

SCIENCE
Earth and Space Science
Grade 4
Moon Watching

Overview

The concepts of day and night, our moon's phases, and our seasons are fundamental to the earth sciences and are easily linked together for instruction purposes; however, their causes are often not well understood despite the fact that most people have some experiences with them.

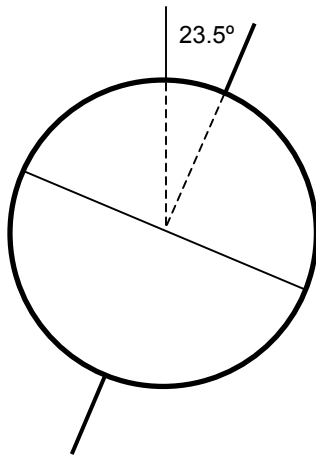
This unit will start by examining shadows, then move to the concepts of day and night, and conclude with the phases of the moon and eclipses. In order to build such a knowledge effectively, it should be done as pieces and spread throughout the school year. Throughout this unit, additionally, the students will be required to make observations, record them, and communicate them to others. These inquiry skills are basic to all of the sciences and applicable in many fields besides science.

Benchmarks

- ESS-E-B2** demonstrating how the relationship of Earth, the Moon, and the Sun causes eclipses and moon phases
- ESS-E-B3** observing and recording the changing appearances and positions of the Moon in the sky at night and determining the monthly pattern of lunar change
- SI-E-B4** developing explanations by using observations and experiments

Teacher Preparation

Day and night are produced by the emission of visible light from the Sun and the rotation of Earth on its axis. Nuclear fusion within the Sun takes hydrogen atoms and converts them into heavier elements, releasing energy in the process. This energy takes the form of radiation, most of which occurs at wavelengths to which our eyes are sensitive (i.e., visible light). Since fusion is occurring constantly in the Sun, the emission of visible light occurs continuously. Because Earth is far enough away from the Sun that one may consider its light to travel in beams of radiation that are parallel to each other, only half of Earth is illuminated by solar radiation at any given time. The half that is illuminated is experiencing day while the other half is experiencing night. The rotation of Earth on its axis, in a counterclockwise sense when viewed from above the North Pole, is responsible for moving the surface through this field of light so that most points experience some number of daylight hours during any given 24-hour period. The exact number of hours of daylight is dictated by the time of the year and the tilt of Earth



on its axis relative to a line perpendicular to the plane in which Earth and the Sun reside (currently 23.5°).

Solar radiation and the moon's revolution in a counterclockwise fashion around Earth (when viewed from above the North Pole) produce the phases of the moon. The portion of the moon we see at any given time is determined by the relative positions of the sun, the moon, and Earth. The new moon occurs when the portion of the moon illuminated by the sun faces away from Earth. The full moon occurs when the portion of the moon illuminated by the sun faces Earth. As one sees more of the illuminated portion of the moon from Earth, the moon is waxing. It is waning when one sees less of the moon over time. One sees a solar eclipse when the moon blocks the sun's rays from shining on Earth and a lunar eclipse when Earth blocks the sun's rays from shining on the moon. Since the sun is the source of the light that illuminates the moon and since solar radiation is constantly being emitted, one may see the moon both in daylight and at night, with the determining factor again being the relative positions of the three bodies.

Materials/Equipment

- paper
- crayons
- sidewalk chalk
- rubber-ball models of Earth or 3 inch Styrofoam balls
- bamboo skewers
- shoeboxes
- flashlights
- pushpins in four colors
- scissors
- straight edges
- pencils
- markers
- pipe cleaners
- Instructions for Modifying Your Shoebox
- Lunar calendars
- Ping-pong balls
- clear light bulb (at least 60 watts)
- clip-on light socket
- music stand or tripod

Day 1
(45 minutes)

Materials/Equipment

- paper
- crayons
- sidewalk chalk

Set or Opener

1. Begin the unit early in the morning by providing each student with paper and crayons.
2. Lead the students in a whole-group discussion about shadows and what causes them. Emphasize the point when they indicate that the sun is needed to produce shadows.
3. Ask the students to use their crayons to draw a picture of themselves, their shadow, and the sun, being as realistic as possible.

