National Aeronautics and Space Administration

NASA CONNECT™

Ancient Observatories: Timeless Knowledge©

An Educator Guide with Activities in Mathematics, Science, and Technology

Educational Product	
Educators	Grades 6-8

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NASA CONNECT™: *Ancient Observatories: Timeless Knowledge* is available in electronic format. Find a PDF version of the educator guide for NASA CONNECT™ at the NASA CONNECT™ web site: **http://connect.larc.nasa.gov**

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AIAA FOUNDATION
www.aiaa.org

CHRISTOPHER NEWPORT UNIVERSITY
www.cnu.edu

ITEA International Technology Education Association
www.iteawww.org

AECC Aerospace Education Coordinating Committee
www.nasa.gov

http://sunearth.gsfc.nasa.gov/

NCTM
www.nctm.org

NSTA National Science Teachers Association
www.nsta.org

NEC
NEC Foundation of America
www.nec.com

Knowitall.org
http://knowitall.org

NASA CONNECT™

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An Educator Guide with Activities in Mathematics, Science, and Technology

Program Overview

Hands-On Activity

AIAA FOUNDATION Registered users of NASA CONNECT™ may request an American Institute of Aeronautics and Astronautics (AIAA) classroom mentor. For more information or to request a mentor, e-mail **nasaconnect@aiaa.org**.

Acknowledgments: Special thanks to Summer 2004 Educators in Residence, Chris Giersch, and the National Council of Teachers of Mathematics (NCTM).

PROGRAM OVERVIEW

educator guides

SUMMARY & OBJECTIVES

In NASA CONNECT™: *Ancient Observatories: Timeless Knowledge,* students will learn how cultures from ancient times to the present have used the Sun and other objects in the sky to mark the passage of time. They will see how archaeoastronomers use ancient observatories to predict seasons and special events. Using simple tools of geometry and the angle bisector method, students will measure the movement of the Sun and find solar noon for their location. By conducting inquiry-based and web activities, students will make connections between NASA research and the mathematics, science, and technology they learn in their classrooms.

STUDENT INVOLVEMENT

Inquiry-Based Questions

Host, Jennifer Pulley, and NASA engineers and scientists will pose inquiry-based questions throughout the program. These questions allow the students to investigate, discover, and critically think about the concepts being presented. When viewing a videotape or DVD version of NASA CONNECT™, educators should pause the program at the designated segments so students can answer and discuss the inquiry-based questions. During the program, Jennifer Pulley and NASA engineers and scientists will indicate the appropriate time to pause the tape or DVD. For more information about inquiry-based learning, visit the NASA CONNECT™ web site, **http://connect.larc.nasa.gov**.

Teacher note: : It is recommended that you preview the program before introducing it to your students so that you can become familiar with where the pauses occur.

Hands-On Activity

The hands-on activity is teacher created and is aligned with the National Council of Teachers of Mathematics (NCTM) Standards, the National Science Education (NSES) Standards, and the International Technology Education Association (ITEA) Standards for Technological Literacy. Students will make sun shadow plots by marking ends of shadows made by the Sun and a gnomon (a stick used to cast shadows). After students have made their sun shadow plot, they will use it to determine the direction of true north.

Web Activity

The activity is aligned with the National Council of Teachers of Mathematics (NCTM) Standards, the National Science Education (NSES) Standards, and the International Technology Education Association (ITEA) Standards for Technological Literacy. Norbert has lost his watch and he needs to be able to tell the time of day so he doesn't miss any important appointments. The ancients could tell time by using a sundial. In this activity, you will learn about angles and symmetry and study sundials by using measurement, plotting, and analysis of data.

RESOURCES

Teacher and student resources enhance and extend the NASA CONNECT™ program. Books, periodicals, pamphlets, and web sites provide teachers and students with background information and extensions.

hands-on activity

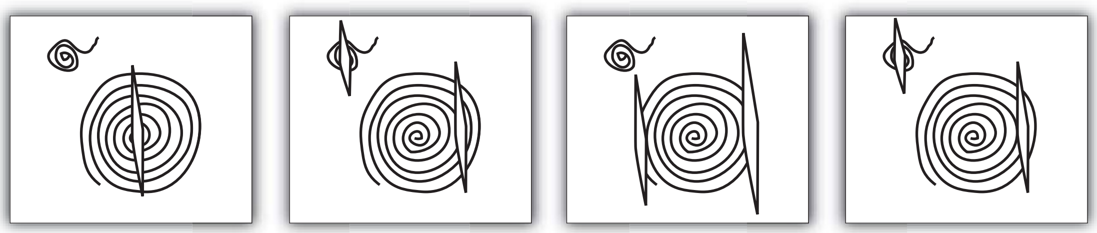
BACKGROUND

BACKGROUND

Archaeoastronomy comes from the word archaeology, which refers to the study of ancient people and their culture, and the word astronomy, which refers to the study of matter in outer space, is the study of the religious and mythological beliefs of ancient cultures, combined with their studies and practices of astronomy. Many cultures have built celestial observatories that use the Sun and the shadows made by the Sun to predict seasons and events, such as summer and winter solstices and vernal and autumnal equinoxes, and also to measure time. Myths and legends explain and help us understand these natural phenomena.

