Simple Circuits

1st year physics laboratories

University of Ottawa

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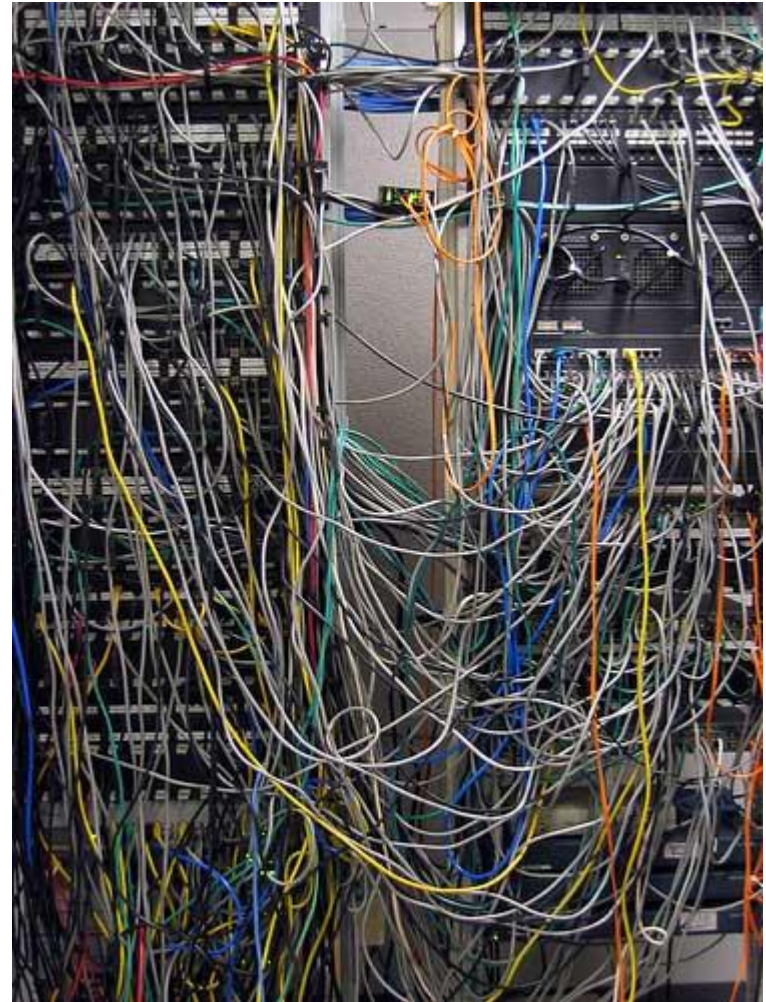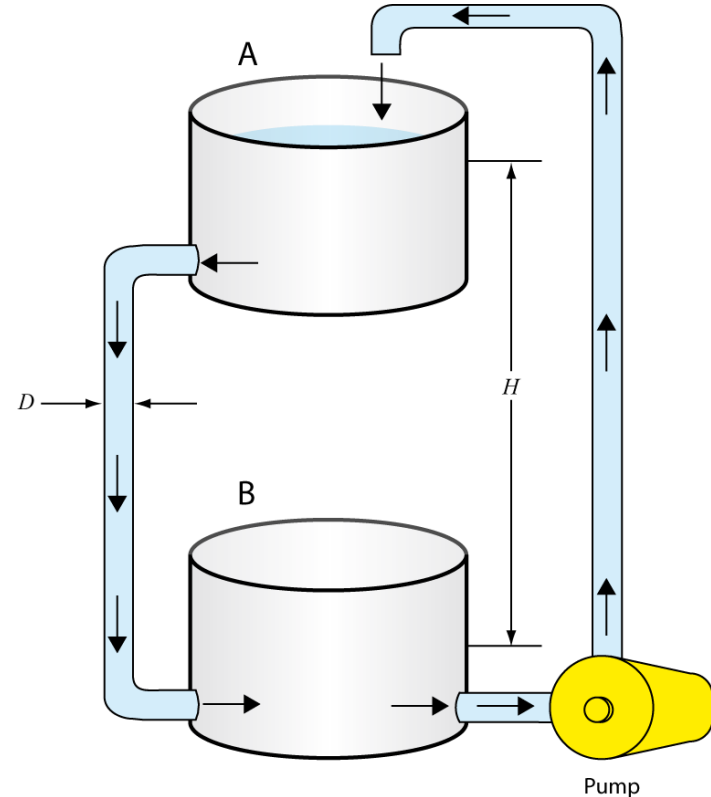
INTRODUCTION

- An electrical circuit consists of a closed loop with a number of different elements through which electric current passes.

- Important variables are voltage (V), current (I), resistance (R), and conductance (C).

- Consider the water pump analogy to understand voltage.

CURRENT, VOLTAGE, and OHM'S LAW

- **Conductivity and resistivity:**

  - Conductivity is defined as $\sigma = (l/A)C$ l is length, A is area.
  - Resistivity is $\rho = 1/\sigma$
  - Resistance, R, of an element is its ability to limit current flow.

- **Ohm's Law:** $\Delta V = RI$

  - Defines the relationship between electric potential, current, and resistance.
  - A plot of voltage vs current in a circuit will have a slope equal to the resistance.

KIRCHOFF's RULES

- The Junction Rule (conservation of charge)
  - The sum of the currents entering any junction must equal the sum of the currents leaving that junction.

- The Loop Rule (conservation of energy)
  - The sum of the voltage changes across each element around any closed circuit loop must be zero.

