Teacher's Preparatory Guide

LED Circuit Combination

Purpose

The purpose of this activity is to show an LED in a circuit. This activity will introduce diodes in simple circuits so that future activities may build upon this idea to conclude with micro/nano-circuits. LED brightness corresponds with the amount of current flowing through it. Resistor values within series, parallel, and combination circuits change the total current of a circuit.

Time required: 2 Class Periods (45 – 55 minutes each)

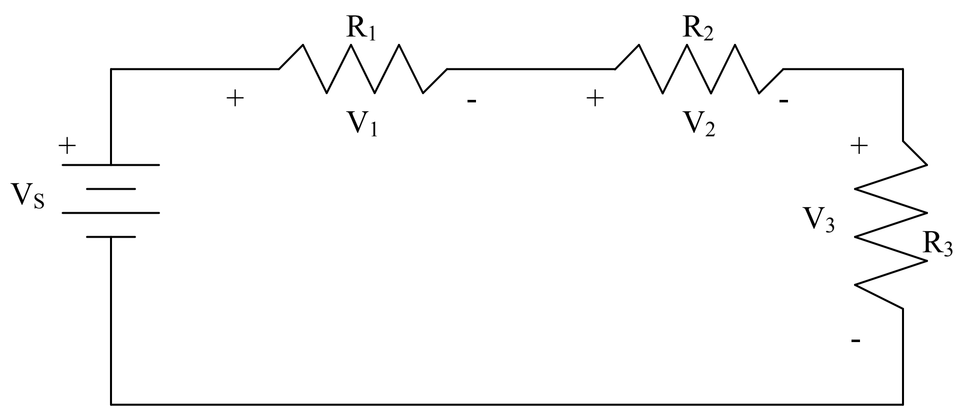
Level: High School

Teacher Background

Circuit Analysis

Circuit analysis information can be found in any physics textbook. Summarize the branch method and/or Kirchhoff's Rules.

1. Branch Method (Series Circuits)



$$I = I_1 = I_2 = I_3 = \ldots$$
$$\Delta V = V_1 + V_2 + V_3 + V\ldots$$
$$R_{eq} = R_1 + R_2 + R_3 + \ldots$$

$$V_1 = \frac{R_1}{R_1 + R_2 + R_3} V_S \qquad V_2 = \frac{R_2}{R_1 + R_2 + R_3} V_S \qquad V_3 = \frac{R_3}{R_1 + R_2 + R_3} V_S$$

$$V_1 = IR_1 \qquad V_2 = IR_2 \qquad V_3 = IR_3$$
$$I = \frac{V_1}{R_1} \qquad I = \frac{V_2}{R_2} \qquad I = \frac{V_3}{R_3}$$

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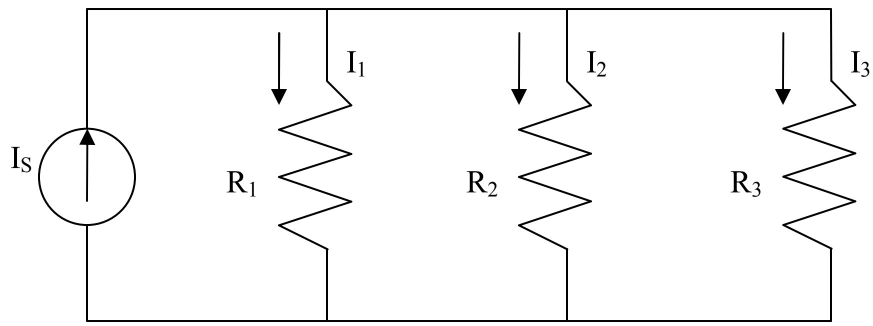
2. Branch Method (Parallel Circuits)



$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \qquad R_{eq} = \left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right]^{-1}$$

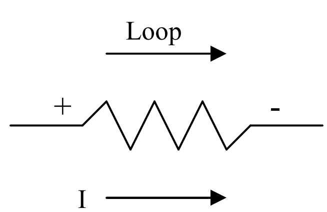
$$R_{eq} = \frac{R_2 R_3}{R_2 + R_3}$$

$$I_1 = \frac{\frac{1}{R_1}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} I_S \qquad I_2 = \frac{\frac{1}{R_2}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} I_S \qquad I_3 = \frac{\frac{1}{R_3}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} I_S$$

