Making A Sundial

Student Objectives
The student will:
- design, construct and demonstrate the use of a gnomon by constructing a sundial
- track the movement of a shadow cast by the gnomon over the course of a day
- predict the length of shadow at a specified time.

Key Words
gnomon
sundial

Time:
Construction (20 minutes)
Data Recording (4, ten minute sessions)
Discussion (30 minutes)

Materials:
- paper plates, 9 in. white
- plastic drinking straws
- pencils (regular, red, and blue)
- rulers
- scissors
- tape
- sidewalk chalk (white or yellow)
- compass

Background Information

A sundial is an instrument that indicates time of day by the shadow cast on a surface of an object that is marked to show hours or fraction of hours. Although any object whose shadow is used to determine time is called a gnomon, the term is usually applied to a style, pin, metal plate or other shadow-casting object that is an integral part of a sundial.

It is not known when the sundial was invented, or who invented it. Sundials can be found in many ancient civilizations, including the Babylonian, Greek, Egyptian and Roman. Sundials exist in most countries, in various forms, differing in construction according to the culture's knowledge of astronomy and mathematics.

The earliest extant sundial, an Egyptian instrument of 1500 BC, is a flat stone on which is fixed an L-shape bar whose short vertical limb casts a shadow measured by markings on the longer horizontal limb. During the 1st century AD, the sundial was greatly improved by setting the gnomon parallel to the earth's axis of rotation so that the apparent east-to-west motion of the sun governs the swing of the shadow.

At the present time, the oldest known "dials" used to tell time are those of Grecian origin and said to have been invented by Chaldean Berosus, who lived about 340 BC. Four of these sundials were discovered in Italy between the years 1746 and 1762. It is also evident that this

form of sundial was used by the Arabians (who gave great study to gnomonic), and was also popular among the Romans.

The earliest known sundials in England are those of Saxon origin found on some of the oldest churches. Most of the early examples are semi-circular, and although the spaces into which the dial is divided vary considerably in number and size, they seem to point to the early Norse practice of dividing time into tides.

One of the earliest English historians records the fact that the hours were shorter or longer according to the seasons, and this testimony is born out by existing dials found on faced stones built into porches, windows, and corners of buildings. These dials consist of circles and half-circles, divided by lines which radiate from a hole in the center to the circumference. The number of lines differ considerably and the spaces are also of unequal size.

In later years the face of the dial was more divided, and gradually moved from being quite plain in appearance to taking a more ornate shape. Sundials continued to be placed into use long after clocks were available, and in the 17th Century many fine specimens were erected. Until watches began to be made in numbers the sundial ruled supreme. Clocks did not in any way diminish the popularity of sundials, but rather the clocks helped to keep sundials in existence, as clocks stopped running and lost time, sundials were long employed for setting and checking clocks.

Solar time, which is indicated by sundials, and clock time is different and must be correlated by the use of tables showing daily variations between the two. A correction must also be made for the difference in longitude between the position of a sundial and the standard time meridian of a given locality. In fact on the meridian of a given time zone (for instance 75^{o} longitude for Eastern Standard time), "solar noon" only correlates with the Standard Time (not Daylight Savings) on four days during the year: April 16, June 14, September 1, and December 25. Although sundials are still used in many areas, they are regarded today as adornments usually found in gardens. And, because of the problems with our "clock" time as described above, garden sundials will not tell accurate clock time, except by coincidence.

The largest sundial in ancient times was constructed in 1724 in Jaipur, India. This sundial covers almost one acre and has a gnomon over 100 ft high surmounted by an observatory.

Procedure (construction)

1. Pass out materials to students, reminding them of the proper usage of scissors.
2. Ask the students to find the center of the paper plate and mark it with an X. They can do this by folding the plate in half going in both directions.
3. With a pencil, have the students make four placement marks along the edge of the paper plate, with one mark longer than the others. The distribution of the marks around the plate doesn't matter. It is good if each student's marks are different as they will help the students place their plates in the same location for each measurement. If possible, have the plates in the same location all day long, either by staking the finished sundials outside, or marking the ground where each dial is placed.
4. Have the student make four-½ inch cuts lengthwise in one end of the straw. These should be spaced evenly apart, not all together. Flare out the cut pieces and tape the four ends to the plate centered over the X that they wrote on their paper plate. Make sure the

students take their time in taping the straw so it is in the center of the plate and perpendicular to the plate.

