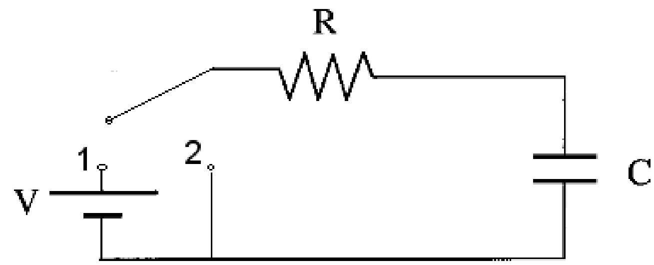
RESISTANCE AND CAPACITANCE IN A DC CIRCUIT



Introduction

Consider the circuit in figure above. If the switch is placed in position 1, the circuit is complete and includes the battery. At this point, current flows through the resistor and capacitor. The capacitor acts like charge reservoir. It is capable of holding an amount of charge $Q_{saturation}=CV$. As the current flows through the capacitor, the charge builds up in the capacitor. As the amount of charge in the capacitor approaches $Q_{saturation}$, the capacitor will have less room for more charge, so the current will become less and less. If one were to keep the switch in position 1 for a long enough time, the capacitor would become (nearly) fully charged and the current would (nearly) cease to flow. In this case, the current is proportional to the room left for more charge in the capacitor ($Q_{saturation}-Q$).

Now, suppose the capacitor is fully charged and the switch is placed in position 2. The capacitor will discharge through the resistor. At first, the capacitor will readily release its charge through the resistor, i.e. the current will be relatively high. As time progresses, the capacitor will have less charge to give away. as a result the current will decrease over time. In this case, the current is proportional to the charge in the capacitor.

Current is the instantaneous flow rate of charge. In any situation where an instantaneous rate of a variable is directly proportional to the variable itself (like both of the cases above), the result is an exponential curve. The current will exponentially decay as a function of time in both of the cases above.

All exponential decays have a characteristic “half-life”. This is the time that it takes for the dependent variable to be reduced by ½. The half-life for both of the cases above is $\tau_{1/2}=ln2\cdot RC$ (Where R is the resistor's resistance and C is the capacitor's capacitance.). In other words, if the current is 1 amp at t=0 seconds, it will be .5 amps at $t=\tau_{1/2}$ seconds later, .25 amps at $t=2\tau_{1/2}$ later, etc...

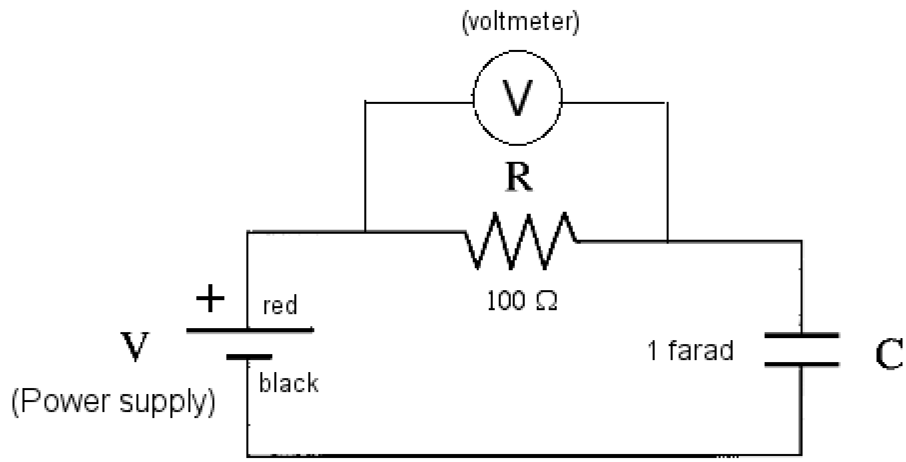
The potential across the resistor will always be proportional to the current. So, everything discussed above for current should work for voltage in the circuit above.

Procedure

You will measuring be two RC decay half-lives. The first will be long enough to measure using a multimeter and a stopwatch. The second half-life will be one that more typically would appear in electronic circuits and will require an oscilloscope and a signal generator.

Part 1

Step 1
Set up the circuit below with the power supply off.



Step 2
Turn on the power supply, adjust it to 2 volts and start the stopwatch. Record the time and voltage every 15 seconds for 5 minutes.

Step 3
Disconnect the wires from the power supply and short them together. Again, record the time and voltage every 15 seconds for 5 minutes.

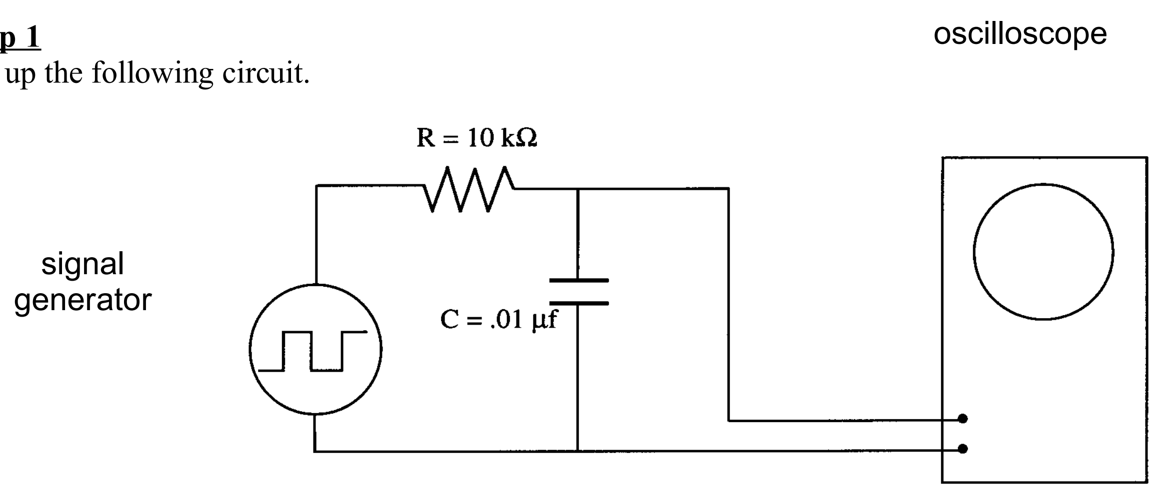
Step 4
Plot the data from step 1 and 2 on separate plots. Find an experimental half-life from both plots.

Step 5
Measure the resistance of R with a multimeter (Disconnect the resistor from the circuit first!). Using that measured resistance and your measured half-life (from step #4) get an experimental value for capacitance of C. The manufacturer claims that this is a 1F capacitor with a 20% tolerance. Does your result coincide with this claim?

Part 2

In this part you be using a square wave to act like the battery and a switch from Part 1. To the capacitor, the input voltage will appear to be switched high and low.

Step 1
Set up the following circuit.



CAUTION:
The negative terminals of the signal generator and oscilloscope may be connected together through the third prong of the power cords. To avoid unwanted connections that may bypass circuit elements make sure that you connect the negative terminal of the oscilloscope to the negative terminal of the signal generator.

Step 2
Set the signal generator to a frequency such that the period of the square wave is significantly longer than your expected RC decay half-life. Why is a longer period important?

Step 3
Record the half-life from the oscilloscope. Compare this to your calculated value.