PHYS 104 Lab 5 electric circuits 2.

Introduction

In this lab you will further examine some simple electric circuits. For your measurements you will use **multi-meters**, which, hopefully, this time will not all get fried.

Theory

**1. RESISTORS IN SERIES**

The elements of a circuit are said to be connected in series if there is only one pathway for the *current* to flow. In figure 1 below you can see two resistors and a **power supply** connected in series. In a circuit in which elements are connected in series *charges* must pass through all the elements as they traverse the circuit. This is analogous to water flowing through a pipe – whatever volume of water flows in one end in a given time interval must exit at the opposite end. The *equivalent resistance* *R*eqfor elements connected in series is given by

*R*eq = *R*1 + *R*2 + *R*3+ *R*4+ *R*5+ *R*6 +… (1)

where  *R*1,  *R*2,  *R*3,  *R*4,  *R*5,  *R*6 are *resistances* of the individual elements in series.

When all elements of a circuit are connected in series the circuit forms a single loop. According to one of the Kirchhoff rules (the loop rule) *potential differences* (*voltages*) across all elements in a single loop must add up to zero.

***R*1**

**Power Supply**

***R*2**

**Figure 1. Series circuit.**

In Part 1 of this lab you will examine a circuit consisting of two resistors and a power supply connected in series.

**2. RESISTORS IN PARALLEL**

In a circuit in which elements are connected in parallel some *charges* will pass through one of the elements and some of the *charges* will pass through the others. In contrast to the series circuit the *charges* do not all follow the same path as they traverse the circuit. This is analogous to water flowing through the pipe which comes to a junction splitting the water flow between two containers – whatever volume of water flows in one end in a given time some of it will flow to either of the containers. The *equivalent resistance R*eq for several elements connected in parallel is given by

 (2)

where *R*1, *R*2, *R*3, *R*4, *R*5, *R*6 are *resistances* of the individual elements.

When connected in parallel the *voltages* across all elements are the same since all their left sides are connected to a common point and all the right sides are connected to another common point. This is a consequence of Kirchhoff loop rule.

***R*2**

**Power Supply**

***R*1**

**Figure 2. Resistors in parallel circuit.**

Another Kirchhoff rule – the junction rule - tells us that at a junction the sum of all *currents* flowing in must equal to the sum of all *currents* flowing out. This is a consequence of the conservation of *charge*.

In Part 2 of this lab you will examine a circuit consisting of two resistors and a power supply connected in parallel.

3 AC/DC Circuit

In **Part 3** of this experiment you will create a crude DC **Power Supply** by sequentially adding components such as *resistor*, a *diode*, and a *capacitor* to a circuit connected to an AC power supply. You have already investigated *resistors* and their role in the circuits. A *diode* is a component that allows the current to flow in one direction only and a *capacitor* allows to temporarily store electric charges and then discharge them at a desired time and rate. You will observe the role a capacitance plays in this circuit.

***APPARATUS***

In this lab we’ll use **multimeters** as **voltmeters** to measure *electric potential difference* (*voltage*), as **ammeters** to measure *current*, and as **ohmmeters** to measure *resistance*. So let’s discuss how they work and how to properly connect them in a circuit.

Let’s say we have a simple circuit consisting of a battery and a resistor as drawn below.

*R*

Δ*V*

If we want to measure *current* that flows through the resistor we need to put **ammeter** in the path of that *current* as shown below.

*R*

A

Δ*V*

We say that we connected the **ammeter** in series with the **resistor**, or the **resistor** and **ammeter** are in series. The elements of a circuit are said to be connected in series if there is only one pathway for the *current* to flow.

**WE ALWAYS CONNECT AMMETER IN SERIES.** Ammeter has very, very tiny *resistance* so there is almost no *voltage* drop across it. When *current* flows in the circuit depicted in figure above all charges must pass through both the **ammeter** and the **resistor**.

If we want to measure *potential difference (voltage)* across some circuit component e.g. a **resistor,** we place the **voltmeter** wires at points a and b, which results in a circuit shown below:

V

*R*

a

b

Δ*V*

We say that we connected the **voltmeter** in parallel to the **resistor**, or the **resistor** and **voltmeter** are in parallel. When connected in parallel the *potential differences* across all elements are the same since all their left sides are connected to a common point and all the right sides are connected to another common point.

**WE ALWAYS CONNECT VOLTMETER IN PARALLEL**. **Voltmeter** has very, very large *resistance* so almost no *current* flows through it, and almost all *charges* pass through the **resistor**.

