Ohms Law II—Elementary DC Circuits with Light Bulbs

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Objectives

The objectives of this experiment are: (1) to develop a conceptual understanding of elementary direct current (DC) circuits, (2) to understand the construction and use of series and parallel circuits, (3) to understand the current flow in simple series and parallel circuits, (4) to learn to properly connect components in series and parallel to make complete circuits, (5) to develop a conceptual understanding of DC circuits in order to predict changes in observables due to changes in the circuits, (6) to develop a conceptual understanding of Ohm’s Law, (7) to develop a conceptual understanding of the power consumption by electrical components, (8) to learn the basic concepts and relationships of current and voltage measurements in DC circuits containing resistors wired in series and parallel, and (9) to develop a conceptual understanding of the total resistance of resistors or light bulbs connected in series and parallel.

Introduction

This lab is intended to be a discovery lab to develop a conceptual understanding of Ohm’s Law and elementary direct current electrical circuits. Light bulbs are used to give a visual indication of the flow of current and power consumed by a resistive element. Series and parallel circuits are studied as well as combinations of the two types. In some cases, you will be asked to draw a schematic of your circuit. By “schematic” we mean that you should use symbols to represent light bulbs, switches, and power supplies rather than literal pictures. We will be using the following symbols:

![Symbols](image)

Figure 1. Symbols used in schematic diagrams.
Theory

Ohm’s Law

Ohm’s Law is the relationship between the current I flowing through a resistance R and the potential drop across it V. The current is directly proportional to the potential difference across the resistance and is inversely proportional to the resistance,

\[ I = \frac{V}{R}. \quad (1) \]

As an alternative, Ohm’s Law may be stated as: The potential difference V across a resistance is directly proportional to the current I flowing through the resistance and the resistance R, or

\[ V = I \times R. \quad (2) \]

Ohm’s Law can be rearranged to define the resistance R so that

\[ R = \frac{V}{I}. \quad (3) \]

If the potential difference across the resistance is measured in volts (V) and the current flowing through the resistance is measured in amperes (A), then the resistance values will be in units of ohms.

Power

Power is defined as the rate of doing work, and electrical power is defined as the amount of electrical energy being expended per unit time. The work \( \Delta W \) (mechanical energy) required to move an electrical charge \( \Delta Q \) through a potential difference V is given by

\[ \Delta W = \Delta Q \times V \quad (1) \]

and power is P is given by

\[ P = \frac{\Delta W}{\Delta t} = V \times \frac{\Delta Q}{\Delta t} \quad (2) \]

so that

\[ P = V \times I. \quad (3) \]

By substituting \( V = I \times R \) into Equation 3, power can also be expressed as

\[ P = V \times I = I^2 R, \quad (4) \]

or

\[ P = I^2 R. \quad (5) \]
Similarly, substituting \( I = \frac{V}{R} \) into Equation 3 yields

\[
P = \frac{V^2}{R}.
\]  

(6)

In summary,

\[
P = VI = I^2R = \frac{V^2}{R}.
\]  

(7)

**Apparatus**

The apparatus is shown in Figure 2 and consists of: (1) a prototype circuit boards with banana jacks for wiring the circuits, (2) a Pasco model PI-9877 power supply, (3) stackable double banana plugs with light bulbs or shorting bars (jumper wires) mounted, (4) stackable double banana plugs with toggle and push button switches, and (5) assorted leads with banana plugs.

The power supply can be adjusted to supply voltages of 0 to 18 volts. The power supply has a voltmeter and ammeter built into it. You can only access either the voltmeter or ammeter, and not both simultaneously. You can toggle between the voltmeter and ammeter by pushing the display button on the power supply. A complete set of basic instructions for using this power supply can be found on the back of the unit. The prototype circuit boards have an array of banana jacks conveniently laid out in a manner to wire and to help expedite the construction of the circuits to be studied. The arrays are constructed such that a minimum number of jumper plugs are needed. Light bulbs rated for 18 volts are supplied mounted to stackable double banana plugs that can installed at a desired position on the circuit board. Connections between banana jacks on the circuit board can be made either by using a stackable double banana plug with a jumper wire across its terminals or with a lead wire with a banana plug on each end.

![Figure 2. Apparatus for Ohms Law experiment to study resistors in series and parallel.](image-url)
Procedure

Part I.

1. Construct the following circuit using the circuit prototype board, light bulb, and power supply.

![Schematic diagram of circuit to be wired with photo.](image)

2. Plug in the power supply and turn on the power supply with the **OFF-ON** slide switch located at the right side of the power supply. The initial reading will be 0 volts and the display will be the voltmeter function. The default setup of the power supply allows the voltage to be changed in 1 volt increments by adjusting the **COARSE** knob. Smaller increments may be made with the **FINE** adjustment control knob.

3. Adjust the voltage of the power supply from 0 to 18 volts in 1 volt increments, pausing at each increment to observe how the output of the light bulb changes.

4. Draw the schematic diagram and record your observations.

5. Open an Excel spreadsheet and make a table of the voltage and current readings as you once again increment the power supply in 1 volt steps from 0 to 18 volts, pausing at each setting to toggle the **DISPLAY** button to read the current.

6. Calculate the resistance of the light bulb for each voltage-current incremental data point and record these in your spreadsheet.

7. Is the resistance constant and why or why not?

8. Make an Excel graph of voltage versus current for your data. Is the graph a straight line? Why or why not?

9. Calculate and record the power consumption of the light bulb at each incremental value.

Part II.

