

4. Obtaining the time constant. Take the reciprocal of the DataStudio constant C as the physics time constant. Calculate the time constant on the Data/Question sheet.

5. Time constant from the decay curve. There is still one more way we can calculate the time constant! Starting from the initial voltage, we can look for the voltage value that is 36.8% of the maximum. Now, how much time passed between the maximum and the 0.368V₀ ... the time constant! Now, we can use the smart tool and the Delta tool to do this, but we have to make a slight modification to how we calculate. If we position the Smart Tool at the first datapoint, and use the Delta tool to drag down a bounding box, we should look for 63.2% of the main voltage to show up in the delta tool vertical range. (If the final voltage is 36.8%, then there must have been a drop of 63.2%!) Follow the directions on the help page to find the time for that 63.2% drop in voltage and record the time constant on the Data/Question sheet.

6. One last way (whew!). As a modification of that previous step – let’s look for the drop after two time constants. This means we want a final voltage that is 36.8% of 36.8% of the original ... or 13.5% of the original – thus, we need to look for a voltage drop of 86.5% of the starting value. Calculate the drop for your particular starting value and use the delta tool to find the time for that (remember, this is twice the time constant) – record your values on the Data/Question sheet.

Questions

Answer on the Data/Question sheet.

a) Consider the time constant values found in sections 4.1, 4.4, 4.5, 4.6. Are they reasonably similar to each other (if one or more is very different, can you speculate as to why?)

b) Based on the way the values were obtained, discuss which values might be the most “reasonable” to use to represent our circuit.

7. Clear fits/areas. If you haven’t already done so, rename this run and clear the area/fit results (to make the graph cleaner). We will want to compare this curve to series and parallel capacitor curves.

Part 5 - Series and Parallel RC circuits

You can observe and measure the equivalent capacitance for series and parallel combinations. For this study you can use two identical capacitors (each 1000 μF).  

![Capacitors wired in series](image1)

![Capacitors wired in parallel](image2)  

We can go back to our original circuit, and use combinations of capacitors in series or parallel.
Capacitors in PARALLEL:

Predictions Answer on the Data/Question sheet.
   a) How will the amount of charge stored on each capacitor change by having two capacitors in parallel (as compared to only one capacitor in the circuit)?
   b) What will be the effect on the voltage decay curve of putting two capacitors in parallel?

1. Measure voltage vs. time for two capacitors in parallel. Repeat the steps in Part 2 to measure the voltage vs. time information for two capacitors in parallel. Name the curve (“parallel”?). [Here is a benefit of the “trigger” effect – this curve will start at almost exactly the same location as the single capacitor data run, thus we can easily compare one circuit to another since they all start discharging at about the same time.]

2. Measurements from the voltage vs. time graph. Record the following information from the graph you obtain on the Data/Question sheet.
   a) How does your C_{effective} compare to the individual capacitance (1000 \, \mu F) of each element (is there a rough ratio between them)?
   b) Can you state a mathematical relationship relating the total capacitance of two capacitors in parallel to the individual capacitance?

Capacitors in SERIES:

Predictions Answer on the Data/Question sheet.
   a) How will the amount of charge stored on each of the capacitors change by having two capacitors in series (as compared to only one capacitor in the circuit)?
   b) What will be the effect on the voltage decay curve of putting two capacitors in series?

3. Measuring voltage vs. time for two capacitors in series. Using the same procedure as before, take Voltage vs. time information using two capacitors connected in series. Name the curve (“series”?).

4. Measurements from the graph. Record the following information from the graph you obtain on the Data/Question sheet.
   a) How does your C_{effective} compare to the individual capacitance of each element (Is there a rough ratio between them)?
   b) Can you state a mathematical relationship relating the total capacitance of two capacitors in series to the individual capacitance?

5. Fit and voltage drop for one of the new curves. Choose one of the recent curves (series or parallel) and perform the fit calculation, and the voltage drop calculation (63.2% only). Record your results on the Data/Question sheets. You might want to hide the other data runs while you do this.

