Stage 1 Physics
Current Electricity

Practical Investigations.
The following are learning tasks. They will help you develop the concepts.

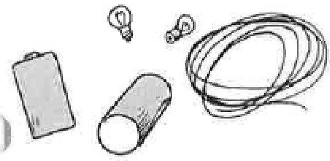
87 Sparky, the Electrician

Purpose

To study various arrangements of a battery and bulbs and the effects of those arrangements on bulb brightness.

Required Equipment/Supplies

size-D dry cell (battery)
6 pieces of bare copper wire
3 flashlight bulbs
3 bulb holders
second size-D dry cell (optional)



Discussion

A dry cell (commonly called a battery) is a source of electric energy. Many arrangements are possible to get this energy from dry cells to flashlight bulbs. In this activity you will test these arrangements to see which makes the bulbs brightest.

Procedure

Make bulb light with one battery

Step 1: Arrange one bulb (without a holder), one battery, and wire in as many ways as you can to make the bulb emit light. Sketch each of your arrangements, including failures as well as successes. Label the sketches of the successes.

1. Describe the similarities among your successful trials.

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Step 2: Use a bulb in a bulb holder (instead of a bare bulb), one battery, and wire. Arrange these in as many ways as you can to make the bulb light.

2. What two parts of the bulb does the holder make contact with?

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Step 3: Using one battery, light as many bulbs in holders as you can. Sketch each of your arrangements, and note the ones that work.

3. Compare your results to those of other students. What arrangement(s) using only one battery made the most bulbs glow?

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Step 4: Diagrams for electric circuits use symbols like the ones in Figure A.

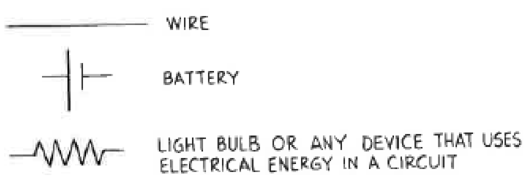
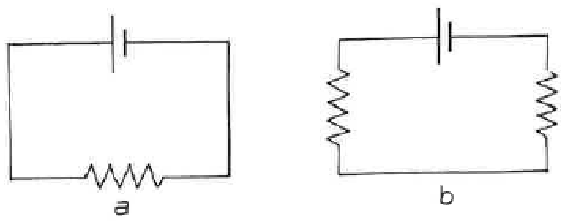


Fig. A

Connect the bulbs in holders, one battery, and wire as shown in each circuit diagram of Figure B. Circuits like these are examples of *series circuits.*



4. Do the bulbs light in each of these series circuits?

Step 5: In the circuit with two bulbs, unscrew one of the bulbs.

5. What happens to the other bulb?

Step 6: Set up the circuit shown in the circuit diagram of Figure C. A circuit like this is called a *parallel circuit.*

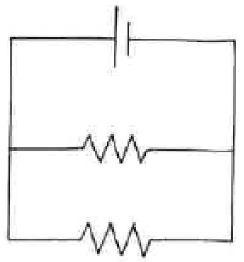


Fig. C

6. Do both bulbs light in this parallel circuit?

Step 7: Unscrew one of the bulbs in the parallel circuit.

7. What happens to the other bulb?

8. In your own words, describe the differences between series and parallel circuits.

Going Further

Step 8: Using two batteries, light as many bulbs as you can. Sketch each of your arrangements, and note the ones that work.

9. What arrangement(s) using two batteries lit the most bulbs?

____

____

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Step 9: Using three bulbs and two batteries, discover the arrangements that give different degrees of bulb brightness. Sketch each of your arrangements, and note the bulb brightnesses on the sketches.

10. How many different degrees of brightness could you obtain using three bulbs and two batteries? Did other students use different arrangements?

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____

____

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88 Ohm, Ohm on the Range—Part I

Purpose

To demonstrate the relationship between the current and the voltage across a resistance in a completed circuit.

Required Equipment/Supplies

milliammeter
6-V voltage source
3 resistors of 3 to 15 ohms
connecting wires
knife switch

Discussion

Water in a pipe requires a pressure difference in order to flow. How much water flows also depends on the resistance offered by the pipe. The rate of water flow through the pipe, the pressure difference between the ends of the pipe, and the resistance of the walls of the pipe are related. In this lab you will be exploring a similar relationship for the rate of flow of electrons in a wire, the voltage difference between the ends of the wire, and the resistance of the wire. You will use a technique similar to the one Georg Simon Ohm used more than a hundred years ago.

Procedure

Measure the current

Step 1: Select the resistor with the lowest resistance. If you do not know how to use the resistor code to determine the manufacturer's value of the resistance, consult your teacher. Connect the resistor, a switch, and an ammeter in series with a 6-volt voltage source, as shown in Figure A. Close the switch.