- Consider the circuit on the following slide…

- Consider point c where the current splits. We have (from the junction rule): $\boxed{I_1 = I_2 + I_3}$

- Consider the loop that goes through R_1 and R_2. We go through the power source and pick up ΔV_0 then pass through the two resistors dropping the voltage to 0:
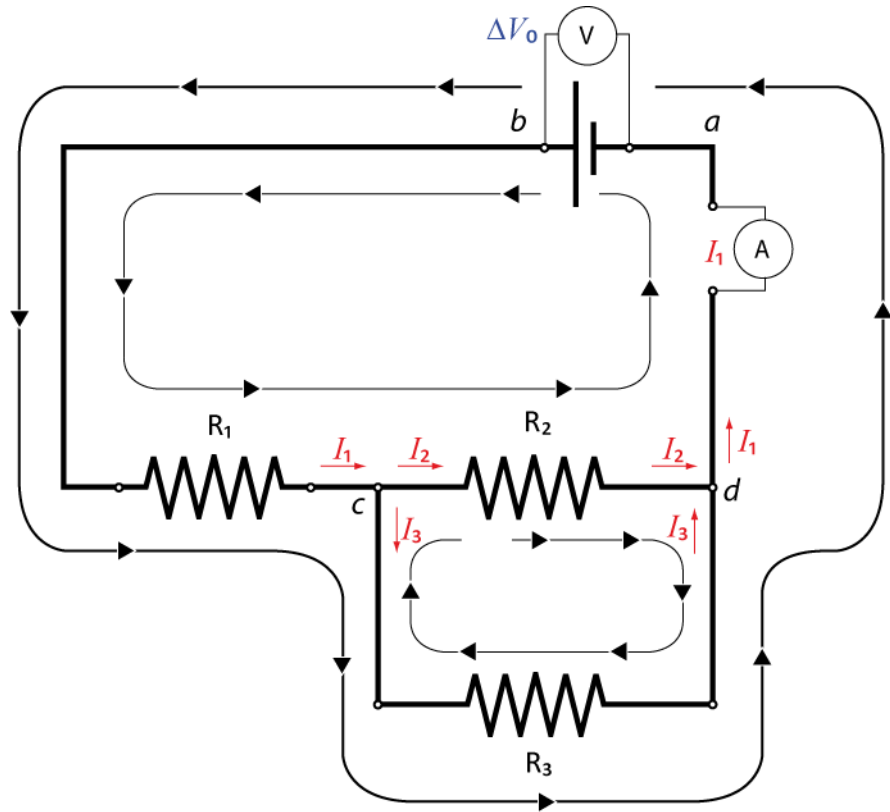
$$\Delta V_0 - \Delta V_1 - \Delta V_2 = 0$$
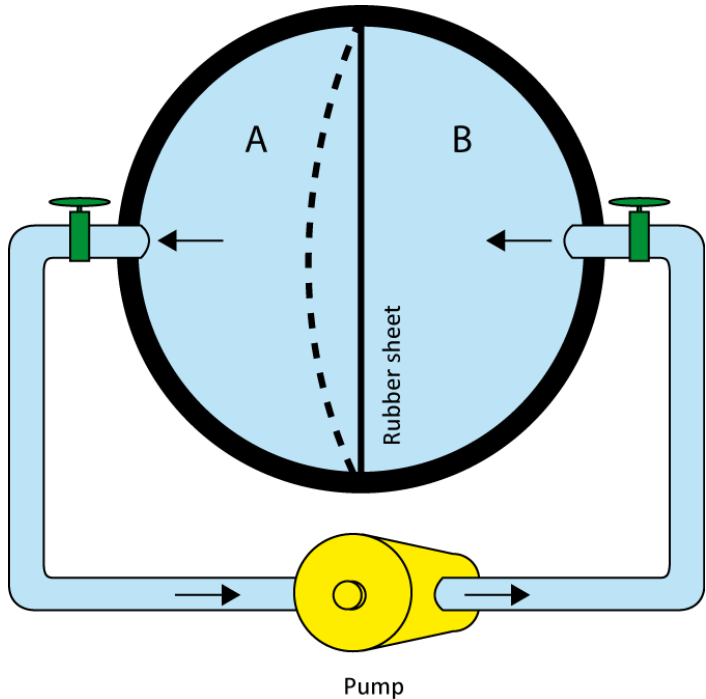$$\boxed{\Delta V_0 - R_1 I_1 - R_2 I_2 = 0}$$

- Consider the small loop that goes through R_2 and R_3. A test charge will drop through R_2 and rise through R_3 therefore we have:

