

# Lab 10: DC RC circuits

Name:

Group Members:

Date:

TA's Name:

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## Objectives:

1. To understand current and voltage characteristics of a DC RC circuit
2. To understand the effect of the RC time constant

## Apparatus:

PASCO voltage-current sensor, power supply (10V), two alligator clips to connect the capacitor, five long banana wires, 25000  $\mu\text{F}$  bipolar capacitor, 100  $\Omega$  and 250  $\Omega$  resistor, PASCO interface with PASCO software, multimeter.

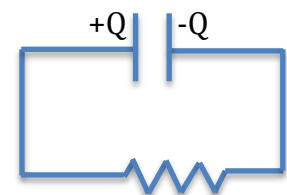
## Part A: RC circuits

In the previous experiment we measured currents and voltages in a series and parallel circuit involving resistors (light bulbs). In a circuit with only resistors and batteries, the current through and voltage across each resistor do not change with time. However, if the circuit involves a capacitor, then the current and voltage across circuit elements do change with time. In this experiment we investigate current and voltage in a series circuit involving a resistor and a capacitor referred to as an RC circuit.

1. The amount of charge that must be moved from one side of the capacitor to the other to establish a voltage,  $V$ , for a capacitor with capacitance,  $C$ , is given by  $Q = CV$ . Calculate the amount of charge that will be pumped if we hook a 10 V battery up to the 25000  $\mu\text{F}$  capacitor. Show your work and pay attention to units.

$Q =$  \_\_\_\_\_

2. A 25000  $\mu\text{F}$  capacitor is charged to 10 V and then connected to a 100  $\Omega$  resistor in the circuit shown to the right. Calculate the amount of current that flows right after we connect the circuit as shown and indicate the direction of current flow on the figure.



RC circuit

$I =$  \_\_\_\_\_

Will the current be the same 10 seconds later? Why or why not?

3. As the current flows in the RC circuit above, what is happening to the amount of charge on each plate of the capacitor? Remember that current is a flow of charge, so pay attention to whether charge is flowing toward or away from a capacitor plate.

4. Based on your answer to Question 3, what is happening to the voltage across the capacitor as time passes and current flows? Remember that the charge and voltage on the capacitor are related by  $Q=CV$ .

5. Based on your answer to Question 4, what will be happening to the voltage across the resistor? Remember the loop rule says that the net voltage around a closed loop is zero.

6. What does your answer to Question 5 imply about what is happening to the current in the circuit? Remember that the voltage across the resistor is given by  $\Delta V_R=IR$ .