The Sun is stationary in relation to Earth, but it appears to move across the sky because the Earth is rotating on its own axis every 24 hours, producing night and day, while revolving around the Sun once each year. For half the year, the Northern Hemisphere is tilted toward the Sun while the Southern Hemisphere is tilted away from it. The reverse is true for the other half of the year, causing the seasons. Summer solstice, the longest day of the year, occurs when one hemisphere is the shortest distance from the Sun. Winter solstice is the shortest day of the year and occurs when one hemisphere is the farthest distance from the Sun. The fall and spring equinoxes occur when both hemispheres are equidistant from the Sun and the length of day and night for both hemispheres are approximately equal.

One example of an ancient observatory that marks the solstices and equinoxes is The Sun Dagger observatory created by the Anasazi Indians of the Chaco Canyon in New Mexico. This observatory puts on a fascinating show during the solstices and equinoxes. At noon during the summer solstice, a dagger of sunlight penetrates the center of a spiral. During the autumnal and vernal equinoxes, a sun dagger passes through the center of a small spiral on the left, and another passes on the edge of a large spiral. At the winter solstice, a big sun dagger passes on either side of the large spiral. Many scientists believe that the Anasazi Indians used this display of shadows to reveal the changing seasons.



Summer Solstice Fall Equinox Winter Solstice Spring Equinox

Several more examples of ancient observatories include Stonehenge in the British Isles, the Hovenweep Ruins in Utah and Colorado, the Cahokia Mounds in southern Illinois, the Caracol Tower at Chichen Itza, Mexico, the Aztec ruins in eastern Mexico, the Temple at Kanak, and the Pyramid of Khufu at Giza in Egypt (**http://www.crystalinks.com/observa.html**). Each of these observatories uses the combination of cultural beliefs and legends, along with science, to brilliantly display the changing effects of the Sun's rays upon the spinning Earth as it orbits the Sun.

INSTRUCTIONAL OBJECTIVES

The students will

- gain experience in measuring angles.
- measure, collect, and analyze data in order to make predictions.
- use the angle bisector method to find true north.
- use ratios to predict the length of shadows cast by a different length gnomon.

NATIONAL STANDARDS

NCTM Mathematics Standards

Number and Operations

Understand numbers, ways of representing numbers, relationships among numbers, and number systems.

- Understand and use ratios and proportions to represent quantitative relationships.

Algebra

Use mathematical models to represent and understand quantitative relationships.

- Model and solve contextualized problems by using various representations, such as graphs, tables, and equations.

Measurement

Use visualization, spatial reasoning, and geometric modeling to solve problems.

- Use geometric models to represent and explain numerical and algebraic relationships.
- Recognize and apply geometric ideas and relationships in areas outside the mathematics classroom, such as art, science, and everyday life.

NSES Science Standards

Earth and Space Science

Earth in the solar system

- The Sun is the major source of energy for phenomena on the Earth's surface, such as growth of plants, winds, ocean currents, and the water cycle. Seasons result from variations in the amount of the Sun's energy hitting the surface due to the tilt of the Earth's rotation on its axis and the length of the day.

Science and Technology

Abilities of technological design

- Identify appropriate problems for technological design.
- Implement a proposed design.
- Evaluate completed technological design or products.

Understanding about Science and Technology

- Many different people in different cultures have made and continue to make contributions to science and technology.

History and Nature of Science

Science as a human endeavor

- Women and men of various social and ethnic backgrounds with diverse interests, talents, qualities, and motivations engage in the activities of science, engineering, and related fields, such as the health professions. Some scientists work in teams and some work alone, but all communicate extensively with others.
- Science requires different abilities, depending on such factors as the field of study and type of inquiry. Science is very much a human endeavor, and the work of science relies on basic human qualities, such as reasoning, insight, energy, skill, and creativity, as well as on scientific habits of mind, such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas.

Nature of Science

- Scientists formulate and test their explanations of nature by using observation, experiments, and theoretical and mathematical models. Although all scientific ideas are tentative and subject to change and improvement in principle, for most major ideas in science, there is much experimental and observational confirmation. Those ideas are not likely to change greatly in the future. Scientists do and have changed their ideas about nature when they encounter new experimental evidence that does not match their existing explanations.

ITEA Standards for Technological Literacy

Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.

NASA RELEVANCE

Through the centuries, people of all cultures have been curious about the Sun and have wanted to better understand and explain how it affects life on Earth. Many cultures have used legends to explain their observations of the Sun. Many have built observatories, marking the position of the shadows the Sun casts on specific days like the summer and winter solstices and the spring and fall equinoxes. People throughout history have been able to use their growing knowledge about the Sun to help them make choices concerning planting crops, keeping track of time and seasons, using the Sun for solar energy, safety issues concerning the Sun, and Earth's overall relationship with the Sun. Currently, NASA is studying the solar storms, solar flares, solar wind, sunspots, and their effects on human beings. Events on the Sun affect the Earth's magnetosphere, weather, magnetic fields, satellites, and much more. By investigating Earth's relationship with the Sun, NASA can discover how to improve our lives and further explore and discover the universe.