Body

1. After the students have completed their drawings, take them outside on a sunny day and ask them to carefully observe their shadows and to record what they see on another sheet of paper or on the back of the sheet they used above.
2. Discuss what they observe. They should notice that they are between the sun and the shadow, that the shadow is dark and gray or black, that the shadow is attached to them at their feet, and that the shadow is featureless (i.e., it does not have eyes, a nose, or a mouth).
3. Discuss that shadows are produced by light being intercepted by an object such as our bodies and prevented from continuing in a straight line to illuminate the surface. The surface appears dark in the area where our bodies prevent light from striking it. As long as we are standing on the ground, our shadow is attached to our feet because that is the portion of our body closest to the ground. The shadow is featureless because we need light to distinguish features. Since our shadows are produced by the absence of light, they cannot have features.
4. Ask the students if there is any way for their shadow not to be attached to them. When a person jumps into the air, his shadow is present but no portion of his body is touching the ground, so his shadow is not attached to his body.

Closure

1. Have the students work in pairs to use the sidewalk chalk to outline each other's shadow and feet on the sidewalk around the school or in the school parking lot.
2. Students should place their initials inside the outline of their feet because they will have to return and stand in the same spot two more times on this day.
3. Around noon, take the students outside again and have them re-draw their shadows. Each student should place his feet in the same spot as he did earlier in the day and his partner should use a piece of different-colored chalk to draw the shadow's outline.
4. Ask the students to describe what has happened to their shadows. They should have become shorter because the sun is higher in the sky, and they should be oriented in a different direction because of the sun's movement from east to west during the day.
5. Ask the student's to predict what will happen to their shadows if they re-draw them later in the afternoon.
6. Take the students outside again near the end of the school day and have their shadows re-drawn with a piece of chalk of a different color than used previously.
7. Discuss what has happened to the shadows and how this compared to what was predicted. The shadow should have become longer and its orientation should have continued to change in the same direction as was previously observed.
8. Ask the students what caused these changes. They should indicate that they understand that the movement of the sun through the sky caused the changes.

Days 2 and 3
(45 minutes each)

Materials/Equipment

- rubber-ball models of Earth or 3 inch Styrofoam balls
- bamboo skewers
- shoeboxes
- flashlights
- pushpins in four colors
- scissors
- straight edges
- pencils
- markers
- pipe cleaners
- Instructions for Modifying Your Shoebox

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. To construct the model, divide the students into teams of two or three and distribute the Instructions for Modifying Your Shoebox.
2. Have each team find the center point of the top and the bottom of the shoebox. These points can be found by using a straight edge to draw straight lines diagonally across each piece. The center point of each piece is located where the two diagonal lines intersect.
3. Have the students puncture both the top and bottom of the box using the scissors and insert the skewer through the holes so that it can stand vertically.
4. Next, the skewer should be removed from the box and inserted into the ball so that it serves as the axis of rotation if the ball serves as Earth.
5. If a Styrofoam ball is being used, have the students use a marker to draw the equator and the continents on their model.
6. Then have them stick their pushpins into the ball so that they are all in the northern hemisphere but roughly at the same latitude and equally spaced around the ball. For best results, the pins should be placed slight more than half way between the equator and the pole (e.g., at about 50° latitude).
7. Have the students use their scissors to cut windows in each of the four sides of the box. The windows should be centered on each side and should be approximately 8 cm in length. The height of the window should be cut such that it begins approximately 2 cm above the bottom of the box and ends at a point such that the shoebox top does not overlap the

window top. This requirement will allow the window to move on the “hinge” that is created by cutting along the top, right side, and bottom of each window but not cutting along the left side.

8. Have the students place one end of the skewer into the hole in the bottom of the box and the other end of the skewer in the hole in the top of the box so that the ball is inside the box when the top is placed on it.
9. The ball should be adjusted along the skewer so that it is easily seen from each of the windows.
10. Give each group a flashlight and darken the room.
11. Discuss the closing portion of the shadow activity previously completed and ask the student to recall how their shadow changed during the day.
12. Then ask them to use the flashlight to represent the sun by shining it through one of the windows and to duplicate the pattern they observed with their shadows, this time using the pushpins as their bodies.