$$-\Delta V_2 + \Delta V_3 = 0$$
$$\boxed{-R_2 I_2 + R_3 I_3 = 0}$$

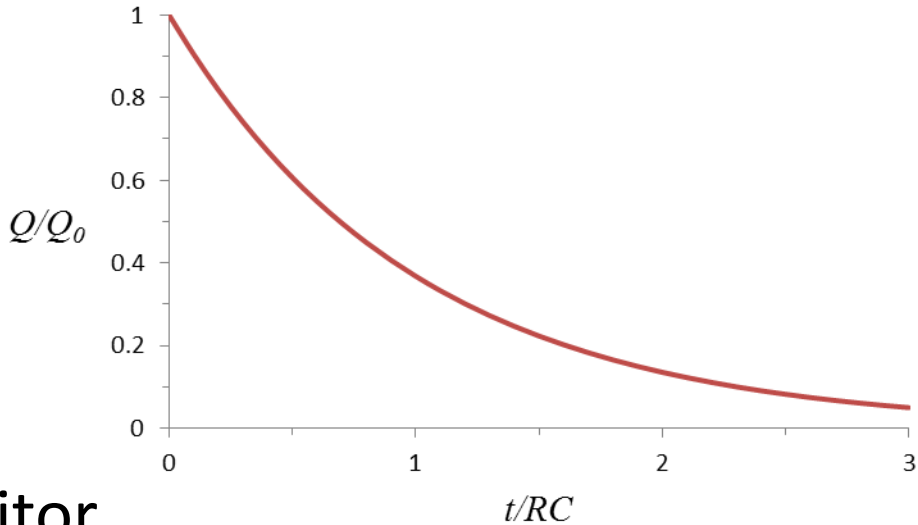# SAMPLE CIRCUIT

CAPACITORS IN CIRCUITS

- A capacitor is used to store electrical energy in a circuit.

- A simple analogy can be seen in the figure of the hollow sphere divided into two equal volumes.

- RC Circuits:

  - In an RC circuit, the capacitor discharges its stored energy through the resistor.

  - The charge in the capacitor, Q, is expressed using the exponential function:

$$Q = Q_0 e^{-t/RC}$$

DISCHARGE of a CAPACITOR in RC CIRCUIT

- In $Q = Q_0 e^{-t/RC}$, RC is the relaxation time.

- When $t = RC$, the charge has dropped down to $e^{-1} = 0.368 = 36.8\%$ of its original value.

- The figure to the right shows how the charge on the capacitor is depleted as a function of relaxation times.

- In this lab you will measure the relaxation time using a digital oscilloscope which is precise enough to measure very small timescales.

OBJECTIVES

1) Measuring **a resistance value** using colour code and Ohmmeter

2) Verify **Ohm's law** using a simple circuit on a breadboard

3) Investigate simple circuits with **resistors in series and parallel**.

4) Review **Kirchoff's rules** for circuit analysis.

5) Investigate simple circuits with **combinations of capacitors** and **resistor-capacitor (RC) circuits**.
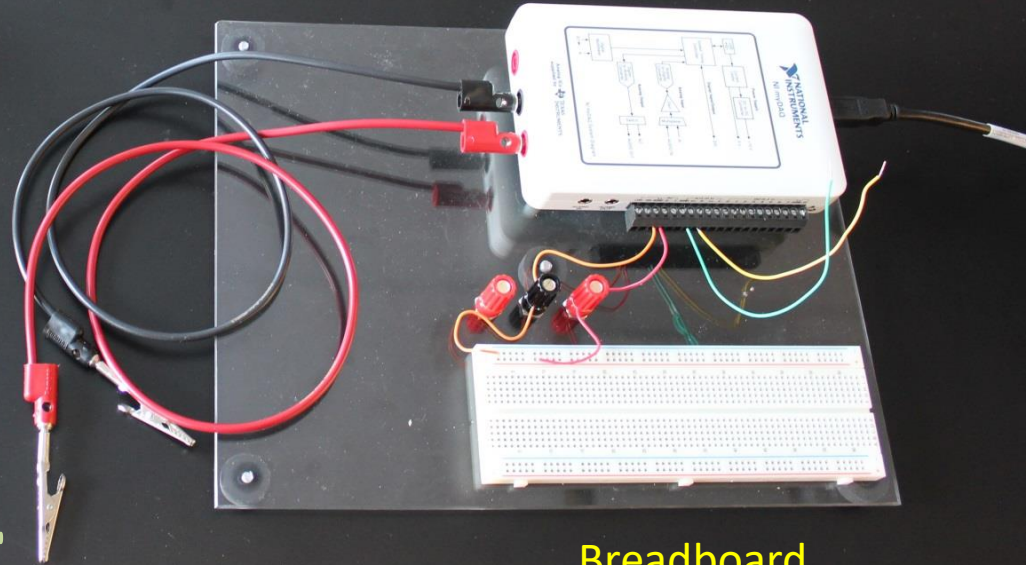
TUTORIALS!

