

Solar Energy and Tray Angle

BROWARD COUNTY ELEMENTARY SCIENCE BENCHMARK PLAN

Grade 5—Quarter 2

Activity 18

SC.B.1.2.2

The student recognizes various forms of energy (e.g., heat, light, and electricity).

SC.B.1.2.3

The student knows that most things that emit light also emit heat.

SC.B.1.2.4

The student knows the many ways in which energy can be transformed from one type to another.

SC.B.1.2.5

The student knows that various forms of energy (e.g., mechanical, chemical, electrical, magnetic, nuclear, and radiant) can be measured in ways that make it possible to determine the amount of energy that is transformed.

SC.H.1.2.1

The student knows that it is important to keep accurate records and descriptions to provide information and clues on causes of discrepancies in repeated experiments.

SC.H.1.2.2

The student knows that a successful method to explore the natural world is to observe and record, and then analyze and communicate the results.

SC.H.1.2.3

The student knows that to work collaboratively, all team members should be free to reach, explain, and justify their own individual conclusions.

SC.H.1.2.4

The student knows that to compare and contrast observations and results is an essential skill in science.

SC.H.1.2.5

The student knows that a model of something is different from the real thing, but can be used to learn something about the real thing.

SC.H.2.2.1

The student knows that natural events are often predictable and logical.

SC.H.3.2.2

The student knows that data are collected and interpreted in order to explain an event or concept.

ACTIVITY ASSESSMENT OPPORTUNITIES

The following suggestions are intended to help identify major concepts covered in the activity that may need extra reinforcement. The goal is to provide opportunities to assess student progress without creating the need for a separate, formal assessment session (or activity) for each of the 39 hands-on activities at your grade.

1. Ask students if there is one season during which the Sun's rays are almost directly overhead. (summer) Ask, *What variable was tested in this controlled experiment?* (We tested the effect of the angle of incoming solar radiation.) Challenge the students to write a single sentence that ties together the season of the year and the variable they studied in this activity. (During the summer season where we live, the Sun's rays are directly overhead, and they warm Earth more than in other seasons.)
2. Use the Activity Sheet(s) to assess student understanding of the major concepts in the activity.

In addition to the above assessment suggestions, the questions in bold and tasks that students perform throughout the activity provide opportunities to identify areas that may require additional review before proceeding further with the activity.

Solar Energy and Tray Angle

OBJECTIVES

Students investigate how the angle of the sun's rays in relation to a solar collector affect the amount of energy absorbed by the solar collector.

The students

- ▶ measure the change in water temperature in two solar trays placed at different angles to the Sun
- ▶ conclude that the tray most directly facing the Sun will absorb the most energy
- ▶ graph their results
- ▶ discuss the connection between the tilt of Earth on its axis and the seasons

SCHEDULE

About 1 hour

MATERIALS

For each student

- 1 Activity Sheet 18, Parts A and B

For each team of four

- props (see Preparation)*
- 1 ruler*
- 2 solar tray covers
- 2 solar trays, black
- 1 thermometer, Celsius
- 2 tumblers, large

For the class

- 2 containers, 6-L
- 12 L water, tap*
- DSR *Earth, Moon, and Sun*

*provided by the teacher

PREPARATION

- 1 Make a copy of Activity Sheet 18, Parts A and B for each student.
- 2 Select an area outdoors where 16 solar collectors can be left undisturbed for 40 minutes in direct sunlight.
- 3 At least two hours before the start of the activity, place two 6-L containers of tap water in the shade near where the students will conduct their experiments.
- 4 Students will need items with which to prop up their trays. They may use notebooks or books, but be aware that water might be spilled on them.
- 5 Each team of two will need two black solar trays, two solar tray covers, two tumblers, a ruler, props for one of the trays, and a thermometer.

BACKGROUND INFORMATION

A controlled experiment is one in which two setups are tested side by side. The setups are identical in every way except for the introduction of a variable—a changeable factor or condition—in one of the setups. In a controlled experiment, only one variable is tested at a time.

As students have already seen, many variables can affect the absorption of solar energy by a solar collector. These variables include the color of the tray, the volume of water in the tray, and the length of time the tray is exposed to the Sun.

In this activity, students will conduct a controlled experiment in which the variable is the angle at which the Sun's rays strike their solar trays. As they will discover, when the Sun's rays strike a tray directly, more of the solar

energy is absorbed by the tray. The more energy that is absorbed, the higher the temperature of the water in the tray will rise.