PREPARING FOR THE ACTIVITY

Student Materials *(per class)*

- 1 pointed gnomon *(skewer stick or thin straws work well)*
- 1 large cardboard box 5 to 10 cm tall (copy paper box lids work well)
- protractor
- ruler
- markers
- glue
- 11- x 17- in. sheet of paper (28 cm x 47 cm)
- patty paper *(thin paper used for tracing)*
- masking tape
- scissors
- compass

Time for Activity

- **Day 1:** Watch the video and activity setup
- **Day 2:** 3 minutes every half hour for data collection
- **Day 3:** Data analysis and creation of Sun Shadow Box
- **Day 4:** Check results of Sun Shadow Box predictions

Teacher note: *This activity works best on days that are not windy because the wind keeps the gnomon from standing straight up. Also, students should never look directly at the Sun!*

Vocabulary

Global Positioning System (GPS) — A system of satellites, computers, and receivers that determines the latitude and longitude of a receiver on Earth by calculating the time difference for signals from different satellites to reach the receiver.

gnomon — An object, such as the style of a sundial that projects a shadow used as an indicator of the time of day

shadow — An area that is not or is only partially lit up because an opaque object is blocking the light between the area and the source of light

solar noon — The time or point at which the Sun's position is at its highest elevation for that day

true north — The direction of the North Pole from your current position. Magnetic compasses are slightly incorrect due to effects of the Earth's magnetic field. GPS units correct for magnetic influences.

Sun — The star that is the basis of the solar system and that sustains life on Earth, being the source of heat and light. It has a mean distance from Earth of about 150 million kilometers (93 million miles), a diameter of approximately 1,390,000 kilometers (864,000 miles), and a mass about 330,000 times that of Earth.

sundial — An instrument that indicates local apparent solar time based on the shadow cast by a central projecting pointer (gnomon) on a surrounding calibrated dial

THE ACTIVITY
Sun Shadows

Lesson Description

ENGAGE

Discuss the following questions with students. A demonstration with a pencil and a flashlight could help facilitate discussion.

1. What causes a shadow?

   Answer: An object blocking the path of light causes a shadow.
2. What does your shadow look like shortly after the Sun comes up?

   Answer: Shadows are the longest shortly after the Sun comes up and right before it goes down.
3. What happens to the length of your shadow as noon approaches?

   Answer: Your shadow gets shorter.
4. At what time of the day is your shadow the shortest?

   Answer: Your shadow is the shortest around noon, when the Sun's position is directly overhead.
5. What happens to the length of your shadow as evening approaches?

   Answer: Your shadow gets longer.
6. Why does your shadow change throughout the day?

   Answer: The Sun's position in the sky changes, causing shadows to be at different angles and lengths.
7. Compare your shadow shortly after sunrise to your shadow shortly before sunset.

   Answer: Your shadow shortly after sunrise and shortly before sunset is close to the same length but is on different sides of your body.
8. Can predict a shadow's movement?

   Answer: Yes, we can predict a shadow's movement because we can predict the position of the Sun.
9. How does a shadow give us information about the time of day?

   Answer: Shadows that are made as a result of the Sun tell us the Sun's position in the sky. Changes in the position of the Sun help us measure time of day.

Show the NASA CONNECT™ program, *Ancient Observatories: Timeless Knowledge*.

EXPLORE

Students will make sun shadow plots by marking the ends of shadows made by the Sun and a gnomon (a stick used to cast a shadow) every half hour throughout the day. Students will observe and record how the length and position of shadows change throughout the day as a result of the Earth's spin changing its position to the Sun. Once students have mapped most of a school day's worth of shadows, they will measure and record the shadow angles and lengths.

Activity Setup

Suggestion: Do the data collection as a class. Then, each group of 2–3 students will analyze and use the data to make predictions later in the activity.

As a class

1. Turn the cardboard box upside down and make a very small hole in its center by using the point on the scissors.
2. Tape the large paper to the top of the cardboard box lid and mark its center with a dot.
3. Through this dot, draw two lines that are perpendicular to each other. Draw one line horizontally so it passes through the dot; draw the second line vertically so it passes through the dot.
4. Stick the gnomon through the dot and the hole in the cardboard so that 10 cm of the gnomon is sticking straight up out of the box. Use a protractor to make sure that the gnomon is perpendicular to the box.
5. Use tape to keep the gnomon standing straight up and make sure that exactly 10 cm is sticking up out of the box. This step is very important! It works well to tear the tape just a little up the middle and wrap both sides of the tear in the tape around your gnomon; then flatten the tape around the gnomon and onto the box. Wrap with a few more pieces of tape and your gnomon should stay securely in place. See Figure 1 for activity setup.

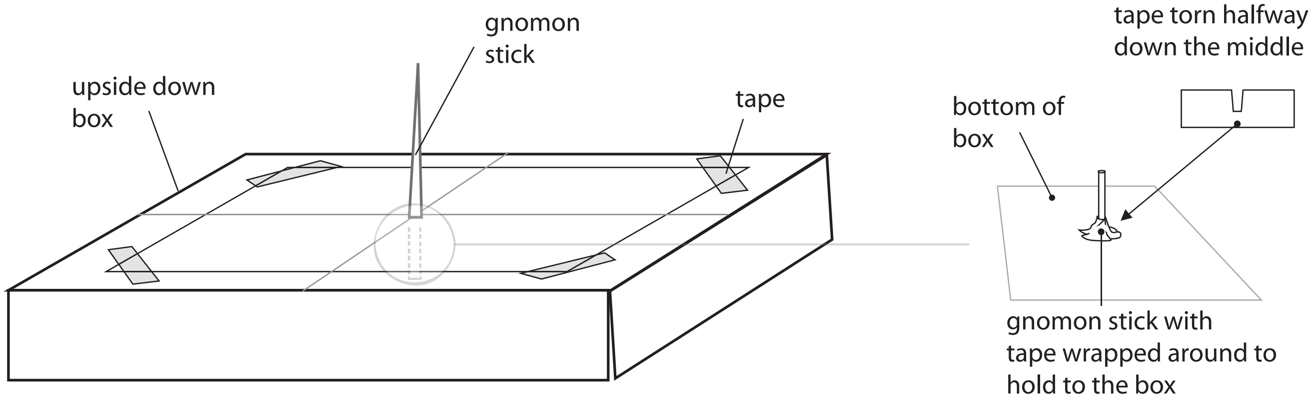


Figure 1: Activity Setup

The Activity

On a clear, sunny day, find a large flat area outside *(such as the school parking lot)*. Place the longest edge of the box along the edge of the parking lot or along a painted mark on the parking lot, tennis court, or basketball court. Tape your box to the ground on all four sides to make sure that it does not move at all throughout the day. See Figure 2. **Note:** *Mark this exact spot because you will be returning to it later in the activity.*