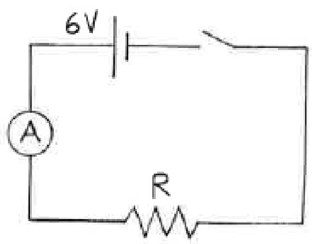

Fig. A

1. What is the current as measured by the ammeter?

Replace resistor

Step 2: Open the switch. Replace the resistor with a resistor that has twice the original resistance. Keep the voltage the same as in Step 1.

2. Predict whether the current reading will be greater than, less than, or the same as the current reading in Step 1.

Close the switch.

3. What is the current reading?

Replace resistor again

Step 3: Open the switch. Replace the resistor of Step 2 with an even larger resistor. Maintain the same voltage as in Step 1.

4. Predict whether the current reading will be greater than, less than, or the same as the current reading in Step 2.

Close the switch.

5. What is the current reading?

Analysis

6. You have now produced three different currents with three different resistances and a constant voltage. Apparently there is some relationship between the voltage V, the current I, and the resistance R. What is the relationship?

89 Ohm, Ohm on the Range—Part II

Purpose

To determine the relationship between the current and the voltage across the resistances in series circuits.

Required Equipment/Supplies

3 milliammeters
4 voltmeters
6-V voltage source
3 resistors of 3 to 15 ohms
knife switch
connecting wire

Discussion

Resistors can be connected end to end, or *in series,* in a circuit. What is the total resistance in the circuit when they are connected in series? Also, what happens to the currents and voltages across the resistance? This experiment explores these questions.

Procedure

Compute resistance for simple circuit

Step 1: Connect a resistor, a switch, and an ammeter in series with a voltage source. Connect a voltmeter across the resistor, as in the circuit diagram in Figure A. (The resistance of the resistor is labeled R_1. The two meters are shown as circles with an A for *ammeter* or a V for *voltmeter.*)

Close the switch. Measure the current I through the resistor and the voltage V across it. Record your measurements. Compute the resistance R_1, using the relation $R_1 = V/I$.

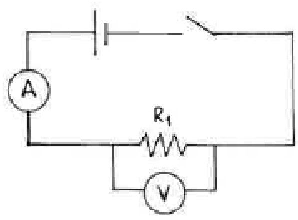

Fig. A

current I = ________

voltage V = ________

computed resistance R_1 = ________

1. How does your computed value of the resistance compare to the manufacturer's rated value?

____

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Add a second resistor **Step 2:** Modify the circuit to include a second resistor in series, as in the diagram in Figure B.

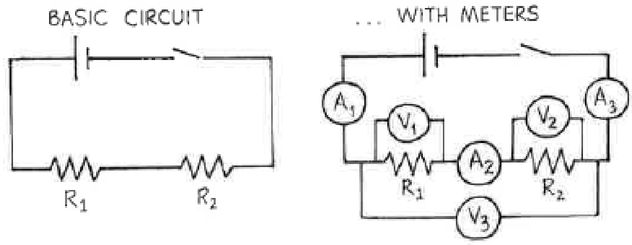

Fig. B

2. Predict whether the current measured by ammeter A_1 will be greater than, less than, or the same as the current measured in Step 1.

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____

3. Predict whether the voltage across the resistor used earlier in Step 1 will be greater than, less than, or the same as it was in Step 1.

____

____

____

Measure and record the actual currents and voltages.

current through A_1 = ______ current through A_2 = ______ current through A_3 = ______

voltage V_1 = ______ voltage V_2 = ______ voltage V_3 = ______

4. How do the three current readings compare?

____

____

5. How do the three voltage readings compare?

____

____

____

Compute resistances **Step 3:** Compute the values of resistances R_1 and R_2. Show your work.

R_1 = ________ R_2 = ________

6. What is the relationship among the current in the circuit, the *sum* of the resistances, and the voltage across all the resistances?

____

____

____

Predict current for three resistors

Step 4: Record the manufacturer's rating of each of the three resistors.

R_1 = __________

R_2 = __________

R_3 = __________

Arrange all three resistors, the switch, and the voltage source as shown in Figure C. With the switch closed, measure and record the total voltage V_4 across all three resistors.

