The Garden Sundial

Grades 2 – 10
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Objective

1. Students will be able to explain the movement of the sun across the sky during the day.
2. Students will be able to use a sundial.
3. Students will be able to discuss how the earth's tilt affects sundial accuracy.
4. Students will be able to use the metric system to measure distances.

AAAS Standards

Science

- Grades 6 – 8, The Earth: By the end of 8th grade students will know that because the earth turns daily on an axis that is tilted relative to the plane of the earth's yearly orbit around the sun, sunlight falls more intensely on different parts of the earth during the year.
- Grades K – 2, The Earth: By the end of 2nd grade students should know that some events in nature have a repeating pattern.
- Grades 9 – 12, Systems: Understanding how things work and designing solutions to problems of almost any kind can be facilitated by systems analysis.

Math

- Grades 3 – 5, Numbers: By the end of 5th grade students should know that in some situations, "0" means none of something, but in others it may be just the label of some point on a scale.
- Grades 9 – 12, Symbolic Relationships: By the end of 12th grade students should know that any mathematical model, graphic or algebraic, is limited in how well it can represent how the world works.

Materials

- Clothesline or heavy string at least 5 meters in length
- Sidewalk chalk or paint
- Compass
- 2 stakes or other place holders
- 8 rocks or dial markers

- Meter stick
- Straight edge at least 18″ long
- A clean flat blacktop surface
- Permanent marker, 2 colors.

Background

Students can build a garden sundial on any level surface with a clear view of the southern horizon. The sundial can be drawn with chalk or paint, or set in concrete. Sundials can be large or small, but should be sized so that a student's shadow falls over the noon line at the equinox (usually March 21 or September 20).

Students will need to clear the sundial area---the more level the site the better the sundial will work. Various points and lines must be drawn on the ground or marked with stones. The students will be the gnomon or pointer of the sundial.

Sundials are not extremely accurate timekeepers for several reasons. We live in a world divided into time zones one hour wide. Most large cities and suburbs in the United States are located close to the center of a time zone, but sundials will be off about 10 minutes because they are not at the precise center of a time zone. Also, the length of the day changes as the Earth moves closer to and farther from the Sun during the year. A day is shorter in January than in June!

Content

Predict: (Engagement and assessing prior knowledge)

- In 30 seconds list as many ways to tell time as you can.
- How would you know what time it is if you are stranded on a desert island?
- What is time?
- Is it daytime for everyone on earth at the same moment?

Method: (Body of the lesson)

1. Choose a level patch of ground about 10 ft by 10 ft and make sure it is clear of debris.
2. Make a mark at the center of the patch. Standing at this mark, use a compass and straight edge to draw a meridian line based on true North-South (not magnetic North). This line should be the length prescribed by the data table according to your latitude. (See references)
    a. The difference between Magnetic North and True North is called the **variation**. To convert magnetic readings to true, you need to find the variation for your particular location. Maps such as U.S. Geological Survey maps, aviation charts and marine charts all list the variation. Because variation changes from location to location, you need to get a

map for your area. Variation is listed in terms of degrees east or west. If it is east variation, you subtract the number of degrees from the magnetic direction to obtain the true direction. If it is west variation, you add the number of degrees to the magnetic direction to obtain the true direction.
   b. Find the variation for your location here: http://www.ngdc.noaa.gov/geomagmodels/struts/calcDeclination
3. Half way down the North/South line draw a perpendicular line 5 meters in length to create a "+" mark in the center of the chosen area. You now have a North/South line, an East/West line as well as the center of the ellipse. This will be the point from which all measurements are made.
4. Next step is to draw the ellipse. Measure a piece of clothesline 5 meters long. Tie loops in both ends. The total length should be 5 meters.
5. To find the foci of the ellipse fold the string in half. Place the center of the string at the top of the North/South line and spread out the ends until they make a triangle with the East/West line. These are the foci. Use steaks to hold the loops in place.
6. Have another student put the chalk inside the clothesline and stretch the clothesline until it is taut along the N-S line toward North. Move the chalk along the clothesline in both directions making sure to apply pressure against the clothesline at all times. When done, you will have half an ellipse.
7. Do the same thing on the south side to complete the ellipse (not essential.)
8. It is time to mark the hours along the north side of the ellipse. Note that what you will be marking is the "center" of each hour. The location markers can be found in the attachment (or references for other latitudes). The same locations can be used in daylight savings time if you add an hour (so that 12 noon becomes 1 p.m.) Starting at one end of the clothesline measure out the measurements in the attachment on the clothesline and mark them with a permanent marker.
9. Place one end of the clothesline at the center of the ellipse. Stretch the string along the N-S line; this point will be your 12:00 noon mark. Mark this spot with a rock or chalk. Pull the clothesline around the ellipse towards the East until you hit the next mark on the clothesline. This will be your 1:00 pm mark. Continue toward the East for as many points as you like and then repeat toward the West.
10. The final step is determining where the gnomon or pointer is placed. These locations are shown as footprints in the diagram as they show where the student stands to use the sundial. This location varies depending upon the month of the year. Use the measurements in the attachment to determine where to draw the "feet" or standing mark. You may mark them on the same rope using a different color permanent marker. These are from the center determined in step 3. If the sundial is temporary only the point for the current month is needed.

When the sundial is drawn, have students stand on the markings and see where their shadow falls. They should be able to tell the time to within 12 minutes.

Activity Extensions

1. Have them calculate the direction of true north.

2. Can you determine whether you are at the center of a time zone or near the edges? Compare an accurate clock or watch to the sundial to see if the sundial is fast or slow. People in the western part of a time zone see the Sun rise late (their sundial runs slow); people in the eastern part of a time zone see the Sun rise early (their sundial runs fast.)
3. Have them determine how to layout the East-West line.
4. Have students do conversions from feet to inches and to the metric system.
5. Have students explain how to alter the sundial to allow for daylight savings time
6. What happens if the gnomon is not vertical? What is the difference when you tilt along the N-S line and the E-W line?
7. We describe an easy way to draw an ellipse that uses the property of an ellipse that the sum of the lengths of lines from the foci to the ellipse is a constant. Other methods using only circles and straight lines can be used. Have the students research these methods and compare the accuracy of the methods.
8. Although the ellipse and hour markers are quite accurate, the gnomon points are only approximations to the actual locations. An ambitious student can look up how to apply more precise times and the effects of the "equation of time" to calculate more precise locations for the footprints.

Live-It: (Assessment questions)

- (Knowledge) Write a poem about measuring time using the vocabulary words you learned today.
- (Comprehension) Why do we have time zones?
- (Comprehension) Why does the sundial have to be lined up with a compass?
- (Application) Alter the sundial for daylight savings time.
- (Analysis) What happens if you use magnetic North to draw the ellipse?

<u>Resources</u>

- All instructions for this sundial plus calculations for different sizes and latitudes can be found here:
  - http://www.mysundial.ca/sdu/sdu_dialling_guides_analemmatic_sundial.html
- A nice picture of a sundial for London with accurate gnomon points.
  - http://www.hartrao.ac.za/other/sundial/sdllon.html
- The mathematics of garden sundials
  - http://pass.maths.org.uk/issue11/features/sundials/
- True North Variation – Magnetic North Declination by zip code.
  - http://www.ngdc.noaa.gov/geomagmodels/struts/calcDeclination

Notes and Reflections

NASA Solar Dynamics Observatory 2008
http://sdo.gsfc.nasa.gov/epo/educators/resources.php