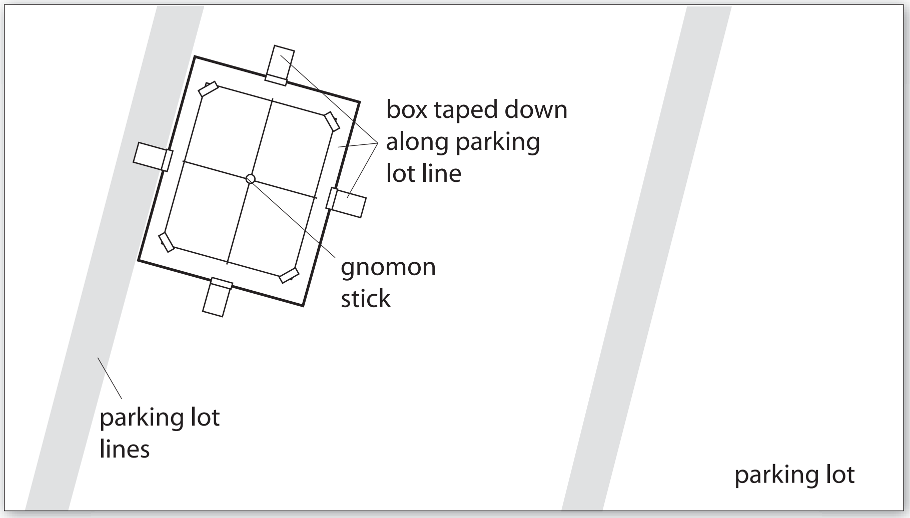


Figure 2: Layout

Starting as early in the morning as possible, mark the end of the gnomon's shadow every half hour until the end of the day. Next to each dot, label the time of day that it was marked. One student from each group or class can be responsible for marking the end of the shadow at each half hour until school is over. See Figure 3.

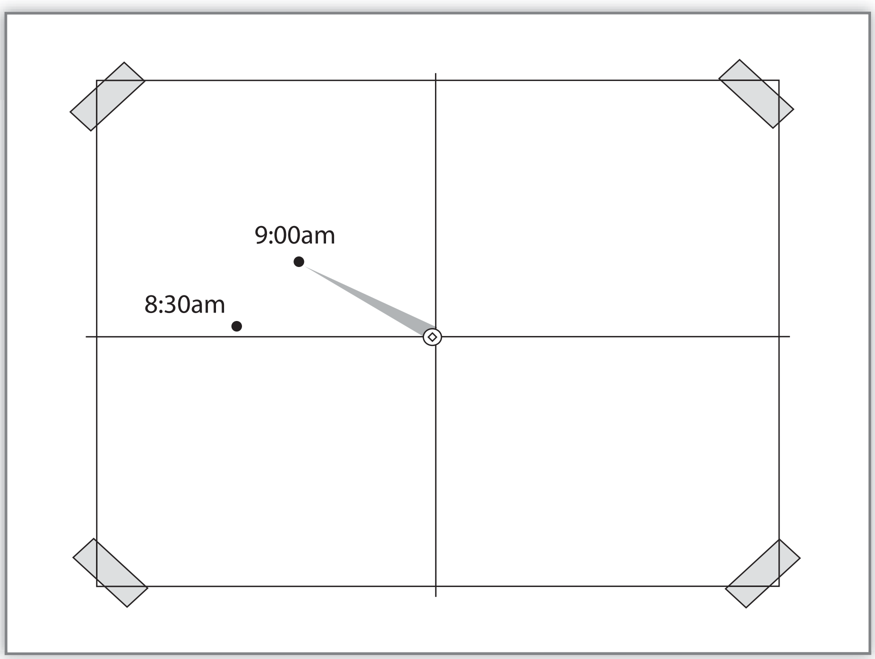


Figure 3: Sample marking

Draw straight lines from each dot to the hole in which the gnomon was placed. Measure and record in Table 1 the angle between the horizontal line drawn through the center of the paper and each marked shadow. Next, measure and record the length of each shadow in Table 1. Remember, accuracy is very important. See Figure 4