If we want to use the **multimeter** as an **ohmmeter** to measure the *resistance* of a **resistor** we **MUST DISCONNECT THE RESISTOR FROM THE BATTERY** (or other power supply).We just clip the wires at the sides of the **resistor**:

Ω

*R*

In this case the **multimeter** uses its own internal battery with established *voltage* and measures *current* and uses **Ohm’s law** to find the *resistance*.

Procedure

Part 1. Resistors in series.

1. Set the **Power Supply** to about 5V.
2. Set one of the multimeters to function as a voltmeter and use it to measure ΔV produced by the **Power Supply -** see figure 3. **BE CAREFUL NOT TO CONNECT THE AMMETER ACROSS THE POWER SUPPLY, OR YOU WILL BLOW A FUSE!!!** We need this measurement since the scale on the **Power Supply** itself is not very precise. Record this value. Turn off the power supply without changing its setting.

A Ammeter

V Voltmeter

*R*1, *R*2 Resistors

Power Supply

V

**Figure 3. Measuring voltage of the Power Supply.**

1. Select resistors with nominal *resistances* of *R*1 = 2200 Ω and *R*2 = 1000 Ω. Use **ohmmeter t**o measure their actual **resistances**. Record these values. Are they within the tolerances?
2. Use the actual measured values of the *resistances* to calculate the equivalent *resistance*.
3. Connect the two resistors in series and use the **ohmmeter** to measure their combined *resistance*. Record this value and compare it with the value obtained in step 4 by finding % difference. Discuss the outcome.
4. Based on the measured values for *equivalent resistance* and the *voltage* across the **Power Supply** predict what should be the *current* in the circuit.
5. Construct a series circuit as shown in figure 1. Turn on the **Power Supply** without changing its settings.

A Ammeter

V Voltmeter

*R*1, *R*2 Resistors

***R*1**

**Power Supply**

A

***R*2**

B

C

**Figure 4. Resistors in series circuit**

1. Insert an **ammeter** into your circuit as shown in figure 4 and measure *I*, the *current* through the circuit. Record this value and compare it with your prediction by finding % difference. Discuss the outcome.
2. Move the **ammeter** to location B. Measure the *current*. Record this value. Is it the same as in the original location? Should it be? Why or why not?
3. Move the **ammeter** to location C. Measure the *current*. Record this value. Can you now confirm that the *current* for a series circuit is the same everywhere?
4. Disconnect the **ammeter** from the circuit.
5. Use the **voltmeter** to measure the values of *voltage* across each resistor. To measure ΔV1 the *voltage* drop across *R*1 resistor connect the **voltmeter** as shown in figure 5a. To measure ΔV2 the *voltage* drop across *R*2 resistor connect the **voltmeter** as shown in figure 5b. Record these values.
6. Is the sum of the *voltage* drops across each resistor the same as the *voltage* across the **Power Supply** i.e. do you confirm ΔV = ΔV1 + ΔV2 for the loop? Compare these two values finding % difference. Did you confirm Kirchhoff loop rule? Discuss.

14. Turn off the **Power Supply** without changing its setting.

1. b)

A Ammeter

V Voltmeter

*R*1, *R*2 Resistors

***R*1**

**Power Supply**

***R*2**

V

***R*1**

**Power Supply**

***R*2**

V

**Figure 5. Resistors in series circuit.**

Part 2. resistors in parallel

1. Use the actual measured values of resistances of your two resistors from part 1 step 3 to calculate the *equivalent resistance* for those two resistors connected in parallel.

2. Disconnect the **Power Supply** and then connect the two resistors in parallel and use the **ohmmeter** to measure their combined *resistance*. Record this value and compare it with the value obtained in part 3 step 1 by finding % difference. Discuss the outcome.

3. Construct a parallel circuit as shown in figure 2.

4. Turn on the **Power Supply** without changing its setting.

a) b)

***R*2**

**Power Supply**

***R*1**

V

***R*2**

**Power Supply**

***R*1**

V

**Figure 6a and 6b.**

5. Measure the values of *voltage* drops ΔV1 and ΔV2 across each resistor by placing the **voltmeter** as shown in figures 6a and 6b. Record these values. Is ΔV1 across *R*1 the same as ΔV produced by the **Power Supply?** Is ΔV2 across *R*2 the same as ΔV produced by the **Power Supply?** Are ΔV1 and ΔV2 the same? Should they all be the same? Why or why not? Discuss. Remove the **voltmeter** from the circuit.

6. Use the measured value for the *voltage* across **Power Supply** and the *equivalent resistance* to predict *I*tot the total *current* in the circuit.

