The Sun's Path Across the Sky

Overview

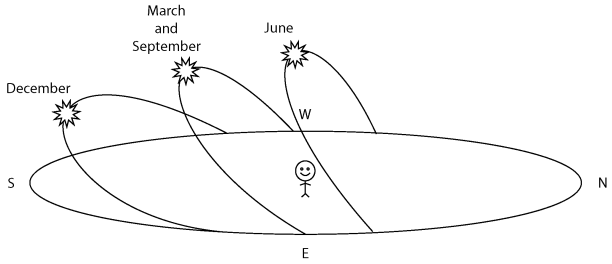
In this activity, students mark the shadow of a short pole in successive class periods to record the sun's path across the sky during a day. A few exploratory shadow activities help them understand the relationship between the shadow and the sun's position. During the next class period, students make sense of the changing shadow in terms of the sun's movement across the sky. They also speculate about what might change about this pattern during the year, and try to assign the correct season to each of four seasonal shadow plots. Afterward, the teacher demonstrates the change in the sun's path using a web-based animation. Students understand that the sun's arc moves lower and southward in winter, and higher and northward in summer. Throughout this guide, all information in italics is a "teacher tip."

North Carolina Essential Science Standards

6.E.1.1 Explain how the relative motion and relative position of the sun, earth and moon affect the seasons, tides, phases of the moon, and eclipses.

Background

The sun seems to move predictably across the sky, rising in the east and setting in the west. However, the sun's path across the sky changes a little bit every day. In different seasons, the sun takes different paths through the sky, as in figure below.



The reason for this has to do with how the Earth orbits the sun in space. If you could watch the Earth orbit the sun for a year, you would see it sweep out a nearly circular path along a flat plane, as if it were going around the edge of a plate. You might expect the Earth's North Pole to stand straight up as if the Earth were a top spinning on the edge of the plate, but it doesn't. Instead, the pole is tilted with respect to the plate – the Earth spins at an angle to the plate, and always faces the same direction in space. Depending on where the earth is in its orbit around the sun, the North Pole might point toward the sun, away from it, or somewhere in between. When it points toward the sun, at the summer solstice in June, we in the Northern Hemisphere have a longer day; the sun rises in the northeast and sets in the northwest, and is nearly overhead at noon. When the North Pole points neither toward nor away from the sun (equinoxes in September and March), the sun rises due east and sets due west, and day and night are equal. At the winter solstice in December, it rises far to the southeast and sets far to the southwest, and never gets very high. If you are interested, several phone apps track the sun's path at your location.

Materials

Materials for the whole class

- sun post (toilet plunger)
- droplight with bulb
- extension cord
- magnetic compass
- sidewalk chalk
- BLM 2 to project
- mobile phone or tablet capable of taking pictures and some means to get the pictures to your computer for projection.

Materials for individual students

- *science notebook

Materials for pairs of 2 students

- * a blank sheet of white copier paper
- 5-inch tube with small (#5.5) stopper
- copy of BLM 3 Seasonal Shadow Maps

* *supplied by the teacher*

Preparation

1. Do this activity on a sunny day with few clouds. Find a flat, level, paved surface outdoors with a clear view of the sky to the east, south, and west. The surface needs to be smooth enough to draw on with sidewalk chalk. Before class, do the following:
   - Place the sun post and its base at the location you choose and trace its round base on the pavement with sidewalk chalk.
   - Use the compass to find due South. Mark an S on the pavement due South of the plunger and draw a straight line from the S to the circle, continuing a few inches up the rubber base of the plunger.
   - Have sidewalk chalk ready for students to mark shadow locations.
2. Make 1 copy of BLM 3 Seasonal Shadow Maps per pair of students. Either cut out the individual squares before class, or set aside time and give out scissors for students to do it in class.
3. Be ready to project http://astro.unl.edu/naap/motion3/animations/sunmotions.html. Get familiar with it and practice using it. Enter our latitude (use 36˚ North) and a date and time when you want to see the sun's position and run the animation.
4. For the Exploration, have the droplight and extension cord ready. Have the 5-inch tubes with stoppers ready to give out to pairs of students.

Exploration

1. Explain that, because it's dangerous to look directly at the sun, we will track the sun's position in the sky by following the movement of a shadow. This exploration will help us understand what the shadow tells us.
2. Stand in the center of an open space with the light switched off. Ask students to have their notebooks with them, and give each pair of students a sheet of paper and a small

tube with stopper. Ask pairs of students to form a circle on the floor with each pair about 7 or 8 feet away from you, orient the paper with a short edge toward the light, and stand the tube, with stopper on top, at the short edge of the paper nearest the light.

3. Darken the room. When you turn on the drop light, the pair's job is to watch the tube-and-stopper's shadow. Hold the drop light at your ankles and turn it on. Slowly raise the bulb to your waist, over your head as high as you can reach, then lower it to your ankles. Ask students what they notice.
4. Turn on the room lights and ask everyone (in place) to write in their notebook a rule that relates the height of the light to the length of the shadow.

Procedure Day 1 (20 minutes): The Path of the Sun During One Day

The goal of Day 1 is for students to chart the position of the sun's shadow during each class period during the school day. Bring the compass with you when you go outside.

1. Take everyone outside to the sun shadow post. Show the class how you found South using the compass and point out the S marked on the pavement due South of the plunger. Be sure the plunger base is in its chalk tracing, with a single chalk mark that goes from the pavement to the base of the plunger. This mark keeps the plunger always turned the same way.
2. Ask a student to clearly chalk the tip of the post's shadow on the pavement and write the time (write large) to the North of the mark. Without blocking the sun and shadow, stand to the South of the plunger and take a cell phone picture of the shadow, mark, and time. Include the post in the photo. Be sure that no person or their shadow is in the picture. Leave room for all of the other entries in the picture (the last picture of the day includes all of the marks). The time at each mark should be readable when you project the last photo. Showing these photos as a sequence works best when all of the photos are framed the same way.
3. Leave the mark, time, and plunger in place and take the class in. Send the photo from your device to your computer so that you can project it.
4. Repeat this for each class during the day.

Procedure Day 2: The Path of the Sun During One Day, Continued

1. For each class, begin by projecting the photo of the shadow mark and time that that class made. Ask students where they think the shadow mark was during the next (and previous) class periods. Ask for reasons as follows:
   - Is the shadow longer or shorter? What does the lengthening or shortening of the shadow mean about the movement of the sun over time?
   - Has the shadow moved in any other way besides getting longer or shorter? How? What does the movement of the shadow around the plunger mean about the movement of the sun over time?
2. Project photos of shadow marks taken by other classes, starting with those nearest in time to the present class period. Discuss each picture. End with the picture taken at the end of the day. Get students to respond to this prompt in their notebooks:

Describe how the shadow moved throughout the day, and what that means about the way the sun moved. [examples: rises in a different place than it sets, gets higher during the day]

Procedure Day 2: The Path of the Sun Through the Year

1. The following steps can either be done on the same day as the previous two steps, or on another day. Ask the class what they notice about the sun's movement over a whole year. How is it different in different seasons? What do they think the shadow patterns that they made would look like in another season? Always the same or different? If different, how? Ask for examples. *[longer shadows in winter, shorter in summer, etc. - it's OK if they don't know.]*
2. Project the web site: http://astro.unl.edu/naap/motion3/animations/sunmotions.html for all to see. Enter our 36˚ latitude, today's date and time, and un-click "show the ecliptic." Orient the class to what they are seeing. Point out the stick figure and its shadow. Set the time for when you recorded the sun shadow and see if it matches what is on the poster paper. Run the animation and ask the class to watch the path of shadow. Is it like the path on the poster?
3. Give each pair of students the four squares cut out from BLM 3, Seasonal Shadow Maps. Each square shows shadow positions like the photos your class made. Each square shows the track of shadows at 7 different hours of a day in a different season. The white circle is the position of the plunger *[these are adjusted for daylight savings time, showing the plunger due South of the noon mark. This will be different from yours]*. The squares are in random order, labeled B, L, C, and I in their lower left corners. The pair's challenge is to assign a season to each card and have a reason for the season they choose. When they finish, ask them to put the seasons in order, starting with Winter on the left, ending with Fall on the right. Allow 5 minutes. It is not important to get the right answer, but it is important to have reasons for choices.
4. Have pairs of students compare their sequence and season labels with others in the room. Lead a discussion about similarities and differences between their arrangements.
5. Do not give students the answer at this time. *[Using the labels at the lower left of each square, the sequence for Winter through Fall is C, I, B, L]* **Key:**

6. To help connect the path of a shadow to the path of the light that makes it, use the bulb to make shadows for the class. Form pairs of students. Set out a tube with stopper on a piece of paper and ask students to gather where they can all see the shadow it makes when you darken the room and switch on the bulb.
7. Ask students to watch the shadow. Make a low arc by starting with the bulb at your ankles, moving across the space in front of the tube, and raising the bulb only to your waist when directly in front of the tube. Continuing across the space, lower the bulb

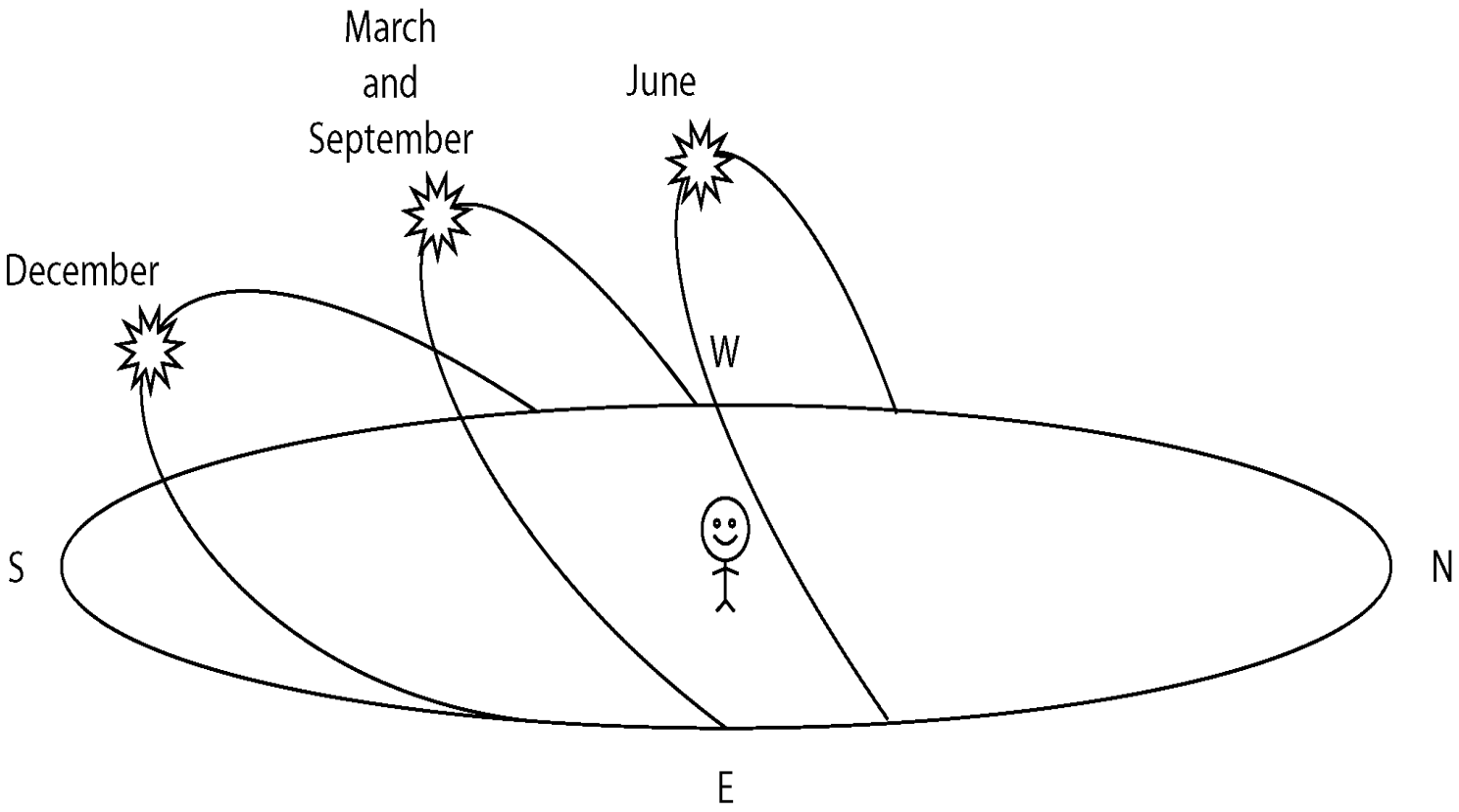
to your ankles when you are all the way across. When you finish, ask students how the shadow moved. This is like the path of the sun in winter.

8. Repeat with a higher arc, starting with the light at your ankles. This time, make your path a little closer to the tube, raise the light overhead when you are directly across from it, and lower it to reach your ankles when you are all the way across. Ask how the shadow moved. How was it different? This is like the path of the sun in summer.
9. Ask students to assign seasons to the Seasonal Shadow Maps again to see if they understand. This time, they should correctly assign winter and summer. It is not important to correctly sort Spring and Fall, but either I or L should be between Summer and Winter. The small difference in these shadow paths is not important.
10. Project BLM 2 and ask the class to predict what they think the shadow might look like at the same time of day that they recorded 3 months from now. Also, in 6 months and 9 months.
11. Project http://astro.unl.edu/naap/motion3/animations/sunmotions.html. Un-click "show the ecliptic," enter 36˚ latitude and enter the current date. Set the animation mode at continuous and leave the default speed of 3 hours/second. Click "start animation" to show a day. Review what the class has already seen.
12. Click "step by day" and leave the default speed of 15 days/second. Click "start animation." The yellow band is the path of the sun moving through the seasons at 15 days per second. There will no longer be a sun revolving or a shadow, but the class will see the path of the sun change as the seasons progress.

Reflection/Discussion

- Use the website animation to play "guess the season." To do this, block the right hand side of the projection with a piece of paper, so that the class can't see the date.
- Ask: Where is the sun in the morning? [East.] At midday? [High in the sky in the South.] In the evening? [West.]
- What changes does the arc of the sun go through in different seasons? *[The arc is far to the south and low in the winter; higher in the sky in spring and fall, and highest in summer.]*

BLM 2



BLM 3 Seasonal Shadow Maps