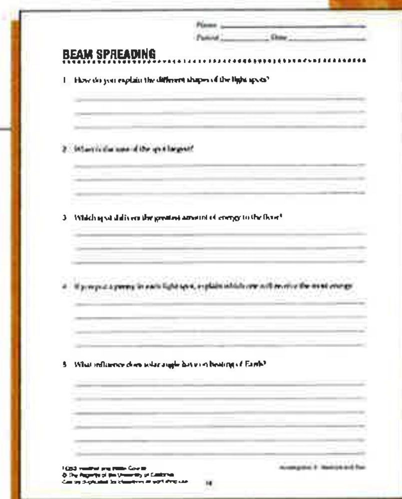
MATERIALS FOR PART 3

SUN ANGLE AND SOLAR HEATING

FOR EACH GROUP

4 *Weather and Water Lab Notebooks*

- *Beam Spreading*, page 13



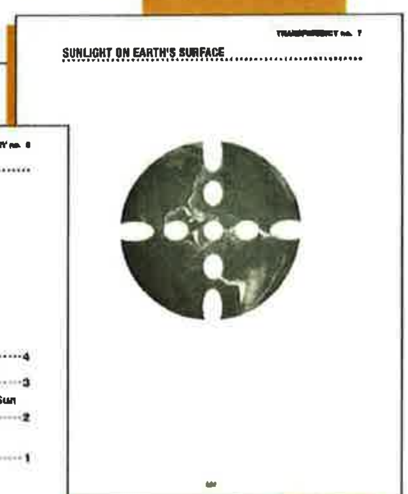
Lab Notebook, p. 13

FOR THE CLASS

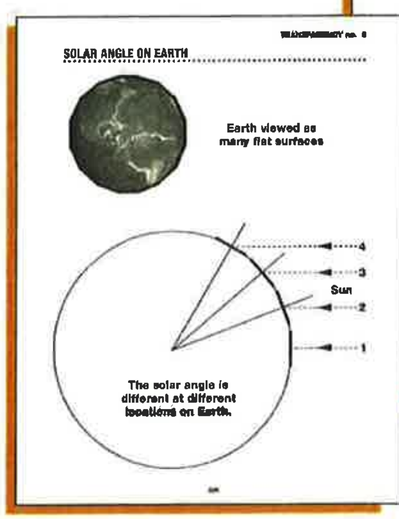
1 Convection-chamber cover
1 Flashlight *
1 Meterstick *
1 Piece of paper *
2 Stout rubber bands or a roll of masking tape *
1 Globe (at least 12″), on stand *
1 Overhead projector *
1 Transparency no. 5 called *Solar Angle*
1 Transparency no. 6 called *Solar Angle on Earth*
1 Transparency no. 7 called *Sunlight on Earth's Surface*

FOR ASSESSMENT

- *Assessment Chart for Investigations 3 and 4*
- Notebook paper *
- Quick write (from Part 1)
- Response sheet (from Part 2)
- *Mid-summative Exam 3*



Transparency no. 7



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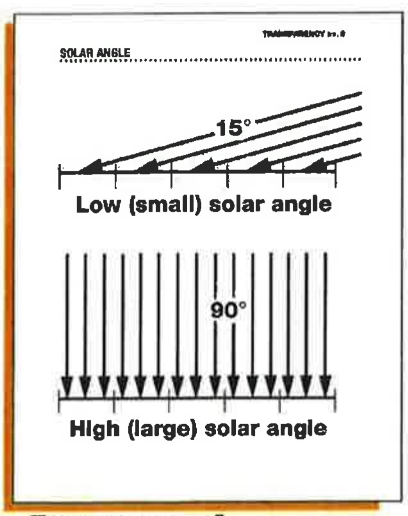


