Lab Experiment: RC circuits and electrical meters

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Family Name:	___________	______________	______________	______________
First Name:	___________	______________	______________	______________
Student Number:	___________	______________	______________	______________

Objectives:

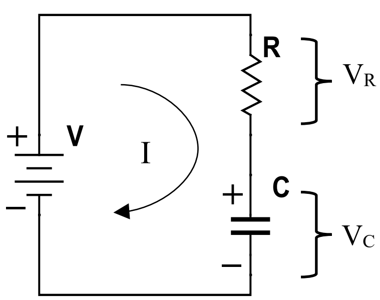
Part 1: Study the behavior of the time dependent potential difference across a capacitor in a simple RC series circuit.

Part 2: Learn two ways to measuring resistance with an ammeter and a voltmeter and explain how they differ and how to connect ammeter and a voltmeter in a circuit.

Part 1: Charging a Capacitor

Equipment:

- Power supply
- One large capacitor (about 2500μF), Resistance box
- Multimeter
- 4 banana cables
- Stopwatch (online)

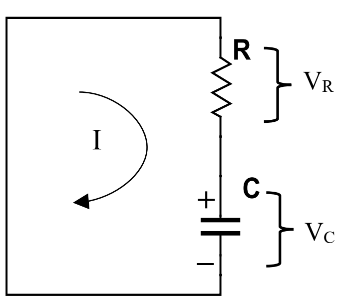


When a capacitor is charged through a resistor by a constant voltage source, the voltages across the capacitor and resistor change exponentially with time. That is,

$$V_C = V\left(1 - e^{-\frac{t}{RC}}\right)$$

$$V_R = Ve^{-\frac{t}{RC}}$$

Where V is the applied voltage.



Likewise, when a capacitor is discharged through a resistor, the voltage are given by

$$V_C = V_0 e^{-\frac{t}{RC}}$$

$$V_R = -V_0 e^{-\frac{t}{RC}}$$

Where V_0 is the initial voltage across the capacitor.

The rate at which the capacitor charges or discharges can be characterized by the time constant RC. When **charging,** *RC* is the time that it takes for the capacitor voltage to increase from zero voltage to 0.632 times the charging voltage, since at *t=RC*

$$V_C = V(1 - e^{-1}) = V_C = V(1 - 0.368) = 0.632V$$

Similarly, when **discharging,** *RC* is the time for the voltage to fall to 0.368 times its initial value, since at *t=RC*

$$V_C = V_0 e^{-1} = 0.368V_0 \qquad \text{i. e, 36.8\% of the original value}$$

Procedure:

1. Set the resistance of the resistance box to 5000 Ω. Check its actual value with the multimeter. If you read a bad value (~MΩ) change the resistance. Try in the range 4000 to 7000 Ω.

   R=___________________Ω

   For the lab you will use the above resistor and a capacitor with a capacitance of the order 2500µF. What is the time constant for this *RC* combination?

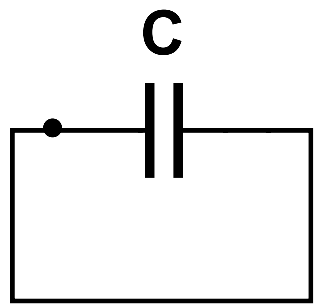
   τ= ___________________sec

2. Before starting check the DC voltage of the power supply – it should be set at 5V. Measure the voltage using the multimeter. Record the applied voltage.

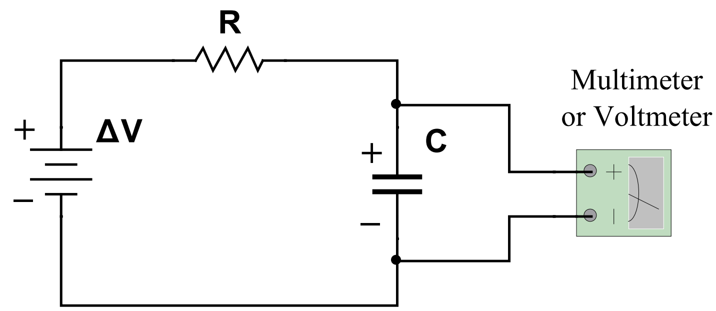
   V=___________________V

3. First we need to make sure the capacitor is discharged.
   Question:
   What does it mean that a capacitor is discharged?