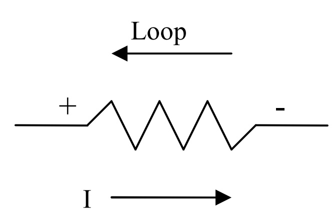
$$I_S = I_1 + I_2 + I_3 + \ldots$$
$$V_S = V_1 = V_2 = V_3 = V\ldots$$

3. Kirchhoff's Rules
   a. Junction Rule
      At any junction point, the sum of all currents entering the junction must equal the sum of all currents leaving the junction.
   b. Loop Rule
      The sum of the changes in potential around any closed path of a circuit must be zero.

Resistance



$\Delta V = -IR$



$\Delta V = IR$

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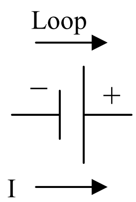
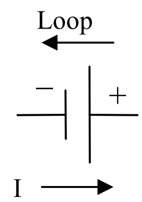
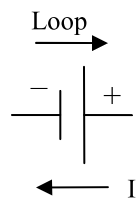
Voltage



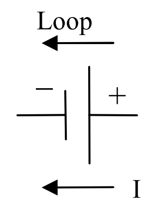
$\Delta V = +\varepsilon$



$\Delta V = -\varepsilon$



$\Delta V = +\varepsilon$



$\Delta V = -\varepsilon$

Ohm's Law

Georg Simon Ohm discovered that materials have an ohmic, or linear, region. His equation (Eqn 1) explains that as the potential difference (ΔV) increases, so does the current (I), and the relationship is linear to a point. The slope of a voltage vs. current plot yields the resistance (R). Temperature affects the resistance. If a resistor heats up, the value of its resistance increases, and the resistor is now considered non-ohmic. Non-ohmic materials have a non-linear relationship between voltage and current.

$$\Delta V = IR \qquad \text{Eqn 1}$$

LEDs

Figure 1 shows typical LEDs used in electrical circuits. LEDs are found in digital clocks, remote controls; light up watches, and traffic lights. An LED creates light without the use of a filament. Incandescents use filaments to light their bulbs. Besides shining light, incandescents also emit heat. LEDs do not heat up; therefore less energy is lost thereby making them more efficient than the typical incandensent light bulb. Below is an explanation of the technology used within LEDs.

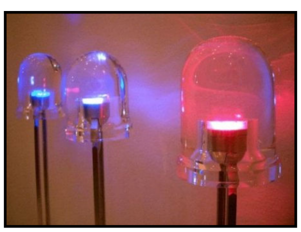


Figure 1. Photograph of LEDs. *(www.ohgizmo.com/wp-content/uploads/2007/10/led_of_led_1%20(Custom).jpg)*

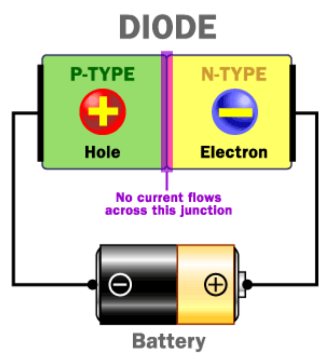


Figure 2. No current flow. *(electronics.howstuffworks.com/led1.htm)*

LEDs are made from semiconductors. Semiconductors have the

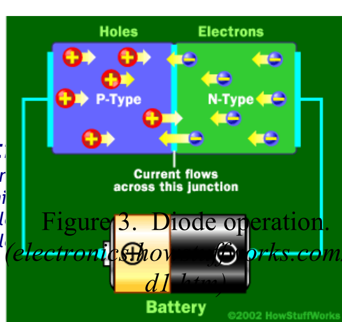


Figure 3. Diode operation. *(electronics.howstuffworks.com/led1.htm)*

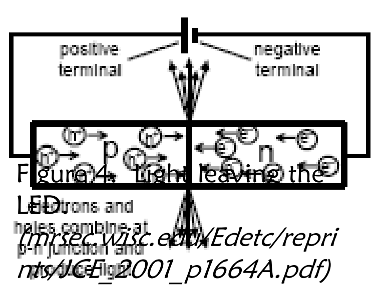


Figure 4. Light leaving the LED. *(mrsec.wisc.edu/Edetc/reprints/ICE_2001_p1664A.pdf)*