Transparency no. 5

* Supplied by the teacher

GETTING READY FOR PART 3

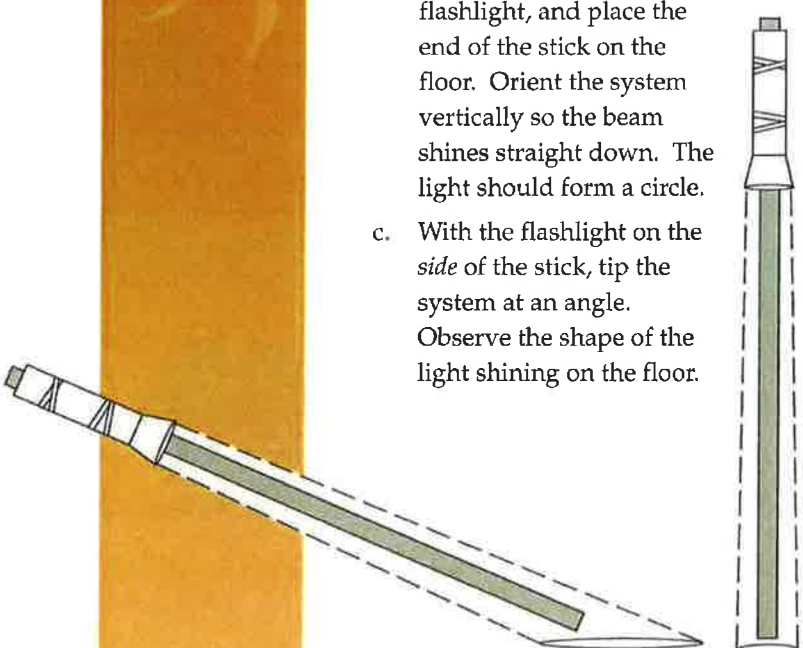
1. PREPARE FOR BEAM-SPREADING DEMONSTRATION

You will need a flashlight with a good beam of light for the first demonstration of beam spreading. Set up and practice the demonstration.

a. Attach the flashlight to the meterstick with rubber bands (or masking tape). The flashlight should be aimed along the length of the stick.

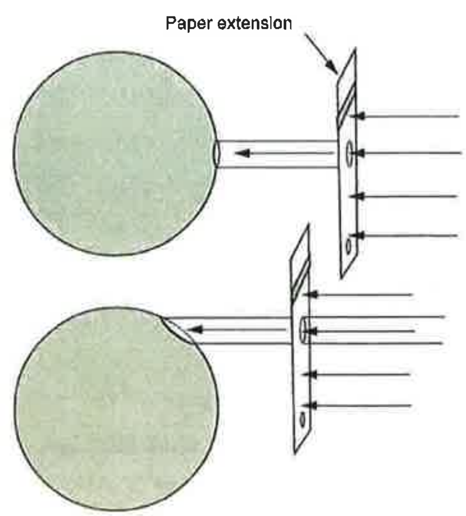
b. Darken the room, turn on the flashlight, and place the end of the stick on the floor. Orient the system vertically so the beam shines straight down. The light should form a circle.

c. With the flashlight on the *side* of the stick, tip the system at an angle. Observe the shape of the light shining on the floor.



This demonstration method maintains a constant distance from light to floor and a constant light position. Students will compare the area of light and the solar angle.

The second demonstration shines light from the overhead projector onto a globe. You mask the flood of light with the metal cover of the convection chamber. You may have to extend the cover's area by taping a piece of paper to its edge.



Practice moving the cover to train the beam of light on several locations on the globe to demonstrate the effect of beam spreading.

2. PLAN ASSESSMENT: MID-SUMMATIVE EXAM

Make copies of *Mid-summative Exam 3*. Give the assessment when you have finished this investigation and feel that students have a good understanding of the reasons for seasons.

Give each student a copy of the exam. See the scoring guide in the Assessment chapter.

3. PLAN SELF-ASSESSMENT

The reasons for the seasons is a difficult concept because students need to consider so many factors and relationships. It is also important for students to reflect on how their knowledge and ideas have changed over time.

After you have reviewed and/or scored the exam, return it to students, along with the quick write from Part 1 and *Response Sheet—Seasons and Sun* from Part 2. After a class discussion, students will review how their thinking has changed, and have one more opportunity to clarify any remaining misunderstandings. See the scoring guide in the Assessment chapter.

CONDUCTING PART 3

SUN ANGLE AND SOLAR HEATING

1. REVIEW SUNLIGHT HOURS AND SEASONS

Review the reading and the seasons exercise with the globe and model Sun. Revisit these ideas.

- Earth rotates on its axis to produce day and night.
- The tilt of Earth's axis produces changes in day length over the course of a year (one revolution of Earth around the Sun).
- Summer (summer solstice) occurs when the axis is angled toward the Sun; winter (winter solstice) occurs when the axis is angled away from the Sun.
- Seasons are opposite in the Northern and Southern Hemispheres.

