

Lab 15 Exploring Solar Collectors

Name: _____ Lab Partner(s): _____

Driving Question

Using the sun to heat water is not a new idea. Humans have been harnessing the thermal energy of the sun for centuries. Today, solar thermal systems are found on rooftops around the world, providing affordable, pollution-free hot water for millions of people.

In most US homes, water is heated using electricity, natural gas, or oil. Since most of our electricity is generated from fossil fuels, it is safe to say that most water in the United States is heated using energy from fossil fuels. The burning of fossil fuels releases pollution into the environment and is believed to contribute to global climate change.

Since it takes a large amount of energy to heat water, it can be a significant portion of our energy bills. Replacing a traditional water heater with a device that can heat water using energy from the sun is not only good for the environment, it can also be a great way to save money on your energy bill.

Solar collectors take advantage of the greenhouse effect in order to heat water. Have you ever noticed how surprisingly warm it is inside a car that has been parked in the sun? Sunlight easily passes through the glass windows and is converted into heat when it hits the interior of the car. Some of that heat passes back through the glass, but a lot of it gets trapped inside. In a solar collector, this trapped heat warms the water that is circulating through the system.

A solar collector system used to heat water generally includes the following parts:

- A solar collector positioned to face the sun so it can catch and absorb sun light
- A transparent cove
- A heat insulating backing for the solar collector
- A fluid, either water or antifreeze, flowing through the collector, usually in tubes
- An insulated tank to store the heated water
- (optional) A pump and controls to move the water through the system
- (optional) A back-up energy source (electric or natural gas)

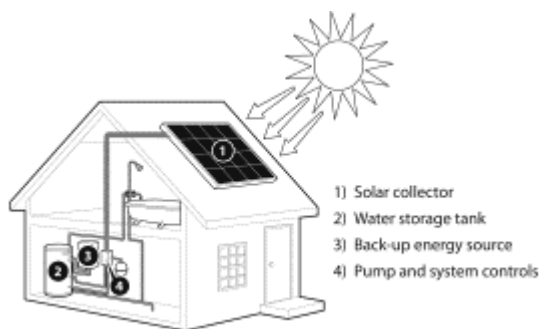


Figure 1: A solar collector system

The KidWind Solar Thermal Exploration Kit that you will use in this experiment is a model of what is called an active or forced circulation system. This type of solar water heater requires a pump to move water from the storage tank to the collector. Most solar water heaters in the United States are forced circulation systems because this type of system works well even when temperatures drop below freezing. Passive systems that do not use an electric pump are also common, but are not practical for colder climates where the water may freeze.

The color of the solar absorber affects the ability of the solar collector to take advantage of the greenhouse effect. Every color reflects a certain amount of light while absorbing the rest as heat energy. In this experiment, you measure the reflectivity of various colors using a light sensor, and then compare these values to the reflection value of aluminum foil. Aluminum foil will arbitrarily be assigned a reflectivity of 100 percent. You will calculate percent reflectivity using the relationship

$$\% \text{ reflectivity} = \frac{\text{value for paper}}{\text{value for aluminum}} \times 100$$

After determining the best color for the background of the solar collector, you will set up a solar collector and measure the change in water temperature during data collection.

Objectives

- Use a light sensor to measure reflected light.
- Use a temperature sensor to measure changes in temperature.
- Calculate percent reflectivity of various colors.
- Use results to design and set up a solar collector.
- Determine the temperature change of the water in a solar collector.

Materials

- Temperature sensor
- 2 utility clamps
- Light Sensor
- lamp and 150 W light bulb
- KidWind Solar Thermal Exploration Kit
- 2 pieces of paper of different colors
- Ring stand
- Aluminum foil
- Tape
- Ruler

Preliminary Questions

1. One of the many advantages of using a solar water heating system to heat water for your home is that it can be retrofitted to older buildings. Identify two other advantages and also two disadvantages of using solar collectors for heating water.
2. What design factors, other than color, affect the efficiency of a solar collector?

3. What colors will you test for reflectivity and absorption? Predict the rank of the pieces of paper, in terms of the paper's reflectivity, from least to greatest. Create a second list that ranks the paper's ability to absorb heat, from least to greatest.

Procedure

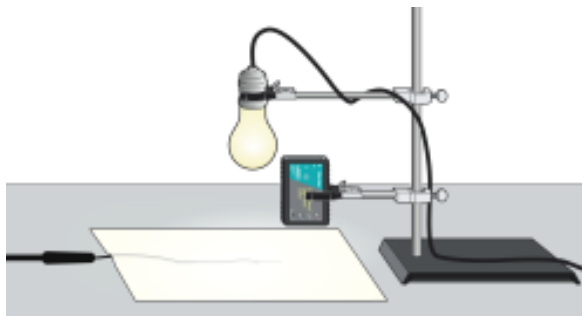
Part I: Light Reflectivity and Heat Absorption



1. Open *SPARKvue* and build a page with two graphs.
2. Connect the light and temperature sensors.
3. Set up the data-collection mode.
 - (a) Click or tap Mode to open Data Collection Settings.
 - (b) Change Time Units to min.
 - (c) Change Rate to 6 samples/min and End Collection to 10 minutes.
 - (d) Click or tap Done.
4. Set up the equipment for data collection.
 - (a) Tape the cable of the temperature sensor to the table surface.




- (b) Bend the tip of the temperature sensor to make sure that the sensor does not touch the tabletop during data collection (or you will measure the temperature of the table).

