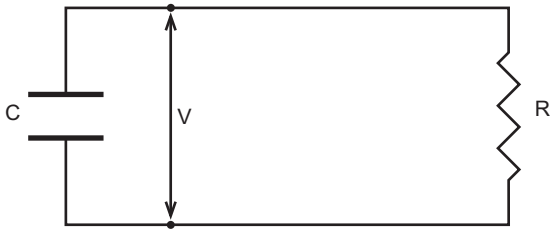
Activity 8: Capacitor Discharge

Equipment*	Quantity
Xplorer GLX	1
Voltage Probe	1
Capacitor (between 0.015 and 1 F)	1
Resistor (between 100 and 1000 Ω)	1
Battery and battery holder ("AA," "C," "D," or similar)	1
Alligator Clip Leads	4

*Use separate electronic components or the PASCO EM-8678 Charge/Discharge board, which includes a capacitor, resistors, and battery holder.

Background



In the circuit pictured above, the rate at which the voltage, *V*, decreases is directly proportional to the voltage. Mathematically, this can be written:

(eq. 1) $$\frac{dV}{dt} = -\tau V$$

where dV/dt is the rate of voltage change, and τ is a constant greater than 0 known as the Capacitive Time Constant. The negative sign indicates that the voltage *decreases* over time.

Equation 1 can be rewritten:

(eq. 2) $$\ln\frac{V}{V_0} = -\tau t$$

where V is the voltage at any given time, t; and V_0 is the voltage at $t = 0$.

In this experiment, you will create a circuit like the one in the diagram. The GLX will measure and graph voltage over time as the capacitor discharges. From the collected data, you will determine the capacitive time constant, τ, of your circuit.

Before You Begin

Start a new experiment on the GLX.

1. Press (⌂) to go to the Home Screen.

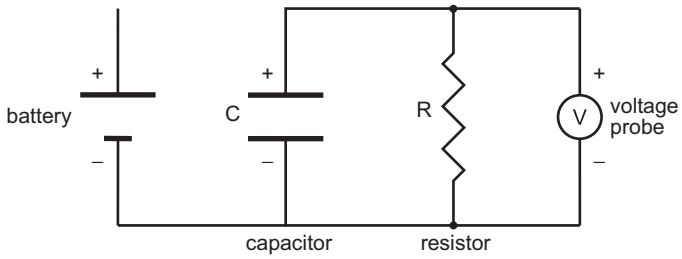
2. Use the arrow keys to highlight the Data Files icon and press (✓) to open the Data Files screen.

3. Press (F4) to open the Files menu and press (1 pqrs) to select New File.

4. When the GLX asks if you would like to save the previous file, press (F1) to save or (F2) not to save.

Procedure

Equipment Set-Up



1. Create the circuit pictured above. Note that the negative terminal of the battery is connected, but the positive terminal is not. The voltage probe is connected so that it will measure the voltage across the capacitor.

2. Record your values of capacitance and resistance. (Measure them directly if you have capacitance and resistance meters, or record their nominal values.)

   C = _____

   R = _____

GLX Set-Up

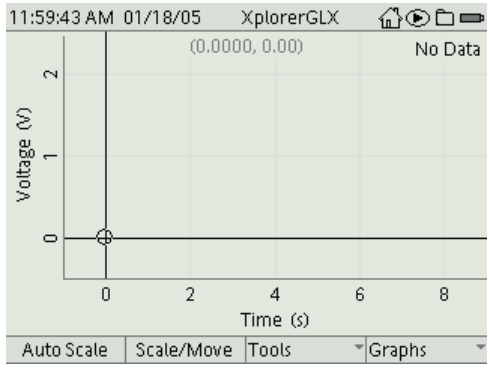
1. Connect the voltage probe to the GLX.

a) Connect the voltage probe to the voltage port on the left side of the GLX.

b) If there are other sensors connected, remove them.

2. Set up the Graph to plot Voltage versus Time.

Press ⌂ to return to the Home Screen; press F1 to open the Graph. The display will be automatically set up to graph Voltage versus Time.



Graph prepared to plot *V* vs. *t*

Data Collection

1. Charge the capacitor by temporarily connecting the positive terminal of the battery to the positive terminal of the capacitor. Keep the connection for about 5 seconds before proceeding to the next step. (Do not leave this connection in place for too long, as it will drain the battery.)

2. Disconnect the positive terminal of the battery and immediately press ▶ to start data collection.

3. Press F1 to automatically scale the Graph.

4. After the voltage has dropped below 0.1 V, press ▶ to stop data collection.

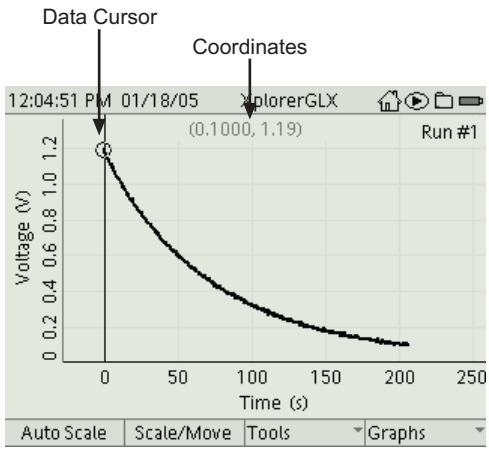
Analysis

From Equation 2, it is apparent that, on a graph of $\ln(V/V_0)$ versus t, the slope would equal $-\tau$. In this analysis, you will find the value of the constant V_0, calculate $\ln(V/V_0)$ for every recorded value of V, create a graph of $\ln(V/V_0)$ versus Time, and find its slope.