ability to be insulators or conductors with some manipulation from scientists/engineers. A semiconductor with extra electrons (free electrons) is called N-type material. These free electrons want to move to an area of positive charge. Semiconductors with extra "holes" (positive charge) are called P-type materials. The holes have a tendency to move towards the negatively charged electrons. A diode consists of both types of semiconductors as shown below. Diodes will only allow current to flow in one direction. Figure 2 shows a simple circuit in which current will not flow through. The electrons contained on the N-type material are attracted to the positive terminal of the battery. The P-type material contains the holes, acting as positive charges, which are attracted to the negative terminal of the battery. If the battery were switched as shown in Figures 3 and 4, the electrons and holes would be drawn to each other in attempt to reach the other side. On the way to the opposite wall, to reach the appropriate battery terminal, the holes and electrons interact. As they collide with one another they momentarily reach a higher energy level and then release the energy as light, in the case of a light emitting diode (LED).

As previously mentioned, current only flows in one direction in an LED. Semiconductors have varying resistance which depends on the voltage and current flow. An ohmmeter will not work in finding the resistance. LEDs are not Ohmic materials, meaning the relationship between current and voltage is not linear. To find the resistance measure the current at different voltages. Figure 5 shows the housing and structure of the LED. The terminal pins separately attach to the P-N diode. When the light is emitted it will hit the sides of the plastic case. Depending on the angle it might go right through or reflect off and cross the plastic covering at the top.

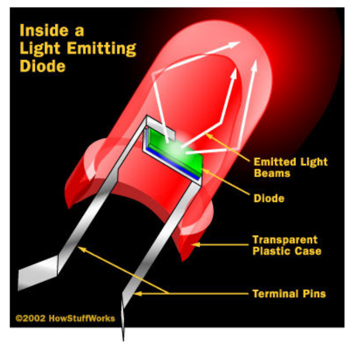


Figure 5. LED structure.
(static.howstuffworks.com/gif/led-diagram.jpg)

Breadboard Basics

Check out the sites listed below to learn the basics of breadboards:
http://www.technologystudent.com/elec1/bread1.htm
http://www.holtsoft.com/turing/resources/engineering/Appendices/Breadboard%20Basics.pdf

Materials (For each lab set-up)

- Ammeter
- Breadboard
- Multimeter (to measure resistance and voltage)
- Power supply/battery
- Jumper wires
- LED (Holiday bulb or regular)
- Three resistors (Any values)
- Switch

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Advance Preparation
Purchase LEDs and breadboards if you do not already have them. 3V batteries work best as a potential difference source. All can be purchased at Radio Shack.

Safety Information
No safety concerns because the experiment uses low voltage.

Directions for the Activity

1. The students should already know the basics of circuit analysis and Ohm's Law.
2. Review breadboard basics so that the students are able to construct what is shown on the circuit schematic to the breadboard.

Procedure (from Student Activity Guide)

Student Worksheet

LED Circuit Combination

Objective

The objective of this lab is to use LEDs to show the current flow through the path of a series, parallel, and combination circuit. The relationship between current flow and LED brightness will be illustrated when a constant potential difference is applied across the circuit.

Materials

- Ammeter
- Breadboard
- Multimeter (to measure resistance and voltage)
- Power supply/battery
- Jumper wires
- LED (Holiday bulb or regular)
- Three resistors
- Switch

Procedure

1. Test the polarity of the LED with a battery or power supply of 3V or less.
2. Choose three resistors with different resistances and record their values (from the color code and measured with an ohmmeter) in Table 1.

