Reflection and Absorption of Light

Would you feel cooler wearing a light- or dark-colored shirt on a hot, sunny day? The color and texture of an object influences how much radiant energy from the sun the object will absorb or reflect. Every color reflects a certain amount of light while absorbing the rest as heat energy. The amount of reflected light is called the color's *light reflectance value*. Dark colors with low light reflectance values tend to reflect little light while absorbing lots of heat energy, whereas light colors with high reflectance values reflect a lot of light and absorb little energy. People in warm, sunny climates are more likely to purchase light-colored cars since they don't heat up as quickly as dark-colored ones. Many house paints come with a predetermined light reflectance value to guide consumers when making color choices for their homes. Since Earth's surface is made of many colors and textures, it is heated unevenly. Snow, ice, and clouds reflect a lot of energy back into space, while green forests and vegetated lands absorb energy.

In this experiment, you will investigate the relationship between the percent reflectivity of various colors and the temperature change due to energy absorption. You will measure the amount of light reflected from paper of various colors using a light sensor and calculate percent reflectivity. You will also use a temperature probe to measure the temperature change of the air under the paper due to energy absorption by the paper.

OBJECTIVES

- Use a light sensor to measure the amount of reflected light.
- Calculate percent reflectivity of various colored paper.
- Use a temperature probe to estimate the amount of energy absorbed by the paper.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis app
Go Direct Light and Color
Go Direct Temperature
lamp with 100 W equivalent bulb
aluminum foil
white paper
black paper
2 other pieces of colored paper
ring stand
utility clamp
tape
ruler

PROCEDURE

1. Launch Graphical Analysis. Connect the Go Direct Light and Color Sensor and the Go Direct Temperature Probe to your Chromebook, computer, or mobile device.

2. Set up the data-collection mode.
   a. Click or tap Mode to open Data Collection Settings.
   b. Change Rate to 0.1 samples/s and End Collection to 600 s.
   c. Click or tap Done.

3. Prepare the sensors for data collection.
   a. Secure the temperature probe to the table by placing a piece of tape across the handle. The tip of the probe should not be touching the tabletop.
   b. Place the piece of white paper over the temperature probe.
   c. Use a utility clamp and ring stand to fasten the Go Direct Light and Color Sensor 5 cm above the table top as shown in Figure 1. The sensors should be facing down toward the table.
   d. Position the lamp so that the bulb is 10 cm above the table top and next to the Light and Color Sensor.
   e. The classroom lights should be on.

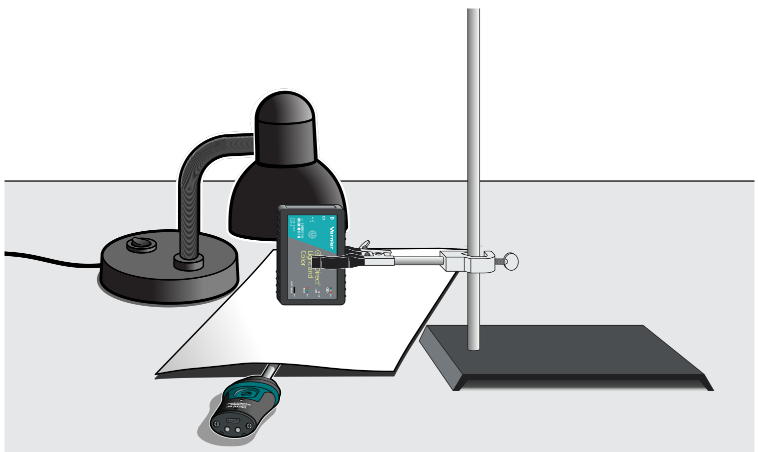

Figure 1

4. Switch on the light bulb and click or tap Collect to start data collection.

5. When data collection is complete, determine and record the mean light reflection value and the minimum and maximum temperature readings.
   a. Turn off the light bulb when data collection is complete.
   b. Click or tap Graph Tools, , for the illuminance graph and choose View Statistics.
   c. Record the mean light reflection value in your data table (to the nearest whole lux).
   d. Click or tap Graph Tools, , for the temperature graph and choose View Statistics.
   e. Record the minimum and maximum temperature readings (round to the nearest 0.1°C).

6. Repeat Steps 4–5 for black paper and aluminum foil. If time allows, make and record readings for two additional colors of paper.

DATA

Color	White paper	Black paper	Aluminum	________	________
Starting temperature (°C)					
Final temperature (°C)					
Change in temperature (°C)					
Reflection value (lux)					
Percent reflectivity (%)			100		

PROCESSING THE DATA

1. Subtract to find the change in temperature for each color paper.
2. Which color paper had the largest temperature increase?
3. Which color paper had the smallest temperature increase?
4. Solar collectors can be used to absorb the sun's radiation and change it to heat. What color would work best for solar collectors? Explain.
5. Calculate the percent reflectivity of each color paper using the following relationship:

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

   Show your work in the data table above.

