

Lab Exercise #3: ELECTRIC CIRCUITS 2

OBJECTIVES

- Understand the current and voltage distribution for a circuit of light bulbs connected in combination of parallel and series circuit.
- Interpret resistor codes.
- Understand how resistors combine when wired in series, parallel or a combination of the series and parallel.
- Apply Kirchhoff's Laws to a resistor network.

Preparation

Review the main results from the last experiment and answer the following questions:

- **Q1: What is Ohm's law? Explain in your own word its meaning.**
- **Q2: Draw a series circuit with three resistors. Label the currents and voltages in the circuit diagram and write down the equations that relate those currents and voltages.**
- **Q3: Same as the previous question for three resistors in parallel.**

EQUIPMENT

DC Power Supply

Circuit Board (w/ bulbs)

Wires

Resistors

Voltage, Current and Resistance Probes

If using the Dual Channel amplifier, make sure that the voltage probe is plugged into "Probe 1" and the current probe is connected to "Probe 2" of the Dual Channel amplifier. Otherwise, connect the differential voltage probe into channel 1 of the LabPro jack and the current probe into channel 2. Connect the resistance probe into channel 3 of the LabPro jack. Now start LoggerPro. We need to tell the computer what type of experiment to do: Choose Open in the File menu. Open the folder labeled PSU; now double-click on the Electric Circuits 2 file. Your screen should show now a Volt, Ampere, and Ohm meter. Next you need to zero all three probes.

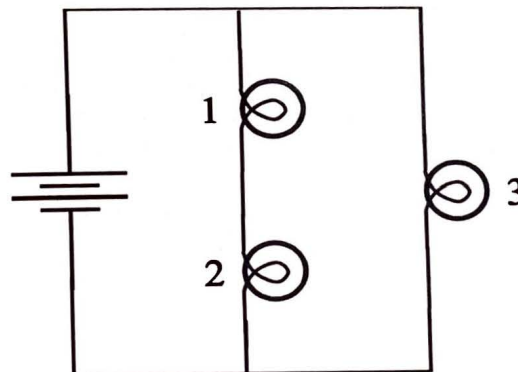
The three light bulbs in your circuit board can be either connected in series, parallel or in two different combination circuits. If you do not remember the brightness of the light bulbs for the series and parallel circuit connect the bulbs again for those basic arrangements. Next, wire the three light bulbs as shown below. Connect the red power cable from the DC power supply to the circuit board by inserting the red and black wires into the 5V output terminals of the power supply to the external power terminals on the circuit board (J1 and J2). Set the power source switch (SW1) to "External" and turn on the power supply. Now measure the current through and the voltages across each light bulb, and record it in the table below. Remember to connect the current probe in series and the voltage probe in parallel.

Table 1

	Current	Voltage
Bulb 1	0.01 mA	0.03 V
Bulb 2	0.01 mA	0.02 V
Bulb 3	0.03 mA	0.05 V

- Q4: In Figure 1, which bulbs are in parallel? Which bulbs are in series?
- Q5: Describe the relative brightness of the three bulbs in the circuit shown in Figure 1. Explain the brightness in terms of currents and voltages.

Figure 1



PART 2: Resistors and Resistor Codes

In this activity, you will explore the role of resistors in simple circuits and learn to read the colored codes printed on them.

PREPARATION

In your investigation of Ohm's Law, you used a resistor instead of a light bulb. While all electrical devices – from light bulbs to toasters to motors - have electrical resistance, most electronic applications (computers, televisions, VCR's, stereos, etc.) have resistors in their circuitry to provide a specific amount of resistance. Unlike light bulbs, the resistance of a resistor doesn't change much as its temperature changes. Most common resistors are made of graphite (a form of carbon) mixed with a binder or glue and encased in a plastic sleeve that has a series of colored bands on it. The colored bands represent a code for the value of the resistance. This value is not precise, but it's quite close and useful for selecting resistors. Below is a table to help you decode these values. Note that the "first" band is the one closest to the end of the resistor.