6. Annotate and print a graph. Rename this last run (“series”) and show all the data runs (single, series, parallel), and scale the graph to show about 20 seconds (we want to emphasize the differences between the three). You want to print a copy for the final report – if you don’t print in color, you might want to annotate the curves (either by hand or via DataStudio) to indicate which graph is which. See the annotation help page for tips. Save the experiment file when finished!
Part 6 - Building a Capacitor

Overview: Now that we have some familiarity with how capacitors react in a circuit with resistors, we can investigate the properties involved in constructing a capacitor (plate area and separation). Any two conductors separated by an insulator can be electrically charged so that one conductor has a positive charge and the other conductor has an equal amount of negative charge; such an arrangement is called a capacitor. A capacitor can be made up of two strange shaped blobs of metal or it can have any number of regular symmetric shapes such as that of one hollow sphere inside another, or one hollow rod inside another. To complete the next few activities you will need to construct a parallel plate capacitor and use a multimeter to measure capacitance. Thus, you'll need the following items:

- 2 sheets of aluminum foil
- Pages in a "fat" textbook (or a thick pad of paper)
- A digital multimeter (with a capacitance mode)

How does the capacitance depend on the separation of the plates?

You can make a parallel plate capacitor out of two rectangular sheets of aluminum foil separated by pieces of paper. A textbook works well as the separator for the foil as you can slip the two foil sheets between any number of sheets of paper and weight the book down with something heavy to compress the capacitor. (We will do that by placing the book on the floor and standing on it.) You can then use your digital multimeter in its capacitance mode for the measurements.

Predictions Answer on the Data/Question sheet.

a) As the separation between the foil sheets increases, what do you think will happen to the capacitance of our "textbook" capacitor?

b) What do you predict the mathematical relationship will be between the capacitance and the separation distance?

1. Setting up the parallel plate capacitor. If it is not already prepared, arrange the homemade parallel plate capacitor as shown in the diagram below. The aluminum sheets are set up so that they cover most of the page of the textbook. One will stick out one end of the book (to connect to one clip of the meter), and the other foil sheet will stick out the other end of the textbook (to connect to the other clip of the meter). [The power supply is NOT needed for this! Just the meter, foil sheets, and the book!]

2. Put one page of the book between the aluminum foil. Carefully align the aluminum foil sheets with one page of the textbook sandwiched between them. Pick a page near the back, but avoid the last pages, they are sometimes "thicker" than normal.

3. Prepare book to “squeeze” the capacitor. Put the textbook down on the floor (front face up, so the capacitor end is near the floor) and connect the multimeter to it (use alligator clips to connect to the aluminum foil that sticks out the ends of the book. When you measure the capacitance of your "parallel
plates", be sure the aluminum foil pieces are arranged carefully so they don't touch each other and "short out".

4. Finding the thickness of the pages. How thick is one page? Count a large number of pages in the textbook (several hundred) and measure the thickness of that section with a digital caliper. (Remember that if you use page 1 to page 400, that is really only 200 pieces of paper.) Record your information on the Data/Question sheet.

5. Measuring capacitance. Set the multimeter on the 20 nF (nanoFarad = 10^{-9} F) scale, and carefully stand on the textbook to compress the pages and record the reading on the last row of the chart on the Data/Question sheet. (Add the other pages as indicated in the chart after each reading.) (It would be best to stay with the 20 nF scale as much as possible, even if the readings get small … switching scales will change the inner circuitry of the meter and the readings may not match up as well).


Question Answer on the Data/Question sheet. What does the chart illustrate about the mathematical relationship between capacitance and the separation of the plates?

How does capacitance depend on area of the plates?

Prediction Answer on the Data/Question sheet. How do you think the area of the capacitor plates affects the capacitance?

7. Measuring effect of area on capacitance. Place 4 pages in between the aluminum foil sheets. The capacitance you have measured up to this point has been using the full areas of the two sheets. Record that number from the previous chart. Slide one of the sheets out part way (from the end), so that it overlaps the other sheet only by 3/4 of its area (1/4 out of the book). Take a measurement of the capacitance. Then move the same foil so it is only halfway covering the other foil sheet, and then 1/4 of the area. Fill in the chart on the Data/Question sheet.

Question Answer on the Data/Question sheet. What is the mathematical relationship between the capacitance and the plate area, as seen from your chart?
**DATA/QUESTION SHEET FOR LAB 9 - CAPACITORS AND RC CIRCUITS**

**Part 1 - Capacitor Discharging - Visual Method with Light bulbs**

Predictions

a) What will happen to the bulb when it is connected only to the charged capacitor?