2. RAISE SOLAR-ENERGY QUESTIONS

Ask,

- *What kind of weather do you generally associate with summer?*

Students usually suggest that the summer is hotter. Ask,

- *What is it about summer that makes it hotter? What happens to produce more heat?*

Students often suggest that the longer days of summer provide more time for things to heat up. Ask,

- *Longer days result in more time for the Sun's energy to be absorbed by the land, water, and atmosphere. But could there be more to the story?*

3. DEMONSTRATE LIGHT ON A SURFACE

Get your flashlight and meterstick setup. Dim the room lights. Tell students,

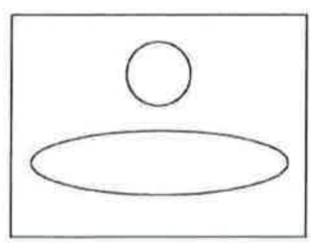
I am going to use this flashlight beam to represent a beam of light from the Sun. Observe the spot of light where the beam hits the floor.

Shine the beam straight down at the floor and slowly tip the system (with the flashlight on the *side* of the stick) so that the beam intersects the floor at a steadily declining angle. Repeat the process several times.

4. CIRCLE THE LIGHT SPOTS

To emphasize the beam spreading, put a piece of paper on the floor, shine the light straight down, and have a student trace the light spot.

Repeat the process with the light shining at an angle. The result might look like this.



5. INTRODUCE LIGHT AS ENERGY

Tell students,

Light is a form of energy. This flashlight and the Sun are both sources of light energy.

I used this flashlight to shine light energy on the floor. This paper shows the area that the energy beam covered at two different times.

Ask students to open their lab notebooks to page 13, *Beam Spreading.* Tell them,

*Discuss the demonstration in your groups. Work together to answer the first three questions on the **Beam Spreading** sheet.*

- *How do you explain the different shapes of the light spots?*
- *When is the area of the spot largest?*
- *Which spot delivers the greatest amount of energy to the floor?*

6. DISCUSS BEAM SPREADING

Ask students to share the ideas discussed in their groups. See the answers in the Teacher Answer Masters. Reinforce these observations.

- The size and shape of the light spot changes, depending on the angle of shine.
- The light spot gets bigger as the angle between the beam of light and the floor gets smaller.
- The amount of light energy in the beam stays the same, so both light spots deliver the same amount of energy to the paper.

Tell students,

Energy travels from the Sun to Earth as radiation. Radiant energy travels in rays. The number of rays hitting a given area is the energy density. When lots of rays hit an area, energy density is high. When few rays hit an area, energy density is low.

The flashlight puts out a steady beam of light rays that is about 5 cm across. When the light beam falls on a surface from directly above (90°), the area it covers is a circle about 20 cm^2.

When the angle that the light is coming from changes from 90° to 15°, the beam falls on an oval surface about 60 cm^2.

The amount of light in the flashlight beam does not change. All that changes is the angle at which the light strikes the surface.

Project transparency no. 5, *Solar Angle*, and continue.

*The angle at which light strikes a surface is called **solar angle.** These low-solar-angle rays are hitting Earth's surface at about 15°. Light rays shining from directly overhead have a high solar angle. These are hitting Earth's surface at 90°.*

Notice that the incoming rays of light are equally spaced in both beams. But because of the solar angle, three times as many rays are falling on Earth when the light comes from a high solar angle. Therefore, the density of energy is greatest when light shines on a surface at a 90° angle.

*The way a light beam covers a larger area when it hits a surface at an angle is called **beam spreading.***

Think about this. If you spread some jam evenly on a cracker and the same amount of jam evenly on a slice of bread, the jam will be thicker on the cracker than on the bread. You will get more jam with each bite of cracker than with each bite of bread.

7. ANSWER THE PENNY QUESTION
Ask students to turn their attention to the fourth question on the *Beam Spreading* sheet. Give them 3 minutes to write their answer.

Students should understand that the solar angle determines the energy density. Because the surface area of a penny does not change, the amount of energy hitting it varies with the solar angle. The greater the solar angle, the greater the energy it will receive.

8. DEMONSTRATE BEAM SPREADING ON A GLOBE
Bring your globe forward. Tell students,

This is a model of Earth. Sunlight travels 150 million kilometers in absolutely straight lines and uniform density to get here.

We can look at how light spreads when it hits Earth's surface by masking all of the light except for one column of rays by putting a barrier with a hole between Earth and the Sun.

Set up the demonstration.

a. Aim the overhead projector into the room. This is the Sun.

