

Ohms Law I--DC Circuits with Light Bulbs

PhET Lab I with Ammeters and Voltmeters

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Objectives

The objectives of this experiment are: (1) to understand and use Ohm's Law, (2) to learn, understand, and calculate power consumption by electrical components, (3) to learn, understand, and use resistors connected in series and parallel, (4) to learn the basic concepts and relationships of current and voltage measurements in DC circuits containing resistors wired in series and parallel, (5) to learn the relationships of the total resistance of resistors connected in series and parallel, and (6) to learn to use ammeters, voltmeters, ohmmeters, and multimeters to properly measure voltages, currents, and resistances.

Introduction

This laboratory exercise uses a computer simulation called the Circuit Construction Kit (CCK) that allows you to build electrical circuits that behave like real circuits. This program was developed by the Physics Education Technology (PhET) project at the University of Colorado at Boulder and is an ongoing effort to provide an extensive suite of simulations for teaching and learning physics. The program is a java program and is accessed by clicking on the CCK-DC icon  on the desktop of the laboratory computer. Alternatively, the program can be run on-line by accessing the PhET Web site at URL: http://phet.colorado.edu/new/simulations/sims.php?sim=Circuit_Construction_Kit_DC_Only. The CCK workspace is shown in Figure 1. In the white box towards the right, you can find wires, resistors, batteries, light bulbs, and switches. You can drag them out onto the workspace and connect them as needed. By right-clicking on the component you can change its value, read its value, or remove it from the workspace. Right-clicking a connection node allows you to split the junction so the connection is broken and to allow the addition of another component.

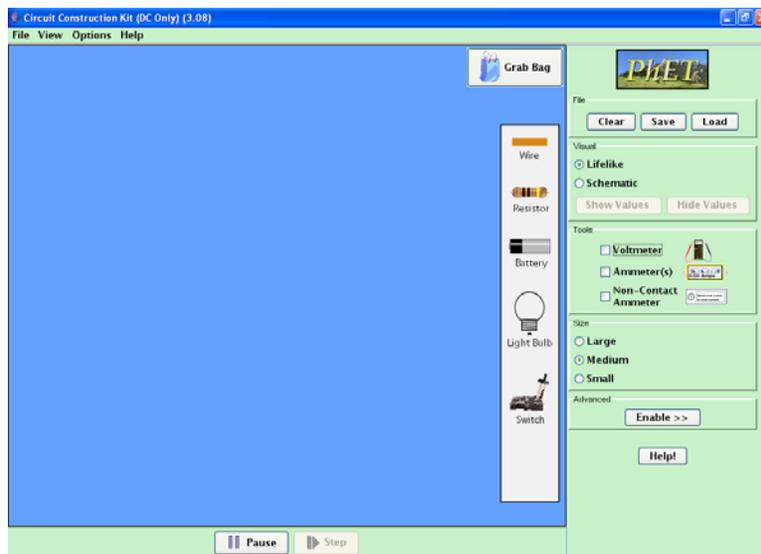


Figure 1. Circuit Construction Kit (CCK) workspace.

On the far right you can find options panels and measurement tools such as a voltmeter and two types of ammeters. One ammeter has to be placed properly in the circuit to be read and the other is a non-contact meter that can be used to hover over a component to read the current flowing through it. The test probes of the voltmeter can be moved around and connected to various points to read the voltage between them. The voltmeter reads the correct polarity of the voltage. If a switch is placed in a circuit, the switch may be opened and closed left-clicking on its center and moving it appropriately.

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 resistors, light bulbs, and batteries rather than literal pictures. We will be using the following symbols:

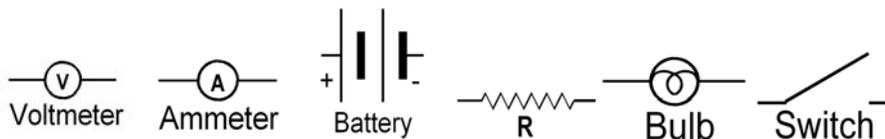


Figure 2. Symbols used in schematic diagrams.