The seasons result from the angle at which the Sun's rays strike Earth as it revolves on its axis around the Sun. For part of the year, the northern hemisphere is tilted toward the Sun, resulting in the warmer temperatures of the summer season. Six months later, the northern hemisphere is tilted away from the Sun, resulting in the colder temperatures of the winter season. Because of this tilt, when it is summer in the northern hemisphere, it is winter in the southern hemisphere; when it is winter in the northern hemisphere, it is summer in the southern hemisphere (see Figure 18-1).

▼ Activity Sheet 18, Part A

Solar Energy and Tray Angle

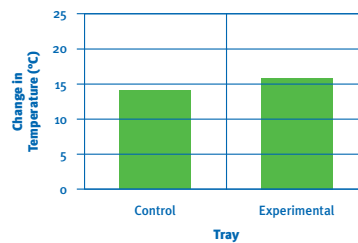
Starting Time _____	Ending Time _____		
	Starting Temperature (°C)	Final Temperature (°C)	Change in Temperature (°C)
Control Solar Tray (level)	20°C	34°C	+ 14°C
Experimental Solar Tray (elevated)	20°C	36°C	+ 16°C

1. Record the starting temperature of the water and the starting time.
2. Draw and describe your solar trays. Include information such as the position and elevation of each tray, the position of the sun, and the time of day and time of year.

▼ Activity Sheet 18, Part B

Solar Energy and Tray Angle

3. After 40 minutes, record the final temperatures and the ending time. Calculate and record the change in temperature for each tray.
4. Make a bar graph showing the temperature change in each tray.



5. The final temperature of the elevated tray was higher than the final temperature of the level tray by _____ °C.
6. What is the relationship between the angle at which the Sun's rays hit a tray and the temperature of the water in that tray?

The more direct the rays, the higher the temperature.
The more angled the rays, the lower the temperature.

Guiding the Activity

- 1 Write the terms *variable* and *controlled experiment* on the board.

Remind students that a **variable** is a condition that can be changed, or varied, in an experiment. A **controlled experiment** is an experiment designed to test only one variable at a time.

Ask, **Why do you think it is important to test only one variable at a time?**

Explain that if a scientist were to include more than one variable in a given experiment, he or she would not know which variable was responsible for any changes observed in the outcome of the experiment.

Ask, **What are some of the variables that were tested in earlier activities?**

Tell students that in this activity they will conduct a controlled experiment. The variable they will test will be the angle at which the sun's rays strike a solar tray. They can manipulate that angle by changing the position of the tray.

- 2 Tell the students that one tray in this experiment will be the control tray; it will be placed on level ground. The other tray will be the experimental tray; it will be propped up at one end so that the sun's rays strike it at a more perpendicular angle. Tell them that the height at which they elevate the experimental tray will depend on the time of day and the time of year—in other words, the position of the Sun in the sky at the time the experiment is conducted.

Additional Information

Students should realize that in order to study the effects of one variable on the outcome of an experiment, it is important that all other conditions remain unchanged so that any change in outcome can be attributed to the variable and not to some other factor.

Students should recall the following variables: cover versus no cover, color of tray, volume of water, and length of time exposed to the sun.

Guiding the Activity

- 3 Next, describe the relationship between the change of seasons and the angle at which the Sun's rays strike Earth at different times of the year.

Explain that Earth is tilted on its axis and that it makes one complete revolution around the Sun about every 365 days (one year). During summertime in the northern hemisphere, temperatures are warm because the northern hemisphere is tilted toward the Sun. At this time of year, the Sun's rays strike the northern hemisphere more directly than at any other time of year. During the winter, the opposite is true: The northern hemisphere is tilted away from the Sun, and the Sun's rays strike the northern hemisphere at an angle greater than at any other time of the year.

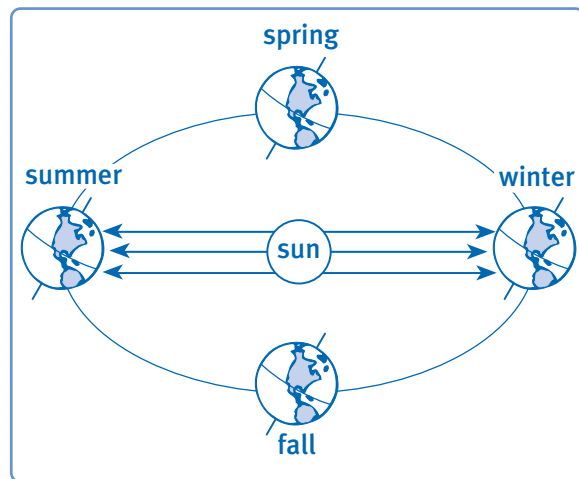
As appropriate, read or review pages 6 and 11 from the Delta Science Reader *Earth, Moon, and Sun*.