Body

1. After 10 or 15 minutes of exploration, ask the students to discuss what they discovered. Guide them to the understanding that rotating the ball in a counterclockwise fashion (when viewed from above the North Pole) will duplicate what they observed with their shadows.
2. Discuss how this situation models what happens with Earth and the sun. The flashlight, kept in a fixed location, acts like the sun, providing the source of light needed to create shadows. The ball spinning on the skewer acts like Earth rotating on its axis. We notice the shadow pointing away from the sun and rather long initially. As the ball is rotated, the shadow continues to point away from the sun but shortens until the pin is in the plane determined by the skewer and the flashlight. Then the shadow lengthens as the ball continues to be rotated.
3. Next ask the students how much of the ball is illuminated. Since the ball is a sphere, half of it will be in light and the other half will be dark. The reason for this effect is that the half facing the flashlight is blocking the light from the dark half, just like our bodies blocked the light to produce our shadows.
4. Remind the students that there are 24 hours in each day and tell them that Earth rotates at a constant speed. Ask them how much time passes when a pin makes one complete rotation with Earth and to demonstrate this with their model. The answer is 24 hours since one complete rotation of Earth defines a day.
5. Next ask the students where the sun is located when it is noon and to demonstrate this with their models for one of the pins. They should realize that the shortest shadow occurs roughly at noon and should rotate the ball so that the pin is directly beneath the flashlight. If this does not occur, guide the students to that realization by reminding them of their shadows outside.

6. Ask the students if it is light or dark at the pin. The answer is *light*. Ask the students if it is day or night at the pin. The answer is *day*.
7. Ask the students how much time elapses when Earth makes one half of a revolution and to again demonstrate this with their model. The answer is *12 hours*.
8. Ask the student what time it is if someone were located where the pin is. Since the pin was initially located at its noon and 12 hours passed during the time it took for it to make one half of a rotation, the answer is *midnight*. Ask the students if it is dark or light at the pin. The answer is *dark*. Ask them if it is day or night at the pin. The answer is *night*.
9. Ask the students how much time elapses when Earth makes one quarter of a revolution and to again demonstrate this with their model. The answer is *6 hours*.
10. Ask the students what time it is if someone were located where the pin is. Since the pin was located at its midnight and 6 hours passed during the time it took for it to make one quarter of a rotation, the answer is *6 A.M.*
11. Next ask the students what the times are at the other pins. The answers are *noon*, *6 P.M.*, and *midnight*, as one moves in a counterclockwise fashion around the ball.
12. Ask the students to demonstrate one day for one of the pins by rotating the ball in one complete revolution. Make sure they understand where midnight, 6 A.M., noon, and 6 P.M. are.
13. Ask them at what time the pin changes from night to day. The answer is *6 A.M.* Tell them that this change corresponds to a time called *sunrise*.
14. Ask them at what time the pin changes from day to night. The answer is *6 P.M.* Tell them that this change corresponds to a time called *sunset*.
15. Ask the students to look on the Internet or in the local newspaper to find the time of sunrise and sunset for tomorrow. Most likely, these times will not be 6 A.M. and 6 P.M., respectively, because the tilt of Earth on its axis causes the illumination of Earth's surface to be symmetric about the equator only at the equinoxes when the sun is above the equator. However, these differences will provide a natural question that will lead the students to the closure activity.

Closure

1. Ask the students what would happen to the number of daylight hours if Earth were tilted on its axis relative to the sun. Record their predictions.
2. Then have the students poke another hole in the top of the shoebox and stick the upper part of the skewer into it so that Earth is now tilted. This setup more correctly models the actual tilt of Earth on its axis.
3. To help in determining the amount of time any particular location experiences daylight, have each group draw a circle on the shoebox top with the new location of the skewer at the center of the circle. They should then divide the circle into 24 equal segments and indicate them with tick marks around the edge of the circle. To do this, have them divide

the circle in half, then in quarters, and then in eighths. Each eighth should then be divided into thirds.

4. Give each group a pipe cleaner and have them wrap this around the upper portion of the skewer after it has been re-inserted into the shoebox top. One end of the pipe cleaner should point outward from the skewer so that it serves as a pointer to the tick marks on the circle. By using this device, the students can judge time.
5. Then darken the room and have them investigate the question “How does the number of daylight hours change across the across the surface of Earth if it is tilted?” Be sure that the students control other variables such as the location of the sun. Different groups may get different answers if they shine the light into different windows of the box. If this situation occurs, you can discuss the results in terms of hemisphere tilted toward or away from the sun and obtain consistency in the results.
6. The number of daylight hours at a given location will change when Earth is tilted as follows.