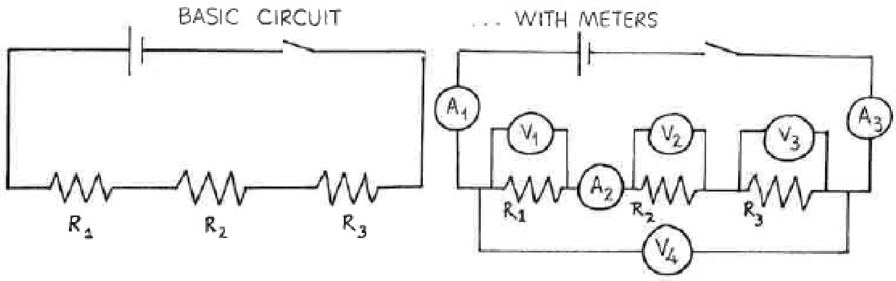

Fig. C

total voltage V_4 = __________

7. What is the total resistance in the circuit?

____

____

8. Predict what the three ammeters in Figure C will read.

____

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Measure the currents and voltages

Step 5: Measure the currents and voltages on ammeters and voltmeters placed as in Figure C.

current through A_1 = ______ current through A_2 = ______ current through A_3 = ______

voltage V_1 = ______ voltage V_2 = ______ voltage V_3 = ______

9. How do your measured values of the currents through ammeters A_1, A_2, and A_3 compare to the values you predicted in Step 4?

Compute resistances **Step 6:** From your current and voltage measurements, compute the values of resistances R_1, R_2, and R_3. Show your work.

R_1 = ________ R_2 = ________ R_3 = ________

10. Divide V_4 by the current. How does the result compare to the sum of the resistances you computed?

Analysis

11. How do the currents in different parts of a series circuit compare?

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12. Describe the relationship among the voltage of the source and the voltages across each resistance in a series circuit.

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13. Describe the relationship among the sum of the resistances and the sum of the voltages across each.

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14. One reason there may be variation between your predicted and measured values is that your meter may not have been zeroed properly. Another is that manufacturers guarantee the value of a resistor to be only within a specified percentage, or tolerance, of the stated value. When the fourth band is gold, the tolerance is 5%; silver, 10%; black (or no fourth band at all), 20%. Are your results consistent with the tolerances of the resistors you used?

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90 Ohm, Ohm on the Range—Part III

Purpose

To determine the relationships among the voltages, currents, and resistances in a parallel circuit.

Required Equipment/Supplies

4 ammeters
4 voltmeters
3-V voltage source
connecting wires
3 resistors of equal resistance (3 to 10 ohms)
2 additional resistors of different resistance (3 to 15 ohms)
knife switch

Discussion

When electric current takes a variety of paths in going from one place to another, we have a parallel circuit. Ohm's law takes on added interest in such a circuit.

Procedure

Compute resistance for simple circuit

Step 1: Connect a resistor, a switch, and an ammeter in series with a 3-volt voltage source. Connect a voltmeter across the resistor, as in the circuit diagram in Figure A.

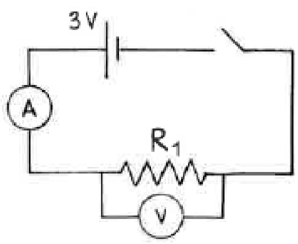


Fig. A

Close the switch, and record the current through the resistor and the voltage across it. Compute the resistance R_1, using Ohm's law.

current = ________

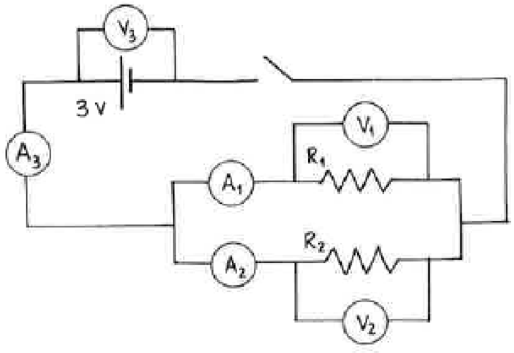
voltage = ________

computed resistance R_1 = ________

Add resistor in parallel

Step 2: Place a second resistor of equal resistance in parallel with the first resistor, as in the diagram in Figure B. Also add the additional ammeters and voltmeters shown in the diagram.

Fig. B



1. Predict whether the current measured by ammeter A_3 will be greater than, less than, or the same as the current measured in Step 1.

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2. Predict whether the voltage V_1 across the first resistor will be greater than, less than, or the same as it was in Step 1.

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Close the switch. Measure and record the actual currents and voltages.

current through A_1 = ______	current through A_2 = ______	current through A_3 = ______
voltage V_1 = ______	voltage V_2 = ______	voltage V_3 = ______

3. How do the three current readings compare?

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4. How do the three voltage readings compare?

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Compute resistances **Step 3:** Compute the values of resistances R_1 and R_2. Show your work.

R_1 = ________ R_2 = ________

Compute the equivalent resistance of the circuit by dividing the voltage of the source by the current through the source.

equivalent resistance = ________

5. How does the equivalent resistance of the circuit compare with the two values you computed for the individual resistances?