1. What was the voltage recorded at $t = 0$?

Press the up arrow key to move the Data Cursor to the first recorded point. The coordinates of the point are displayed at the top of the Graph.

V_0 = _____



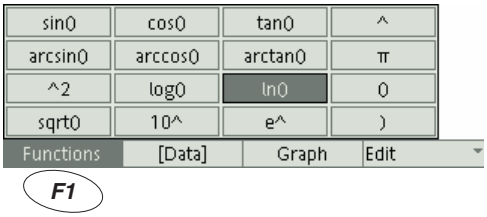
2. Create a calculation for $\ln(V/V_0)$.

a) Press (⌂) to return to the Home Screen; press (F3) to open the Calculator.

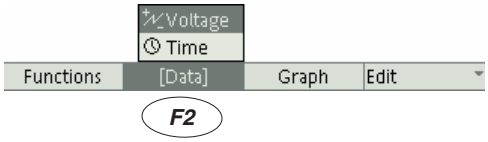
b) On a blank line, enter:

ln([Voltage (V)]/v0) (✓)

To insert the ln() function, press (F1) to open the Functions menu, used the arrow keys to highlight ln(), and press (✓).

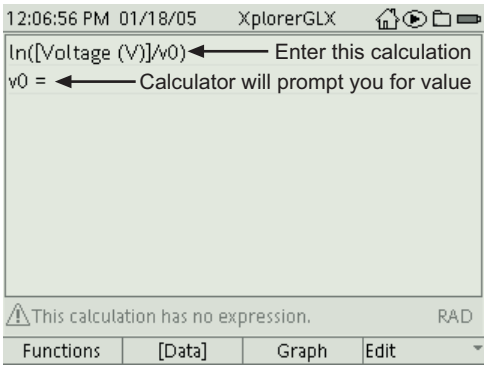


To insert [Voltage (V)], press (F2) to open the [Data] menu and select Voltage.



To type the letter v on the GLX keypad using multipress text input, turn *off* Num Lock* and press (2tuv) several times until the letter v appears.

c) The Calculator will prompt you on the next line to enter the value of v0. Type the initial voltage and press (✓).



*For more information on multipress text entry, see page 103.

*If Num Lock is on (as indicated by the icon 🔒 in the lower right corner of the screen), press (F4) then press (1pqrs) to open the Edit menu and turn off Num Lock.

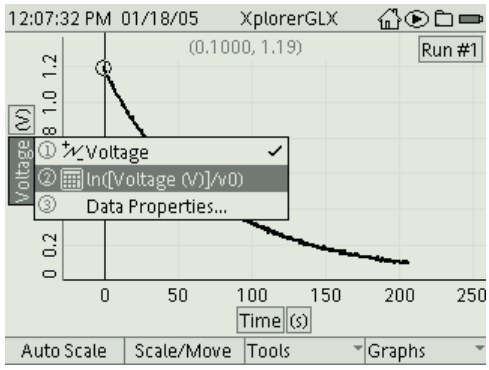
For more information on multipress text entry, see page 103.

3. Make a graph of $\ln(V/V_0)$ versus t.

a) Press ⌂ to return to the Home Screen; press F1 to open the Graph display.

b) Press F4 to open the Graphs menu; press 6mno to select New Graph Page.

c) Press ✓ *twice* to highlight the data source menu. Select ln(v/v0) from the menu



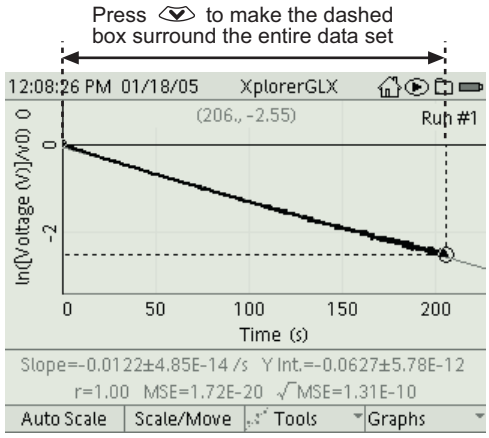
4. Apply a linear fit and find the value of τ.

a) Press F3 to open the Tools menu; press 5jkl to select Linear Fit.

b) Press the down arrow key to make the dashed box surround the entire data set.

c) The slope of the best-fit line equals τ.

τ = _____ (include units)



5. (Optional) Repeat the experiment with different resistors. Make a graph of R versus τ. What is the relationship between time constant and resistance?

6. (Optional) Repeat the experiment with different capacitors. Make a graph of C versus τ. What is the relationship between time constant and capacitance?