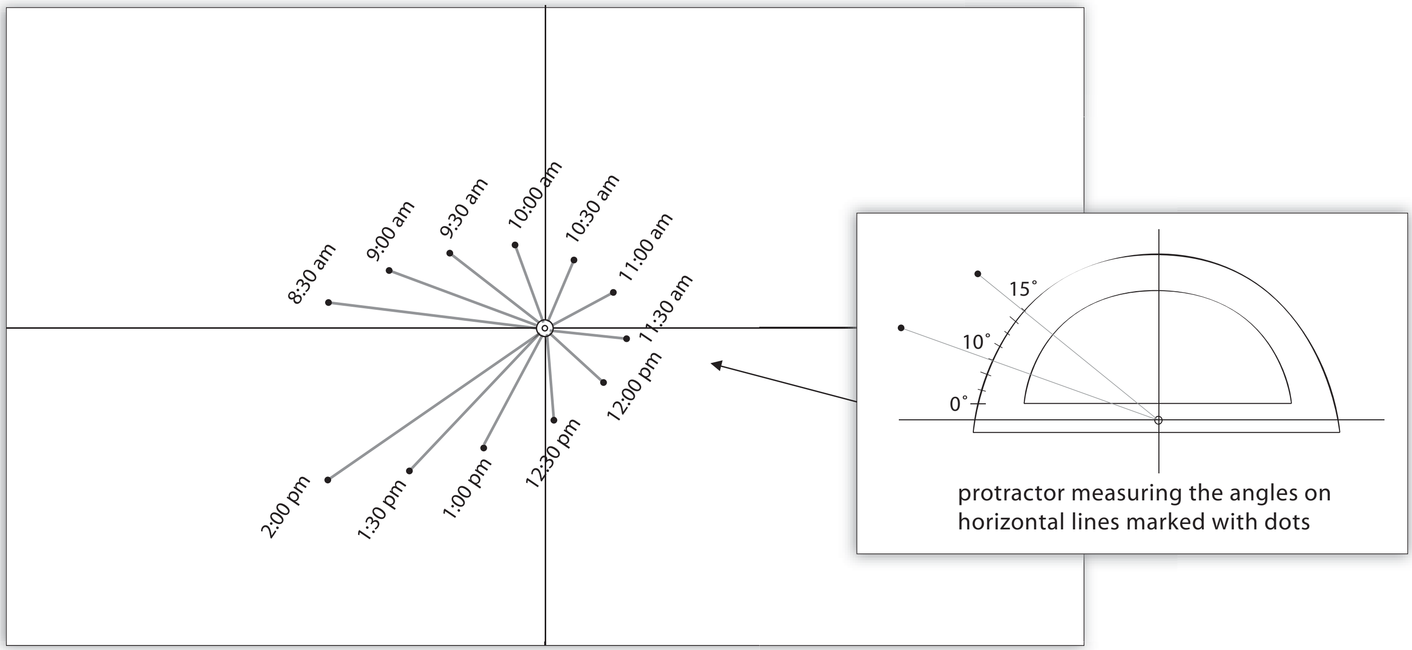


Figure 4: Sample Measurement

Table 1: Sun Shadow Plot Data

Time														
Angle from horizontal line (deg)														
Length (cm)														

EXPLAIN

The students will find and label true north on their sun shadow plots by using the angle bisector method. They will verify local solar noon by using shadow length times and sunrise/sunset times. The students will also show how the curve of shadows would continue through the evening hours.

- Find and label true north by using the angle bisector method.

This method works because the shadow length is always symmetrical about the true north shadow, which occurs at solar noon. Next are three angle bisector methods you can use to find true north:

Using Patty Paper: Find one AM shadow and one PM shadow that are as close in length as possible. On a piece of patty paper, trace these two lines. Fold the patty paper so the two lines are on top of each other. The fold is the bisector of the angle created by these two lines. Use this tracing paper to draw the angle bisector on the original sun plot. When the plot is in its outside marked position, this line points towards true north.

Using a Protractor: Measure the angle between one AM shadow and one PM shadow that are the same length. Divide the number of degrees of the angle in half. Measure this number of degrees from one of the lines (towards the other line) and mark a new line; label it true north.

Using a Compass: Use the standard construction method for finding the angle bisector. Label the bisector true north.

Teacher Note: Anyone who has a GPS available can use it to verify the direction of true north.

• Verify local solar noon by using shadow length times and sunrise/sunset times.

Shadow length times: Find the midpoint time between the times when the two shadows are the same length. This time is local solar noon, the time when the shadow points towards true north. Next is an example of how to determine the midpoint time.

Teacher Note: *It is much easier to find the time for true north when working with military time. Military time is a 24-hour time with no AM or PM designation. For example, 2:00 PM in military time is 1400 hours. The following chart shows regular time with the corresponding military time.*

Regular Time	Military Time	Regular Time	Military Time
Midnight	0000	Noon	1200
1:00 am	0100	1:00 pm	1300
2:00 am	0200	2:00 pm	1400
3:00 am	0300	3:00 pm	1500
4:00 am	0400	4:00 pm	1600
5:00 am	0500	5:00 pm	1700
6:00 am	0600	6:00 pm	1800
7:00 am	0700	7:00 pm	1900
8:00 am	0800	8:00 pm	2000
9:00 am	0900	9:00 pm	2100
10:00 am	1000	10:00 pm	2200
11:00 am	1100	11:00 pm	2300

Example:

Time A:	11:25 AM
Time B:	2:40 PM

1. Convert Time A to minutes:
   11:25 AM = 11 hours x (60 minutes / 1 hour) + 25 minutes = 685 minutes

2. Add 12 hours to time B, making it military time: 2:40 PM = 14:40

3. Convert Time B to minutes:
   14 hours x (60 minutes / 1 hour) + 40 minutes = 880 minutes.

4. Average Time A and Time B in minutes:
   (685 minutes + 880 minutes) / 2 = 783 minutes

5. Convert the average time back into hours and minutes:
   783 minutes / (60 minutes/hour) = 13.05 hours

6. Convert .05 into minutes:
   (.05 x 60 minutes) = 3 minutes

7. Average Time in hours and minutes: 13:03 = 1:03 pm (regular time)

Sunrise/Sunset Times: Use the newspaper, Internet, or television to find the sunrise and sunset times for the day of the activity. Determine the midpoint between the two times. This midpoint calculation will also give you solar noon, the time when the shadow points towards true north. The suggested method is to convert the times into minutes. Use the previous example as a guide to determine the average time between sunrise and sunset.

