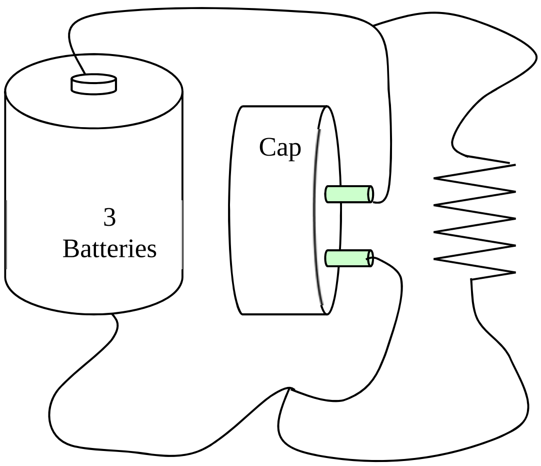
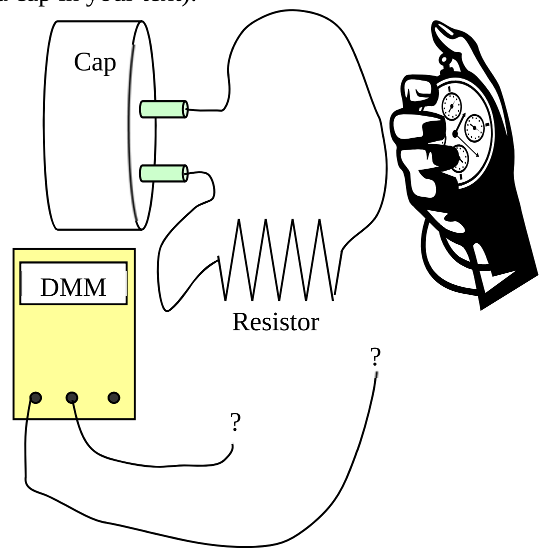
RC Transients

Part I: RC Circuit

Below you see a picture of two circuits (and a giant hand holding a stopwatch…or is it tiny?): one with a battery, resistor and a capacitor & one with only a resistor and a capacitor. In this experiment you first charge the capacitor(s). Higher capacitance implies higher amounts of stored energy. The energy will dissipate according to an exponential decay with time constant $\tau = RC$ (look up discharging a cap in your text).



Charging the capacitor



Discharging the capacitor

Get the materials. You will be running the first part of this experiment with the following RC combinations:

C=0.1 F with R=4.7 kΩ (measure the actual value of resistance with a DMM)
C=0.1 F with R=1 kΩ (measure the actual value of resistance with a DMM)
C=0.025 F with R=4.7 kΩ (measure the actual value of resistance with a DMM)
Calculate the time constants and predict which combination should decay the fastest/slowest.

First charge the cap. Connect a resistor and a capacitor in parallel (start with the slowest RC). Connect the cap (and thus also the resistor) in parallel with 3 batteries provided by your instructor (or use a 4.5V current limited DC source). Measure the voltage across the cap to ensure it has reached 4.5 V (or the max voltage put out by the batteries).

Now disconnect the batteries/power. Immediately after disconnecting the battery portion of the circuit you should start a stopwatch and simultaneously record the ***DC voltage*** across the resistor with a DMM. With your stopwatch tabulate the voltage versus time ON THE RESISTOR ONLY. Take values for a length of time equal to 5τ at roughly 10-30 second intervals. *If you want to you could try to get this going using Data Studio but I expect your final results to done using Excel.*

Repeat the same experiment with different *RC* combinations. Use a 0.1 F cap with a resistor of about 4.7 kΩ, a 0.1 F cap with a resistor of about 1 kΩ, and a 0.025 F cap with a resistor of about 4.7 kΩ. Measure all resistors to get accurate values for the resistance.

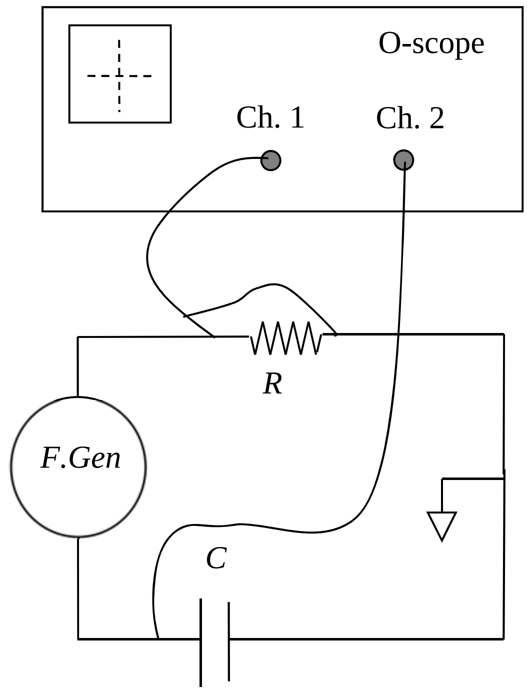
Check! Keep track of your data and label it well so you don't get confused. By now you should have three data sets showing one column of t and the other column being V. Be sure each data set is label with both the R and the C used for that data set.