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 ΔW (mechanical energy) required to move an electrical charge ΔQ 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

$$P = \frac{V^2}{R}. \quad (6)$$

In summary,

$$P = VI = I^2R = \frac{V^2}{R}. \quad (7)$$

Procedure

Part I.

1. Construct the following circuit using the CCK.

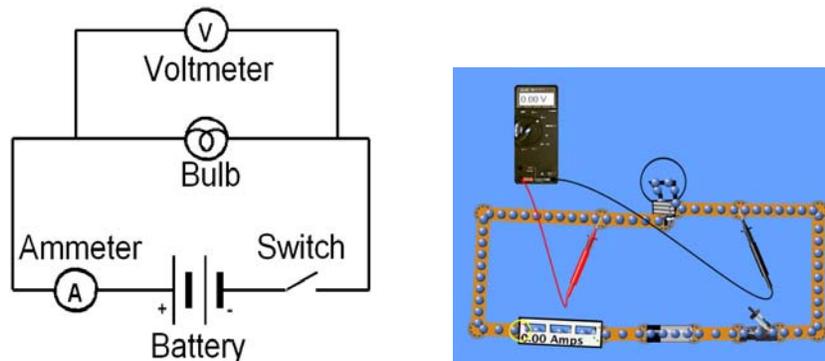


Figure 3. Schematic diagram of circuit to be constructed with the CCK program and the workspace of the simulation.

2. Open and close the switch and notice the light bulbs reaction.
3. Right-click on the battery and adjust its voltage to 30 volts.
4. Open and close the switch again and notice the difference in the emitted light.
5. Use the simulation voltmeter to read and record the voltage across the light bulb.
6. Note the polarity of the battery and the direction that the simulated current is flowing. Is the simulation the flow of positive or negative charges.
7. Read and record the current flowing through the light bulb.
8. Calculate the resistance of the light bulb.
9. Calculate and record the power consumption of the light bulb.
10. Right-click on the light bulb and choose the “Show Value” option to display its resistance. Compare your calculation with this value.

Part II.

1. Construct the following circuit using the CCK by adding a second light bulb in series with the first.

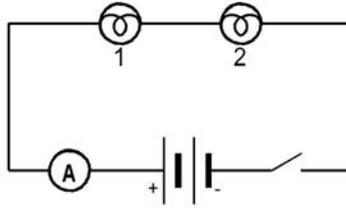


Figure 4. Schematic diagram of two light bulbs in series to be constructed with the CCK simulation program.

2. 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. Read and record the voltage across each of the light bulbs, the voltage across the two together, and across the terminals of the battery.
4. Read and record the current flowing to the two light bulbs.
5. Use the non-contact ammeter by placing its crosshairs over points in the circuit to read the current along the circuit from one battery terminal to other. Place it at points between:
 - a) the battery and in-line ammeter,
 - b) the in-line ammeter and light bulb number 1
 - c) light bulb number 1 and light bulb number 2
 - d) light bulb number 2 and the switch
 - e) the switch and the battery
6. What can you say about the current in this series circuit at these points?
7. Calculate the resistance of each light bulb and the two together in series.
8. Calculate and record the power consumption of each of the light bulbs.
9. How does the consumption of power of the two bulbs in series compare with the power consumption of the single light bulb? Is this consistent with your observations of relative intensity?

Part III.

1. Construct the circuit shown in Figure 5 using the CCK by placing the second light bulb in parallel with the first.

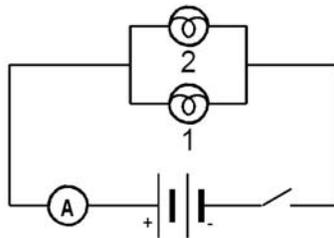


Figure 5. Schematic diagram of two light bulbs in parallel to be constructed with the CCK simulation program.

2. 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. Read and record the voltage across each of the light bulbs, the voltage across the two together, and across the terminals of the battery.
4. Read and record the current flowing to the two light bulbs.
5. Use the non-contact ammeter by placing its crosshairs over points in the circuit to read the current along the circuit from one battery terminal to other. Place it at points:
 - a) between the battery and the in-line ammeter,
 - b) between the in-line ammeter and the two light bulbs in parallel
 - c) just before and after light bulb number 1
 - d) just before and after light bulb number 2
 - e) between the two light bulbs in parallel and the switch
 - f) between the switch and the battery
6. What can you say about the current in this parallel circuit at these points?
7. Calculate the resistance of each light bulb and the two together in parallel.
8. Calculate and record the power consumption of each of the light bulbs.
9. How does the consumption of power of the two bulbs in parallel compare with the power consumption of the single light bulb? Is this consistent with your observations of relative intensity?