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Add third resistor in parallel **Step 4:** Add a third resistor of equal resistance in parallel with the first and second resistors, as shown in Figure C. Also add the additional ammeter and voltmeter, as shown. Close the switch. Measure and record the currents and voltages.

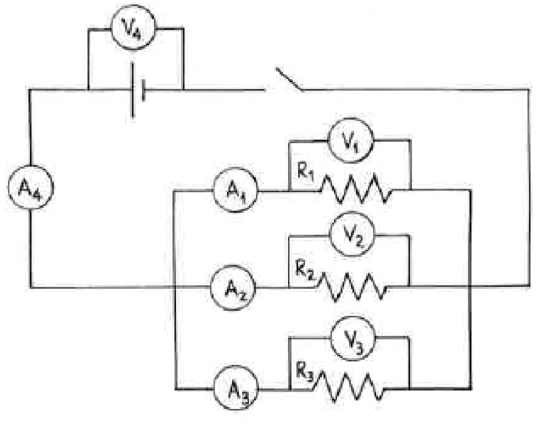

Fig. C

current through A_1 = ______ current through A_2 = ______

current through A_3 = ______ current through A_4 = ______

voltage V_1 = ______ voltage V_2 = ______

voltage V_3 = ______ voltage V_4 = ______

Compute the resistances

Step 5: From your current and voltage measurements, compute the values of resistances R_1, R_2, and R_3. Show your work.

R_1 = ________ R_2 = ________ R_3 = ________

Compute the value of the equivalent resistance of the circuit.

equivalent resistance = ________

6. How does the equivalent resistance of the circuit compare to the three individual resistances you computed?

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Repeat using different resistors

Step 6: Repeat Step 4 using three resistors of unequal resistance.

current through A_1 = ______ current through A_2 = ______

current through A_3 = ______ current through A_4 = ______

voltage V_1 = ______ voltage V_2 = ______

voltage V_3 = ______ voltage V_4 = ______

Compute the resistances

Step 7: From your current and voltage measurements for Step 6, compute the values of resistances R_1, R_2, and R_3. Show your work.

R_1 = ________ R_2 = ________ R_3 = ________

Compute the value of the equivalent resistance of the circuit.

equivalent resistance = ________

7. How does the equivalent resistance of the circuit compare to the three individual resistances you computed?

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Analysis

8. Describe the relationship among the currents in a parallel circuit.

9. Describe the relationship among the voltages in parallel branches of a circuit.

10. Describe the relationship among the equivalent resistance and the individual resistances in a parallel circuit.

91 3-Way Switch

Purpose

To explore ways to turn a light bulb on or off from one of two switches.

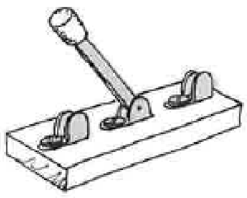
Required Equipment/Supplies

2.5-V dc light bulb with socket
connecting wire
2 single-pole double-throw switches
2 1.5-V size-D dry cells connected in series in a holder

Discussion

Frequently, multistory homes have hallways with ceiling lights. It is convenient if you can turn a hallway light on or off from a switch located at either the top or bottom of the staircase. Each switch should be able to turn the light on or off, regardless of the previous setting of either switch. In this activity you will see how simple but tricky such a common circuit really is!

Procedure



SINGLE POLE DOUBLE-THROW SWITCH

Step 1: Examine a 3-volt battery (formed from two 1.5-volt dry cells connected from the positive terminal of one to the negative terminal of the other). Connect a wire from the positive terminal of the battery to the center terminal of a single-pole double-throw switch. Connect a wire from the negative terminal of the same battery to one terminal of the light bulb socket. Connect the other terminal of the light bulb socket to the center terminal of the other switch.

Devise working circuit

Step 2: Now interconnect the free terminals of the switches so that the bulb turns on or off from either switch. That is, when both switches are closed, closing one switch in the opposite direction will always make the bulb turn on or off.

Diagram 3-way switch

Step 3: Draw a simple circuit diagram of your successful circuit.

Reverse polarity of battery

Step 4: The polarity of a battery can be reversed in a circuit by switching the connections to the positive and negative terminals. Predict whether your successful circuit will work if you reverse the polarity of the battery.

prediction: ____________________

Now reverse the polarity and record the result.

result: ____________________

Interchange battery and bulb

Step 5: Predict whether your successful circuit will work if you reconnect the circuit so that the battery is where the light bulb is now, and vice versa.

prediction: ____________________

Now try it, and record your results.

results: ____________________

Analysis

An ordinary switch has an "on" setting, which closes the circuit at that point, and an "off" setting, which opens the circuit at that point. On the switches you used in this activity, what function do the two "closed" settings on each switch have? Can either setting keep the circuit open independently of how the other switch is set?

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