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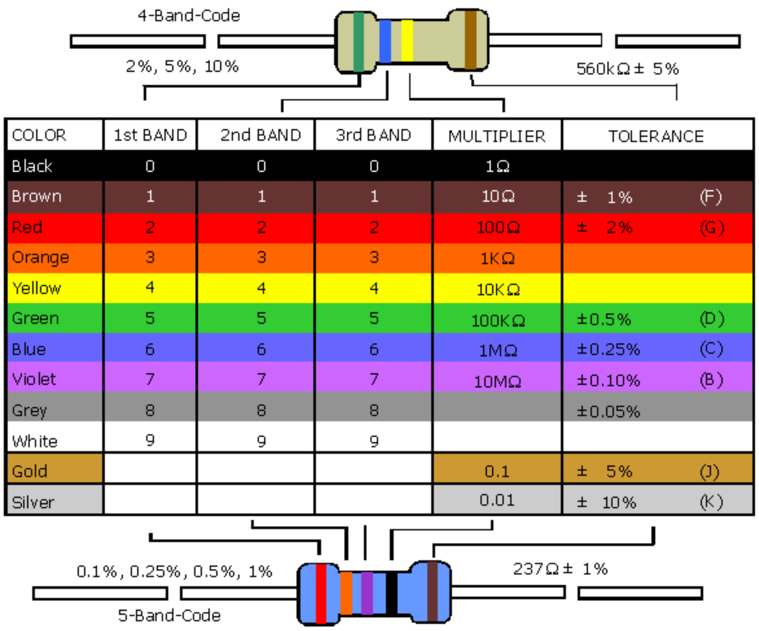

COLOR	1st BAND	2nd BAND	3rd BAND	MULTIPLIER	TOLERANCE
Black	0	0	0	1Ω	
Brown	1	1	1	10Ω	± 1% (F)
Red	2	2	2	100Ω	± 2% (G)
Orange	3	3	3	1KΩ	
Yellow	4	4	4	10KΩ	
Green	5	5	5	100KΩ	±0.5% (D)
Blue	6	6	6	1MΩ	±0.25% (C)
Violet	7	7	7	10MΩ	±0.10% (B)
Grey	8	8	8		±0.05%
White	9	9	9		
Gold				0.1	± 5% (J)
Silver				0.01	± 10% (K)

Figure 1. Resistor color code chart.

Table 1. Resistor data table.

Resistor	Color Code	Measured Resistance (Ω)	Color Coded Resistance (Ω)
R_1			
R_2			
R_3			

Part A: An LED in a Series Circuit

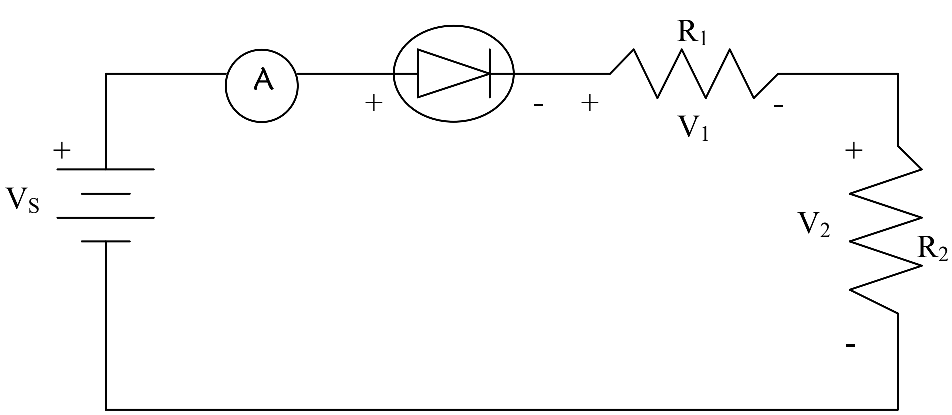

Figure 2. Series schematic circuit.

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3. Create a series circuit with resistor one (R_1) in the breadboard provided.
4. Add an ammeter between the battery and LED to record the current.
5. Attach the breadboard circuit to a 3V potential difference.
6. Does the LED light up? If it does not, change the polarity of the LED.
7. Measure the voltage across the resistor with the voltmeter or multimeter. Record the values in Table 2.
8. Measure and record the voltage across the LED.
9. Record the ammeter current (total current).
10. Disconnect the power supply.
11. Add another resistor (R_2) in series and repeat steps 4 through 10, but place the values in Table 3.
12. Add another resistor (R_3) in series and repeat steps 4 through 10, but place the values in Table 4.

