Capacitors

1. Editable Microsoft Word versions of the student pages and pre-configured TI-Nspire files can be found on the CD that accompanies this book. See *Appendix A* for more information.

2. We designed this experiment around resistors and capacitors available at Radio Shack.

3. This experiment can be done with either the Differential Voltage Probe or the Voltage Probe. The 30-Volt Voltage probe is not recommend for this lab.

4. If possible, prepare students by doing an experiment with a 1 F capacitor and a flashlight bulb. Charge the capacitor and discharge through the bulb. Observe the brightness decrease with time. By using the large 1 F capacitor, the change is brought to a human scale.

5. The experiment calls for 10 μF, non-polarized capacitors, since they can be placed in the circuit either way. These are often sold for use in loudspeaker crossover circuits. Any voltage rating can be used, but lower voltage-rated capacitors are usually less expensive. If you choose to use an ordinary polarized electrolytic capacitor, the negative side of the capacitor must be connected to the negative battery terminal (with the resistor in between), or the circuit will not work. In fact, if wired backward, electrolytic capacitors can be destroyed.

6. Resistors are typically marked with a tolerance of 5 or 10%. Capacitors often have 10% or 20% tolerances. Do not expect outstanding agreement with the marked values. You may want to have students measure the resistance with a good ohmmeter and the capacitance with a trusted capacitance meter, if available.

7. Other combinations for *R* and *C* can be used. If the time constant *RC* is significantly different from 2 s, then you will need to adjust the data collection parameters. As a general guide, take data for a duration of approximately 5 time constants, and during that time gather about 500 points. If the time constant is too short, it becomes difficult to coordinate discharging the capacitor by throwing the switch and initiating data collection.

8. You may want to show students that the ohm × farads is equivalent to seconds:

$$\text{ohm} \times \text{farad} = \left(\frac{\text{volt}}{\text{ampere}}\right) \times \left(\frac{\text{coulomb}}{\text{volt}}\right) = \left(\frac{\text{coulomb}}{\text{ampere}}\right) = \frac{\text{coulomb}}{\left(\frac{\text{coulomb}}{\text{second}}\right)} = \text{second}$$

9. If you have the student flip the switch on the circuit just as they start data collection, the entire graph will be of charging or discharging. In these cases, the value of the A fit parameter will be a meaningful value. For discharges, it will be the initial voltage.

10. If you are using a multi-channel interface like the TI-Nspire Lab Cradle, this activity can be done using triggering. To set up triggering do the following:

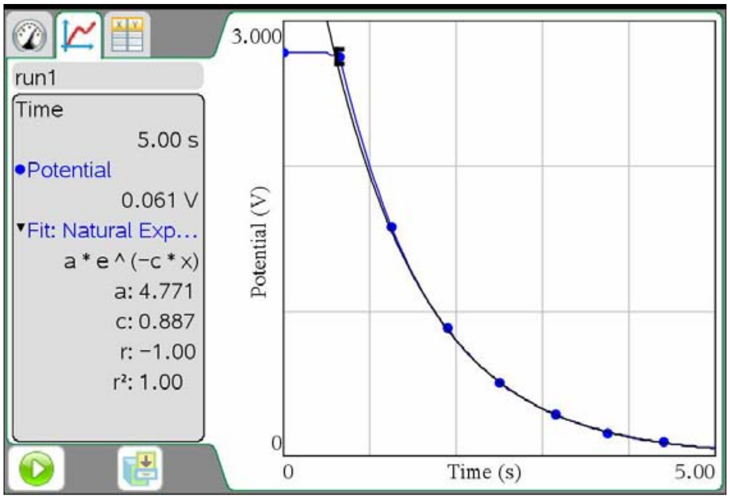
    a. Charge the capacitor for 10 seconds with the switch in the closed position.
    b. Watch the reading on the screen and note the maximum value reached. You will need this value in a later step.

c. Choose Advanced Set Up ► Triggering ► Set Up from the Experiment menu.
d. Select your voltage probe as the sensor to use as the trigger.
e. Select **Decreasing through Threshold** as the type of trigger to use.
f. Enter a trigger level of 90% of the maximum voltage you observed in step b as the threshold in units of the sensor. For example, if your maximum voltage was 5 V, enter 4.5.
g. Select OK.
h. After you start data collection, you will see the *Waiting for Trigger* message. Open the switch to discharge the capacitor. Data collection will begin automatically when the voltage decreases across the trigger threshold. Your graph will be displayed after data collection is complete.

ANSWERS TO PRE-LAB QUESTIONS

1. Graph is a decaying exponential. The first few values are 1000, 900, 810… (with integer part of 10% taken each time).
2. Second graph decays more quickly: 1000, 800, 640…

SAMPLE RESULTS



Typical graph of 100 kΩ resistor shown with natural exponential curve fit.

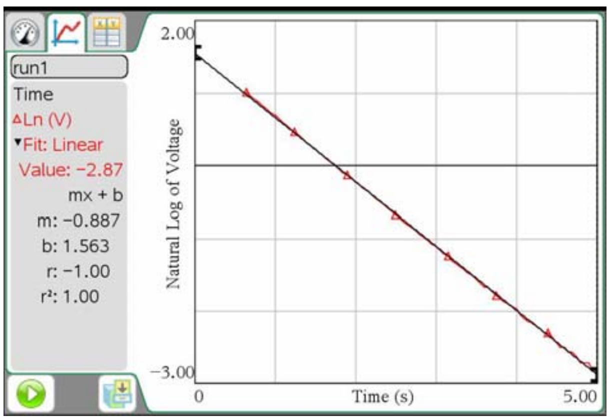
	Resistor	Capacitor	Time constant	Fit parameters		
Trial	R (Ω)	C (F)	RC (s)	A	C	1/C
Discharge 1	100×10^{3}	10×10^{-6}	1.0	4.77	0.89	1.12
Discharge 2	47×10^{3}	10×10^{-6}	0.47	9.5	1.74	0.58

ANSWERS TO QUESTIONS

1. The inverse of the fit constant C is approximately the same as the time constant. The fit parameter A corresponds to the potential across the capacitor at $t = 0$, in volts. The parameter C corresponds to 1/RC and has units of inverse seconds.
2. Since the capacitor values are typically good to only ±20%, some variation is to be expected.
3. Students can calculate maximum and minimum possible values for the product of resistance and capacitance and see if values calculated from the curve fits fall within that range.
4. Decreasing the value of the resistor allowed the capacitor to discharge and charge more quickly.

EXTENSIONS

1. The slope of this line is the opposite of the C value in the natural exponential model. The absolute value of the reciprocal of the slope is the time constant.



2. After one time constant, approximately e^{-1} or 37% of the potential remains. After two time constants, the potential is reduced to 13% of the initial potential and after three the potential is down to 5%.
4. The light bulb is not *ohmic*; that is, the current is not proportional to the potential across it. As the current starts to flow through the wires, the bulb's filament is cool. The wires warm up quickly and their resistance increases. As a result, a graph of potential *vs.* time is not a simple exponential.
5. Different values for *R* and *C* will create different time constants. If, however, the product *RC* is the same, the time constant will be the same.
6. Capacitors in parallel behave as a single capacitor with the sum of the individual capacitances. The time constant should be doubled.
7. Two equal capacitors in series behave as a single capacitor with half the capacitance of one of the individual capacitors. The time constant will be cut in half.