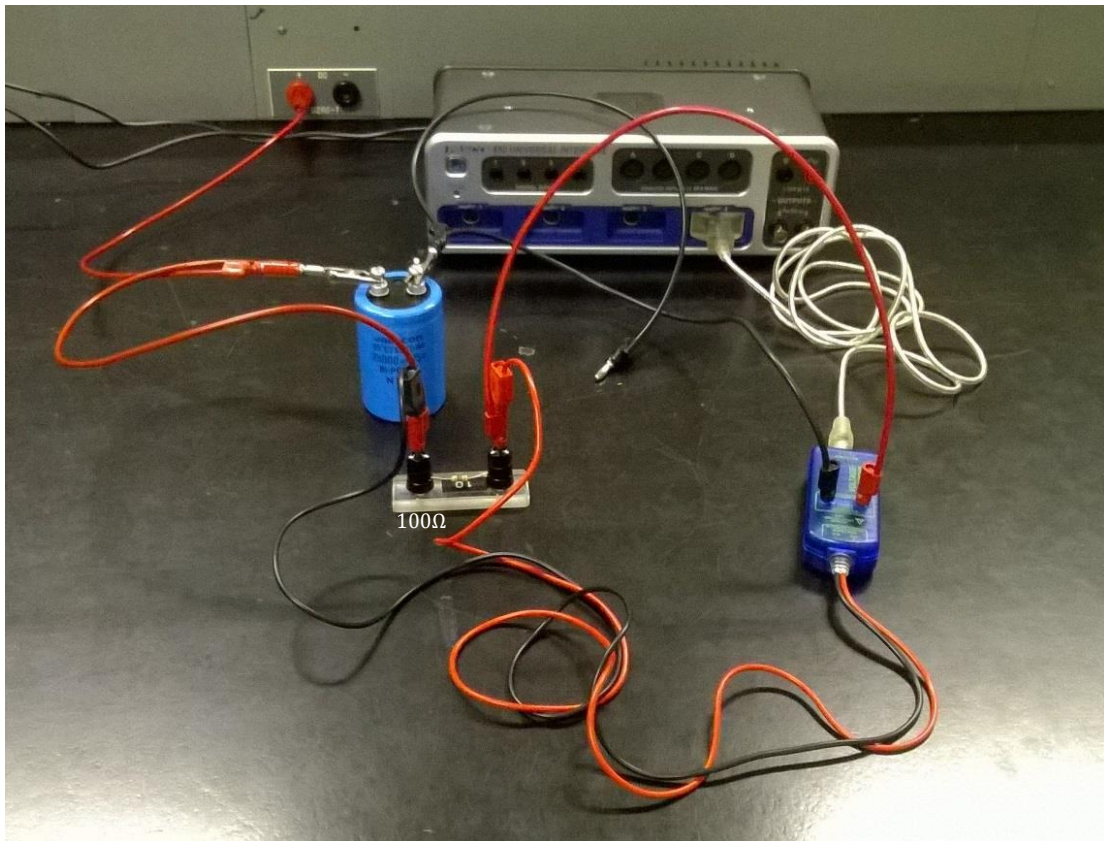
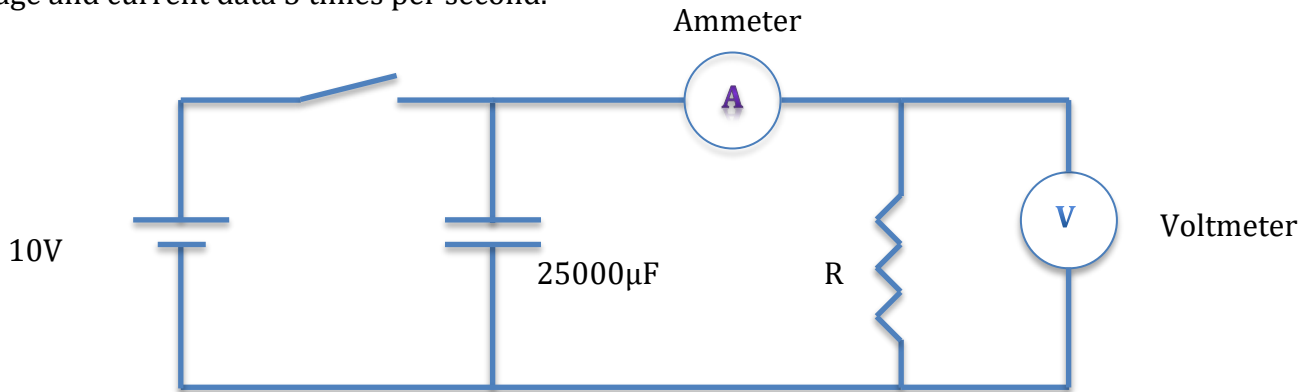
7. If the current in the circuit decreases, what does that mean about the rate at which the charge (and voltage) on the capacitor changes?

8. Sketch your predictions for the graphs of voltage across the resistor versus time and current in the circuit versus time for the RC circuit.



## Part B: Qualitative investigations of voltage vs. time and current vs. time

Now make the following circuit. Do not connect the circuit to the power supply first. Wait for TA's approval before you begin. Use  $R=100\Omega$  resistor and blue cylindrical  $25000\mu\text{F}$  bi-polar capacitor (note + and - signs). You will be using PASCO voltage-current sensor to measure voltage and current across the resistor and capacitor. Select the data sampling frequency to be 5 Hz that means the sensor collects voltage and current data 5 times per second.



Once the circuit is connected, open Capstone software and click on the two-graph template. Choose the vertical axis to be voltage in one graph. Choose current to be the vertical axis in the other graph. Both should have horizontal axis as time. If the vertical axis does not show voltage/current options that means either the sensor is faulty or no good connection to the interface.

Now connect the power supply and charge the capacitor. (In the picture, black wire would be connected to the negative terminal of the power supply).

Start recording data while the power supply is connected and then disconnect the power supply. Record data for about 10-12 seconds and stop recording. You should have a nice voltage vs. time graph and a current vs. time graph. If necessary practice doing this several times until you are satisfied with the graph. Keep the best run and delete the others.

9. How does the shape of the voltage vs. time and current vs. time graphs compare with your predictions in Question 8?

10. How would you describe the slope of the curve and how it is changing as time increases?

11. If we used a larger resistor in the circuit, would the current be larger, smaller, or the same right after we disconnect the power supply?

12. Based on your answer to Question 11, do you predict that the discharge of the capacitor will be faster, slower, or the same if we use a larger resistor? Explain why.