Part IV.

1. Construct the circuit shown in Figure 6 using the CCK by placing two light bulbs in series with each other in parallel with a third one.

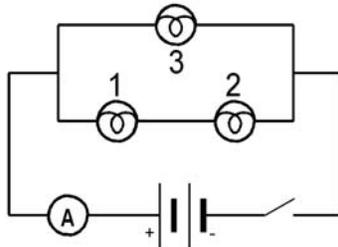


Figure 6. Schematic diagram of the circuit to be constructed with the CCK simulation program that has two light bulbs in series with each other in parallel with a third bulb.

2. Close the switch and notice the relative intensity of each light bulb to each other.
3. Read and record the voltage across each of the light bulbs, the voltage across the two in series, and across the combination, and across the terminals of the battery.
4. Read and record the current flowing to the three light bulbs.
5. Use the non-contact ammeter to read the current along the circuit from one battery terminal to other. Place it at points:
 - a) between the battery and the in-line ammeter,
 - b) between the in-line ammeter and the three light bulb combination

- c) just before and after light bulb number 1
 - d) just before and after light bulb number 2
 - e) just before and after light bulb number 3
 - f) between the three light bulb combination and the switch
 - g) between the switch and the battery
6. What general statement can you make about the currents in these parts of the circuit?
 7. Calculate the resistance of this combination of light bulbs.
 8. Calculate and record the power consumption of each of the light bulbs.
 9. Calculate and record the power consumption of the three light bulbs in combination.
 10. How does the consumption of power of the three bulbs compare with the power consumption of each of the single light bulbs in this circuit? Is this consistent with your observations of relative intensity?

Part V.

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

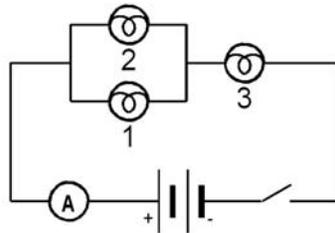


Figure 7. Schematic diagram of the circuit to be constructed with the CCK simulation program that has two light bulbs in parallel with each other that are in series with a third bulb.

2. Close the switch and notice the relative intensity of each light bulb to each other.
3. Read and record the voltage across each of the light bulbs, across the two in parallel, across the third resistor in series, across the combination, and across the terminals of the battery.
4. Read and record the current flowing to the three light bulbs.
5. Use the non-contact ammeter to read the current along the circuit from one battery terminal to other. Place it at points:
 - a) between the battery and the in-line ammeter,
 - b) between the in-line ammeter and the three light bulb combination
 - c) just before and after light bulb number 1
 - d) just before and after light bulb number 2
 - e) across bulbs 1 and 2 in parallel
 - f) just before and after light bulb number 3

- g) between the three light bulb combination and the switch
 - h) between the switch and the battery
6. What general statement can you make about the currents in these parts of the circuit?
 7. Calculate the resistance of this combination of light bulbs.
 8. Calculate and record the power consumption of each of the light bulbs.
 9. Calculate and record the power consumption of the three light bulbs in combination.
 10. How does the consumption of power of the three bulbs compare with the power consumption of each of the single light bulbs in this circuit? Is this consistent with your observations of relative intensity?

Part VI.

1. Add a switch to the circuit used in Part V as shown in Figure 8 by placing it in the circuit branch containing light bulb number 2. (Alternatively, you can just move the switch to this new position and leave out the first position.)

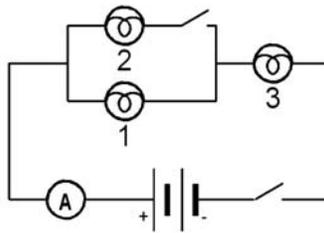


Figure 8. Circuit used in Part V with switch added to branch of circuit with bulb number 1.

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