1. Construct the following circuit by adding a second light bulb in series with the first.
2. With the power supply adjusted to 18 volts, close the switch and notice the relative intensity of each light bulb to each other and to the intensity of the single bulb before the second was added.

3. Is the light from each bulb brighter, dimmer, or about the same as the light emitted from the single bulb?

4. How does the light emitted from the 2 bulbs compare with each other?

5. Estimate the change in the light emitted from bulb #1 when the second bulb was added? 2X, 3X, 4X, 8X, \(\frac{3}{4}X\), \(\frac{1}{2}X\), \(\frac{1}{4}X\), \(\frac{1}{8}X\)?

6. Read and record the current flowing to the 2 light bulbs. Using Ohm’s Law calculate the total resistance and power consumed by the 2 bulbs in series with the power supply adjusted to 18 volts.

7. How does the total resistance of the two bulbs in series compare with the resistance of the single bulb?

8. How does the total consumption of power used by the two bulbs compare with the power consumed by the single bulb at 18 volts and is this consistent with your observations of relative intensity?

9. What is the current flowing through bulb #1 and the current flowing through bulb #2?

10. Using Ohm’s Law and assuming the resistance of each bulb is exactly the same, what is the voltage across bulb #1 and the voltage across bulb #2?

11. Using this information, calculate and record the power consumption of each of the light bulbs.

12. Do these results agree with your intuition that says that since each bulb is the same, each consumes \(\frac{1}{2}\) the total power used by the 2 together?

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Part III.

1. Construct the following circuit by placing the second light bulb in parallel with the first.
Figure 5. Schematic diagram of two light bulbs in parallel.

2. With the power supply adjusted to 18 volts, close the switch and notice the relative intensity of each light bulb to each other and to the intensity of the single bulb before the second was added.
3. Is the light from each bulb brighter, dimmer, or about the same as the light emitted from the single bulb?
4. How does the light emitted from the 2 bulbs compare with each other?
5. Estimate the change in the light emitted from bulb #1 when the second bulb was added? 1X, 2X, 3X, 4X, 8X, ¼X, ½X, 1/3X, ¼X, 1/8X?
6. Read and record the current flowing to the 2 light bulbs. Using Ohm’s Law calculate the total resistance and power consumed by the 2 bulbs connected together in parallel with each other and with the power supply adjusted to 18 volts.
7. How does the total resistance of the two bulbs in parallel compare with the resistance of the single bulb?
8. How does the total consumption of power used by the two bulbs compare with the power consumed by the single bulb at 18 volts and is this consistent with your observations of relative intensity?
9. What is the current flowing through bulb #1 and the current flowing through bulb #2 assuming that the bulbs are identical as they should be?
10. Using Ohm’s Law and assuming the resistance of each bulb is exactly the same, what is the voltage across bulb #1 and the voltage across bulb #2?
11. Using this information, calculate and record the power consumption of each of the light bulbs.
12. Do these results agree with your intuition that says that since each bulb is the same, each consumes ½ the total power used by the 2 together?

Part IV.

1. Construct the circuit shown in Figure 6 by placing two light bulbs (bulbs #’s 2 and 3) in series with each other that are in turn in parallel with a third one (bulb #1).
Figure 6. Schematic diagram of the circuit to be constructed that has two light bulbs in series with each other in parallel with a third bulb.

2. Before closing the switch, predict which bulbs will be brighter, the same, and dimmer from the others.
3. Close the switch and notice the relative intensity of each light bulb to each other. Were your predictions correct?
4. Read and record the total current flowing to the three light bulbs.
5. Calculate the total resistance of this combination of light bulbs and record your results.
6. Calculate and record the total power consumption of these light bulbs in combination as they are connected.
7. Which light bulbs have the same current flowing through them and which light bulb(s) have more current flowing through them than either one or both of the other two.
8. Using your results of Parts II and III, what are the currents and voltages associated with each of the three light bulbs.
9. What is the power consumption of each of the three light bulbs in this combination.

Part V.

1. Construct the circuit shown in Figure 7 by placing two light bulbs in parallel with each other that are in turn in series with a third one.

Figure 7. Schematic diagram of the circuit to be constructed that has two light bulbs in parallel with each other that are in series with a third bulb.
2. Before closing the switch, predict which bulbs will be brighter, the same, and dimmer from the others.
3. Close the switch and notice the relative intensity of each light bulb to each other. Were your predictions correct?
4. Read and record the total current flowing to the three light bulbs.
5. Calculate the total resistance of this combination of light bulbs and record your results.
6. Calculate and record the total power consumption of these light bulbs in combination as they are connected.
7. Which light bulb(s) have the same current flowing through them and which light bulb(s) have more current flowing through them than either one or both of the other two.
8. Using your results of Parts II and III, what are the currents and voltages associated with each of the three light bulbs.
9. What is the power consumption of each of the three light bulbs in this combination.

Part VI.

1. Add S2, a push button switch mounted on a yellow dual banana plug, to the circuit used in Part V as shown in Figure 8 by placing it in the circuit branch containing light bulb number 2.

![Figure 8. Circuit used in Part V with switch added to branch of circuit with bulb number 1.](image)

2. With switch number 1 (S1) closed, predict what will happen to the relative intensities of the three light bulbs when switch number 2 (S2) is closed.
3. Close switch number 2 to check your prediction.
4. Provide an explanation for your observation.