

SCIENCE
Earth and Space Science
Grade 8
Seasons

Overview

Everyone has some experience with our seasons yet this topic is frequently misunderstood. A key concept in understanding this phenomenon is that, for a given amount of energy input, the more mass doing the absorbing, the less the temperature change of that body. In the opening activity, the students collect and graph data about shadow length to provide evidence that the angle at which sunlight strikes Earth changes during the year. The unit then uses a model previously developed to consider day and night to explain how the intensity of the solar radiation reaching Earth and the number of daylight hours varies with latitude at the equinoxes and solstices. In the closing activity, the students view “A Private Universe” videotape and respond in writing to the explanations for seasons offered by graduates and faculty members of Harvard College.

Benchmarks

- ESS-M-C7** modeling and explaining how seasons result from variations in amount of the Sun’s energy hitting the surface due to the tilt of Earth’s rotation on its axis and the length of day
- SI-M-A4** developing descriptions, explanations, and graphs using data

Teacher Preparation

Contrary to popular belief, our seasons are not caused by variations in the distance between the Sun and Earth. The two factors that primarily contribute to producing our seasons are a product of Earth’s revolution about the Sun and the tilt of its axis relative to the plane in which Earth revolves around the Sun. These two factors are the number of hours of daylight experienced at a location and the intensity or directness of the solar radiation being absorbed during those hours.

Materials/Equipment

- an outside object of fixed length located where it receives unobstructed sunlight
- meter sticks or tapes
- graph paper
- markers
- pencils
- shoeboxes
- bamboo skewers

- 3-inch Styrofoam balls or rubber-ball models of Earth
- scissors
- protractors
- flashlights
- “A Private Universe” videotape (optional)
- vcr
- paper
- pipe cleaners
- thermometers
- Styrofoam cups
- graduated cylinders
- beakers
- pennies

Day 1
(45 minutes)

Materials/Equipment

- an outside object of fixed length located where it receives unobstructed sunlight
- meter sticks or tapes
- graph paper
- markers

Set or Opener

1. At the beginning of the school year, tell the students that you are going to put a new pool in your backyard next summer. To make sure that the pool is warm and to reduce your costs for heating it, you want it to be in sunlight as much as possible.
2. Ask them how you might go about determining where to locate the pool. During the discussion, you should be looking for someone to mention shadows from surrounding obstructions like trees, your house, or neighbors' houses. Specifically, you need to know when the shadows are longest and therefore cover the greatest area.
3. Query them about what they know about shadows by doing a whole-discussion with the class. At some point, one of them should indicate that shadow length changes during the year.
4. Once they have identified this issue, tell them that the class is going to investigate the question of when shadow length of greatest.

Body

1. If the class has never designed an experiment before, guide them through the process of identifying and controlling variables, specifying measurement techniques, determining how they will present the data, and specifying how they will use the data to answer the question being considered. In this case, the independent variable is time (day of the year and time of the day) and the dependent variable is shadow length. Measurement techniques include reading a clock and calendar for time and using a meter stick or tape to determine shadow length. The data should be graphed using a line graph (since the dependent variable is continuous over time) with time along the x-axis and shadow length along the y-axis. The time of the longest shadow will be determined when the line graph reaches a peak.

2. Part of the experiment will involve measuring a fixed object. Work with the class to select something in the school vicinity that will not change its length and will not be moved during the year. The shadow of the object should be a few meters in length at the time of measurement.
3. Since shadow length decreases from sunrise to noon and then increases from noon to sunset, it would be best to select a measurement time around mid-morning when the shadow is neither too long nor too short. It is important that this time be a constant from day to day so that the hour-to-hour variation in length during a day is not a factor in the measurements.
4. Select one student to make the necessary measurement for the first week. If possible, one person should perform this duty for at least a week so that the variation resulting from differences in human judgment is minimized. This job then can be rotated through the class members.

Closure

1. Once the class is back inside, have a students establish the basic graph with title and axes. Then have someone plot the first point.
2. The class should predict what the length of the shadow will be at the next class meeting.
3. In subsequent meetings, have the student assigned to perform the measurement take his reading before or at the beginning of class and then plot the point and connect it to the previous one with a straight line.
4. Be sure to discuss any unusual measurements that may occur. Generally they will result from human error but these types of events represent good opportunities to discuss what are reasonable variations in real data.
5. Make sure that predictions are made for the next class meeting and any deviations from prior predictions are discussed.
6. This activity usually can be concluded shortly after the students return to classes in January since the longest shadow will be observed at the winter solstice.
7. By then, the students will have noticed changes in the outside temperature and you can begin investigating seasons.