- You should have read the following tutorials before coming to the lab session:
  - Building circuits
  - Using a multimeter
- The tutorials contain vital information on how to manipulate the electronics you will be using in the lab today to investigate simple circuits!
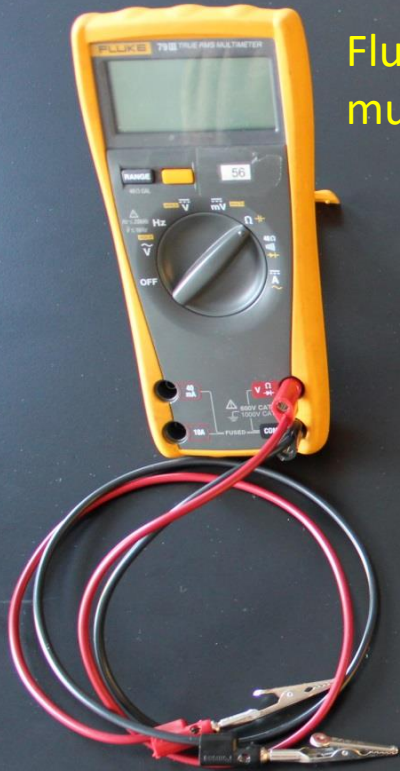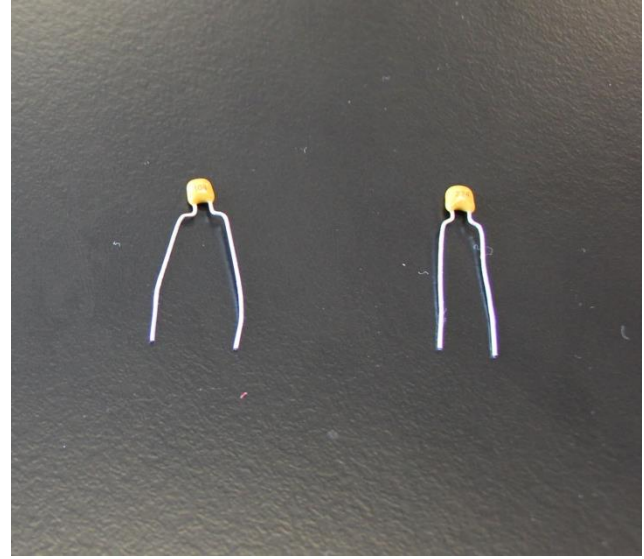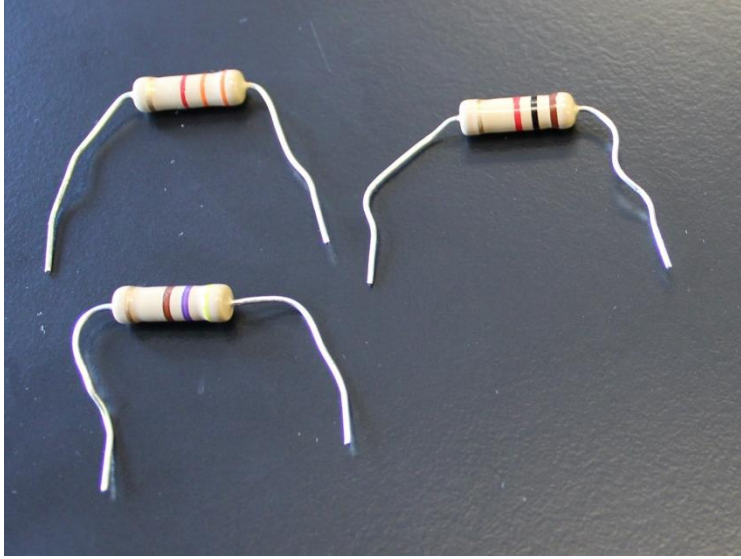
Fluke multimeter

myDAQ:

- Multimeter
- Power supply
- Oscilloscope
- Function generator

EQUIPMENT

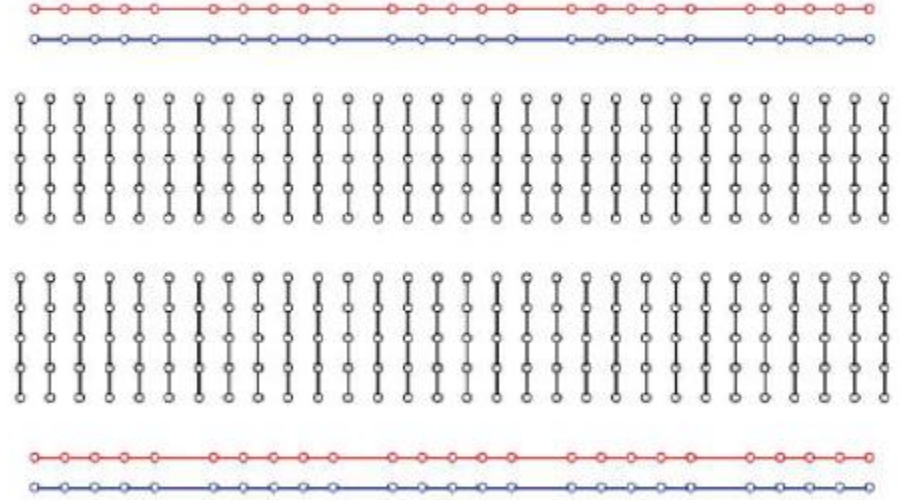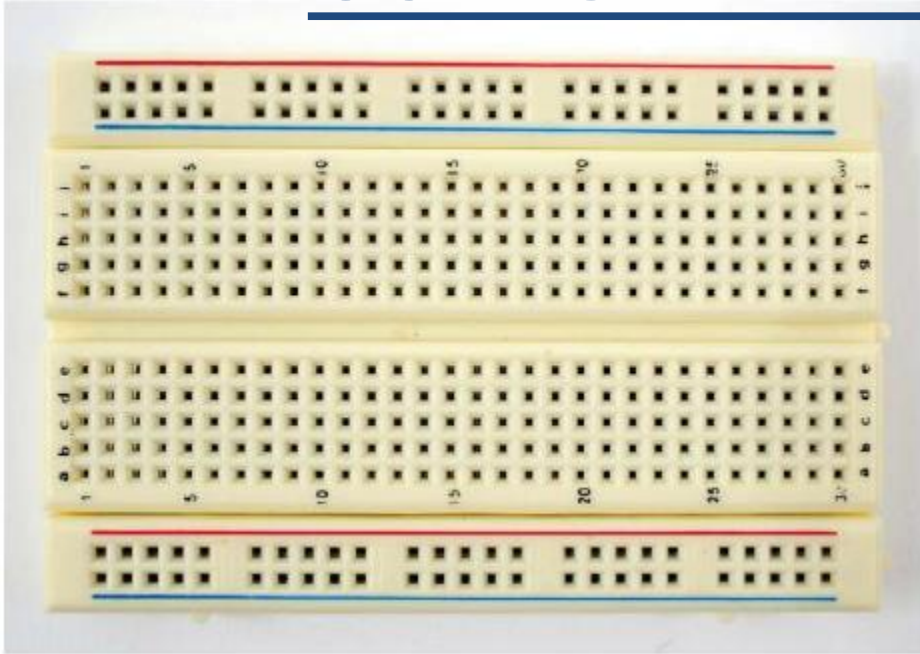Breadboard

RESISTORS AND CAPACITORS

- The resistors have a colour code on them that gives their rated resistance and uncertainty.
- The capacitors use a 3 digit code – the first two numbers are the value and third number is the multiplier times pF: 543 means 54 x 1000 pF = 54nF.