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. The reason for these results is that, while the sun still illuminates half of Earth at any given time, the tilt of Earth on its axis causes the hemisphere tilted toward the sun to have a greater portion of its area in light, thus experiencing more daylight hours. Correspondingly, the hemisphere tilted away from the sun has less of its area illuminated and experiences fewer daylight hours. The number of daylight hours is the same in both hemispheres only when Earth’s axis is perpendicular to the line connecting Earth and the sun.

Days 4 and 5
(10 minutes and 45 minutes, respectively)

Materials/Equipment

- Lunar calendars
- ping-pong balls
- pencils
- clear light bulb (at least 60 watts)
- clip-on light socket
- music stand or tripod

Set or Opener

Day 4

1. Ask the students when they can see the moon. Most often, the answer will be at night; however, the moon can be seen during the day at some times.
2. Tell the students that you would like them to investigate this question by observing the moon each day over the next four weeks.
3. Distribute the lunar calendar to each student and instruct the class to draw a picture of the moon in the box for each day. They also should record the time of their observation and the date in the appropriate place of each box.

Body

Day 5

(do this after the lunar calendar is completed)

1. Do a whole-group discussion about what the lunar calendar shows. Students should observe the moon phases as the new moon waxes toward a full moon and the full moon wanes toward the new moon. They should also notice that the moon is visible during the day at some times and at night at other times.
2. Prior to class, use a nail or scissors to poke a hole in each ping-pong ball and screw the light bulb into the light socket, clamping it onto the music stand so that the bulb faces upward.
3. Distribute ping-pong balls and pencils to each of the students and have them place the ping-pong balls on the sharpened end of the pencils.
4. Have the students form a circle around the music stand, with each of them facing inward.
5. Darken the room and turn on the clear light bulb.
6. Have the students hold the pencil at arm's length in front of them and slightly above their heads.

7. Tell them that the ping-pong ball represents the moon, the light bulb represents the sun, and they represent Earth.
8. Ask them to compare what they see now with what they observed of the moon. This configuration of the three bodies represents the new-moon phase when the moon is located between Earth and the sun. They should notice that the portion of the moon facing them is dark because the half facing the sun is illuminated and blocking the sunlight.
9. Next have the students turn slowly toward their left until they have completed half of a circle, meanwhile continuing to hold the moon out in front of their faces. Have them describe what they observe. They should notice that the portion of the moon that is illuminated increases (or waxes) until they see an entire circle (the full moon).
10. Then have the students turn slowly toward their left until they have returned to facing the light bulb, meanwhile continuing to hold the moon out in front of their faces. Have them describe what they observe. They should notice that the portion of the moon that is illuminated decreases (or wanes) until they return to the full moon situation.
11. Ask the students to use this set-up to explain what they observed about the moon over the past four weeks. They should follow the same type of demonstration that they just completed, with the moon revolving about Earth.
12. Explain to the class that the moon revolves about Earth approximately once per month and that the phases of the moon therefore repeat themselves roughly every 30 days.

Closure

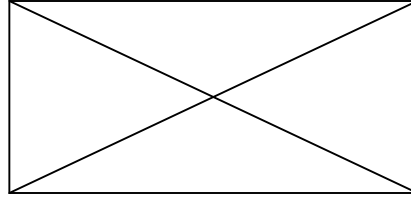
1. To close the activity, have the students remain in the circle around the music stand but lower the moon until it is directly in line between their eyes and the light bulb.
2. Have them move the ball slightly to the right so that they see the light bulb. Then have them move it slowly to their left and ask them to describe what they see.
3. They should notice that the ball blocks their view of the light bulb. Explain that this situation models what happens when a solar eclipse occurs. For a solar eclipse, the moon moves between the sun and the earth.
4. Next have them keep the moon at the same height and move slowly toward their left until they face away from the light.
5. Have them describe what they see. They should notice that their heads block the light from the bulb when they would normally see a full moon. This situation represents a lunar eclipse and occurs when the shadow of Earth falls onto the moon.