Days 2 and 3
(after completion of prior activity; 45 minutes each)

Materials/Equipment

- pencils
- shoeboxes
- bamboo skewers
- 3-inch Styrofoam balls or rubber-ball models of Earth
- scissors
- protractors
- flashlights
- Instructions for Modifying Your Shoebox
- pipe cleaner
- thermometers
- Styrofoam cups
- graduated cylinders
- beakers
- pennies
- paper

Set or Opener

In this portion of the unit, the students are going to construct a model of Earth and the Sun. Each group of students should be told to bring a shoebox to class for this activity.

1. If you are using Styrofoam balls, have the students use markers to draw the continents and equator on its surface. Smooth surfaces are best.
2. Divide the students into teams of two or three and distribute the Instructions for Modifying Your Shoebox.
3. Have each team follow the instructions on the sheet to create their models.
4. Have the students insert a straight pin into the surface of the ball so that it is positioned approximately at 45° latitude in the northern hemisphere. Leave half of the pin sticking out of the ball.
5. Give each group a flashlight and darken the room.
6. Then ask them to use the flashlight to represent the Sun by shining it through the windows and to duplicate the pattern they observed with the shadow of the object just studied.

Body

1. After 10 or 15 minutes of exploration, ask the students to discuss what they discovered. Guide them to the understanding that the pattern could be duplicated if the angle of the light coming into the surface of the Earth changes. For long shadows, the light comes in at a fairly shallow angle because the hemisphere is tilted away from the Sun. For short shadows, the light comes in more nearly from directly above the object, and this event occurs when the hemisphere is tilted toward the Sun.
2. Some students may question you because this demonstration had the Sun (flashlight) moving around the Earth. If they don't notice this mistake, ask them if Earth moves around the Sun or the Sun moves around Earth and to think about what they just did.
3. Ask them to fix this error by keeping the flashlight in one location but to reproduce the change in the shadows. The correct model will occur when the upper portion of the skewer remains pointed at a fixed position (say at a vent in the ceiling of the room) while the box is moved around the flashlight. To keep the Sun shining into the box, the flashlight will have to be turned with the box. Turning the flashlight may seem inappropriate at first but doing so really just represents the fact that the Sun's radiation is emitted in all directions.
4. At this point, have the students draw a circle on the outside of the box top around the skewer. Then have them divide the circle into 24 equal pieces by drawing tic marks around the edge of the circle, first dividing it in half, then in quarters, and then in eighths. Each eighth should then be divided into three equal pieces.
5. Have the students wrap the pipe cleaner around the skewer so that one end sticks out as a pointer. The circle and pointer will help them determine time.
6. Ask the students to determine how many hours of sunlight various latitudes get when the light shines on the ball from each of the four windows. They should observe the following.

Hemisphere	Daylight hours
Tilted toward light	Increase from equator toward pole
Tilted away from light	Decrease from equator toward pole
Both hemispheres equidistant from light	Uniform across both hemispheres

7. While they are investigating this, heat a pitcher of water so that it is warm. Put five pennies in one Styrofoam cup and ten pennies in an identical cup so that each group has a set of cups.
8. Ask the students how the amount of time the Sun shines on a location may affect its temperature. They should realize that the longer sunlight is available to heat Earth, the hotter it should become.
9. They should have noticed that the pole facing the Sun receives 24 hours of daylight at some time during the year. Based on their conclusion about the relationship between hours of sunlight and temperature, they may wonder why the pole remains cool. Ask them to explain this fact.
10. After some discussion, distribute the cups, two thermometers, a graduated cylinder, and a beaker of warm water to each group. Ask them to determine the temperature of the pennies and the water then to predict what the final temperature of the water-penny mixture will be when they pour the same amount of water into each cup. The pennies are at room temperature, the same temperature indicated on the thermometer not in the water.
11. They should then perform the experiment. One thermometer should be placed in each cup after the water is poured in. The only restriction is that the water must cover all of the pennies. By pouring a fixed amount of water with a uniform temperature into each cup, they are providing the same amount of energy to each mixture. Because there is twice as much mass to be warmed in the cup with ten pennies compared to the cup with five pennies, the former will end up cooler than the latter.
12. Ask the students to take a piece of paper and cut out a square 1 cm on each side. Have them to place this square into the flashlight beam so that the shadow appears on the ball's surface. Have them move the square up and down (but at a constant distance from the light) and observe the change in the shape of its shadow. Applying this to the problem at hand, one sees that a given amount of the Sun's energy is spread out over a large area near the poles and a small area near the latitude where the light is directly overhead. Just as a given amount of energy heated ten pennies less than five pennies, so a given amount of solar radiation will produce a cooler temperature when heating a large area (more mass) compared to a small area. Thus, the poles remain cool even when they receive sunlight continuously because the intensity of the solar radiation is small.
13. Introduce the vocabulary (season names, equinoxes, and solstices), noting that summer begins (summer solstice) in a hemisphere when it is tilted toward the Sun and that winter begins (winter solstice) when a hemisphere is tilted away from the Sun. The autumnal equinox (beginning

of fall) occurs when the Sun is over the equator as Earth revolves counterclockwise (when viewed from above the North Pole) between summer and winter. The vernal equinox (beginning of spring) occurs when the Sun is over the equator as Earth revolves counterclockwise between winter and summer