7. Insert the **ammeter** into the circuit as shown in figure 7. Measure *I*tot. Record this value and compare it with the predicted value by calculating % difference. Discuss the outcome.

***R*2**

**Power Supply**

***R*1**

**A**

**Figure 7. Resistors in parallel circuit.**

8. Move the **ammeter** into location indicated in figure 8a and measure *current I*1 through resistor *R*1. Record this value.

9. Move the **ammeter** into location indicated in figure 8b and measure *current I*2 through resistor *R*2. Record this value.

a) b)

***R*2**

**Power Supply**

***R*1**

**A**

***R*2**

**Power Supply**

***R*1**

**A**

**Figure 8. Resistors in parallel circuit**

10. Calculate *I*1 + *I*2 and compare it with *I*tot the *current* you measured in step 7 by calculating % difference. Discuss the outcome. Which Kirchhoff rule did you confirm? Through which resistor more *current* flew? Why? Discuss.

11. Check relation:  . Why should this relation hold? Discuss your results.

Part 3. AC/DC Circuit

1. Using the 10 kΩ *resistor* build the circuit shown in figure 9. The Wavetek output is connected to channel “A” of the oscilloscope and so it triggers the **scope**. Channel “B” of the **oscilloscope** can be now used to measure the *voltage* across the *resistor*. Use a BNC to banana connector to connect to the **Wavetek** **Signal Generator,** andtwo **Voltage Sensors** to analog channels “A” and “B” of the **Interface Box**.
2. Turn the **Wavetek** **Signal Generator** on. The on/off switch is on the back.



**Figure 9. Resistor circuit.**

1. Set the **Wavetek** **Signal Generator** to a sine wave with amplitude of about 5V peak-to-peak, a *frequency* of about 60Hz, and DC offset to zero. The digital display of the **Wavetek** **Signal Generator** shows these quantities one at a time, and you can switch between them by pressing **Display Select** button. The **Amplitude knob** will allow you to control the peak-to-peak *voltage*, the **DC offset knob** will allow you to control the DC offset. To set the *frequency* to 60 Hz, press the **Frequency Range button** for 200 Hz, and then adjust it with the **Frequency knob**.
2. Open the **Data Studio** and **'Create Experiment'**. In the **'Experiment Setup'** from the list of sensors select the **'Voltage Sensor'** icon and connect it to the analog channel “A” and “B” on the picture of the **'Interface Box'.**
3. Open the **'Scope'** display for channel “A” first, and then drag the icon of **'Voltage Channel “B”'** to the same **scope** display, so the signals from both can be viewed on the same window.
4. Click the **'START'** button to begin recording data.
5. Make sure you can view both signals on the **scope** clearly. You may need to adjust triggering and/or V/div.
6. Click **'STOP'** to freeze the display. Print and discuss the two waveforms. How does this circuit work? What role does the *resistor* play in this circuit?
7. Now add a *diode* to the circuit as shown in figure 10 and observe the waveforms. The *diode* will only allow current to pass in one direction, so it should cut out the positive or negative part of the sine curve. If it cuts out the positive half of the sine curve, reverse the diode so it cuts out the negative part. Print out and discuss the display. How does this circuit work? What role does the diode play in this circuit?



**Figure 10. Diode added to the circuit.**

1. We now have a circuit with pulsating DC-the *current* only goes in one direction, but it is not steady. We can improve the situation by adding the *capacitor* as shown in figure 11.



**Figure 11. Capacitor added to the circuit.**

1. Set up the circuit so that the *capacitor* can easily be changed and begin with *C* = 0.47 **F. Make sure that the *diode* is connected so that the negative part of the signal is eliminated and that *capacitor* is connected with the proper polarity. The *capacitor* will charge up when the circuit is positive and then slowly discharge through the *resistor*. The result is a DC output with a ripple. Print out and discuss the scope’s display. How does this circuit work? What role does the capacitor play in this circuit?
2. Try larger capacitances of 1 **F, 10 **F, 22 **F, and 100 **F. How do they change the waveform? Print out the display generated by each circuit and discuss the results.

**Save your data once you acquired it.**

**Print tables and graphs you have made and attach them to your report.**

**SAVE PAPER.**

**Delete your files from the computer when finished.**

**Disconnect all equipment, close all applications, and log off your PC.**

**lab 5 Report** Name……………………………...

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Introduction:

Data Presentation:

Part 1. Resistors in series

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3.

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13.

PART 2 Resistors in parallel.

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Part 3. AC/DC Circuit

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12.

**REMINDERS:** Include units.

Make sure to attach all your data and graphs. No data = No credit

Please do not hand in the manual, just the report.

conclusion: