Activity 2: Where is the Sun?

Time Required: 30 minutes

Materials List

Group Size: 3

Each group needs:

- 12" wooden skewer
- Protractor
- 12' measuring tape
- Compass

To share with the entire class:

- Level

Youth Handouts

Student Handout: Where is the Sun?
Sample Class Datasheet

Learning Objectives

After this activity, students should be able to:

- Measure the solar angle at their location at the current time (both time of year and time of day).
- Measure the solar azimuth at their location at the current time (both time of year and time of day).
- Explain that a solar oven would need to be moved throughout the day to always face the sun.

Introduction:

As was discussed in the first activity, during this module you will be designing and building a solar oven. Now, you will be measuring the direction and angle of the sun in order to figure out where to place your solar ovens to maximize the energy they receive from the sun.

A solar oven is heated by capturing the sun's energy. Would you point something that was trying to capture the sun's energy such as a solar panel or a solar oven in the same direction in the morning as you would in the afternoon? [Answer: No, the sun rises towards the east and sets towards the west.] Therefore, a solar oven or solar panel that moves with the sun can capture more energy than a solar panel that is left in one place. Since we will be testing our solar ovens during this program [most likely in the afternoon], we need to measure the direction of the sun at the current time of day to know which direction we should point our solar ovens when testing them.

Does the time of year affect the position of the sun in the sky?
[The answer is yes. The sun is higher in the sky in the summer and lower in the sky in the winter. If they don't get this, you might ask the students the following question.]

What causes the seasons?
[Answer: The tilt of the earth as it travels around the sun causes the seasons. This causes the sun to appear higher in the sky in the summer and lower in the sky in the winter.]

The position of the sun can be determined with two parameters – the local time and the day of the year. In this case, the local time is not simply the time in the time zone, but the time specific to your exact longitude. As we will see in this activity, true noon will not occur exactly at noon. True noon is the time that the sun is due south and casts the shortest shadow. Beginning at dawn, the sun moves higher and higher in the sky until true noon. Then, it begins to move lower and lower always moving from east to west. Throughout the year the sun rises in the east, but in the winter it rises further south and does not rise as high. As summer approaches, the sun rises further north and rises higher. In order to use your solar oven at a different time of year, you might find it useful to test the position of the sun in the sky at that time of year as well.

How would you describe the location of the sun right now?
[Answer: Students may have a number of answers for this. They may point at it. They may say it is in a certain direction. They may start comparing its current location in the sky to various reference points.]

Solar engineers locate the sun in the sky using two different measurements.

1) The **solar azimuth** is the angle the current direction of the sun makes with due south. You will be using a compass to find this angle. Since it is difficult to point a compass towards the sun exactly, you will be using the shadow of a vertical stick to find this angle.
2) The **solar angle** is the vertical angle between the sun and the horizon. In order to determine the solar angle, you will be using a vertical stick and then drawing on the handout. [Instructors Note: This value is also known by the terms altitude and elevation, but the students will likely find these terms more difficult because they contradict the more standard definitions of solar elevation and solar altitude. You do not need to bring these up in the lesson unless a student brings them up, but if you are searching for more information on the topic, you may find these terms useful.]

Vocabulary

Word	Definition
Solar Azimuth	The angle between the line from the observer to the sun projected on the ground and the line from the observer to due south.
Solar Angle	The vertical angle between the location of the sun in the sky and the horizon.
Magnetic Declination	The angle that separates true north from magnetic north.
Latitude or Parallels	The angle on a sphere above or below the equator. These lines are parallel with one another and can be formed by slicing the sphere parallel to the equator.

Summer/Winter Solstice	The time at which the sun is directly overhead of the Tropic of Cancer/Capricorn (respectively). The day on which this event falls is also referred to as the solstice and is the longest/shortest day of the year (respectively).
Spring/Fall Equinox	The time at which the sun is directly overhead of the equator. The day on which this event falls is also referred to as the equinox and has approximately the same amount of daylight as night. The term equinox is a word derived from Latin meaning equal night.
Tropic of Cancer	23° 26′ 22″ north of the equator. This is the most northern point on the globe that receives sunlight from directly overhead (solar angle can reach 90 degrees).
Tropic of Capricorn	23° 26′ 22″ south of the equator. This is the most southern point on the globe that receives sunlight from directly overhead (solar angle can reach 90 degrees).

Procedure

Before the Activity: 10 Minutes

Find a location where students can place their sticks vertically into the ground. An ideal location is next to a level sidewalk such that the shadow of the stick falls onto the sidewalk. Use the included level to locate a portion of sidewalk that is approximately level.

Look up the solar azimuth and solar angle (shown as altitude on this website) for the day and location you will be doing this activity. The appendices provide this data and were calculated for Ashville, NC, and for Greenville, NC, on September 15 to provide one set of data for students to compare their numbers to. Select the location that is nearest to you. This data was obtained from the following website maintained by the United States Navy. If you do this experiment on a different date or far from one of those locations, you may want to visit the website and generate a table for your location. Note that this website does not take into account Daylight savings time. If it is the summer, and Daylight savings time is in effect, add 1 hour to each of the times on the table generated by the website.
http://aa.usno.navy.mil/data/docs/AltAz.php
Make copies of this table for each of the student groups.

Finally, look up the magnetic declination for your location to find out how much the compass varies from true north. The following map shows that the magnetic declination for North Carolina is approximately between 4-8 degrees west of north.
http://www.spacecom.com/customer_tools/html/body_mag_dec_map.htm

The National Oceanic and Atmospheric Administration (NOAA) provides an online calculator for the magnetic declination at specific locations. You will just need the current date and your zip code.
http://www.ngdc.noaa.gov/geomagmodels/struts/calcDeclination

For a declination west of north such as the 4 to 8 degrees west of north declination in North Carolina, the declination you provide to your students will be positive. For a declination east of north, the declination you provide to your students will be negative.

During the Activity:

The students may already be outside following the first activity of the module. If that's the case, feel free to give the students the handouts and materials and let them follow along.

While students are working, watch the students making their measurements to ensure the sticks are vertical. Also, encourage the students to take care while making their measurements.

After the students have collected their data, you can go back inside to analyze it. Be sure to tell the students what value they should use for the magnetic declination.

Processing and Activity Closure:
Each group of students should take their measurements and use the worksheet to determine the solar azimuth and solar angle. Groups should submit their values for (solar azimuth and solar angle) to the class data table by writing it on a class datasheet or writing their data on the chalkboard. The students can then average the class data for the day. Students can compare their data to the tabulated angles provided either in the appendix or printed out by the instructor prior to class.

The following sun applet shows the movement of the sun's position at noon throughout the year. If you have access to a computer, students may find this useful in developing an understanding of how the solar angle at noon is related to the time of year.
http://cwx.prenhall.com/bookbind/pubbooks/lutgens3/medialib/earthsun/earthsun.html

If you have time, students can graph the published data on the same graph. The x-axis should be the solar azimuth and have a range of 90 to 270 degrees and the y-axis should be the solar angle. The published data will be the only data at multiple points throughout the day, but the students will observe where in the path of the sun their measurements were taken. Once the published data is graphed, some students will have a better comprehension of the true noon, the time at which the sun is highest in the sky.

Embedded Assessment
Collect and copy pages 11-13 from each group. Use the student calculations on these pages to ascertain whether they can properly calculate the solar angle and solar azimuth.

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Student Handout: Experiment - Where is the sun?

Name: ____________________________________

Date: ______________________

Measuring the current Solar Azimuth and Solar Angle

1. Use the level to find a section of concrete that is relatively level. Your instructor may already have done this.
2. Insert your wooden stick into the soil right next to the concrete making sure that the shadow from the stick falls onto the concrete.
3. Use the measuring tape to make sure that exactly 8 inches of the stick is above the level concrete.
4. Use the protractor to make sure that the stick is perpendicular (at a 90 degree angle) to the concrete in all directions. This will ensure that the stick is exactly vertical.
5. You are now ready to take your measurements.
6. In the data table below, there are a number of rows. You only need to fill out the first row. If you take measurements at different times or dates for your location in the future, you can put your data in other rows. This could help you utilize your solar oven at other times during the year.
7. At the top of your data table, write the city and state in which you are taking the measurement. This is your location on Earth since the location in the sky is different depending on where you are on Earth.
8. Write the value provided by your instructor for the magnetic declination at your location. The magnetic declination is the amount true north varies from magnetic north.
9. In the first two columns, write down the time and date of the measurement.
10. Measure the length of the shadow from the base of the stick to the end of the shadow. Write the length in inches in the third column where it says “Shadow Length.”
11. Place your compass on the ground. The red arrow on the compass points north. Orient your compass so that the red arrow is pointing exactly away from the vertical stick. Take a second stick and lay it on the ground so that it is touching the base of the first stick and is directly in line with the arrow of the compass. Make sure the first stick remains vertical.
12. Now, use your protractor to measure the angle between the shadow and the second stick. Write that angle in the fourth column where it says “Shadow Angle.” We are measuring this angle relative to north. If it is in the morning, the shadow will be on the west side of north, and you should write the angle as a negative number. If it is in the afternoon, the shadow will be on the east side of north, and the angle will be positive.

Data Analysis

In your groups, it is now time to utilize the data you have collected and calculate the solar azimuth and the solar angle.

Compute the solar azimuth by adding the value for the magnetic declination provided by your instructor and then adding 180° to the angle to account for the fact that the shadow points in the direction opposite the direction of the sun. Write the solar azimuth in the appropriate column on the data table.

(Shadow Angle) + (Magnetic Declination) + 180 = Solar Azimuth

____________ + _________________ + 180 = ___________

The solar angle can be calculated using the Solar Angle Handout below. This graph represents a side view of the experiment. The vertical stick extending 8 inches above the sidewalk is shown on the left side of the sheet of paper. Along the bottom, mark how far the shadow extended as a dot on the horizontal axis. Now connect the dot with the top of the line representing the vertical stick. You now have drawn a right triangle. Use your protractor to measure the angle in the lower right hand corner. This is the solar angle.

If you are interested in exploring this further, the solar angle can also be calculated using something called trigonometry. To do this, you can use the inverse tangent function. Since we know the height of the stick is 8 inches and the length of the shadow the solar angle is:

$$\tan^{-1}\left(\frac{8}{ShadowLength}\right) = SolarAngle$$

You could use this equation with sticks of various heights by substituting the length of the stick for the number 8.

Solar Angle Calculation Handout

The solar angle can be calculated using the Solar Angle Handout. These two lines represent a side view of the experiment. The vertical line extending 8 inches above the sidewalk is shown on the left side of the sheet of paper. It is exactly 8 inches long. Along the bottom, mark how far the shadow extended as a dot on the horizontal line. Now connect the dot with the top of the line representing the vertical stick. This will run over some of this text. You now have drawn a right triangle. Use your protractor to measure the angle in the lower right hand corner. This is the solar angle. Please write this angle below

Solar Angle (°) = _______

8 Inch
vertical
stick

Mark the length of the shadow you measured

Data table

Location: _______________

Magnetic Declination: _______________ (Provided by instructor)

Date	Time	Take Shadow Measurements		Use Your Measurements to Calculate Sun's Location	
		Shadow Length (in)	Shadow Angle (°)	Solar Angle	Solar Azimuth