5. Measure and cut the straw to a height of 2 inches.

Procedure (data collection, day 1)

1. The first time working with their sundials should be as early in the morning as possible.
2. Pass out pencils, rulers, and chalk. The students will need to have the sundial that they previously made.
3. Have the students place their sundials in a sunny spot of asphalt or concrete. Have them make four chalk marks, which line up with the ones that they made on the edge of their plate. Remind them that one of the marks on their sundial is longer than the others, so one of their chalk marks should also be longer. Have the students write their initials inside the sundial tracings. The marks will help them place their sundial in the same location when they come out later in the day.
4. Have the students carefully trace the straw's shadow on the plate with a pencil, and then darken in the shadow so it can be easily seen. At the top of the shadow the students record the time of day.
5. Students measure the length of the shadow they traced and record it on their worksheet, along with the time of the day.
6. The students should then draw a representation in the third box on their worksheet of where the sun is located in the sky. To do this, have the student stand on the north side of the plate (facing toward the south) directly facing their straw. They should then record the position of the Sun on the worksheet. (Note: Warn them to never look directly at the Sun!)
7. Repeat steps 4 through 6, at least three more times before 2 pm.
8. After the last measurement, ask students to predict where they think the shadow of the straw will be at 2 pm and where the sun will be in the sky.
9. Using a red pencil, have them outline the predicted shadow on their sundial and the sun on their worksheet.

Procedure (data collection, 2pm same day or next day)

1. Return the sundials to the marked locations (from day 1) at 2 pm, and have the students determine how close their tracings in red are to where the shadow of the straw is actually falling on their sundial. Then with the blue colored pencil the students should trace the actual 2 pm shadow and place the sun in its appropriate position on their worksheet.
2. Students should complete their Science Journal pages.
3. Lead a discussion of their findings and the reasons for the apparent motion of the Sun. Allow students to modify their answers in their Science Journal as their knowledge of the subject increases.

Key Words and Definitions

- **gnomon** – the raised projection on a sundial, which casts the shadow
- **sundial** – a sundial consists of the dial plate marked out with hour lines, and a "gnomon", the raised projection that casts the shadow. The inclined edge of the gnomon, called the

"style", is the time-telling edge of the gnomen. The style must be parallel to the Earth's rotation for the sundial to be accurate throughout the year..

Further Research

1. Decorate your sundial with "sun" art.
2. Make a paper sundial using the Nasa Make and Take pattern found here: **https://sunearthday.nasa.gov/2005/images/Sun_Dial_pdf.pdf**
3. Make a sundial that is suitable for a garden installation. Line a springform pan with waxed paper. Pour plaster of paris (or concrete mix) into pan. Sundials could be imprinted with objects (leaves, hands, etc) while still wet, or could have small objects (marbles, pieces of tile or stones) imbedded in them. Before plaster is set, stick a wooden dowel, plastic rod or metal rod into the center for the gnomon. Support the gnomon in an upright position until the sundial dries. One way to do this would be to tape strips of cardboard or heavy paper bracing from the gnomon to the sides in several places. Sundials may be painted with sun markings when dry.
4. Research Stonehenge. Make clay models of the circle of stones.

Related Reading

- ***About Time: A First Look at Time and Clocks*** by Bruce Koscielniak (HMH Books for Young Readers, 2013)
  An introduction to time and the history of timekeeping from earliest time to the present.
- ***Dark as a Shadow*** by Lawrence Lowery (NSTA Kids, 2014)
  Time for shadow play! After reading about how light and objects interact to create shadows, young children won't be able to resist twisting, wiggling, bending, and shaking to see the phenomenon for themselves. Written in lively rhymes, this book makes it fun to learn why shadows change in length throughout the day and disappear at dark.
- ***The Story of Clocks and Calendars*** by Betsy Maestro (HarperCollins, 2004)
  This book follows the history of clocks and calendars and the cultures behind the inventions.

