Experiment 4 Solutions: RC Circuits

Question 1:
What is the resistance of the resistor? Using the two-point method, what is the time constant of this circuit? Using this time constant and the typical expression for an RC time constant, what is the capacitance of the capacitor?

To measure the resistance just put the resistor across the battery leads and measure current for 1 V (10 mA → $R = 100 \, \Omega$). Using the two point method we randomly pick a first point on the decay (green cursor, $V = 4.741 \, V$) and then calculate $1/e$ of this (1.744 V). Put the second (red) cursor as close to this voltage as possible. This gives a time difference of $\tau = 10 \, \text{ms}$. Using $R = 100 \, \Omega$ from above, $C = \tau/R = 100 \, \mu F$. 
**Question 2:**

Using the logarithmic method, what is the time constant of this circuit? Using this time constant, what is the capacitance of the capacitor?

For variety I measure the slope of the current, $-0.098$ ms$^{-1}$, (the voltage is the same) so:

$$
\tau = \frac{-1}{\text{slope}} = \frac{-1}{-0.098 \text{ ms}^{-1}} \approx 10.2 \text{ ms} \quad \Rightarrow \quad C = \frac{\tau}{R} = \frac{10.2 \text{ ms}}{100 \Omega} = 102 \mu\text{F}
$$

Note that the curve begins to roll over as the data quality becomes worse. Stick near the top where it is linear.

**Question 3:**

Using one of the two methods used above, what is the time constant of this new circuit? Is there any difference between this circuit (where the battery "turns off") and the one you solved analytically in class (where a switch opens next to the battery)? If so, what? If not, why not?

Here I fit the slope of the voltage and found $-0.19$ ms$^{-1}$, so:

$$
\tau = (-\text{slope})^{-1} = (-0.19 \text{ ms}^{-1})^{-1} = 5.3 \text{ ms}
$$

The resistors are in parallel and hence have a net resistance of $50 \Omega$, so the time constant is shorter.

This circuit is different than the one we solved in class because there the 2nd resistor was cut out of the circuit on discharge when the switch was opened, so the charge and discharge time constants were different. Here both resistors are always effectively in parallel (note that that isn’t obvious – you need to short out the battery to see it).