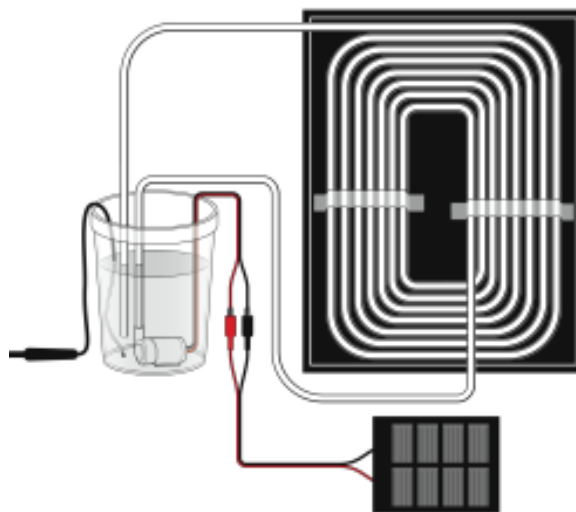
- (c) Place one of your pieces of paper over the temperature sensor.
- (d) Use a utility clamp and ring stand to fasten a light sensor 5 cm above the paper.



5. Switch on the light bulb and click or tap Collect to start data collection.
6. When data collection is complete, turn off the lamp and determine and record the mean light reflection value and the minimum and maximum temperature readings.
 - (a) Click or tap Graph Tools, , for the temperature graph and choose View Statistics. Record the minimum and maximum temperature readings (round to the nearest 0.1°C).
 - (b) Click or tap Graph Tools, , for the illuminance graph and choose View Statistics. Record the mean light reflection value in your data table (round to the nearest whole lux).
7. Repeat Steps 4-5 two times (once for the second piece of paper you are testing and a second time for a piece of aluminum foil).
8. Complete the Processing the Data and Analysis Questions sections for Part I before continuing to Part II.

Part II: Solar Collector

1. Disconnect the light sensor from *SPARKvue*. Leave the temperature sensor connected. Click or tap File, , and choose New Experiment. Click or tap Sensor Data Collection.
2. Click or tap Mode to open data collection settings.
 - (a) Change Time Units to min.
 - (b) Change Rate to 6 samples/min and End Collection to 20 minutes.
 - (c) Click or tap Done.
3. Set up the solar collector in a sunny place.
 - (a) If your tray is a color other than the color you determined during Part I, line the tray with paper to change its color.
 - (b) Arrange the tubing in the box so water will flow through it. If necessary, tape down the tubing to hold it in place (see figure below).
 - (c) Put the cover on the solar collector.
 - (d) Connect the tubing to the water pump and secure the pump to the bottom of the water storage container.
 - (e) Add water to the storage container. Measure the amount of water added.
 - (f) Place the free end of the tubing into the water.
 - (g) Position the temperature sensor in the water storage container. If necessary, tape it in place.
 - (h) Connect the solar panel to the wires from the pump (red to red and black to black) using the alligator clips. Note: If the solar panel is receiving sunlight, the pump will start working when the panel and pump are connected. Cover the solar panel before you connect the wires and then uncover it when everything is in place.



- Click or tap Collect to start data collection.
- When data collection is complete, a graph of temperature vs. time is displayed. Determine the starting temperature and maximum temperature. Record these values in the data table.

Data Table*Part I: Light Reflectivity and Heat Absorption*

Color			Aluminum
Starting temperature ($^{\circ}\text{C}$)			
Final temperature ($^{\circ}\text{C}$)			
Change in temperature ($^{\circ}\text{C}$)			
Reflection value (lux)			
Percent reflectivity (%)			

Part II: Solar Collector

Color	
Starting temperature ($^{\circ}\text{C}$)	
Maximum temperature ($^{\circ}\text{C}$)	
Change in temperature ($^{\circ}\text{C}$)	

Processing the Data

Part I: Light Reflectivity and Heat Absorption

1. Subtract to find the change in temperature for each color paper.
2. Calculate the percent reflectivity of each color paper.

Part II: Solar Collector

1. Subtract to find the change in temperature.

Analysis Questions

Part I: Light Reflectivity and Heat Absorption

1. Which color paper had the largest temperature increase?

2. Which color paper had the smallest temperature increase?

3. Solar collectors can be used to absorb the sun's energy and change it to heat. What color would work best for solar collectors? Explain.

4. Which color paper has the highest reflectivity?

5. Which color paper has the lowest reflectivity?

6. What relationship do you see between percent reflectivity and temperature change?

Part II: Solar Collector

1. Sketch or print your graph. Describe what happened to the temperature of the water during data collection. Did the water heat up at a consistent rate?

2. Compare your results to the data collected by other groups. Which variables account for differences between your data and the results of the other groups?

3. If you were going to re-design your solar collector to try to make it heat water more quickly, what would you do?

Extend

1. There are two general categories of solar collector: flat plate collectors and evacuated tube collectors. Research the two categories and explain why you would chose to install one over the other based on their differences.
2. Other than heating water for use in a home, what else do people use solar collectors for?
3. Research what would be involved in retrofitting your own home to use a solar collector to heat air, water, or generate electricity. Consider installation costs and cost savings over time.
4. Collect data for the solar water heater for longer than 20 minutes. How hot does the water get after an hour? Eventually, does the temperature stop rising?
5. Makes changes to your solar collector and collect data again to see if you get a greater increase in temperature.
6. Measure the mass of water heated in the solar collector and use the specific heat capacity of water to calculate the amount of energy used to heat the water

$$Q = mc\Delta T,$$

where Q is the heat supplied, m is mass, c is specific heat capacity of water, and ΔT is the change in temperature.