Internet Sites

http://www.fsec.ucf.edu/en/research/buildings/fenestration/disney.htm
The Team Disney and Florida Solar Energy Center Sundial, which is built into the center of a building, is one of the largest sundials in the world.

http://www.nsta.org/publications/interactive/aws-din/aws.aspx
National Science Teacher Association. Astronomy with a stick--Daytime astronomy activities.

https://www.youtube.com/watch?v=1SN1BOpLZAs
Following the Sun: Crash Course Kids #8.2, kid friendly video explaining why shadows change length and direction. Good follow-up review for *Making a Sundial* activity.

Making A Sundial

Florida NGSS Standards & Related Subject Common Core

			.1	.2	.3	.4	.5	.6	.7	.8
Grade 3										
The Practice of Science	**Big Idea 1**	**SC.3.N.1**	**X**		**X**			**X**		
Grade 4										
The Practice of Science	**Big Idea 1**	**SC.4.N.1**	**X**			**X**		**X**		
Grade 5										
The Practice of Science	**Big Idea 1**	**SC.5.N.1**	**X**							
Language Arts	**Third Grade:** LAFS.3.SL.1.1 **Fourth Grade**: LAFS.4.SL.1.1 **Fifth Grade:** LAFS.5.SL.1.1									

Third Grade Benchmarks
Science--Big Idea 1: The Practice of Science
- SC.3.N.1.1 - Raise questions about the natural world, investigate them individually and in teams through free exploration and systematic investigations, and generate appropriate explanations based on those explorations.
- SC.3.N.1.3 - Keep records as appropriate, such as pictorial, written, or simple charts and graphs, of investigations conducted.
- SC.3.N.1.6 - Infer based on observation.

Language Arts–Standards for Speaking and Listening
- LAFS.3.SL.1.1 - Engage effectively in a range of collaborative discussions with diverse partners on grade 3 topics and texts, building on others' ideas and expressing their own clearly.

Fourth Grade Benchmarks
Science--Big Idea 1: The Practice of Science
- SC.4.N.1.1 - Raise questions about the natural world, investigate them individually and in teams through free exploration and systematic investigations, and generate appropriate explanations based on those explorations.
- SC.4.N.1.4 - Attempt reasonable answers to scientific questions and cite evidence in support
- SC.4.N.1.6 - Keep records that describe observations made, carefully distinguishing actual observations from ideas and inferences about the observations.

Language Arts–Standards for Speaking and Listening
- LAFS.4.SL.1.1 - Engage effectively in a range of collaborative discussions with diverse

partners on grade 4 topics and texts, building on others' ideas and expressing their own clearly.

Fifth Grade Benchmarks

Science--Big Idea 1: The Practice of Science

- SC.5.N.1.1 - Define a problem, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigations of various types such as: systematic observations, experiments requiring the identification of variables, collecting and organizing data, interpreting data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.

Language Arts–Standards for Speaking and Listening

- LAFS.5.SL.1.1 - Engage effectively in a range of collaborative discussions with diverse partners on grade 5 topics and texts, building on others' ideas and expressing their own clearly.

National Next Generation Science

Third Grade Standards

Note: Related Common Core Language Arts Standards are listed in the Florida section above.

Fourth Grade Standards

Note: Related Common Core Language Arts Standards are listed in the Florida section above.

Fifth Grade Standards

Science--Earth's Place in the Universe

- 5-ESS1-2 - Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.

Note: Related Common Core Language Arts Standards are listed in the Florida section above.

Making A Sundial

Use your sundial data worksheet to help you answer the questions below.

Questions:

1. How did the shadows move across your plate?

_____

_____

_____

_____

2. When was the shadow the longest? Where was the Sun?

_____

_____

3. When was the shadow the shortest? Where was the Sun?

_____

_____

4. Why do you think the shadows change length?

_____

_____

_____

_____

_____

5. How could you use a shadow to tell the time of day?

_____

_____

_____

_____

_____

6. How accurate was your prediction for where the shadow would fall at 2 pm?

_____

_____

Sundial Data Sheet

Date_____

Time	How long is the shadow?	Where is the Sun in the sky? (Remember, NEVER look at the Sun!)