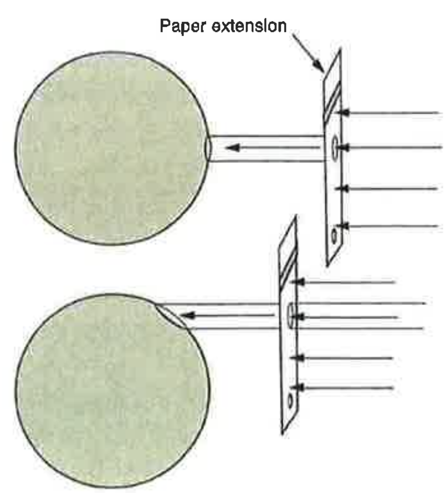
b. Position the globe in the flood of light 3–5 m (10–16′) from the projector. Dim the room lights.

c. Hold the convection-chamber cover about a meter from the globe, allowing light to shine through the larger hole onto the globe.

d. Move the beam of light to various positions on the globe to show the effects of beam spreading.

9. DISCUSS THE GLOBE DEMONSTRATION
While you move the beam of light around on the globe, ask,

- *When the beam of light hits the globe near the center of the equator, what shape is the light?* [Round.]
- *When the beam of light hits the right or left side of the globe near the equator, what shape is the light?* [A long oval.]
- *When the beam of light hits the globe a little bit north or south of the equator, what shape is the spot of light?* [Just a little oval.]
- *When the column of light hits the globe near the poles, what shape is the spot of light?* [A long oval.]
- *What time of day is the solar energy most intense?* [Noon, when the Sun is at a high (large) solar angle.] *Least intense?* [Sunrise and sunset, when the solar angle is low and the energy spreads over a large area.]



- *What regions of the planet are subjected to the most intense solar radiation?* [The tropics near the equator.] *The least intense solar radiation?* [The north and south polar regions.]

10. REINFORCE SOLAR ANGLE

Project transparency no. 6, *Solar Angle on Earth.* Tell students,

Because Earth is round, the angle at which light hits it is different from place to place. Light does not come to Earth from different angles; light strikes surfaces that are at different angles. The angle between the incoming rays of light and the surface of the land is the ***solar angle.*** *We can see this if we think of Earth's surface as made of lots of little flat areas.*

In this illustration we see four rays of light coming to Earth. Ray 1 happened to strike Earth exactly perpendicular to the surface. The solar angle is 90°.

Light ray 2, however, did not strike perpendicular to the surface because the surface is farther north. The solar angle, when compared to Earth's surface, is about 60°. Light rays 3 and 4 hit the surface at even smaller angles, perhaps 45° and 30°.

Project transparency no. 7, *Sunlight on Earth's Surface.* Point out that light energy from the Sun is distributed over a larger area when it hits Earth's surface at an angle. The beam spreads more and more the farther north or south you go.

Beam spreading does the same thing as you move east and west. In the morning and evening the solar angle is low, so the beam spreading is large. In the middle of the day the Sun's energy is most intense because the Sun is overhead at a high solar angle.

11. THINK ABOUT SOLAR ANGLE AND SOLAR ENERGY

Tell students,

The results of our two demonstrations provided this information.

The greater the solar angle, the greater the density of radiant energy. Light shining from directly above is most intense; light coming at an angle is less intense.

Solar energy is most intense during the middle of the day in the region of the tropics. Energy is least intense in the morning and evening and extreme north and south regions of the planet.

Write these two results on the board and ask students to transcribe them to a blank page in their lab notebook.

Tell students,

Almost all of the energy coming to the planet Earth is solar energy. Light absorbed by the land, water, and air is converted to heat. Heat is the form of energy that makes things happen in the atmosphere. Atmospheric activities are what we call weather.

Ask students to talk in their groups to come up with an answer to question 5 on the *Beam Spreading* sheet.

- *What influence does solar angle have on heating of Earth?*

12. PUT IT TOGETHER

Call on each group to offer its ideas about solar energy and Earth heating.

Summarize and focus their ideas after the discussion.

- Areas of the planet where solar radiation shines directly down on Earth are subjected to more intense energy than areas that experience beam spreading. The greater the amount of energy absorbed, the hotter the area becomes. This is why the hottest part of Earth is in the region of the tropics. This is also why mornings and evenings are cool, and the hottest part of the day is in the middle.
- Because Earth's axis is tilted 23.5°, the Northern Hemisphere receives more intense solar energy in the summer months, making summer hotter. During the winter months, sunlight strikes the Northern Hemisphere at a low solar angle, resulting in less heating from solar radiation.