RESISTOR COLOUR CHART

- Example:
  1- Red (2)
  2- Black (0)
  3- Orange (10^3)
  4- Gold (5%)

- Resistance value:
  20×10^3 Ω ± 5%
 (20 ± 1) kΩ

- You will use this chart to complete **PART 1**.

|	1st band	2nd band	3rd band	4th band
	1st significant figure	2nd significant figure	Multiplier	Tolerance
Silver	-	-	10^{-2}	10%
Gold	-	-	10^{-1}	5%
Black	-	0	1	-
Brown	1	1	10	1%
Red	2	2	10^2	2%
Orange	3	3	10^3	-
Yellow	4	4	10^4	-
Green	5	5	10^5	0.5%
Blue	6	6	10^6	0.25%
Violet	7	7	10^7	0.1%
Grey	8	8	10^8	-
White	9	9	10^9	-

USING THE BREADBOARD

- On the left is a sample of the type of breadboard you will be using.
- On the right is the hidden connection pattern of the pins in the board.

BUILDING A CIRCUIT FROM A DIAGRAM
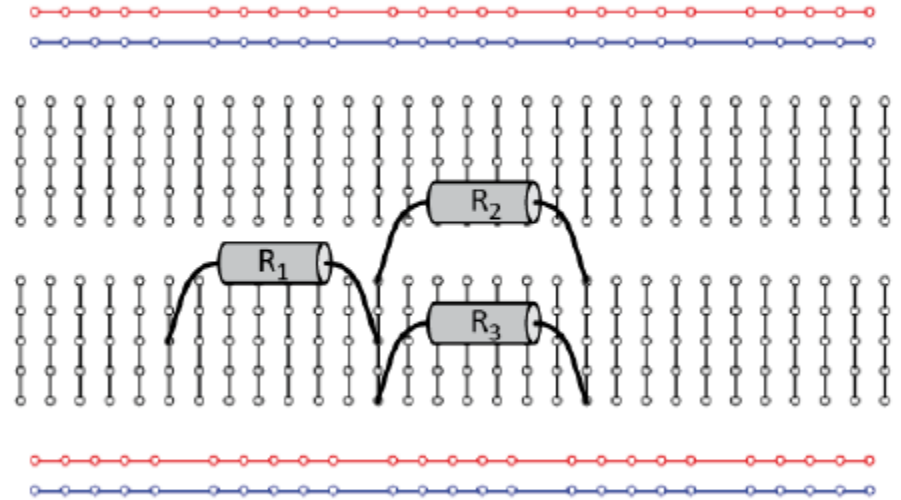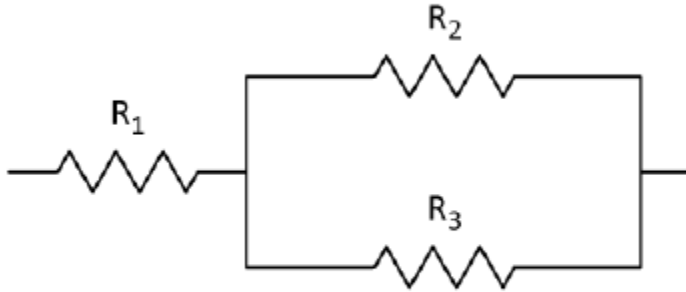
- On the left is the circuit diagram of a combination of resistors in series and parallel.

- On the right is an example of how you can connect the resistors using the hidden connection pattern.

SETTING UP VOLTMETER AND AMMETER
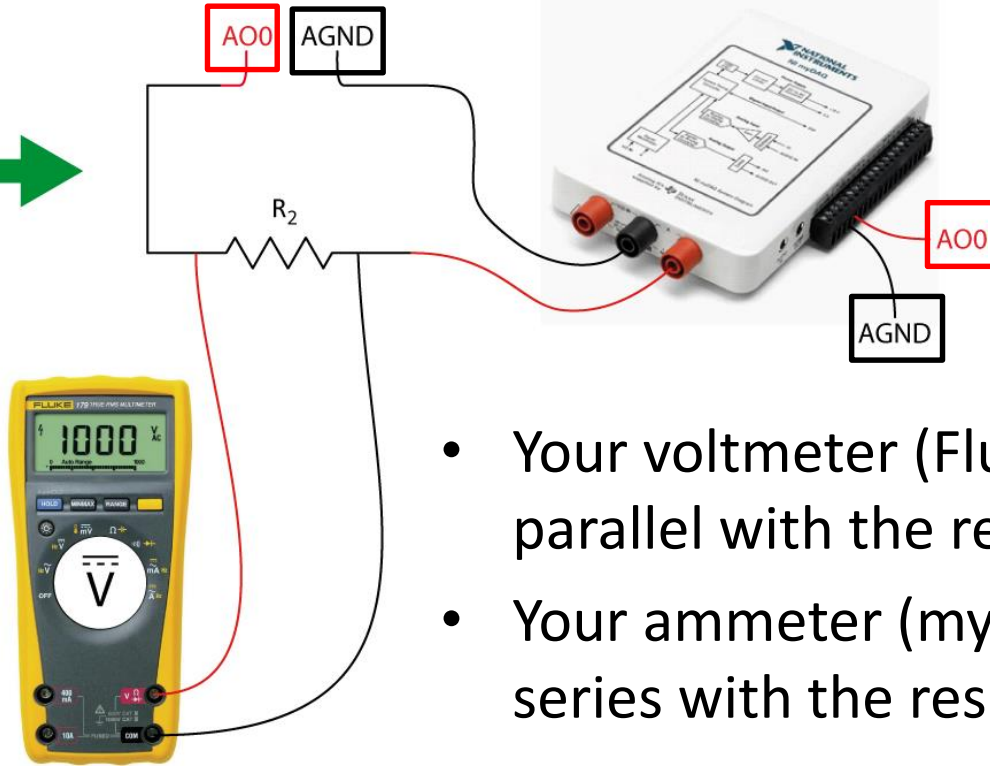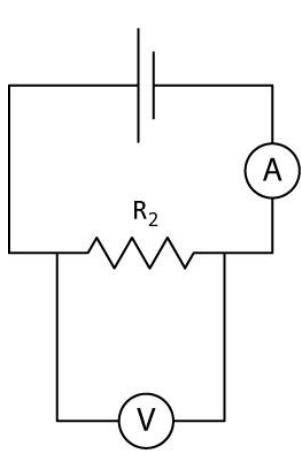
- Your voltmeter (Fluke) will be in parallel with the resistor.