   To discharge it, simply connect both ends of the capacitor using one cable as shown in the picture below (and wait about 5 seconds):



4. **Turn off** the power supply and build the circuit. Take a close look at the circuit diagram below. It is important that you connect the negative output of the DC power supply to the end of the capacitor that has a minus sign "-" on it (the shorter side of the capacitor) and the positive output of the DC power supply to the resistor and then the resistor to the end of the capacitor that has a plus sign "+" on it (the longer side of the capacitor). If you do not connect the components accordingly to the right polarity, the capacitor might blow up and be dangerous (if you're not sure, ask the instructor to check). Set the multimeter to measure DC voltage and connect it as show in the diagram below:



5. **Take the measurement:**
Open a stopwatch at: http://tools.arantius.com/stopwatch. Turn on the power supply (which should be kept at 5V), look on the multimeter for the value of V_C, the voltage across the capacitor and measure the time that V_C takes to reach 1V. Then discharge again the capacitor (step 3) and repeat to measure the time to charge to 1.5V, 2V … 4.5V.

Voltage Across the Capacitor, V_C (V)	**Time (s)**
1	
1.5	
2	
2.5	
3	
3.5	
4	
4.5	

6. **PLOT 1:** Using Excel, plot V_C as a function of time. Determine RC by finding the time at which the voltage has increased to 63.2% of the power supply value. Assume that you do not know the capacitance and calculate it from the measured resistance R and the time constant you just determined.

C=__________________μF

7. **PLOT 2:** Now plot this same data in semi-log format. Plot the natural log of $\left(1 - \frac{V_C}{V}\right)$ on the vertical axis and the time on horizontal axis: $y=\ln\left(1 - \frac{V_C}{V}\right)$ and x=t. Draw a single "best fit" straight line through your data and determine RC from this line. What capacitance does it correspond to?

C=__________________μF

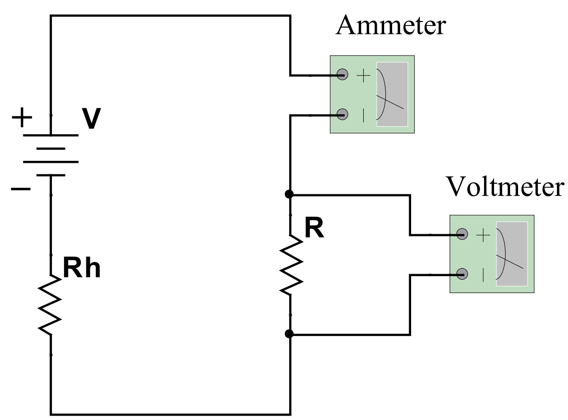
How does this compare with the value given on the capacitor?

Part 2: Ammeter – Voltmeter Methods

Equipment:

- Power supply
- One resistor of a value 10 Ohms
- Resistance box or Rheostat
- Ammeter and Voltmeter
- 6 banana cables

We will use the circuit below to measure the resistance using this method.



In this circuit, the current measured by the ammeter divides between the resistance R and the voltmeter in parallel. The voltmeter is a high resistance instrument and draws little current as long as the voltmeter resistance R_V is much greater than R. Thus,

$$R = {}^{V}/_{I} \quad if \quad R_V > R$$

For a more accurate measurement, the resistance of the voltmeter must be taken into account. The current drawn by the voltmeter is

$$I_V = {}^{V}/_{R_V}$$

and the total current measured by the ammeter is

$$I = I_R + I_V$$

The true current through the resistance is

$$I_R = I - I_V$$

And from Ohm's Law

$$R = \frac{I}{I_R} = \frac{V}{I - I_V} = \frac{V}{I - {}^{V}/_{R_V}}$$

1. Setup the first circuit, where R is the unknown resistance and R_h is the rheostat (variable resistance). Do not connect the power supply until the professor has checked it. (Use the 10 ohm resistor on the circuit board for R).

2. Familiarize yourself with the ammeter and voltmeter. There are three scale connections with the black binding post common for the three scales. It is good practice to start with the highest scale to prevent damaging the instrument. The scale setting may be changed to a lower scale after the general magnitude the measurement is known.
   Attention should also be given to the proper connection of the meters. Connect + to + and – to –.

   Do not connect the power supply until the professor has checked it.
3. The current in the circuit is changed by varying the rheostat resistance R_h. This is done by sliding the rider to a new position. Activate the circuit and take three different readings of the ammeter and the voltmeter corresponding to the different rheostat settings. Be sure to use one scale setting for the three data points. Record the data in Data Table 2. Deactivate the circuit.

4. Record the resistance of the voltmeter for the scale setting used in the acquisition of the data.

Table 2:

R=________________Ohms R_V=_______________Ohms

Rheostat Setting	V (Volts)	I (Ampere)	R (ohms)
1			
2			
3			

Average R=_______________
% error=_________________

Family Name:___________________

First Name:_____________________

Student Number:_______________________

PRE-LAB TEST

Experiment 2 – RC Circuits

1. When a capacitor is **charged** through a resistor by a constant voltage source, what is the voltages across the capacitor and a resistor?

2. When a capacitor is **discharged** through a resistor by a constant voltage source, what is the voltages across the capacitor and a resistor?