Table 2

First Band:	First Digit	
Second Band:	Second Digit	
Third Band:	Exponent x in multiplier 10^x	
Fourth Band:	Tolerance	
BLACK	0	<u>FOURTH BAND</u>
BROWN	1	
RED	2	NONE $\pm 20\%$
ORANGE	3	SILVER $\pm 10\%$
YELLOW	4	GOLD $\pm 5\%$
GREEN	5	RED $\pm 2\%$
BLUE	6	
VIOLET	7	
GRAY	8	
WHITE	9	

Look at the resistors you have been given, and try to decode the resistance of one of them. If you are not sure, ask your instructor to tell you if you have done this correctly.

- **Q6:** Consider a simple circuit with a battery and one resistor. What do you predict will happen to the current in the circuit if the resistor is replaced by one with twice the resistance? Explain.

PART 3: Resistance

In this activity, you will learn how the effective resistance of a resistor network depends upon whether the resistors are in series or parallel.

PROCEDURE

For this section you will use 3 resistors on the circuit board: the 10Ω , 51Ω , 68Ω . Following the procedure explained by your lab instructor, use the Resistance probe to measure the actual resistance of each of the three resistors. Record these measurements.

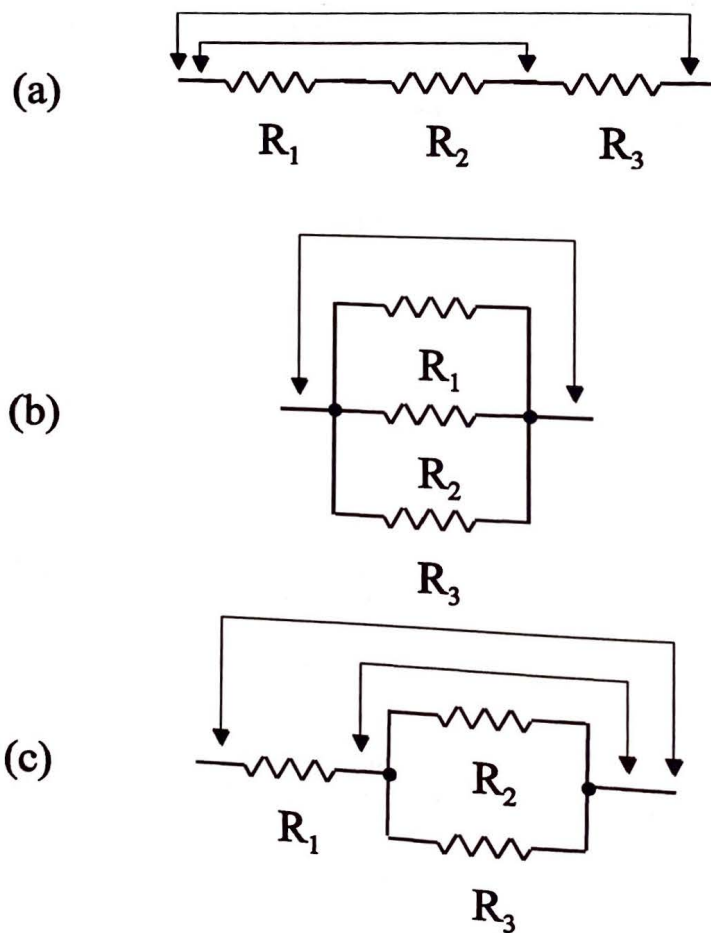
Order the resistors such that $R_1 < R_2 < R_3$. Determine the percentage difference between the measured and the coded resistance value.

- Q7: How does this experimental error compare to the tolerance coded on the resistors?

Connect the three resistors into the series circuit in Figure 2a, and do not connect the resistors to the power supply. Using the resistance probe, measure resistances between the points at the ends of the arrows as shown in Figure 2a. Record these values.