Connect all the dots that mark the ends of the sun shadows to give you a curve. Predict and draw in a different color, and use symmetry around the true north line to show how the curve of shadows would continue through the evening hours.

The total curve should end up being a symmetrical U-shape. See Figure 5.

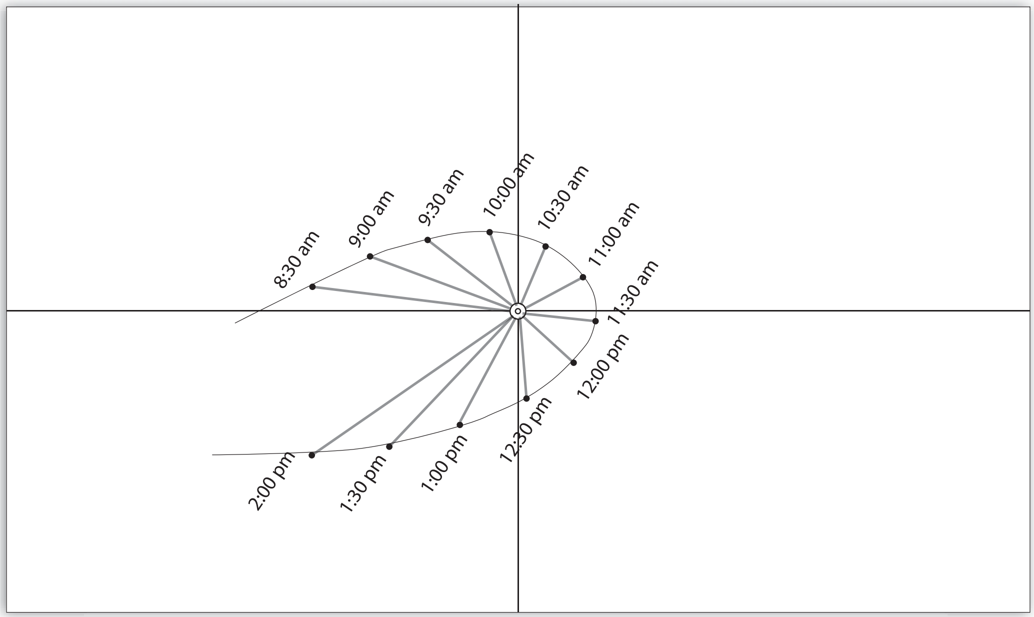


Figure 5

Discussion Questions

1. How do shadow lengths change?

   Answer: Early in the day they are longer, and as they approach true north, they get shorter and then longer again.

2. How do the positions and angles of the shadows change? In which direction do they move (clockwise or counterclockwise)?

   Answer: The shadows move clockwise in a horseshoe or U shape.

3. What do the changing positions and angles tell you about how the position of the Sun changes throughout the day? Does the Sun's position in the sky change in a clockwise or counterclockwise direction? Draw a picture to explain your answer.

   Answer: The Sun's position changes in a counterclockwise direction.

4. When are shadows the shortest? When are they the longest? Draw a picture explaining your answer.

   Answer: The shadows are shortest when the Sun's position is straight overhead and longer during the morning and evening hours.

5. How do you think the curve would change if you used a different sized gnomon to cast the shadow?

   Answer: The curve would be in the same shape, but the length of the shadows would be different in proportion to the difference in size.

6. Will the curve be the same throughout the year?

   Answer: The shape of the curve will be the same, but the positions and lengths of shadows will be different due to the tilt of the Earth.

7. What causes the changes in shadows, the moving Earth or the moving Sun? Draw a picture to explain your answer.

   Answer: The Sun's position does not change. The spinning and tilt of the Earth cause a change in shadow lengths and angles.

EXTEND

Use Your Data To Predict

Design a shadow box to place in the sunlight in the same orientation as your original shadow plot. Use a gnomon of a different length than you used before. Determine and record in the Shadow Box Data Chart the angle and length of the shadow for each time. On the shadow box, place or glue small objects or marks (stickers, pictures, small toys) where you predict the ends of the shadows will be cast at several times during the day. Have one of these times be when a shadow is cast on true north. Make a special marking for true north.

Shadow boxes can be decorated to express the group's theme. Students can write stories to accompany their design that explain the sun/shadow relationship in legend form.

Hint: *Use the angles and shadow lengths from your original shadow plot to decide where to place objects.*

Shadow Box Data

Time					
Angle from baseline (deg)					
Length (cm)					

EVALUATE

The angle at any given time should be very close to the angle measured at that time on the previous plot (assuming that very few days have passed between making the first shadow plot and making the sun shadow box). For this portion of the activity, consider the angles to be the same at any given time on the two different days.

The lengths can be calculated by setting up ratios of the gnomon length to the shadow length at each time; then, use this ratio to determine the length of the new shadow each time you have a different gnomon length.

For Example:

First gnomon length = 10 cm

At 9:30 AM, shadow length = 13 cm

The ratio of the shadow length to the gnomon length is 13 cm: 10 cm or 13 cm / 10 cm = 1.3

Second gnomon length = 7 cm

Multiply 7 cm by 1.3. Thus, 9.1 cm is the shadow length at 9:30 AM for the second gnomon.