- Your ammeter (myDAQ) will be in series with the resistor.

- You will build this circuit in **PART 2** to verify Ohm's law.

myDAQ DIGITAL MULTIMETER
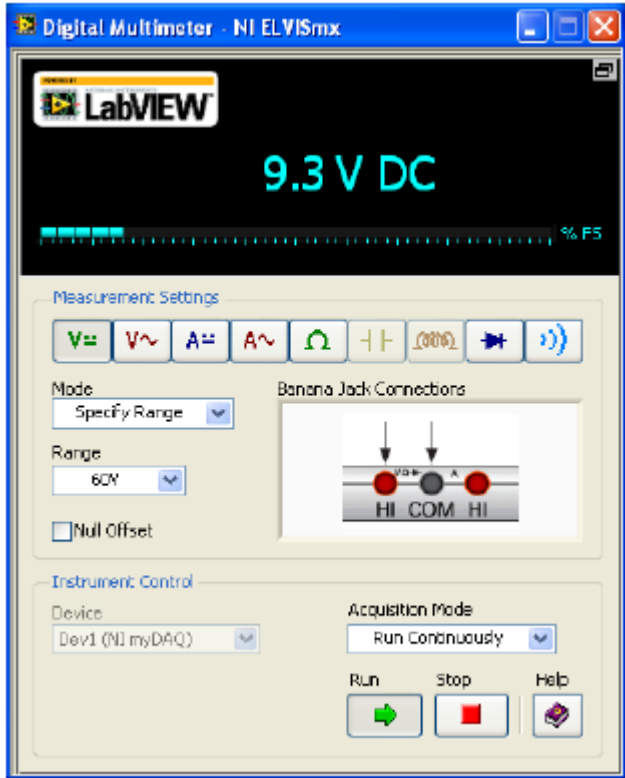
- The digital multimeter program is located on your desktop.

- You can use the software to measure voltage, current and resistance.

- The range can be specified or leave it on auto mode so that the software will determine your range for you.

- Depending on what variable you are measuring, you might need to change the position of the banana cable.

DC Level POWER SUPPLY PROGRAM

- The DC Level Power Supply program is located on your desktop.

- The correct channels for output (myDAQ AO 0) should be selected then click the "Start" button.

- You can change the voltage output in as necessary (range is 0 – 5 V) ("hit Enter").

- The voltage output is shown on the graph.
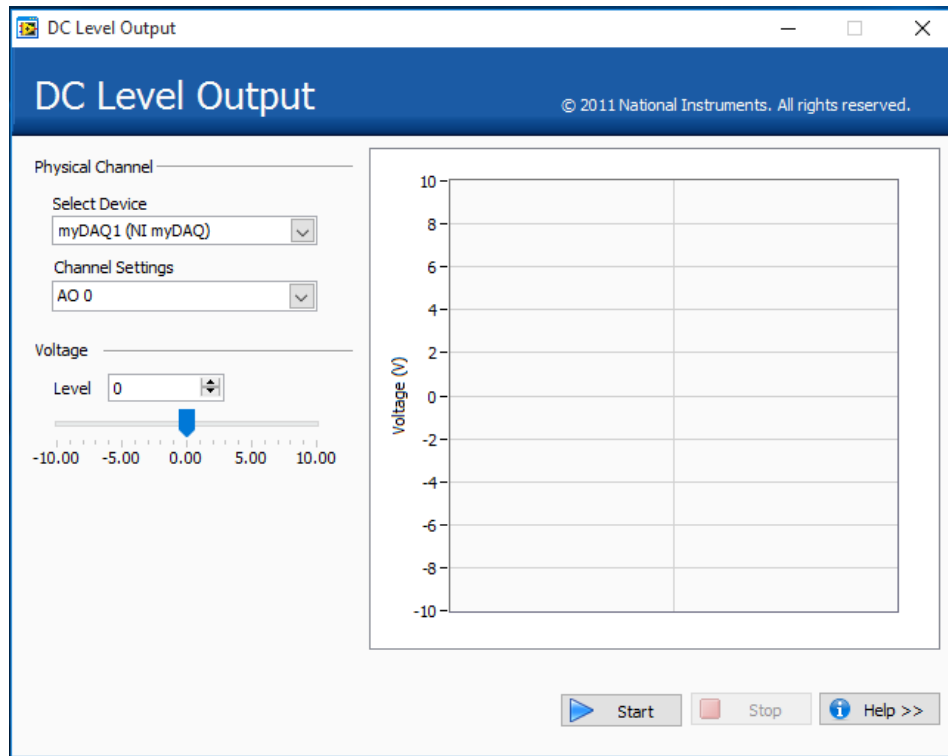
A CIRCUIT WITH SEVERAL RESISTORS

- In **PART 3** you will measure the effective resistance of various combinations of resistors in series and parallel.