- 4 Distribute a copy of **Activity Sheet 18, Parts A and B** to each student. Divide the class into teams of two and distribute two black solar trays, two solar tray covers, two thermometers, and two tumblers to each team. Tell students to collect all of the materials, including their props, Activity Sheet 18, Parts A and B, and a pencil, and take them to the predetermined location outdoors.

- 5 Have each team fill two tumblers with water from the 6-L containers and measure the starting temperature of the water. Each team member should record the temperature on Activity Sheet 18, Part A. (The starting temperature should be the same for both the control and the experimental trays.)

Have the students pour one tumbler of water into each solar tray, distribute the water evenly among the troughs, and attach a cover to each tray.

Additional Information



▲ **Figure 18-1.** The seasons and the angle of the Sun's rays hitting Earth.

Warn students that water may accidentally spill on the props during the activity, so they should choose their props accordingly.

Make sure that the students position both trays so that they face the sun in the same direction.

Guiding the Activity

Next, have the teams prop up one of their solar collectors so that it faces the Sun more directly. Allow students to replace any water that gets spilled while positioning the trays.

Have the students use a ruler to measure the height of the elevated side of the experimental tray. Tell students to record on their activity sheets the time at which their experiments were set up (starting time).

Tell the students that they will return to the site in about 40 minutes to measure the temperature of the water in each tray. Return to the classroom. Have the students bring their tumblers, thermometers, activity sheets, and the two 6-L containers with them.

- 6** Once back in the classroom, tell students to draw and describe their setups on Activity Sheet 18, Part A.

- 7** Return to the site about 40 minutes after setting up the experiments. Have the students bring their tumblers, thermometers, and activity sheets with them.

Tell the teams to pour the water from the experimental tray into one tumbler and the water from the control tray into another tumbler and to measure the temperature of the water in each tumbler. Have them record on their activity sheets the final temperatures and the time at which they were taken (ending time).

When the students have finished, tell them to dump out the water, collect all of the materials, and return to the classroom.

Additional Information

Note: Remind students that every tray should contain one tumbler of water—no more and no less. It is important that the two trays in each team contain the same amount of water.

Encourage students to include details, such as the elevation and position of each tray, the position of the Sun in the sky, and the time of day and time of year.

Guiding the Activity

Additional Information

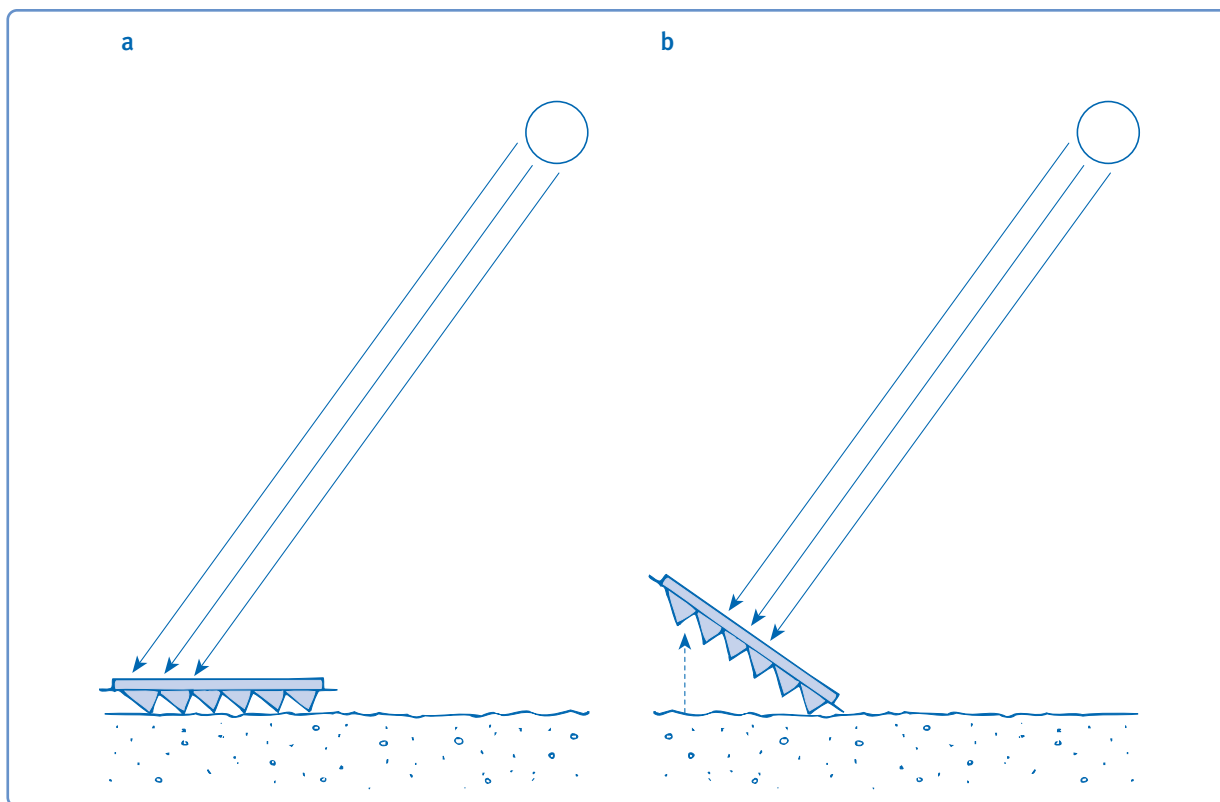
- 8 Once back in the classroom, begin a discussion of the results of the experiment. Ask, **Which of the two trays was the more efficient solar collector?**