___________________________________________________________________________
___________________________________________________________________________

b) Will the brightness of the bulb remain steady, or change with time?

___________________________________________________________________________
___________________________________________________________________________

3. Discharging the capacitor.

Questions

a) Describe what you observed of the brightness of the bulb over time after it was only connected to the capacitor.

___________________________________________________________________________
___________________________________________________________________________

If your predictions did not match your observations, can you think of an explanation?

___________________________________________________________________________

**Part 2 - Simple RC circuit - voltage/current vs time**

Prediction

Based on your observations in the bulb section, what do you think will be the shape of the curve of voltage vs. time for the resistor?

___________________________________________________________________________
___________________________________________________________________________

Questions

How did your prediction match your observation?

___________________________________________________________________________

___________________________________________________________________________
Part 3 - Calculating the Charge on the Capacitor

1. Starting voltage.
   Record that voltage here: \( V_0 = \) ____________ volts

   The capacitance of the capacitor: \( C = 1000 \, \mu F = 1 \times 10^{-3} \, F \)

2. Calculating charge on the capacitor.
   \( Q_0 = CV_0 = \) ________________ coulombs (unit of Coulomb = Volt•Farad)

4. Finding the integral.
   Integral (area) = ________________ volt-seconds

5. Calculating the charge. To calculate the charge, divide the integral value by the known resistance (\( R = 2200 \, \text{ohms} \) ). Also calculate the % difference with the calculated charge value from section 3.2.
   \[
   \text{Charge} = \frac{\text{integral}}{R} = Q_0 = \) ________________ coulombs
   \[
   \text{% difference with previous calculation (3.2)} = \) ________________ %

\[
\left( \text{% difference} = \left| \frac{\text{difference between values}}{\text{average of values}} \right| \times 100 \right)
\]

Part 4 - Voltage vs Time Relationship

1. Calculating the time constant from the resistance/capacitance values. We also have the values of the resistance (2200 ohms) and the capacitance (\( 1 \times 10^{-3} \, F \)), and can calculate the time constant.
   \[
   \text{Time constant} = RC = \tau_{\text{theoretical}} = \) ________________ seconds

4. Obtaining the time constant.
   \[
   \text{Time constant} = \tau_{\mu} = RC = \frac{1}{[\text{DataStudio C constant}]} = \) ________________ seconds
   \[
   \text{% difference between these time values (4.1 and 4.4)} = \) ______________ %

5. Time constant from the decay curve.
   \( V_0 = \) ________________ volts \hspace{2cm} (measurement)
   \( \Delta V = (0.632) \, V_0 = \) ________________ volts \hspace{2cm} (calculation)
   \( \Delta t \, (\text{time for drop of 0.632}V_0) = \) ______________ sec \hspace{2cm} (measurement)

   \[
   \text{Time constant} = \Delta t = \) ______________ seconds \hspace{2cm} (calculation)
   \[
   \text{% difference with } \tau_{\text{theoretical}} \, (\text{Part 4.1}) = \) ______________ %

6. Two time constants! (and a microphone?)
   \( V_0 = \) ________________ volts \hspace{2cm} (measurement)
   \( \Delta V = (0.865) \, V_0 = \) ________________ volts \hspace{2cm} (calculation)
\[ \Delta t \text{ (time for drop of } 0.865V_0) = \text{__________________ sec} \text{ (measurement)} \]

Time constant \( \Delta t/2 = \text{__________ seconds} \) (calculation)

\% difference with \( \tau_{\text{theoretical}} \) (Part 4.1) = ____________ \%

Questions
a) Consider the time constant values found in sections 4.1, 4.4, 4.5, 4.6. Are they reasonably similar to each other (if one or more is very different, can you speculate as to why?)

___________________________________________________________________________

___________________________________________________________________________

b) Based on the way the values were obtained, discuss which values might be the most “reasonable” to use to represent our circuit.

___________________________________________________________________________

___________________________________________________________________________

Part 5 - Series and Parallel RC circuits

Capacitors in PARALLEL:

Predictions
a) How will the amount of charge stored on each of the capacitors change by having two capacitors in parallel (as compared to only one capacitor in the circuit)?