- In **PART 4** you will verify Kirchoff's rules using the circuit shown on the right along with your voltmeter (FLUKE) and ammeter (myDAQ) to measure the voltage and current at different sections.
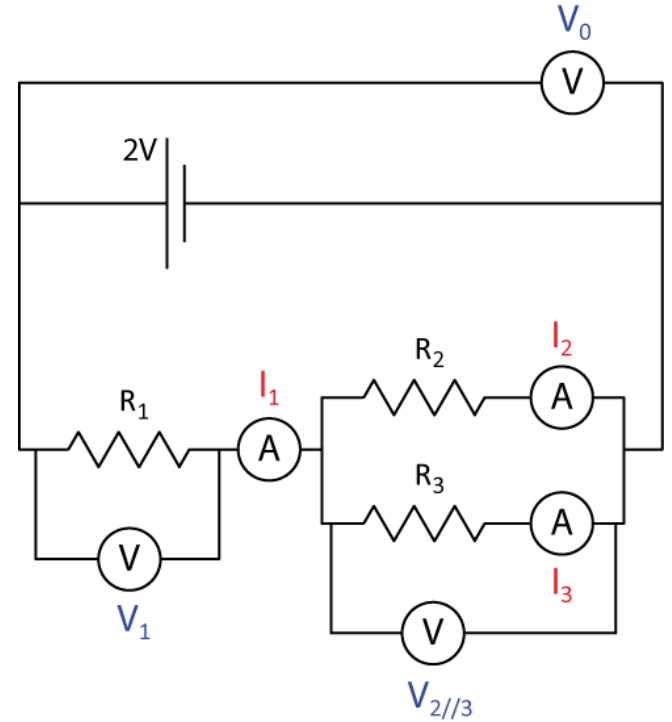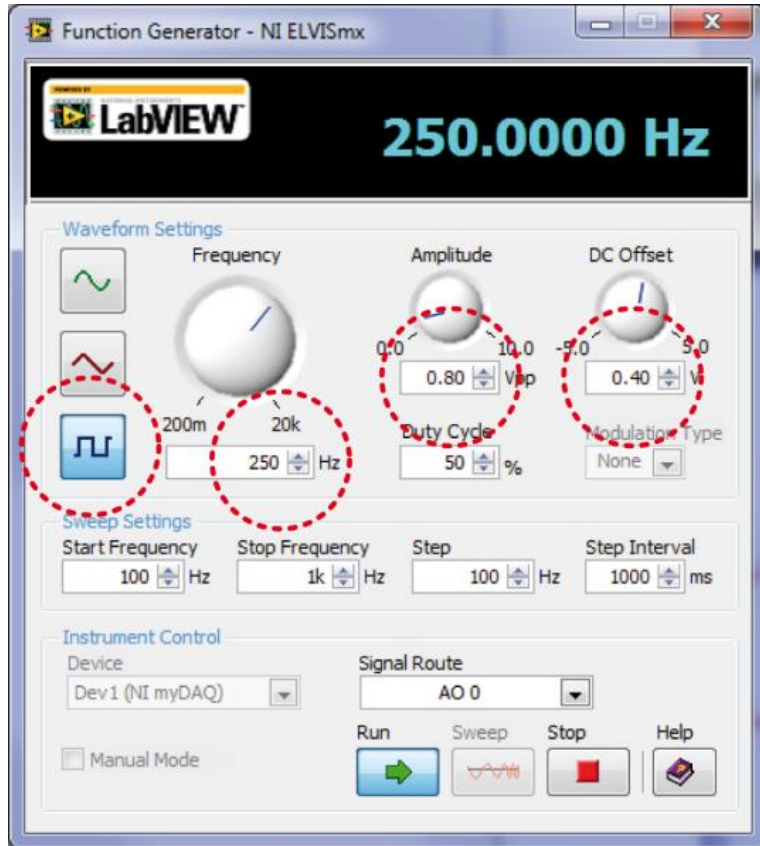
SETTING UP YOUR RC CIRCUIT (PART 5)
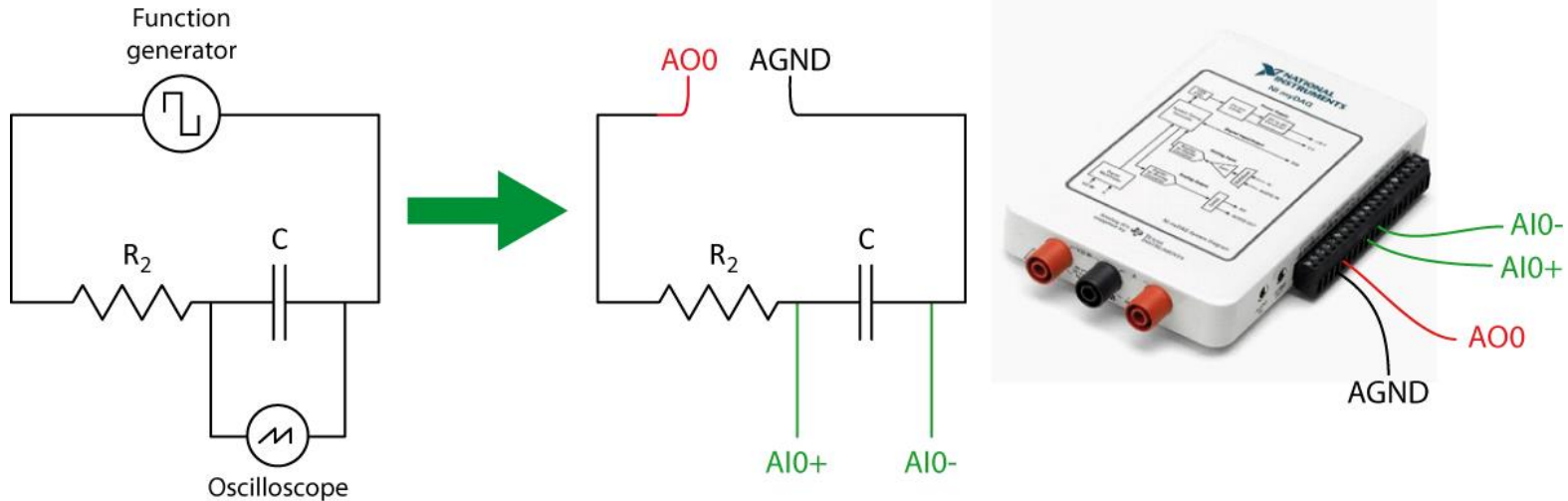
- You will use the myDAQ as both the power supply **function generator** (AO0, AGND) and a **digital oscilloscope** (AI0+, AI0-).
- The oscilloscope will measure the voltage on the capacitor as a function of time through the charging and discharging stages.