Part 1: Graphing Mayhem!

Plot the voltage on the resistor versus time (V_R vs. t) for the three sets of data. Be sure to show the appropriate curve fit on the plot with regression coefficient and equation on a linear-linear plot. Determine τ from the trendline equation.

Plot lnV_R vs. t for the three sets of data. Perform the appropriate curve fit to the data and notice what happens to the curve defined by your data. Determine τ from the trendline equation. Which graph gives a more accurate value of τ? See checklist for what to include for your report.

Part II: Another RC Circuit



Select a capacitor and resistor set such that τ is about 0.1 msec (try R=1kΩ and C=0.1μF). Connect a function generator with a square wave function (if none is available use the PASCO interface box) to R and C as shown to the right. Set the function generator to produce a 1 kHz square wave with 2.0 V amplitude and DC offset of 1.0 V (you may need to hit the 20dB button). To do this first connect the function generator to the scope directly (without the R and C) and adjust the dials until it is reading appropriately. Use DC coupling (press the Ch1 menu button to get to this).

Connect the leads of the 10x probe from Channel 1 as seen in the diagram. Use the coupling switch set to DC mode (not AC mode like last week). The ground should be connected between the resistor and capacitor (not between the resistor and the function generator). **The function generator will need to be floated from ground using the grounding plug adapters.**

Now connect a second 10x probe to channel 2 of the scope. You need not use the ground connection because the ground connection is already between the resistor and capacitor from channel 1. Connect the lead of the probe to the opposite side of C in order to read the voltage across the capacitor. Display both channel 1 and channel 2 of the scope at the same time. What do you notice about the voltages on the cap and resistor? Do they add up to the voltage across the function generator? Try using the INVERT button (press the Ch2 menu button to get to this). What happens? Should you be using the INVERT button? Hint: read conclusion questions.

SKETCH the waveforms seen on channel 1 of the scope.

- You may choose to use a flash drive to export the waveform to your computer and print it in lieu of sketching.
- Be sure to modify the time scale and voltage scale so that the sketch scope displays the largest possible waveform that includes one decay.
- Label your sketch with the scale of each axis.
- Specifically note the time required for the voltage to decrease to half of the maximum value ($t_{½}$).
- Determine the time constant from $t_{½}$.

Conclusions:

Part I:

1) How do the time constants relate to the fitting parameters of your graph? Specifically, for each RC combination list the theoretical and experimentally determined time constants (τ) with percent differences. Explain both predicted trends and discrepancies.
2) Could we have plotted the voltage on a capacitor instead of the resistor; what would differ and what would remain the same? Explain and defend your answer.
3) What sources of error dominate the experiment? How could the experiment be improved?

Part II:

4) In Part II you noted the time to drop to half of the maximum voltage. Use this information to determine the capacitance of the cap you used in the experiment (and if available compare to the known value with a percent difference). Hint: consider $\tau = RC$ and also include the input impedance of the function generator if appropriate. 5) Why is it reasonable to compare an inverted channel 2 signal to a non-inverted channel 1 signal (hint: how should $V_R + V_C$ compare to V_{fg})?
6) When comparing the two signals, what happens to the voltage (absolute value) on the resistor over time? What happens to the voltage (absolute value) on the capacitor over time? What is true about the sum of these two voltages over time?

Checklist:

- Raw data (with borders) with variables(not words) as column headings (in italics) and units (not italics)
- Three graphs (use graph which determines τ most accurately: V_R **vs.** t or **ln**V_R **vs.** t)
- On each graph show trendline, R^2, and calculation of τ
- Sketch/print-out of waveforms for part II showing approximately 1-2 periods of the waveform
- Annotate your sketch/print-out with the time for the V_R to drop by 50%
- Determine the time constant from $t_{½}$
- Answer all conclusion questions using full sentences