14. See if the students understand that the intensity of the solar radiation and the number of daylight hours determine seasons by asking them to link together what they have learned so that they can explain the temperature variations over the four seasons to a partner. Start in groups of two, then increase to groups of four. Then do a whole-group discussion.
15. Conclude this portion of the activity by asking the students to label each window with the season names that are appropriate when the light enters that window. They should draw a horizontal line on the door and write the name of the season in the northern hemisphere above the line and the name of the season in the southern hemisphere below the line. Check to be sure they are correct using the following.

Hemisphere	Season (Northern Hemisphere/Southern Hemisphere)
North tilted toward window	Summer/Winter
Next window counterclockwise when viewed from above	Fall/Spring
South tilted toward window	Winter/Summer
Next window counterclockwise when viewed from above	Spring/Fall

Closure

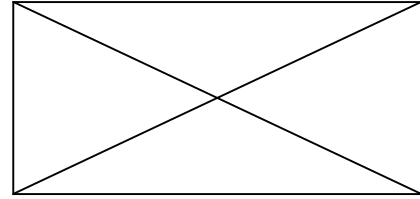
1. If possible, show the students the beginning portion of the videotape “A Private Universe,” ending the tape after the first set of interviews with graduates.
2. Ask the students to comment on the way seasons were explained by these people by writing a brief essay. Tell them to make sure they comment on why they think these people gave incorrect explanations.

Resources

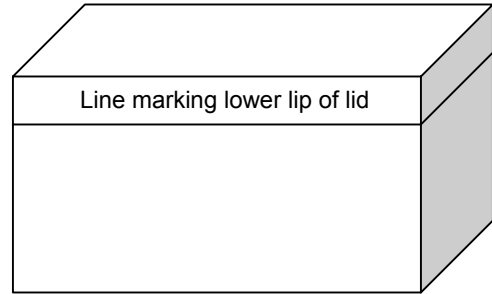
(activities, data sheets, lab sheets)

Instructions for Modifying Your Shoebox

1. Turn your shoebox so that it is resting on its top. Use the ruler to draw a line diagonally from corner to corner on the bottom of the box. Using your scissors, make a small hole where the two lines intersect.



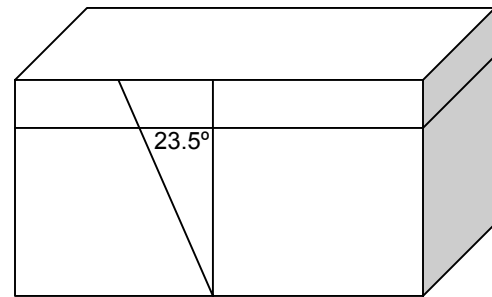
2. Turn the box right side up and draw a line around the box underneath the lid.



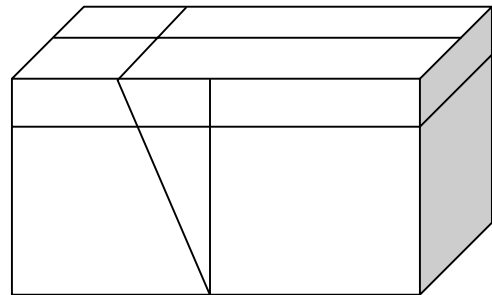
3. Remove the lid and use your ruler to locate the center point on each of the short sides. Then use the ruler and pencil to connect them with a straight line.



4. Use the ruler to find the midpoint of the box along the bottom and top edge of each of the long sides and connect those points. Use the protractor to draw a line that is rotated 23.5° from this line.

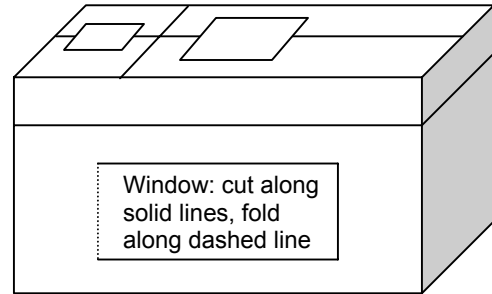


5. Place the lid on the box and draw a line across it that connects the ends of the lines you just drew. Use your scissors to poke a small hole through the lid where this line crosses the other line on the box top.