Resources

(activities, data sheets, lab sheets)

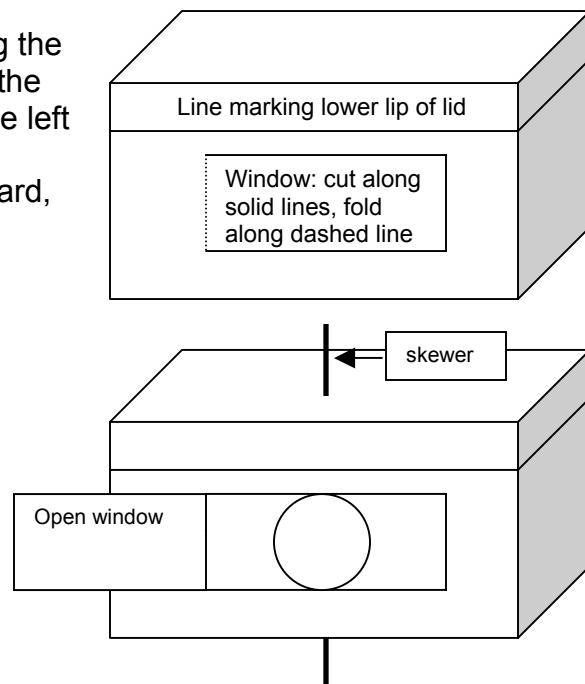
Instructions for Modifying Your Shoebox

1. Take the top off of your shoebox. Use the ruler to draw a line diagonally from corner to corner on the inside of the top. Do the same thing for the other two corners so that you have a big X on the inside of the box top.



2. Do the same thing with the bottom of the shoebox.
3. Take your scissors and carefully poke a small hole in the box top where the two lines you have drawn cross. Then do the same thing with the bottom of the shoebox.
4. Now take the skewer and use the pointed end to enlarge the holes you made with the scissors so that they are just big enough for the skewer to fit into.
5. You next need to cut windows in the other four sides of the box. Before you do this, put the top on the box and draw a line around the outside of the box, just below the bottom lip (the part that hangs down each side). Your windows must be between this line and the bottom of the box.
6. 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.

7. 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.
8. Now bend each window outward, using the left side as a hinge.



Name: _____

Lunar Calendar

Class: _____

For each day over the next four weeks, observe the moon and draw a picture of it in the appropriate box below. Be as accurate as possible. Also record the date and time of your observation in the space provided within the box. Start your recording in the upper-most left box. On successive days, use the next box to the right. If you cannot see the moon on a given date, leave the box blank. Once a row is complete, move to the left-most box on the next row.

Week	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
1	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____
2	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____
3	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____
4	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____	Date: _____ Time: _____

Assessment

1. A young girl is walking along the sidewalk when she spots a dollar ahead of her. When she reaches the dollar, she looks down and notices that she does not have a shadow. If she were going home to eat, what meal would be served to her?
 - a. breakfast
 - b. lunch
 - c. dinner
 - d. bedtime snack

2. Which of the following locations has the greatest annual variation in the number of daylight hours?
 - a. the equator
 - b. 20°N
 - c. 40°S
 - d. 60°N
 - e. the South Pole

3. If Earth became more tilted on its axis, what would happen throughout the year to the number of hours of daylight received at your home? Explain your answer.

Answers:

1. (b) The sun must be nearly directly overhead for the girl to not see her shadow. Since the sun is most closely overhead near noon, the girl must be going home for lunch.
2. (e) The poles experience 24 hours of daylight in summer and 24 hours of darkness (0 hours of daylight) in winter. No other latitude experiences this great of a variation in the number of daylight hours.
3. As Earth becomes more tilted on its axis, the number of daylight hours will increase in summer and decrease in winter. The reason for this is that, as the tilt increases, a greater portion of the summer hemisphere is illuminated in comparison to 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 partially correct answer is given. A partially correct 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.

There are many great sites on the Internet for images of Earth and the moon. One such site is hosted by NASA (<http://www.nasa.gov/gallery/index.html>).

There are also many sites that allow the students to explore shadows and light. Two possibilities are the following.

- <http://www.phy.ntnu.edu.tw/java/shadow/shadow.html>
- http://www.exploratorium.edu/snacks/colored_shadows.html

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
- An excellent site showing the phase of the moon at any date and time between 1800 and 2199 A.D.
- Recent and upcoming eclipses of the sun and moon
- 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.