Course and Section_______ Names ___________________________

Date____________ ____________________________________

DC CIRCUITS PH106 EXPERIMENT

Introduction

In this experiment you will determine how voltages and current are distributed resistors circuits. In this experiment you explore how voltages and charges are distributed in a capacitor circuit. Resistor can be connected in several ways: in this experiment we study the series and the parallel combinations. You will also examine the charging of a capacitor in a *RC* circuit.

Equipment

Power supply, Multimeter, three 470 Ω, one 1000 Ω, one 12.4 kΩ, one unknown (brown) resistors, one 2200 μF polar capacitor, five cables.

Theory

Resistors are electronic devices with fixed value of resistance *R*. The resistance *R* depends on the physical and geometrical proprieties of the device and is given operationally by the Ohm Law which states that the amount of current *I* passing through a resistor is directly proportional to the voltage difference across it.

$$I = \frac{\Delta V}{R}$$

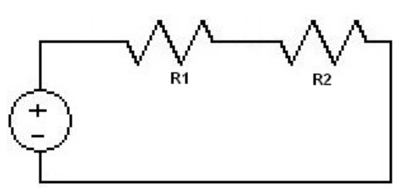
The schematic symbol of a resistor or is 

<u>Series</u>

In a series connection the components are connected at a single point, end to end.
When the series combination is connected to a power supply ΔV, the currents on each resistors I_1, I_2 are equal to current *I* through the equivalent resistor *R*. The potential difference across each resistor add to ΔV

$$I = I_2 = I_2$$

$$\Delta V = \Delta V_1 + \Delta V_2$$



The equivalent *R* is

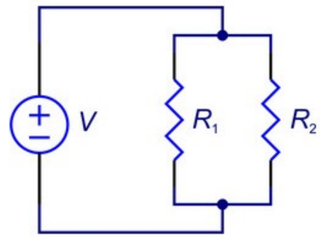
$$R = R_1 + R_2$$

Parallel

When the parallel combination is connected to a power supply ΔV, the currents on each resistors I_1, I_2 add to the current I through the equivalent resistor R. The potential difference across each resistor are equal to the potential difference ΔV.

$$I = I_1 + I_2$$

$$\Delta V = \Delta V_1 = \Delta V_2$$



The equivalent resistance R is

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

Preliminary questions

You have three identical resistors. You connect two of them in series and to a 12 V power supply. If you add the third resistor in series with the others two.

1. How does the voltage across the first two resistors changes?

2. How does the equivalent resistance change?

3. How does the current through the first two resistors change?

You have three identical resistors. You connect two of them in parallel and to a 12 V power supply. If you add the third resistors in parallel with the others two.

4. How does the voltage across the first two resistor changes?

5. How does the equivalent resistance change?

6. How does the current through the first two resistors change?

PART 1 – Resistor combinations

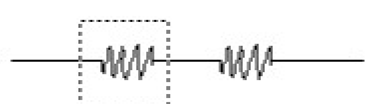
Procedure

Step 1. Turn on the power supply and set the DC voltage to 10 V.

7. Measure the actual power supply voltage V_{PS} with the multimeter and record it below

V_{PS} = ______________V

Step 2. Connect two 470 Ω resistors in series.



8. Measure V_1 across R_1 (the resistor in the dashed box) and record it below.

V_1 (measured) = _____________ V

Next, you want to compute the expected value of V_1 by using the given equations

9. Calculate the equivalent resistance R_{12}

10. Calculate the total current I

11. Calculate the expected value of V_1

V_1 (expected) = _____________ V

12. Calculate the percentage error (assuming the exact value = measured value) of V_1

% error = (|measured - expected| / measured) x 100 = ___________

Step 3. Connect the unknown resistor R_2 (brown with no color code) in series with the R_1 = 470 Ω resistor and to the power supply. By taking measurements of voltage is possible to find the resistance of the unknown resistor.

13. Measure the voltages across each resistor

V_1 (measured) = _________ V,

V_2 (measured) = _________ V,

14. Calculate the resistance of R_2 using the values of V_1, V_2 and R_1. Think about the value of the current I through each resistors.

R_2 (expected) = __________ Ω.

15. Use the multimeter to measure the resistance of the unknown resistor

R_2 (measured) = __________ Ω.

16. Calculate the percentage error assuming the exact value = R_2 (measured)

% error = (|measured - expected| / measured) x 100 = ___________

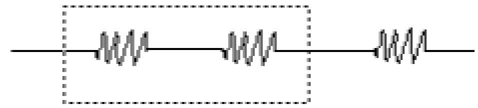
Step 4. Connect three 470 Ω resistors in series and measure the voltage across each resistor.

17. Are your results consistent with your prediction 1?

Step 5. Connect three 470 Ω resistors in parallel and measure the voltage across each resistor.

18. Are your results consistent with your prediction 4?

Step 6. Connect two 470 Ω resistors and the 1000 Ω resistors in series, put the 1000 Ω in the middle.



19. Measure the voltage across the box $V_{BOX} = V_{12}$.

V_{12} (measured) = ________ V,

Next, you want to compute the expected value of V_{12} using the given equations.