Student Handout

Sun Shadows

Caution: Sunshine in normal amounts is perfectly safe; however, you must observe one very important safety rule: NEVER LOOK DIRECTLY AT THE SUN! The Sun is so bright that it can cause serious damage to your eyes.

Setup

As a class

1. Turn the cardboard box upside down and make a very small hole in the center of the box by using the pointed end of the scissors. Tape the large paper to the top of the lid of the cardboard box and mark its center with a dot.
2. Through this dot, draw two lines that are perpendicular to each other. Draw one line horizontally so it passes through the dot. Draw the second line vertically so it passes through the dot.
3. Stick the gnomon through the dot and through the hole in the cardboard so that 10 cm of the gnomon is sticking straight up out of the box. Use a protractor to make sure that the gnomon is perpendicular to the box.
4. Use tape to keep the gnomon standing straight up and make sure that exactly 10 cm is sticking up out of the box. This step is very important! It works well to tear the tape just a little up the middle and wrap both sides of the tear in the tape around your gnomon. Flatten tape around the gnomon and onto the box. Wrap a few more pieces of tape and your gnomon should stay securely in place.

See Figure 1 for activity setup.

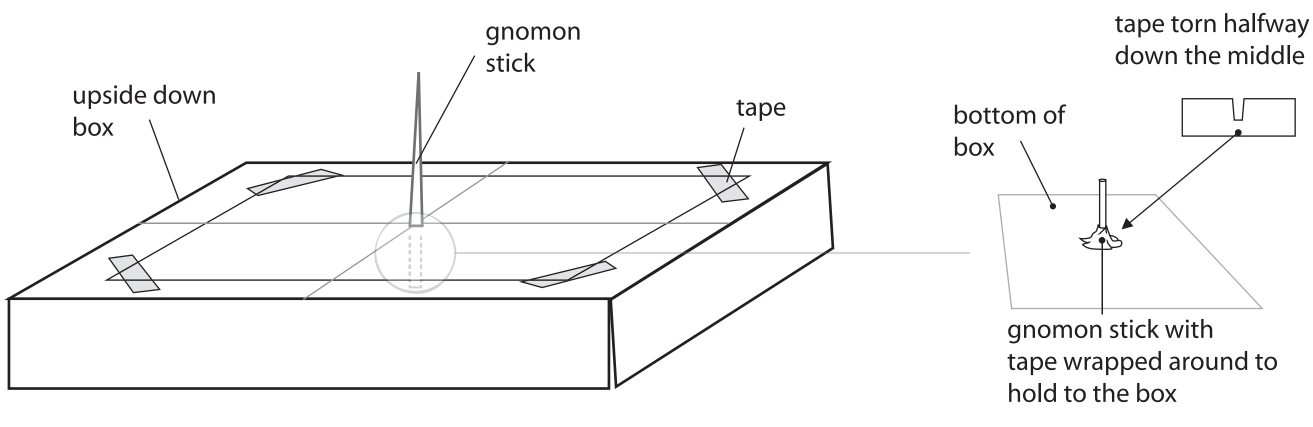


Figure 1: Activity Setup

Student Handout

Sun Shadows

The Activity

On a clear, sunny day, find a large, flat area outside such as the school parking lot. Place the longest edge of the box along the edge of the parking lot or along a painted mark on the parking lot, tennis court, or basketball court. Tape your box to the ground on all four sides to make sure that it does not move at all throughout the day. See Figure 2. Note: Mark this exact spot because you will be returning to it later in the activity.

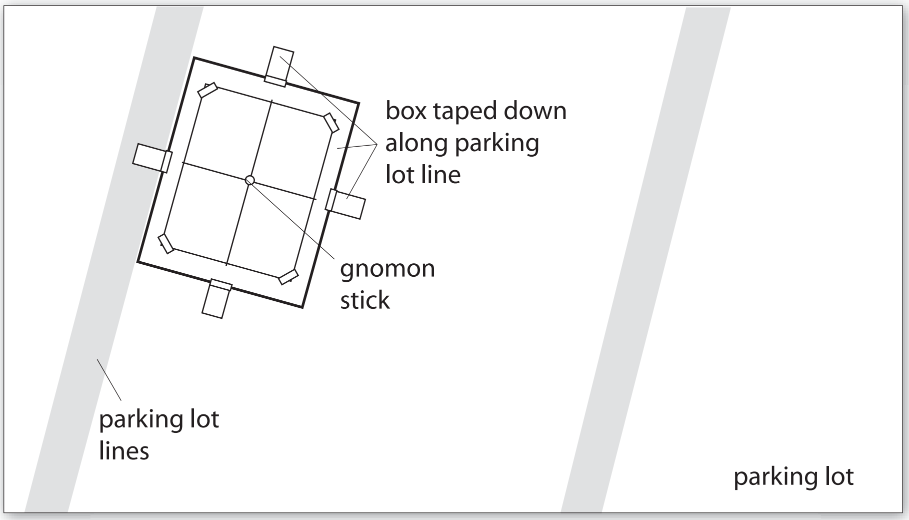


Figure 2: Layout

Starting as early in the morning as possible, mark the end of the shadow of the gnomon every half hour until the end of the day. Next to each dot, label the time of day that it was marked. One student from each group or class can be responsible for marking the end of the shadow at each half hour until school is over. See Figure 3.