Show students Figure 18-2. Ask, **Which tray received the more direct sunlight, the tray that was placed on level ground, or the tray that was elevated at one end? How would you explain this?**

Have students graph their results and answer the questions at the bottom of the activity sheet.

Results may vary, but, assuming that the Sun was not directly overhead, students should have found that after 40 minutes in the Sun, the water in the experimental (elevated) tray was warmer than the water in the control (level) tray.

Students should conclude that, because of the position of the Sun in the sky (assuming it was not directly overhead), the tray that was elevated at one end received more direct sunlight than the tray that was on level ground. This should be confirmed by the fact that the water in the elevated tray got warmer than the water in the level tray.



▲ **Figure 18-2.** The Sun's rays striking the tray a) at an angle, and b) directly.

REINFORCEMENT

The importance of the angle of the Sun's rays can be demonstrated by rotating the collector 90° so that the flat sides of the troughs in the tray no longer face the Sun. Rotating the tray will yield a change in water temperature that is even less than that of the level tray.

CLEANUP

Return the 6-L containers, solar trays, covers, tumblers, and thermometers to the kit. Have students return the props to their proper place.

Connections

Science Challenge

Have students do the following long-term project to observe the changing length of an object's shadow throughout the seasons. Push a long pole firmly into the ground in a sunny location outdoors. At solar noon (adjust for Daylight Savings Time), push a small marker into the ground at the tip of the pole's shadow. Repeat this activity at noon once a week for as many months as possible. Students will see that the shadow lengthens toward winter, then shortens toward summer. To demonstrate that the shadow's length is a result of the angle of the Sun's rays, hold one end of a string at each marker and pull it taut over the top of the pole.

Science Extension

Demonstrate the changing seasons with a small globe to represent Earth and a flashlight to represent the Sun's rays. Start with Earth's axis tilted toward the Sun, and explain that this shows Earth's position in June, the beginning of summer in the Northern hemisphere. Move Earth to the autumn, winter, and spring positions in its orbit, making sure that you keep the axis tilted in the same direction throughout the entire orbit. At each seasonal position, ask students to note the angle at which the Sun's rays strike the Northern Hemisphere. If students have difficulty relating the tilt of the axis to seasonal changes, repeat the demonstration with the axis held straight up and down through the orbit. Students will see that without the tilt, any part of Earth receives the Sun's rays at the same angle throughout the year.

Science and the Arts

Students might enjoy creating artwork with solar energy. Give each student a piece of light-sensitive paper, and tell students to

arrange a variety of objects on the paper to form a picture or an abstract design. Have them expose their set-ups to direct sunlight until the paper turns pale blue (about 2-5 minutes). Then have them remove the objects from the paper and, while protecting it from strong light, soak it in a container of water for about one minute, then dry flat. The image should sharpen as the paper dries.

Science and Language Arts

Ask students how many meanings of *degrees* they know. Students might mention degrees of temperature, degrees of elevation, degrees of latitude and longitude, the degrees used to measure angles (which is the same meaning as degrees of elevation), and educational degrees.

Science and Social Studies

Suggest that students research and report on the building techniques used by ancient peoples to take advantage of the Sun's lower position in the sky to keep their homes warmer in winter. For example, Native American cliff dwellings such as Mesa Verde in Colorado are oriented toward the southwest to receive the Sun's rays as directly as possible in winter.

Science, Technology, and Society

Encourage students to investigate solar collectors that rotate so the Sun's rays strike them at the most direct angle throughout the day. Do such collectors "sense" the Sun's position in the sky, or are they programmed with timers that move them to follow the Sun? Ask volunteers to report their findings to the rest of the class.