20. Calculate the equivalent resistance R_{12}

21. Calculate the equivalent resistance R_{123}.

22. Calculate the total current I

23. Given I, what is the value of the current I_{12}?

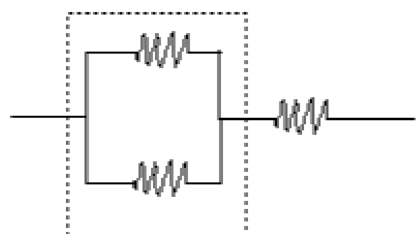
24. By knowing R_{12} calculate the expected value of the voltage across the box

V_{12} (expected) = _____________ V

25. Calculate the percentage error of V_{12}

% error = (|measured - expected| / measured) x 100 = ___________

Step 7. Remove the 1000 Ω resistor. Connect three 470 resistors as shown into the figure (to the right) and to the power supply.



26. Measure the voltage across the box $V_{BOX} = V_{12}$.

V_{12} (measured) = ________ V,

Next, you want to compute the expected value of V_{12} by using the given equations.

27. Calculate the equivalent resistance R_{123}.

28. Calculate the total current I

29. Calculate the voltage across V_3 (by knowing I_3 and R_3)

30. By knowing V_{PS} and V_3 calculate the expected value of the voltage across the box

V_{12} (expected) = _____________ V

31. Calculate the percentage error of V_{12}

% error = (|measured - expected| / measured) x 100 = ___________

PART 2 – RC Circuit

Theory

When a capacitor is charged through a resistor by a constant voltage V_{PS} provided by the power supply, the voltages across the capacitor and resistor change exponentially with time.

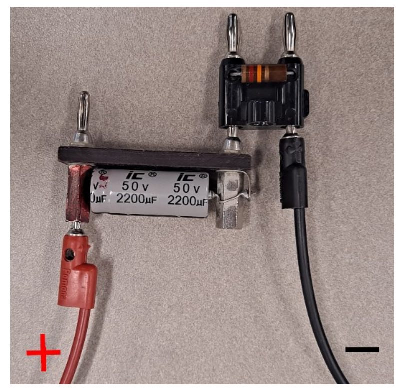
$$V_C(t) = V_{PS}\left(1 - e^{-\frac{t}{RC}}\right) \qquad V_R(t) = V_{PS}e^{-\frac{t}{RC}}$$

Procedure

Step 1. First we need to make sure the capacitor is discharged. To discharge it, simple connect both ends of the capacitor using one cable as shown in the picture to the right.

32. Why would connecting both ends of a capacitor discharge it?

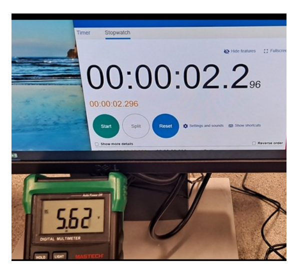
Step 2. <u>Turn off</u> the power supply and set up the *RC* series combination. Use the R = 12.4 kΩ resistor. <u>Very important</u>: match the polarity. Connect the positive end (red) of the capacitor to positive output (red) of the power supply. Failure to do so might result in the explosion of the capacitor (no fun, check with the TA if you are not sure). Do not connect yet the cable from the resistor to the negative output of the power supply.



Step 3. Search online for a web–based stopwatch, or use an app on your phone to measure time intervals. Make sure the stopwatch has the lap function and know how to use it to record different times as an event takes place. You will measure time intervals as the V_C increases from 0 V to V_{PS} = 8 V.

Step 4. Turn on the power supply and set V_{PS} = 8 V. Connect the multimeter to measure the voltage V_C across the capacitor. Connect the cable from the resistor to the negative output of the power supply. You will see V_C increasing, measure the times and the corresponding voltages.

A simple way to collet the data is to use a smartphone to record a video which shows both the time on the stopwatch and the voltage on the meter.



Analysis

33. Collect you data in the table below. It important to take a few values of voltage relative to the initial time interval (the first 10 seconds). It will take about a minute to reach V_C = 8 V

V_C (V)												V = 8 V
Time (s)												

34. Use the multimeter to measure the resistance of the resistor. R = ____________

35. The capacitor has capacitance of about C = 2200 μF. Calculate the time constant

$$\tau = RC = \_\_\_\_\_\_\_\_\_ \text{ (s)}$$

36. When $t = \tau$ the value of V_C should be about 63% of V_{PS} , that means $V_C = 0.63 \times 8.0$ V = 5.0 V. By looking at your data, does V_C reach 5.0V in about the time interval given by τ?

If not, you might have to repeat S*tep 2 – Step 4* to collect better data.

37. Plot your data in semi log format: $ln(1 - V_C /V_{PS})$ on the vertical axis and t on the horizontal axis. How is the slope of this plot related to R and C ? Show your calculations.

38. What is the numerical value of the slope?

39. Print and submit a copy of your plot.

40. Use the value of the slope and of the resistance to estimate the capacitance.

C (measured) = _________ μF

39. Calculate the percentage error, assuming the exact value C = 2200 μF

% error = (|measured - exact| / exact) x 100 = __________

TURN OFF THE MULTIMETER and THE POWER SUPPLY