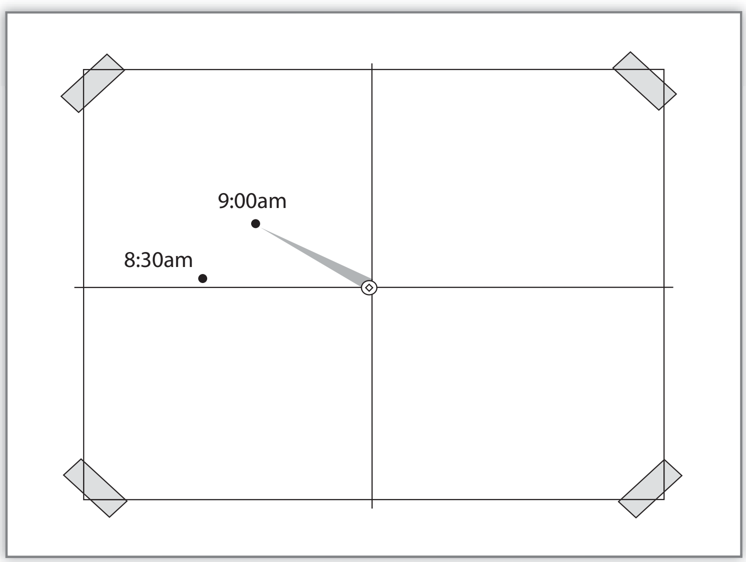


Figure 3: Sample marking

Student Handout

Sun Shadows

Draw straight lines from each dot to the hole in which the gnomon was placed. Measure and record in Table 1 the angle between the horizontal line drawn through the center of the paper and each marked shadow. Next, measure and record the length of each shadow in Table 1. Remember, accuracy is very important. See Figure 4.

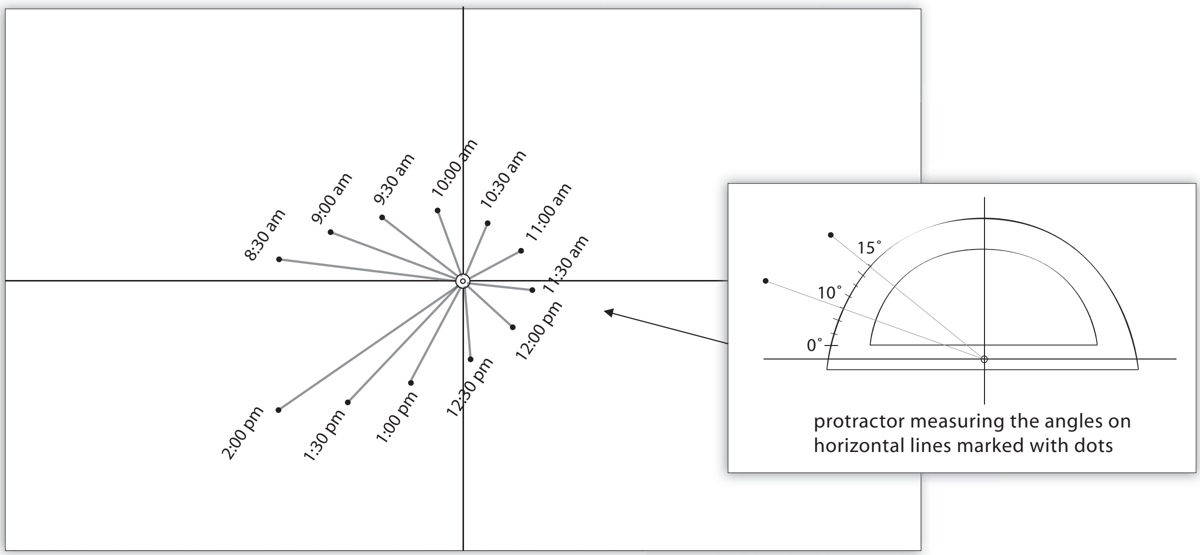


Figure 4: Sample measurement

Table 1: Sun Shadow Plot Data

Time														
Angle from horizontal line (deg)														
Length (cm)														

Using the angle bisector method, find and label true north on your Sun Shadow Plot.

Verify local solar noon by using shadow length times and sunrise/sunset times.

Connect all the dots that mark the ends of the sun shadows to give you a curve. Predict and draw in a different color and use symmetry around the true north line to show how the curve of shadows would continue through the evening hours.

Student Handout
Sun Shadows

Discussion Questions

1. How do the shadow lengths change?
2. How do the positions and angles of the shadows change? In which direction do they move (clockwise or counterclockwise)? What do the changing positions and angles tell you about how the position of the Sun changes throughout the day? Does the Sun's position change in a clockwise or counterclockwise direction? Draw a picture to explain your answer.
3. When are shadows the shortest? When are they the longest? Draw a picture explaining your answer.
4. How do you think the curve would change if you used a different sized gnomon to cast the shadow?
5. Will the curve be the same throughout the year?
6. What causes the change in shadows, the moving Earth or the moving Sun? Draw a picture explaining your answer.

Use Your Data to Predict

Design a shadow box to place in the sunlight in the same orientation as your original shadow plot. Use a gnomon of a different length than you used before. Determine and record in the chart below the angle and length of the shadow for each time. On the shadow box, place, draw, or glue small objects or marks (stickers pictures, small toys) where you predict the end of the shadows will be cast several times during the day. Have one of these times be when a shadow is cast on true north. Make a special marking for true north.

Hint: *Use the angles and shadow lengths from your original shadow plot to decide where to place objects.*

Shadow Box Data

Time					
Angle from baseline (deg)					
Length (cm)					

Sun Shadows

RESOURCES

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