Table 2. Data for the first series circuit.

Resistor	Resistor Value (Ω)	Resistor Voltage (V)	Current (A)
R_1			
LED			

Table 3. Data for the second series circuit.

Resistor	Resistor Value (Ω)	Resistor Voltage (V)	Current (A)
R_1			
R_2			
LED			

Table 4. Data for the third series circuit.

Resistor	Resistor Value (Ω)	Resistor Voltage (V)	Current (A)
R_1			
R_2			
R_3			
LED			

Part B: An LED in a Parallel Circuit

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13. Create a parallel circuit with R_1 and R_2 on the breadboard.
14. Add an ammeter and LED in series with the battery. Look at Figure 3 for help.
15. Connect the breadboard circuit to a 3V power supply or battery.
16. Does the LED light up? If it does not, change the polarity of the LED.
17. Measure the voltage across the resistors with the voltmeter or multimeter. Record the values in Table 5.
18. Measure and record the voltage across the LED.
19. Record the ammeter current (total current).
20. Disconnect the power supply.
21. Add another resistor (R_3) in parallel and repeat steps 17 through 20, but place the values in Table 6.

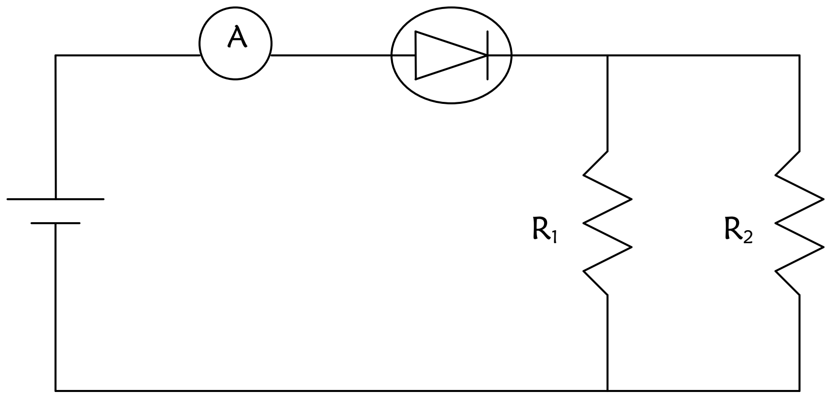

Figure 3. Setup for the first parallel circuit.

Table 5. Data for the first parallel circuit.

Resistor	Resistor Value (Ω)	Resistor Voltage (V)	Current (A)
R_1			
R_2			
LED			

Table 6. Data for the second parallel circuit.

Resistor	Resistor Value (Ω)	Resistor Voltage (V)	Current (A)
R_1			
R_2			
R_3			
LED			

Part C: An LED in a Combination Circuit

22. Create a combination circuit with R_1, R_2, and R_3 on the breadboard.
23. Add an ammeter, LED, and R_1 in series with the battery. Look at Figure 4 for help.

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24. Connect the breadboard circuit to a 3V power supply or battery.
25. Does the LED light up? If it does not, change the polarity of the LED.
26. Measure the voltage across the resistors with the voltmeter or multimeter. Record the values in Table 7.
27. Measure and record the voltage across the LED.
28. Record the ammeter current (total current).
29. Disconnect the power supply.