Also find the resistances for the parallel circuit (Figure 2b) and the combination circuit (Figure 2c). Record your measurements. Compare each measurement with the theoretical equivalent resistance using percent difference.

Figure 2



- Q8: What equations describe the total resistance for the series, parallel and combination circuit?

- Q9: Does the total resistance changes when you swap resistors (e. g. you exchange R_1 with R_2) for any of the circuits? Explain.
- Q10: Simplify the equations found in Q8 for the case: $R_1=R_2=R_3$.

PART 4: Kirchhoff's Rules & Non-Trivial Circuits

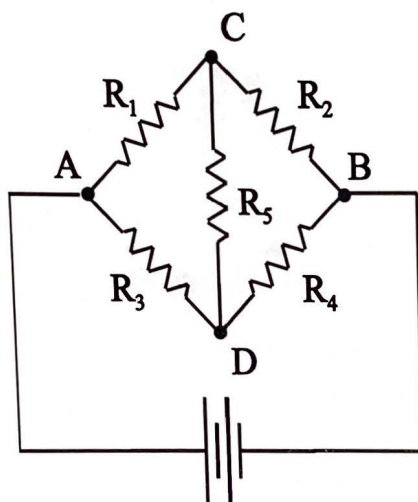
In this lab you will investigate Kirchhoff's Rules for electrical circuits, an especially useful method for more complicated circuits. You will construct what is called a "bridge circuit" and analyze it using Kirchhoff's Rules.

PREPARATION

Examine the circuit diagram for the bridge circuit as shown in Figure 3.

- Q11: State Kirchhoff's Loop Rule. State Kirchhoff's Junction Rule.

Figure 3. Bridge circuit



PROCEDURE

Connect the circuit shown in Figure 3 on the breadboard (J8) using the resistors given to you by your instructor ($R_1=51\ \Omega$, $R_2=33\ \Omega$, $R_3=27\ \Omega$, $R_4=68\ \Omega$ and $R_5=10\ \Omega$). Record all the individual resistor values used in Table 3.

-With no current flowing (i.e. before connecting to the power terminals) measure the total resistance between points A and B.

Now connect your circuit to the power terminals and switch on the power. Measure the voltage across each resistor, as well as the total voltage between points A and B. Record the voltages in Table 3.

Now measure and record the currents through each individual resistor and the total current leaving the batteries by inserting the current probe in series. Record the currents in Table 3. You will need to break the circuit and insert the current probe for each measurement.

Table 3

	Resistance (Ω)	Voltage (V)	Current (A)
Resistor 1	51	0.29	0.9
Resistor 2	33	0.13	1.2
Resistor 3	27	0.07	0.3
Resistor 4	68	0.06	0.2
Resistor 5	10	0.05	0.3
	$R_{AB} =$	$V_{AB} =$	$I_A = I_B =$

ANALYSIS

Use your experimental results to analyze the circuit in terms of Kirchhoff's Rules. Consider the net current flow into and out of each of the four nodes, and determine whether the junction rule is supported by your data. Determine the net voltage drop around *at least three closed loops* and determine whether or not your data supports the loop rule. (Pay close attention to your sign convention.)

In addition, verify if Ohm's law is satisfied for at least three resistors and for the total resistance.

- Q12: Why do you think this circuit is called a "non-trivial" circuit? Did you need to use Kirchhoff's Rules to analyze this circuit? Can you analyze it using the series/parallel method?

WRAPPING UP

- Q13: Under what conditions are Kirchhoff's Rules necessary to analyze a circuit?
- Q14: Do you think that the resistance of a voltage probe is large or small? Why?
- Q15: Do you think that the resistance of a current probe is large or small? Why?
- Q16: Can you think of a mechanical analogy to resistance? Explain your analogy.

PLEASE CLEAN UP YOUR AREA AND STRAIGHTEN YOUR CHAIRS, SO THE STATION IS READY FOR THE NEXT STUDENTS TO USE IT.