13. ASSESS PROGRESS: MID-SUMMATIVE EXAM

When you think students are ready, have them take *Mid-summative Exam 3.*

BREAKPOINT

14. ASSESS PROGRESS: SELF-ASSESSMENT

Return three pieces of work to students.

- Quick write (from Part 1)
- *Response Sheet—Seasons and Sun* (from Part 2)
- *Mid-summative Exam 3*

Have students review each assessment and briefly discuss how their thinking has changed and what they did in class that changed their thinking. Have the class list all the factors and relationships that need to be considered when talking about the reasons for the seasons.

Have students review their responses on *Mid-summative Exam 3* and revise and expand their explanations and drawings. Students should number sentences that they think are incomplete or inaccurate, and write revisions with corresponding numbers on a separate sheet of paper. Additional information can be added as well.

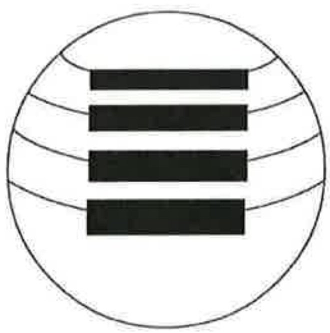
EXTENDING THE EXPERIENCE

1. EXPERIMENT WITH SOLAR HEATING

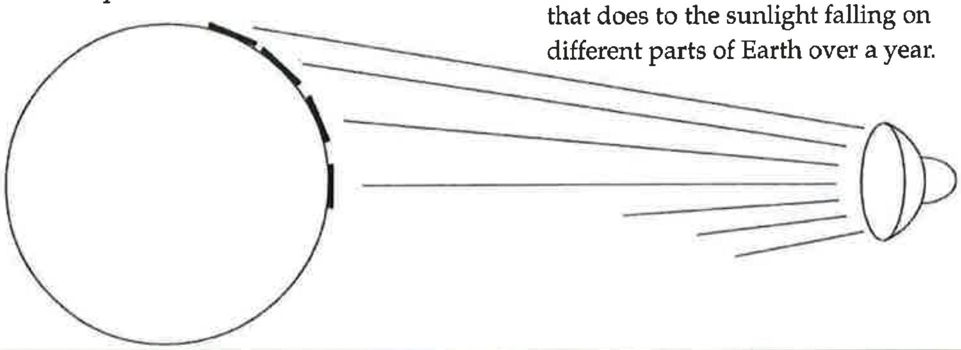
The effect of solar angle can be explored with a globe and a sunny window (or an infrared heat lamp). You will also need four temperature strips from the kit (30–36°C). These are first introduced and used in Investigation 4, Part 2, Step 18.

Set up the investigation as follows.

a. Attach the four temperature strips to the globe at latitudes 0° north, 20° north, 40° north, and 60° north.



b. Position the globe in a sunny window, or position a heat lamp a meter or so from the globe. Make sure the lamp is centered directly over the middle of the thermometer strip on the equator.



c. Monitor the color changes at the various latitudes. Blue is warmest, green is warm, yellow is a little warm, brown is cool, and black indicates too little energy to elicit a response.

You may have to fuss a bit with the distance to get results that are within the range of the temperature strips. This experiment will help students establish the relationship between solar angle and the heating of Earth's surface.

2. COMPARE CITIES

The Seasons simulation on the *FOSS Weather and Water* CD-ROM allows students to compare two cities at different latitudes for several variables—sunrise time, sunset time, hours of light, or average temperature. Have students use this feature to gather data to answer a question they have about day length and seasons.

3. CHANGE EARTH'S TILT

The Seasons simulation on the *FOSS Weather and Water* CD-ROM has an Advanced setting. In this setting you can view Earth from the North Pole or South Pole. In addition, the menu can be used to change Earth's tilt from 23.5° to 1°, 45°, and 90° and see what that does to the sunlight falling on different parts of Earth over a year.

4. INVESTIGATE DAY LENGTH AND SUNSETS ON CD-ROM

There are two movies on the *FOSS Weather and Water* CD-ROM that students can use to further investigate seasons and Sun. *Pacific Coast Day Length* is a set of movies that can be used to explore how day length changes with the seasons in the San Francisco Bay area. *Pacific Coast Sunsets* is a movie of the movements of the sunset location along the horizon over the San Francisco Bay area. For information on using QuickTime movies, see the CD-ROM User Guide.