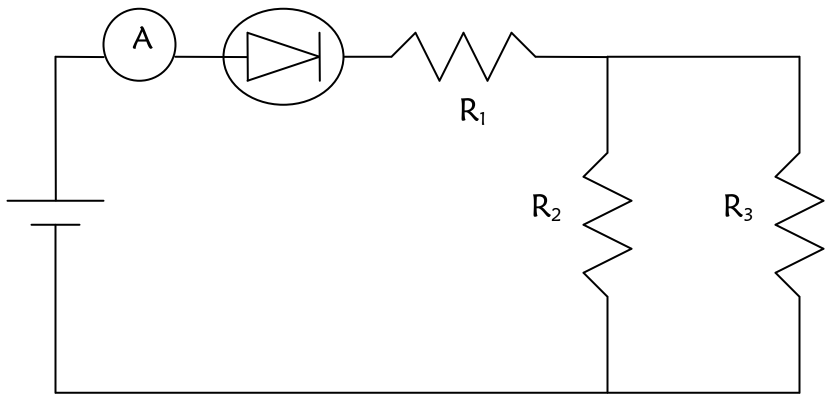

Figure 4. Setup for the first combination circuit.

Table 7. Data for the combination circuit.

Resistor	Resistor Value (Ω)	Resistor Voltage (V)	Current (A)
R_1			X
R_2			X
R_3			X
LED			

Analysis and Conclusion

1. In Part A, what happened to the LED as resistors were added?
2. In Part B, what happened to the LED as resistors were added?
3. Of all the circuits in this experiment which one caused the LED to shine the brightest? How do you know?
4. If there were a parallel circuit like the one shown in Figure 4. Which LED would be the brightest? Why?

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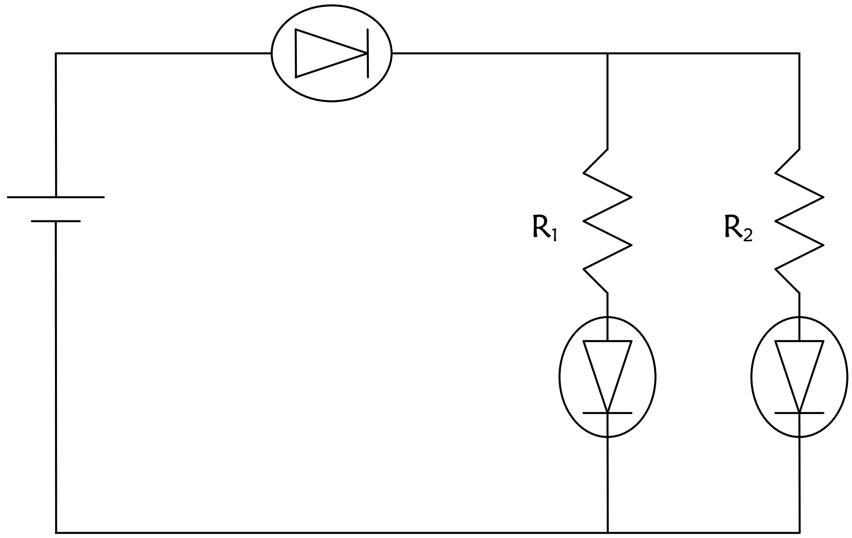

Cleanup:

Disconnect the battery or power supply. Return all circuit components to their proper containers.

Worksheet (with answers)

1. In Part A, what happened to the LED as resistors were added?
   The brightness decreases and so did the total current.
2. In Part B, what happened to the LED as resistors were added?
   The brightness increased and so did the total current.
3. Of all the circuits in this experiment which one caused the LED to shine the brightest? How do you know?
   The one with the highest current.
4. If there were a parallel circuit like the one shown in Figure 3. Which LED would be the brightest? Why?
   The LED in series with the ammeter and battery has the brightest LED because it has the most current flowing through it. The other LEDs have split current stemming from the total current.

Assessment

Answer the analysis and conclusion section questions.

Resources:

To learn more about nanotechnology, here are some web sites with educational resources:

http://www.technologystudent.com/elec1/bread1.htm
http://www.holtsoft.com/turing/resources/engineering/Appendices/Breadboard%20Basics.pdf
http://www.nnin.org
http://mrsec.wisc.edu

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Georgia Performance Standards

SP5. Students will evaluate relationships between electrical and magnetic forces.

b. Determine the relationship among potential difference, current, and resistance in a direct current circuit.
c. Determine equivalent resistances in series and parallel circuits.

National Science Education Standards

Physical Science Standards

- Structures and properties of matter
- Interactions of energy and matter
- Conservation of energy
- Structure of atoms

Science and Technology

- Understandings about science and technology

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