myDAQ FUNCTION GENERATOR

- The Function Generator software is located on the desktop.

- You will use the square wave function.

- You will set the frequency, voltage, and DC offset as instructed.

- A duty cycle of 50% means that for each pulse, half of the cycle will be at your required voltage and half will be at 0.

myDAQ DIGITAL OSCILLOSCOPE

- Oscilloscope = Volmeter!!!
- You first need to set the vertical (voltage) and horizontal (time) scales.
- You need to set a trigger type and voltage. This is a minimum voltage reading necessary for your trace to appear on the oscilloscope.
- The graph should show one full cycle (charging and discharging the capacitor).
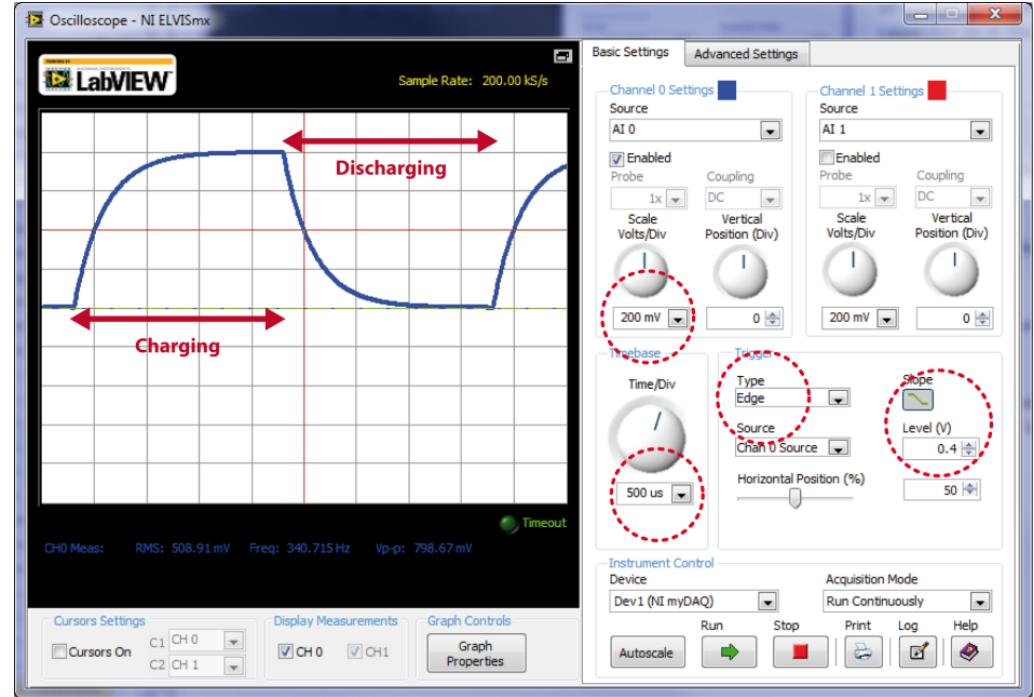
- You will export the data to Logger Pro to do a fit and find the capacitance.

CLEAN UP

- Turn off the computer and **don't forget to take your USB key.**
- Turn off the Fluke multimeter. Disassemble your circuit and put back the three resistors and the two capacitors in your wire kit box.
- Please recycle scrap paper and throw away any garbage. Please leave your station as clean as you can.
- Push back the monitor, keyboard, and mouse. Please push your chair back under the table.

- Thank you!

DUE DATE

The report is due at the end of the lab session.
Please give it to your TA.

You are about to complete your last physics lab for this semester!