13. Now with the power supply disconnected, change the resistance to 250  $\Omega$ . Follow the steps above to collect and get the current and voltage graphs for the discharge of the capacitor. Once you have good graphs for 100  $\Omega$  and 250  $\Omega$  resistors keep the power supply disconnected until you begin to take data later. Display both voltage vs. time curves (100  $\Omega$  and 250  $\Omega$ ) on the same graph. Also display both current versus time curves on one graph. Selecting both runs from the 'third item from the left of Graph menu' can do this. Now take snap shot of the graphs using the camera icon from the menu and paste them to a word document. Save the word document.

14. Is the discharge faster, slower or the same with 250  $\Omega$  as it was with 100  $\Omega$ ? Does this match your prediction?

### Part C: Quantitative investigations of voltage vs. time and current vs. time

As might have guessed from the shape of the current and voltage curves, the discharge process follows an exponential decay curve. The voltage across the capacitor ( $\Delta V_C$ ) at time  $t$  is expected to be given by  $\Delta V_C = \Delta V_0 e^{-t/RC}$ , where  $\Delta V_0$  is the initial voltage of the capacitor at  $t = 0$ . Since  $\Delta V_0$  is the voltage at one particular time, it is a constant in this equation. So the only variable on the right side of the equation is  $t$ .

15. The exponent of the exponential function contains  $RC$  for the given circuit, which is called the time constant. Use the units of  $R$  and  $C$  to find units of  $RC$ . Write ohms in terms of volts and amps and write farads in terms of volts and coulombs. Simplify until you get something simple. Show your work below.

Units of  $RC$  are \_\_\_\_\_

16. If we increased either  $R$  or  $C$ , then the value of  $RC$  would increase. Is this consistent with what you observed when you changed the resistor from  $100 \Omega$  to  $250 \Omega$ ? Explain how.

17. Now we are going to experimentally determine the time constant of the discharge from the voltage vs. time data and use that to find the capacitance of the blue cylindrical capacitor. First we need accurate values for the resistance of the  $100 \Omega$  and  $250 \Omega$  resistors we will be using. Disconnect the resistor from the circuit before you use a multimeter to measure the resistances.

$R_1 =$  \_\_\_\_\_  $R_2 =$  \_\_\_\_\_

18. Put the  $100 \Omega$  resistor back into the circuit. Now we need to choose a different template to collect just the voltage -time data for the discharging capacitor. Use the template with table and graph. Select the vertical axis to be voltage and the other as time. Also for the table heading select the left column heading to be time and the other to be voltage. Select the frequency to be 2 Hz. Now connect the power supply to the circuit and follow the procedure that you did earlier to collect data for about 10-12 seconds.

19. From your table pick a point just after the discharge begins to be the first data point. Then select data at equal time intervals, about one second apart. Record data below and also create an Excel spreadsheet.

$t(s)$	$\Delta V_C (V)$

20. Plot the voltage versus time data from your table and then fit an exponential curve to the data. Label the axes and make sure you display the equation for your exponential fit. Label the graph and then copy and paste it to your Word document. Write the equation of the exponential fit below.

$$\Delta V_C =$$

21. From your equation identify the RC time constant and attach the correct units.

$$RC = \underline{\hspace{4cm}}$$

22. Use the time constant and your measured value of R to calculate the capacitance, C.

$$C = \underline{\hspace{4cm}}$$

23. How close is your measured value of C to what is labeled on the capacitor?

24. Now replace 100  $\Omega$  resistor with 250  $\Omega$  and repeat the measurement of voltage vs. time. Again record data after the discharge begins

$t(s)$	$\Delta V_C (V)$

25. Plot the voltage versus time data from your table and again fit an exponential curve to the data. Label the axes and display the equation for your exponential fit. Label the graph and then copy and paste it to your Word document. Write the equation of the exponential fit below.

$$\Delta V_C =$$

26. From your equation identify the RC time constant and use it and your measured value of R to calculate the capacitance, C.

$$RC = \underline{\hspace{4cm}}$$

$$C = \underline{\hspace{4cm}}$$

27. Is this value of C similar to what you found in Question 22 using the 100  $\Omega$  resistor?

## Part D: Conclusions

28. Do the experimentally determined capacitance measurements match the value marked? Are they close?

29. Would the capacitor discharge more quickly or more slowly if we had used a capacitor with a smaller value of capacitance? Explain.

30. Why does the capacitor charge almost instantly when the switch is closed?

31. Why does the capacitor discharge more slowly when the switch is opened compared to charging?

### Instructions on how to submit the graphs:

1. Open a word document and type the names of all present group members.
2. If you need help finding slopes using Excel, please talk to your TA.
3. Copy your Excel graphs (with title and axis labels) to your Word document.
4. Print the document and attach it to the lab write-up.