___________________________________________________________________________

___________________________________________________________________________

b) What will be the effect on the voltage decay curve of putting two capacitors in parallel?

___________________________________________________________________________

___________________________________________________________________________

2. Measurements from the voltage vs. time graph.

\[ V_0 = \text{_____________ volts} \quad R = \text{__________ ohms} \]

\[ \text{Integral} = \text{_____________ volts-sec} \quad Q = \text{integral} / R = \text{_____________ coulombs} \]

Then, if \( Q=VC_{\text{effective}} \), then for parallel capacitors: \( C_{\text{effective}} = Q/V = \text{_____________ F} = \text{______} \mu\text{F} \)

Questions
a) How does your \( C_{\text{effective}} \) compare to the individual capacitance (1000 \( \mu\text{F} \)) of each element (is there a rough ratio between them)?

___________________________________________________________________________

b) Can you state a mathematical relationship relating the total capacitance of two capacitors in parallel to the individual capacitance?

___________________________________________________________________________
Capacitors in SERIES:

Predictions  

a) How will the amount of charge stored on each capacitor change by having two capacitors in series (as compared to only one capacitor in the circuit)?

___________________________________________________________________________

b) What will be the effect on the total capacitance of the system of putting two capacitors in series?

___________________________________________________________________________

4. Measurements from the graph.

\[ V_{\text{max}} = \text{__________} \text{ volts} \]
\[ R = \text{__________} \text{ ohms} \]
\[ \text{Integral} = \text{__________} \text{ volts-sec} \]
\[ Q = \text{integral} / R = \text{__________} \text{ coulombs} \]

Then, if \( Q = V C_{\text{effective}} \), then for series capacitors:

\[ C_{\text{effective}} = \frac{Q}{V} = \text{__________} \text{ F} = \text{_______} \mu \text{F} \]

Questions  

a) How does your \( C_{\text{effective}} \) compare to the individual capacitance of each element (Is there a rough ratio between them)?

___________________________________________________________________________

b) Can you state a mathematical relationship relating the total capacitance of two capacitors in series to the individual capacitance?

___________________________________________________________________________

5. Fit and voltage drop for one of the new curves.  

Which curve (series/parallel)? ________

Time constant = \( \tau_{\text{fit}} = RC = \frac{1}{[\text{DataStudio C constant}]} = \text{__________} \text{ seconds} \)

\[ V_0 = \text{__________} \text{ volts} \]
\[ \Delta V = (0.632) V_0 = \text{__________} \text{ volts} \]
\[ \Delta t \text{ (time for drop of 0.632} V_0) = \text{__________} \text{ sec} \]

Time constant = \( \tau_{\text{drop}} = \Delta t = \text{__________} \text{ seconds} \)  \( \text{ (calculation) } \)

\% difference with \( \tau_{\text{fit}} \) (Part 5.5) = \text{__________} \%

Part 6 - Building a Capacitor

How does the capacitance depend on the separation of the plates?

Predictions  

a) As the separation between the foil sheets increases, what do you think will happen to the capacitance of our "textbook" capacitor

___________________________________________________________________________

b) What do you predict the mathematical relationship will be between the capacitance and the separation distance?

___________________________________________________________________________
4. Finding the thickness of the pages. How thick is one page? Count a large number of pages in the textbook (several hundred) and measure the thickness of that section with a digital caliper. (Remember that if you use page 1 to page 400, that is really only 200 pieces of paper.)

\[
\text{# of pages measured } \quad \text{thickness of that stack } \quad \text{m}
\]

Thickness of one page = total thickness / # pages = __________ m

5. Measuring capacitance.

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<tr>
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Question: What does the chart illustrate about the mathematical relationship between capacitance and the separation of the plates?

How does capacitance depend on area of the plates?

Prediction: How do you think the area of the capacitor plates affect the capacitance?

7. Measuring effect of area on capacitance.

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<tr>
<td>Capacitance (nF)</td>
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</table>

Question: What is the mathematical relationship between the capacitance and the plate area, as seen from your chart?

How do I write up this lab? … What is required for this lab report?

Consult the Rubric for this experiment and the “Lab Report Instructions” document (both found on the Lab Schedule page).

Questions/Suggestions -> Dr. Scott Schneider - S_SCHNEIDER@LTU.EDU

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