6. Which color paper has the highest reflectivity?
7. Which color paper has the lowest reflectivity?
8. What relationship do you see between percent reflectivity and temperature change?
9. What types of surfaces might give a planet a high reflectivity? Explain.
10. Does the planet Earth have high reflectivity? Why or why not?

EXTENSIONS

1. Design an experiment to test the reflectivity of sand, soil, water, and other materials. Perform the experiment you designed.

2. Design an experiment to test the effect of texture on reflectivity. Perform the experiment you designed.

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1. In the Electronic Resources you will find multiple versions of each student experiment—one for each supported data-collection software (Graphical Analysis, LabQuest App, Logger *Pro*, and EasyData). Deliver to your students the version that supports the software and hardware they will use. Sign in to your account at **vernier.com/account** to access the Electronic Resources. See Appendix A for more information.
2. Heavy construction paper works well in this experiment. Try to obtain pieces with the same texture and thickness. Rectangular 10 cm × 20 cm pieces work well. The construction paper and aluminum foil can be saved for reuse.
3. It is important to use a light bulb that gives off a good amount of heat, such as a 100 W equivalent incandescent bulb. LED and compact fluorescent bulbs do not put off enough heat for this investigation.
4. Remind students to not look right at or touch the light bulbs, even if turned off, because they can harm their eyes and be very hot.
5. If you are using calculators for data collection, the student version of this activity contains two methods. Use Method 1 if you are collecting data with light sensor and an EasyTemp or a temperature probe connected to an EasyLink. Use Method 2 if you are collecting data with a light sensor and a temperature probe connected to a LabPro or CBL 2.
6. For additional information about the Vernier probeware used in this experiment, including tips and product specifications, visit **www.vernier.com/manuals** and download the appropriate user manual.
7. If you are using Go Direct sensors, see **www.vernier.com/start/go-direct** for information about how to connect your sensor.

ESTIMATED TIME

We estimate that this experiment can be completed in one 45–55 minute class period.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Analyzing and interpreting data	ESS2.A Earth Materials and Systems ESS2.D Weather and Climate	Cause and effect

SAMPLE DATA

Material	White paper	Black paper	Aluminum foil
Starting temperature (°C)	22.5	21.5	21.0
Final temperature (°C)	31.1	33.3	23.8
Change in temperature (°C)	8.6	11.8	2.8
Reflection value (lux)	3000	668	4884
Percent reflectivity (%)	61.4	14.1	100

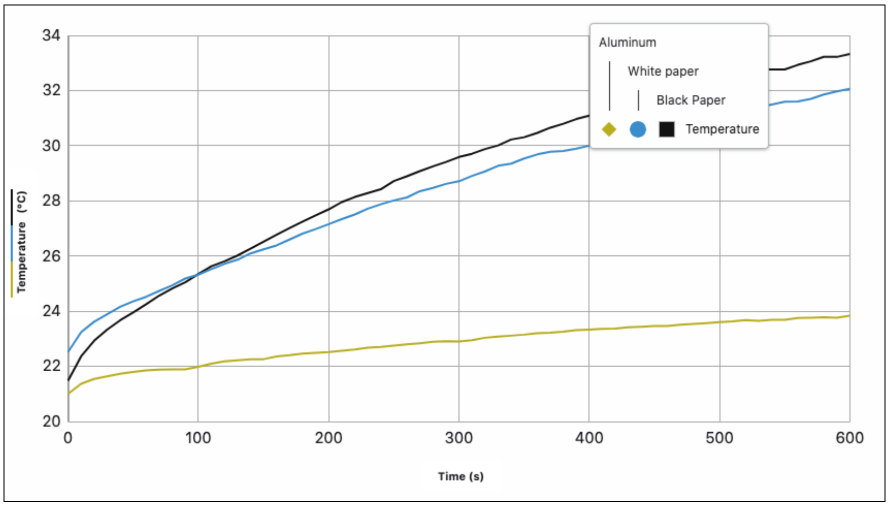

Figure 1

ANSWERS TO QUESTIONS

1. See the Sample Data.
2. Black paper had the largest temperature increase.
3. White paper had the smallest temperature increase.
4. Black would work best for a solar collector since it absorbs radiant energy best.
5. See the Sample Data.
6. White paper has the highest reflectivity.
7. Black paper has the lowest reflectivity.
8. The lower the reflectivity, the greater the temperature change.
9. Snow, ice, sand, clouds, and water would be expected to give a planet high reflectivity.

10. Planet Earth has high reflectivity because much of it is covered by snow, ice, sand, clouds, and water. The results of this experiment suggest that dark-colored parts of Earth, such as forests and green cropland, would have lower reflectivity.

ACKNOWLEDGMENT

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