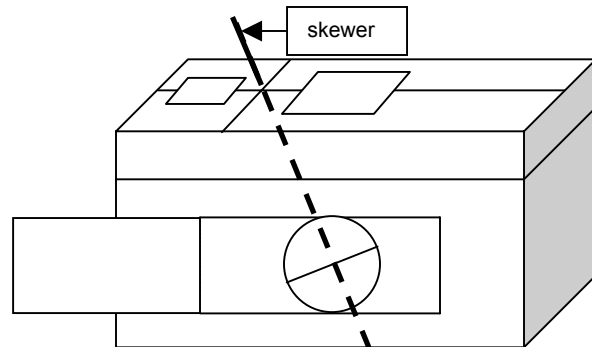


6. Now take the skewer and use the pointed end to enlarge the holes you made in the top and bottom so that they are just big enough for the skewer to fit into.

7. Use a marker or pencil and a ruler to draw windows about 8 cm in length centered on each of the four sides of the box. The bottom of your windows should be about 2 cm from the bottom of the box and should not touch the line you drew under the top's lip.



8. Use your scissors to cut along the top, right side, and bottom of the windows. Do not cut along the left side of the windows.
9. Now bend each window outward, using the left side as a hinge.
10. Do the same thing with the box top, making two more windows along the long axis of the box, one on each side of the hole.
11. Place the skewer through the center of the ball, then insert the skewer through the holes in the top and bottom of the box so that the ball is inside the box when the lid is closed.



12. Adjust the ball's position on the skewer so that it is visible in the side windows.
13. Then put the lid on the box.

Assessment

1. Maria lives in Argentina and notices that the Sun is rising earlier and earlier each morning and setting later and later each afternoon. What season could it be in Argentina?
 - a. Summer or fall
 - b. Winter or spring
 - c. Fall but not summer
 - d. Summer but not fall

2. On a specific day, many people are looking forward to snow in Canada. What might people in South Africa be getting ready to do?
 - a. go snow skiing
 - b. rake leaves
 - c. go to the beach

3. The tilt of Earth on its axis is influential in determining our seasons. If that tilt increased from 23.5° to 40° , what might happen to our seasons? Explain your answer.

Answer Key: Assessment, page 117

1. (b) Since the number of daylight hours is increasing over time, the hemisphere must have passed the winter solstice but not yet reached the summer solstice. Thus, it could be either winter or spring.
2. (c) If it is snowing in the Northern Hemisphere, it most likely is winter. Thus, it is probably summer in the Southern Hemisphere. In summer, people go to the beach.
3. Increasing the tilt of Earth's axis will cause summers to become hotter and winters to become colder. This result occurs because solar radiation will be more direct and the number of daylight hours will increase in the summer hemisphere while the radiation will be more indirect and the number of daylight hours will decrease in the winter hemisphere.

Score	Answer
5	The correct answer is given. The correct explanation is given.
4	The correct answer is given. A partially correct explanation is given.
3	A correct answer is given. No explanation is provided or an incorrect explanation is given.
2	A correct answer is given. No explanation is provided or an incorrect explanation is given.
1	A partially correct answer is given. No explanation is given or an incorrect explanation is provided.
0	No answer and no explanation are given or an incorrect answer and an incorrect explanation are given.

Reference links

Most of the material needed for this unit can be found at supermarkets, arts and craft stores, or discount stores. If you are going to use Styrofoam balls, select smooth-surfaced ones rather than textured ones since they reflect light better. If you can only find textured ones, coat them with a white latex paint by dipping them into a container of paint and allowing the excess to drip off. You generally can locate rubber balls with the continents and oceans indicated on them in novelty catalogs. They often are listed as stress relievers. One source for them is [epromos.com](http://www.epromos.com) (<http://www.epromos.com>), where they are listed as multicolor global stressballs.

The U.S. Naval Observatory (<http://aa.usno.navy.mil/data>) is an excellent source for information related to this unit. Among the things you can find there are the following.

- Table of sunrise/sunset and moonrise/moonset times for an entire year for most locations
- Dates and times for equinoxes and solstices

If you do not have access to the Internet, you generally can find sunrise and sunset times in your local newspaper or on the local TV weather broadcast.

Climate data (temperatures and precipitation amounts) can be found for many stations around the world at the web site maintained by the National Climatic Data Center (<http://www.ncdc.noaa.gov>). If this site is visited from a computer within an education domain, data generally can be downloaded for free. Otherwise, a nominal charge is imposed. A particularly good tool on this site is the Climate Visualization page, allowing one to graph temperatures over time. (<http://lwf.ncdc.noaa.gov/oa/climate/onlineprod/drought/xmgr.html>)

The videotape "A Private Universe" by Matthew H. Schneps can be purchased from the location below.

Pyramid Films
PO Box 1048
Santa Monica CA 90406.
(\$95 plus \$5 shipping and handling fee)

Exploring the Earth in Motion module from Aries: Hands-on Science for Grades 3-8
Harvard-Smithsonian Center for Astrophysics. 1-800-225-3214
Charlesbridge Publishing, 85 Main Street, Watertown, MA 02472
www.charlebridge.com